COLORADO **CLIMATE PLAN**

State Level Policies and Strategies to Mitigate and Adapt

Executive Summary

In Colorado, climate change presents a broad range of challenges.

Colorado has warmed substantially in the last 30 years and even more over the last 50 years.[1] Future estimates project temperatures rising an additional 2.5ºF to 5ºF by 2050,[2] meaning the warmest summers from our past may become the average summers in our future. With increasing temperatures come shifts in snowmelt runoff, water quality concerns, stressed ecosystems and transportation infrastructure, impacts to energy demand; and extreme weather events that can impact air quality and recreation. The challenges we face will affect everyone, and require collaborative solutions.

The goal of this document is to promote state policy recommendations and actions that help to improve Colorado's ability to adapt to future climate change impacts and increase Colorado's state agencies level of preparedness, while simultaneously identifying opportunities to mitigate greenhouse gas emissions (GHG) at the agency level. In this plan, the major sectors of the state government are addressed, specific actions are called for, and policy recommendations are made. Because addressing climate change is best addressed collaboratively, this plan has been developed collectively by the Department of Natural Resources (DNR), the Colorado Department of Public Health and Environment (CDPHE), the Colorado Energy Office (CEO), the Colorado Department of Transportation (CDOT), the Colorado Department of Agriculture (CDA), the Office of Economic Development and International Trade (OEDIT), and the Department of Local Affairs (DOLA), with input from key stakeholders.

This plan has also been developed to meet the requirements of C.R.S. 24-20-111, which calls for the development of a state climate plan setting forth a strategy to address climate change and reduce greenhouse gas emissions while taking into account previous state actions and efforts. This plan represents advances in the discussion on how to best address climate change at the state level, however, we know that more conversations are necessary and we look forward to a continued dialog with climate experts and the public. Therefore, over the next year, each state agency that has helped to develop this plan will hold public engagement sessions on climate change that are specific to their sector. This will include:

- The CDPHE, following the release of the Environmental Protection Agency's (EPA) final Clean Power Plan, will expand outreach to stakeholders, government agencies, and interested Coloradans in a public process to develop and implement a state plan to substantially reduce carbon dioxide emissions from fossil fuel fired EGUs. The CDPHE will host meetings and solicit public comment to gather ideas and attempt to reach some consensus on the most cost-effective ways to reduce emissions while preserving or enhancing electric grid reliability and the economy. The CDPHE will continue to fully cooperate with the Public Utilities Commission, the CEO and the General Assembly to optimize the state plan.
- The Colorado Parks and Wildlife Commission will serve as the public forum for future conversations on fish and wildlife adaptation. The Commission will schedule a series of conversations in the next year to hear recommendations from experts and the public about science and management options to inform management decisions.
- The CWCB will continue to be a leader on climate change adaptation in the water sector and will host an open discussion with experts and the public on climate change at a board meeting(s) during fiscal year 2016. CWCB staff will also engage with stakeholder groups around the state to gather feedback on this plan and recommendations to explore and enhance future actions.

- The CEO, in conjunction with the Public Utilities Commission, will continue to serve as subject matter experts concerning energy efficiency technologies, markets, and practices involving electric utility end-users. In this role, Colorado Energy Office will convene one or more forums over the next year to engage stakeholders and ensure energy efficiency options best fit within a compliance plan for the state. The development of these forums will also include collaboration with the CDA, who has partnered with the CEO on several energy programs.
- The DOLA will deliver trainings to local government planners and emergency managers on integrating information regarding changing hazard risks and resilience principles into local plans and land use codes using their forthcoming Colorado Hazard Mitigation and Land Use Planning Guide as a framework.
- The Colorado Tourism Office will include as session on climate change as part of the agenda at their annual conference. The conference will be held in Crested Butte in September.
- The CDA will work with the Colorado Association of Conservation Districts to provide an informative, science-based panel and discussion at the annual conference for conservation districts to explore the projected climate change impacts on production agriculture in Colorado and steps that can be taken to adapt and prepare for those changes.
- The CDOT will work with the State Transportation Advisory Commission to develop a stakeholder engagement process to take place over the next year.

In 2007, Governor Bill Ritter, Jr. released a Climate Action Plan laying out goals for the state through 2050. The plan was primarily focused on mitigation efforts and detailed a handful of measures that would help in reducing overall GHG emissions. Since that time the state has moved forward with many of these measures and has worked to implement additional mitigation efforts as well as greatly expand adaptation initiatives. Federal regulation has also expanded to address some of the goals laid out in 2007. Major State actions, such as the adoption and expansion of Colorado's Renewable Energy Standard (RES) also simultaneously addressed several the 2007 goals, and positioned the state well to respond to the recently released EPA Clean Power Plan rule. Below is a timeline illustrating the measures that have been accomplished since the 2007 plan was released.

Colorado is a state full of talented innovators who come together to tackle challenges and overcome obstacles on a daily basis. That collaboration and creative thinking is at the heart of this plan. The strategies and recommendations laid out here, in addition to the proposed stakeholder engagement opportunities, are commitments by state agencies to continue moving us forward and provide state level policies and strategies to mitigate and adapt. Over the coming months state agencies will work to incorporate the recommendations of this plan, schedule opportunities for continued stakeholder engagement, and continue to ensure that we are taking steps to reduce our greenhouse gas emissions in a balanced and responsible way, while also pursuing adaptive strategies that protect the core elements that make Colorado such a desirable place to live, work, and play.

[1] Jeff Lukas et al., Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation 2nd Edition (Colorado Water Conservation Board, 2014), 2.

[2] Lukas, Climate Change in Colorado, 3.

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Abbreviations & Acronyms

AD	Anaerobic digestion
CO_2	Carbon dioxide
CDA	Colorado Department of Agriculture
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CEO	Colorado Energy Office
CLEER	Clean Energy Economy for the Region
CNG	Compressed natural gas
CPW	Colorado Parks and Wildlife
CWCB	Colorado Water Conservation Board
DHSEM	Division of Homeland Security and Emergency Management
DNR	Department of Natural Resources
DOLA	Department of Local Affairs
EGU	Electric Generating Units
EPA	Environmental Protection Agency
EV	Electric Vehicle
GHG	Greenhouse gases
HFC	Hydrofluorocarbon
IECC	International Energy Conservation Code
$MMTCO_2e$	Million Metric Tons Carbon Dioxide Equivalent
NEPA	National Environmental Policy Act
NSPS	New Source Performance Standards
OEDIT	Office of Economic Development and International Trade
PV	Photovoltaic
RES	Renewable energy standard
SWAP	State Wildlife Action Plan
VMT	Vehicle miles traveled
VOC	Volatile organic compound

1

Introduction

Colorado is a spectacular, vibrant, and economically diverse state with much to offer residents and visitors alike. Annually, tens of thousands of people move here,[1] and millions visit.[2] Our mountains, rivers, and trails are world renowned; as are our laboratories, breweries, universities, and agricultural products. Yet the Colorado that we know and love faces real challenges with a changing climate. Our response to a changing climate is not a partisan issue; rather it is an economic development issue, a public health issue, a natural resource issue, and an emergency response issue. While the science is not perfect and we do not know the exact effects that will result from rising temperatures, we have enough information and confidence in the science to move forward in addressing this issue in a meaningful way, despite the uncertainty. Practical strategies to address the threats and impacts of a changing climate will help safeguard our citizens, land owners, and businesses. This plan sets a path forward that will ensure Colorado state agencies are both doing our part to responsibly mitigate greenhouse gases (GHG) and that we are adequately preparing for the changes we cannot prevent. Being pro- active and prepared will ensure that Colorado remains a spectacular, vibrant, and economically diverse state for generations to come.

The potential impacts of a changing climate are broad and reach across many sectors, as reflected in the scope and content of this report. Impacts range from the resilience of our iconic native species to the durability of our transportation infrastructure. The state's natural resources and habitats will experience changes as temperatures warm, making conditions more suitable for invasive species and increasing potential for more severe wildfire. In addition to wildfire,[3] other extreme weather events may become more common, ranging from droughts to floods.[4] Streams that flow from the mountains and into our reservoirs will warm, allowing for higher nutrient and bacteria content in the water; and wildfire in watersheds may result in sediment loading from recent burns.[5] Snowpack will likely melt off several weeks earlier, altering flow regimes for fish and water users alike.[6] With warmer temperatures, overall runoff will likely decrease while crops will simultaneously need more water to grow as evapotranspiration rates increase.[7]

As new generations are born and people move to Colorado for its high quality of life and economic opportunity, agricultural producers will face additional challenges balancing environmental conditions with the increasing demand to feed Colorado's growing population.[8] Protecting the air quality of our state will become increasingly important and safeguarding public health will be imperative. As heat, drought, and fire events increase in frequency, additional strain will be placed on our infrastructure and the pristine locations where people recreate may become more threatened or inaccessible.[9] This multitude of impacts presents far-reaching challenges throughout the state and requires proactive, coordinated efforts to enable Colorado state agencies to work to protect those resources and to adapt where necessary. At the same time efforts to curb GHG emissions will help to mitigate impacts,[10] but must be balanced with economic stability.

Colorado has warmed 2°F in the last 30 years and 2.5°F in the last 50 years (Figure 1-1).[11] This warming has resulted in an increasing trend in heat waves and, along with other factors, has led to a shift in the timing of peak runoff by 1 to 4 weeks, drier soils, and more frequent and severe wildfire.[12] Future estimates project temperatures rising an additional 2.5 to 5°F by 2050.[13] This additional warming will affect our water quantity and quality as well as our energy development, transportation, public health, tourism, and agriculture.[14] In short, a changing climate impacts all sectors of Colorado's economy.

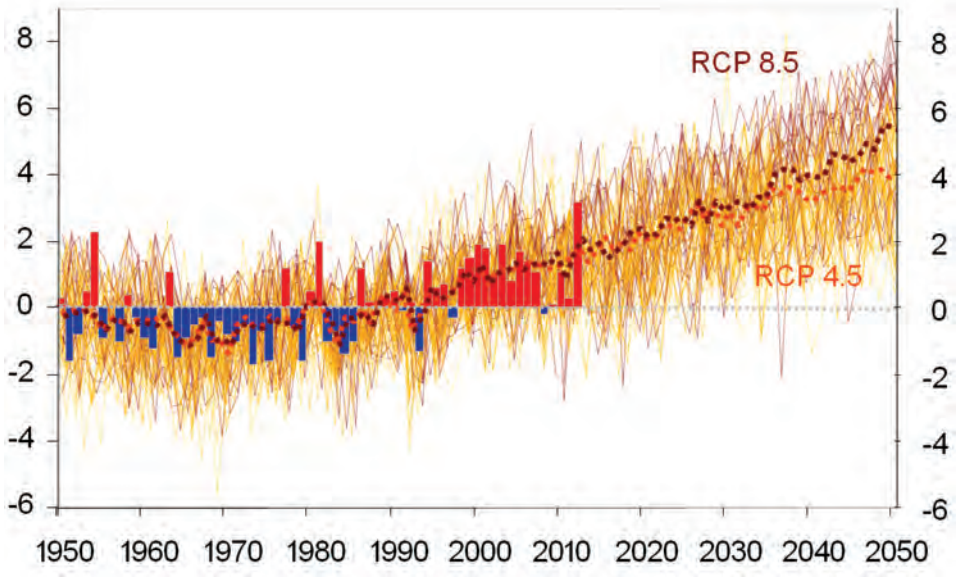
1.1 OBJECTIVE OF THIS PLAN

The goal of this document is to promote state policy recommendations and actions that help improve Colorado's ability to adapt to future climate change impacts and increase Colorado's state agencies level of preparedness, while simultaneously identifying opportunities to mitigate greenhouse gas emissions at the agency level. In this plan, the major sectors of the state government are addressed, specific actions are called for, and policy recommendations are made. Because addressing climate change is best addressed collaboratively, this plan has been developed collectively by the Department of Natural Resources (DNR), the Colorado Department of Public Health and Environment (CDPHE), the Colorado Energy Office (CEO), the Colorado Department of Transportation (CDOT), the Colorado Department of Agriculture (CDA), the Office of Economic Development and International Trade (OEDIT), and the Department of Local Affairs (DOLA), with input from key stakeholders.

This plan has also been developed to meet the requirements of Colorado House Bill 13-1293 codified as *C.R.S. 24-20-111*, which calls for the development of a state climate plan that sets forth a strategy to address climate change and reduce greenhouse gas emissions, while taking into account previous state actions and efforts.[15] This plan represents advances in the discussion on how to best address climate change at the state level, however, we know that more conversations are necessary and we look forward to a continued dialog with climate experts and the public.

Figure 1-1

Observed annual temperatures are shown as red and blue bars relative to a 1971-2000 baseline. Projected temperatures are shown by yellow lines (middle-emission scenario; RCP 4.5) and red lines (high emissions scenario: RCP 8.5). The heavy dashed lines are the average projection for each emissions scenario.



Source: Adapted from Lukas et.al, Climate Change in Colorado, 2014

1.2 ONGOING EFFORTS IN COLORADO

Addressing climate change will take a concerted effort by all Coloradans and involve a two-pronged approach. We must reduce our own emissions, where possible, while still preparing for and adapting to future effects beyond our control. Colorado alone cannot prevent climate change; it is simply not possible to reduce our own emissions enough to overcome global patterns. But we can do our part, and we have made great strides on this front so far. In 2004, Colorado became the first state to establish a statewide Renewable Energy Standard (RES), which remains one of the strongest in the nation. In 2010, the Colorado General Assembly passed the Clean Air Clean Jobs Act, which aims to reduce emissions through the conversion of coal-fired power plants to natural gas and other low emitting sources.[16] In 2014, we became the first state in the nation to directly regulate oil and gas methane emissions.[17] We rank eighth in the nation for cumulative solar electric capacity[18] and tenth for wind capacity and number of turbines.[19] We are home to one of the largest anaerobic digester facilities in the United States,[20] and our energy companies have sharply reduced pollutants by transitioning to cleaner burning sources,[21] Xcel Energy now provides 22 percent carbon-free electricity within Colorado and projects this will continue to grow.[22] In 2012 alone, the state's programs prevented 5.5 million tons of carbon dioxide (CO_2) emissions, and we project that by 2030, GHG emissions per unit of Gross State Product will be reduced by nearly 37 percent over the 2005 baseline.[23] Colorado is on the right track, and federal regulations may quicken this pace.

Results of Colorado's Renewable Energy Standard

0.54%

Percent of renewable energy generated in Colorado in 2004

14.36%

Percent of renewable energy generated in Colorado in 2014

Colorado's Renewable Energy Standard was originally passed in 2004, and was expanded in 2013.

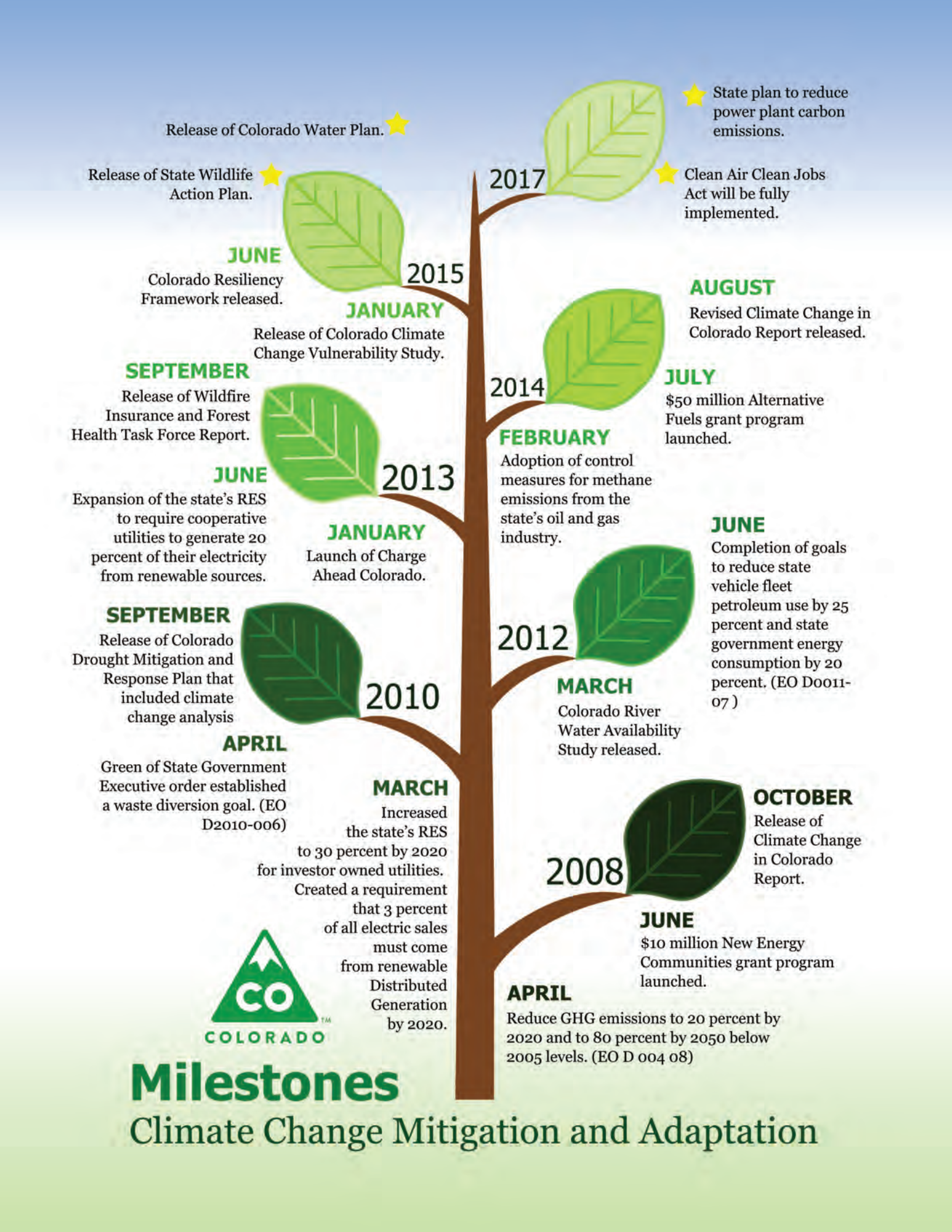
In 2007, Governor Bill Ritter Jr. released a Climate Action Plan laying out goals for the state through 2050. The plan was primarily focused on mitigation efforts and detailed a handful of measures that would help in reducing overall GHG emissions. Since that time, the state has moved forward with many these measures and has worked to implement additional mitigation efforts as well as greatly expand adaptation initiatives. Federal regulation has also expanded to address some of the goals laid out in 2007; for example, the Environmental Protection Agency's (EPA) GHG reporting rule and the federal GHG standards for motor vehicles eliminated the need for Colorado to enact state level legislation or regulations on these issues. Major state actions, such as the adoption and expansion of Colorado's RES also simultaneously addressed several of the 2007 goals, and positioned the state well to respond to the recently released EPA Clean Power Plan rule. The rule establishes a federal goal for Colorado that goes beyond existing state initiatives and results in substantial reductions of GHG emissions. Successfully achieving federal emissions reduction requirements under this rule, and continuing to advance goals from the 2007 climate plan, will require sustained long term efforts by state agencies and other stakeholders.

Several of Colorado's state agencies are actively involved in the implementation of past initiatives, working to move Colorado towards a future more resilient to changes in climate. Yet efforts to do this can be affected by forces outside the immediate control of state government. In 2007 Colorado's economy was strong, and the national economic health was flourishing. But by late 2008, the nation and the state began to experience the most significant economic decline since the Great Depression. This multiyear downturn resulted in sizable cuts to agency budgets, mandatory furloughs for staff and restrictions on federal spending. The programs and initiatives that were laid out in the 2007 plan were not immune to these cuts and progress on some efforts slowed. While Colorado has come out of the recession strong, many programs have permanently changed, and we must now operate under the realities of today.

Despite our efforts, some effects from a warming climate cannot be entirely prevented, and Colorado will have to adapt. Some effects are already apparent, such as earlier spring runoff and increased drought and wildfire; while others are further out on the horizon. Our state agencies have begun to incorporate these changes into recovery and resiliency efforts, such as the Colorado Resiliency Framework, the State Wildlife Action Plan, and through-

Milestones

Climate Change Mitigation and Adaptation



out Colorado's Water Plan, which sets forth strategies, policies and actions to meet our water needs. Proactive preparedness will enable Colorado to respond in a timely and cost-effective manner, despite uncertainty, while also providing the chance to look for opportunities resulting from these changes.

This Climate Plan builds on the solid foundation that already exists and ensures we take a collective, common-sense approach to address the issues. Lastly, and perhaps most importantly, state government is working together and with public and private-sector experts across the state to share the knowledge that we have, the innovation we have developed, and our collective capital. Colorado is a resilient state, and together we are well-positioned to face this challenge.

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[1] Division of Local Government, Colorado State Demographer, Colorado Migration in 2013 (January 2015), 1. http://www.colorado.gov/cs/Satellite?blobcol=urldata&blobheadername1=Content-Disposition&blobheadername2=Content-Type&blobheadervalue1=inline%3B+filename%3D%22Colorado+Migration+2013.pdf%22&blobheadervalue2=application%2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1252051980454&ssbinary=true.

[2] Longwoods International, Colorado Travel Year 2013 (May 2014), 10. http://www.colorado.com/sites/default/master/files/Colorado2013VisitorFinalReportOnline_final.pdf.

[3] Karen Decker and Michelle Fink, *Colorado Wildlife Action Plan Enhancement: Climate Change Vulnerability Assessment*. (Colorado Natural Heritage Program, Colorado State University: 2014).

[4] Jeff Lukas et al., Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation 2nd Edition (Colorado Water Conservation Board, 2014), 60.

[5] United States Environmental Protection Agency, *Watershed Modeling to Assess the Sensitivity of Streamflow, Nutrient, and Sediment Loads to Potential Climate Change and Urban Development in 20 U.S. Watersheds* (2013).

[6] Lukas, *Climate Change in Colorado*, 75

[7] Colorado Water Conservation Board, *Colorado Water Availability Study Phase I Report* (2012). , ES12-15 http://cwcbweblink.state.co.us/WebLink/ElectronicFile.aspx?docid=158319&searchid=78f0eafa-0b8f-4d8a-9ff3-faf67cc82f52&dbid=0.

[8] CWCB, *Water Availability Phase 1*, ES12-15

[9] Amber Childress et al., Colorado Climate Change Vulnerability Study (January 2015), 110, http://wwa.colorado.edu/climate/co2015vulnerability/co_vulnerability_report_2015_final.pdf.; Childress et al., *Vulnerability Study*, 133

[10] "Profile Analysis: Colorado," U.S. Energy Information Administration, accessed April 3, 2015, http://www.eia.gov/state/analysis.cfm?sid=CO.

[11] Lukas, Climate Change in Colorado, 2.

[12] Lukas, Climate Change in Colorado, 2.

[13] Lukas, Climate Change in Colorado, 3.

[14] Childress et al., Vulnerability Study, 2.

[15] C.R.S §24-20-111

[16] C.R.S §40-3.2-202

[17] 5 CCR 1001-9

[18] "Solar Industry Data," Solar Energy Industries Association, accessed April 23, 2015, http://www.seia.org/research-resources/solar-industry-data.

[19] American Wind Energy Association, Colorado Wind Energy. http://awea.files.cms-plus.com/FileDownloads/pdfs/Colorado.pdf.

[20] "Project Detail: Heartland Biogas Project," EDF Renewable Energy, accessed April 3, 2015, http://www.edf-re.com/projects/detail/heartland_biogas_project/.

[21] C.R.S §40-3.2-201 through §40-3.2-210

[22] Xcel Energy. Forging our Path Corporate Responsibility Report for 2014. Accessed June 30, 2015. https://www.xcelenergy.com/staticfiles/xe/Corporate/CRR2014/community/operations-numbers.html

[23] Colorado Department of Public Health and the Environment, Colorado Greenhouse Gas Inventory-2014 Update Including Projections to 2020 & 2030 (October 2, 2014). 48, EX. 2-10. https://www.colorado.gov/pacific/sites/default/files/AP-COGHGInventory2014Update.pdf.

2

Water

In Colorado's semi-arid environment, water influences nearly all aspects of our economy. On average, the state as a whole receives only 17 inches of precipitation annually, ranging from seven inches in the San Luis Valley to as much as 60 inches in the mountains.[1] Snowpack is our biggest reservoir and the source of 70 percent of our surface water. Yet, in the past 30 years Colorado has warmed substantially, bringing earlier snowmelt, shifting peak runoff by as much as a month, and increasing drought severity.[2] At the same time, demands for water resources continue to increase as populations grow and warmer temperatures drive up crop irrigation requirements. While Colorado is no stranger to a variable climate, these trends are likely to continue and may become more pronounced in the coming decades as Colorado warms an additional 2.5ºF to 5ºF by mid-century.[3]

The ability to adapt and remain flexible is the key to increasing Colorado's climate resiliency in the water sector. How we use and manage our limited water resources will determine our ability to respond and react to the effects of climate change. Adaptation in the water sector can come in many forms, from infrastructure and regulatory changes to better integration of science into Colorado's Water Plan. Proactive and integrated planning, collaboration and implementation will increase our options as effects become more apparent in the future.

2.1 WATER SUPPLY

Four major river systems have headwaters in Colorado (the Arkansas, the Colorado, the Platte, and the Rio Grande),[4] producing approximately 15 million acre-feet of water annually. Of that we consume roughly 5 million acre-feet, and the other 10 million acre-feet flow out of Colorado to 18 downstream states and Mexico. The majority of water, 89 percent, is consumed by agriculture; municipalities consume 7 percent, while large industry consumes the remaining 4 percent.[5] Large swings in Colorado's water supply from year to year are common, and a series of reservoirs exist to hold water from winter and spring precipitation and deliver it when demand is greatest, during the summer months. However, climate change threatens to alter how and when precipitation falls in the state, and warmer temperatures will affect runoff, stream flow, evaporation and soil moisture. Examining how our most precious natural resource will be affected and working to conserve and adapt where necessary will help to ensure a more secure water future.

Over the past seven years, the CWCB has produced or participated in several studies and assessments of how water resources will be impacted by climate change, with those findings reported in: *Climate Change in Colorado*,[6] *The Colorado River Water Availability Study*,[7] *The Joint Front Range Climate Change Vulnerability Study*,[8] the *Colorado Drought Mitigation and Response Plan*,[9] the *Colorado River Basin Water Supply and Demand Study*,[10] and *Colorado's Water Plan*.[11]

The most likely impact on water supplies from climate change will be a shift in the timing of runoff. Projections indicate that runoff timing will shift an additional one to three weeks earlier by mid-century because of increased temperatures.[12] This may affect water-right holders who traditionally divert surface water during the crop growing season, for example, or those with limited access and rights to water storage options. It is also likely to result in decreased late-summer streamflow because of both increased temperatures, resulting in earlier snowmelt, and the projection that precipitation is likely to increase in the winter months but decrease in the summer months.[13] At the same time, increased population, higher crop irrigation requirements, and longer growing seasons will put additional pressure on a changing water supply.[14]

While projections of future precipitation change do not agree about whether Colorado's annual precipitation will increase or decrease, the future warming—which is shown in all projections—will reduce the runoff produced for a given amount of precipitation. Therefore, the projections show a tendency towards decreasing future annual streamflows for all of Colorado's rivers.[15] Runoff and streamflow may be further altered by the presences of dust-on-snow events that lead to early snowmelt.

In addition to changes in runoff caused by warming, the widespread tree mortality caused by bark beetle infestations in Colorado's lodgepole pine and spruce forests has likely affected both the amount and timing of runoff, as well as water quality, in the most-affected watersheds.[16] Working to preserve and improve forest and ecosystem health will help protect our watersheds and have beneficial effects on both water quality and supply. Ecosystem health is further discussed in Chapter 8.

2.1.1 INFRASTRUCTURE

Colorado has an extensive system for water storage and distribution. This system is necessary given that the majority of our surface water originates west of the continental divide, while the majority of the demand for water consumption is located east of the divide. Much of the infrastructure built to move and hold water was constructed before 1970.[17] Older, more weathered, infrastructure subjected to high climate variability may be strained as soils move and shift because of saturation, drying and freezing. Maintaining and improving upon this network comes with great challenges and investment requirements independent of climate change; yet, this becomes increasingly more important under a changing climate. Proactive leak detection and regular maintenance on distribution systems can help to ensure that Colorado's water delivery infrastructure remains viable even under severe conditions. As municipalities make improvements to their water, wastewater, and storm water systems, they should consider projected climate change effects in the engineering and design to the extent practicable. Making small incremental changes year by year, and building systems that can be adapted over time, can be a cost-effective and practical way to increase the resiliency of these systems. If utilities are building new infrastructure, variations as a result of climate change should also be considered to the extent practicable. Colorado offers assistance to water providers and communities who wish to improve their water efficiency through the Water Efficiency Grant Fund, Energy/Mineral Impact Assistance Fund and low interest loans for raw-water projects.[18] Federal agencies have also begun to invest in improving the resilience of our nation's water infrastructure through programs such as the Environmental Protection Agency's Climate Ready Utilities and the Bureau of Reclamation's Water Smart initiatives.[19]

Stretching existing supplies through reuse and water sharing agreements will provide more options to meet demands in the future and temporarily supply water from one region or sector to another. A few major potable reuse projects have been completed in Colorado, and momentum toward researching direct potable reuse as a source of supply is increasing. Water reuse can fill a critical gap in water supply availability, but better understanding is also needed of how reuse may decrease return flows and impact downstream users.[20] Nevertheless, these are also subject to effects of climate change, and that should be closely examined before enacting agreements.

In addition, the variability that exists in Colorado's climate, with both floods and droughts commonly occurring, Colorado may require additional storage. Increased storage will enable water to

be held during times of surplus and released when demand is greatest. This could substantially aid users, such as farmers and municipalities, who have the greatest demand for water in the summer months when peak runoff has already passed. Because of the challenges that exist in building new reservoirs, additional storage may instead come from enlargement or reallocation of existing reservoirs, thereby making better use of infrastructure already in place. Dam enlargement can be less costly, less environmentally harmful, and somewhat less contentious than construction of entirely new storage facilities—making it a more ideal solution to meet our needs for additional storage. The Colorado Division of Water Resources is analyzing opportunities throughout the state where enlargement potential exists.[21] Further exploration of these opportunities may help increase the state's climate resilience. Climate change should be considered to the extent practicable to maximize the usefulness of the overall project goals and objectives.

Efforts to decrease the amount of energy and greenhouse gases required for water transport should also be considered to reduce overall emissions. The energy-water nexus is complex as production of one depends on the other. Water is often used to generate power, and power is often required to move and treat water. How we untangle this nexus in the coming years may influence overall emissions. Further discussion of the nexus between water and energy is included in Chapter 4.

As utilities seek new supplies they must also meet environmental regulations that are predicated on fixed regulatory standards that may become more difficult to comply with in a warming climate. For example, utilities must abide by the Safe Drinking Water Act as well as the Clean Water Act, both of which set standards that are likely to be affected by a warming climate. In some instances, such as with Maximum Contaminant Level, the United States Environmental Protection Agency has the ability to make modifications that will afford utilities more flexibility to adapt to climate change, while in other instances increasing flexibility would require changes to existing law. The state should work with utilities and federal agencies to proactively identify and address these concerns and streamline processes.[22]

As Colorado works to ensure a secure water future, we do so with a long history of dealing with uncertainty. Economics, population, and land use are all elements we have factored into long term planning in the past. Now as we continue moving forward we must factor in the uncertainties that a changing climate also brings. Scenario planning, a technique used by Colorado's Water Plan, is a comprehensive way to look at and better understand the array of uncertainties we face concerning our water future. As a result, climate change is an integral element sewn throughout Colorado's Water Plan.

To better understand where we are going we also need the data to understand where we are, consequently, we should invest in and maintain a climate-monitoring network for Colorado to provide complete and accurate data to compare to the projected changes. Quality data on current and past conditions will help us to make more-informed policy decisions, provide a glimpse of our trajectory, and guide us how to best prepare. This is especially relevant for the management of our limited water resources, which are unique in that they have the ability to affect "almost all aspects of society and the economy, in particular health, food production and security, domestic water supply and sanitation, energy, industry, and the functioning of ecosystems."[23] Currently, Colorado has a patchwork of monitoring stations unevenly distributed across the state, whereas neighboring states, such as Oklahoma, have a comprehensive system designed to measure weather events at a county or sub-county level.[24]

2.2 WATER DEMANDS

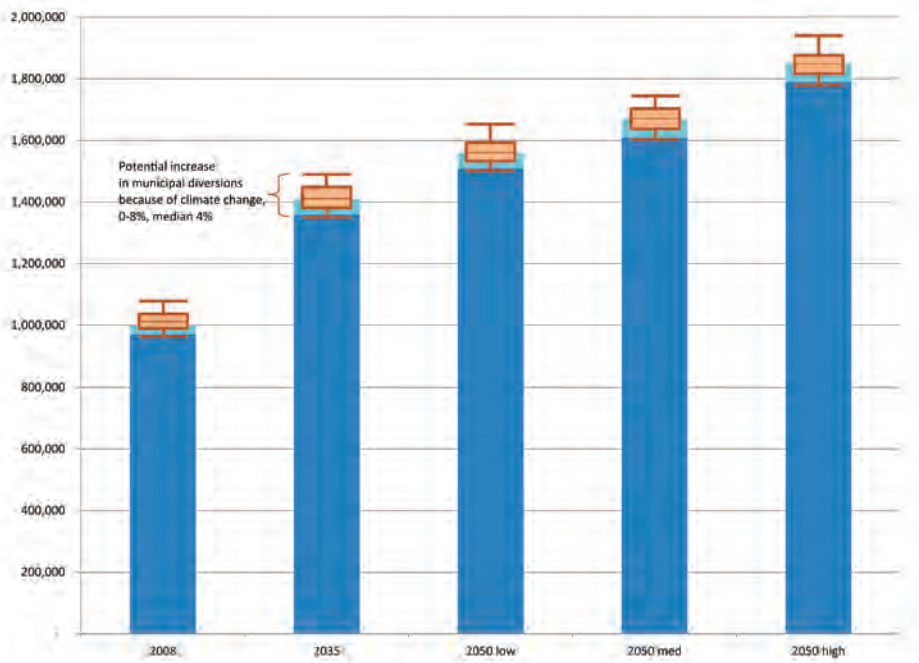
Colorado's greatest water demands come from agriculture and municipalities, both of which are sensitive to weather conditions during the summer months when demand is the greatest. As temperatures increase both sectors will experience increases in demand as a result. The degree to which climate change could impact demands varies across the state because of differences in climate zones, outdoor irrigation requirements, potential temperature increases, and potential changes in precipitation.[25]

The effects of climate change on annual municipal diversions (in acre-feet) are projected to range from 0-8 percent (Figure 2-1).[26] If Colorado experiences a future where population increases, the climate warms, and precipitation decreases (a scenario developed by the Interbasin Compact Committee and known as hot growth),[27] an additional million acre-feet annually may be needed by mid-century to meet demands. However, if Colorado experiences slower population growth coupled with historical temperature conditions, the additional annual demand, beyond 2008 levels, is approximately 600,000 acre-feet.[28] This represents both indoor and outdoor demands.

Figure 2-1

Projected change in municipal water diversions (acre-feet) with range of climate change increases.

This graphic illustrates increases in projected municipal diversions as a result of population growth (dark blue bar). The box and whisker plots show the possible range of increase from climate change, 0-8 percent, while the light blue box represents the median projected increase of 4 percent.



As temperatures warm urban grasses will also require more water under increasing evapotranspiration rates, affecting irrigation requirements for municipal outdoor irrigation demands. Adapting to lower water use vegetation may help to alleviate pressure on municipal water providers. Acceptance of these landscapes has grown dramatically over the last 15 years as Colorado municipalities have increased their education and outreach resulting in increased water use efficiency. Nevertheless, as density continues to grow so too will overall demand for water. Increased water-use efficiency will help to ensure that resources are used wisely. Colorado municipalities have made great strides on this front over the past 10 years, decreasing their per-capita demands by approximately 20 percent, integrating long range demand planning into broader water resource planning, and implementing water efficiency best practices at an ever-increasing rate.[29] Today, Denver Water, the municipal water provider for Colorado's largest metropolitan area, has a treated water demand that is less than the treated water demand of 1980, despite a steadily increasing population.[30]

Agricultural producers are perhaps the most aware of the importance of water and the impacts that occur when shortages exist. Working with producers and water providers alike to design flexible options that allow them to manage their water rights in ways that benefit their business, community, and land is also important as agriculture demands for water increase under altered climatic conditions.

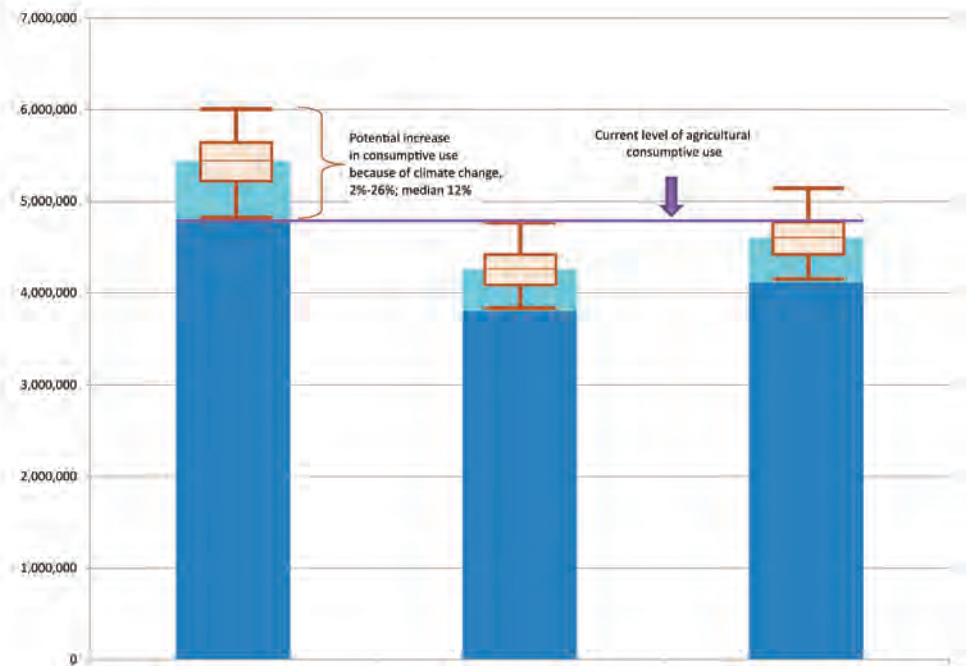
While variability will exist across the state, higher temperatures and longer growing seasons in the future could increase water consumption anywhere from 2 to 26 percent on agricultural lands in production (Figure 2-2).[31] More frequent or severe droughts could also affect agricultural production and slow economic agricultural activity. During the 2012 drought, the state experienced foregone agricultural revenues of $409 million and an additional loss of $317 million in secondary spending in local communities.[32]

In western Colorado, crops alone are likely to see an increase in annual irrigation requirements ranging from eight to 29 percent on average by 2040 and 20 to 43 percent on average by 2070.[33] This is in part a result of a longer growing season that may extend anywhere from a week to more than a month.[34] In some regions of the state, a longer growing season may result in increased agricultural production provided adequate water is available. This may help to bolster local economies and increase food security. However, in areas where sufficient water is not available this increase in crop irrigation requirements could affect producer's ability to sustain some crops.

Figure 2-2

Projected agricultural water demands (acre-feet) with range of climate change increases.

This graphic illustrates increases in projected agricultural consumptive use water demands as a result of climate change (light blue box) in addition to crop consumptive demands (dark blue bar). The decline in the dark blue box illustrates the projected decrease in agricultural production acres over time. The box and whisker plots show the range of increase from climate change, 2-26 percent, while the light blue box represents the median projected increase of 12 percent, which is the "low agricultural use" scenario falls below current levels of agricultural consumptive use.



2.3 WATER QUALITY

Water quality and water quantity are inextricably connected; both are vital for Colorado's future. Managing both conjunctively is important for the continuation of the state's healthy environment, diverse economy, and quality of life. It is not sufficient just to have enough water, but that water also has to be of high enough quality for the many ways Coloradans use it, from drinking and wildlife protection to agriculture and recreation. This is especially true given climate projections that include potential water quality impacts on Colorado's water supply.[35]

While location-specific effects are difficult to ascertain with available data, broader analysis shows that warming air temperature, changes in streamflow timing, decreased streamflow, increased stream and lake temperature, and an increase in wildfire and other watershed disturbances could have the following effects:

- Higher concentrations of pollutants including metals, sediment, nutrients, and salinity.[36]
- Impairment of aquatic organisms that live in coldwater habitats such as trout.[37]
- Increasing the range of non-native fish species into coldwater habitats that may harm native fish species through increased predation and competition.[38]
- Increasing levels of organic matter such as algae and thus increased disinfection byproducts that are costly to remove to meet drinking water quality standards.[39]
- Increases in erosion and sediment transport.[40]
- Changes in nutrient and sediment loads.[41]

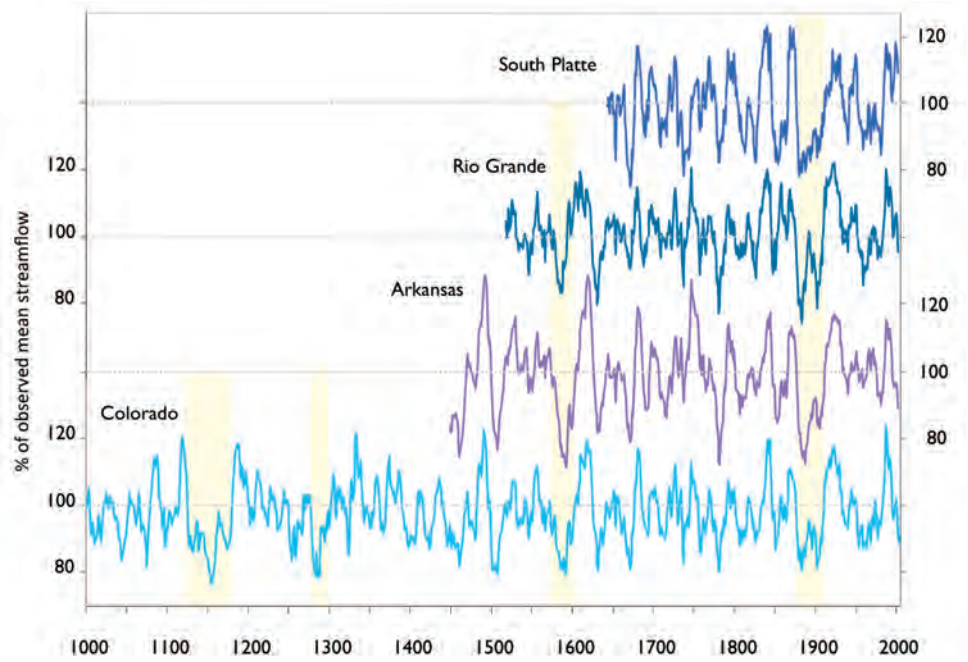
At the state level, water quality and quantity are managed separately based on different constitutional, statutory and regulatory provisions. However, state and federal statutes that protect in-stream water quality recognize the importance of protecting water rights while still providing the authority to impose water pollution controls. The federal statute protecting drinking water quality also recognizes integration with water quantity by including protections for source water that reduce treatment costs. Over the past 40 years, Colorado water quality management programs have benefitted exercising water rights by ensuring clean water for uses such as growing crops, providing drinking water, and enjoying water-based recreation. Multiple state agencies work collaboratively to address potential impacts to water quality from climate change.

As Colorado prepares for potential climate change impacts, improved integration of water quality and quantity planning and management activities is crucial. Opportunities to minimize future impacts must be prioritized to ensure Coloradans continue to have access to safe and clean water. Locally, watershed coalitions exist in some areas to address overall watershed health and restoration

Figure 2-3

Tree-ring reconstructed streamflows for four major Colorado river basins

Tree-ring reconstructed water-year streamflows as percent of observed mean, showing the 10-year running average, for four gages representing major Colorado basins: the Colorado River at Lees Ferry, AZ (762–2005, here shown from 1000–2005), the South Platte River at South Platte, CO (1634–2002), the Rio Grande at Del Norte, CO (1508–2002), and the Arkansas River at Salida, CO (1440–2002). All four records show the occurrence of droughts before 1900 that were more severe and sustained than any modern droughts. The yellow shading highlights several notable multi-decadal paleodroughts, in the mid-1100s, the late 1200s, the late 1500s and the late 1800s. The 20th century was unusual in having two persistent wet periods and no droughts longer than 10 years.



Source: Lukas, Climate Change in Colorado, 2014; Data: TreeFlow web resource; http://treeflow.info

in a multi-stakeholder, multi-objective manner.[42] At the state level, Colorado state agencies will work with regulators to modify existing standards that are set on static climate conditions, such as streamflow temperatures, so that those being regulated are able to reasonably meet the rules under a changing climate.

2.4 EXTREME EVENTS

In nine out of every ten years, a portion of the state experiences some level of drought conditions.[43] While some type of flooding occurs every year in our state, major flood disasters strike less frequently; on the order of once every decade.[44] These extremes carry natural, economic, and societal burdens; and it is important to understand how climate change may affect the frequency, duration, and intensity of these natural hazards.

Globally, models indicate that the frequency and magnitude of extreme precipitation is projected to increase.[45] The projections for Colorado generally indicate that cool-season heavy precipitation events will follow this global tendency towards increasing frequency and magnitude in the future, but summer extreme precipitation events may not increase. And our paleoclimate record shows droughts that are longer lasting and more intense than those experienced in the Twentieth and early Twenty-First centuries (Figure 2-3),[46] Coupled with increased temperatures that indicate more drought, longer growing seasons and higher levels of evapotranspiration, these projections reinforce that the past should not be the only mechanism used to plan for the future and that planning for multiple possible futures with a range of variability will increase overall preparedness.

When flood and drought extremes are directly examined under future climate conditions, considerable variability exists across the state. On the Colorado River at Cameo, the average intensity for drought events is somewhat greater than the historical intensity (-24 percent versus -19 percent respectively); while the intensity of surplus spells is considerably lower than the historical surplus (27 percent versus 46 percent respectively). When the range across the different climate projections is considered, future projected drought intensities for the same length event range from -19 percent to -32 percent; while surplus intensities range from 17 percent to 38 percent. The frequency of such events depends on which climate projections are used.[47] In most projections, droughts become more severe, and wet spells are not as wet, compared to historic conditions.

This range of uncertainty can make planning difficult, but it is certain that these extreme events will continue in Colorado. Being prepared for a variable climate will increase our resilience going forward. For example, the Colorado Water Plan uses a scenario approach to plan for multiple plausible futures; this approach helps to ensure that the state is prepared for whatever future is realized. In addition, the state offers drought planning and implementation grants through the Water Efficiency Grant Fund,[48] tools and resources, and technical assistance for improved drought preparedness. In addition, the Colorado Resiliency and Recovery Office is spearheading efforts to help communities increase their resilience through the development of a statewide resiliency framework that will guide Colorado's ongoing support of local resiliency planning and implementation efforts. These efforts include recovery from recent and future disasters as well as everyday activities that set communities up to thrive and minimize impacts amidst changing conditions and threats. The framework represents the states long term commitment and investment into a resilient future in the face of extreme events and will serve as a resource for local communities, businesses, and individual citizens. Resiliency requires coordination and collective action from a multitude of stakeholders this framework will serve to support, cultivate and empower a culture of resiliency in Colorado. The Framework provides a starting point to guide activities that will be undertaken and climate change is a piece of this.[49]

2.5 STRATEGIES AND POLICY RECOMMENDATIONS

There are opportunities to develop strategies and incentives that help to build a more resilient Colorado under a changing climate. Colorado's Water Plan describes water policies aimed at increasing climate resilience within Colorado's water sector. The following are possible approaches that support the work and build on the foundation laid by Colorado's Water Plan. They are listed in no particular order.

- Promote and encourage water efficiency and/or conservation at the local and state agency level.
- Encourage water providers to do comprehensive integrated water resource planning, geared toward implementing the best practices at the higher customer participation levels to achieve state endorsement of projects and financial assistance.
- Support water sharing agreements where feasible and cost effective.
- Explore options to increase reuse of fully consumable water.
- Encourage opportunities for reservoir enlargement statewide (where feasible and cost effective) that could be used for municipal, agricultural, recreational and environmental purposes.
- Support improvements in Colorado's water infrastructure system by providing low-interest loans and grants, and encourage partnerships and resource-sharing with federal agencies.
- Promote and encourage drought preparedness through comprehensive drought planning and mitigation implementation.
- Identify climate change risks related to integrated water quality and water quantity management.
- Incorporate climate variability and change into long-term, statewide water planning efforts.
- Work with regulators to modify existing water quality standards to factor in climatic change into regulations.
- Work with utilities and federal agencies to identify and address regulatory barriers to climate preparedness and adaptation.
- Assist local communities in building resilience through the development and implementation of regional and local resiliency plans.
- Collaborate across jurisdictions to protect and restore ecosystems associated with healthy watersheds Fund and enhance existing weather monitoring systems.
- Fund and enhance stream and lake quantity and quality monitoring.

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3

Public Health

As a national leader in the response to climate change, Colorado has taken proactive steps to reduce GHG emissions. The state has enacted innovative legislation, regulations, and policies at the state and local level that have done so cost effectively. Colorado is rightfully proud of its success.

The EPA stated in 2009 that without effective adaptation, climate change is likely to affect public health.[1] Air quality, water quality, vector-borne disease, and extreme weather events are all areas of public health concern.[2] While some uncertainty exists regarding the direct correlations between climate change and public health, Colorado is working proactively on a number of fronts to ensure the protection of public health and the environment.

This chapter discusses Colorado's current and proposed strategies for mitigating and adapting to climate-related public health effects. These strategies include GHG and air pollution reduction strategies, environmental policies and regulations, monitoring, public outreach, and emergency response. Water quality is addressed in Chapter 2. Some strategies mitigate the full spectrum of public health effects by reducing GHG emissions, while others address specific public health concerns. Colorado uses data from its recently updated GHG inventory (which summarizes the amount of greenhouse gases released into the atmosphere) and from other sources to develop these initiatives.[3] Colorado will continue to assess the effectiveness of its mitigation and adaptation measures and refine them as appropriate.

3.1 ACTIONS TO MITIGATE GREENHOUSE GAS EMISSIONS

3.1.1 ELECTRIC GENERATING UNIT REGULATIONS

Fossil-fuel-fired electric generating units (EGUs) are the largest source of GHG emissions in the United States and in Colorado. In June 2013, the Obama Administration released the President's Climate Action Plan, a major component of which is to reduce carbon dioxide emissions from fossil-fuel-fired EGUs.[4] The EPA responded in part by adopting a Clean Power Plan on August 3, 2015 to reduce GHG emissions from existing EGUs and simultaneously adopting carbon limits for new, modified and existing EGUs.[5]

EPA's regulations require certain new fossil fuel-fired EGUs to either use natural gas combined cycle technology or to use partial carbon capture and storage for new coal-fired EGUs under Section 111(b) of the Clean Air Act.[6] On

August 3, 2015, the EPA finalized guidelines for existing EGUs.[7] These guidelines are based on Section 111(d) of the Clean Air Act, and as a result, the EPA's Clean Power Plan is sometimes referred to as "Section 111(d)."[8] Colorado must adopt a plan to implement the EPA's Section 111(d) standards for existing units, or the EPA may impose a federal plan to do so. The Clean Power Plan imposes state-by-state carbon dioxide reduction goals for existing EGUs. Under the EPA's proposal, Colorado must either reduce the rate of carbon dioxide emissions from covered existing fossil fuel-fired EGUs to 1,174 pounds of CO_2 per megawatt hour of electricity by 2030, or reduce the mass of carbon dioxide emissions to 29,900,397 short tons per year by 2030.[9] Based on EPA's adjusted 2012 baselines, the CDPHE calculates that these targets represent a 38% reduction in the rate of carbon dioxide emissions or a 31% reduction in the mass of emissions. This represents a substantial reduction from the largest source of GHG emissions. Colorado's early actions have put the state in a better position to meet the EPA's emission reduction goals. The CDPHE has already begun to engage with the Public Utilities Commission, the CEO, and stakeholders to craft and promulgate a plan that meets federal requirements and substantially reduces GHG emissions from Colorado EGUs in a cost effective manner. Through this process, which will expand to include the public at large, these agencies will analyze direct EGU emissions and the reductions achievable from renewable energy and energy efficiency. The CDPHE anticipates requesting an extension under the EPA's proposed timeline and would adopt a state plan no later than September 6, 2018. This initiative will be one of the largest GHG reduction strategies for Colorado in the coming years.

In addition, as described in Chapter 4, EGUs must comply with the state RES, demand side management (energy efficiency) programs, and the Clean Air – Clean Jobs Act. In 2012 alone, these programs avoided more than 5.5 million tons of carbon dioxide emissions,[10] nearly 14 percent of the 2010 carbon dioxide emissions from Colorado EGUs.[11] These programs simultaneously achieved major reductions of conventional pollutants. Many EGUs are subject to additional emission limits under the Regional Haze Rule, a program to improve visibility in national parks and wilderness areas.[12] By 2018, Colorado's regional haze implementation plan will result in approximately 70,000 tons of pollutant reductions annually, including approximately 35,000 tons of nitrogen oxides,[13] a pollutant that directly affects visibility and public health and is also a precursor of ozone.

3.1.2 OIL AND GAS REGULATIONS

Colorado has comprehensive regulations that reduce emissions of all pollutants from the oil and gas sector, simultaneously protecting public health and avoiding GHG emissions. These regulations include permit requirements, New Source Performance Standards (NSPS), National Emission Standards for Hazardous Air Pollutants, and the state's Ozone Action Plan, among others.[14] Colorado was one of the first states to require "green completions" of oil and gas wells, thereby reducing emissions from wells after they are hydraulically fractured.

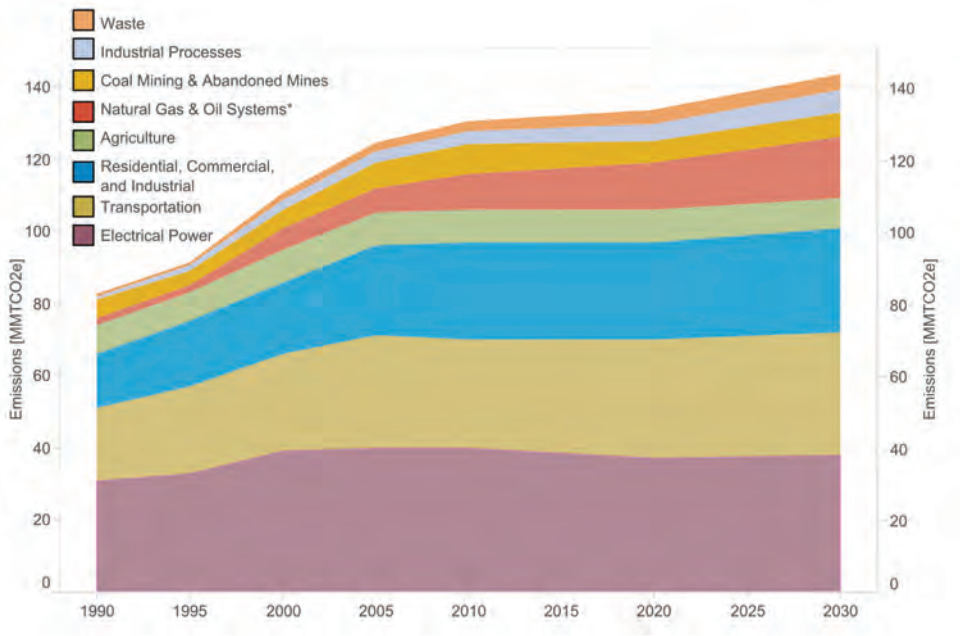
In 2014, the Colorado Air Quality Control Commission updated its Regulation Number 7 to directly limit emissions of all hydrocarbons, including methane, and not just traditional pollutants.[15] Colorado is the first state in the nation to directly regulate oil and gas methane emissions in this manner. The rule revisions require oil and gas facilities to detect and repair leaks using infrared cameras or other approved instrument technologies. These changes are being phased in over time and will take full effect by 2016. Regulation 7 will reduce methane, ethane, and volatile organic compound (VOC) emissions from new and existing facilities across the state. Approximately 65,000 tons per year of methane and ethane will be prevented from entering the atmosphere, directly and permanently reducing emissions of GHGs. The new regulations reduce emissions of VOCs, another ozone precursor, by more than 93,000 tons per year.[16]

Regulation 7 operates in tandem with federal regulations governing the oil and gas sector. Following Colorado's lead, the EPA adopted an NSPS for this sector in 2012[17] that requires green completions at hydraulically fractured natural gas wells and imposes additional air quality requirements. In August 2015, the EPA proposed to expand its NSPS by directly regulating methane, requiring leak detection, and covering more types of oil and gas facilities.[18] EPA estimates that its proposal would reduce nationwide methane emissions by 340,000 to 400,000 short tons in 2025. The CDPHE will evaluate EPA's proposal in light of Colorado's experience, and may submit comments to EPA or revise Colorado's regulations as appropriate.

Figure 3-1

Summary of Colorado GHG Emissions by Sector ($MMTCO_2e$).[24]

*Modified to account for Colorado Oil and Gas Conservation Commission well counts.



3.1.3 GHG REDUCTIONS FROM LANDFILLS

Municipal solid waste landfills emit gas that is rich in methane and contains some hazardous air pollutants. The EPA adopted regulations in 1996 requiring landfills to capture or control landfill gas emissions.[19] On August 14, 2015, the EPA proposed changing its regulations to cover additional landfills. Compared to current requirements, the 2015 proposed rules would reduce nationwide methane emissions from new and existing landfills by a total of about 487,000 metric tons per year, beginning in 2025. This is the equivalent of about 12.2 million metric tons of carbon dioxide per year. The proposed rules would also reduce emissions of volatile organic compounds, including some air toxics, by a total of approximately 3,100 metric tons per year.[20]

3.2 COLORADO GREENHOUSE GAS INVENTORY

Emission inventories summarize, by source, the amount of air pollutants discharged into the atmosphere during a given time period. They are an important part of Colorado's GHG mitigation and adaptation strategies. Inventories guide regulatory decisions and inform the public about the sources and magnitude of GHG emissions. The CDPHE updated the state's GHG inventory in 2014, as required by Executive Order.[21] The 2014 Update relies on 2010 data. The CDPHE solicited and responded to public comments when it prepared the 2014 Update. Figure 3-1 summarizes Colorado's GHG emissions.[22]

While the 2014 Update is Colorado's most recent and accurate inventory of GHGs, some of the state's numerous GHG emission reduction strategies are too recent to be accounted for. Part or all of the emission reductions achieved by the RES, the 2010 Clean Air – Clean Jobs Act, Colorado's 2014 oil and gas air quality rule-making (Regulation 7), and the EPA's Clean Power Plan are not reflected in the 2014 Update. Colorado anticipates that future inventories will reflect the benefits of these new programs, which are substantial.

The 2014 Update shows that power generation and transportation are consistently the two largest sources of Colorado's GHG emissions, with electrical power generation representing approximately 25-35 percent and transportation approximately 25 percent of GHGs (varies by year). The third largest sector, at approximately 20 percent, is residential, commercial, and industrial fuel use.[23]

Carbon dioxide is by far the largest contributing GHG in the state, representing 75 percent of emissions in 2010, and is projected to remain at a similar percentage through 2030.[25] Methane is the next highest contributing GHG. Methane is emitted from many sources including coal mines, agriculture, and oil and gas facilities. Colorado's GHG inventories will continue to serve as a valuable tool for developing and refining regulatory measures.

3.3 CLIMATE CHANGE AND AIR QUALITY

3.3.1 OZONE

Ozone is a pollutant that causes airway inflammation, coughing, throat irritation, decreased lung function, and other respiratory symptoms. Emissions from automobiles, power plants, oil and gas facilities, and other human activities have raised ozone concentrations above naturally occurring background levels. Higher temperatures and climate change appear to be associated with increased ozone formation and increased emissions of VOCs, an ozone precursor.[26]

Colorado mitigates the effects of ozone through statewide regulations and an Ozone Action Plan that is designed to attain national ozone standards within the Denver Metropolitan Area/North Front Range non-attainment area.[27] The CDPHE adopted new requirements in 2014 to further reduce ozone concentrations[28] and is preparing to revise its State Implementation Plan (SIP). Many aspects of Colorado's ozone regulations also reduce methane as a co-benefit.

The CDPHE uses an extensive network of monitoring stations throughout the state to measure ozone concentrations. Data from the monitoring network facilitates both mitigation and adaptation. The CDPHE uses the data to issue Air Quality Advisories, an important adaptation tool that allows at-risk individuals to avoid exposure by remaining indoors during high ozone days.

The CDPHE is working with partners and stakeholders to revise Colorado's ozone SIP by 2016. The SIP must contain sufficient emission control measures to demonstrate attainment of the current ozone standard by 2017. The SIP must also achieve a 15-percent reduction in VOC emissions within the ozone non-attainment area between 2011 and 2017. The EPA is scheduled to update the federal ozone standard in October 2015. Colorado might need additional emission reductions if the standard is lowered.

3.3.2 PARTICULATE MATTER

Particulate matter is a mixture of small particles and liquid droplets in the air. Industrial facilities, automobiles, combustion, and even dust contribute to particulate matter. High levels of particulate matter in the atmosphere affect public health and welfare and can cause death among people with respiratory conditions. Dust storms related to high winds and increasingly dry soils occur more frequently in the southeast, south-central, and western slope regions of Colorado.[29] Figure 3-2 shows a severe dust storm, one of seven Colorado dust storms tracked during the winter of 2012-2013.

Figure 3-2

Haboob (Dust Storm) in Lamar, CO

Colorado mitigates these effects through statewide particulate matter regulations.[30] All areas of the state now meet federal health-based standards. Seven areas of the state where particulate matter previously exceeded national standards are now covered by State Implementation Plans to maintain continued compliance. Colorado regulates industrial facilities, street sanding and sweeping, wood burning, and other activities that emit or contribute to particulate matter in the atmosphere.

Colorado maintains a surveillance program to evaluate blowing dust and public health threats. This surveillance program has climate change applications.[31] Blowing dust advisories are issued to inform residents about these events. Each advisory suggests simple actions individuals can take to protect themselves and their families. The advisory protocols are incorporated into local air-quality plans.

The state will continue to implement its particulate matter regulations and plans in accordance with the Clean Air Act. The CDPHE will monitor, evaluate, and report events where particulate health standards are exceeded. The CDPHE will periodically revise Colorado's particulate matter regulations and State Implementation Plans and will adopt additional measures to reduce emissions as necessary and appropriate to meet air quality standards.

3.4 VECTOR-BORNE DISEASE

A number of studies have projected increased incidence of vector-borne diseases as temperatures warm because of climate change.[32] Studies indicate that the spread of West Nile virus is, in part, related to climatic conditions.[33] Hantavirus, and some tick-related diseases, have been associated with heavy rainfall and other meteorological factors.[34] There is uncertainty regarding these associations, and they vary depending on the specific vectors, meteorology, ecology and epidemiologic factors.[35]

State and local government agencies in Colorado work cooperatively to minimize the spread of vector-borne diseases. The CDPHE tracks a number of diseases and publishes an annual assessment.[36] Colorado has set a goal of developing an electronic disease reporting system to improve the state's ability to monitor, detect, and respond to outbreaks or unusual trends in infectious diseases.[37] Colorado will continue to evaluate disease rates and possible links to climate variables.

Prevention, monitoring, and reporting are important tools to mitigate and adapt to the effects of vector-borne diseases. Colorado will continue to notify the public of disease outbreaks and prevention techniques. If changes in the nature and extent of vector-borne diseases become apparent, mitigation and adaptation strategies will be coordinated into statewide plans as appropriate.

3.5 PUBLIC HEALTH ASPECTS OF EMERGENCIES AND DISASTERS

Colorado has experienced several natural disasters in recent years, including historic floods in September 2013 and a major drought and wildfires in 2012 and 2013. High temperatures present a public health concern because of the increased possibility of heat-related deaths or health effects, and in some cases constitute an emergency.[38] Colorado has experienced an increase in heat waves over the past 50 years and 30 years.[39]

In addition to their effects on physical health, natural disasters are associated with mental health problems.[40] Wildfires, floods, and severe weather can cause extreme anxiety or long-term mental health problems such as depression, post-traumatic stress disorder, or suicide. Longer lasting events, such as droughts, may also have adverse mental health effects.[41]

Colorado maintains a robust emergency response system that uses an all-hazards approach. These programs help Colorado mitigate and adapt to the public health effects of emergencies or disasters. The Colorado Department of Public Safety, Division of Homeland Security and Emergency Management (DHSEM), manages and coordinates emergency operations at the state level. The DHSEM implements a comprehensive all-hazards emergency management program that includes activities and services covering the five phases of emergency management: prevention, protection, mitigation, response, and recovery.[42] The DHSEM developed a State Emergency Operations Plan that identifies the roles, responsibilities, and actions of Colorado government in disasters. The State Emergency Operations Plan priorities for incident management include saving lives, protecting health and safety, mitigating the damages and effects of emergencies or disasters, and facilitating recovery, among others.[43]

Colorado follows the Emergency Support Function system, a response support system that assigns 15 Emergency Support Functions, such as firefighting, emergency management, and search and rescue, to appropriate agencies.

The CDPHE is the lead for State Emergency Support Function 8, Public Health and Medical. All resource requests come from local response efforts into the Emergency Support Function system, and the public health and medical components of those requests are then funneled to the CDPHE. These resource requests include, but are not limited to, technical support for behavioral health, disease surveillance and outbreak control, drinking water and wastewater, food safety, hazardous materials (including radiation materials), waste management, hospital resources and medical supply monitoring, ambulance transportation and patient tracking, and activation and deployment of the federal Strategic National Stockpile. For example, if hospital care is overwhelmed during a disease outbreak, the CDPHE identifies additional resources to help hospitals manage surge capacity.

3.6 STRATEGIES AND POLICY RECOMMENDATIONS

Colorado has extensive programs in place to reduce GHG emissions, mitigate public health risks, and adapt to a changing environment. Approaches to further promote climate resilience within the public-health sector are listed below.

- Coordinate with the Public Utilities Commission, the CEO, and additional stakeholders to develop and implement a Colorado-specific plan to substantially reduce carbon dioxide emissions from fossil fuel fired EGUs, in accordance with the EPA's Clean Power Plan.
- By 2016, adopt an ozone State Implementation Plan with sufficient control measures to demonstrate attainment of the current ozone standard by 2017.
- Fully implement Colorado's 2014 oil and gas emission regulations, evaluate the resulting reductions of methane and other pollutants, and evaluate potential refinements to those regulations.
- Continue to monitor and evaluate particulate matter levels and issue public health advisories as appropriate.
- Continue to assess potential correlations between vector-borne diseases and climate factors, incorporate the results into public health guidance, and communicate any revised risk reduction measures to local governments and the public.
- Emphasize climate-related disaster preparedness in emergency response plans and exercises.

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[2] U.S. Environmental Protection Agency, *Endangerment and Cause or Contribute Findings*, 69-79; National Research Council, *Advancing the Science of Climate Change,* National Academies Press (2010).

[3] CDPHE, "Colorado Greenhouse Gas Inventory – 2014 Update" (October 2, 2014), 3-4, https://www.colorado.gov/pacific/sites/default/files/AP-COGHGInventory2014Update.pdf.

[4] President's Climate Action Plan, Executive Office of the President (June 2013), https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf.

[5] U. S. Environmental Protection Agency "Clean Power Plan," accessed August 24, 2015, http://www2.epa.gov/cleanpowerplan.

[6] "Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units," 13-14, Aug. 3, 2015, available at http://www.epa.gov/airquality/cpp/cps-final-rule.pdf (Federal Register publication pending).

[7] "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units," Aug. 3, 2015, available at http://www2.epa.gov/sites/production/files/2015-08/documents/cpp-final-rule.pdf (Federal Register publication pending).

[8] 42 U.S.C. § 7411(d).

[9] U.S. Environmental Protection Agency, "Clean Power Plan: State at a Glance," Aug. 3, 2015, available at http://www.epa.gov/airquality/cpptoolbox/colorado.pdf.

[10] Unpublished data from Colorado Public Utilities Commission

[11] Colorado Greenhouse Gas Inventory – 2014 Update, 37 (Ex. 2-2).

[12] 40 C.F.R. § 51.308.

[13] CDPHE, "Colorado Visibility and Regional Haze State Implementation Plan for the Twelve Mandatory Class I Federal Areas in Colorado" (Rev. November 20, 2014), 159-63. https://www.colorado.gov/pacific/sites/default/files/AP_PO_Regional-Haze-State-Implementation-Plan-Nov-2014.pdf.

[14] Colorado Air Quality Control Commission Regulation Nos. 3, 6 and 8, https://www.colorado.gov/pacific/cdphe/aqcc-regs; "Denver Metro Area & North Front Range Ozone Action Plan" (December 12, 2008), https://www.colorado.gov/pacific/sites/default/files/AP_PO_Denver-Ozone-Action-Plan-2008.pdf.

[15] Colorado Air Quality Control Commission Regulation No. 7, https://www.colorado.gov/pacific/sites/default/files/5-CCR-1001-9_0.pdf.

[16] CDPHE Air Pollution Control Division, "Final Economic Impact Analysis for Proposed Revisions to AQCC Regulations No. 7" (January 30, 2014), 33.

[17] 40 C.F.R. Part 60, Subpart OOOO.

[18] U.S. Environmental Protection Agency, *Oil and Natural Gas Sector: Emission Standards for New and Modified Sources* (August 18, 2015), http://www.epa.gov/airquality/oilandgas/actions.html (Federal Register publication pending).

[19] 40 C.F.R. Part 60, Subparts CC and WWW.

[20] "Standards of Performance for Municipal Solid Waste Landfills," Aug. 14, 2015, and "Emission Guidelines and Compliance Times for Municipal Solid Waste Landfills," Aug. 14, 2015, both available at http://www.epa.gov/ttn/atw/landfill/landflpg.html (Federal Register publication pending).

[21] Executive Order D 004 08 (April 22, 2008).

[22] Colorado Greenhouse Gas Inventory – 2014 Update, 43 (Ex. 2-9).

[23] Colorado Greenhouse Gas Inventory – 2014 Update, 3-4.

[24] Colorado Greenhouse Gas Inventory – 2014 Update, 43 (Ex. 2-9).

[25] Colorado Greenhouse Gas Inventory – 2014 Update, 4.

[26] U.S. Environmental Protection Agency, *Endangerment and Cause or Contribute Findings*, 75-76.; Howard H. Chang et al., "Impact of Climate Change on Ambient Ozone Level and Mortality in Southeastern United States," *International Journal of Environmental Research and Public Health* 7:2866 (2010), 2866-2880, https://facultas.wordpress.com/2010/07/19/impact-of-climate-change-on-ambient-ozone-level-and-mortality-in-southeastern-united-states/.

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[41] OBrien, et al., *supra* note 42; Berry, et al., *supra* note 43.

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[43] Colorado Division of Homeland Security and Emergency Management, *State of Colorado Emergency Operations Plan 2013* (2013), 16, http://www.dhsem.state.co.us/emergency-management/operations/state-emergency-operations-plan.

4

Energy

Energy fundamentally shapes Colorado, from powering homes and businesses to the transportation of people and goods; it touches nearly every aspect of life. It is also a major economic driver in the state. In 2012, Colorado's energy industry employed more than 122,000 people.[1] It also produced more than $41 billion in revenue and $24 billion in exports.[2] Energy also affects the air we breathe and the water upon which we rely. The energy sector is unique in that energy-related activities are fundamentally linked to a changing climate. Through bipartisan legislation, responsible regulation, and groundbreaking programs, Colorado is working to promote innovative energy production and efficient energy consumption practices that benefit the economic and environmental health of the state and reduce its vulnerability to climate change. This chapter describes Colorado's electricity generation from fossil fuel and renewable resources, electricity demand and energy efficiency efforts, the water-energy nexus, transportation, and the efforts to reduce GHG emissions from energy production currently underway in Colorado. Recommendations for strategies and policies to continue addressing climate change within the energy sector also are provided.

Table 4-1

Cumulative Installed Renewable Energy Capacity in Colorado, 2013

Wind Power	2,332 MW
Solar Photovoltaic	360 MW
Solar Thermal Electric	4 MW
Geothermal Power	0 MW
Hydropower	650 MW
Biomass Power	18 MW
TOTAL	3,364 MW

Source: American Council on Renewable Energy (ACORE) Renewable Energy in the 50 States: Western Region. (September 2014)

4.1 ELECTRICITY GENERATION

Colorado's diverse portfolio of economically competitive energy resources for electricity generation includes both fossil fuel energy resources such as coal and natural gas, and a wide range of renewable energy resources. This diversity stems from the state's multitude of programs, policies, and financial incentives, including one of the most ambitious renewable energy standards in the nation. These initiatives are reducing GHG emissions from the power sector and are helping Colorado become a leader in clean energy.

4.1.1 RENEWABLE ENERGY

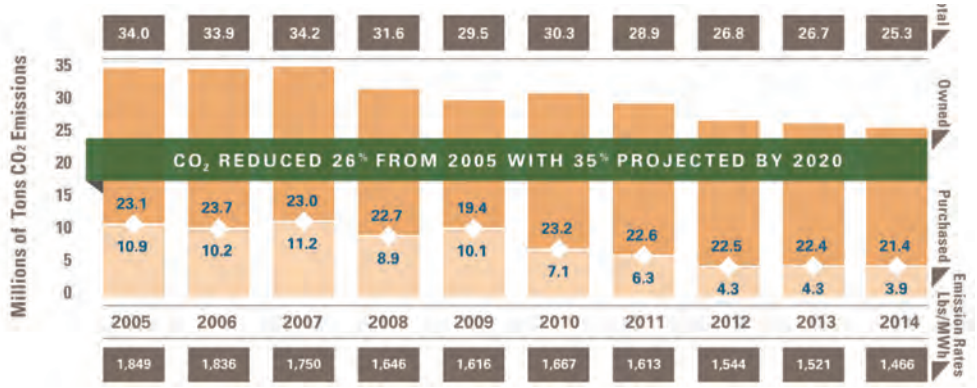
In 2004, Colorado passed the first voter-led RES in the nation, requiring electricity providers to obtain a minimum percentage of their power from renewable energy sources. The legislature has increased the amount of renewable energy required several times since 2004. HB10-1001 required investor-owned utilities to generate 30 percent of their electricity from renewable energy by 2020, of which 3 percent must come from distributed energy resources.[3] The most recent update, requires cooperative utilities to generate 20 percent of their electricity from renewable sources.[4] The RES has sparked the development of hundreds of new renewable energy projects across the state, generating thousands of jobs and helping to reduce the state's GHG emissions. As an example, Xcel Energy calculated that the combination of the RES, Colorado's demand side management requirements, and the Clean Air Clean Jobs Act (HB10-1365) avoided 5.5 million tons CO_2 emissions from utilities in 2012, with more reductions projected by 2020 (Figure 4-1).[5]

From the Eastern Plains to the mountainous West, Colorado has significant wind and solar resources throughout the state. Spurred in part by state policies and incentives, Colorado has one of the strongest renewable energy industries in the country, ranking eighth in the nation in 2013 for total solar capacity and tenth for installed wind generation capacity, with approximately 2300 MW of capacity.[6] Currently, Colorado's installed capacity of solar photovoltaic is 398 MW.[7] The ongoing development of this resource is supported by tax credits and utility rebates that encourage homeowners and business owners to install solar panels on their homes and businesses.

Colorado also is exploring opportunities for small-scale hydroelectric power, geothermal power, energy from biomass, and other innovative, renewable energy resources. Among these innovative technologies, small hydroelectric power has been the most widely adopted, with nearly 40 facilities with nameplates under 10 MW already operational in Colorado's mountainous western region.[8] The state is working to encourage further development of small-scale hydropower and hydromechanical projects through the Regional Conservation Partnership Program, which is made up of the Colorado Department of Agriculture, the U.S. Department of Agriculture Natural Resources Conservation Service-Colorado, Rural Development-Colorado, the CEO, and nine other partners. This team initiated the Hydropower Partnership Project, which facilitates the development of low-impact small hydropower on new and existing pressurized irrigation systems, making it easy for agricultural producers to use hydropower in their irrigation operations. The project aims to install 30 integrated hydromechanical or hydroelectric power systems across Colorado over the next four years.[9]

Figure 4-1

Xcel Energy's CO_2 Emission Reductions in Colorado



Source: "2014 Carbon Dioxide (CO_2) Reporting Worksheet" accessed April 29, 2015.

Anaerobic Digestion Helping Mitigation in the Agricultural Sector

The number of dairy farms in Colorado is steadily increasing, bringing new opportunities for biomass energy production. Waste disposal created by large livestock operations can create challenging environmental problems, but there are methods to reduce these negative effects and improve the environment. Sound manure management practices and investments in waste to energy facilities can create better air quality, reduce emissions of greenhouse gases, and improve groundwater quality.[a] Anaerobic digestion (AD) is of particular interest as a renewable energy source for the agricultural sector. A study done by the EPA in 2011 found Colorado to be in the top ten states for electricity production potential on dairy operations.[b] A recent market assessment conducted by graduate students at the University of Colorado identified the potential market size and areas in Colorado for AD projects. According to their findings, nearly 30 dairy farms have the potential economic feasibility for on-site digesters with co-digestion capabilities.[c] Based on EPA methane-reduction calculations for anaerobic digesters, this would result in a reduction of approximately 237,000 tons of CO_2 equivalency per year.[d]

These co-digestion systems would also divert approximately 363,000 tons of food waste per year, resulting in the removal of an additional 238,000 tons of CO_2.[e] A number of barriers and technological hurdles would need to be overcome to achieve the widespread use of AD systems. The barriers to on-site digesters in Colorado include manure-management practices, operation size, time and knowledge limitations, financing, and the need for additional feedstock. The CEO is currently working on an Anaerobic Digestion Toolkit for dairy farmers to use when considering the implementation of an AD system on their farm. Continued evaluation of the market is necessary to help advance the adoption of AD in Colorado's dairy industry.

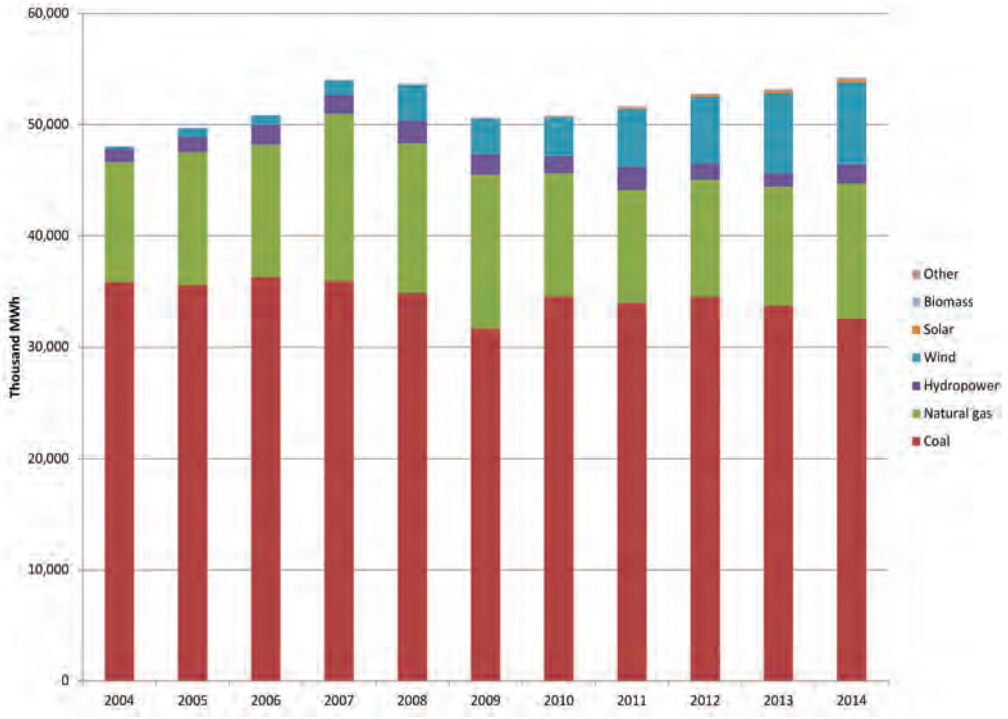
In fact, one of the country's largest digesters is already being built right here in Colorado. The Heartland Biogas Project represents a prime example of how waste-to-energy technology can offer new potential for waste management, renewable energy production, and GHG reduction for both our state and the US.

With six 1.7 million gallon digester systems, the project will work to convert feedstock from dairy farms into 4,700 MMBtu of raw biogas per day (in addition to various fertilizer-grade products).[6] The biogas is then supplied to the Sacramento Municipal Utility District after it has been processed into pipeline-quality renewable natural gas (producing an equivalent of 20 MW).[f] In addition to biogas, the project will create valuable peat moss, nutrient effluent, and soil amendments.[g]

The digester, which is being built near LaSalle in Weld County, is a joint project between EDF Renewable Energy and Heartland Renewable Energy.[h]

Figure 4-2

Colorado Annual Net Generation[11]



Colorado is home to world-class geothermal resources, which currently are used directly for pools, spas, greenhouse agriculture, aquaculture, space heating, and district-wide heating. According to the National Renewable Energy Laboratory, Colorado ranks fifth among the states in total heat energy available below a depth of 10,000 feet.[10] Colorado recently has made new investments to encourage geothermal electric and direct-use projects. In 2014, the state helped a project in Pagosa Springs to secure a $3.8 million grant from the U.S. Department of Energy. Additionally, the Colorado Energy Office coordinated with the DOLA to award that same project an Energy/Mineral Impact Assistance Grant totaling $1.8 million. This Pagosa Springs project plans to incorporate multiple revenue streams from agricultural greenhouses and the sale of electric power. Initial plans call for a 2-4 MW binary power plant to be constructed. This project is currently drilling test wells in identified locations to further the analysis of the resource.

Since 2004, when Colorado's RES was passed into law by voters, Colorado has increased the amount of renewable energy in the state (Figure 4-2) from 0.54 percent of total annual electricity generated to 14.36 percent in 2014.[12]

Table 4-2

Investor-owned Utility Energy Savings from Utility DSM programs 2009-2013

	2009	2010	2011	2012	2013	TOTAL	
Xcel Energy	219,611,146	252,014,416	311,643,169	400,675,909	384,229,680	**1,568,174,320**	Energy Savings (KWh)
	59,796	*67,373*	*75,659*	*90,647*	*81,040*	***374,515***	*Demand Savings (KW)*
Black Hills*		4,553,767	17,295,547	18,561,256	31,740,049	**72,150,619**	Energy Savings (KWh)
		1,157	*3,915*	*4,850*	*6,747*	***16,669***	*Demand Savings (KW)*
Statewide						**1,640,324,939**	Energy Savings (KWh)
						391,184	*Demand Savings (KW)*

**Black Hills reports data on non-calendar year cycle.*
Therefore, the data for 2010 represent 2009-2010 data, 2011 data represent 2010-2011 data and so forth.

4.2 ELECTRICITY DEMAND

Climate change will have a variety of physical impacts on Colorado's energy supply and demand. In particular, climate change has the potential to alter future electricity demands through long-term shifts and short-term perturbations. Energy efficiency will play a major role in helping to address any surge in electricity demand. Continued investment in energy efficiency programs will help the state prepare for any major impacts and shifts. Colorado's energy efficiency market has been an integral part of driving economic growth and bringing environmental benefits to the state. Through a variety of policy initiatives, programs, and financial incentives in the commercial, residential, agricultural, and industrial sectors, the state has demonstrated the value of energy efficiency investments.

4.2.1 ENERGY REDUCTION/EFFICIENCY

In 2007, the Colorado Legislature passed HB-1037, requiring investor-owned gas and electric utilities to develop demand-side management (DSM) programs to encourage energy efficiency. HB-1037 set goals for the reduction of electricity sales and electric-peak demand by 5 percent of the 2006 level by 2018. To meet these goals, utilities offer DSM programs that provide rebates to customers for the installation of energy efficiency measures in their homes or businesses. Since the programs began in 2009, Colorado's investor-owned gas and electric utilities have reduced electricity sales by 1,640,324 megawatt-hours (MWh) and electricity demand by 391 MW (Table 4-2).[13]

In addition to the DSM programs required by state statute, several Colorado's cooperative and municipal utilities have voluntary DSM programs. These energy efficiency policies and programs are driving energy savings and GHG emissions reductions in Colorado.

With residential buildings consuming 23.2 percent of the total energy in Colorado, the greatest opportunity for the state to conserve energy is increasing the efficiency of homes and buildings. By supporting the proper installation of just a few key technologies related to space and water heating, the state helps Colorado residents realize many benefits, including a 20 percent to 30 percent cost reduction on their monthly utility bill, improved indoor air quality, enhanced comfort and health and increased property value. The specific programs and initiatives driving this effort are detailed in the next column.[14]

- The Residential Energy Efficiency Program through the CEO focuses on increasing awareness and offering tools for Colorado residents to reduce energy bills and consumption. Offering a suite of incentives, programs and technical assistance, the residential program includes support for both newly constructed and existing homes:
  - Green Real Estate Initiative: More commonly known as the Green MLS (multiple listing system), this statewide initiative is designed to include energy efficiency and renewable energy upgrades into the searchable fields in the MLS that real estate agents use to help home buyers search for homes. Currently, 90 percent of homes in the state are listed on the MLS and include energy upgrades done to the home.[15]
  - Colorado Energy Saving Mortgage: Developed from HB13-1105, this program provides a tiered incentive (up to $8000) to encourage the purchase of highly efficient homes. Homes that qualify for the Energy Saving Mortgage are 30 percent more efficient on average than a new home equivalent.[16]
  - Energy Codes: The most cost-effective way to ensure the long-term efficiency of a home is to implement the most up-to-date building energy code that increases the minimum threshold for basic efficiency. The CEO and the DOLA have played key roles in code adoption by offering training to local code officials, contractors, designers, plan reviewers, and architects, ensuring that local jurisdictions have the capacity to review the new code and a workforce that can design and build according to the adopted code. The CEO and the DOLA also have developed an online toolkit to provide Colorado counties and municipalities with the tools and information needed to implement and benefit from the 2009 International Energy Conservation Code (IECC). Even without a 2009 IECC baseline code, 90 percent of all new homes built in 2014 met the 2009 IECC standards.[17]

Low-income households carry a greater energy burden than other households, often spending 10 percent to 15 percent of household income on energy compared to the statewide average of 3 percent to 5 percent.[18] The Low-Income Weatherization Assistance Program offered by the CEO provides energy efficiency retrofit services to income-qualified residents. In 2013-14, the Weatherization Assistance Program delivered services to 3177 eligible single and multifamily units throughout the state. The associated installed measures saved clients more than 490,000 therms of natural gas and more than 2 million kWh.

Since 1995, the state's Energy Performance Contracting Program, administered by the CEO, has been a valuable tool that 142 state agencies, schools, colleges and universities, and local governments have leveraged to finance energy efficiency improvements in public facilities. This innovative financing mechanism allows building owners to achieve energy savings without up-front capital expenses, making this a cost-effective business decision. As of June 2014, Colorado's energy performance contracting project investments total $447.4 million. These results rank Colorado third in total investments and fifth in per capita investments, according to the Energy Services Coalition's national Race to the Top. Additionally, energy performance contracting projects can be found in communities across 75 percent of Colorado's counties, guaranteeing more than $28 million in annual utility cost savings.[19]

Committed to ensuring that energy efficiency services are available statewide, the Colorado Dairy and Irrigation Efficiency Pilot Program was launched in 2014 to help make energy efficiency more accessible for Colorado dairy producers and agricultural producers using electrically powered irrigation. Working with a broad group of government, industry, and utility partners, the project is designed to address the barriers that prevent producers from investing in energy efficiency. By bringing existing resources and partners together and leveraging new funding, the state created a turnkey approach for the agricultural community. Through a third-party technical contractor, free energy audits and technical support were provided to 12 agricultural producers. Eight producers implemented improvements, investing $233,000 and leveraging $168,000 in incentives, including utility rebates. These improvements are projected to yield $47,000 in annual cost savings. Building on the success of the pilot project, a statewide program launched in 2015 that is available to all Colorado dairies and producers with powered irrigation.[20] In addition to providing turnkey energy efficiency services, the program provides preliminary renewable energy assessments for solar PV, solar thermal, and ground-source heat pumps to interested producers.

Transportation programs promote the adoption of alternative fuels to take advantage of Colorado's natural resources, lower fuel costs, reduce air emissions, and drive the market for clean technology. In 2013, the CEO and the Regional Air Quality Council formed a partnership to create Charge Ahead Colorado. Charge Ahead Colorado is designed to alleviate "range anxiety" by expanding electric vehicle charging infrastructure, thereby encouraging more consumers to consider purchasing an electric vehicle. Charge Ahead Colorado funded the installation of 92 stations, including 86 Level 2 chargers and six Level 3 fast chargers. In that same year, the Colorado legislature established an electric vehicle charging fund, supported by a portion of annual electric vehicle registration fees. Through these and other efforts, Colorado now boasts more than 170 publicly available charging stations. In addition, the State launched the ALT Fuels Colorado program in June 2014. It is aimed at expanding options for compressed natural gas-powered vehicles and fueling stations statewide. At the time, Colorado had only 18 publicly accessible compressed natural gas fueling stations, many of which were located within the Denver Metro and Front Range areas. By 2017, the program will have added between 20 and 30 additional publicly available compressed natural gas stations along major transportation corridors, thereby removing barriers to intrastate natural gas vehicle travel.[21]

4.3 WATER-ENERGY NEXUS

The "water-energy nexus" is the relationship between water and energy resources. Understanding the interactions, interdependencies, synergies, conflicts, and trade-offs between these two resources is necessary in identifying and implementing mutually beneficial strategies for their management and use.[22] Put simply, water conveyance requires energy, and energy production requires water.

There are two key strategies to pursue within the water-energy nexus:

1. Optimizing the efficiency of water use in energy production, electricity generation, and end use systems.
2. Optimizing the energy efficiency of water storage, treatment, distribution, and end use systems.

Electricity generation in Colorado totaled 5,524,000 MWh in 2013. The demand for power requires an annual consumptive use of more than 55,000 acre-feet of water, which represents one percent or less of Colorado's total consumptive use.[a]

While coal and natural gas are the primary fuel sources for electricity generation in Colorado, accounting for 65 percent and 20 percent in 2012, respectively,[23] each requires different amounts of water for their processes. Renewable energy generation can have some consumptive water use, depending on the technology, but overall renewable energy resources require substantially less water to operate than fossil fuel generation. In fact, solar requires no water and has helped Colorado save more than 300 million gallons of water since 2007.[24] Colorado's Renewable Energy Standard not only required utilities to generate a portion of their electricity from renewable sources, but also indicated that the measure would "minimize water use for electricity generation."[25]

Water also is used for oil and gas production and coal extraction in Colorado. There are more than 52,000 active oil and gas wells in Colorado. The primary uses for water are in the drilling and completion phases, including cooling the drill bit and bringing drill cuttings to the surface, as well as the hydraulic fracturing (fracking) process. The Colorado Oil and Gas Conservation Commission began requiring oil and gas operators to report the volume of fluids used in hydraulic fracturing in June 2012. It is estimated that 0.13 percent of Colorado's total 2012 water use was used for oil and gas development.[26] Most of the water in coal extraction is used for mining, washing, and transporting coal. There are nine actively producing coal mines in Colorado with an average consumptive water use of 165 acre-feet per year.[27]

The water-energy nexus also includes the energy that is required for water storage, treatment, and distribution, as well as water and waste-water treatment. Water supplies carry vastly different energy intensities, depending on where they originate and how they are conveyed. Some water supplies in Colorado are almost purely conveyed using gravity, while other supplies are very energy intensive, requiring a large amount of electricity to pump water from deep underground.[28]

To reduce the energy intensity of water use, water utilities in Colorado are implementing water conservation measures at the end-user level. An example of this is Denver Water's Conservation Plan, which includes residential and commercial rebates for water-efficient appliances and incentive contracts for indoor water-saving projects to help offset the cost of installing or upgrading equipment.[29] The state also offers programs such as the Water Efficiency Grant Fund to help communities develop water efficiency plans and Energy Performance Contracting and Energy Savings for Schools which address both energy and water usage.

4.4 ENERGY PRODUCTION (OIL AND GAS, COAL)

Colorado has a long history of energy production stretching back to the mid-nineteenth century. Coal mining began in the state at a small mine near Boulder in 1859,30 and an oil seep was found near Florence in 1860. While attempts to drill that site were unsuccessful until 1881, the Florence Field is the oldest continuously operating oil field in the United States.[31]

Today, mining and energy production is an important part of the state's economy, and Colorado is one of the nation's top energy-producing states. According to the Energy Information Administration, in 2013, Colorado was ranked sixth among states for production of natural gas,[32] seventh for production of crude oil,[33] and eleventh for production of coal.[34] In 2013, the mining sector (including oil and gas production) added nearly $20 billion to the state's economy through operations, investment, and production of minerals, oil and gas. That sector accounted for approximately 6.7 percent of the state's total economy in 2013.[35]

While energy production provides strong economic benefits to Colorado, the extraction of fossil fuels also results in the emission of greenhouse gases. Using the EPA's State Inventory Tool, the CDPHE estimates that methane emissions from coal mining and abandoned mines in 2010 was 7.54 million metric tons carbon dioxide equivalent ($MMTCO_2e$) (approximately 29 percent of Colorado's methane emissions), and emissions from natural gas and oil systems was 10.05 $MMTCO_2e$, which is approximately 39 percent of Colorado's methane emissions.36 Additional information on the state's GHG inventory can be found in chapter three.

[a] CEO calculations based on utility resource plans.

4.4.1 MITIGATION EFFORTS

Colorado has encouraged electricity generated from coal mine methane. In 2013, the Colorado General Assembly passed SB-252, which added electricity generated from coal mine methane as an "eligible energy resource" for Colorado's Renewable Energy Standard. Including coal mine methane in the RES encourages and incentivizes the development of projects to capture coal mine methane.

Colorado also has undertaken many efforts to reduce GHG emissions from energy production. For example, two mines in Gunnison County use mine methane to heat facilities and generate electricity. The West Elk Mine uses mine methane for heating, avoiding 18,800 $MTCO_2e$ in emissions annually,[37] and the Elk Creek Mine uses methane to generate electricity, avoiding 362,900 $MTCO_2e$ in emissions annually.[38]

Additionally, several state and federal regulations are likely to reduce GHG emissions from energy production. In 2014, Colorado adopted first-in-the-nation rules to reduce methane emissions from oil and gas development. In 2015, the Obama Administration announced an executive action directing the EPA to develop rules to reduce methane emissions from the oil and gas sector by 40 percent of 2012 levels by 2025. Further, EPA recently introduced regulations on CO_2 emissions from existing power plants. The Clean Power Plan is expected to bring down the rate of emissions from existing fossil fuel plans by 35 percent in Colorado.

4.5 STRATEGY AND POLICY RECOMMENDATIONS

- Assure the timely and complete attainment of the state's RES 2020 goals. Assist all utilities (investor-owned, municipal and cooperative) in identifying and implementing best practices for integrating cost-effective renewable resources, both utility-scale and distributed.
- Assist all electric utilities in incorporating all feasible energy efficiency activities into resource planning and EPA air quality compliance plans.
- Integrate cost-effective water savings into all energy efficiency programs administered by the state.
- Engage with energy companies to encourage and promote the most water-efficient technologies for energy extraction.
- Encourage energy companies to continue collaborating with agricultural and environmental interests when managing their water portfolio.
- Identify, test, and implement techniques to reduce water usage in the oil and gas industry through reuse of produced water. Focus specifically on options that yield both water and energy usage reductions.
- Aid in the commercialization of emerging electric generation technologies that reduce greenhouse gas emissions, such as coal mine methane capture, anaerobic digestion of agricultural waste, geothermal and small/micro hydro.
- Aid in the commercialization of clean technologies in the oil and gas development sector, such as methane capture, waste heat recovery and related technologies that increase efficiency and reduce adverse environmental impacts.
- Reduce market barriers to the development of all cost-effective and technologically viable alternatives to gasoline and diesel fueled transportation.
- Increase access to capital for commercial, residential, agricultural and industrial customers seeking to improve the energy performance of their facilities.

APPENDIX

Colorado Energy Efficiency Legislation (since 2005)

2005

SB05-143 Amendment 37 Renewable Energy Standards (adoption)
HB05-1162 Energy Efficiency Standards Appliances
HB05-1133 Energy Efficiency Program Funding
SB05-001 Optional Low Income Energy Assistance

2006

HB06-1200 Low-Income Energy Assistance Funding
HB06-1147 Gas Utility Energy Efficiency

2007

SB07-246 Create Clean Energy Fund
HB07-1281 Increase Renewable Energy Standard
HB07-1146 Energy Conservation Building Codes
SB07-051 High Performance State Buildings
HB07-1037 Natural Gas Utility Energy Efficiency
HB07-1309 Oil & Gas Interest School Energy Efficiency

2008

HB08-1387 Low-Income Energy Assistance Funding
HB08-1350 Facilitate Financing Renewable Energy Projects
SB08-184 Colorado Clean Energy Finance Program
SB08-147 Increase Energy Efficiency State Buildings
HB08-1270 CICs Allow Energy Efficiency Measures
SB08-078 Energy Efficiency Historical Preservation Grant

2009

HB09-1350 New Energy Jobs Creation Act
SB09-039 Conserve Energy Tiered Rates Incentive
HB09-1126 Encourage Solar Thermal Installations

2010

SB10-207 Finance State Energy Efficiency Projects
HB10-1365 Clean Air Clean Jobs
HB10-1331 Governors Energy Office Green Building Incentive Program
HB10-1328 New Energy Jobs Creation Act
HB10-1333 Green Job Colorado Training Pilot Program

2011

HB11-1160 Governors Energy Office Green Building Incentive Program

2012

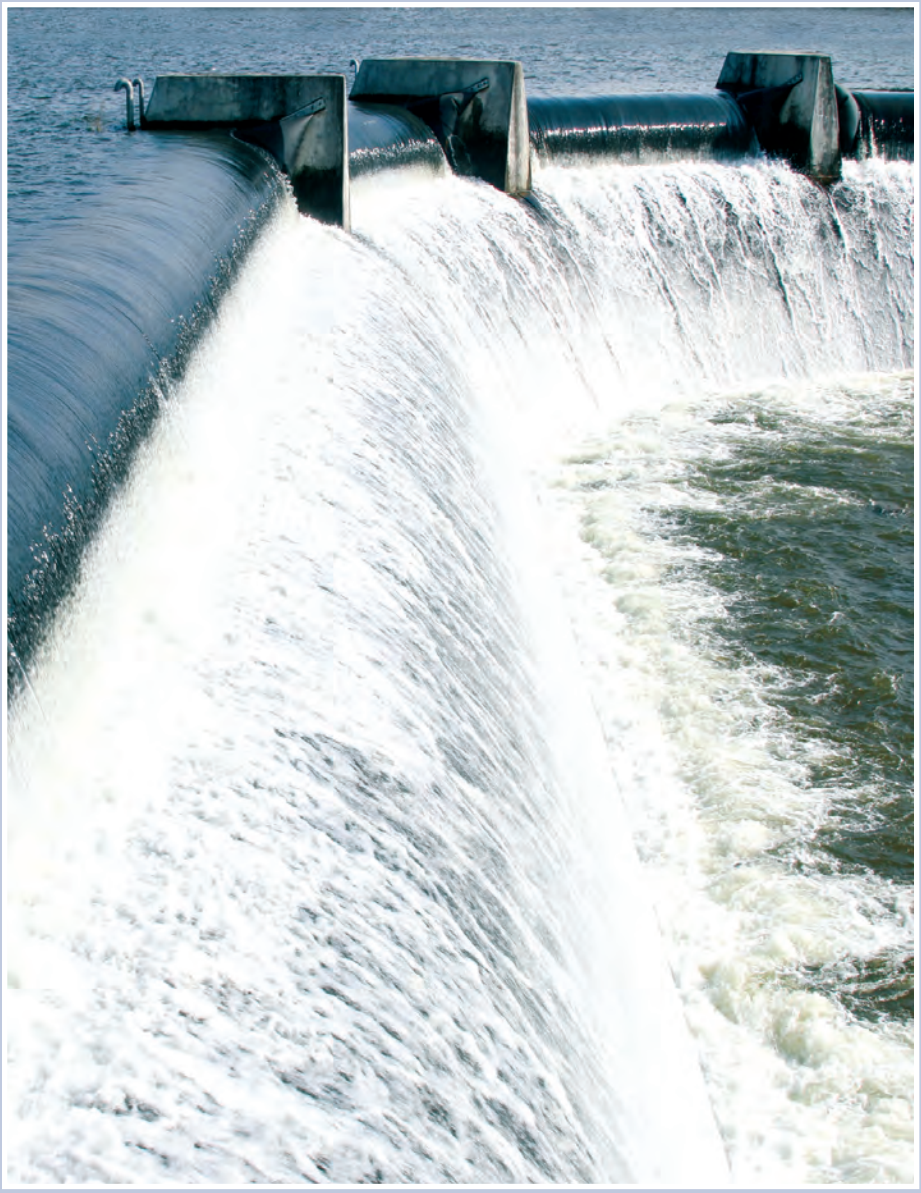
HB12-1315 Reorganization of Governor's Energy Office
HB12-1028 Continue Low Income Energy Related Assistance

2013

SB13-279 K-12 School Energy Resource Efficiency
SB13-212 Energy District Private Financing Commercial Buildings
HB13-1105 Energy Savings Mortgage Program
SB13-028 Track Utility Data High Performance State Buildings

2014

SB14-202 Funding For Energy Efficiency In Schools
SB14-186 Efficient School & Community Performance Contract



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[2] Colorado Office of Economic Development and International Trade (OEDIT), 2003–2013 data for Colorado from Economic Modeling Specialists International (EMSI).

[3] House Bill 10-1001, codified at § 40-2-124(1)(c)(I)(D), C.R.S.

[4] Senate Bill 13-252, codified at § 40-2-124 (1)(c)(V.5), C.R.S.

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Sidebar

[a] Laura Wolton and Sandra Lozo, *Colorado Market Assessment of Agricultural Anaerobic Digesters: Prepared for the Colorado Energy Office* (Boulder: University of Colorado – Boulder, 2014), 5. http://www.colorado.gov/cs/Satellite?blobcol=urldata&blobheadername1=Content-Disposition&blobheadername2=Content-Type&blobheadervalue1=inline%3B+filename%3D%22Anaerobic+Digestion+Study.pdf%22&blobheadervalue2=application%2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1252058642819&ssbinary=true

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[e] Laura Wolton and Sandra Lozo, *Colorado Market Assessment of Agricultural Anaerobic Digesters: Prepared for the Colorado Energy Office* (Boulder: University of Colorado – Boulder, 2014), 25.

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[i] "Project Detail."

5

Transportation

Transportation systems are designed to withstand local historical weather and climate conditions and to last 50 years or longer. Therefore, it is important to understand how future climate might affect these investments in the coming decades. In Colorado, winter precipitation events are expected to increase in frequency and magnitude, while in other seasons conditions that lead to droughts and wildfire are also projected to become more frequent.[1] A comprehensive analysis of the specific impacts of climate change on Colorado's transportation system has not yet been done to date; however, a recent study on the vulnerability of climate change in Colorado determined that there are two primary sensitivities in Colorado's transportation sector:

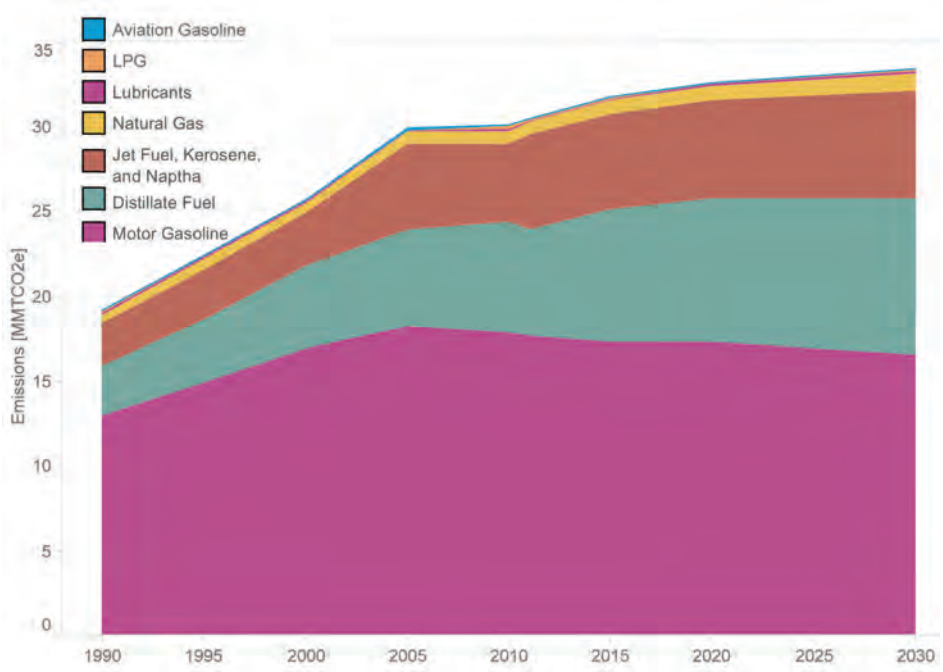
1. The sensitivity of road, rail, and airport infrastructure to the physical effects of extreme heat and heavy precipitation; and,
2. The sensitivity of travel behavior and safety to impaired visibility and traction from wildfires and precipitation events.[2]

The transportation system aids Colorado's economy through employment opportunities and freight movement, in addition to providing vital infrastructure for other state sectors including tourism and recreation. While transportation is a critical element of Colorado's economy and warmer future temperatures can threaten the sustainability and resilience of our economy and infrastructure, as a sector, transportation is a significant contributor of GHG emissions (Figure 5-1). Nationally, transportation activities accounted for 27 percent of U.S. GHG emissions in 2013, the largest contributor after electricity generation. Of this 27 percent, the largest sources of GHGs were passenger cars (43 percent), freight trucks (22 percent), light-duty trucks, which include sport utility vehicles, pickup trucks, and minivans (18 percent), commercial aircraft (6 percent), rail (3 percent), pipelines (3 percent), and ships and boats (2 percent).[3] Nearly 97 percent of transportation GHG emissions came through direct combustion of fossil fuels (coal, petroleum, natural gas, propane, methane, and kerosene), with the remainder due to carbon dioxide (CO_2) from electricity (for rail) and Hydrofluorocarbons (HFCs) emitted from vehicle air conditioners and refrigerated transport.[4] To minimize transportation impacts to climate change, steps must be taken to decrease GHG emissions, while proactively mitigating and adapting for likely impacts.

Figure 5-1

Transportation Sector Emissions in Colorado by Fuel Type[5]

1990-2010 values are extracted from CO_2 emissions from combustion of fossil fuel sub-sheet. The State Inventory Tool Projection Tool is used for 2011-2030 values.



5.1 LAND-BASED TRANSPORTATION

Historical climate data is no longer an adequate indicator of future impacts, and projected changes could increase the risk of delays, disruptions, damage, and failure across our land-based transportation systems. As a result, those designing, sustaining, and building transportation systems must incorporate mitigation and adaptation strategies to prepare for the future. Climate change will likely impact roadways and railways through higher temperatures, more frequent and intense heat waves, flooding, increased winter precipitation, and more severe storms (Table 5-1).[6] Given the long life span of transportation assets, planning for system preservation and safe operation under current and future conditions constitutes responsible risk management.[7] The challenge is proactively planning for these changes in a cost effective and feasible manner.

5.1.1 ROADWAYS AND BRIDGES

Colorado has more than 88,000 roadway miles and 8260 bridges to maintain. The vehicle miles traveled (VMT) on our state highway system is now more than 27 billion miles—an increase of 57 percent since 1990. During the same time, our road capacity (or new lane miles) increased by only two percent. Projections show that VMT is expected to grow by another 47 percent by 2040.[8] This increase in VMT may make it challenging to reduce overall emissions despite the increasing fuel efficiency of vehicles because of improved technology and more stringent Corporate Average Fuel Economy (CAFE) standards. Increasing traffic volume may lead to greater congestion and the increased emissions associated with operational inefficiencies.

Generally speaking, as the climate warms, it may become more costly to build and maintain roads and highways. Larger temperature variations resulting in drastic freeze and thaw cycles are extremely damaging to roadways, causing buckling and heaving of pavement[10] and increased instance of rock fall in the mountains. Increased precipitation intensity is associated with reductions in traffic safety, decreases in traffic efficiency (such as speed and roadway capacity), and increases in traffic accidents.[11] These climate changes can shorten the life expectancy of highways and roads by requiring increased maintenance and repair, which results in vehicle congestion, as well as limiting access to businesses and properties.

Table 5-1

Potential Roadway Transportation Impacts

Increases in very hot days (days where the maximum temperature exceeds 90°F) and heat waves (heat waves as three or more days where daily heat index exceeds 90°F.) = higher high temperatures, increased duration of heat waves

- Increased thermal expansion of bridge joints and paved surfaces, causing possible buckling and degradation (can cause pavement to soften and expand, causing rutting and potholes).
- Concerns regarding pavement integrity, traffic-related rutting and migration of liquid asphalt, greater need for maintenance of roads and pavement.
- Maintenance and construction costs for roads and bridges; stress on bridge integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coats, and sealants.
- Asphalt degradation, resulting in possible short-term loss of public access or increased congestion of sections of road and highway during repair and replacement.
- Limits on periods of construction activity, and more nighttime work.
- Vehicle overheating and tire degradation.

Higher Winter Precipitation

- Regional changes in snow and ice removal costs, environmental impacts from salt, sand, and chemical use.
- Changes in pavement designs.
- Increased cost for avalanche mitigation with high intensity snow events.

Increase in Intense Precipitation Events

- Increases in weather-related delays and traffic disruptions.
- Increased flooding of evacuation routes.
- Increases in flooding of roadways and tunnels.
- Increases in road washout, landslides, rock fall, and mudslides that damage roadways.
- Drainage systems likely to be overloaded more frequently and severely, causing backups and street flooding.
- Areas where flooding is already common will face more frequent and severe problems.
- If soil moisture levels become too high, structural integrity of roads, bridges, and tunnels (especially where they are already under stress) could be compromised.
- Standing water may have adverse effects on road base.
- Increased peak streamflow could affect scour rates and influence the size requirement for bridges and culverts.

Increase in Drought Conditions

- Increased susceptibility to wildfires, causing road closures due to fire threat or reduced visibility.
- Increased risk of mudslides, flooding, and debris flows in areas deforested by wildfires.

5.1.2 RAILWAYS

Fourteen privately owned freight railroads operate in Colorado and own more than 2800 miles of track in the state. Approximately one-third of total freight tonnage moved in Colorado travels by rail.[12]

Climate change related impacts (Table 5-2) may disrupt, halt, or reroute railway traffic, which can have substantial impact on the mobility of people and freight operations, thus causing a negative economic effect. Derailments have the potential to threaten the health and safety of Colorado communities. More frequent and severe heat waves may require track repairs, speed restrictions, and shorter trains to avoid derailments. Damage from wildfires, flooding, or debris flows could disrupt freight and railway operations and require railway lines and infrastructure to be rebuilt or raised in future expansion projects.15 As the climate warms, it could become more costly to build and maintain railways and associated infrastructure, including tunnels and bridges.

Table 5-2

Potential Railway Transportation Impacts[13]

Increases in very hot days (days where the maximum temperature exceeds 90°F) and heat waves (heat waves as three or more days where daily heat index exceeds 90°F.) = higher high temperatures, increased duration of heat waves

- High temperatures can force rail lines out of alignment in what are called ''sun kinks'' or ''heat kinks.''
- Extreme heat can cause rails to expand and buckle.[14]
- Uneven thermal expansion when shade covers nearby sections, thereby posing the risk of warp and misalignment.

Higher Winter Precipitation

- Regional changes in snow and ice removal costs.
- Increase in snow slides.
- Degraded railway operations due to lowered visibility, icing, and snowdrifts.

Increase in Intense Precipitation Events

- Increases in weather-related delays.
- Increases in flooding of railways and tunnels.
- Increases in railway washout, landslides, and mudslides that damage railways.
- Areas where flooding is already common will face more frequent and severe problems.
- If soil moisture levels become too high, structural integrity of railways, bridges, and tunnels (especially where they are already under stress) could be compromised.

Increase in Drought Conditions

- Increased susceptibility to wildfires, causing railway closures because of fire threat.
- Increased risk of mudslides and debris flows in areas deforested by wildfires.

5.2 AIR TRANSPORTATION

The Colorado Airport System includes a total of 74 public-use airports.[16] With more than 53 million passengers traveling through, Denver International Airport is the largest of Colorado's airports, the fifth-busiest airport in the United States, and the fifteenth-busiest airport in the world.[17] The airport is a primary economic engine for the state of Colorado, generating more than $26 billion annually.[18] As such, effects on Colorado's air transportation system (Table 5-3) can have substantial economic ramifications.

Impacts from climate change may affect airplanes, airports, and airstrips, which can affect air travel, infrastructure, and the economy. As with roadways, increased heat can cause buckling of runways. Periods of extreme heat may cause airplanes to face cargo restrictions, flight delays, and cancellations because hot air is less dense, which reduces mass flowing over the wing to create lift. The problem is more critical at high altitude airports where runways must be long enough for large aircraft to build up enough speed to generate lift. Runways may need to be lengthened or flights delayed or cancelled because of extreme heat.20 Heavy winter precipitation can lead to an increased cost for snow removal and deicing operations.

Table 5-3

Potential Air Transportation Impacts[19]

Increases in very hot days (days where the maximum temperature exceeds 90°F) and heat waves (heat waves as three or more days where daily heat index exceeds 90°F.) = higher high temperatures, increased duration of heat waves

- Heat-related weathering and buckling of airport and runway pavements and concrete facilities.
- Heat-related weathering of vehicle stock.

Higher Winter Precipitation

- Regional changes in snow and ice removal costs, environmental impacts from salt and chemical use.
- Changes in pavement designs.

Increase in Intense Precipitation Events

- Impacts on structural integrity of airport facilities.
- Destruction or disabling of navigation aid instruments.
- Damage to runway, pavement drainage systems, and other infrastructure.
- Increases in weather-related delays.
- Increased stormwater runoff, causing flooding, delays, and airport closings.
- Impact on emergency evacuation planning, facility maintenance, and safety management.

Increase in Drought Conditions

- Increased susceptibility to wildfires, causing airport facility closures because of fire threat or reduced visibility.

5.3 MITIGATION

Colorado is home to approximately 5 million people and 3 million jobs. By 2040, the population is expected to increase by 47 percent to nearly 7.8 million, with the number of people age 65 and older representing approximately 1.4 million or 18 percent of the total.[21] Because of these projections, Colorado is facing a growing demand for mobility and services throughout the state. There are several opportunities to decrease emissions and GHGs that are used and supported throughout the state, including:

- Using innovative vehicle technologies and advanced engine management systems (e.g. start-stop technology, engine heaters, truckstop electrification).
- Infrastructure development and support of alternative fuels to save money, reduce emissions, reduce our dependence on foreign oil, and strengthen the local economy. Certain alternative fuel vehicles may also qualify for a tax credit in Colorado.
- Encouraging the adoption of more fuel-efficient vehicles in line with advancing CAFE standards.
- Transportation infrastructure that uses traffic management, including Intelligent Transportation Systems, to minimize traffic congestion.
- Consumer information including campaigns for eco-driving and the use of alternative modes and transportation fuels.
- Promoting the utilization of multimodal transportation options including increased use of bikes, car-pooling, walking, and rapid transit.
- Tax incentives for low carbon products/processes.
- New cars will become cleaner as federal GHG and corporate average fuel economy standards take effect for light-, medium- and heavy-duty vehicles.[22] Improving the efficiency of fleet vehicles, conserving fuel, saving money, and reducing emissions through changes in driving behaviors. Research by the National Renewable Energy Laboratory shows that improving driving behaviors can reduce vehicle fuel use by 7 to 15 percent. Savings can be up to 20 percent for aggressive drivers that implement efficient driving techniques.[23]

Additional efforts are included in Section 5.4 Adaptation.

5.3.1 IDLE REDUCTION

Colorado Revised Statute 42-14-101 more commonly known as the "puffer" law, allows law enforcement officers across the state to immediately ticket individuals who have left a vehicle running unattended for any period of time.[24] Some local jurisdictions have adopted anti-idling ordinances that limit idling of all motor vehicles operating in their community. In 2011, the Colorado trucking industry joined with local governments and clean air advocates in Colorado to create a set of recommendations for a statewide idling standard. C.R.S 42-14-101, allows communities to limit idling to five minutes within a sixty-minute period for large, commercial diesel vehicles (14,000 lbs. or more). This consistent guideline enables commercial drivers to comply with the law and protect Colorado's air quality across the state, rather than having to follow a diverse patchwork of local regulations.[25]

Clean Air Schools – Engines Off! is a collaborative effort between the federal, state, and local governments in Colorado to improve regional air quality by reducing vehicle idling, a significant source of air pollution. EnginesOff.com acts as a statewide resource for idle reduction efforts.[26] So far, the program has achieved an average emissions reduction of 62 percent at schools where the program has been implemented.

Together with the City and County of Denver Environmental Quality Division, Denver Public Schools, Jefferson County Public Schools, Mothers for Clean Air Colorado, and the Regional Air Quality Council, the Denver Metro Clean Cities Coalition is partnering to reduce both the volume and duration of idling vehicles at schools through the pilot program Clean Air at Schools: Engines Off.[27]

5.3.2 TRANSIT DEVELOPMENT

Transit services will be an essential piece of the state's future transportation network, addressing the mobility needs of an increasing and aging population, as well as contributing to the economic, social, and environmental health of the state as it grows. In addition to reducing VMT, transit projects can also use alternative fuels. Electric buses and natural gas-fueled buses reduce emissions when compared to gasoline or diesel vehicle emissions. If electric vehicle charging stations are provided at transit stops, it can incentivize riders to drive electric vehicles to and from stations.

The Colorado Department of Transportation Division of Transit and Rail developed its first ever Statewide Transit Plan in March 2015 to address future needs and guide the CDOT's future transit investments and actions. Transit needs and recommendations were developed based on local, state, and federal input.[28]

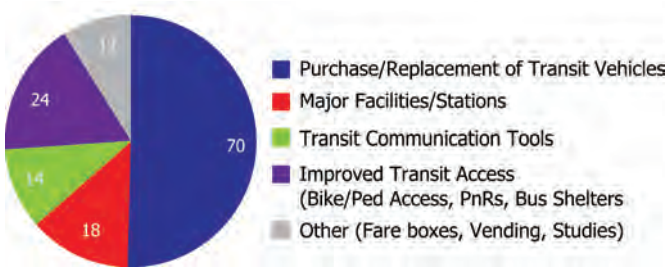
The RTD FasTracks Program is a multi-billion dollar comprehensive transit expansion plan to build 122 miles of new commuter rail and light rail, 18 miles of bus rapid transit, 57 new transit stations, 21,000 new parking spaces at light rail and bus stations, and bus service for convenient bus/rail connections across the eight county district. FasTracks is RTD's 2004 voter-approved plan to expand transit across the Denver metro region.

Bustang, the CDOT's new interregional bus service, will offer Monday through Friday express transit services to the communities of Fort Collins, Loveland, Denver, Lakewood, Monument, Colorado Springs, Frisco, Vail, Eagle and Glenwood Springs. Bustang will connect major populations, employment centers and local transit entities while offering commuters more travel choices, alleviating congestion and consequently reducing emissions that contribute to GHG.

Senate Bill 09-108, codified as C.R.S 42-4-508, is also known as the Funding Advancements for Surface Transportation and Economic Recovery Act of 2009 (FASTER). FASTER allows the State of Colorado to improve roadway safety, repair deteriorating bridges, and support and expand transit. The bill generates approximately $200 million yearly for state transportation projects. FASTER supports transit projects with $15 million yearly and provides state funds for transit. This has been instrumental in helping maintain existing local transit systems, in guiding toward regional bus transit service, and in determining the feasibility of a high-speed rail system. FASTER transit funds are split between local transit grants ($5 million per year) and statewide projects ($10 million per year). Among the types of projects that have been awarded are the purchase or replacement of transit vehicles and the construction of multimodal stations (Figure 5-2).[29] By funding and promoting transit options, FASTER is assisting to reduce the number of vehicle trips and reducing the growth of VMT, thus reducing vehicle emissions.

Figure 5-2

Number of FASTER Transit Grants and Projects



Source: "FASTER TRansit Grants," Colorado Department of Transportation, accessed April 2, 2015, http://www.codot.gov/projects/faster/faster-transit-grants.

5.3.3 COMPACT AND CONNECTED LAND USE PATTERNS

Encouraging compact development and redevelopment that is located near public and other modes of transportation reduces vehicles miles traveled, thereby reducing GHGs and at the same time promoting efficient use of infrastructure, improving public health, and elevating environmental stewardship.[30] A meta-analysis of studies concluded that people living in places with twice the density, diversity of uses, accessible destinations, and interconnected streets drive approximately a third less than otherwise comparable residents of low-density sprawl.[31] Colorado is a home rule state, and land use-related actions at the state government level include educating and encouraging local jurisdictions to consider the multiple benefits of smart growth.

An example of this is the Colorado Sustainable Main Streets Initiative of 2010, which was developed after agencies agreed through Executive Order to collaborate under the leadership of the DOLA. The Sustainable Main Streets Initiative used a collaborative, integrated process to leverage technical and financial resources to help communities enhance the sustainability of their downtowns. The communities that benefited from this initiative included the urban neighborhood of Five Points in Denver, the Town of Fowler, and the Cities of Monte Vista and Rifle.

The DOLA Community Development Office has also developed guidance on model land use codes and is developing a guide for local communities on how to integrate data on risks from climate change and natural hazards into land use planning processes.

5.3.4 ALTERNATIVE FUEL DEVELOPMENT

Refuel Colorado is an effort by the CEO to encourage the adoption of alternative fuel vehicles in Colorado to lead a cheaper, cleaner, domestic transportation future. Refuel Colorado is an effort to provide businesses and consumers the information they need to assess the pros and cons of alternative fuel vehicles.[32]

Refuel Colorado Fleets is a statewide consultation program that assists fleet managers and local leadership in identifying opportunities to take advantage of alternative fuel vehicles. The program acts as an energy coaching program to help identify the advantages of alternative fuel vehicles and determine what type of vehicle makes economic sense. The energy coaches then guides fleet managers through the acquisition process, providing technical expertise on issues such as fueling, incentives, maintenance, and safety.[33]

Additional information on alternative fuel development can be found in Chapter 4.

5.4 ADAPTATION

In the transportation sector, comprehensive, proactive adaptation planning is only starting to develop, as historically the focus has been on mitigation and reducing GHGs. Nevertheless, many agencies and localities are beginning to plan and act to address the unavoidable impacts that will occur in the future. Adaptation planning at the local, state, and national levels can limit the damage caused by climate change, as well as reduce the long-term costs of responding to the climate-related impacts that are expected to grow in number and intensity in the decades to come. Increased focus on enhancing agency partnerships during transportation planning, design, and construction will allow adaptation to be integrated into current transportation processes.

Transportation planning is a critical process for the CDOT and its local partners. Throughout the process, the CDOT works extensively with the 15 Transportation Planning Regions (including five Metropolitan Planning Organizations), local elected officials, and the public to ensure that everyone has a voice in the statewide and regional planning processes. The overarching direction of CDOT's planning efforts is the Statewide Transportation Plan, a vision document that outlines what our multimodal transportation options will look like in Colorado over the next 10 to 25 years, and it connects funding scenarios, business practices, and partnering efforts.

The 2040 Statewide Transportation Plan places a strong emphasis on safety, asset management (capital maintenance), mobility, and economic equality. It also sets the stage for investigating measures or strategies aimed at improving the sustainability and resiliency of the statewide transportation system in the face of climate change and extreme weather events.

National Environmental Policy Act (NEPA) requires federal agencies and agencies using federal funding, approvals, and/or permits to consider the potential environmental consequences of their proposals, document the analysis, and make this information available to the public for comment before implementation. The NEPA process is required prior to all federally funded transportation projects going to design and construction. GHG emissions are generally discussed in NEPA environmental documents under Federal Highway Administration guidance. However, on December 18, 2014, draft guidance was released for public comment that describes how federal departments and agencies should consider the effects and implications of GHG emissions and climate change in their NEPA reviews.[34]

Addressing both climate change mitigation and adaptation issues upfront in highway and transportation planning (during the NEPA process) may help to facilitate decision-making and to improve efficiency at the program and project level.

The Moving Ahead for Progress in the 21st Century Act (MAP-21) federally funds surface transportation programs.[35] As a MAP-21 requirement, each state is required to develop a risk-based, asset-management plan for the National Highway System to improve or preserve the condition of the assets and the performance of the system. The CDOT is currently considering how to define and identify risk, and incorporate the mitigation of risk into the preservation of road and bridge assets. The risk of flooding from an extreme weather event is an example of risk that is being assessed in developing strategies for preserving transportation assets.

The September 2013 flood affected parts of Colorado from the Front Range foothills through the Eastern Plains, along the South Platte River, and to the Nebraska border. The recovery from this event included temporary and permanent repairs to transportation infrastructure. The CDOT oversaw development of a methodology and tool to assess risk and resiliency that quantifies the benefit to cost ratios of resiliency alternatives for damaged roadways slated for permanent repair. This methodology is used to evaluate the relative risks and costs of damage severity and roadway criticality to determine the return on investments in accordance with Federal Highway Administration Emergency Repair

policies. Although this tool was developed specifically for the flood repair projects, some of the concepts are being considered in the identification, development or prioritization of other transportation project improvements.[36] Specific challenges identified during the flood recovery efforts include deficiencies of knowledge, tools and skills, funding, monitoring, and communication in the design, construction, and management of resilient infrastructure assets, further detailed in the Colorado Resiliency Framework.[37]

The Federal Emergency Management Agency coordinates the federal government's role in preparing for, preventing, mitigating the effects of, responding to, and recovering from all domestic disasters, whether natural or man-made, including acts of terror.[38] The Federal Emergency Management Agency is currently researching and working on several options to address climate change including:

- Updating federal emergency preparedness plans to include potential climate change impacts and set guidelines for state preparedness plans.
- Modernize programs to support climate resilient investment.
- Pre-disaster planning for recovery and mitigation (focus on future risks).
- Identify and seek to remove or reform barriers.
- Reform policies and programs that may inadvertently increase vulnerability.
- Support and encourage smarter, more climate-resilient investments.
- Manage lands and waters for climate preparedness and resilience.
- Provide information, data, and tools for climate change preparedness and resilience.

The Federal Emergency Management Agency and the CDOT have been working closely with local agencies to share information and data while preparing to be more resilient in the future.

5.5 STRATEGIES AND POLICY RECOMMENDATIONS

There are several opportunities for Colorado to develop strategies for addressing the issue of climate change as relates to the statewide transportation system. These strategies can be broadly categorized as those that seek to reduce the emission of greenhouse gases from the transportation sector (thereby reducing the likelihood and intensity of climate change impacts) and those that aim to prepare the transportation system to deal with whatever climate change impacts do occur in the future.

- Promote and encourage fuel-efficient vehicle technologies and programs to reduce vehicle emissions.
- Continue to support strategies and develop new strategies to reduce GHG emissions, reduce the growth of VMT and alleviate congestion. More specific strategies can be found in the Colorado Resiliency Framework.[39]
- Encourage local, state, and federal entities to assess climate-related risks to transportation systems and take action to improve their resilience.[40]
- Improve communication, data sharing, and collaboration between local, state, and federal entities related to climate change mitigation and adaptation programs and activities for transportation.
- Work to promote education of the traveling public on the impacts of GHGs associated with transportation while concurrently educating and training local, state, and federal entities and their staff on climate change adaptation concepts and strategies.
- Consider the incorporation of climate change impacts into transportation design, asset inventory and management processes, and transportation system investment decision-making.
- Provide guidance to local governments on land use planning strategies to promote efficient use of public resources and reduce GHG emissions through compact, transit-oriented development that utilizes smart growth practices and complete streets.
- Identify climate-related impacts and develop a standard method of recording impacts and costs of climate-related effects.

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6

Agriculture

Agriculture is one of Colorado's largest economic drivers, a $40-billion-dollar industry that provides a safe, abundant food supply for Colorado, the United States, and the world.[1] More than 35,000 farms and ranches[2] employ 170,000 people[3] and operate on more than 52 million acres across the state.[4] Colorado's dominant agricultural products include cattle and calves, wheat, and corn,[5] but the state is also known for the quality and wide variety of its livestock, fruit, and vegetable commodities. The success of this industry is closely tied to the health of the land, where farmers and ranchers have acted as stewards beginning with when Colorado was first cultivated. A variable climate has always been part of agriculture in Colorado, but a changing climate introduces new challenges. With spring runoff projected to shift even earlier, streamflows projected to decrease, and heat waves, drought, and wildfires all projected to increase in frequency and severity because of climate change, the Colorado of the future is unlikely to look like that of the past.[6] While this chapter focuses on adaptation, there are also many opportunities for GHG reductions in the agricultural energy sector, those efforts are covered in detail in Chapter 4.

6.1 IRRIGATION

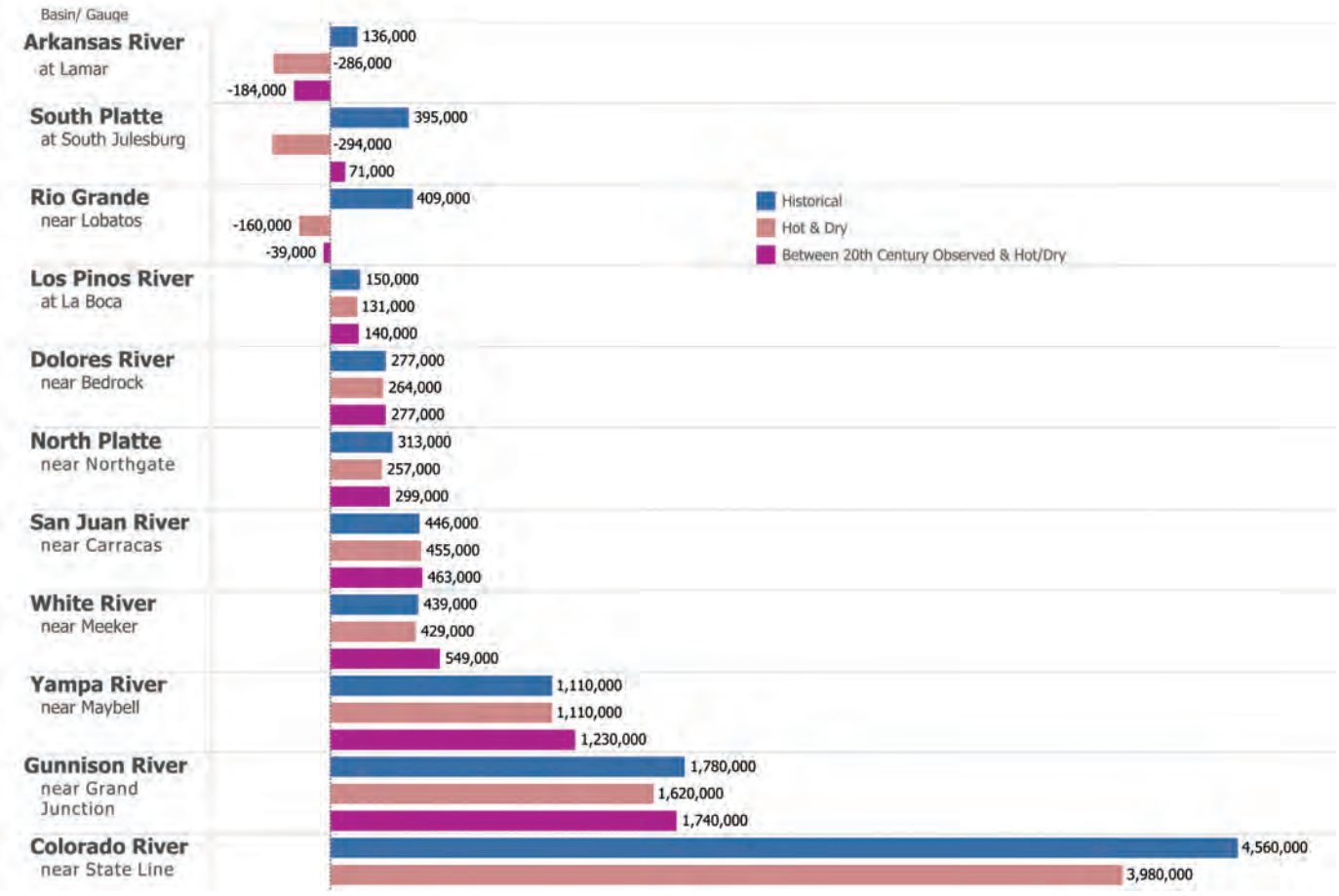
Irrigation is a critical piece of agricultural success in Colorado's semi-arid environment. While some crops and forage can grow on natural precipitation, many also require supplemental irrigation to maximize production. Approximately 2.6 million acres of agricultural land are irrigated in Colorado,[7] diverting 11 million acre-feet of water.[8] However, as temperatures increase, evapotranspiration increases, resulting in higher crop irrigation requirements.[9] This means it will take more water to grow the same crops.

The 2012 Colorado River Water Availability Study showed that crop irrigation requirements are projected to increase by 8-29 percent by 2040 and 20-43 percent by 2070, depending on the climate scenario used.[10] Coupled with this, runoff is projected to shift 8 to 14 days earlier over the same time period. If a shift in growing season does not coincide with the shift in runoff, the result may be that irrigation water is not available during the time of year when the demand is the greatest, thereby decreasing production. In some instances, irrigation requirements may increase to such a degree that producers choose to grow fewer water-intensive crops; in other instances, producers may feel that leasing their water rights for non-irrigation uses is more profitable than growing a crop, or they may choose to do a combination of the two. These adaptation decisions affect not only the farms and producers, but also the landscapes and communities where these farms are located. Fallowing land by choice or because of lack of sufficient irrigation water can affect the soil health, public health, and economic activity of a region.

Figure 6-1

Projected Gauged Flows for 2050 (acre-feet/year)

Projected depleted flows for 2050 in acre-feet per year at 11 different sites around the state. Hot and Dry is defined as the 75th percentile of climate projections for crop irrigation requirement (water use), and the 25th percentile for natural flows. In other words, only 25 percent of projections have lower natural flows and 25 percent of projections have a higher crop irrigation requirements. Between 20th century observed and Hot and Dry is defined at the 50th percentile for both natural flows and crop irrigation requirements. This scenario is the middle of the range of severity. Historical or current conditions, which is no change in runoff or crop irrigation requirement fall at roughly the 9th and 67th percentiles, respectively; this means that 91 percent of runs show increases in crop irrigation requirement and approximately two thirds show reductions in runoff.



As our climate warms, those agricultural users who have senior water rights (giving them first priority to water that is available in a given year) may have more options available to them for adaptation than agricultural users with junior water rights (who have access to their water only after all senior water rights have been fulfilled). Additionally, as the climate of Colorado shifts, past records of stream flows become a less reliable guide for the future. In some scenarios developed for the Interbasin Compact Committee, projected gauged flows in 2050 are negative. Under those scenarios, some existing uses, both senior and junior, would be unable to obtain their historical supply of water (Figure 6-1).[11] The Arkansas and the Rio Grande Rivers have negative projected gauged flows under both Interbasin Compact Committee climate scenarios; the South Platte has a negative projected flow under the "hot and dry" climate scenario. In Figure 6-1, the more negative the value, the greater the magnitude of the projected deficit. Therefore the "hot and dry" scenario, which shows the greatest deficit, would likely result in the greatest impact to users. In all of these cases both senior and junior water right holders would be affected by the presence of little to no water in the river. Additionally, the shift in timing of runoff may affect the water available for users if their water rights are dependent upon a time period in addition to volume.

Continued monitoring, research, and planning are critical to determining whether future supplies will meet future demands and continue to fulfill existing demands. Addressing and adapting to these challenges will require collaboration and innovative solutions.

6.2 PRODUCTION

Colorado has a thriving agricultural sector, but changes to the climate, driven largely by increasing temperatures, can affect production. In some cases these effects could increase production, as described below. In many other cases, production is projected to be negatively affected. Understanding where the agricultural industry is vulnerable to a changing climate helps the state better prepare and adapt. Additionally, changes to operations on farms and ranches may result in improved carbon sequestration, helping to mitigate overall GHG emissions.

The Colorado Climate Change Vulnerability Study cites several production-related vulnerabilities that exist under a warmer climate.[12] These include:

- Crop yields may decrease due to increased heat stress.
- Crop yields may be reduced due to increased severity of droughts.
- The prevalence of weeds and pests may increase due to a longer growing season.
- The prevalence of weeds may increase due to CO_2 fertilization.

While warmer temperatures resulting in a longer growing season (ranging from 8 to 32 days in 2040 and 21 to 46 days in 2070)[13] could help to increase production in some areas of the state, lack of sufficient water and increased heat stress during that period may negate any potential gains. Producers in cooler regions of the state with adequate irrigation water are more likely to benefit from the longer growing season. Others are more likely to see crop losses associated with increased heat stress and lack of sufficient moisture. Ensuring that ample water storage is available for producers may help them adapt to warmer conditions and may decrease losses because of lack of water availability. However, studies also show that net evaporation (evaporation minus precipitation) is projected to increase for reservoirs throughout the West because of increased temperatures, and consideration should be given to this expectation.[14] Increased CO_2 levels may help some crops, such as wheat, produce a larger yield but may also result in an increase in weeds.[15] An increased occurrence of weeds and pests may also affect production or require changes to operations during a longer growing season.

Extreme weather, including both drought and flood, can have serious effects on the agricultural sector and production levels. The Palmer Drought Severity Index already shows a trend towards more severe soil-moisture droughts over the last 30 years, and climate projections indicate that droughts, heat waves, and wildfires are likely to increase in frequency and severity by the middle of this century.[16] In 2012, it is estimated that lost revenues resulting from drought in the agricultural sector alone exceeded $409 million statewide.[17] When secondary and tertiary economic effects on local communities are factored in, the loss increases to $726 million statewide.[18] Not only do these events affect production during the discrete event, but they can inhibit production for multiple growing seasons. For instance, ranchers forced to cull herds in response to drought may need several years for the native range to recover to sustain previous stocking levels; headgates and diversion structures damaged by floods will take time to be repaired or replaced; and wildfires may degrade soil quality such that it may take some time before the soil can support native species or grazing. At the same time, frost hazards are likely to decrease, which could bring benefits to some growers such as fruit orchards.

One adaptation strategy that may make sense for some producers is to alter their crops to better fit the changing climate. For example, if Denver warms 2°F, its climate would become more similar to that of Pueblo's today; if warming reaches 4°F, the Mile High City would more closely resemble the climate of Lamar; and with an increase of 6°F, Colorado's largest city would be analogous to New Mexico's largest city: Albuquerque.[19] Crops that thrive in Pueblo, Lamar, and Albuquerque are different from those that thrive along the northern Front Range today. This shift may result in the cultivation of entirely different crops, or it may mean planting new variations of existing crops that are better suited for warmer and drier conditions. Adopting the cultivation practices and requirements for new crops as well as entering new marketplaces will not come without challenges and investments. What is also unclear is the extent to which new technologies and practices will help reduce the negative impacts of such changes in temperature. However, researchers at Colorado State University are already working to develop pioneering approaches to tackle these issues, making Colorado a national leader in agricultural innovation.[20]

6.3 SOIL HEALTH AND CONSERVATION

Healthy soils provide nutrients to crops, hold water to nourish plants, and filter pollutants. Consequently, soil health is an important component of a producer's ability to grow high quality products. Yet climate change has the potential to negatively impact soil quality. More severe and persistent droughts, wildfire, and severe heat can degrade the quality of soils. Degraded soils require more management, more added nutrients, and more water to support a crop, increasing management costs to producers.

Scientists have predicted that within the next 20 years, global food demand will increase by 50 percent.[21] Along with increasing demands on energy and clean water, demands on the earth's soil resource to feed that population will be greater than ever.[22] As soil organic carbon has volatilized and diminished, the soil health of the earth's arable land has declined. Carbon-depleted soils become less productive and more dependent on additional inputs to produce crops.

Farming Colorado's arid high plains requires maximizing soil uptake of rain water and melted snow for storage and crop use. Reduced soil permeability results in reduced or prevented groundwater recharge and exacerbates the effects of limited precipitation or prolonged drought periods. Furthermore, enhanced soil permeability can decrease the extent to which precipitation runs off the surface instead of infiltrating into the soil profile. The greatest challenge, and the most important need for improving soil health, is in dryland settings. No-till farmers have achieved substantial successes in dryland farming by leaving standing residue from soil organic matter.

6.4 STRATEGIES AND POLICY RECOMMENDATIONS

There are opportunities to develop strategies and incentives that improve Colorado's crop and rangeland resiliency as well as its long-term sustainability and productivity.

- Promote increased water storage solutions that help producers adapt to changing conditions and decrease production losses due to lack of water availability.
- Partner with research institutions and federal agencies to support producers' efforts to mitigate and adapt to climate change through improved irrigation efficiency and enhanced tillage practices.
- Support federal and state programs that improve soil health, such as by increasing soil organic carbon and sequestration, promoting long-term research into land management practices that build soil health, and examining state and local land-use policies that reduce soil erosion on arable lands.

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7

Tourism & Recreation

Colorado is known around the globe for its majestic mountains and superior recreational opportunities, including: 12 national parks and monuments, 42 state parks, 300 wildlife areas, 25 ski areas, 14 gold-medal fisheries, 23 million acres of public land, and thousands of miles of hiking, biking, and running trails. Annually, more than 64 million trips are taken to Colorado,[1] resulting in $17.3 billion in visitor spending, which in turn generates $976 million in tax revenues,[2] making tourism one of the state's largest economic drivers. Outdoor recreation accounts for more than 13 percent of all jobs in the state,[3] and has a total economic output of $34 billion dollars annually. With 90 percent of all Colorado adults participating in some form of outdoor recreation, residents of this state value recreation very highly. Yet, all this is vulnerable to climate change and variability as many of these activities are dependent on climate. At the same time, tourism can also contribute to GHG emissions. Globally it is estimated that 5 percent of carbon emissions can be attributed to tourism.[4] Balancing a thriving tourism industry with the challenges presented by a changing climate requires proactive and innovative thinking.

A significant portion of Colorado's economy is reliant on tourism and in some locations tourism is the economic engine of entire towns and cities. For these locations, climate change threatens not only physical ecosystem health, but it poses a threat to the long-term economic viability of the communities by impacting things such as season length, infrastructure, and snowpack. For example, reduced snowpack or drought conditions may lead to conditions that are ripe for wildfire, the presence or the even the perception of wildfire nearby, can result in depressed tourism and recreation in a specific location or region. In communities that are dependent on tourism and recreation, wildfire can deter visitors in both the short-term due to safety concerns, and long-term because of accessibility or aesthetic issues.[5] Alternatively, in some instances, Colorado's recreation dependent towns may be well situated to cope with climate change. High elevation ski resort towns may initially see an overall economic benefit because of their ability to remain relatively cooler than lower elevation locations, resulting in a competitive advantage over ski areas elsewhere in the country, despite the potential loss of shoulder season snow sports.[6] Diversification offers a strategy for these communities to mitigate the impacts of climate change by providing a broader variety of recreational opportunities throughout the year that can stabilize historical shoulder season and off-season revenues. Although climate change poses substantial concerns for natural resource based recreation and tourism communities, the adaptive capacity is high for the recreation and tourism sector,[7] positioning these towns to better address potential changes and challenges.

7.1 SUMMER RECREATION & TOURISM

It has been said that people come to Colorado for the winter but they stay because of the summer. Sunny days, moderate temperatures, and endless recreational opportunities offer great appeal. However, the impacts of climate change are already affecting our natural resources and the recreation sector, and these effects are likely to continue into the future.

Over the past 50 years statewide temperatures have increased across all seasons, with the largest increases in the spring (3.4ºF) and summer (2.4ºF); over the last 30 years, summer has warmed more than any other season.[8] These increases, along with lower snowpack and dust-on-snow, affect peak runoff, shifting it by one to four weeks with larger shifts projected in the future.[9] Changes in peak runoff greatly influence the rafting community, and a shorter faster runoff may shorten the overall rafting season.[10] If the peak runoff, historically in June and July, shifts by a few weeks or a month then it falls during the school year—before many are taking summer vacations or are planning weekend trips. Additionally, if streamflows in late summer decrease, veteran rafters may perceive the experience as too mellow and choose to go elsewhere. However, families with novice rafters may find the calmer waters very appealing. Outfitters and the Colorado Tourism Office will need to be cognizant of messaging and marketing so the right clientele is on the river at the proper time of year. This industry has done a superior job of adapting their messaging during time of drought, as in 2012, which helped protect revenues.

Warmer temperatures and shifts in precipitation patterns will also affect summer recreation and tourism. In the majority of climate models, summer precipitation decreases[11] and temperatures increase to such a degree that a typical year in 2050 will likely be warmer than the warmest years we have experienced so far.[12] The result is more heat waves, drought, and wildfire—all of which can influence visitors' perception and deter tourism to Colorado. Aside from the perception issues associated with wildfire, this natural disaster may further negatively influence tourism through road, trail, and campground closures.[13] Warming temperatures, wildfires, and droughts can also force wildlife out of their preferred habitat, potentially affecting hunting and wildlife-viewing experiences, a $3 billion industry.[14] Nevertheless, it is critical to keep in mind that Colorado is a large state and wildfires tend to be very localized, this must be reinforced in social media and marketing—there is still a lot of Colorado to explore.

Changes to streamflow volumes and temperature also greatly affect fish populations, especially cold water fish such as trout.[15] Colorado residents alone log more than 1 million days of fishing activity. Non-residents log an additional 9 million and spend on average approximately $100 each day,[16] which results in nearly $2 billion in economic output.[17] Temperature-induced habitat reduction can affect fish populations and consequently affect angling experiences. Rising temperatures may also affect gold medal status which may also deter anglers from fishing in Colorado.

Forest health may also affect summer tourism and recreation in the state. Since 2000, warm and dry conditions have enabled bark beetles to thrive, resulting in widespread tree mortality across 4 million acres of Colorado.[18] While beetle infestation may influence runoff and snowmelt,[19] it can also affect visitor experience as aesthetics may deter people from recreating through dead tree stands. The same is true post-wildfire. In these situations, marketing other areas of the state that are less affected may be an adequate adaptation strategy. The Colorado Resiliency Framework addresses these issues and some strategies to tackle them post disaster, including an open for business campaign.[20] Nevertheless, it is important that we work with our partners at the federal and local levels to maximize resources, reduce local effects, and preserve community vitality following a disaster. Buffalo Creek Park is a great example of an area that has remained extremely popular with mountain bikers despite being located in a burn scar.[21]

Federal efforts at wildlife conservation and land management under a changing climate may also help Colorado adapt, as 37 percent of the state's land is owned by federal agencies, with an additional 5 percent owned by state agencies.[22] Proper management of these areas will help to maintain habitat health for wildlife and preserve recreational opportunities for Coloradans and tourists alike. Federal agencies have increased their efforts on climate change preparedness and resiliency following a November 2013 executive order from President Obama.[23]

In contrast, droughts and heat waves during the summer time may actually have a positive influence on tourism and recreation in the Centennial State. Drought means less rain, which affords visitors plenty of opportunities to enjoy the outdoors. It may also mean less mud on trails, which can result in increased access for hikers and bicyclists.[24] Heat waves, which tend to be more regional in nature, can often attract visitors who are seeking respite in the high elevation mountains where temperatures are relatively cooler. This effect was observed in 2012, when visitation was strong.[25]

7.2 WINTER RECREATION & TOURISM

Winter tourism and recreation in Colorado is seemingly synonymous with snow sports. During the 2013-2014 season, the state's ski areas saw 12.6 million visits.[26] But to continue to thrive, these hills need the right combination of temperatures and precipitation. In Colorado, models show an increase in mid-winter precipitation but a decrease in April 1 snowpack.[27] As the state with the highest mean elevation nationally, Colorado is in a unique position in that the majority of our resorts are located in the high mountains. Since temperature generally decreases as elevation increases, these resorts are likely to maintain skiable terrain through mid-century, even while other resorts around the nation and world struggle. Initially, this may result in an increase in winter recreation and tourism in Colorado. However, as temperatures continue to warm beyond mid-century, more effects are likely to surface, especially during the shoulder seasons.

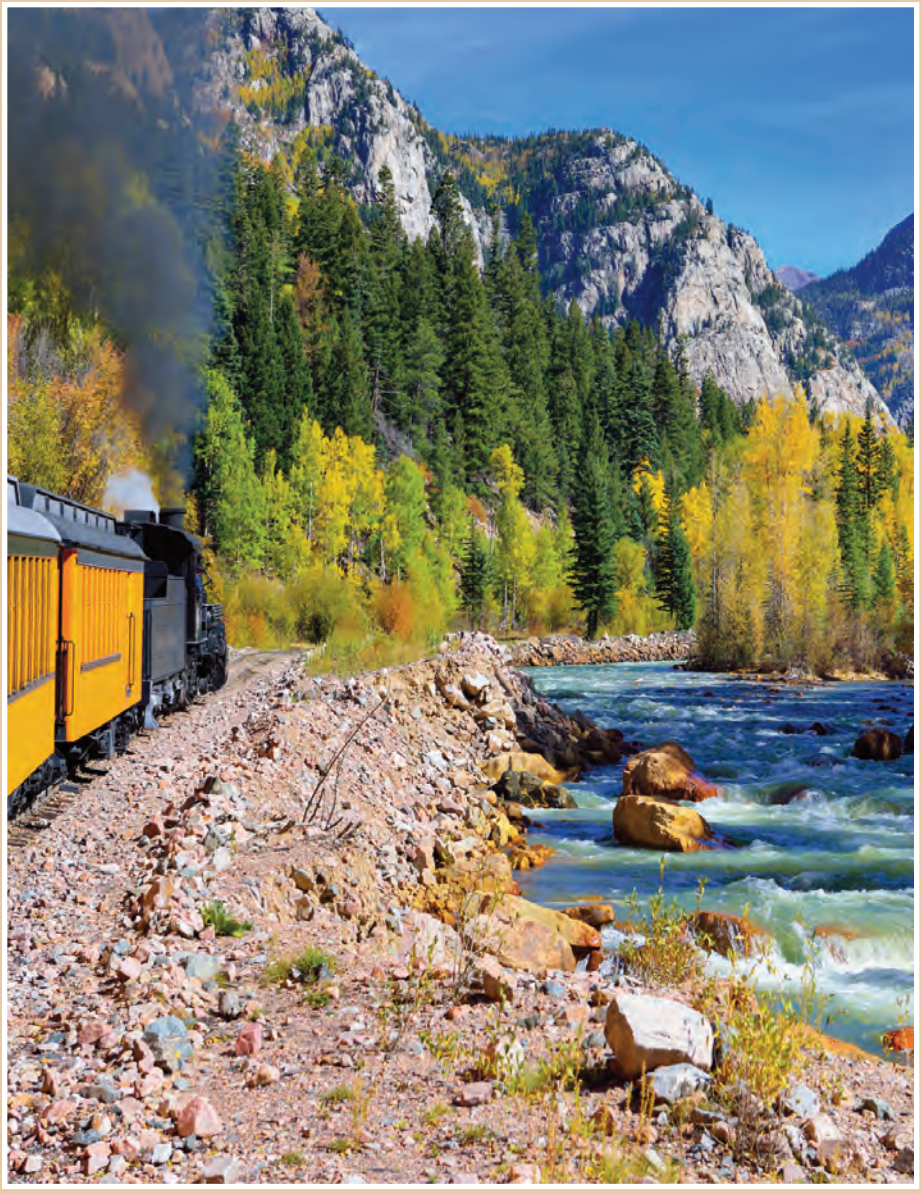
Snow-dependent recreation that is not occurring on a mountain, but rather at relatively lower elevations, is also likely to feel the effects of warmer temperatures. Activities such as snowmobiling, cross country skiing, and ice fishing all may face challenges because of warming temperatures, decreased snowpack, and shifts in the timing of snowmelt and runoff. Dust-on-snow events have already resulted in earlier snowmelt. As soils around the Southwest continue to dry, increased dust events are likely, resulting in further shifts to snowmelt. The effects of beetle kill may also alter the landscape and affect snow accumulations, snowmelt, and runoff timing and volume.[28] Lastly, climate change has the potential to influence avalanches in Colorado, which could affect not only resort operations, but also backcountry users on skis, snowmobiles, or snowshoes.[29] However, preparations are already underway in this sector of the economy, and many resorts have implemented adaptation strategies to address the effects of a warmer climate.

For decades the industry has dealt with climate variability largely through investment in snowmaking equipment and water rights. More recently, resorts have opened beginner areas higher up on the mountain and installed lifts that can service a wider array of abilities. They have also expanded their warm weather attractions such as mountain biking, diversifying their revenue stream. These strategies should be encouraged and enhanced in the coming decades.

7.3 MITIGATION

While approximately 5 percent of emissions on a global scale are attributable to tourism, it is unclear what percentage of Colorado's emissions is a result of the tourism and recreation industry.[30] Globally there have been efforts to curb emissions within the sector, and widespread adoption of these measures will likely benefit Colorado. Further expansion of public transit, for example, could help reduce GHGs as well as congestion, while still providing viable transit for tourists and those seeking recreational opportunities, especially along the Front Range. This is further discussed in Chapter 5.

For recreation, efforts are underway to reduce the greenhouse gas emissions of resorts in Colorado. For example, Aspen Skiing Company has committed to reducing CO_2 emissions by 25 percent by 2020, has invested $5.5 million to develop the first large coal mine methane-to-electricity project in the U.S., has built a 147kW solar electricity system, and has supported numerous renewable-energy projects within their operations.[31] Similarly, Vail Resorts reduced its electricity and natural gas usage by more than 10 percent over four years, eliminating nearly 23,000 metric tons of CO_2, and has pledged to reduce usage an additional 10 percent by 2020.[32] They have invested $4 million to increase the energy efficiency of snowmaking systems and partnered with local energy providers and the CEO to conduct extensive energy efficiency studies.[33]



7.4 STRATEGIES AND POLICY RECOMMENDATIONS

- Partner with federal and local agencies to preserve and protect forest health and wildlife habitat, and to reduce wildfire risk.
- Examine National Park Service climate preparedness activities for possible collaboration.
- Frequently update a strategic marketing plan for the tourism industry that addresses natural hazards and climate change.
- Encourage diversification of activities at recreational areas statewide.
- Encourage broader business continuity planning to include post disaster strategies.

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8

Ecosystems

Ecological systems support Colorado's residents and key economic sectors, and the state is blessed with a diversity of them. Eighteen dominant ecosystems, each made up of several land cover types, serve as habitat for plant, aquatic, and terrestrial species across the state. Ecosystems support clean water supplies, plant pollination, wildlife diversity, and recreational opportunities. The ability of ecosystems to continue to produce these services is challenged by effects associated with climate change.

Climate change may affect Colorado's ecosystems in many ways, including by increasing the ability of invasive species to establish and spread, elevating the severity of wildfires, and altering habitats that support plant, fish, and wildlife species. When intact, forested ecosystems function as a carbon sink, helping to reduce emissions of a major greenhouse gas; yet they are susceptible to fire and disease. Effects of climate change such as drought and early snowmelt could lead to forest die-offs from drought-related stress, decreased likelihood of tree regeneration after a fire, and thus decreased forest productivity.[1] Grassland ecosystems in Colorado will be particularly impacted by drought and changed precipitation patterns; reduced plant growth will increasing the potential for these ecosystems to become CO_2 sources rather than sinks.[2] Alpine ecosystems are at risk of decreased plant seasons as temperatures warm, raising the levels of nitrogen and phosphorous and creating water quality issues in populated areas.[3] Other reports have comprehensively assessed the vulnerability of Colorado's ecosystems to a changing climate.[4]

Any changes to ecosystems because of the effects of climate change are likely to trigger changes in current resources management strategies. In order for state agencies to adequately manage natural resources, managers must first understand the potential for future impacts to ecosystems and resources, then tailor their practices to account for a projected future climate.

8.1 FOREST HEALTH AND WILDFIRE

8.1.1 INTRODUCTION

Wildfire is an essential element in the natural cycle for forests worldwide. Critical ecosystem functions are served by a regular cycle of fire. For example, soils depend on nutrients replenished through fire, pests are controlled by the heat, and many tree species rely on the extreme temperatures of wildfire for healthy regeneration.

Several forest types, primarily low-elevation Ponderosa Pine, have historically maintained a low tree density through frequent, low intensity wildfire. When public land management agencies adopted a policy of immediate fire suppression, those historic patterns were disrupted. No longer maintained by routine, relatively benign wildfires, forests became denser and accumulated heavy fuel loads. Today, scientists agree that a century of aggressive fire suppression, along with private land management decisions, has contributed to unhealthy densities in many forest types, and those forests are more vulnerable to unnaturally intense and damaging wildfires.[5] Indeed, excessively large and intense wildfires can have a powerfully negative effect on the ecosystem. Sterilized soils are much more susceptible to erosion, and eroded hillsides feed sediment into rivers and reservoirs downstream. Strontia Springs Reservoir near Denver is one high-profile example of this pattern. Following the 1996 Buffalo Creek Fire and the 2002 Hayman Fire, erodible soils poured into the reservoir, choking the water supply with sediment. Denver Water partnered with the U.S. Forest Service to drain the reservoir and improve water quality, which cost $33 million.[6]

Those costs occur within the context of overall fire suppression costs. In addition to the more obvious costs associated with wildfire, such as damage to homes and assets of value, there are a range of indirect costs as well. While the fire is underway, businesses are likely to lose customers, tourism will decrease, and those with respiratory health problems may need medical attention. Longer term, rehabilitation of forests, roads, watersheds, and utility corridors can drive up costs. The 2002 Hayman Fire ultimately cost the state $207 million,[7] and it is considered one of the most expensive fires in the state's history.

Add to that the steady and increasing development of homes adjacent to fire-prone public forested lands, and the combination is a daunting management challenge. In 2010, an estimated 313,000 housing units existed in this high risk area, called the Wildland-Urban Interface (WUI). Colorado State University researchers estimate that by the year 2030, the size of Colorado's WUI will have increased to 720,000 homes.[8] Headwaters Institute notes that 84 percent of private lands in the high-risk zone are currently undeveloped. If the wildfire risk we currently face in the WUI is only 16 percent of the scale of the problem to come, more aggressive steps may need to be taken.

The challenge is further complicated by the fact that Colorado has long struggled to maintain a forest-products industry. By all accounts, the markets are weak and the economics of timber harvest have been inverted; where once the U.S. Forest Service earned money on contracted timber sales, it now expends money on "service" contracts. With declining federal budgets, the agency has fallen behind in clearing out the hazardous fuels that contribute to extreme wildfires. Where perhaps one hundred years ago unbroken landscapes of healthy forests were common, we now see overly dense, disease-infested, wildfire-prone ecosystems that many scientists consider abnormal.

Overlaying the climate change context on this already challenging situation adds complexity. As hotter, more damaging, more intense, and more frequent wildfires have become the norm, scientists point to the trend as indicative of a changing planet. It can be difficult to separate the many variables at play, but we know that fire is a participant in the dynamics of climate change. As temperatures increase and snow melts earlier, wildfires begin earlier in the season and have become more frequent. At the same time, those fires release CO_2, contributing to the ongoing rise in global temperatures. Research shows that these patterns are manifested in measurable ways, with more large wildfires, significantly more area burned, longer seasons, and longer duration for fire events.[9]

8.1.2 ADAPTATION

The most important piece of the forest health and wildfire dilemma is adaption. The term "fire-safe communities" has gained traction across the West as towns with acreage in the WUI have learned that fire is inevitable. The goal is not to eradicate fire, but to minimize the risk to assets of value. Many of non-profit organizations address this through public outreach and grants to local governments. More than 100 communities in Colorado have been certified "FireWise," indicating their implementation of a suite of tactics designed to remove local fuels and protect homes.

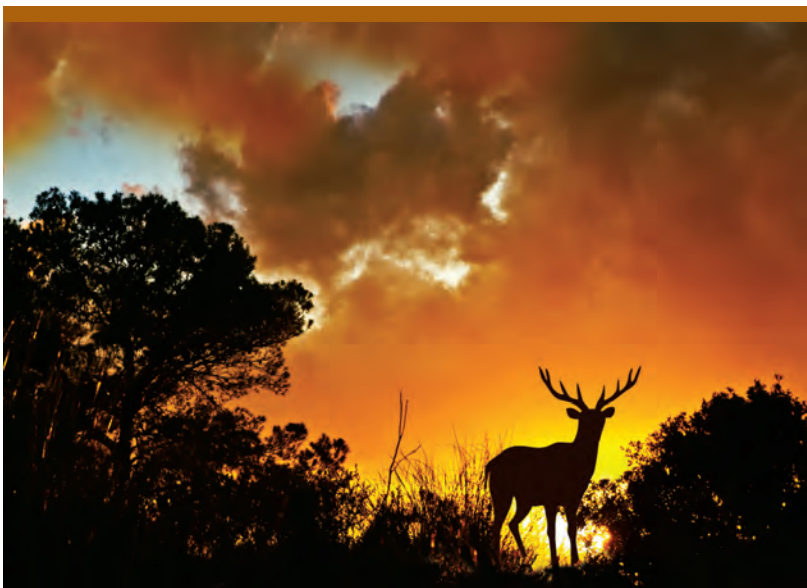
Similarly, two grant programs exist in Colorado to help private landowners who live in the WUI treat their property to minimize risk. The Colorado State Forest Service's Restoration Grant program is funded at $1.2 million a year, and accepts applications from across the state.[10] The Department of Natural Resources' Wildfire Risk Reduction Grant Program was funded with $9.8 million in 2013.[11] Both programs require matching funds and both have contributed to a reduction in hazardous fuels in high-risk areas.

The use of prescribed fire is essential for the adaptation task. Only fire can accomplish the range of ecosystem benefits the forest needs. Mechanical fuel removal may succeed in reducing biomass, but it fails to rejuvenate the complete system.

Federal land management agencies are essential partners in both mitigation and adaptation efforts. Given Colorado's mixed ownership landscape, the state cannot reduce fire risk without a close partnership. One helpful tool is the Good Neighbor Authority, which allows state forestry agencies to conduct hazardous-fuels reduction projects across ownership lines into adjacent federal land. Colorado has successfully piloted this authority since 2000. Based in large part on the successes in Colorado, the authority was legislatively extended to all states in 2014.[12]

Available funding is a limiting factor to mitigating risk. With only two relatively small grant programs funded by the state that are available to help homeowners address this risk, there is room for improvement. Many believe that homeowners who chose to build in the WUI should bear the brunt of the costs for reducing the risk that can threaten not only their homes but the state's tax base. For this reason, many fuels reduction efforts are targeted through public outreach and education. These important efforts must be matched with real resources, both in the form of funding for fuels-reduction work and in technical support. Local, state, and federal agencies must work in concert to provide these key resources, to incentivize private landowners who have an immediate stake in their own safety, and to leverage funding so that risk does not fall disproportionately on those with insufficient means. Additional funding, enhanced partnerships, and better outreach would improve outcomes.

Risk could be further mitigated by focusing on reducing the number of new homes built in fire-prone landscapes. Governor Hickenlooper convened the Wildfire Insurance and Forest Health Task Force in 2013 to consider the role of private home insurance companies in reducing wildfire risk, and the Task Force developed a series of recommendations. Chief among the suggestions was the need for better information about risk in the WUI. The group recommended investing in the development of a mapping system that would feature parcel-level data. With that information, potential homeowners, realtors, and insurance companies could know the extent to which a property in question is considered high risk, the reason for the high risk rating, and possible actions that could mitigate that risk. Once that information was made available, the group felt that market forces could potentially drive a stream of additional actions, many of which would serve to better inform homeowners about how to manage risk from wildfire.



8.2 FISH AND WILDLIFE

8.2.1 INTRODUCTION

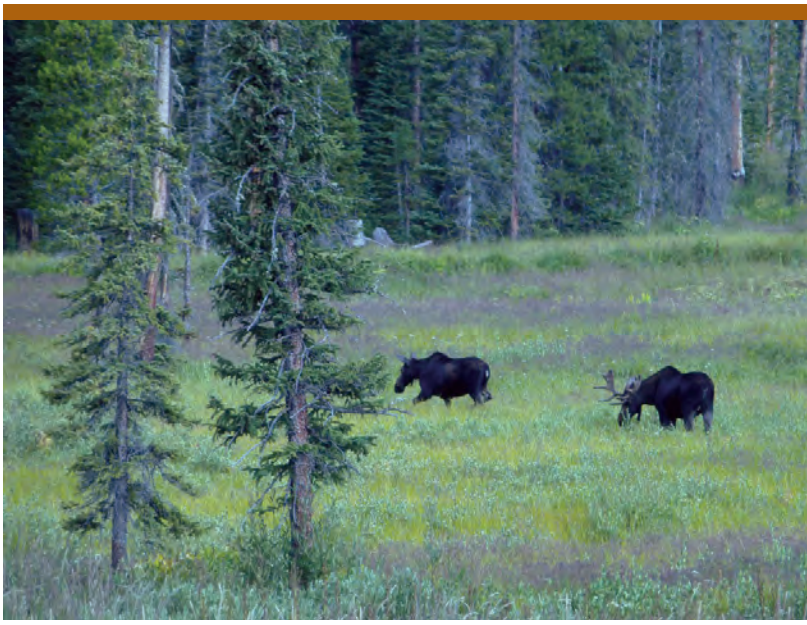
Coloradans heavily value wildlife, natural places, and outdoor recreation;[13] and wildlife contributes to a multi-billion-dollar, outdoor recreation economy in the state. In 2012 alone, Colorado residents and visitors spent more than $21 billion on outdoor recreation trips and equipment, a large portion of which were directly related to wildlife through activities like hunting, fishing, and birding.[14] As the state's wildlife agency, Colorado Parks and Wildlife (CPW) is entrusted with the responsibility of perpetuating fish and wildlife resources and ensuring outdoor recreational opportunities for current and future generations.

Eighteen dominant ecological systems comprise Colorado's landscape and serve as habitat for the many hundreds of species managed by CPW.[15] Future projected climatic changes have the potential to alter habitat and water supplies that support wildlife. For decades, biologists and resource managers at CPW have studied species and their habitat to manage for seasonal and cyclical changes. Now wildlife managers must understand the potential for future changes and adapt management practices to maintain wildlife populations for future public enjoyment.

8.2.2 ADAPTATION

CPW is revising their State Wildlife Action Plan (SWAP), which outlines a 10-year vision for managing Colorado's fish, wildlife, and their habitat. A component of the revised plan will, for the first time, include a vulnerability assessment to identify the degree of climate change expected in several key habitat types across the state. The assessment studies the difference between current and future conditions for climate factors believed to influence the distribution of habitat types as well as the resulting response of those habitat types to the changed conditions. The final SWAP will be submitted to the U.S. Fish and Wildlife Service for their approval in September 2015. To date, CPW has already received and incorporated significant public input into the plan.[16]

To inform the climate portion of the SWAP revision, CPW conducted a thorough analysis of the vulnerability of priority wildlife habitat under an altered climate. CPW, in collaboration with the Colorado



Natural Heritage Program, U.S. Geological Survey, and the North Central Climate Science Center, studied projected exposure to climate change, sensitivity of priority habitat types to expected changes, and the adaptive capacity of these habitat types to respond to changes. Ultimately, the study produced a vulnerability assessment rating for thirteen priority habitats in Colorado.[17]

The results of climate modeling out to 2050 indicate broadly that all areas of the state are likely to experience some degree of warming. Precipitation projections are more variable: some models project drier than current conditions, and some project wetter. Even slightly wetter conditions may not be sufficient to maintain soil moisture conditions as experienced in the recent past when combined with expected increases in temperature.[18] Most wildlife habitat will not shift quickly, but within the 30-year timeframe we will likely begin to see altered ecosystem composition.[19] By mid-century, future wildlife habitat will likely be warmer, especially on the eastern plains.[20]

Aquatic habitat was not directly considered in the SWAP vulnerability assessment, but CPW biologists have known for decades that aquatic species in Colorado may be uniquely affected by climatic changes. Increased temperatures and decreased precipitation pose a threat to aquatic species because increased water temperatures and reduced stream flows directly alter habitat suitability and may increase the spread of non-native species and diseases.[21] Reduced stream flows may also exacerbate the fragmentation of aquatic habitat. Studies on aquatic species by CPW research scientists often contain water temperature and hydrologic

components. While the focus of the studies may be initiated for other purposes, many also address issues related to potential climate change, such as thermal tolerances of native aquatic species.[22]

Past work conducted by CPW scientists has focused on evaluating effects of fluctuating water levels in reservoirs to help forecast the effects of drought on fish populations.[23] CPW has been working with scientists at Colorado State University and the U.S. Geological Survey to evaluate the potential impact of climate change on high-elevation cutthroat trout waters and to model persistence of cutthroat trout populations given a variety of factors, including variables associated with climate change.[24] Other work cooperatively conducted by CPW and Colorado State University includes a study of eastern plains fishes to determine if populations will be at risk because of increasing temperatures and changes in hydrological patterns. Researchers have already begun to investigate whether stream-habitat improvement efforts can help stabilize water temperatures in degraded areas. Ongoing stream-habitat work includes an emphasis on fish passage features to improve connectivity of habitats and allow fish to migrate to avoid becoming stranded in areas of unsuitable habitat.

Vulnerability assessments are essential for helping wildlife managers respond to a changing climate. Projected exposure to climate change is one factor that influences the vulnerability of a species or habitat. Any efforts to mitigate the impacts of projected future climate changes will reduce stresses on species and their habitat, allowing them to be more resilient and adaptable.

True vulnerability of habitat is likely to be determined by their capacity to adapt to changes. Species-specific adaptation was not a factor that the state's vulnerability assessment was able to precisely evaluate, and it is important to note that factors besides climate change place stresses on species that can affect future populations. Species resiliency and adaptation can be affected to some extent by management actions. Therefore conservation targets and management actions articulated in the revised SWAP will be a critical tool to ensure species are able to thrive in Colorado under future climate conditions.

8.3 STRATEGIES AND POLICY RECOMMENDATIONS

There are opportunities to affect policy and to develop strategies and incentives to increase the resiliency of Colorado's ecosystems. The following are possible approaches.

- Continue to support funding and technical support for homeowners who live in areas with high risk of wildfire. Focus efforts on mitigation and the reduction of hazardous fuels around homes.
- Develop and improve incentives for homeowners to encourage personal responsibility for risk reduction. Combine incentives with robust outreach and education.
- Enhance the availability of parcel-level data, so that homeowners and potential home-buyers can accurately assess the level of risk associated with a given property. Make data available to insurance companies, emergency personnel, and local governments.
- Submit a State Wildlife Action Plan to the U.S. Fish and Wildlife Service by the end of September 2015 that includes a vulnerability assessment of 13 priority habitats based on projected climate change.
- Update the SWAP, including climate-related elements, no less frequently than every 10 years.
- Work with state, federal, and non-governmental partners to model projected distribution of species, to the extent that available data supports analyses.
- Coordinate among CPW, the CWCB, the private sector, and municipalities to consider how future water-supply projections will impact aquatic habitat.
- Continue to investigate ways to reduce impacts of climate change in aquatic systems through stream-habitat improvement and connectivity.

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9

Partner Efforts

While this Climate Plan is primarily about the role the state will play in reducing GHG emissions and preparing for the effects of climate change, it is also important to acknowledge what is being done by local communities and businesses here in Colorado. The state's efforts are further enhanced by partnership with municipal and county efforts, as well as with work being done by the business sector.

This chapter illustrates some of that work. It is by no means an exhaustive list of everything every community in Colorado is doing about climate change. Nor is this chapter (or the examples it highlights) meant to be either prescriptive or an endorsement: every community has their own needs and must choose how to act in a manner that best suits them. This chapter is meant to serve as a guide to what has been successful so far (and what can potentially be successful for other communities around the state in the future).

In many ways, Colorado businesses and local communities are the best suited to confront the effects of climate change in Colorado. Likewise, many of the actions that are needed are best implemented at the local level. Already local governments around the state have adopted new alternative fuel sources to power their communities, have committed to reducing GHG reduction targets, and have put forth innovative solutions for planning and mitigating for future changes.

9.1 LOCAL COMMUNITIES

All around the U.S., local communities are taking the initiative to address climate change. According to a survey conducted by the U.S. Conference of Mayors from 2013-2014, more than half of the cities surveyed (149 of 282) have formally committed to reducing GHG emissions.[1] And this holds true for Colorado as well: Seventeen communities (including Aspen, Basalt, Boulder, Carbondale, Denver, Dillon, Durango, Frisco, Glenwood Springs, Gunnison, Ignacio, Nederland, New Castle, Pagosa Springs, Telluride, Crested Butte, and Westminster) have signed the U.S. Conference of Mayors Climate Protection Agreement, pledging to meet or beat the Kyoto Protocol emission reduction targets.[2]

In 2009, several of those communities and others, along with the Colorado Municipal League and the Colorado Association of Ski Towns, formed the Colorado Climate Network to support efforts by local governments in tackling climate change.[3] As part of their efforts, the network formed the Colorado Local Resilience Project, comprising 78 project participants from 30 local governments and six other related local organizations.[4] The project released a report in April 2015 putting forth recommendations for local governments to make their communities more resilient to the effects of climate change.

The report outlines six main conclusions as well as 36 specific recommendations that touch on assessing, planning, and managing for resilience; developing and sharing information; engaging the public and stakeholders; and building capacity.[5]

There are several communities around the state that have already shown success implementing new ideas or committing to GHG emission reductions. The following examples from around the state represent a cross section of communities doing just that.

9.1.1 GRAND JUNCTION

The city of Grand Junction has a population of just fewer than 60,000 and serves as the county seat for Mesa County. Grand Junction is a driving force for alternative fuels use in the state, perhaps the most visible example of which is its recent biogas project.

In the winter of 2014 the city began building its Persigo Biogas Project, which uses the digester gas produced at the Persigo wastewater treatment facility. The Persigo project captures this gas, scrubs it, transports it via pipeline, and then compress it to fuel the city's and the Grand Valley Transit fleets.

The Persigo Wastewater Treatment Plant produces 120,000 cf/d of methane, 16 percent of which is used to heat the digester process. Before the completion of this project, 100,000 cf/d (the equivalent of 400 gallons of gasoline) was typically flared or wasted to the atmosphere. The majority of this wasted methane is now being converted and used for fueling purposes.

The biogas project offers significant economic benefits to the city by creating a reliable, renewable transportation fuel source with significantly less price volatility. It also has significant environmental benefits. Every gallon equivalent of biogas converted to compressed natural gas (CNG) not only off-sets a gallon of diesel fuel being burned, but it also eliminates the flaring of the excess gas at the treatment plant, thereby reducing pollutants in the valley. Actual emissions vary by engine, but CNG Heavy Duty Vehicles have been found to reduce emissions relative to conventional diesel vehicles by emitting 75 percent less carbon monoxide, 95 percent less Particulate Matter and 49 percent less mono-nitrogen oxides. On average, each CNG-fueled truck reduces emissions by the equivalent of 325 vehicles annually.[6]

9.1.2 FORT COLLINS

Fort Collins, located on the Front Range north of Denver, is the fourth largest city in Colorado and has a population of 156,000. Since the 1990s, Fort Collins has been a pioneer in planning for reductions in GHG emissions and measuring progress made towards their goals.

In 1997, Fort Collins joined the Cities for Climate Protection Campaign, the first international initiative that aims to facilitate emissions reduction of local governments. Two years later, the city council set its first GHG goals. In 2008, the council renewed its commitment to climate protection by adopting Colorado's 2007 statewide Climate Action Plan goals to reduce emissions 20 percent below 2005 levels by 2020 and reduce emissions 80 percent below 2005 levels by 2050.[7] This was accompanied by the adoption of the city's own climate action plan, a blueprint for furthering its reduction goals while advancing multiple other city objectives. In March 2015, the council went even further, setting a goal to achieve 80-percent reductions from its 2005 emissions levels by 2030 and achieving carbon neutrality by 2050.[8] A recently published Climate Action Plan Framework will help the city achieve these emissions reduction targets.[9]

In addition to developing climate change plans and frameworks, Fort Collins has also delineated measureable goals for emissions reductions and tracking their progress. In its 2013 Climate Action Status Report, Fort Collins was able to quantify its progress towards reaching its GHG reduction goals. The report showed that while in 2012 and 2013 the total carbon emission increased over the previous years, overall community emissions were down by 4.9 percent from 2005 and that per capita emissions in Fort Collins were at 15.3 metric tons CO_2e/year, down 17.7 percent from the 2005 levels of 18.6 metric tons CO_2e/year.[10]

Other municipalities are also making strides towards more resilient communities such as Denver (with its 2014 Climate Action Plan) and Lakewood (with its 2015 Sustainability Plan).

9.1.3 GARFIELD COUNTY COMMUNITIES

Communities in Garfield County have joined together to make progress on achieving targets for energy efficiency, renewable energy and petroleum independence. In 2009, a DOLA New Energy Communities grant and local match launched a countywide effort, and in 2012 the 10 local government partners carried the effort forward by forming the Garfield Clean Energy Collaborative.

Garfield Clean Energy is a local government authority that provides programs and services to help households, businesses, and local governments become more energy efficient and reduce energy costs. The 10 Garfield Clean Energy members are Parachute, Rifle, Silt, New Castle, Glenwood Springs, Carbondale, Garfield County, the Garfield County Public Library District, Colorado Mountain College, and the Roaring Fork Transportation Authority. Services are delivered by Clean Energy Economy for the Region (CLEER).

To date, Garfield Clean Energy has helped 295 businesses, 378 households, and 55 government buildings make energy upgrades that are saving more than $603,000 per year. Since 2010, these projects have stimulated investments of $7.3 million in materials purchased from retailers and work by 169 contractors, and have reduced greenhouse gas emissions by 15,200 tons. It's a partnership effort that boosts the local economy, and the results help energy utilities reach their goals for demand-side conservation.[11]

Garfield Clean Energy used some of its original DOLA grant funds to install 23 renewable energy systems on public buildings countywide, generating 365 kW of solar electric power.[12] The organization continues to assist local governments, businesses and households in reaping the benefits of renewable energy, providing technical assistance that resulted in 1048 kW of solar capacity added in 2015. A tally of government-owned solar energy systems in Garfield County shows a total of 4.6 MW of generating capacity, an amount equal to the average annual electrical use of 1170 homes.[13]

By working toward energy efficiency and renewable energy targets, two Garfield Clean Energy members—Rifle and Carbondale—have tackled even more ambitious goals.

9.1.3.1 Rifle's Renewable Energy Program

Rifle, a city of more than 9000 in Garfield County known for its natural gas drilling and oil shale exploration has become a leader in renewable energy use. The city started by partnering with SunEdison in 2009 to install two solar arrays that produce a combined 2.3 MW; a 1.7 MW array powers the city's wastewater plant and a 600 kW array powers the city's water intake pumps. This jumpstarted a process that now boasts 325 watts per person of solar power, the highest per-capita solar production in the nation.[14] Rifle city government has also achieved net zero status, producing at least as much electricity as it draws from the grid. The estimated annual value of the solar power it produces tops half a million dollars, according to estimates from Garfield Clean Energy.[15]

9.1.3.2 Town of Carbondale

Clean energy and climate protection have been an important part of the Carbondale economy for more than 20 years. The town of 6500 is the original home of Solar Energy International, as well as renewable energy and energy efficiency firms and organizations. Some are located in the town's 100 percent solar-powered community center. The town government's climate action plan, adopted in 2006, has been a catalyst for increased renewable energy on government facilities, energy efficient building codes, and innovative programs to reach home buyers and low-income families and seniors.[16]

In 2014, town trustees and two nonprofits, CLEER and CORE, launched Carbondale Clean Energy 2020. A citizen's technical advisory group worked with CLEER and CORE to determine carbon reductions to-date, and to analyze what more needs to be done throughout the community to reach the town's climate and energy targets by 2020. The effort also produced a resolution dedicating at least 20 percent of the town's mineral severance and mineral lease revenues toward reaching climate and clean energy goals through grants, rebates, and services.[17]

Carbondale's Residential Efficient Building Program encourages "cost-effective and sustainable building methods to create durable, energy-efficient structures that conserve natural resources, promote the efficient use of building materials, and improve indoor air quality." The program also sets requirements for renewable energy.[18] Carbondale also adopted the 2012 International Green Construction Code, regulating all new commercial construction and large remodels.[19]

Similar to Rifle, Carbondale is using power purchase agreements to finance solar arrays, generating 168 kW at five facilities. Its high school will be net-zero for electricity use once a 379-kW array is installed in 2015.[20] Carbondale is a "Solar Friendly Community," as certified by the U.S. Department of Energy.[21] The town has also adopted a tree ordinance to protect and develop a healthy urban forest and park system, and has an extensive bike and pedestrian network to encourage low-carbon transportation.[22]

9.1.4 BOULDER COUNTY

Boulder County has developed many plans and tools to help support local jurisdictions in implementing mitigation and adaptation measures. In 2012 for example, Boulder County published the Boulder County Environmental Sustainability Plan, which has guided its initiatives on climate change and other measures of sustainability.[23] The County has also considered how climate change will affect the ability to carry out business as usual. Early in 2012, Boulder County developed a Climate Change Preparedness Plan that identifies the potential impacts of climate change, explores the implications of these changes in the context of resource management institutions, and outlines opportunities for adaptation planning efforts.[24]

Boulder County has achieved substantial carbon emissions reduction through its energy efficiency programs. The EnergySmart program is a collaborative partnership with Boulder County, the City of Boulder, the City of Longmont, and the local utilities, Xcel Energy and Platte River Power Authority. Collectively, the program for home and business energy efficiency has saved an estimated 18,666 MWh and 1,079,300 therms annually and reduced an estimated 20,700 metric tons of carbon dioxide equivalent annually in Boulder County, the equivalent to taking 4330 cars off the road.[25] The EnergySmart program also helped businesses and residents install water-saving appliances, saving an estimated 24.3 million gallons of water annually.[26] Through the Weatherization Assistance Program (WAP), a state and federally-funded program administered by Boulder County to assist qualifying homeowners, county partners reduced an estimated 4240 metric tons of CO_2e countywide between 2009 and 2013, the equivalent of taking 890 cars off the road.[27]

In addition, Boulder County has institutionalized its energy and water efficiency measures by establishing a green building code that requires newly constructed homes in Boulder County to be far more efficient than the national building codes. When Boulder County conducted a Sustainability Impact Overview for the years 2011-2013, the study concluded that the county's initiatives collectively had resulted in reduced GHG emissions equal to powering 41,000 homes.[28]

9.2 COLORADO'S BUSINESS COMMUNITY

Colorado is home to many companies that incorporate climate friendly practices into their everyday operations. Not only do these practices have a positive impact on reducing GHGs, but they also make good business sense.

9.2.1 BREWERIES

Colorado's brewing industry is one of the biggest and most robust in the country,[29] likewise it is one of the leaders in putting in place actions that mitigate and adapt to the effects of climate change. Ten percent of the signatories to the Climate Declaration are made up of locally owned and operated breweries.[30] The Climate Declaration is a call to action for breweries from around the country committing them to a number of actions to monitor and reduce their environmental impact.[31] One brewery who signed on to the declaration is Fort Collins-based New Belgium, Colorado's largest craft brewery. According to their 2015 sustainability report, nearly 13 percent of the company's energy comes from renewable sources, including solar and harvested methane.[32] New Belgium has also committed to tracking their GHG emissions and reducing them to 14 kg of CO_2e per hectoliter by 2015. The Odell Brewing Company, another Fort Collins-based brewery and signatory to the Climate Declaration, powers 95 percent of their operations through wind generators and the other 5 percent through solar panels. The company also recaptures steam to use for heat in their brewing process.[33] MillerCoors, with their largest brewery located in Golden, has identified its own environmental sustainability strategy, which includes a goal to reduce their per-barrel carbon footprint by 25 percent before 2020.[34]

9.2.2 BUSINESS COLLABORATION

One of the ways in which Colorado's business community is approaching the challenges posed by climate change is through stakeholder groups such as Environmental Entrepreneurs (E2). E2 is a nonpartisan, national community of business owners who promote smart policies with both economic and environmental benefits. E2 members come from a broad business base, ranging from clean energy and clean tech to real estate and finance, and beyond. Collectively, members have founded or funded more than 1700 companies and created 570,000 jobs, and they manage more than $100 billion in venture and private equity capital that will be invested in the companies of tomorrow.

COLORADO'S WATER PLAN

In December 2015, the CWCB will release the state's first-ever water plan. Colorado's Water Plan will lay out priorities for water use throughout the state as well as dynamic strategies needed to meet Colorado's future water needs. Colorado's Water Plan considers a range of possible future conditions and develops a practical, adaptive, and balanced path forward for meeting these needs through stakeholder engagement and sound science.

Given the challenge that climate change presents in predicting future water supplies (and demands) (See Chapter 2), Colorado's Water Plan does more than prepare for the most likely future: It incorporates the uncertainties posed by climate change by looking at a broad spectrum of futures, each with different levels of water supplies, water demands, and social values. The plan identifies a portfolio of needed actions for each possible future scenario as well as decision points (or signposts) that allow future planners to determine which scenario the state is headed for.[1]

Going further, Colorado's Water Plan also identifies which specific actions out of those portfolios are common to all of the future scenarios and need to be done no matter what, to close future supply shortages. These actions, called "no and low regrets" actions, are prioritized in Colorado's Water Plan as well as in each of the individual river basins' implementation plans. The remaining actions, called "adaptive strategies," are all dependent on the specific scenario (or mix of scenario characteristics) encountered in the future and will be evaluated based on future information.

Taking into account the unpredictability of factors driving Colorado's future, the ability to plan for multiple scenarios presents a much more comprehensive tool to plan and prepare for what lies ahead.

The Rocky Mountains Chapter was founded in 2007. Since then, it has grown to 75 members and is focused on state level efforts in Colorado. Members have companies in renewable energy, EV, battery storage and building efficiency industries. The Rocky Mountains Chapter has supported legislation to advance and promote renewable energy and energy efficiency, as well as policies that promote conservation and reuse of water resources. The Rocky Mountains Chapter also hosts educational events for members and guests. Two of the chapter member companies are highlighted in more detail below.

9.2.2.1 Community Energy Solar

Since its inception in 1999, Community Energy has led the development and construction of more than 1000 MW of wind and solar energy generating facilities across the United States, representing more than $2 billion in total project investment. In Colorado, Community Energy is currently developing one of the largest solar photovoltaic (PV) projects east of the Rockies, a 120 MW project located just outside Pueblo, Colorado, which when complete will supply solar generation to Xcel Energy under a 25-year purchase agreement approved by the Colorado Public Utilities Commission. The project will ultimately be comprised of more than 450,000 PV modules, will generally produce power nicely matched to meet Colorado's daily summer air conditioning loads, will generate enough power for more than 31,000 homes in its first year, and over the course of the project's 25-year life will reduce CO_2 emissions in Colorado by approximately 3.5 million tons.[35]

9.2.2.2 Cool Energy

Cool Energy is a Colorado-based family company that aims to harness and reuse lost heat that is intrinsic to many industrial processes. This heat is vented into the atmosphere every day without harnessing the energy it contains. Cool Energy uses the technology they developed in the ThermoHeart™ Engine, which converts low-temperature wasted heat into clean electricity and has demonstrated high conversion efficiency and operating reliability. What is more, the remarkable projected payback period is as short as one year, making this technology not only a great source of clean energy, but also cost effective for businesses.[36] While it is only now moving to market, this emerging technology has the potential to reduce the emission of 10 million tons of CO_2 annually and save companies $2.5 billion dollars in energy costs.[37]

9.2.3 DENVER WATER[38]

Denver Water is a leader in understanding and preparing for the new and complex challenge of climate change and adaptation. As Colorado's oldest and largest drinking water provider, Denver Water reliably provides high-quality drinking water to nearly one-quarter of all Coloradans. Being prepared for the future, therefore, is of the utmost importance. Denver Water is one of the first water utilities in the nation to consider climate change in their long-range planning and has applied cutting-edge approaches to planning for deep uncertainty such as scenario planning and robust decision-making. Over the last year they have been actively investigating the viability of various adaptation strategies.

Planning for climate change in Colorado is particularly challenging because the projections of future conditions range significantly. To better understand the potential risks and challenges, Denver Water directly engages with climate scientists to "co-produce" the data, tools, and methods needed to incorporate climate change into their planning. These collaborations keep Denver Water at the forefront of climate science while providing critical feedback and encouraging climate scientists to better meet decision-making needs.

Coordinating with other water utilities is key to the success of Denver Water's climate adaption program. Their initiation and leadership on the 2012 Joint Front Range Climate Change Vulnerability Study led to the development of tools and data Front Range water utilities needed to examine their vulnerability to climate model projections. Nationally, Denver Water works extensively with other large water utilities through groups like the Water Utility Climate Alliance. These collaborations allow Denver Water to pool resources, have a strong, unified voice and learn from other water utilities leading the way in climate adaptation.

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10

Moving Forward

In Colorado, climate change presents us with a broad range of challenges. Projections from climate data indicate that the warmest summers from our past may become the average summers in our future. With increasing temperatures, shifts in snowmelt runoff, water quality concerns, or extreme weather events that can impact air quality, transportation and infrastructure, the challenges we face will affect everyone, and require collaborative solutions.

Yet, by acknowledging potential impacts head on, assessing where we are most vulnerable, and by offering meaningful actions now and across all sectors, Coloradans will be in a better position to mitigate, and adapt to, the effects of climate change. Thankfully, Colorado is already leading the charge. Our commitment to an RES was the first in the nation, as was our regulation of methane from oil and gas development. Colorado's Water Plan provides innovative solutions to meet the water needs of all Coloradans long into the future, and factors in how a changing climate may affect our supplies, demands, and ecosystems.

The strategies and recommendations laid out in the plan are commitments by state agencies to continue moving us forward and provide state level policies and strategies to mitigate and adapt. Those strategies and recommendations, also included in each sector chapter, are summarized below.

Water

- Promote and encourage water efficiency and/or conservation at the local and state agency level.
- Encourage water providers to do comprehensive integrated water resource planning, geared toward implementing the best practices at the higher customer participation levels to achieve state endorsement of projects, and financial assistance.
- Support water sharing agreements where feasible and cost effective.
- Explore options to increase reuse of fully consumable water.
- Encourage opportunities for reservoir enlargement statewide, where feasible and cost effective that could be used for municipal, agricultural, recreational and environmental purposes.
- Support improvements in Colorado's water infrastructure system by providing low-interest loans and grants, and encourage partnerships and resource-sharing with federal agencies.
- Promote and encourage drought preparedness through comprehensive drought planning and mitigation implementation.

- Identify climate change risks related to integrated water quality and water quantity management.
- Incorporate climate variability and change into long-term, statewide water planning efforts.
- Work with regulators to modify existing water quality standards to factor in climatic change into regulations.
- Work with utilities and federal agencies to identify and address regulatory barriers to climate preparedness and adaptation.
- Assist local communities in building resilience through the development and implementation of regional and local resiliency plans.
- Collaborate across jurisdictions to protect and restore ecosystems associated with the Healthy Watersheds Fund and enhance existing weather monitoring systems.
- Fund and enhance stream and lake quantity and quality monitoring.

Public Health

- Coordinate with the Public Utilities Commission, the CEO, and additional stakeholders to develop and implement a Colorado-specific plan to substantially reduce carbon dioxide emissions from fossil fuel fired EGUs, in accordance with the EPA's Clean Power Plan.
- By 2016, adopt an ozone State Implementation Plan with sufficient control measures to demonstrate attainment of the current ozone standard by 2017.
- Fully implement Colorado's 2014 oil and gas emission regulations, evaluate the resulting reductions of methane and other pollutants, and evaluate potential refinements to those regulations.
- Continue to monitor and evaluate particulate matter levels and issue public health advisories as appropriate.
- Continue to assess potential correlations between vector-borne diseases and climate factors, incorporate the results into public health guidance, and communicate any revised risk reduction measures to local governments and the public.
- Emphasize climate-related disaster preparedness in emergency response plans and exercises.

Energy

- Assure the timely and complete attainment of the state's RES 2020 goals. Assist all utilities (investor-owned, municipal and cooperative) in identifying and implementing best practices for integrating cost-effective renewable resources, both utility-scale and distributed.
- Assist all electric utilities in incorporating all feasible energy efficiency activities into resource planning and the EPA air quality compliance plans.
- Integrate cost-effective water savings into all energy efficiency programs administered by the state.
- Engage with energy companies to encourage and promote the most water-efficient technologies for energy extraction.
- Encourage energy companies to continue collaborating with agricultural and environmental interests when managing their water portfolio.
- Identify, test, and implement techniques to reduce water usage in the oil and gas industry through reuse of produced water. Focus specifically on options that yield both water and energy usage reductions.
- Aid in the commercialization of emerging electric generation technologies that reduce GHG emissions, such as coal mine methane capture, anaerobic digestion of agricultural waste, geothermal, and small/micro hydro.
- Aid in the commercialization of clean technologies in the oil and gas development sector, such as methane capture, waste heat recovery, and related technologies that increase efficiency and reduce adverse environmental impacts.
- Reduce market barriers to the development of all cost-effective and technologically viable alternatives to gasoline and diesel fueled transportation.
- Increase access to capital for commercial, residential, agricultural, and industrial customers seeking to improve the energy performance of their facilities.

Transportation

- Promote and encourage fuel-efficient vehicle technologies and programs to reduce vehicle emissions.
- Continue to support strategies and develop new strategies to reduce GHG emissions, reduce the growth of VMT and alleviate congestion. More specific strategies can be found in the Colorado Resiliency Framework.
- Encourage local, state, and federal entities to assess climate-related risks to transportation systems and take action to improve their resilience.
- Improve communication, data sharing, and collaboration between local, state, and federal entities related to climate change mitigation and adaptation programs and activities for transportation.
- Work to promote education of the traveling public on the impacts of GHGs associated with transportation while concurrently educating and training local, state, and federal entities and their staff on climate change adaptation concepts and strategies.
- Consider the incorporation of climate change impacts into transportation design, asset inventory and management processes, and transportation system investment decision-making.
- Provide guidance to local governments on land use planning strategies to promote efficient use of public resources and reduce GHG emissions through compact, transit-oriented development that utilizes smart growth practices and complete streets.
- Identify climate-related impacts and develop a standard method of recording impacts and costs of climate-related effects.

Agriculture

- Promote increased water storage solutions that help producers adapt to changing conditions and decrease production losses due to lack of water availability.
- Partner with research institutions and federal agencies to support producers' efforts to mitigate and adapt to climate change through improved irrigation efficiency and enhanced tillage practices.
- Support federal and state programs that improve soil health, e.g., by increasing soil organic carbon and sequestration, promoting long-term research into land management practices that build soil health, and examining state and local land-use policies that reduce soil erosion on arable lands.

Tourism & Recreation

- Partner with federal and local agencies to preserve and protect forest health and wildlife habitat, and to reduce wildfire risk.
- Examine National Park Service climate preparedness activities for possible collaboration.
- Frequently update a strategic marketing plan for the tourism industry that addresses natural hazards and climate change.
- Encourage diversification of activities at recreational areas statewide.
- Encourage broader business continuity planning to include post disaster strategies.

Ecosystems

- Continue to support funding and technical support for homeowners who live in areas with high risk for wildfire. Focus efforts on mitigation and the reduction of hazardous fuels around homes.
- Develop and improve incentives for homeowners to encourage personal responsibility for risk reduction. Combine incentives with robust outreach and education.
- Enhance the availability of parcel-level data, so that homeowners and potential home-buyers can accurately assess the level of risk associated with a given property. Make data available to insurance companies, emergency personnel, and local governments.
- Submit a State Wildlife Action Plan to the U.S. Fish and Wildlife Service by the end of September 2015 that includes a vulnerability assessment of 13 priority habitats based on projected climate change.
- Update the State Wildlife Action Plan, including climate-related elements, no less frequently than every 10 years.
- Work with state, federal, and non-governmental partners to model projected distribution of species, to the extent that available data supports analyses.
- Coordinate among CPW, the CWCB, the private sector, and municipalities to consider how future water-supply projections will impact aquatic habitat.
- Continue to investigate ways to reduce impacts of climate change in aquatic systems through stream-habitat improvement and connectivity.

In addition to the strategies and recommendations laid out in the chapters and above, each sector will engage in specific stakeholder engagement opportunities over the next year to further the discussion on how Colorado can address climate change and its associated effects going forward. Feedback from each of these sessions will be used to inform the implementation of the recommendations and strategies listed above. The opportunities for further engagement are outlined below.

- Following EPA's recently released Clean Power Plan, the CDPHE will expand its outreach to stakeholders, government agencies, and interested Coloradans in a public process to develop and implement a state plan to substantially reduce carbon dioxide emissions from fossil fuel fired EGUs. The CDPHE will host meetings and solicit public comment to gather ideas and attempt to reach some consensus on the most cost-effective ways to reduce emissions while preserving or enhancing electric grid reliability and the economy. The CDPHE will continue to fully cooperate with the Public Utilities Commission, the CEO and the General Assembly to optimize the state plan. The CDPHE anticipates submitting an initial state plan to the EPA by June 2016, adopting a final state plan by December 2016, and submitting a final state plan to the EPA by June 2017. The final plan could be extended by another year if Colorado partners with another state to develop a multi-state plan.

- The Colorado Parks and Wildlife Commission will serve as the public forum for future conversations on fish and wildlife adaptation. The Commission will schedule a series of conversations in the next year to hear recommendations from experts and the public about science and management options to inform management decisions.

- The CWCB will continue to be a leader on climate change adaptation in the water sector and will host an open discussion with experts and the public on climate change at one or more board meetings during fiscal year 2016. CWCB staff will also engage with stakeholder groups around the state to gather feedback on this plan and recommendations to explore and enhance future actions.

- Based upon the EPA Clean Power Plan Rule, energy efficiency may be a significant contributor to compliance plans. Viable energy efficiency options need to deliver electricity usage reductions during the compliance period of the Clean Power Plan, in a manner that is measurable, verifiable, and reliable. The CEO, in conjunction with the Public Utilities Commission, will continue to serve as subject matter experts concerning energy efficiency technologies, markets, and practices involving electric utility end-users. In this role, the CEO will convene one or more forums over the next year to engage stakeholders and ensure energy efficiency options best fit within a compliance plan for the state. The development of these forums will also include collaboration with the Colorado Department of Agriculture, which has partnered with the CEO on several energy programs.

- Deliver trainings to local government planners and emergency managers on integrating information regarding changing hazard risks and resilience principles into local plans and land use codes using the DOLA's forthcoming Colorado Hazard Mitigation and Land Use Planning Guide as a framework.

- Annually, the Colorado Tourism Office hosts a conference where the brightest minds in tourism come together. This year, for the first time, climate change will be included as part of the agenda. This will be an opportunity to both educate those in attendance about possible impacts as well as hear from those on the ground what they need most to build resilience and how the state can help to support that effort. The conference will be held in Crested Butte in September.

- The CDA will work with the Colorado Association of Conservation Districts to provide an informative, science-based panel and discussion at the annual conference for conservation districts to explore the projected climate change impacts on production agriculture in Colorado and steps that can be taken to adapt and prepare for those changes.

- The CDOT will work with the State Transportation Advisory Commission to develop a stakeholder engagement process to take place over the next year.

Lastly, the Governor's office and the Cabinet, are currently reviewing Greening Government goals and directives proposed by the newly reconstituted Greening Government Leadership Council. The executive order will address office-space related energy and water use, vehicle fuel use, and environmentally preferential purchasing as it relates to all state government operations. It is currently anticipated that the executive order will be issued before the end of the first quarter of fiscal year 2016.

Colorado is a state full of talented innovators who come together to tackle challenges and overcome obstacles on a daily basis. That collaboration and creative thinking is at the heart of this plan. Over the coming months state agencies will work to incorporate the recommendations of this plan, schedule opportunities for continued stakeholder engagement and continue to ensure that we are taking steps to reduce our GHG emissions in a balanced and responsible way, while also pursuing adaptive strategies that protect the core elements that make Colorado such a desirable place to live, work, and play.

Contributing Agencies and Offices

Colorado Energy Office
Colorado Resiliency and Recovery Office
Department of Agriculture
Department of Local Affairs
Department of Natural Resources
Department of Public Health and the Environment
Department of Transportation
Office of Economic Development and International Trade

Thank You

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The Nature Conservancy
Western Water Assessment/CIRES/University of Colorado
Southwest Energy Efficiency Project
Xcel Energy
350 Colorado

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Pg. 66 Moose – *Courtesy Colorado Department of Transportation*
Pg. 70 Grand Junction AD – *Courtesy City of Grand Junction*
Pg. 71 Rifle Solar Array – *Courtesy City of Rifle*
Pg. 73 Light Install – *Courtesy Clean Energy Economy for the Region*
Pg. 82 Electric Vehicle Charging – *Courtesy Colorado Energy Office*

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