COLORADO **CLIMATE PLAN**

State Level Policies and Strategies to Mitigate and Adapt

COLORADO **CLIMATE PLAN**

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] This means 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 demands, and extreme weather events that can impact air quality and recreation. The challenges we face will affect everyone, and they require collaborative solutions. For communities with inequitable living conditions, such as low-income and communities of color living in more polluted areas, climate change is likely to exacerbate existing vulnerabilities.

The goal of this document is to set clear and specific emission reduction goals for the State of Colorado, to identify opportunities to mitigate greenhouse gas emissions, and to promote state policy recommendations and actions that increase Colorado's state agencies level of preparedness for impacts we cannot avoid. This plan is organized by key sectors, including water, energy, transportation, public health, agriculture, and tourism, among others. Each chapter lays out some of the key ways climate change will occur in the state and identifies how those shifts will likely affect that particular sector, such as how an increase in wildfires will affect tourism and public health or how warmer temperatures and earlier snowmelt will affect agriculture and water-resource planning. In addition, each chapter describes many of the measures that are already being implemented —by state agencies as well as by local entities and private actors—to address these climatic changes. Finally, each chapter identifies specific goals and policy recommendations that can help that sector best adapt to and mitigate some of the most harmful effects climate change. 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 stakeholders through a public comment process.

This plan has also been developed to meet the requirements of Colorado Revised Statute § 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 an ongoing dialog with climate experts and the public.

In 2014 Governor John Hickenlooper released a comprehensive Colorado Climate Plan that promoted state policy recommendations and actions to 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. A lot of progress has been made since the release of that document, but there have also been significant changes in both global and federal climate policy. Those changes resulted in a need for the State to further clarify its own Colorado specific goals and objectives with regard to greenhouse gas emissions emission reductions.

On July 11, 2017 Governor John Hickenlooper signed an executive order committing the state to additional climate action. The executive order declares it to be the goal of the State of Colorado to achieve the following:[3]

- Reduce statewide greenhouse gas emissions by more than 26 percent from 2005 levels by 2025;
- Reduce carbon dioxide emissions from the electricity sector by 25 percent by 2025 and 35 percent by 2030 from 2012 levels; and
- Achieve electricity savings of 2 percent of total electricity sales per year by 2020.

The executive order also commits the State to:

- Work strategically with any interested utility or electric cooperative on a voluntary basis to maximize use of renewable energy without increasing costs to taxpayers;
- Create a statewide electric vehicle plan, which can be found here: https://tinyurl.com/COElectricVehiclePlan
- Develop a greenhouse gas emissions emissions tracking rule through the Department of Public Health and Environment;
- Identify opportunities to partner with local governments on locally-led climate goals and resilience actions;
- Institutionalize the state's greening government initiative;
- Formalize and expand upon cross-agency actions to provide economic development strategies and other supportive services to communities impacted by the changing energy landscape, and submit a written annual report detailing those efforts and accomplishments.

Consequently state agencies are working closely with our partners in the private sector and in local government to execute and implement the executive order. Achieving these goals will not be easy and will require significant collaboration, but it will also help to safeguard Colorado's air, natural resources, economy, and way of life for generations to come. Because climate change is a global issue the State has also joined the United States Climate Alliance; a bipartisan coalition of states and unincorporated self-governing territories in the United States that are committed to upholding the objectives of the 2015 Paris Agreement on climate change. Additionally, the Alliance provides an opportunity to share information and best practices, which can help Colorado to further improve and refine our own Climate Plan.

The various chapters of this plan seek to identify the most significant effects of climate change and to delineate the scope of the issue for future progress. The plan also seeks to highlight the determination and innovative spirit of Colorado. This determination and spirit are demonstrated by endeavors such as our work with utilities and local communities to transition to new, clean, and safer forms of power production; our efforts to promote electric vehicles and build the infrastructure across the state to support them; our commitment to not only create Colorado's first Water Plan but also find ways to fund its implementation; our resolve to tackle water quality and air quality head on and protect the health of citizens; our push to reduce wildfires and protect ecosystems for wildlife and human benefit, and our efforts to help producers and business save money through energy efficiency. And perhaps most important of all is our collaboration with others—because together we are better.

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 goals, strategies, and recommendations laid out here—and those we are still working to develop—are commitments by the state to continue moving us forward and provide Colorado specific policies and strategies to mitigate and adapt. Over the coming months state agencies will work to incorporate the goals of the executive order and the measures laid out in this plan, schedule opportunities for continued collaboration, and continue to ensure that we are taking steps to clean our air and 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.

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[1] Jeff Lukas et al., *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation* (2014), 2, accessed January 15, 2018, http://wwa.colorado.edu/climate/co2014report/Climate_Change_CO_Report_2014_FINAL.pdf.
[2] Ibid., 3.
[3] Exec. Ord. D2017-015, "Supporting Colorado's Clean Energy Transition," (July 11, 2017), accessed January 15, 2018, https://www.colorado.gov/governor/sites/default/files/executive_orders/climate_eo.pdf.

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Abbreviations & Acronyms

4R	Rural Response, Recovery, and Resilience program
AD	Anaerobic digestion
AgEE	Agricultural Energy Efficiency
CAFE	Colorado Department of Agriculture
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
CO_2	Carbon dioxide
CPW	Colorado Parks and Wildlife
DHSEM	Division of Homeland Security and Emergency Management
DMNFR	Denver Metropolitan/North Front Range
DNR	Department of Natural Resources
DOLA	Department of Local Affairs
DSM	Demand-side Management
E2	Environmental Entrepreneurs
EGU	Electric Generating Units
EPA	Environmental Protection Agency
EV	Electric Vehicle
FERC	Federal Energy Regulatory Commission
FTA	Federal Transit Administration
GCE	Garfield Clean Energy
GDP	Gross domestic product
GHG	Greenhouse gases
HFC	Hydrofluorocarbon
HPTE	High-Performance Transportation Enterprise
IECC	International Energy Conservation Code
ITS	Intelligent Transportation Systems
KW	Kilowatts
$MMTCO_2e$	Million Metric Tons Carbon Dioxide Equivalent
MW	Megawatts
MWh	Megawatt hours
NEPA	National Environmental Policy Act
NSPS	New Source Performance Standards
OEDIT	Office of Economic Development and International Trade
PV	Photovoltaic
RES	Renewable energy standard
RAQC	Regional Air Quality Council
RCPP	Regional Conservation Partnership Program
SMM	Sustainable materials management
SWAP	State Wildlife Action Plan
SWSI	Statewide Water Supply Initiative
VMT	Vehicle miles traveled
VOC	Volatile organic compound
WUI	Wildland-urban interface

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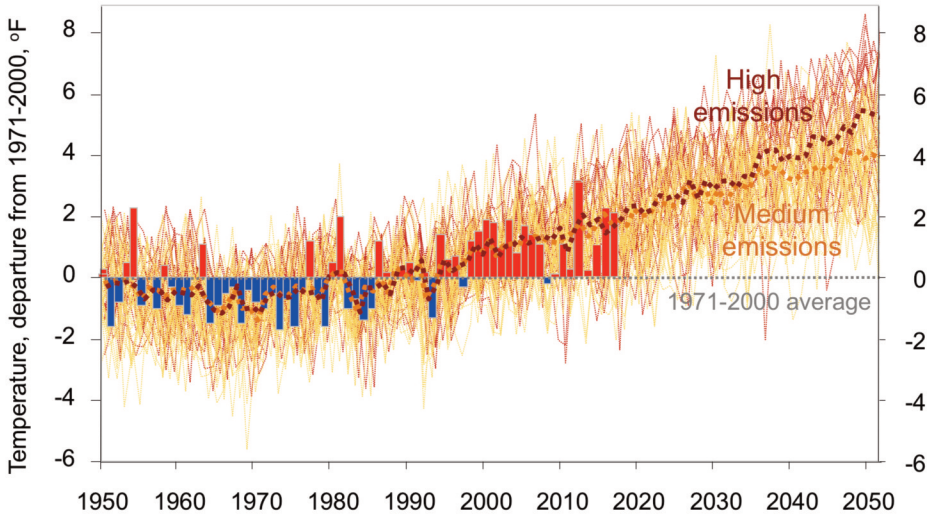
Introduction

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, landowners, and businesses. This plan sets specific statewide goals to responsibly mitigate greenhouse gases ("GHG") and advances our preparations for the changes we cannot prevent. Being proactive 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]

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

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 that requires proactive, coordinated efforts to enable Colorado to work to protect those resources and to adapt where necessary. At the same time, efforts to curb GHG emissions 26 percent economy wide by 2025 will help to mitigate impacts.[10]

Colorado has warmed 2ºF in the last 30 years and 2.5ºF 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 drier soils, a shift in the timing of peak runoff by one to four weeks, and more frequent and severe wildfires.[12] Future estimates project temperatures rising an additional 2.5 to 5ºF 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 set clear and specific emission reduction goals for the State of Colorado, to identify opportunities to mitigate greenhouse gas emissions, and to promote state policy recommendations and actions that increase Colorado's state agencies level of preparedness for impacts we cannot avoid. This plan is organized by key sectors that include, among others: water, energy, transportation, public health, agriculture, and tourism. Each chapter lays out the key ways climate change will occur in the state and identifies how those shifts will likely affect that particular sector—such as how an increase in wildfires will affect tourism and public health or how warmer temperatures and earlier snowmelt will affect agriculture and water-resource planning. In addition, each chapter describes many of the measures that are already being implemented—by state agencies as well as by local entities and private actors—to address these climatic changes. Finally, each chapter identifies specific goals and policy recommendations that can help that sector best adapt to and mitigate some of the most harmful effects climate change. 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 stakeholders through a public comment process.

This plan has also been developed to meet the requirements of Colorado House Bill 13-1293, codified as Colorado Revised Statute § 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 must take place and we look forward to a continued dialog with climate experts, business leaders, our local partners, and the public to build on what we have already achieved and to push ourselves to achieve much greater reductions.

The various chapters of this plan seek to identify the most significant effects of climate change and to delineate the scope of the issue for future progress. The plan also seeks to highlight the determination and innovative spirit of Colorado. This determination and spirit are demonstrated by endeavors such as: our work with utilities and local communities to transition to new, clean, and safer forms of power production; our efforts to promote electric vehicles and build the infrastructure across the state to support them; our commitment to not only create Colorado's first Water Plan but also find ways to fund its implementation; our resolve to tackle water quality and air quality head on and protect the health of citizens; our push to reduce wildfires and protect ecosystems for wildlife and human benefit, and our efforts to help producers and business save money through energy efficiency. And perhaps most important of all is our collaboration with others—because together we are better.

1.2 ADVANCING HEALTH EQUITY AND ENVIRONMENTAL JUSTICE

Climate change—because it can enhance existing stressors—can have more of a negative impact on vulnerable populations. This is due to the inequitable distribution of social, political, and economic power. These power imbalances can result in systems (economic, transportation, land use, etc.) and conditions that drive health inequities.[16] As a result, communities with inequitable living conditions, such as low-income and communities of color often living in more heavily polluted areas, face climate change impacts that can compound and exacerbate existing vulnerabilities.[17] Climate action requires addressing the inequities that create and intensify community vulnerabilities to increase overall health through strategically directing investments to improve living conditions for people facing disadvantage. To effectively mitigate the impact of climate change on underserved populations throughout Colorado, health equity and environmental justice considerations need to be embedded in our planning efforts on energy, transportation, food access, housing, land use planning, and other systems that affect health outcomes. Colorado seeks to align programming, communications and resources to strategically address these needs. This plan attempts to highlight opportunities for effective policies and programs where this can be done.

1.3 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, keeping costs affordable for our citizens, 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. We rank eleventh in the nation for cumulative solar electric capacity[18] and tenth for wind capacity.[19] Our energy companies have sharply reduced pollutants by transitioning to cleaner burning sources,[20] Xcel Energy now provides 29 percent carbon-free electricity within Colorado and projects this will continue to grow.[21] Statewide power plant CO_2 emissions decreased approximately 12 percent from 2012 through 2017, and we have committed to reduce economy wide GHG emissions 26 percent over the 2005 baseline by 2025.[22]

We have a history of success and have found innovative ways to address complex issues, in 2004, Colorado became the first state to establish a statewide renewable energy standard ("RES") by popular vote, and the RES remains one of the strongest in the nation. In 2010, the Colorado General Assembly passed the Clean Air Clean Jobs Act, which has reduced emissions through the conversion of coal-fired power plants to natural gas and other low emitting sources.[23] In 2014, we became the first state in the nation to directly regulate oil and gas methane emissions.[24] Yet we know there is still more that needs to be achieved if we are to reduce the impacts of a changing climate. On July 11, 2017 Governor John Hickenlooper signed an executive order committing the state to additional climate action. The executive order sets forth the following statewide goals: [25]

- Reduce statewide greenhouse gas emissions by more than 26 percent from 2005 levels by 2025;
- Reduce carbon dioxide emissions from the electricity sector by 25 percent by 2025 and 35 percent by 2030 from 2012 levels; and
- Achieve electricity savings of two percent of total electricity sales per year by 2020.

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- Work strategically with any interested utility or electric cooperative on a voluntary basis to maximize use of renewable energy without increasing costs to taxpayers;
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- Identify opportunities to partner with local governments on locally-led climate goals and resilience actions;
- Institutionalize the state's greening government initiative;
- Formalize and expand upon cross-agency actions to provide economic development strategies and other supportive services to communities impacted by the changing energy landscape, and submit a written annual report detailing those efforts and accomplishments.

Colorado's state agencies are actively involved in carrying out the executive order as well as continued implementation of ongoing initiatives, working to drive down emissions and move Colorado towards a future more resilient to changes in climate. These efforts are moving us in the right direction, and as we continue to make progress towards, and ultimately achieve, these goals it will be critical for the State and our partners to further build on these efforts to ensure that our actions continue to drive down emissions and are commensurate with what is needed to achieve our long term objectives.

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 throughout 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 and ensures we take a collective, common sense approach to address this pressing issue, while holding ourselves to high but achievable goals. 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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[6] Lukas, 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.
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[12] Lukas, 2.
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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 7 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 climate science into water planning. 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. Agriculture consumes the majority of water (89 percent); 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, streamflow, 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 nine years, the CWCB has produced or participated in several studies and assessments of how climate change will affect water resources, 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]

A shift in the timing of runoff is one highly probable effect on water supplies that will result from climate change. Projections indicate that runoff timing will shift an additional one to three weeks earlier by mid-century because of increased temperatures.[12] For example, this may affect water-right holders who traditionally divert surface water during the crop-growing season, and it may affect those with limited access and rights to water storage options. It is also likely to result in decreased late-summer streamflow both because of increased temperatures—causing earlier snowmelt—and because of 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, projections uniformly reinforce that future warming will reduce the runoff produced for a given amount of precipitation. As such, the projections show a tendency towards decreasing future annual streamflows for all of Colorado's rivers.[15] A recent study looking at the broader Colorado River Basin found that for every 1ºF of warming flows could decline 4 percent; which indicates flows in the Colorado River could be 20 percent below average by 2050 and 40 percent by 2100.[16] In addition, runoff and streamflow may be further altered by the presence of dust-on-snow events that lead to earlier 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. Working to preserve and improve forest and ecosystem health will help protect our watersheds and have beneficial effects on both water quality and supply. Healthy watersheds[17] may also help to safeguard environmental and recreational water needs as well. Scientists expect that if temperatures continue to increase, the range of suitable habitat for cold-water fish species will diminish.[18] Ecosystem health is further discussed in Chapter 9.

2.1.1 INFRASTRUCTURE

Colorado has an extensive system for water storage and distribution. This system is necessary given that most of the state's surface water originates west of the Continental Divide, while most 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.[19] 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 this infrastructure comes with great challenges and investment requirements that are 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 stormwater 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 ways to increase the resiliency of these systems. For instance, municipalities may consider upsizing stormwater pipes to accommodate heavier precipitation. When building new infrastructure, utilities should take into account (to the extent practicable) how climate change might affect the infrastructure over time. Colorado offers assistance to water providers and communities who wish to improve their water efficiency through the Water Efficiency Grant Fund, the Energy/Mineral Impact Assistance Fund, and low interest loans for raw-water projects.[20] 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 Creating Resilient Water Utilities[21] and the Bureau of Reclamation's Water Smart initiatives.[22]

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 com-

pleted 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 affect downstream users.[23] Nevertheless, these are also subject to the effects of climate change, and that should be closely examined before enacting agreements.

In addition, because of 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. Some may also look to Aquifer Storage and Recovery where feasible. 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 additional storage needs. The Colorado Division of Water Resources is analyzing opportunities throughout the state where enlargement potential exists.[24] 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 5.

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.[25]

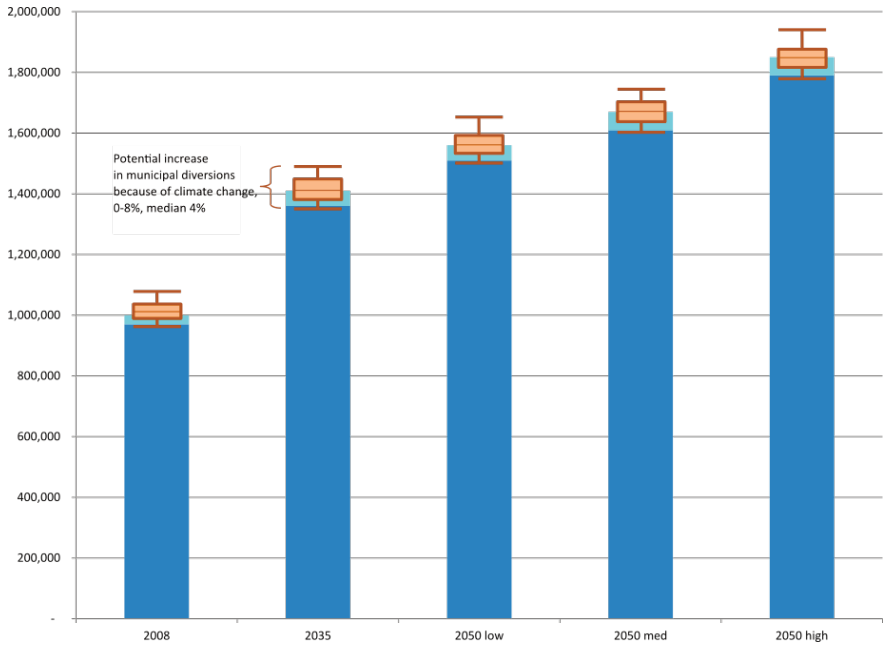
As Colorado works to ensure a secure water future, we do so with a long history of dealing with uncertainty. Economics, population, and land use are all elements we have factored into long-term planning in the past. Now as we continue moving forward we must factor in the uncertainties that a changing climate also brings. Scenario planning, a technique used by Colorado's Water Plan and the Statewide Water Supply Initiative, 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 water planning in Colorado.

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."[26] 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.[27]

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 to 8 percent), while the light blue box represents the median projected increase of 4 percent.



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 affect demands varies across the state because of differences in climate zones, outdoor irrigation requirements, potential temperature increases, and potential changes in precipitation.[28]

The effects of climate change on annual municipal diversions (in acre-feet) are projected to range from 0 to 8 percent (Figure 2-1).[29] 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),[30] 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.[31] This represents both indoor and outdoor demands.

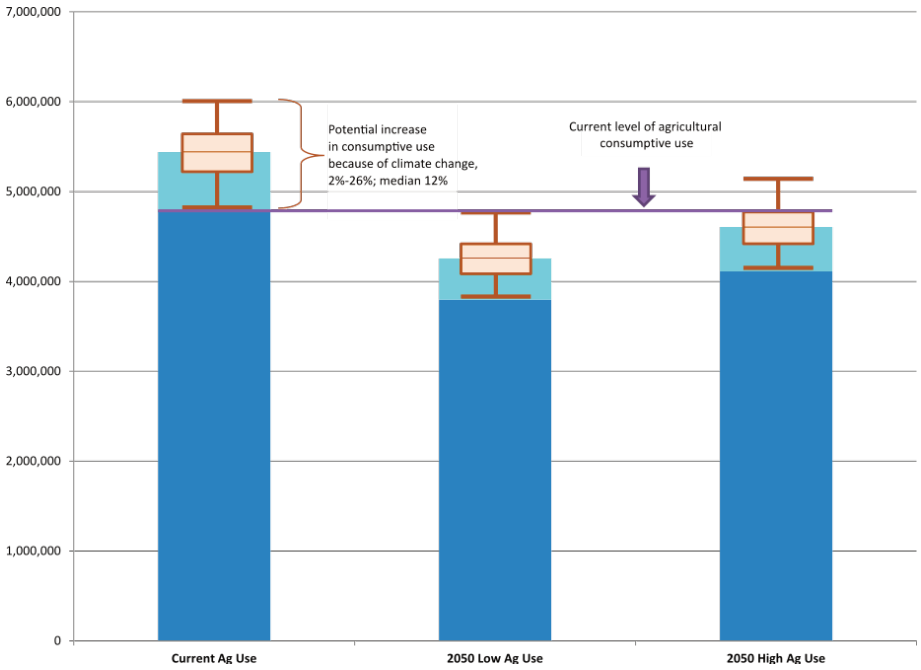
Higher temperatures will also affect irrigation requirements for municipal outdoor irrigation demands as increasing evapotranspiration rates mean urban grasses will require more water. Shifting to lower-water-use vegetation may help to alleviate pressure on municipal water providers. Acceptance of these 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 population 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.[32] 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.[33]

Agricultural producers are perhaps the most aware of the importance of water and the effects of shortage. Working with producers and water providers alike to design flexible options that allow them to manage their water rights in ways that benefit their businesses, communities, and lands is also important as agriculture demands for water increase under altered climatic conditions.

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 to 26 percent. The light blue box represents the median projected increase of 12 percent, which is based on the "low agricultural use" scenario and, due to a projected decrease in production, falls below current levels of agricultural consumptive use.



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).[34] 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.[35]

In western Colorado, crops alone are likely to see an increase in annual irrigation requirements ranging from 8 to 29 percent on average by 2040 and 20 to 43 percent on average by 2070.[36] This is, in part, a result of a longer growing season that may extend anywhere from a week to more than a month.[37] 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.

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 must 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.[38]

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.[39]
- Impairment of aquatic organisms that live in cold-water habitats, such as trout.[40]
- Increasing the range of non-native fish species into cold-water habitats that may harm native fish species through increased predation and competition.[41]

- Increasing levels of organic matter such as algae and thus increased disinfection byproducts that are costly to remove to meet drinking-water quality standards.[42]
- Increases in erosion and sediment transport.[43]
- Changes in nutrient and sediment loads.[44]

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 worked to ensure clean water for uses such as growing crops, providing drinking water, and enjoying water-based recreation. Multiple state agencies work collaboratively to address potential effects on water quality from climate change.

As Colorado prepares for potential climate change impacts, an 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 in a multi-stakeholder, multi-objective manner.[45] 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.

Water: A Health Equity and Environmental Justice Perspective

Access to safe and healthy drinking water is an essential human right and a key component of health equity and environmental justice. Ninety-eight percent of Coloradans served by community public drinking water systems have access to water that meets all health-based standards. That said, as compared to more affluent communities, underserved communities are disproportionately served tap water with aesthetic challenges—such as unusual color or odor—that, while not posing health risks, may nevertheless cause consumers to question water safety.[46]

The Behavioral Risk Factor Surveillance System (BRFSS), the longest running and largest ongoing collection of public health behavior data in the United States, found in 2011 that participants in the lowest income group (less than $15,000 annually), were more likely to spend financial resources on bottled/vended water (27.3 percent) than those in the highest income group (12.1 percent) (more than $50,000 annually). In addition, higher rates of bottled/vended water consumption were observed in Black and Hispanic participants (30.0 percent and 30.6 percent, respectively) than in Whites (11.9 percent).[47] Other research also suggests that these negative perceptions, particularly among immigrant Latino populations in the U.S., are associated with a higher consumption of bottled water, juice, and sugar-sweetened beverages, contributing to incidences of obesity and oral health problems.

Organizations such as the Colorado Department of Public Health and Environment (CDPHE), Denver Water, and Delta Dental are working to dispel misconceptions among immigrant and minority communities about the safety of Colorado's tap water. As climate change progresses and populations increase, there may be an increase in water sources with less desirable quality, which could lead to more communities with more expensive and/or less desirable drinking water. Continued education and policy work will be needed to ensure that all of Colorado's people have access to clean, affordable and healthy drinking water.

2.4 EXTREME EVENTS

In nine out of every ten years, a portion of the state experiences some level of drought conditions.[48] While some type of flooding occurs every year in our state, major flood disasters strike less frequently—on the order of once every decade.[49] These extreme events 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.[50] 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).[51] Coupled with increased temperatures that indicate more drought, longer growing seasons, and higher rates 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.

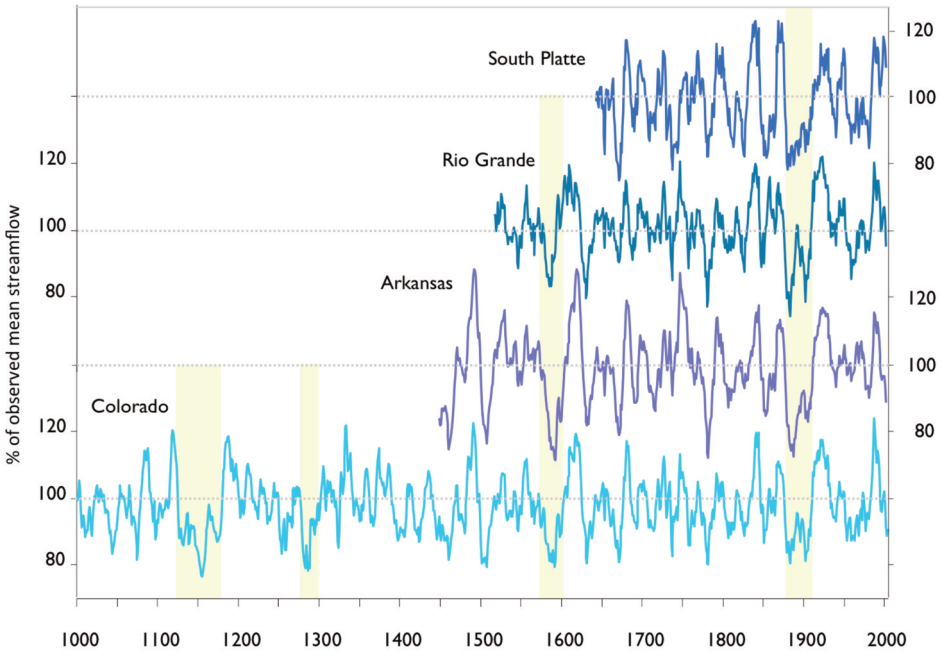
When flood and drought extremes are directly examined under future climate conditions, considerable variability exists across the state. On the Colorado River at Cameo, the average intensity for drought events is projected to be somewhat greater than the historical intensity (-24 percent versus -19 percent respectively); however, 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.[52] In most projections, droughts become more severe, and wet spells are not as wet, compared to historic conditions. However, studies do indicate that the intensity of short duration intense rainfall events may increase in a warmer climate. This is concerning as these events can often be associated with flooding.[53]

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's Water Plan and the Statewide Water Supply Initiative use 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,[54] tools and resources, and technical assistance for improved drought preparedness. The Colorado Resiliency and Recovery Office spearheads efforts to help the State of Colorado and communities increase their resilience through implementation of the statewide Colorado Resiliency Framework, which guides Colorado's ongoing support of local resiliency planning and implementation efforts and serves as a resource for local communities, businesses, and individual citizens. Efforts include building resiliency into disaster recovery as well as taking proactive, everyday measures that set communities up to thrive and minimize effects from changing conditions and threats. Recent collaboration between various state agencies and local governments provide an example with how this process can breed success. The Framework provides a starting point to guide activities that will be undertaken, and climate change is a piece of this.[55]

Figure 2-3

Tree-ring reconstructed streamflows for four major Colorado river basins[56]

Tree-ring reconstructed water-year streamflows (as percent of observed mean) show 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 twentieth 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

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

Climate change poses a threat to human health.[1] The impacts on human health are significant and varied.[2] Air quality, water quality, vector-borne disease, and extreme weather events, among other areas, are all public health concerns.[3] 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 reducing and adapting to a number of significant climate-related public health effects. These strategies include air pollution reduction strategies, environmental policies and regulations, disease and risk monitoring, public outreach, and emergency response. Greenhouse gas mitigation is addressed in Chapter 4 and water quality is addressed in Chapter 2. Colorado will continually assess the effectiveness of its mitigation and adaptation measures and refine them as appropriate.

3.1 ACTIONS TO MITIGATE GREENHOUSE GAS EMISSIONS

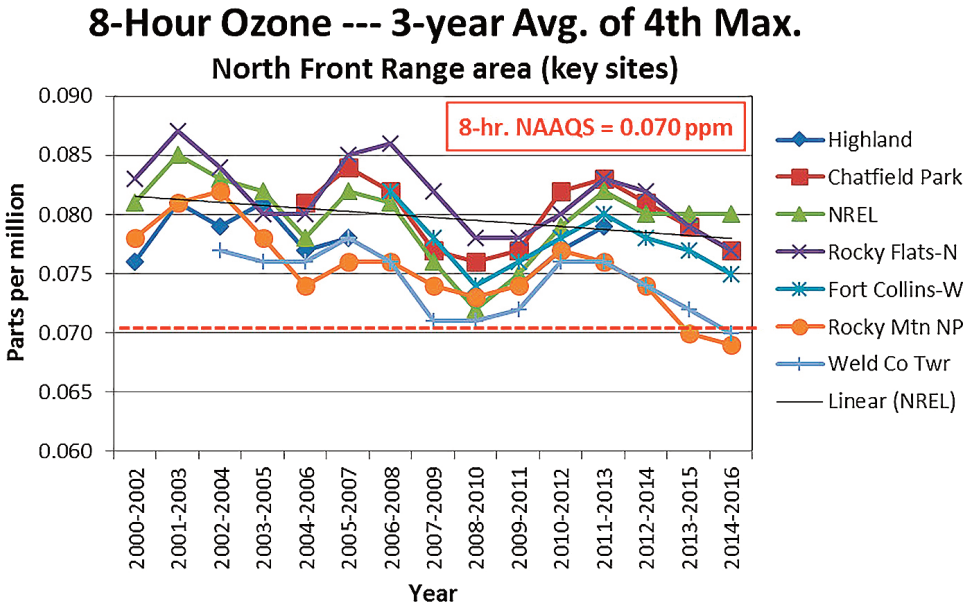
3.1.1 OZONE

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. Climate change and higher temperatures appear to be associated with increased ozone formation and increased emissions of volatile organic compounds ("VOCs") and nitrogen oxides, which are ozone precursors.[4] Research published since the 2015 Colorado Climate Plan provides additional evidence that climate change is likely to result in higher ozone concentrations.[5]

Three-year average ozone concentrations for 2015-2017 exceed federal standards in the Denver Metropolitan/North Front Range "DMNFR") nonattainment area. This problem is not new, and Colorado has a well-developed strategy for reducing ozone concentrations and limiting the public health impacts. Ozone concentrations fluctuate, but even as Colorado's growing economy, population, and vehicle fleet bring new sources of emissions to the state concentrations have gradually improved over time. Figure 3-1 shows the gradual decrease in ozone concentrations between 2000 and 2017 at the monitoring stations in the DMNFR nonattainment area where the highest concentrations have been observed.[6] Continued efforts will be needed to meet the new federal standard of 70 parts per billion, which EPA adopted in 2015[7]—especially as climate change and international emissions push background ozone concentrations higher.[8]

Figure 3-1

8-Hour Ozone—3-Year Average of 4th Max



Colorado mitigates ozone concentrations and the health impacts of ozone through regulatory and non-regulatory measures. Colorado adopted an Ozone Action Plan in 2008,[9] set a national precedent in 2014 by adopting rules to limit the emissions of both methane and VOCs from oil and gas operations,[10] and revised its State Implementation Plan—an EPA required plan for reducing ozone—in November 2016. The 2016 State Implementation Plan revision contains several emission control measures, including air quality regulations, vehicle emission inspections, transportation measures, incentive programs, and public outreach, among others. It estimates that within the ozone nonattainment area, anthropogenic emissions of VOCs will decrease by 33 percent and nitrogen oxides by 27 percent between 2011 and 2017.[11] The Colorado Department of Public Health and Environment ("CDPHE") revised the ozone rules on November 16, 2017[12] to further reduce VOC emissions. Many of Colorado's ozone control strategies have the co-benefit of reducing methane or carbon dioxide emissions.

The CDPHE is the state entity responsible for regulating air quality, and it utilizes an extensive network of monitoring stations throughout the state to measure ozone concentrations. Data from the monitoring network facilitates climate adaptation by allowing the state to develop more effective air quality strategies. The CDPHE uses the data to monitor long-term progress as well as to issue Air Quality Advisories,[13] an important adaptation tool that allows at-risk individuals to avoid exposure by remaining indoors on days when ozone levels are high.

3.1.2 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.[14] Drought in these areas can significantly exacerbate blowing dust problems. Figure 3-2 shows a severe dust storm, one of seven Colorado dust storms tracked during the winter of 2012-2013.

Colorado mitigates these effects through statewide particulate matter regulations.[15] 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.[16]

Figure 3-2

Haboob (Dust Storm) in Lamar, CO PHOTO BY JANE STULP

While Colorado has been successful in reducing anthropogenic particulate matter emissions, high particulate matter emission concentrations from blowing dust remain a problem. To address these periodic episodes, Colorado maintains a surveillance program to evaluate blowing-dust and public-health threats. 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.

3.2 VECTOR-BORNE DISEASE

A number of studies have projected increased incidence of vector-borne diseases as temperatures warm because of climate change.[17] Studies indicate that the spread of West Nile virus is, in part, related to climatic conditions.[18] Hantavirus and some tick-related diseases have been associated with heavy rainfall and other meteorological conditions.[19] However there is uncertainty regarding these associations, and they vary depending on the specific vectors, meteorology, ecology and epidemiologic factors.[20]

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. 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.[2] 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.

3.3 HARMFUL ALGAL BLOOMS

In many of Colorado's water bodies, large-scale blooms of algae have been occurring more frequently, due to higher nutrient loads and increasing ambient surface water temperatures.[22] One type of algae known as blue-green algae, or cyanobacteria, is capable of producing harmful toxins and thus presents an ecological, public and animal health threat. Lengthier warm weather seasons are also increasing the number of months of the year that blooms are likely to occur.[23]

Multiple state and local government agencies in Colorado work cooperatively to monitor and respond to blooms of potentially toxic algae. The CDPHE tracks cyanobacterial test results and reports the presence of toxins online.[24] Colorado has already begun to work collaboratively to standardize and improve the state's ability to monitor, detect, and respond to harmful algae blooms. Resources to guide water managers on when and how to sample, test, interpret, and respond to positive test results were created in 2017 and include public health actions, such as posting no contact advisories in affected areas. CDPHE will also continue to work with the Rocky Mountain Poison and Drug Center and local public health agencies to investigate illnesses reported to be associated with toxic algae.

3.4 FOOD-BORNE ILLNESS

There is a known seasonality for foodborne and enteric pathogens, with higher rates of illness during warmer months.[25] Changing global temperatures are likely to yield more days of warm weather per year, resulting in higher rates of enteric disease.[26] Possible reasons for increased enteric disease in warmer months include increased pathogen load in grown food items (produce), increased lapses in food safety and temperature (in prepared foods), and human behavior around food.[27] Warming sea surface temperatures are also contributing to increased pathogens in seafood, such as vibrio parahaemolyticus in oysters, which are distributed throughout the United States.[28] Extreme weather events, such as high rain and flooding, are associated with increased enteric pathogens, such as Salmonella.[29] Extreme weather events may also impact parasite burden in feed animals, increasing risk among farm workers.

Colorado food producers, processing plants, and distribution and retail facilities are regulated and inspected by local, state, and federal agencies to ensure the safety of food entering the supply chain. Systems are in place to inform consumers of food recalls and monitor and respond to foodborne illnesses. Colorado investigates outbreaks of foodborne illness and enteric disease through interviews, medical records, site visits, testing of people, food or the environment, and conducting epidemiological studies. Affected individuals are informed of health risks and control measures are enacted, such as closing a restaurant or recalling food.

3.5 PUBLIC HEALTH ASPECTS OF EMERGENCIES AND DISASTERS

Colorado has experienced several natural disasters in recent years, including a major drought and wildfires in 2012 and 2013, historic floods in September 2013, spring floods in 2015, and blizzards in 2016. The frequency and intensity of wildfires in Colorado and the western United States are expected to increase with rising temperatures and drier summers.[30] 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.[31] Colorado has experienced an increase in heat waves, wildfires, and drought over the past 50 years, and experts project that this trend will continue.[32]

In addition to their effects on physical health, natural disasters are associated with mental health problems.[33] 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.[34]

3.5.1 EMERGENCY RESPONSE SYSTEM

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 four phases of emergency management: mitigation, preparedness, response, and recovery. The Colorado Hazard and Incident Response and Recovery Plan identifies the roles, responsibilities, and actions of Colorado state agencies and others during and after disasters.[35] Operational priorities for incident management include life safety, health of the public, environmental protection, and recovery, among others.[36]

Colorado follows the Emergency Support Function system, which 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 Services. Colorado also follows the Recovery Support Function system, where the CDPHE is the state lead agency for Behavioral Health Services, Public Health, and Debris Management. Resource requests flow from local response efforts into the Emergency Support Function and Recovery Support Function systems. 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.

3.5.2 HEAT-RELATED ILLNESS

Colorado's climate has warmed substantially over the past 30 years,[37] and extreme heat events—defined as weather that is much hotter than average for a particular time and place—are already occurring and expected to become more common, more severe, and longer-lasting as our climate changes.[38] While even a small increase in the number of extreme heat events can cause or contribute to heat stress illness and death, the heat index in Colorado is mitigated by relatively low humidity and mortality due to extreme heat is limited. However, an average of 32 people are hospitalized and about 250 Coloradans seek emergency department care each year for heat-related illness.[39]

Extreme heat events are the leading cause of death from all weather-related hazards, and certain vulnerable populations are at increased risk, including children, pregnant women, older adults, and those with existing chronic conditions such as respiratory, cardiovascular, and kidney-related diseases.[40] Equity issues exist for individuals who do not have access to air conditioning for employment, mobility, income, or other reasons. Temperatures are generally amplified in urban areas, and disruptions to electricity and water supplies are known to exacerbate heat-related health problems. Finally, these illnesses and deaths are largely preventable through preparedness and adaptation strategies. For these reasons, CDPHE continues to monitor deaths, hospitalizations, and emergency room visits due to heat events, and such data are reported on the National Environmental Public Health Tracking Network.[41]

3.6 STRATEGIES AND POLICY RECOMMENDATIONS

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

- Evaluate and adopt additional ozone control measures as needed to attain federal standards.
- Continue to monitor and evaluate air quality, including ozone and particulate matter concentrations, and issue public health advisories as appropriate.
- Continue to assess potential correlations between climate change, vector-borne diseases, heat-related illness and harmful algal blooms. Incorporate the results into public health guidance and communicate any revised risk reduction measures to local governments and the public.
- The CDPHE, the Rocky Mountain poison center, and local public health agencies will continue to investigate and respond to illnesses reported to be associated with toxic algae.
- The CDPHE and local public health agencies will continue to investigate individual cases and outbreaks of enteric and foodborne pathogens, implementing surge capacity plans as necessary.
- Emphasize climate-related disaster preparedness in emergency response plans and exercises.

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[9] Colorado Air Quality Control Commission, *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.
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[11] Moderate Area Ozone SIP for the Denver Metro and North Front Range Nonattainment Area (Nov. 17, 2016), § 4-11 at Table 14, http://raqc.org/documents/sip/.
[12] Air Quality Control Commission Regulation No. 7, Control of Ozone via Ozone Precursors (Colorado Register publication pending).
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[14] Colorado Department of Public Health and Environment, *Colorado 2013 Air Quality Data Report* (2014), 20-21, 35-37, 61-62, 64-65.
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[16] Air quality monitoring data is available at http://www.colorado.gov/airquality/.
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[38] USGCRP Climate and Health Assessment, *supra* note 1, 44-45.
[39] USGCRP Climate and Health Assessment, *supra* note 1, 44; Environmental Public Health Tracking Network, www.cdc.gov/ephtracking.
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4

Greenhouse Gas Emissions

Colorado is warming, and is projected to continue warming in the future. The decisions the State makes today will influence the scope and extent of future climate change. By choosing to mitigate the impacts of anthropogenic climate change and reduce Colorado's greenhouse gas ("GHG") emissions, we will not only reduce the effects of climate change but also benefit from cleaner air, better health, and a stronger economy.

In the past, federal standards on appliance efficiency, vehicle mileage, power plant emissions, and other climate programs have helped to address emissions at the national level. However these programs and regulations are currently under review and their future is uncertain, making it more important than ever to develop a state-specific plan. This chapter lays out Colorado solutions and local actions that our citizens, businesses, and government agencies can take to reduce emissions. We cannot solve this problem entirely by ourselves, but if we tackle our own emissions and work collaboratively through partnerships like the United States Climate Alliance, we can still avoid the most harmful impacts of a warming climate.

Colorado joined the U.S. Climate Alliance in July of 2017, because we feel that together we are more equipped to address this complex challenge and reduce emissions. The Climate Alliance is a coalition of states committed to reducing GHG emissions consistent with the goals of the 2015 Paris Agreement. Colorado will actively participate on a number of subcommittees to address issues relevant to our state as well as share tools, data, and information with other member states. While this coalition is young, is it already proving to be incredibly effective.

While the challenge of reducing emissions is great, we are proving that we do not have to choose between a healthy economy and emission reductions.[1] From 2011 to 2014 Colorado "cleantech" industries grew—more than 22 percent,[2] greater than the national average—and now supports more than 66,000 jobs across the entire state.[3] We rank first in the nation for wind manufacturing and in the top three for wind-related employment. Over a 15-year period from 2000 to 2014, the United States' gross domestic product ("GDP") grew while CO_2 emissions decreased.[4] During the same time frame, state GDP in Colorado grew 27.5 percent while Colorado's carbon intensity (CO_2 emissions per unit of GDP) fell by 15.7 percent and CO_2 emissions per person fell by 13.1 percent.[5] Global energy-related CO_2 emissions were flat in 2014 and 2015, while global GDP grew more than 3 percent per year.[6] While these market trends can result in some adverse localized impacts or disruptions as our energy economy transitions, the state is committed to assisting those communities through programs like the Rural Response, Recovery, and Resilience program ("4R") described in Chapter 10. Through collaboration and innovation, cleaner energy and clean technologies go hand in hand with overall economic growth.

By acknowledging national and global trends and transition to cleaner energy, Colorado will be better positioned to seize opportunities for our energy producing state. Those who take action and seize the opportunity to develop new industries and new jobs will reap both the environmental and economic benefits.

4.1 GREENHOUSE GAS REDUCTION GOALS

Governor Hickenlooper set four GHG reduction goals in July 2017 when he signed Executive Order D 2017-015, "Supporting Colorado's Clean Energy Transition:"

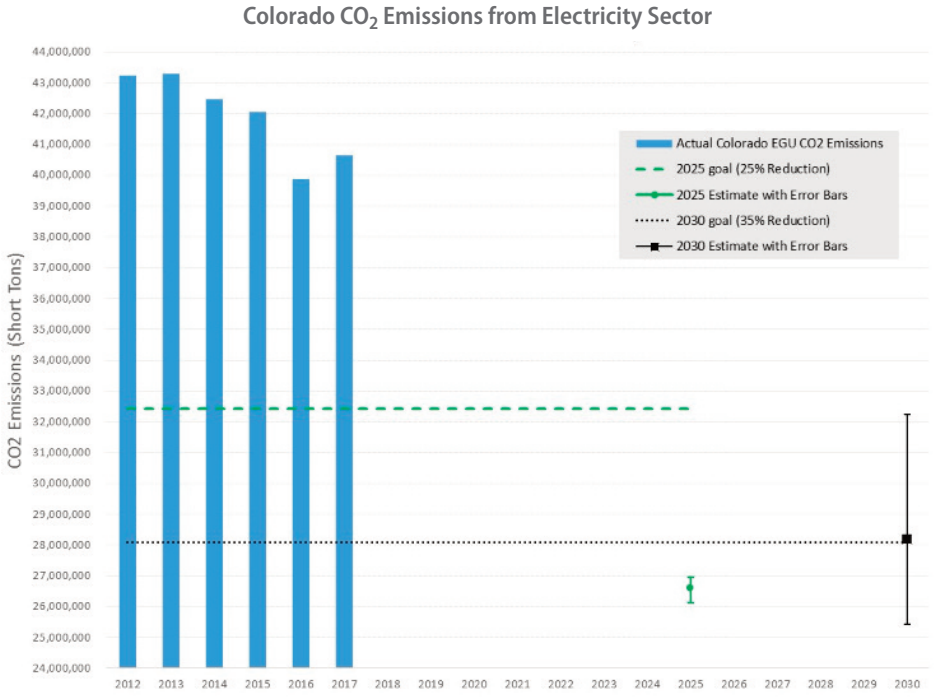
- Reduce GHG emissions statewide by more than 26 percent by 2025, as compared to 2005 levels;
- A 25 percent reduction in CO_2 emissions from the electricity sector by 2025, as compared to 2012 levels;
- A 35 percent reduction in CO_2 emissions from the electricity sector by 2030, as compared to 2012 levels; and
- Achieve electricity savings of 2 percent of total electricity sales per year by 2020 through cost-effective energy efficiency.

These goals reflect both the policies that Colorado has already implemented to reduce GHG emissions as well as the desire and need to work towards more ambitious economy-wide reductions. The state's ongoing efforts with the utility sector have put Colorado in a good position to meet the electricity sector CO_2 goals. Figure 4.1 shows the actual and estimated future CO_2 emissions from fossil fuel electric generating units statewide. From 2012 through 2017, power plant CO_2 emissions have decreased approximately 12 percent and are projected to decline even more by 2035 based on planned and proposed changes to the electric generating fleet. Assuming these anticipated changes proceed as planned, Colorado will remain on track to meet or exceed its electricity sector CO_2 goals for both 2025 and 2030.

Figure 4-1

Colorado CO_2 Emissions from Electricity Sector

Figure 4.1 depicts actual CO_2 emissions from Colorado's fossil fuel–fired electric utility generating units between 2012 and 2017, using data from the EPA's Air Markets Division and Energy Information Administration.[7] The decrease in emissions between 2012 and 2017 is due in part to the retirement of certain electric generating units, including the Clark Generating Station, Arapahoe Units 3 and 4, Cherokee Unit 3, Valmont Unit 5, and Martin Drake Unit 5; the change in operation of Cherokee Unit 4 to burn natural gas instead of coal; and the growth in wind, solar, and other renewable generation. The estimates of 2025 and 2030 emissions reflect the planned or proposed retirements of Craig Unit 1, Nucla Generating Station, and Comanche Units 1 and 2. Craig Unit 1 may be replaced with natural gas generation, which would affect this projection, and the retirement of Comanche Units 1 and 2 is still awaiting approval by the Public Utilities Commission. The estimates also include the addition of renewable and natural gas generation based on utilities' public statements, electric resource plans, and energy efficiency projections. The range of the estimates for 2025 and 2030 is due to uncertainty regarding future electric demand, the portfolio of generation assets, the potential retirement or degradation of renewable energy resources, the utilization of electric generating units, and energy efficiency savings.



While we have made significant progress, there is still much work ahead that will require significant collaboration and the innovative thinking that Coloradans are known for. Meeting the statewide goal of reducing total GHGs emission over 26 percent by 2025 will be much more challenging. State agencies are working to develop strategies to achieve this goal and look forward to working with stakeholders to refine and implement the progressive GHG reduction strategies needed to meet this goal. As power-generation emissions decline and transportation emissions continue to grow, the state must also find new ways to move people and goods across our vast and diverse landscape.

4.2 MEASURING AND PROTECTING GHG EMISSIONS

Measuring Colorado's progress toward its climate goals requires the state to estimate both past and future GHG emissions in an emissions inventory. Doing so is a significant undertaking in its own right. Colorado published its most recent GHG inventory in 2014,[8] based on 2010 data, with projections for 2020 and 2030. While the next inventory is not due to be released until 2019,[9] the state is evaluating the available data sources, consulting with the United States Climate Alliance on inventory methods, and determining the best process and a more frequent schedule for reporting GHG emissions. CDPHE is preparing to propose a state regulation that mirrors the current federal GHG reporting requirements. More frequent and reliable data collection would enable the state to have a better understanding of where our emissions are coming from and how to develop strategies to reduce them.

The 2014 inventory relied on an EPA tool known as the State Inventory Tool, and while the 2014 inventory remains the best available data, it does not reflect all of Colorado's GHG reduction initiatives. Most notably, the 2014 inventory misses the recent announcements that certain power plants would retire or switch to natural gas, and that Colorado utilities would significantly expand their renewable generation portfolios. The 2014 inventory projects that CO_2 emissions from electric generating units would drop just 5 percent between 2010 and 2030,[10] but data and proposed changes to the electric generating fleet indicate a much larger reduction.

4.3 SECTOR-SPECIFIC GHG REDUCTION INITIATIVES

The State of Colorado is taking many steps to reduce GHG emissions, as are many local governments, private businesses, utilities, nonprofits, and individuals across the state. Federal efforts continue to result in GHG reductions as well, but are increasingly uncertain. Several GHG reduction measures affecting Colorado's largest sources of GHG emissions are described below.

4.3.1 ELECTRIC GENERATING UNITS

Electric generating units ("EGUs") are one of the largest GHG sources in Colorado. The state began adopting policies to reduce their GHG emissions as early as 2004 and has periodically updated those policies (See Chapter 5). EGUs must comply with the state's renewable energy standard, demand side management (energy efficiency) programs, and the 2010 Clean Air – Clean Jobs Act. In 2012 alone, these programs avoided more than 5.5 million tons of CO_2 emissions, nearly 14 percent of the 2010 CO_2 emissions from Colorado EGUs.[11] These programs simultaneously achieved major reductions of conventional pollutants, such as particulate matter, ozone, sulphur dioxide and nitrogen oxides.[12]

Table 4-1

Reduction of Power Plant Emissions

EGU	Action
Cherokee Unit 3	Retired August 2015
Cherokee Unit 4	Switched to natural gas September 2017
Cherokee Units 5, 6 and 7	Natural gas combined cycle, new in 2015
Valmont Unit 5	Retired March 2017
Martin Drake Unit 5	Retired December 2016
Martin Drake Units 6 and 7	Scheduled to retire by 2035
Craig Station Unit 1	Must convert to natural gas by August 2023 or retire by December 2025
Nucla Generating Station	Must retire by December 2022
Comanche Units 1 and 2	Proposed to retire by 2022 and 2025 and replace with wind, solar and natural gas

In addition to complying with these mandates, Colorado's utilities are responding to global market forces and reshaping their electric generation fleets by shifting power generation toward cleaner burning and renewable units. Table 4.1 identifies significant changes since 2015 that have reduced power plant GHG emissions. Contemporaneously with these changes to fossil fuel EGUs, renewable generation is growing quickly in Colorado. In response to the states Renewable Energy Standard and market forces, Colorado now has more than 3900 MW of wind and solar capacity. See Chapter 5 for more details.

4.3.2 TRANSPORTATION

Colorado's 2014 GHG inventory indicates the transportation sector has historically been the state's second largest source of GHG emissions, and it is quickly becoming the largest. Transportation emissions are projected to increase in 2020 and 2030, while emissions from electric generation are falling. Nationally, transportation sector GHG emissions have already surpassed power plants as the largest source of GHG emissions.[13] Colorado has some programs in place to reduce transportation sector emissions, as described in Chapter 6; and through the Executive Order, the State is preparing to do even more.

State and local governments in Colorado are working to promote multimodal forms of transportation, including light rail, transit buses, ride sharing and bicycles. The state's High-Performance Transportation Enterprise ("HPTE") was formed to aggressively pursue innovative means of financing important surface transportation infrastructure projects that will allow more efficient movement of people, goods, and information throughout the state. Among other things, the HPTE has resulted in a 45 percent increase in bus ridership on U.S. 36 between 2011 and 2016. Operating the I-70 Mountain Express Lane has increased General Purpose lane throughput by 15 percent, with 18 percent faster travel times. Colorado also benefits from federal fuel efficiency and emission standards for motor vehicles, and it has encouraged the federal government to retain more ambitious standards set during the previous administration.

Colorado has recently released a statewide Electric Vehicle Plan to build out key charging corridors that facilitate economic development and tourism while reducing pollution. Funding from the Volkswagen emissions cheating settlement will align with the Electric Vehicle Plan to promote alternative fuel and electric vehicles. In its proposed spending plan for the Volkswagen settlement,[14] Colorado expects to spend $18 million on incentives to replace diesel transit buses with alternative fuel or electric technology, another $18 million for incentives to upgrade medium- and heavy-duty trucks and school buses, and $10 million in incentives for electric vehicle charging stations. These projects are expected to reduce GHG emissions by approximately 50,000 tons per year. Another $12 million would be held in a flexible fund, to be spent on newer technology after approximately five years. The State is working to reduce market barriers to the development of all cost-effective and technologically viable alternatives to gasoline- and diesel-fueled transportation. Through the ALT Fuels Colorado and Charge Ahead Colorado incentive programs, the state has awarded grants for the installation of 613 electric vehicle charging stations, 113 electric vehicles, 10 compressed natural gas fueling stations, and 887 alternative fuel vehicles. For additional information on this see Chapter 6.

4.3.3 BUILDINGS

Buildings are the third largest source of GHG emissions in Colorado.[15] The 2014 GHG inventory categorizes their emissions as Residential, Commercial, and Industrial Fuel Use. This category includes emissions from furnaces, water heaters, boilers, cook stoves, industrial equipment, and other devices that burn fossil fuels.

State and local government agencies are reducing emissions through building codes and energy efficiency measures. The Colorado Energy Office provides training and resources to help local jurisdictions adopt and implement newer building codes. Also, the Energy Performance Contracting Program has completed nearly 200 projects, resulting in the financing of more than $500 million in energy and water-related capital improvement projects. Energy performance has been improved at public school and university buildings, veterans' facilities, libraries, parks, community centers, wastewater treatment plants, prisons, and other government buildings.

The state will continue to work to support the efforts of local communities who wish to improve and strengthen their local efforts to increase energy efficiency of buildings and decrease emissions. 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. As of 2017, 95 percent of construction activity occurs in communities that have adopted the 2009 IECC or greater, and 67 percent of activity occurs in communities that have adopted the 2012/2015 IECC or greater (2012 and 2015 IECC are essentially the same level of efficiency). More programs and initiatives are described in Chapter 5.

4.3.4 OIL AND GAS

Natural gas and oil systems are the state's fourth largest source of GHGs.[16] Colorado has comprehensive regulations that reduce emissions of all pollutants from the oil and gas sector, simultaneously protecting public health and keeping GHGs out of the atmosphere. 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.[17] 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 No. 7 to directly limit emissions of all hydrocarbons—including methane—and not just traditional pollutants.[18] 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. A two-year pilot project in 2013-2015 found that after Colorado began infrared camera inspections, the percentage of facilities where leaks were detected fell more than 70 percent.[19] The 2014 rule changes are estimated to prevent approximately 65,000 tons per year of methane and ethane from entering the atmosphere, directly and permanently reducing emissions of GHGs. The 2014 regulations reduce emissions of volatile organic compounds ("VOCs")—another ozone precursor—by more than 93,000 tons per year.[20] This is the CO_2 equivalent to taking 310,000 cars off the road annually.

In November 2017, the Colorado Air Quality Control Commission revised Regulation No. 7 and its infrared camera inspection requirements within the Denver Metro/North Front Range ozone nonattainment area. The new rule requires more frequent inspections of oil and gas well sites and compressor stations in the Denver Metro and North Front Range ozone nonattainment area. The rules also add a requirement to inspect pneumatic controllers, a common type of equipment. Operators must repair facilities that are found to be leaking or operating improperly, resulting in additional emission reductions. The additional leak inspections are projected to reduce methane emissions by approximately 9400 tons per year.[21] Moving forward, CDPHE is convening a group of stakeholders in January 2018 to develop strategies to reduce statewide emissions of methane and other hydrocarbons from the oil and gas industry.

New technology is also reducing methane and VOC emissions from oil and gas operations. For example, some facilities are able to use multi-stage separators, "tankless production," or other technologies to substantially reduce these emissions. As a result of technological advances and regulatory requirements, Colorado's ozone plan estimates that VOC emissions from oil and condensate storage tanks in the Denver Metro/North Front Range ozone nonattainment area fell by approximately 63 percent between 2011 and 2017, from 216.0 to 78.7 tons per day.[22] VOCs from oil and gas facilities are intermixed with methane, so reducing VOC emissions simultaneously reduces methane. The ozone plan does not estimate GHG emission reductions but they are expected to be significant.

4.4 SUSTAINABLE MATERIALS MANAGEMENT

Beyond driving our cars and using electricity, the materials we produce and consume directly impact GHG emissions. There is potential for significant GHG reductions if we can optimize how we manage the resources within our economy. We all purchase and consume materials on a daily basis. From the food we eat, to the electronics we use, to the buildings we live in, materials are continually produced and directly impact our daily lives. Each phase of a product's life, from materials extraction through end-of-life management, has a carbon footprint. While emissions from waste generation at landfills have traditionally been the main concern of material consumption and waste management, sustainable materials management ("SMM") offers a more holistic approach, identifying opportunities to reduce emissions throughout the entire lifecycle of materials and products. (Figure 4.2). By performing a lifecycle analysis of products, we can identify opportunities to address their environmental impacts, such as reducing GHG emissions, conserving resources by using recycling materials, and reducing costs through improved efficiencies and avoided waste.

From a sector-based approach, GHG emissions associated with solid waste and methane generation by landfills is often viewed as a small component of the total GHG emissions produced by industry. However, when analyzing GHG emissions associated with particular services in the U.S. economy from a systems-based perspective, GHG emissions associated with the provision of goods and food account for an estimated 42 percent of total U.S. GHG emissions, more than passenger transport emissions and more than building HVAC and lighting emissions. Looking at GHG emissions through a lifecycle analysis perspective and a systems-based approach shows us that materials management plays a significant role in reducing GHG emissions.

.4.4.1 LANDFILL DIVERSION

Diverting materials from landfills through recycling and composting are important components of SMM and result in a reduction of overall GHG emissions. Maximizing the recycled content in products results in a significant reduction of GHG emissions and energy consumption by offsetting the need for mining, material extraction, material transport and processing of virgin raw materials.

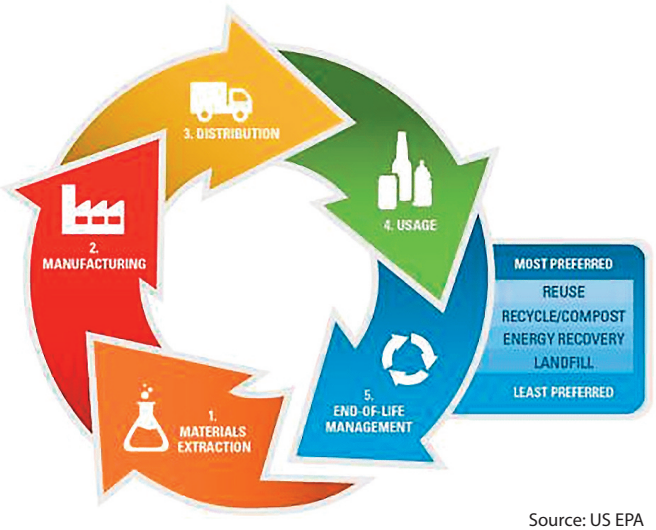
Since 2007, Colorado has tracked GHG emission reductions resulting from the amount and types of materials that are recycled and composted each year. In 2016, 1.8 million metric tons of CO_2 emissions were avoided through recycling and composting efforts in Colorado. This is equivalent to the annual emissions from powering 93,000 Colorado homes.[23]

Currently, Colorado's waste diversion rate of 19 percent is below the national average of 34.6 percent municipal solid waste that is recycled and composted.[24] Increasing the amount of waste diverted in Colorado by recycling and composting plays an important role in reducing GHG emissions. In August 2017, the Colorado Solid and Hazardous Waste Commission approved statewide waste diversion goals aiming to increase the amount of waste diverted over the next 20 years. The new goals challenge Colorado to meet the national average by 2026 and to match the current diversion rate of the best-performing states, around 45 percent, by 2036.

While focusing on increasing waste diversion is important, the state recognizes the need to use a lifecycle approach to accurately measure and address GHG emissions. Conducting additional life-cycle assessments and improving sustainable materials management for specific products such as food, packaging and building materials can have major benefits in reducing GHG emissions in Colorado.

Figure 4-2

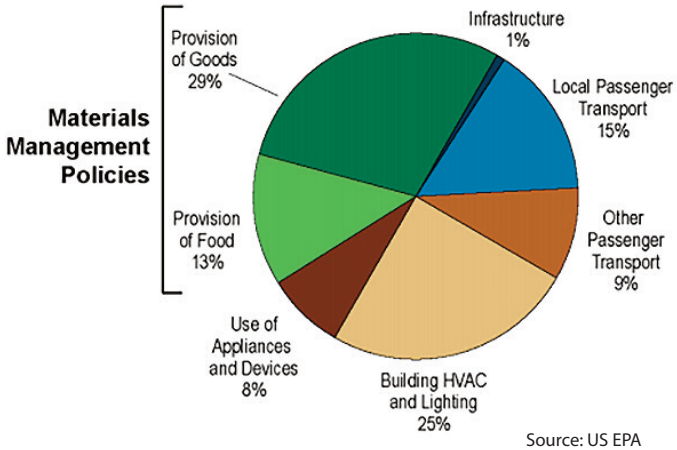
Sustainable Material Management's Life-cycle Perspective



Source: US EPA

Figure 4-3

Systems Based View of U.S. GHG Emissions Highlighting Materials Management



Source: US EPA

4.5 LOCAL GOVERNMENT TARGETS AND INITIATIVES

As described in Chapter 10, many local government entities and coalitions across Colorado are taking significant action to reduce GHG emissions. For example, the Pueblo City Council approved a resolution in February 2017 that established a goal of operating on 100 percent renewable energy by 2035. The City of Aspen Electric Utility announced in September 2015 that it had signed contracts to purchase all of its electricity from renewable sources. In December 2015, the City and County of Denver updated its Climate Action Plan to include a goal of reducing GHGs by 80 percent. Many cities, towns, and counties promote emission reductions, sustainability and energy efficiency. In May of 2017, The Compact of Colorado Communities was established to bring cities and counties together in taking constructive and practical climate action. The Compact's mission is to advance capacity of Colorado cities and counties to develop and implement aggressive climate change initiatives thus ensuring security and economic prosperity. The Compact will accelerate capacity building, alignment of important resources and interests, and drive critical public engagement on climate change action.[25] Other local governments have joined Colorado Communities for Climate Action to advocate for GHG reduction policies. This is only a sample of the actions local governments are taking to mitigate GHG emissions. More initiatives are described in Chapter 10, and momentum continues to build. Governor Hickenlooper's Executive Order directs state agencies to consult and collaborate with local governments to support locally led climate goals and resilience solutions.[26] The Colorado Communities Symposium in early 2018 provides an opportunity for local elected officials and community and business leaders from throughout Colorado to come together with state agency leaders and staff to participate in visioning workshops to collaboratively chart a path forward on how work together to advance climate preparedness and clean energy development in Colorado.

4.6 STRATEGIES AND POLICY RECOMMENDATIONS

Colorado's GHG goals are ambitious. Achieving our goals will require sustained effort, and Coloradans must work together to determine how to achieve smart emission reductions. State agencies will fulfill the directives of Governor Hickenlooper's executive order. Policies that state agencies will pursue include:

- Working with electric utilities or cooperatives on a voluntary basis to maximize the use of renewable resources while maintaining reliability without increasing costs.
- Implement a statewide Electric Vehicle Plan to build out key charging corridors that aligns with the environmental mitigation trust from the Volkswagen settlement.
- Propose a state greenhouse reporting rule by December 30, 2018 that mirrors current federal requirements.
- Prepare annual updates to Colorado's GHG inventory as needed to track progress toward Colorado's climate goals.
- Identify opportunities to partner with local governments to support locally led climate goals and resilience solutions.
- Formalize and expand upon cross-agency efforts to provide economic development strategies and other supportive services to communities impacted by a changing energy landscape.
- Evaluate the potential costs and benefits of adopting California's motor vehicle standards.
- Consult with stakeholders and our state partners in the United States Climate Alliance to identify and implement future GHG reduction strategies for meeting statewide emission goals.

[1] Devashree Saha and Mark Muro, "Growth, Carbon and Trump: State Progress and Drift on Economic Growth and Emissions Decoupling," (Dec. 8, 2016), https://www.brookings.edu/research/growth-carbon-and-trump-state-progress-and-drift-on-economic-growth-and-emissions-decoupling/.
[2] Metro Denver Economic Development Corporation, *ENERGY: Colorado Industry Cluster Profile*, 2 (January 2017).
[3] "Clean Jobs Colorado 2017," E2 (September 2017), 5, accessed January 9, 2018. 5, https://www.e2.org/wp-content/uploads/2017/09/CleanJobsCO_2017.pdf.
[4] Saha and Muro, *supra* note 1.
[5] Saha and Muro, *supra* note 1, Appendixes A and B.
[6] "Decoupling of Global Emissions and Economic Growth Confirmed," International Energy Agency, (March 16, 2016), http://www.iea.org/newsroom/news/2016/march/decoupling-of-global-emissions-and-economic-growth-confirmed.html.
[7] This data set includes reported emissions and electric generation from coal-fired boilers and natural gas combined cycle units. The data set excludes CO_2 emissions from other forms of electric generation, such as biomass, most small boilers, and diesel engines or simple cycle gas turbines used as "peaking" units, but the electric generation from these sources is considered in meeting the electric generation forecast for 2025 and 2030. Colorado estimated future emissions using a simplified model that incorporates projections of future demand growth from utilities' published electric resource plans. It is assumed that future demand growth will be met with in-state generation. The use of different modeling tools or assumptions would result in different projections, and actual emissions are likely to vary.
[8] Steven Arnold, Jim Dileo, and Theresa Takushi, *Colorado Greenhouse Gas Inventory Report* (October 2, 2014), https://www.colorado.gov/pacific/sites/default/files/AP-COGHGInventory2014Update.pdf.
[9] Exec. Order D 004 08, "Reducing Greenhouse Gas Emissions in Colorado" (April 22, 2008).
[10] Colorado Greenhouse Gas Inventory – 2014 Update, *supra* note 8, at 5, Exhibit ES-3.
[11] Ibid., 37 , ex. 2-2.
[12] Unpublished data from the Colorado Public Utilities Commission.
[13] U.S. Energy Information Administration, "Power Sector Carbon Dioxide Emissions Fall Below Transportation Sector Emissions," *Today In Energy* (January 19, 2017), https://www.eia.gov/todayinenergy/detail.php?id=29612.
[14] State of Colorado, *Volkswagen Diesel Emissions Settlement,* accessed January 9,2018, https://www.colorado.gov/cdphe/VW.
[15] Colorado Greenhouse Gas Inventory – 2014 Update, *supra* note 8, Exhibit ES-3.
[16] Colorado Greenhouse Gas Inventory – 2014 Update, *supra* note 8, Exhibit ES-1.
[17] Colorado Air Quality Control Commission Regulation Nos. 3, 6 and 8, (5 Colo. Code Reg. 1001-5, 8, 10). https://www.colorado.gov/pacific/cdphe/aqcc-regs; "Moderate Area Ozone SIP for the Denver Metro Area and North Front Range Nonattainment Area" (November 17, 2016),http://raqc.org/documents/sip/.
[18] Colorado Air Quality Control Commission Regulation No. 7, (5 Colo. Code Reg. 1001-5), https://www.colorado.gov/pacific/sites/default/files/5-CCR-1001-9_0.pdf.
[19] CDPHE Air Pollution Control Division, *Colorado Optical Gas Imaging Infrared Camera Pilot Project Final Assessment* (July 11, 2016), accessed January 15, 2018, https://www.colorado.gov/pacific/sites/default/files/APCD_IRCameraProject_FinalAssessment.pdf.
[20] CDPHE Air Pollution Control Division, "Final Economic Impact Analysis for Proposed Revisions to AQCC Regulations No. 7" (January 30, 2014), 33.
[21] CDPHE Air Pollution Control Division, "Economic Impact Analysis (Final) for Regulation 7, Sections II, XII, XVII, XVIII" (October 4, 2017).
[22] "Moderate Area Ozone SIP for the Denver Metro and North Front Range Nonattainment Area," (Nov. 17, 2016), 4-11, Table 14.
[23] CDPHE, *Hazardous Materials and Waste Management Division Annual Report,* (2017), https://www.colorado.gov/pacific/sites/default/files/HM_DIV_HMWMD-Annual-Report-2017.pdf.
[24] US EPA, *Advancing Sustainable Materials Management: 2014 Fact Sheet* (2016), 2, https://www.epa.gov/sites/production/files/2016-11/documents/2014_smmfactsheet_508.pdf.
[25] Compact of Colorado Communities, accessed September 28, 2017, http://www.CompactofColoradoCommunities.org.
[26] Exec. Ord. D2017-015, "Supporting Colorado's Clean Energy Transition," (July 11, 2017), accessed January 15, 2018, https://www.colorado.gov/governor/sites/default/files/executive_orders/climate_eo.pdf.

5

Energy

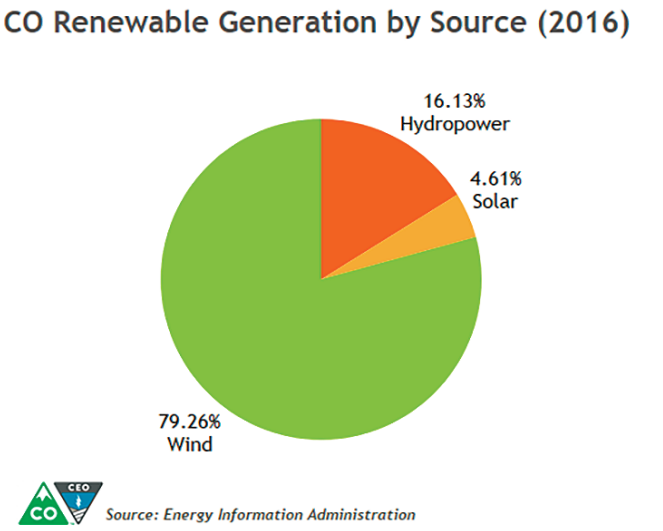
Energy fundamentally helps to shape Colorado: from powering homes and businesses to the transportation of people and goods, it touches nearly every aspect of life. It is also a major economic driver in the state. In 2016, Colorado's energy industry employed 274,760 people.[1] Colorado's real gross domestic product ("GDP") for its energy cluster was $25.6 billion in 2014, which was 9 percent of the state's GDP for that year.[2] In 2017, Colorado had 66,223 clean-energy jobs, where at least some portion of time is spent on renewable energy generation, energy efficiency, advanced grid, advanced transportation, or clean fuels. This field of employment is growing rapidly throughout the state,[3] and helping to contribute to our energy future. In addition, the cost of renewable energy resources is becoming increasingly competitive. Between 2010 and 2015, the average price of wind fell more than 56 percent, while the average price of solar over that same period fell 74 percent.[4] Energy also affects both the air and the water on which we rely.

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 help meet Executive Order D 2017-015.[5] 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 and to help achieve Executive Order D 2017-015 also are provided.

Colorado's diverse portfolio of economically competitive energy resources for electricity generation includes both traditional resources, 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.

5.1 ELECTRICITY GENERATION

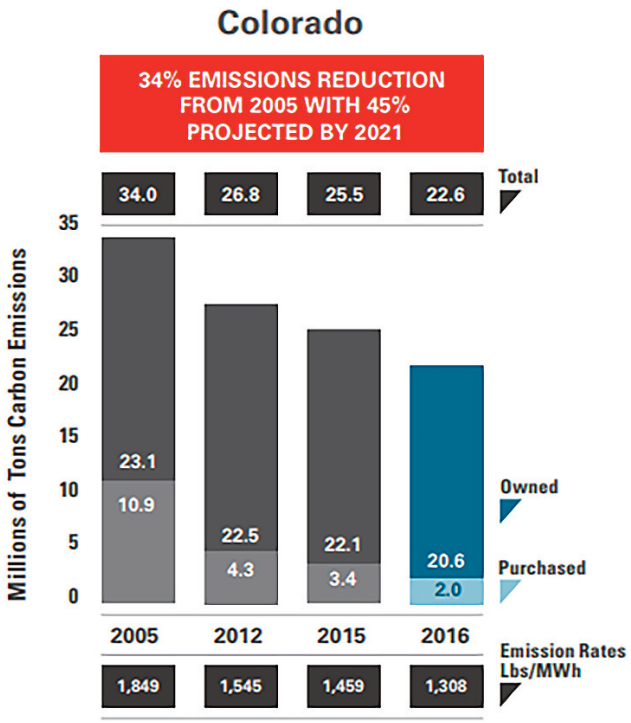
Figure 5-1



5.1.1 RENEWABLE ENERGY

In 2004, Colorado passed the first voter-led renewable energy standard ("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. House Bill 10-1001 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.[6] Cooperative utilities are required to generate 20 percent of their electricity from renewable sources.[7] 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. Resource Rich Colorado estimates that clean-tech energy jobs in Colorado have grown 22 percent in the past five years.[8] Plus, Xcel Energy estimates that it has achieved a 34 percent carbon emissions reduction in its Colorado service territory since 2005.[9] Should the Public Utilities Commission approve its pending Colorado Energy Plan, Xcel Energy believes renewable energy could make up 55 percent of its energy mix by 2026, reducing carbon emissions by 60 percent from 2005 levels.[10]

Figure 5-2



Source: Xcel Energy. Energy and Carbon Emissions Reporting, 2016 Summary

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 eleventh in the nation in 2016[11] for total solar capacity and tenth for installed wind generation capacity,[12] with approximately 3900 megawatts ("MW") of combined capacity.[13] Currently, Colorado's installed capacity of solar photovoltaic is 940 MW.[14] 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.

In addition, the installation of renewable energy in rural Colorado is providing stable and predictable revenue streams to producers who are dealing with low commodity prices;[15] while large-scale wind farms in eastern Colorado are projected to result in an increase of $7.2 million to the local tax base.[16]

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, there are about 60 small hydroelectric generators in Colorado's mountainous western region.[17] The state is working to encourage further development of small-scale hydropower and hydro-mechanical projects through the Regional Conservation Partnership Program ("RCPP"), 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 Colorado Energy Office ("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.[18] The CEO has also been promoting small hydropower through holding Pressure Reducing Valve Workshops throughout the state to educate water providers on the hydropower opportunities on their existing conduit infrastructure. From December 2016 to June 2017, these workshops facilitated in the submission of 11 Federal Energy Regulatory Commission ("FERC") applications totaling nearly 650 kilowatts of new small hydropower projects.[19]

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 Geothermal Resource Council, Colorado's geothermal potential is estimated to be as much as 8900 gigawatt hours, or 17 percent of the state's current energy demand.[20]

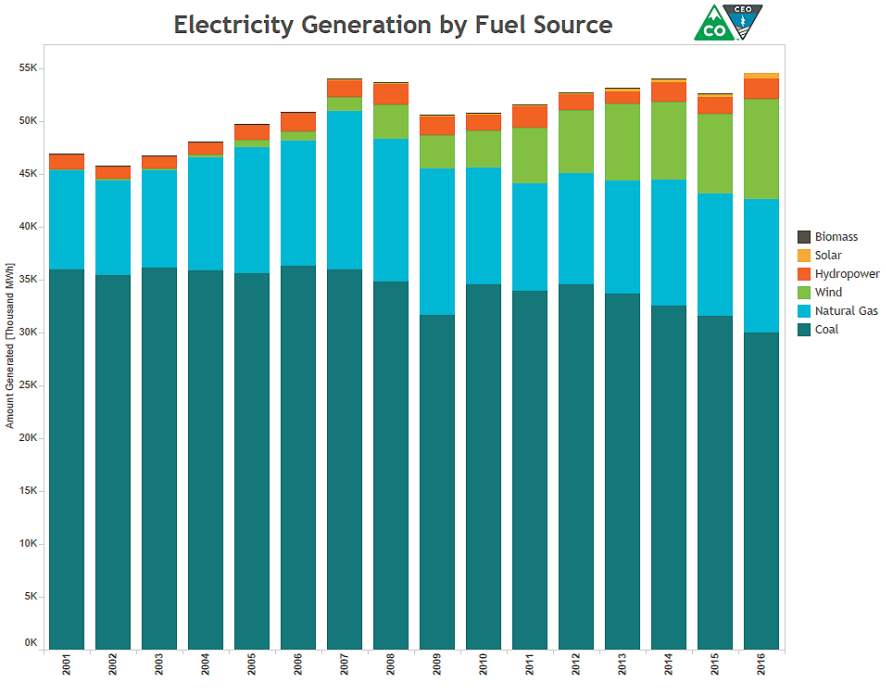
Since 2004 when Colorado's RES was passed into law by voters, Colorado has increased the amount of renewable energy in the state (Figure 5-3) from 0.54 percent of total annual electricity generated to 21.8 percent in 2016.[22]

5.2 ELECTRICITY DEMAND

Climate change will have a variety of physical impacts on both 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

Figure 5-3

Colorado Annual Net Generation[21]



Source: Energy Information Administration

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 effects 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 proven energy efficiency investments are cost effective and drive down energy demand.

5.2.1 ENERGY REDUCTION/EFFICIENCY

In 2007, the Colorado Legislature passed House Bill 07-1037, requiring investor-owned gas and electric utilities to develop demand-side management ("DSM") programs to encourage energy efficiency. House Bill 07-1037 set goals for the reduction of electricity sales and electric-peak demand by 5 percent of the 2006 level by 2018; in 2017 this was extended through House Bill 17-1227, requiring the Public Utilities Commission to set goals of at least 5 percent peak demand reduction and 5 percent energy savings by 2028 as compared to 2018 levels. 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 2,481,298 megawatt-hours ("MWh") and electricity demand by 564 MW.[23]

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 throughout Colorado.

As of 2016, residential customers consumed 36 percent of the total energy in Colorado,[24] therefore 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- 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 below.

- 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 homebuyers search for homes.
  - 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 Department of Local Affairs ("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

Table 5-1

Investor-owned Utility Electric Energy Savings from DSM Programs 2009-2016

	2009	2010	2011	2012	2013	2014	2015	2016	TOTAL
Xcel Energy									
Energy Savings (MWh)	219,611	252,014	311,643	400,676	384,230	391,615	405,703	410,499	**2,775,991**
Demand Savings (MW)	59.8	67.4	75.7	90.6	81.0	81.0	82.9	88.5	**627**
Black Hills Energy									
Energy Savings (MWh)		4,554	17,296	18,561	31,740	17,830	25,827	18,042	**133,850**
Demand Savings (MW)		1.2	3.9	4.9	6.7	4.3	5.5	3.6	**30**
Statewide Investor-Owned Utilities									
Energy Savings (MWh)									**2,909,841**
Demand Savings (MW)									**657**

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

with the tools and information needed to implement and benefit from the 2009, 2012, and 2015 International Energy Conservation Code ("IECC"). As of 2017, 95 percent of construction activity occurs in communities that have adopted the 2009 IECC or greater, and 67 percent of activity occurs in communities that have adopted the 2012/2015 IECC or greater (2012 and 2015 IECC are essentially the same level of efficiency).

- Low-income households carry a greater energy burden than other households, often spending more than 7 percent of household income on energy compared to the statewide average of 3 percent to 5 percent.[25] The Low-Income Weatherization Assistance Program offered by the CEO provides energy efficiency retrofit services to income-qualified residents. In 2016-17, the Weatherization Assistance Program delivered services to 2182 eligible single and multifamily units throughout the state. The associated installed measures saved clients more than 273,000 therms of natural gas and more than 1 million kWh, or average annual bill savings of $200.[26]
- Since 1995, the state's Energy Performance Contracting Program, administered by the CEO, has been a valuable tool that 146 state agencies, schools, colleges and universities, and local governments have leveraged to finance energy efficiency improvements in public facilities.[27] 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 2017, energy performance contracting has invested a total of $546.4 million in Colorado buildings since the program began in 1995. Additionally, energy performance contracting projects can be found in communities across 75 percent of Colorado's counties, resulting in nearly $31 million in annual utility cost savings.[28]

Committed to ensuring that energy efficiency services are available statewide, the Colorado Agricultural Energy Efficiency ("AgEE") Program was launched in 2014 to help make energy efficiency more accessible for agricultural producers, often in rural areas. 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 are provided to agricultural producers. More than 135 producers have participated in the program, and 20,000 MWh of potential electricity savings have been identified through the audits. The program is expected to generate more than $4.5 million in potential savings over a five-year period. The program was also selected for a $1.1 million USDA RCPP award to help finance energy efficiency improvements for Colorado farmers. The award is matched through a $1.3 million cash and in-kind combined contribution from CEO, the Colorado Department of Agriculture, and utility and industry partners. The funds will help finance energy- and water-saving projects identified through CEO's program. 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. The success of the AgEE Program demonstrates that by providing producers with the resources needed to make achieving energy efficiency easy —from the audit to the implementation of measures—they can stay focused on their business while reaping the benefits of energy smart agriculture. The program has gained the support of producers and agriculture organizations around the state. Partners of the AgEE Program include: Colorado Corn, Western Dairy Association, Colorado Potato Administrative Committee, Tri-State Generation and Transmission Association, Colorado Rural Electric Association, Colorado Nursery & Greenhouse Association, CSU Extension, Rocky Mountain Farmers Union, and Xcel Energy.

5.3 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.,[29] 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 for all sectors and resources in Colorado totaled 5,524,000 MWh in 2013. The 2013 demand for power required an annual consumptive use of more than 55,000 acre-feet of water in 2013, which represented one percent or less of Colorado's total consumptive use for that year.[30]

While coal and natural gas are the primary fuel sources for electricity generation in Colorado, accounting for 55 percent and 23 percent in 2016, respectively,[31] 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 between 2007 and 2013.[32] 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."[33]

Water also is used for oil and gas production and coal extraction in Colorado. There are more than 46,000 active oil and gas wells in Colorado.[34] 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.[35] Most of the water in coal extraction is used for mining, washing, and transporting coal. As of 2016, there are nine actively producing coalmines in Colorado with an average consumptive water use of 165 acre-feet per year.[36]

The water-energy nexus also includes the energy that is required for water storage and distribution, as well as water and wastewater 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.[37]

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 Efficiency Plan, which includes rebates for water-efficient appliances and incentive contracts for indoor water-saving projects to help offset the cost of installing or upgrading equipment.[38] 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.

5.4 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.
- Work with utilities to maximize the use of renewable energy, while maintaining reliability and without increasing costs to consumers.
- Assist all electric utilities in incorporating all feasible energy efficiency activities into resource planning and EPA air quality compliance plans.
- Develop baseline and future data of water and emissions from Colorado's energy sector.
- Engage with industry partners and utilities to incentivize and maximize energy efficiency gains in industrial market.
- 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.
- 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

2015

None

2016

None

2017

HB17-1363: Exempt New Energy Requirement If Not Subordinate Lien
HB17-1227: Electric Demand-side Management Program Extension

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6

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] To date, A comprehensive analysis of the specific impacts of climate change on Colorado's transportation system has not yet been performed; however, a recent study on the vulnerability of climate change in Colorado determined that there are two primary sensitivities in Colorado's transportation sector:

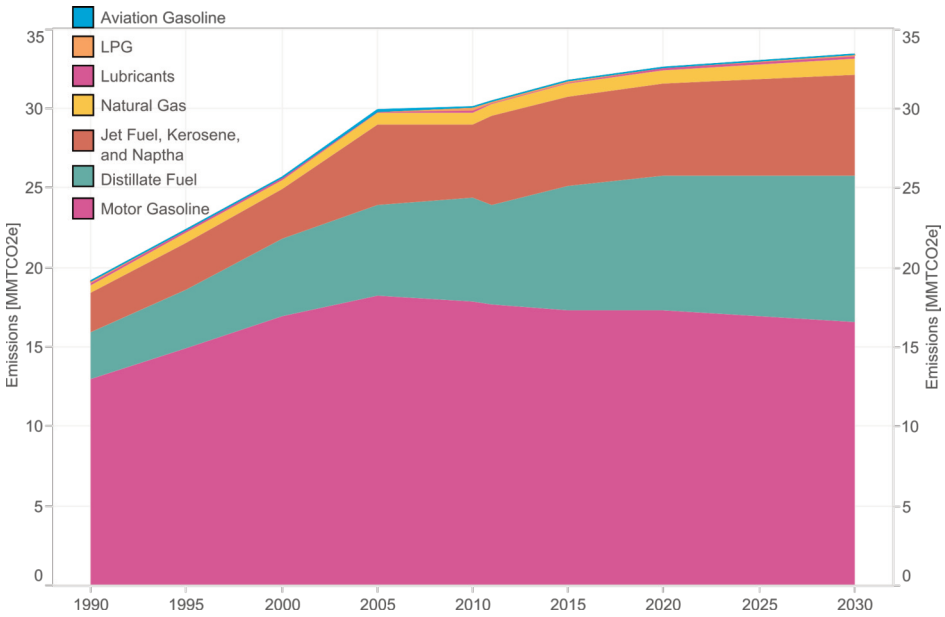
1. The sensitivity of road, rail, and airport infrastructure to the physical effects of extreme heat and heavy precipitation; and,
2. The sensitivity of travel behavior and safety to impaired visibility and traction from wildfires and precipitation events.[2]

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 infrastructure, as a sector, transportation is also a significant contributor of greenhouse gas ("GHG") emissions (Figure 5-1). In 2016, U.S. carbon dioxide emissions from the transportation sector exceeded those from the electric power sector for the first time since the late 1970's.[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 6-1

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 but do not reflect the rapid increase in electric vehicles since 2010.



6.1 LAND-BASED TRANSPORTATION

Climate change poses an increased risk to delays, disruptions, damage, and failures across our land-based transportation systems. 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 and drought, flooding, increased winter precipitation, and more severe storms (Table 6-1).[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.

6.1.1 ROADWAYS AND BRIDGES

Colorado has more than 88,740 roadway miles and 8682 highway bridges to maintain.[8] The annual 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.[9] This increase in VMT presents a challenge to reduce overall transportation 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 increased emissions associated with operational inefficiencies.

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[12] 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.[13] 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 6-1

Potential Roadway Transportation Impacts[10]

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, and 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 control costs, management of potential environmental impacts from roadway deicers and, sand 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 and affect traveler safety.
- 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.
- Increased frequency of dust storms.[11]

6.1.2 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.[14]

Climate change–related effects (Table 6-2) may disrupt, halt, or reroute railway traffic, which can have substantial impact on the mobility of people and freight operations, in turn 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.[18] As the climate warms, it could become more costly to build and maintain railways and associated infrastructure, including tunnels and bridges.

Table 6-2

Potential Railway Transportation Impacts[15]

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.[16]
- 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.
- Increased frequency of dust storms.[17]

6.2 AIR TRANSPORTATION

The Colorado Airport System includes a total of 74 public-use airports, 14 of which support commercial airline service.[19] With more than 58 million passengers traveling through annually, Denver International Airport is the largest of Colorado's airports, the sixth busiest airport in the United States, and the eighteenth-busiest airport in the world.[20] Colorado's aviation system and the activity it supports is a significant economic engine for the state, generating $36.7 billion of economic impact, and supporting more than 265,000 jobs with an annual payroll of $12.6 billion.[21] As such, climate effects on Colorado's air transportation system (Table 6-3) can have substantial economic ramifications.

Impacts from climate change may affect aircraft and airports, which can affect air travel, infrastructure, and the economy. High temperatures, particularly at high altitude airports, may result in aircraft-payload (passengers, cargo, fuel, baggage, etc.) restrictions, flight delays, and cancellations. Reduced payloads, and cancelled or delayed flights have negative economic impacts for aircraft operators.

Table 6-3

Potential Air Transportation Impacts[22]

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 aircraft performance impacts.

Higher Winter Precipitation

Regional changes in snow- and ice-removal costs, and potential environmental impacts from airport snow- and ice-control activities..

Decreased reliability of economically important aviation activity, including air carrier service.

Increase in Intense Precipitation Events

Impacts on structural integrity of airport facilities.

Destruction or disabling of navigation aids.

Damage to runway, pavement drainage systems, and other infrastructure.

Increases in weather-related delays.

Increased stormwater runoff, causing airport operational impacts such as flooding.

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.

Increased frequency of dust storms.[23]

Hot air is less dense than cool air, which reduces aircraft lift and engine performance. This becomes more critical at high altitude airports where runways must be long enough for aircraft to generate adequate lift and performance for safe operation. Runways may need to be lengthened or flights delayed or cancelled because of extreme heat.[24] Heavy winter precipitation can lead to an increased cost for snow and ice-control operations, and reduced time of airport availability for operations.

6.3 MITIGATION

Colorado is home to approximately 5.5 million people[25] and 3 million jobs.[26] By 2040, the population is expected to increase by 38 percent to nearly 7.8 million, with the number of people age 65 and older representing approximately 1.5 million or 23.8 percent of the total.[27] Because of these projections, Colorado is facing a growing demand for mobility and services throughout the state. This presents several opportunities to modernize our transportation systems and decrease emissions, while also meeting growing demands for alternative transportation. This includes:

- Support electric vehicle deployment as well as the associated electric vehicle charging station (EVSE) infrastructure development. As more renewable energy comes online, the air quality benefits from the use of electric vehicles will also increase.
- Using advanced engine management systems (e.g. start-stop technology, engine heaters, truck stop electrification). Adopting alternative fuel vehicles save money, reduce emissions, reduce our dependence on foreign oil, and strengthen the local economy.
- Promote 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.
- Develop and implement multimodal transportation solutions that promote the increased use of pedestrians, bikes, car-pooling, van-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.[28]
- 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.[29]
- Using Connected and Autonomous Vehicle Technology, trucks will be able to platoon on highways. Recent studies have estimated a 9% fuel savings for trucks that platoon, decreasing GHG emissions.

Additional efforts are included in the Adaptation section below.

6.3.1 IDLE REDUCTION

Colorado Revised Statute (C.R.S.) 42-4-1206, 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, unless the car has a remote starter system and adequate security measures.[30] In addition, 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.[31] Commercial diesel vehicles that weigh 14,000 pounds or more and are designed to operate on highways are limited to idling five minutes within a sixty-minute period unless the vehicle activity or circumstance is exempt under the statute. 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.

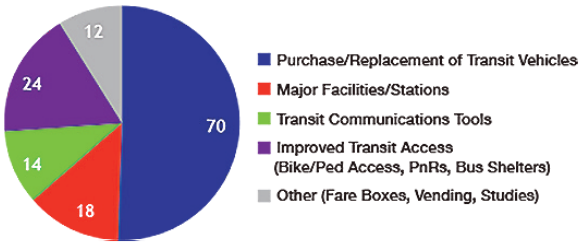
Transportation: A Health Equity and Environmental Justice Perspective

Transportation planning decisions affect communities and individuals and can elevate or harm people's health and quality of life. The Colorado Department of Transportation's (''CDOT"') transportation investments help determine how Coloradans move throughout the state. These investment decisions ultimately help or hinder healthy behaviors, such as doctor visits, job access, and access to the many recreational opportunities Colorado offers. This is especially true for underserved residents, children, older adults, and households without automobiles. CDOT recognizes that the right transportation investments can support healthier communities.

To this end, CDOT is committed to exploring the linkage between health, quality of life, and transportation investments in the 2045 Statewide Transportation Plan (to be adopted in 2020). This analysis will begin with researching initial 'best practices' used by other state Departments of Transportation such as using Health Impacts Assessments in a statewide context and implementing assessment findings. These actions will help CDOT to continue to improve transportation decision-making in our state.

Figure 6-2

FASTER Transit Grants and Projects



Source: "FASTER TRansit Grants," Colorado Department of Transportation, accessed April 3, 2015, http://www.codot.gov/projects/faster/faster-transit-grants.

6.3.2 MULTI-MODAL TRANSIT DEVELOPMENT

Transit services are 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. National level data show significant GHG emission reductions by use of public transportation. The environmental benefits of transit vary based on the number of passengers per vehicle, the efficiency of the bus or train, and the type of fuel used. Yet, even a partially occupied diesel bus emits far fewer GHG emissions per passenger mile than a single occupant vehicle.[32]

Consequently, the state of Colorado is taking many steps to develop transit around the state. The CDOT 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. [33]

In 2015, the CDOT implemented Bustang, a new interregional bus service, that offers express transit services to the communities of Fort Collins, Loveland, Denver, Lakewood, Monument, Colorado Springs, Frisco, Vail, Eagle and Glenwood Springs. Bustang connects major populations, employment centers and local transit entities while offering commuters more travel choices, alleviating congestion and consequently reducing emissions that contribute to GHG. Between July 2015 and December 2017, Bustang carried more than 350,000 passengers a total of 1.7 million miles statewide.

Senate Bill 09-108, codified as Colorado Revised Statute § 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 an important source of funds for maintaining existing local transit systems and expanding regional and interregional bus services. 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 6-2).[34] 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. The state is also planning to dedicate at least $18 million of the state's forthcoming $68.7 million Volkswagen Settlement allocation to supplement Federal Transit Administration ("FTA") and FASTER funding for transit vehicles and better incentivize the broad adoption of alternative fuel vehicles by transit fleets statewide, thereby increasing the emission reduction benefits of transit usage.

In addition to state efforts, many local entities are developing transit in their communities. In the Denver metro area, the Regional Transportation District (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. As of 2017, RTD has completed 50.9 miles of new commuter and light rail (the A, B, R, and W Lines) and 18 miles of bus rapid transit (the US 36 Flatiron Flyer) while constructing extensive new facilities at Denver Union Station and new light rail and commuter rail maintenance facilities across the metro area. Projects currently under construction include the G Line, N Line, and extension of the southeast E,F, and R Lines. The state also has dozens of rural transit agencies that address the mobility needs of its residents, reduce GHG emissions, and reduce congestion. For example, the Roaring Fork Transportation Authority, which operates in several communities around Glenwood Springs and Aspen, is the largest rural transit agency in the nation and provides more than five million passenger trips every year.[35]

6.3.3 COMPACT AND CONNECTED LAND USE PATTERNS

Encouraging compact development and redevelopment that is located near transportation hubs reduces vehicles miles traveled, thereby reducing GHGs and, at the same time, promotes efficient use of infrastructure, improves public health, and elevates environmental stewardship.[36] 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.[37] In order to achieve our statewide emission and resilience goals, we must partner with and support local government efforts, which include land use decisions. This was a key objective in Executive Order D2017-015[38] and the 2018 Colorado Communities Symposium, included discussions on how the state and local communities can work together to achieve their goals and reduce emissions.

6.3.4 ALTERNATIVE FUELS DEVELOPMENT

Colorado promotes the use of alternative fuels in the transportation sector, like electric vehicles ("EVs") and compressed natural gas ("CNG"), propane, and hydrogen vehicles. Alternative fuel vehicles utilize local Colorado resources, diversify the state's transportation portfolio, and promote air quality benefits by reducing consumption of gasoline and diesel.

Although alternative fuel vehicles represent a small share of Colorado's 5.8 million registered vehicles, the market shares are growing rapidly, particularly for natural gas and EVs. As of 2016, Colorado has more than 85,508 alternative fuel vehicles, including biodiesel, flex-fuel, hybrid, electric, natural gas, and propane vehicles. From 2015 to 2016, CNG sales grew from 5.8 million to 8.2 million gasoline gallon equivalents. EV sales have grown rapidly as well, from 20 of the vehicles on Colorado roads in 2011 to 11,931 as of October 2017.[39]

ALT Fuels Colorado

Beginning in September 2014, the Colorado Energy Office ("CEO") and the Regional Air Quality Council ("RAQC") developed the ALT Fuels Colorado program to continue the advancement of the state's adoption of alternative fuels. The two organizations jointly operate the ALT Fuels Colorado program with a $30 million budget funded by federal Congestion Mitigation and Air Quality Improvement Program funds in combination with local matching dollars. The CEO manages half of the funding for publically accessible alternative fueling stations, and the RAQC manages the other half for alternatively fueled vehicles.

The CEO manages $15 million to develop alternative-fueling stations along major statewide transportation corridors with the goal of developing an intrastate system for alternative-fuel vehicle travel. Applications are accepted on an ongoing basis. To date, this program has made awards for 10 publically accessible CNG fueling stations. In 2018, the CEO will begin offering grants for publicly accessible propane fueling stations and EV fast-charging stations along Colorado's transportation corridors.

The RAQC manages vehicle funding to cover the incremental cost of CNG, CNG bi-fuel, electric, and propane-powered fleet vehicle purchases. Both public and private fleets that operate within the State's ozone nonattainment and carbon monoxide maintenance areas along the Front Range are eligible for this funding. Funding levels range from $3000 to $35,000 depending on the size of the vehicle and type of fleet. Applications for this program are open three times per year. To date, grants for 887 vehicles have been awarded.

Charge Ahead Colorado

Charge Ahead Colorado is a program of the RAQC and the CEO designed to improve Colorado's air quality, reduce harmful air pollutants, encourage adoption of EVs and incentivize the widespread distribution of EV charging stations. Under this program, charging station grants cover up to 80 percent of an electric vehicle charging station for Level 2 and DC fast-charging charging stations. Incentives range from $3260 to $16,000 depending on the level of charger purchased. Public and private entities (but not private home owners) can apply for program funding.

The RAQC funding for the program is available in the seven–county Denver metro area, while the CEO's funding is available outside this area statewide. In addition to charging station funding, the RAQC also provides funding for electric vehicles in the seven–county Denver metro area. Vehicle funding covers 80 percent of the incremental cost of a qualified, Buy America compliant EV up to $8260. Only tax-exempt organizations are eligible for vehicle funding due to the $12,500 in state and federal tax credits available to taxpaying entities. To date, the RAQC has awarded funding for 440 stations and 116 electric vehicles, and the CEO has awarded funding for 173 stations.

Refuel Colorado

Refuel Colorado is an effort to provide businesses and consumers the information they need to assess the costs and benefits of alternative-fuel vehicles.[40] Refuel Colorado fleet coaches provide statewide consultation to assist fleet managers and local leadership in identifying opportunities for cost-effective adoption of alternative fuel vehicles. The coaches help identify the advantages of alternative-fuel vehicles and determine what type of vehicle makes economic sense. The fleet coaches then guide fleet managers through the acquisition process, providing technical expertise on issues such as fueling, incentives, maintenance, and safety.[41]

Investment Strategy

Colorado's estimated $68.7 million allocation of funding from the Volkswagen Settlement will also be dedicated to incentivizing the development of electric vehicle charging infrastructure, alternative fuel medium and heavy duty trucks, and alternative fuel transit vehicles with the goal of mitigating the negative impacts of excessive nitrogen oxide emissions resulting from the affected Volkswagen vehicles in Colorado. Colorado's Volkswagen Beneficiary Mitigation plan proposes that 15 percent—the maximum percentage allowed under the terms of the settlement—be allocated for light duty EV charging stations. Station funds will be deployed through Charge Ahead Colorado and ALT Fuels Colorado for community-based and corridor fast-charging stations.

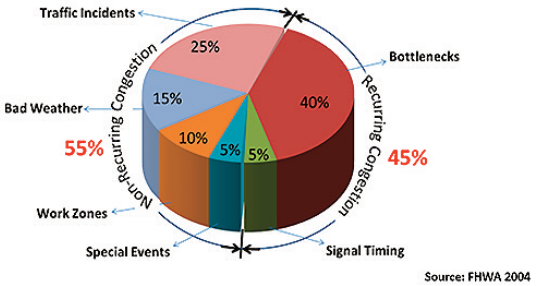
The investments made in alternative fuels infrastructure and vehicles using Congestion Mitigation and Air Quality Improvement Program, Volkswagen Settlement, and other funds will be guided in part by research and modeling of electric vehicle charging station costs, benefits, and locations recently conducted by the RAQC in partnership with the City & County of Denver, National Renewable Energy Laboratory, Southwest Energy Efficiency Project, the CEO, and the CDOT. They will also be aligned with broader planning efforts such as the alternative fuel priority corridors identified under the FAST Act, Regional Electric Vehicle West, the Governor's EV corridor agreement with seven neighboring states, and the Colorado Electric Vehicle Plan. This plan, developed in support of the Executive Order, provides actions and strategies to build out Colorado's fast-charging corridors and ensures that the benefits that come from widespread EV adoption are achieved.

6.3.5 SMART MOBILITY

Much of today's congestion on highways is due to traffic incidents (like crashes), poor weather, poor traffic signal timing, work zones, bottlenecks, and special events which all impact the flow of traffic. The CDOT has formed the Division of Transportation Systems Management and Operations to address these different factors causing congestion. See the figure below, which describes the sources of congestion in urban areas:

Figure 6-3

Sources of Congestion in Urban Areas



"Smart Mobility" through technology means improvements in safety, travel time reliability, modal choices, and environmental benefits to promote the freedom and economic development benefits of travel. Smart mobility very often involves use of Intelligent Transportation Systems (ITS). The Federal Highway Administration defines ITS as, "set of tools that facilitates a connected, integrated and automated system that is information-intensive to better serve the interests of users and be responsive to the needs of travelers and system operators."[42] Using ITS, the CDOT can decrease traffic congestion which ultimately decreases GHG emissions.

The CDOT will initiate the development of a Smart Mobility Plan in fiscal year 2018 to address these different sources of congestion. Three key milestones form the background of need for the Smart Mobility Plan: the development of the CDOT RoadX program in 2015; the launch of the first commercial delivery by autonomous truck with a partnership between Otto; and the State's purchase and trial testing in the summer of 2017 of the first autonomous attenuator truck for work zone. The Smart Mobility Plan will serve as a policy document reflecting Colorado's values for freedom, connection, and experience through transportation to ensure a productive economy, maximize safety, and improve mobility of the traveling public. The types of smart mobility projects may include:

- Using connected and autonomous vehicle technology, heavy freight vehicles will be able to platoon on highways. By traveling sequentially together in the same highway lane using vehicle-to-vehicle communication, up to a 10 percent fuel savings may be achieved by trucks.[43] This will reduce GHG emissions.
- Stopping and starting at traffic signals creates a latency in mobility and burns more fuel. New reactive signal phase and timing projects will allow signals to be coordinated. CDOT will be demonstrating a pilot project on U.S. 85, which will detect freight vehicles and extend green time for trucks.
- Ramp metering projects on interstates will manage congestion. The state is embarking the Smart25 project, which will coordinate ramp meters on 14 interchanges on I-25 in the greater Denver metropolitan area.

The CDOT has embarked upon several efforts to reduce traffic incident clearance time, which both decrease the likelihood of a secondary crash and reduce congestion and GHG emissions. The CDOT has partnered with State Farm insurance and expanded its motorist safety patrol program further north and south on I-25. Colorado State Patrol will co-locate with CDOT in the Traffic Management Center in Golden to improve first responder dispatch times. Unmanned aerial vehicles are being piloted to notify Traffic Management Center operators about crashes. And the CDOT has been training local emergency responders in traffic incident management strategies.

6.4 ADAPTATION

While transportation is a source of emissions, our transportation systems and infrastructure are also at risk of being affected by a changing climate. Many agencies and localities are beginning to plan and act to address the unavoidable impacts that will occur in the future as a result of climate change. 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. Increased focus on enhancing agency partnerships during transportation planning, design, and construction will allow adaptation to be integrated into current transportation processes.

6.4.1 TRANSPORTATION PLANNING

Transportation planning is a critical process for the state 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 the state'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, adopted in 2015, places a strong emphasis on safety, asset management, mobility, and economic vitality. 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.

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

6.4.2 RESILIENCE AND ASSET PLANNING

The historic September 2013 flood affected areas 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 cost-benefit 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, such as the I-70 Risk and Resilience Pilot project.[44] 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.[45]

Stemming from the flood recovery process, a year-long CDOT study known as the I-70 Risk and Resilience Pilot process began in August 2016, and builds on the work completed in the wake of the 2013 flood event. It is a data-driven approach to proactively identify and address vulnerabilities of the transportation system from potential physical threats, such as rock falls, flooding, and landslides. Four hundred and fifty miles of I-70 from the Utah border in the west to the Kansas border in the east have been analyzed for the potential of future damage and closures due to physical threats. The Pilot project identifies assets at high risk and suggests cost effective improvements that could be made now—in advance of a threat occurring—to proactively harden the assets or apply other strategies that reduce future risk. The CDOT plans to apply this process to other key corridors around the state. Moving forward, it is recommended that both the hazard assessments and the risk and resiliency analysis be used in the planning and design of future transportation projects, asset management, operations plans and maintenance practices. Incorporating the lessons learned from the Pilot project into policies and routine procedures can be a tool to address social, economic and environmental stressors including natural disasters, population growth and climate change.

Concurrently, the Moving Ahead for Progress in the 21st Century Act and Fixing America's Surface Transportation ACT established requirements for states to develop and implement a risk-based asset management plan. Colorado developed the first version of the plan in December 2013. The next version will incorporate high-level risk management strategies and will further build upon the successes in planning for risk and resilience. The CDOT will publish an initial version of its new plan in late April 2018, and a complete version will be published in summer 2019.

6.5 STRATEGIES AND POLICY RECOMMENDATIONS

There are several opportunities for Colorado to develop strategies for addressing climate change as relates to the statewide transportation system. These strategies can be broadly categorized as those that seek to reduce the emission of GHGs from the transportation sector and those that aim to prepare the transportation system to deal with the effects of climate change that are unavoidable.

6.5.1 STRATEGIES TO REDUCE GHG EMISSIONS

- Continue to support strategies and develop new strategies to reduce GHG emissions, reduce the growth of VMT and alleviate congestion, as laid out in the Colorado Resiliency Framework[46] and the CDOT Air Quality Action Plan.[47]
- Support new technology, fiber optics, and planning process considerations to reduce GHG emissions by improving traffic operations for improved safety, mobility and reliability.
- 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.
- The CDOT's Division of Aeronautics will continue to work with the Federal Aviation Administration and local airport sponsors to ensure airport infrastructure, facilities and equipment minimize aviation's impact on our climate, and are adaptable to climate change effects, to the extent practicable.

- The CDOT's Division of Transit and Rail will seek to improve statewide transit connectivity by sponsoring and providing grants for regional and interregional bus services. The Division will monitor this goal by tracking the number of miles of regional, interregional, and inter-city passenger service. Increased transit opportunities can reduce single-occupant vehicle travel and reduce GHG emissions.
- The CDOT's Division of Transit and Rail will continue to support local transit agencies by providing grants to rural and small urban transit providers for operational costs and bus purchases. The Division will track ridership in these areas with the goal that transit ridership will increase by 1.5 percent every year. Increased transit opportunities can reduce single-occupant vehicle travel and reduce GHG emissions.

6.5.2 CLIMATE CHANGE ADAPTATION

- 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.
- Encourage local, state, and federal entities to assess climate-related risks to transportation systems and take action to improve their resilience.[48]
- CDOT will continue the development of a process to assess hazards, manage asset inventories, identify areas of high risk, utilize those findings in the design and planning of projects, and establishment of maintenance needs.
- Ensure a robust emergency management program to deal with the immediate consequences of transportation disruption.
- Improve communication, data sharing, and collaboration between local, state, and federal entities related to climate change mitigation and adaptation programs and activities for transportation.
- Identify climate-related impacts and develop a standard method of recording impacts and costs of climate-related effects.

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7

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, and it is the nation's largest producer of millet. The success of this industry is closely tied to the health of the land, where farmers and ranchers have acted as stewards beginning from when Colorado was first cultivated. A variable climate with periods of severe drought 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 5.

7.1 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 3.4 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 to 29 percent by 2040 and 20 to 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 crop irrigation requirements are the greatest, thereby decreasing crop production or increased demands for agricultural water storage opportunities. 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

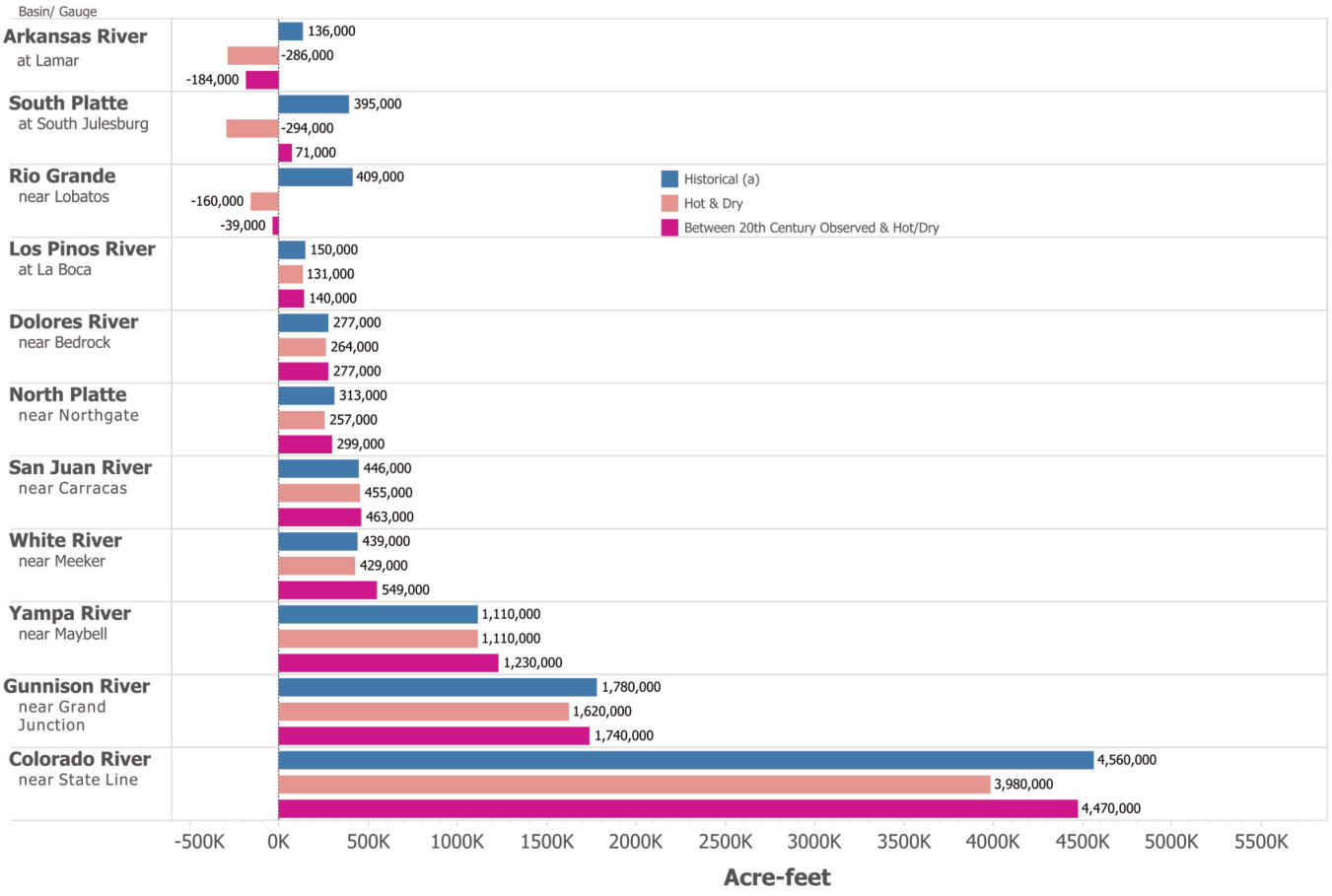
producers, but also the landscapes and communities where these farms are located. Fallowing land by choice or because of lack of sufficient irrigation water can negatively affect the soil health, public health, and ultimate survival of small rural communities in many regions of the state.

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 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 7-1).[11] The Arkansas and the Rio Grande Rivers have negative projected gauged flows under both Interbasin Compact Committee climate scenarios;

Figure 7-1

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 higher crop-irrigation requirements. Between "twentieth 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.



the South Platte has a negative projected flow under the "hot and dry" climate scenario. In Figure 7-1, 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.

These effects are not only seen on surface water flows, but will also impact groundwater return flows, and well irrigation.

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.

7.2 PRODUCTION

Colorado has a thriving agricultural sector, but changes to the climate—driven largely by increasing temperatures—can affect both crop and livestock 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 and fertilization.
- Reduced or untimely precipitation may affect pasture productivity and feed supplies.

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, a 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 adoption of more costly technologies that will better support crops 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 the extended 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 also 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. Bare soils created by the loss of native grass species due to extreme drought often are filled by invasive noxious weed species and can take years to recover in order to fulfill original livestock stocking rates. 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, Denver would be analogous to 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] Farmers and ranchers have traditionally adapted very rapidly to weather changes due to the inherent direct connection of their vocation to the land and the weather. Also producers are rapid adopters of new technology increasing the bushels of corn grown statewide from 10,640,000 bushel in 1917[21] to 134,900,000 bushel in 2015.[22]

7.3 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, which then increase management costs to producers.

Scientists have predicted that within the next 20 years, global food demand will increase by 50 percent.[23] 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.[24] 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 rainwater 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

Food Access: A Health Equity and Environmental Justice Perspective

Affordable healthy food options tend to be less accessible in low-income neighborhoods and while not the sole determinant of healthy eating, access is an essential component.[25] As the climate warms and our food systems respond, food prices may also fluctuate. From a health-equity and environmental-justice perspective, this is likely to have disproportionately negative effects on the development and health of vulnerable populations.[26]

Communities in Colorado and beyond are exploring innovative ways to improve access to healthy foods and provide education that supports healthier choices. Local nonprofits, schools, and community groups are creating community gardens that not only provide access to fresh produce, but also empower individuals and families to learn how to grow and cook their own healthy food. Community garden initiatives such as Denver Urban Gardens (DUG) and Groundwork Greens help meet the needs of residents in Denver-area food deserts. Additionally, Colorado Fresh Food Financing Fund provides nearly $20 million in grants and loans to investors who open grocery stores in designated food deserts.[27] Another innovative program, the Double up Food Bucks Colorado, led by LiveWell Colorado, enables residents on federal nutrition benefits (SNAP or food stamps) to get free fresh produce at participating farmers markets and grocery stores.[28] These are just some of the creative solutions addressing food access issues in Colorado.

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 the previous crop to protect soils from sun and wind and increase soil organic matter.

In 2017 a stakeholder engagement session held at the Governor's Agriculture Forum focused on agriculture and climate change. The primary messages shared with the State at this session included an emphasis on the importance of water storage for long term climate adaptation and resilience, support for climate smart agriculture strategies, and the high feasibility of soil health projects.

7.4 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 low 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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8

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 82 million trips are taken to Colorado,[1] resulting in $19.7 billion in consumer spending, which in turn generates $1.3 billion in state and local tax revenues. Tourism supports 165,000 direct jobs in the state,[2] making it one of the state's largest economic drivers. With 71 percent of all Colorado adults participating in some form of outdoor recreation each year, 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, both tourism and outdoor recreation can also contribute to GHG emissions. Globally it is estimated that 5 percent of carbon emissions can be attributed to tourism.[3] 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 also poses a threat to the long-term economic viability of the communities by affecting 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 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).[4] 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.[5] 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,[6] positioning these towns to better address potential changes and challenges.

8.1 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 (3.4°F) and summer (2.4°F); and over the last 30 years, summer has warmed more than any other season.[7] 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.[8] Changes in peak runoff greatly influence the rafting community, and a shorter faster runoff may shorten the overall rafting season.[9] For example, if the peak runoff—historically in June and July—shifts by a few weeks or a month then the prime rafting season would fall 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[10] 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.[11] 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 impacts to air quality in addition to road, trail, and campground closures.[12] 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.[13] 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.[14] Colorado residents alone log more than one million days of fishing activity. Non-residents log an additional nine million and spend on average approximately $100 each day,[15] which results in nearly $2 billion in economic output.[16] 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.[17] While beetle infestation may influence runoff and snowmelt,[18] 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.[19] 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.[20]

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.[21] Proper management of these areas will help to maintain habitat health for wildlife and preserve recreational opportunities for Coloradans and tourists alike. During previous administrations, federal agencies have increased their efforts on climate change preparedness and resiliency, and Colorado will work with our federal partners to continue these efforts.[22]

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.[23] 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.[24]

8.2 WINTER RECREATION & TOURISM

Winter tourism and recreation in Colorado is seemingly synonymous with snow sports. Annually, the state's ski areas see close to 13 million visits.[25] 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 through mid-century.[26] 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 occurring at relatively lower elevations is also likely to feel the effects of warmer temperatures. Activities such as snowmobiling, cross-country skiing, ice climbing, 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. For instance, the Ouray Ice Park, an international ice climbing venue critical to the economic well being of a small mountain community had to close in the winter of 2016-2017 an entire month early due to warming temperatures and unsafe conditions, thereby resulting in a significant loss of revenue for the town and the region. 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.[27] 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.[28] 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, canopy-tour zip lines and high angle adventure ropes/challenge courses, diversifying their revenue stream. These strategies should be encouraged and enhanced in the coming decades.

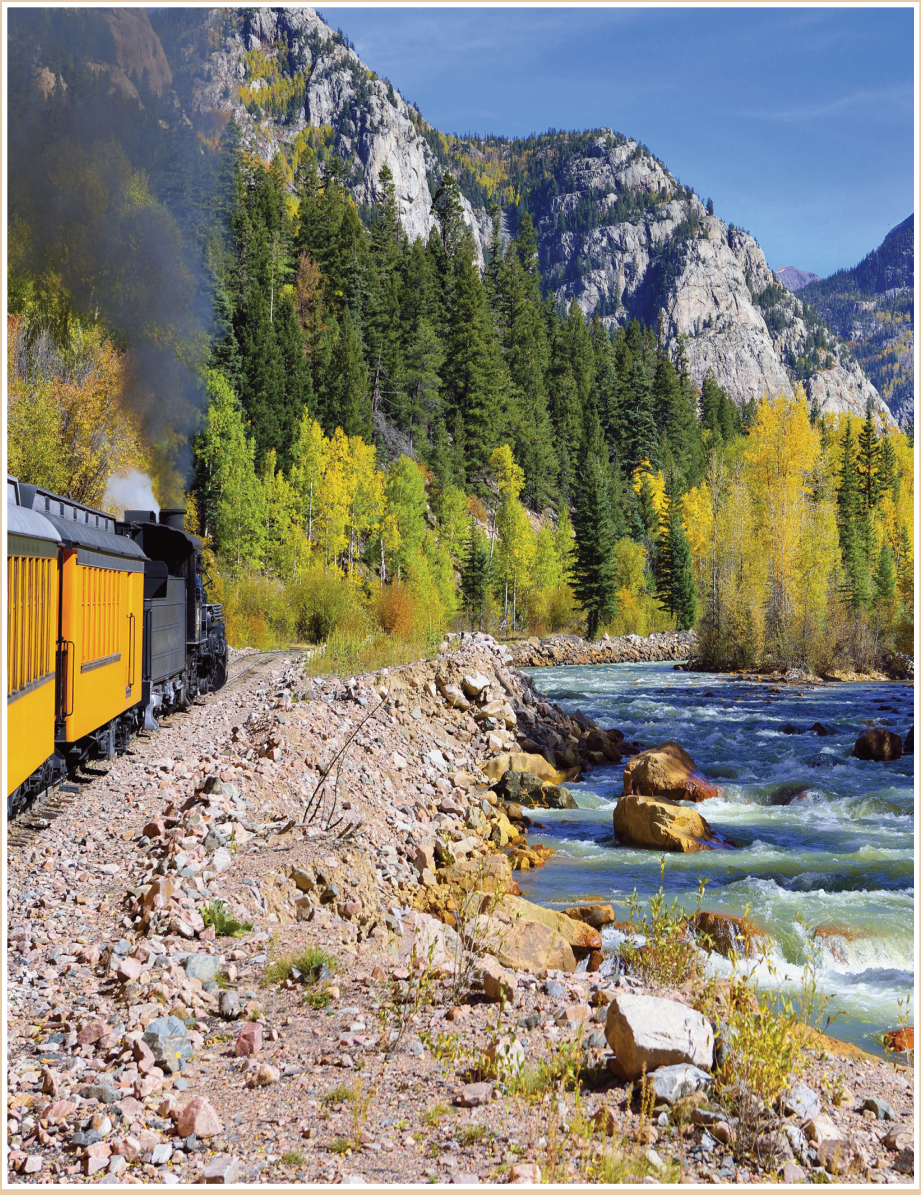
8.3 MITIGATION

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.[29] 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, such as the recent restoration of the Winter Park Ski Train, 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 6.

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 efficiency projects within their operations. Most importantly, Aspen Skiing Company will expand its political power, and that of its allies, to support good policy at the state and federal level.[30] Similarly, in 2017 Vail Resorts launched EpicPromise with the goal of eliminating the environmental impact of its operations by 2030. This includes zero net emissions, zero waste to landfill, and zero net operating impact to forests and habitat. To reach these three goals, Vail Resorts is partnering with nonprofit and community stakeholders in Summit and Eagle counties on efforts to purchase 100 percent renewable energy, increase and invest in educational programs such as tree planting, recycling, and composting, and work with local communities to increase options for reuse and diversion.[31]

8.4 STRATEGIES AND POLICY RECOMMENDATIONS

- Partner with federal, regional and local agencies and entities 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 preparedness and post disaster strategies.



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9

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. Healthy ecosystems support thriving communities with clean air, clean water, 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 insects and 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 offset emissions of carbon dioxide (a major greenhouse gas) through the absorption and long-term storage of carbon in plant tissues. In fact, U.S. forests offset almost 16 percent of the nation's carbon dioxide emissions.[1] Yet, these ecosystems are also 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.[2]

Grassland ecosystems in Colorado will be particularly impacted by drought and changed precipitation patterns; reduced plant growth will weaken the potential for these ecosystems to serve as CO_2 sinks.[3] Alpine ecosystems are at risk of decreased growing seasons as temperatures warm, raising the levels of nitrogen and phosphorous, and creating water quality issues in populated areas.[4] Other reports have comprehensively assessed the vulnerability of Colorado's ecosystems to a changing climate.[5]

Table 9-1

EIGHTEEN TERRESTRIAL ECOSYSTEMS IN COLORADO[6]

System Name General Elevation Range Percent of Colorado Acres	Includes SWReGAP Types:
Alpine Tundra 10,500-11,450 ft. - 3%	North American Alpine Ice Field – note: none in focal majority grid Rocky Mountain Alpine Bedrock and Scree Rocky Mountain Alpine Fell-Field Rocky Mountain Dry Tundra Rocky Mountain Alpine-Montane Wet Meadow
Aspen 7,500-11,000 ft. - 5%	Rocky Mountain Aspen Forest and Woodland Intermountain West Aspen-Mixed Conifer Forest and Woodland Complex
Foothill Shrubland 5,100-8,700 ft. - 1%	Rocky Mountain Lower Montane-Foothill Shrubland
Grasslands (non-shortgrass prairie) 4,600-11,300 ft. - 5%	Southern Rocky Mountain Montane-Subalpine Grassland Western Great Plains Foothill and Piedmont Grassland Inter-Mountain Basins Semi-Desert Grassland
Greasewood 4,400-7,800 ft. - 1%	Inter-Mountain Basins Greasewood Flat
Juniper 4,200-7,800 ft. - 1%	Southern Rocky Mountain Juniper Woodland and Savanna Inter-Mountain Basins Juniper Savanna
Lodgepole Pine 8,000-11,200 ft. - 3%	Rocky Mountain Lodgepole Pine Forest
Mixed Conifer 6,000-11,000 ft. - 1%	Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
Oak and Mixed Mountain Shrub 5,500-9,300 ft. - 4%	Rocky Mountain Gambel Oak-Mixed Montane Shrubland
Pinyon Juniper - Colorado Plateau 4,650-8,500 ft. - 7%	Colorado Plateau Pinyon-Juniper Shrubland Colorado Plateau Pinyon-Juniper Woodland Colorado Plateau Mixed Bedrock Canyon and Tableland
Pinyon Juniper - Southern Rocky Mtn. 5,000-9,500 ft. - 2%	Southern Rocky Mountain Pinyon-Juniper Woodland
Ponderosa Pine 5,700-9,850 ft. - 5%	Rocky Mountain Ponderosa Pine Woodland
Sagebrush 5,000-10,000 ft. - 8%	Inter-Mountain Basins Big Sagebrush Shrubland Inter-Mountain Basins Montane Sagebrush Steppe
Salt Shrub 4,350-7,100 ft. - 1%	Inter-Mountain Basins Mat Saltbush Shrubland Inter-Mountain Basins Mixed Salt Desert Scrub Inter-Mountain Basins Shale Badland
Sand Sage 3,500-6,000 ft. - 3%	Western Great Plains Sandhill Shrubland Western Great Plains Sandhill Prairie, if any
Shortgrass Prairie 3,450-6,500 ft. - 18%	Western Great Plains Shortgrass Prairie
Shrub-Steppe 4,320-8,900 ft. - 1%	Inter-Mountain Basins Semi-Desert Shrub Steppe
Spruce Fir 8,800-12,400 ft. - 7%	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland

Ecosystems are vulnerable to climate change and yet they also offer opportunities to mitigate greenhouse gas emissions. The concept of "natural climate solutions" suggests that conservation, restoration, and certain land management actions can increase carbon storage in the form of land sinks and/or avoid greenhouse gas emissions from activities that would otherwise occur on the land.[7] Scientists estimate that, globally, ecosystems absorb the equivalent of approximately 20 percent of anthropogenic greenhouse gas emissions.[8] Natural carbon solutions, like reforestation, improved forest management, and wetland conservation and restoration, can also increase resilience to climate impacts. While a promising approach, more research is needed to refine methods for implementing natural carbon solutions in the context of competing land uses, as well as estimates of the carbon benefit from implementation.[9]

Any changes to ecosystems because of the effects of climate change, or as an attempt to mitigate the effects, are likely to trigger changes in current resource 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 address projected future climate changes.

9.1 FOREST HEALTH AND WILDFIRE

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, the temperature controls pests, 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.[10] 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, at a price tag of $33 million.[11]

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 is 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 also drive up costs. The 2002 Hayman Fire ultimately cost the state $207 million,[12] and at the time was considered one of the most expensive fires in the state's history. The effect of the Hayman Fire was rivaled by the Black Forest Fire in 2013 which devastated over 14,000 acres; killing two people and destroying nearly 500 homes and more than 200 outbuildings.[13] It is estimated that the total cost exceeded $430 million.[14]

Add to the increasingly severe fires the steady development of homes adjacent to fire-prone public forested lands, and the combination is a daunting management challenge. More than 2 million homes exist in Colorado's wildland-urban interface ("WUI") – the 6.2 million-acre area where structures and other human developments meet or intermingle with wildland vegetative fuels. And this housing number continues to increase.[15] Headwaters Economics notes that 84 percent of private lands in the high-risk zone are currently undeveloped.[16] 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.

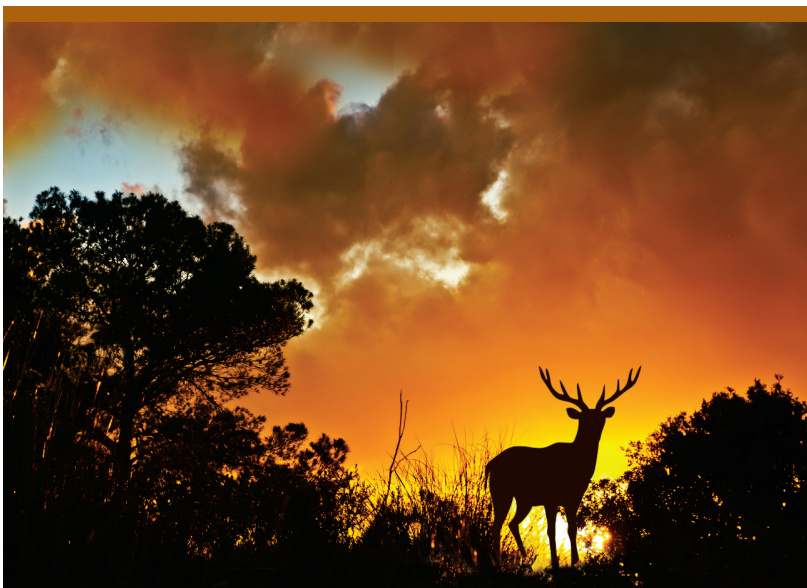
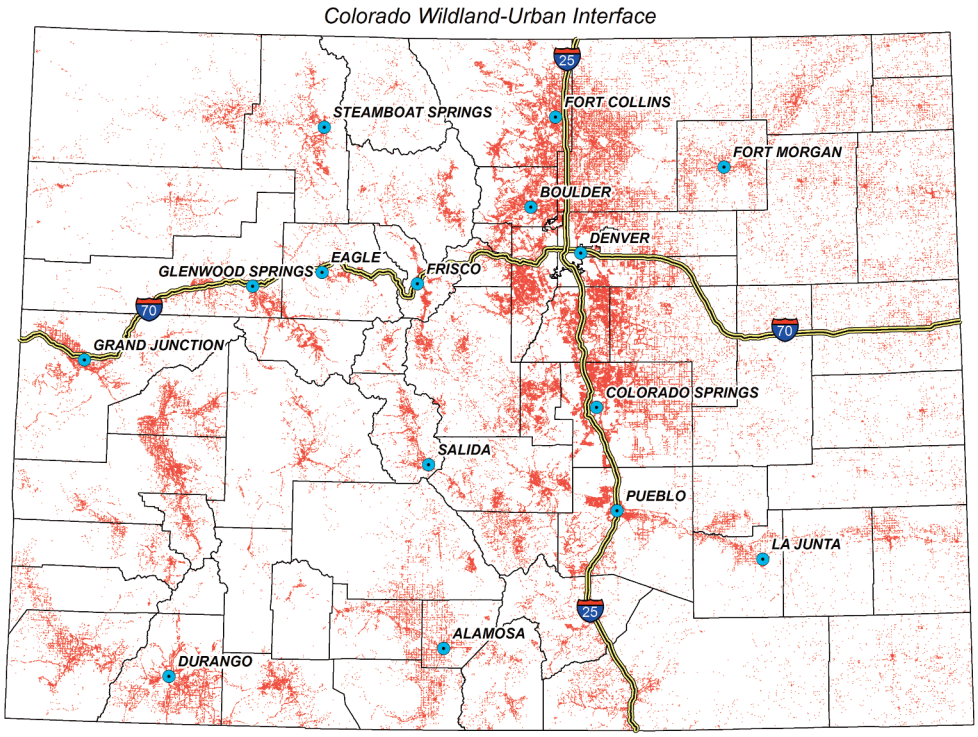


Figure 9-1

Wildland-Urban Interface Lands in Colorado



Active forest management is a critical tool in restoring forest health, reducing the risk of intense wildfires, and mitigating the impacts of climate change. An example of proactive management on a larger scale can be seen in Denver Water's longstanding partnerships with the U.S. Forest Service and Colorado State Forest Service, which has resulted in tens of thousands of targeted acres being treated to reduce wildfire risk and protect critical watersheds. Activities in high-priority areas include reduction of forest vegetation (i.e., forest thinning), maintaining defensible space around utility infrastructures, and creating fuelbreaks along firefighter and resident ingress/egress routes.

Yet a challenge to managing forests in the state is 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—and which are becoming increasingly vulnerable to large-scale bark beetle mortality as average annual temperatures increase.[17]

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 fire seasons, and longer durations for fire events.[18] More detail on the state of Colorado's forests and the risk of fire and insects is available in the 2016 Report on the Health of Colorado's Forests by the Colorado State Forest Service.[19]

9.1.1 ADAPTATION

The most important piece of the forest-health and wildfire dilemma is adaptation. The term "fire-adapted 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 non-profit organizations address this through public outreach and grants to local governments. More than 150 communities in Colorado have been certified "Firewise," indicating their implementation of a suite of tactics designed to remove local fuels and protect homes.

Similarly, 2017 legislation consolidated two existing grant programs in Colorado to help private landowners who live in the WUI treat their property to minimize risk. The Forest Restoration and Wildfire Risk Mitigation Grant Program, administered by the Colorado State Forest Service, is funded at up to $1 million a year through the severance tax operational fund and accepts applications from across the state. This new program, like its predecessors, requires applicants to match the public funds they receive. Since 2009 these programs have contributed almost $20 million in public dollars toward a reduction in hazardous fuels in high-risk areas throughout the state. But the demand for resources to address the forest treatment need is still high.

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.[20]

Available funding is a limiting factor to mitigating risk. With a relatively small grant program funded by the State that is 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 also 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.

We can further mitigate risk 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 Colorado Wildfire Risk Assessment Portal is a web-mapping tool offering information for homeowners, emergency responders, risk planners, realtors, and insurance companies to understand the wildfire risk in an area and possible actions that could mitigate that risk.[21] The Portal is intended not only to raise risk awareness, but also to help emphasize the need for WUI homeowners and communities to take personal responsibility to mitigate that risk.

9.2 FISH AND WILDLIFE

Coloradans heavily value wildlife, natural places, and outdoor recreation;[22] and wildlife contributes to the state's multi-billion-dollar outdoor recreation economy. 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.[23] 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.[24] 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 ecosystem health and future public enjoyment.

9.2.1 ADAPTATION

In 2015 the state revised 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, for the first time, includes 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 state received and incorporated significant public input into the plan. The final SWAP was submitted to the U.S. Fish and Wildlife Service in September 2015 and was approved in March 2016.

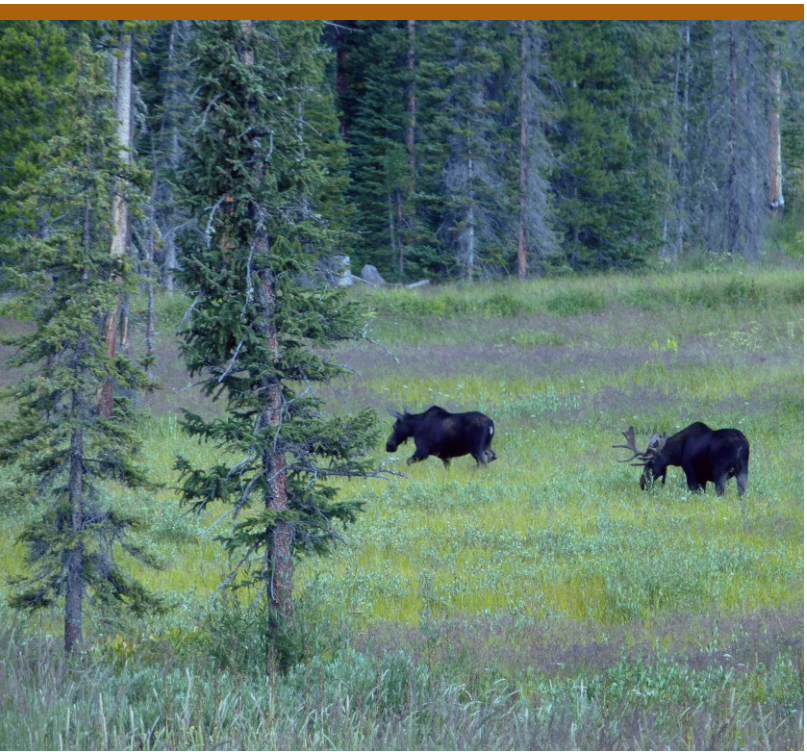
To inform the climate portion of the SWAP revision, the State conducted a thorough analysis of the vulnerability of priority wildlife habitat under an altered climate. The State, in collaboration with the Colorado Natural Heritage Program, U.S. Geological Survey, and the North Central Climate Science 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.[25] This effort received a 2016 Climate Adaptation Leadership Award honorable mention from the National Fish, Wildlife and Plant Climate Adaptation Strategy's Joint Implementation Work Group, in partnership with the Department of the Interior, U.S. Fish and Wildlife Service, Natural Resource Conservation Service, National Oceanic and Atmospheric Administration, U.S. Forest Service, and the Association of Fish and Wildlife Agencies.

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.[26] Most wildlife habitat will not shift quickly, but within the 30-year timeframe we will likely begin to see altered ecosystem composition.[27] By mid-century, future wildlife habitat will likely be warmer, especially on the eastern plains.[28]

Aquatic habitat was not directly considered in the SWAP vulnerability assessment, but 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.[29] Reduced stream flows may also exacerbate the fragmentation of aquatic habitat. Studies on aquatic species by research scientists at CPW 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.[30]

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.[31] The State 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 the persistence of cutthroat trout populations given a variety of factors, including variables associated with climate change.[32] Other work cooperatively conducted by state agencies 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. CPW continues to build upon past work to improve stream connectivity to enhance climate adaptation for fish species. This includes working with local municipalities and water users to install fish passage structures where feasible. One notable example is a fish passage structure installed by the City of Fort Collins at the Fossil Creek Reservoir Diversion on the Cache la Poudre River in 2016, which facilitates passage of all fish species at the location. Additional fish passage projects are in planning and implementation stages across the state.



9.3 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.
- Maintain current data in the Colorado Wildfire Risk Assessment Portal, so that homeowners and others can accurately assess the level of risk associated with their communities, and to best inform insurance companies, emergency personnel, and local governments.
- Encourage forest management on private, state and other lands to help capture and store carbon, reduce wildfire and insect/disease risk, improve wildlife habitat, and achieve other forest management objectives. Recommended management actions may include emphasizing tree diversity, reducing woody fuel loads, helping forests regenerate after fire and other disturbance, and landscape-scale forest restoration projects.
- Promote the utilization of Colorado wood products to improve markets that enable forest management actions.
- Implement conservation targets and management actions in the updated SWAP approved by the U.S. Fish and Wildlife Service.
- 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 Colorado Water Conservation Board, the private sector, and municipalities to evaluate how future water-supply projections will impact aquatic habitat.
- Develop strategies to reduce impacts of climate change in aquatic systems through stream-habitat improvement and connectivity.

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10

Partnerships

Partnerships and collaboration play a central role in achieving this plan's goal of improving Colorado's ability to adapt to and mitigate future climate change impacts, increasing Colorado's preparedness, and identifying opportunities to reduce greenhouse gas emissions ("GHG") throughout the State of Colorado. In accordance with Executive Order D 2017-015, the purpose of this chapter is to outline the importance of meaningful consultation and collaboration with local governments, non-profits, and the private sector to meet the State's goals for GHG reduction. Another purpose is to empower the implementation of locally led climate adaptation and resilience solutions.

This chapter highlights examples of collaborative action already taking place throughout the state and identifies opportunities for future action. It is not an exhaustive list of everything every community or organization in Colorado is doing about climate change. This chapter highlights opportunities for collaboration and innovation, articulates the support the State can provide to communities, and acts as a guide to what has been successful to date and what can potentially be successful for other communities around the state in the future.

10.1 CLIMATE ADAPTATION AND RESILIENCE

In 2015, the State of Colorado developed the Colorado Resiliency Framework ("Framework"), the State's roadmap for resilience. While the Framework was catalyzed by recent disasters, including the record 2012-2013 wildfires and 2013 floods, it provides actionable steps to reduce vulnerability from shocks (acute events such as wildfires, floods, and tornadoes), and stresses (underlying long-term conditions including a lack of affordable housing, poor forest health, and constrained community finances). Evidence shows that climate change has the potential to magnify vulnerability to both shocks and stresses across multiple sectors. The State of Colorado defines resiliency as:

> *The ability of communities to rebound, positively adapt to, or thrive amidst changing conditions or challenges — including disasters and climate change — and maintain quality of life, healthy growth, durable systems, and conservation of resources for present and future generations.*[1]

Communities who are resilient in the face of disasters and climate change display the following key characteristics:

- They are aware of their risks and vulnerabilities, as well as their strengths. This awareness serves as a lens to inform planning, policy, and action.
- They are diverse in perspectives, relationships, culture, and thinking. Diversity of perspectives drives innovation and helps to enhance social capital, which can be one of a community's greatest assets when a disruption occurs.
- They are integrated. Recognizing that communities increasingly rely on complex and interdependent systems, infrastructure and government operations are able to maintain operability even if one component in the overall the system fails.
- They are self-regulating, meaning that they can bend without breaking when under extreme stress.
- They are adaptive. They can anticipate challenges and make necessary changes—sometimes small, and sometimes large —to proactively reduce their vulnerability to acute or persistent disruptions.[2]

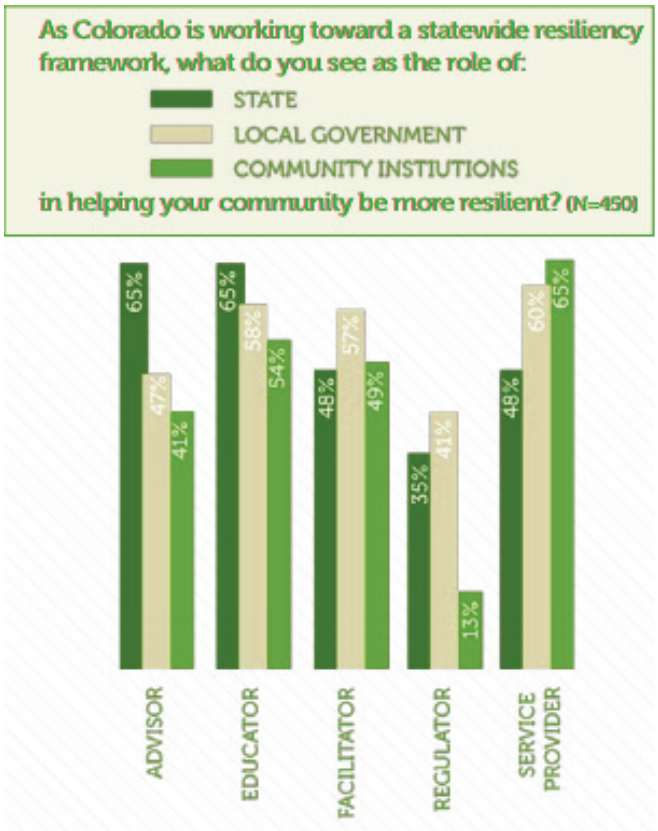
Climate adaptation, while distinct from resilience, is a synergistic approach to addressing the impacts of climate change.[3] Adaptation encompasses adjustments in natural or human systems as a result of expected impacts from climate change. Adaptation actions can be taken before impacts are observed in order to anticipate changes to risk or vulnerability, or it can be taken after the effects and consequences of climate change have already been observed. Adaptation and resilience actions require collaboration across all levels of government, the private sector, and other community institutions. As a partner in this effort, the State of Colorado is committed to supporting communities in building capacity and developing and implementing adaptation and resilience solutions that meet local needs, priorities, capabilities, and vulnerabilities.

10.2 STAKEHOLDER ROLES

During the development of the Resiliency Framework, the State engaged with local governments, businesses, and citizens through a series of surveys, interviews, and focus groups. During the engagement process, the State asked 450 stakeholders, including local government officials, small businesses, climate scientists, leaders from community based organizations, and the general public about their view about the roles and responsibilities of state government, local government, and community institutions in making communities more resilient. Respondents indicated that the State plays an important role as an advisor and educator, and shares a regulatory responsibility with local governments. Local governments play a key role as a facilitator and share responsibility with community institutions, including businesses, as a service provider.

Through the Framework, this Climate Plan, and locally driven efforts, stakeholders have consistently pointed out that while the State plays an important role in advising, developing tools, and providing resources to empower action, that local communities are in many cases best suited to directly confront the effects of climate change in Colorado. Already local governments around the state have adopted new renewable fuel sources to power their communities, have committed to reducing GHG reduction in accordance with or beyond targets of the Paris Climate Accord, and have put forth innovative solutions for planning for and mitigating future changes.

Figure 10-1



10.2.1 STATE CLIMATE ASSISTANCE

The State of Colorado can provide assistance to support and empower regional and locally driven climate adaptation and resilience actions. As outlined in earlier chapters, the State has implemented planning, policy, and regulatory actions to reduce GHG emissions and adapt to changing conditions. In addition, state agencies can provide a range of technical and financial assistance services and support local efforts to cultivate cross-sector and regional partnerships. The State recognizes that addressing challenges associated with climate change requires interdisciplinary coordination and action. The State seeks to make its support to communities as streamlined as possible. Depending on local needs, communities can work with any State agency to tailor appropriate solutions. State agency representatives will be able to coordinate with partners in other departments to expand support as needed.

Table 10-1 **State of Colorado Areas of Expertise and Assistance**

Department of Natural Resources	Department of Public Health & Environment	Colorado Energy Office	Department of Local Affairs
❖ Water sector adaptation ❖ Water supply and conservation ❖ Water delivery infrastructure ❖ Watershed restoration and ecosystem health ❖ Flood risk information and mitigation ❖ Wildlife management ❖ Drought planning and preparedness	❖ Water quality ❖ Air quality ❖ Water and wastewater infrastructure ❖ Public health ❖ Behavioral health ❖ Emergency preparedness ❖ Inventory of GHGs	❖ Renewable energy ❖ Energy efficiency and assurance ❖ Low income weatherization ❖ Energy finance expertise ❖ Alternative fuels vehicles	❖ Resource navigation and interagency coordination ❖ Community development ❖ Community and economic resilience ❖ Watershed restoration and ecosystem health ❖ Land use planning ❖ Affordable housing ❖ Long-term disaster recovery support
Department of Transportation	**Department of Agriculture**	**Department of Public Safety**	**Colorado State Forest Service**
❖ Regional and statewide transportation planning ❖ Snow and ice operations ❖ Roadway maintenance and preservation ❖ Construction management ❖ Rockfall mitigation	❖ Natural resource conservation and management ❖ Soil health and crop production ❖ Environmental health ❖ Emergency preparedness and response ❖ Agricultural market expertise and assistance	❖ Emergency planning ❖ Disaster preparedness ❖ Hazard mitigation ❖ Disaster recovery support	❖ Forest management ❖ Wildfire fuels reduction ❖ Wildfire risk mapping and identification ❖ Community wildfire protection planning ❖ Land use planning ❖ Affordable housing ❖ Long-term disaster recovery support

Below are a few examples of State resources and activities to support climate adaptation and resilience.

10.2.1.1 Climate Planning Resources

- Planning for Hazards: Land Use Solutions for Colorado
  In 2016 the Colorado Department of Local Affairs developed this guide and website (www.planningforhazards.com) to provide Colorado municipalities and counties with tools to reduce risks to hazards, including guidance on developing a local Climate Plan and Resilience Planning. Training and technical assistance to municipalities and counties to implement land use strategies to reduce risks are underway.
- Colorado Wildfire Risk Assessment Portal (CO-WRAP)
  The Colorado State Forest Service created CO-WRAP (www.coloradowildfirerisk.com) to provide public access to information that describes wildland fire risk statewide.
- Hazard Mitigation Planning
  The Colorado Division of Homeland Security and Emergency Management provides data, resources, and technical assistance to support local hazard mitigation planning.
  www.colorado.gov/pacific/mars/mitigation
- Integrating Water into Land Use Planning
  The Colorado Water Conservation Board, the Pace University Land Use Law Center, and the Department of Local Affairs' Community Development Office developed educational water efficiency and conservation materials targeted to Colorado water providers and local government planners, including a series of webinars.
  www.colorado.gov/pacific/cowaterplan/integrating-water-land-use-planning
- Local Drought Planning
  The Colorado Water Conservation Board offers financial and technical support to any local jurisdiction interested in drought mitigation planning, including: guidelines for developing a drought mitigation plan, a Drought Mitigation Toolbox, and Drought Mitigation Planning Grants.
  https://tinyurl.com/LocalDroughtPlanning
- Climate Change in Colorado
  The Western Water Assessment (WWA) in partnership with the Colorado Water Conservation Board, authored a report on climate science relevant for management and planning for Colorado's water resources, focusing on climate trends, climate modeling, and projections of temperature, precipitation, snowpack, and streamflow.
  https://tinyurl.com/ClimateChangeInCO
- CO-Resiliency Resource Center
  The Colorado Resiliency and Recovery Office developed this online platform (www.coresiliency.com) for resiliency knowledge and technical resources to provide government agencies, elected officials, community organizations, the private sector, and individual resiliency champions with knowledge and resources to Understand, Plan for, and Act on resilience.

10.2.1.2 Colorado State Forest Service Nursery

The Colorado State Forest Service Nursery (the Nursery), located in Fort Collins, is leading a unique effort to cultivate trees and plants that are native to—and appropriate to—Colorado's climate. The nursery is one of five such state-managed facilities in the country. At its 130-acre facility, the Nursery grows seedlings for more than 50 native Colorado species of plants and trees to assist private and public landowners and land managers across the state with conservation efforts.[4] The seedlings can be used for a variety of conservation efforts including reducing erosion risk and stabilizing soil; improving wildlife habitat; reforesting areas impacted from wildfires, floods, and pest infestations; sequestering carbon; and using drought-tolerant species.[5]

The Nursery staff take great efforts to ensure that the plants they grow are best suited for Colorado's ecoregions, and thereby have the greatest positive ecological impacts. As conditions continue to change and evolve, the Nursery will continue to play a key role in ensuring that the right seed, in the right place, at the right time is available in order to to preserve and improve our air, water, soil, and wildlife habitats.

10.2.1.3 Rural Response, Recovery and Resilience

During the 2017 legislative session, the State Legislature established the Rural Response, Recovery, and Resilience program ("4R"), which is designed to support community driven efforts to adapt mineral extraction-dependent economies in the face of a changing economic landscape. Coordinated by the Colorado Department of Local Affairs, the program will provide strategic technical and financial assistance to eight pilot counties over a five year period designed to diversify the economy and build community resilience in the face of shocks and economic stresses. Counties currently eligible for this program include Delta, Montrose, Gunnison, Moffat, Rio Blanco, Grand, Clear Creek, and Routt.

10.2.2 LOCAL GOVERNMENTS

All around the U.S., local communities are taking the initiative to address climate change. In the spirit of Colorado's strong local-control tradition, local governments in Colorado are particularly well poised to tailor locally appropriate mitigation, adaptation, and resilience solutions through plans, policies, regulations, investments, and partnerships. There are a number of national and statewide initiatives that bring local governments together to address the impacts of Climate Change. For example, mayors from around the U.S. have formed the Mayors National Climate Action Agenda, known as "Climate Mayors," a peer-to-peer network of communities committed to working together to adopt and uphold the Paris Climate Accord.[6] As of September 2017, 372 Mayors from around the country have committed to upholding the Paris Goals. In Colorado, 16 municipalities have signed the Climate Mayors Pledge.[7]

In the previous version of this climate plan, examples from several communities around the state were provided to highlight the progress being made in Colorado in implementing new ideas for adapting to climate change, enhancing resilience or committing to GHG emission reductions. Additional examples from around the state have been included in this update.

10.2.2.1 City of Fort Collins

Fort Collins, located on the Front Range north of Denver, is the fourth largest city in Colorado and has a population of 161,000. Fort Collins embraces conservation, active lifestyles, and innovative solutions. To that end, the City Council in 2015 set aspirational goals and updated its Climate Action Plan—a roadmap to achieve those goals—to ensure the community's long-term social, economic, and environmental health.

When the goals were adopted in 2015, the City's 2014 inventory showed that emissions were 8 percent below 2005 levels. From 2015 to 2017, the City has increased investments in additional energy efficiency, renewable energy, and overall infrastructure to support the goals. These investments have paid off—the City's 2016 Community Carbon Inventory showed a 12 percent reduction in emissions—all while the population and local economy grew.

In addition to overall emission reductions, the community has reaped significant economic and social benefits from these investments, including the following:

- Businesses are saving more than $9.5 million annually from investments they've made in energy efficiency alone.
- The community has increased locally installed solar capacity by almost 3.5 times from 2014 to 2016, which not only supports cleaner air but helps to avoid future development of additional electricity generation sources.
- 96 percent of Fort Collins residents recycle.
- Transit ridership rose 26 percent from 2015 to 2016.

For more information, visit:
www.fcgov.com/climateaction/reports.php

10.2.2.2 Garfield County Communities

Communities in Garfield County have worked together since 2009 to achieve regional targets for energy efficiency, renewable energy, and petroleum independence, and to use this work to diversify and strengthen the local economy. A Colorado Department of Local Affairs ("DOLA") New Energy Communities grant launched the countywide effort. In 2012, recognizing the long-term economic benefits of clean energy, local government partners formed the Garfield Clean Energy Collaborative.

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

By joining together, this rural region has been able to offer programs, services, technical assistance, and financing in ways that individual small communities typically do not have the resources or capacity to offer. This joint program has led to measurable clean energy, economic, and climate protection progress. The programs are structured around renewable energy, energy efficiency, and clean energy transportation.

Countywide Renewable Energy Program

Garfield Clean Energy used some of its original DOLA grant funds in 2010 to install 23 renewable energy systems on public buildings countywide, generating 365 KW of solar electric power.[8] In most communities, these were the first solar electric systems powering government buildings. Since then, through GCE's efforts and local government initiative, renewable energy has expanded exponentially.

Glenwood Springs Electric, a municipal utility, exceeded its renewable energy portfolio target early in the decade, meeting 32 percent of demand with purchased wind and hydro, and locally with 37 solar energy systems installed on homes and businesses.

Through GCE's technical assistance, local governments across the county capitalized on solar energy. By 2016, schools, libraries, water plants and other government buildings across the county were powered by 42 arrays generating 4.6 MW [9]of electricity, an amount equal to the average annual electrical use of 1170 homes.

Showcase projects include large solar arrays powering 100 percent of the electric needs for water treatment plants in Silt and Battlement Mesa, and an array at Roaring Fork High School in Carbondale, the county's first 100-percent-solar-powered school.

In Rifle, the city government has achieved net zero status, using a portfolio of 15 arrays to generate 2.7 MW—at least as much electricity as it draws from the grid. The estimated annual value of this solar energy tops half a million dollars, according to estimates from Garfield Clean Energy.[10] With a population of 9400, the city is believed to have the highest per-capita solar production in the nation.

The countywide effort has also started a collaboration with neighboring counties to create a "Clean Energy Innovation Corridor," an effort that aims to reach clean energy targets in a three-county region with local renewable energy—and do so in a way that maximizes local job training and economic opportunity.

Countywide Energy Efficiency Program

To date, Garfield Clean Energy has worked with energy utilities to help 258 businesses, 940 households, and 55 government buildings make energy efficiency upgrades that are saving more than $1.2 Million per year. Since 2010, these projects have stimulated investments of $7.4 million in materials purchased from retailers and generated work for 169 contractors. The cumulative effect of these projects is an annual reduction in greenhouse gas emissions of more than 9000 tons. It is a partnership effort that boosts the local economy, and the results help energy utilities reach their goals for demand-side conservation.[11]

In 2015, Garfield Clean Energy and CLEER piloted an energy efficiency program for income-qualified households, in collaboration with Energy Outreach Colorado. With a successful model of service to rural communities created in Garfield County, the CARE program has expanded to serve 22 rural Colorado counties. Within Garfield County to date, the CARE program has provided free energy efficiency upgrades to 244 households, improving home comfort and helping families save on utility costs in communities where affordable housing is a pressing issue.[12]

A countywide planning effort to increase energy efficiency and clean energy in Garfield County, carried out in 2016-17 through Xcel Energy's Partners in Energy program, updated GCE's energy efficiency goal. It now calls for a 20 percent increase in energy efficiency by 2030, using 2015 as the new baseline. The Energy Action Plan was developed by community stakeholders in government, education, and business, as well as other energy utilities and energy producers. The plan targets new areas of focus for

energy efficiency gains in the county, including the natural gas industry, marijuana growing facilities, farms and ranches, and church congregations, as well as building on existing programs that reach out to households, schools, businesses, and governments.[13]

Countywide Petroleum Independence Program

Garfield Clean Energy and CLEER's third main focus area is petroleum independence, focusing on helping the region and other Western Slope counties use cleaner fuels and more energy efficient forms of transportation. The Ride Garfield County program encourages people to walk, ride a bicycle, or use the RFTA transit system as healthy "no car and less car" alternatives. It has engaged hundreds of people to travel thousands of miles on foot or by bicycle or bus.[14]

"Clean car" work has resulted in a "zero to 60" adoption of electric vehicles and installation of electric vehicle ("EV") charging stations in the county. Through a collaboration with the Colorado Energy Office and its Refuel Colorado Fleets program, 23 public EV charge stations were installed in Garfield County between 2013 and mid-2017. GCE played a key role in the 2017 Electric Vehicle Sales EVent, a promotional partnership effort for Garfield, Eagle, and Pitkin counties that resulted in sales of 42 vehicles and an 85-percent increase in public EV charging stations.[15]

10.2.2.3 City of Boulder

The City of Boulder has undertaken multiple efforts to reduce GHG emissions, adapt to climate change, and to build long-term resilience. One such effort is their participation as one of the first 32 cities in the Rockefeller Foundation's **100 Resilient Cities** program. The program is providing funding to hire 100 chief resilience officers worldwide, and to support cities in the development and implementation of holistic resilience strategies.

Boulder finalized and adopted their Resilience Strategy in 2016, one of the first to be completed across the program. Within the Strategy, the City seeks to build on its 40-plus year legacy of open-space preservation and climate action in order to reduce vulnerability to shocks and stresses. Within the discussion of its resilience challenge, the City highlights the reality of an unpredictable future where climate change can magnify the impacts of shocks such as wildfires and floods, as well as underlying social and economic stresses.

The strategy identifies three "frontiers" through which actions are identified and prioritized: Connect and Prepare, Partner and Innovate, and Transform and Integrate.[16] Within those three frontiers, the City identifies specific strategies to make resilience more accessible to citizens, to prioritize city investments that promote community resilience, to make data more accessible to all citizens and stakeholders, and to further foster climate change readiness.[17]

10.2.3 NATIONAL AND REGIONAL COORDINATION AND COLLABORATION

The impacts of climate change do not stop at jurisdictional boundaries. Rather, communities throughout Colorado will share in the impacts and consequences of climate change. There are several examples of regional climate action taking place in Colorado. Launched in May of 2017, the Compact of Colorado Communities (Compact)[18] was established to advance city and county efforts to address climate change, enhance resilience to extreme events, and to develop clean energy solutions. The Compact helps its members to institutionalize critical climate change and clean energy competencies into decision-making, provides important technical support for their efforts, and facilitates knowledge exchange among peers. The 26 city and county members have passed resolutions requiring annual training for elected officials, city managers and senior staff, and also includes a requirement that each member establish an appropriately aggressive goal by 2019 to either deploy a clean energy or energy efficiency initiative, announce a greenhouse gas reduction goal, or establish a climate preparedness plan. The Compact is the only regional network of local governments in the country to focus specifically on capacity building.

In 2014, local governments from around Colorado, the Colorado Municipal League and the Colorado Association of Ski Towns, launched the Colorado Local Resilience Project. Comprising 78 project participants from 30 local governments and six other related local organizations,[19] the Rocky Mountain Climate Organization on behalf of the Colorado Climate Network, 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.[20]

In June of 2016, a group of 15 communities throughout Colorado came together to form Colorado Communities for Climate Action. The coalition advocates for policies to protect Colorado's climate

for current and future generations.[21] The group adopted a policy agenda that addresses both legislative- and executive-branch priorities at the state and federal level.[22]

There are numerous additional organizations that are available as partners and resources to communities and to regions. These organizations can bring technical planning and scientific expertise, support with identifying resources, and help in developing and implementing climate resilience actions.

These organizations include:

Figure 10-2

Organizations

National	State, Regional, and Non-Governmental
100 Resilient Cities	American Planning Association Colorado Chapter
350.org	Change and Health
American Planning Association	Colorado Climate Network
Association of Climate Change Officers	Colorado Counties, Incorporated
Climate Action Network	Colorado Municipal League
ICLEI:Local Governments for Sustainability	Colorado Natural Heritage Program
National Center for Atmospheric Research	Compact of Colorado Communities
National Renewable Energy Laboratory	Conservation Colorado
Natural Resources Defense Council	North Central Climate Sciences Center
Nature Conservancy	Rocky Mountain Climate Organization
Sierra Club	University of Colorado Consortium on Climate
	Western Resource Advocates

10.2.4 UNIVERSITIES

Colorado is home to world-renowned universities that are advancing climate change research through numerous programs and initiatives. These universities can provide critical expertise and scientific support to communities seeking to address climate change. The **Western Water Assessment**, based at the University of Colorado-Boulder and funded by **NOAA's Regional Integrated Sciences and Assessments Program**, carries out research in the Rocky Mountain West region to provide decision makers with information to address water resource vulnerabilities to climate change. In 2014, the Western Water Assessment partnered with the Colorado Water Conservation Board to release the **Climate Change in Colorado** report, which synthesized climate science for managing Colorado's water resources.[23] Programs such as the University of Colorado-Boulder's **Learn More about Climate Initiative** provide opportunities for community members and policy and decision makers to collaborate with, and learn from, scientific experts to create an informed dialog on climate change issues and take action. In addition, Colorado State University's **Colorado Climate Center** provides data and tools from its climate monitoring and research efforts, and its **Center for the New Energy Economy** provides technical assistance for the development of clean energy solutions that will minimize climate impacts like greenhouse gas emissions. Finally, the **University of Colorado Consortium on Climate Change and Health** is a collaborative group from multiple campuses that study the impacts of climate change on community health. They are developing community partnerships throughout Colorado.

10.2.5 FEDERAL AGENCIES

Agencies across the federal government provide ongoing support to the State of Colorado, local governments, businesses, and individuals to address the impacts of disasters, to address community development needs, and to enhance long-term resilience. For example, six federal departments support the state's resilience leadership team, the Colorado Resiliency Working Group.[24] The Federal Emergency Management Agency supports the development of hazard mitigation plans and projects, and it has been working closely with state agencies to develop ways to address resiliency and asset management. The U.S. Department of Housing and Urban Development supports the development of affordable housing that incorporates energy efficiency and weatherization. The U.S. Departments of Agriculture and Interior help communities and the agricultural and natural resources sectors to mitigate and to recover from the effects of droughts, fires, and floods, as well as to manage forests, grasslands, and soil health. Additional federal agencies support social, environmental, economic, and infrastructure related resilience priorities. The State will continue to work closely with our federal partners to increase Colorado's ability to respond to the impacts of a changing climate.

10.2.6 PRIVATE SECTOR

Throughout the U.S., businesses large and small have implemented actions to address the impacts of climate change. Some businesses develop and deploy new technologies that can reduce GHG emissions. Others provide technical expertise to understand the potential impacts of climate change, and to design and deploy solutions to build resilience. 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 and enhancing community adaptability, but they also make good business sense.

10.2.6.1 Colorado's Brewing Industry

Colorado's brewing industry is not only one of the biggest and most robust brewing industries in the country,[25] it is a leader in putting in place actions that mitigate and adapt to the effects of climate change. In 2015, a handful of Colorado's locally owned and operated breweries signed the Climate Declaration, committing to a number of actions to monitor and reduce their environmental impact.[26] One brewery who signed on to the declaration is Fort Collins-based Odell Brewing Company, Colorado's third largest craft brewery. The Odell Brewing Company powers 95 percent of its operations through wind generators and the other 5 percent through solar panels. The company also recaptures steam to use for heat in its brewing process.[27] MillerCoors, with its largest brewery located in Golden, has identified its own environmental sustainability strategy, which includes a goal to reduce its per-barrel carbon footprint by 25 percent before 2020.[28]

In early 2017, the Colorado Department of Public Health and Environment ("CDPHE") started the Sustainable Breweries Assistance Initiative to provide breweries with on-site assessments to document current efficiency metrics for energy, water, air, and waste usage. The program offers pollution prevention techniques and steps for breweries to take to minimize their environmental footprint and improve their bottom line. Sustainable brewing best practices of all scales are being used across the state, including: upgrading fluorescent lights to compact fluorescent lamps or LEDs to save energy, installing low nitrogen-oxide emissions burners in boilers to reduce air pollution, and using clean-in-place methods to save water. The program also acts as a platform for industry leaders to collaborate and exchange information about innovative, impactful, and replicable practices advancing sustainability. Read more at CDPHE's **Sustainable Breweries Assistance Initiative page** for more information about the program or to read about Colorado's nine participating breweries and case studies.

10.2.6.2 District-Scale Collaboration

Colorado is taking action at a district-scale to plan, design, and implement collective strategies for urban sustainable development with the objective to achieve ambitious performance outcomes for resilience and climate protection. The **Denver 2030 District** is "an interdisciplinary public-private-nonprofit collaborative working to create a groundbreaking high performance building district in downtown Denver."[29] The District brings together property owners, managers, and developers with businesses, local governments, and community stakeholders. Through collaboration, leveraged financing, and shared resources, the District benchmarks, develops, and implements creative strategies, best practices, and verification methods for measuring progress towards a common goal: economic prosperity and environmental sustainability. Participants also have access to a "marketplace" that offers products and discounts to cover HVAC systems, high performance windows, advanced metering, LED lighting, EV chargers, and plug load management devices.

The district-wide goal is to reduce building energy use, water consumption, and transportation GHG emissions in downtown Denver—50 percent by 2030. The District's energy goal is compared to 2003 baseline data from the Department of Energy's Commercial Buildings Energy Consumption Survey.[30] The District's water goal is compared to a baseline average of Denver Water's 2010 and 2011 water data. Lastly, the baseline data for the transportation goal was developed with the Downtown Denver Partnership using the data from the 2013 commuter survey to baseline future transportation carbon reductions.[31] As of 2016, the District has made significant progress by achieving a 34 percent reduction in building energy use, and 11 percent reduction in water consumption.

Three communities in the cities of Denver, Boulder, and Fort Collins are exploring the **EcoDistrict** model to develop neighborhood, municipal campus, and district-scale solutions to achieve various urban sustainability and climate goals. Visit the **Incubator Projects + Teams** for more information about participating communities in Colorado.

COLORADO'S WATER PLAN

and Statewide Water Suppy Initiative

In 2015, the Colorado Water Conservation Board ("CWCB") released the state's first comprehensive water plan. Colorado's Water Plan set forth priorities for water use throughout the state as well as dynamic strategies needed to meet Colorado's future water needs. The 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),[32] 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.[33]

The CWCB is currently updating the Statewide Water Supply Initiative ("SWSI"), the state's analysis of water supply and demand, serving as the technical foundation for Colorado's Water Plan. This time, the SWSI analysis uses hydrologic modeling to quantify the scenario planning approach initiated in Colorado's Water Plan. The result will be a consistent and scientifically sound statewide framework for examining future water supply and demand under different scenarios. The SWSI update will also serve to provide a wealth of tools and data to help basin roundtables update local basin implementation plans by better targeting local solutions to identified gaps.

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.

10.3 STRATEGIES AND RECOMMENDATIONS

- Promote safe, resilient, and sustainable communities by providing holistic data, information, and best practices to support local decision making in areas such as addressing vulnerabilities, risk, economic stability, development patterns, housing affordability and availability, transportation, resource conservation, and avoidance of development in high-hazard areas.
- Develop a resilience and climate adaptation financing toolkit for communities to identify opportunities to implement resilience actions.
- Provide guidance for incorporating climate related risks into community planning efforts, including long-range, capital improvement, and emergency plans.
- Develop interactive analytic and data visualization tools that enable communities and regions to assess vulnerability and prioritize climate resilience actions.
- Through guidance, resources, and technical assistance, strengthen the ability of local communities to incorporate resilience and adaptation into various programs, plans, and land use policies.
- Build resilience and adaptation criteria into appropriate state grant, loan, and asset management programs and develop guidance for local governments.

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11

Moving Forward

In Colorado, climate change presents 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 a renewable energy standard ("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 by providing policies and strategies to mitigate and adapt. Those strategies and recommendations cover both long-term and short-term objectives that the state is actively working on. Some are new, while others are ongoing. We are working across agencies and with the Governor's office to prioritize actions for the greatest benefit to Colorado. We always welcome input and ideas from stakeholders. While the action items are also included in each sector chapter, they are summarized on the following pages.

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 as well as mitigation and recovery activities associated with extreme events.
- Assist local communities in building resilience through the development and implementation of regional and local resiliency plans.
- Reconnect river channels with geomorphic floodplains so that average high water and peak flows are attenuated for the benefit of flood hazard mitigation, ecosystem function, and water storage.
- 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.
- Incorporate climate change and resiliency framework into mitigation, preparedness, and recovery activities to extreme events.
- Identify and apply lessons learned to response and outreach activities to future extreme events.
- Incorporate multiple objectives into flood mitigation and response activities to ensure attention to non-consumptive activities while promoting public safety.
- Continue research on the effects of climate change to wildfires, and in turn, the effects of post-wildfire conditions on flood risk.

Public Health

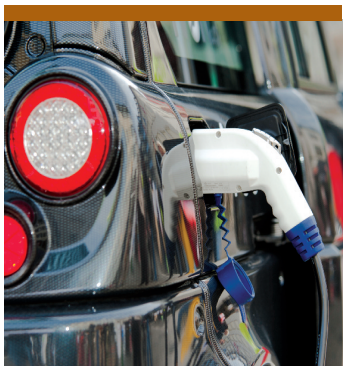
- Evaluate and adopt additional ozone control measures as needed to attain federal standards.
- Continue to monitor and evaluate air quality, including ozone and particulate matter concentrations, and issue public health advisories as appropriate.
- Continue to assess potential correlations between climate change, vector-borne diseases, heat-related illness and harmful algal blooms. Incorporate the results into public health guidance and communicate any revised risk reduction measures to local governments and the public.
- CDPHE, the Rocky Mountain poison center and local public health agencies will continue to investigate and respond to illnesses reported to be associated with toxic algae.
- CDPHE and local public health agencies will continue to investigate individual cases and outbreaks of enteric and foodborne pathogens, implementing surge capacity plans as necessary.
- Emphasize climate-related disaster preparedness in emergency response plans and exercises.

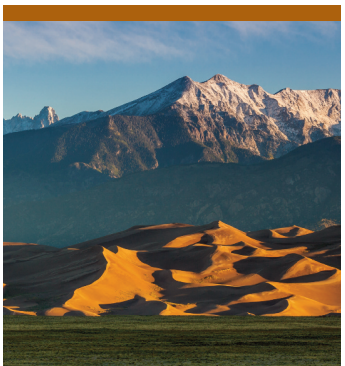
Greenhouse Gas Emissions

- Work with electric utilities or cooperatives on a voluntary basis to maximize the use of renewable resources while maintaining reliability without increasing costs.
- Implement a statewide Electric Vehicle Plan to build out key charging corridors that aligns with the environmental mitigation trust from the Volkswagen settlement.
- Propose a state GHG-reporting rule by December 30, 2018 that mirrors current federal requirements.
- Prepare annual updates to Colorado's GHG inventory as needed to track progress toward Colorado's climate goals.
- Identify opportunities to partner with local governments to support locally led climate goals and resilience solutions.
- Formalize and expand upon cross-agency efforts to provide economic development strategies and other supportive services to communities impacted by a changing energy landscape.
- Evaluate the potential costs and benefits of adopting California's motor vehicle standards.
- Consult with stakeholders and our state partners in the United States Climate Alliance to identify and implement future GHG-reduction strategies for meeting statewide emission goals.

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.
- Work with utilities to maximize the use of renewable energy, while maintaining reliability and without increasing costs to consumers.
- Assist all electric utilities in incorporating all feasible energy efficiency activities into resource planning and EPA air quality compliance plans.
- Develop baseline and future data of water and emissions from Colorado's energy sector.
- Engage with industry partners and utilities to incentivize and maximize energy efficiency gains in industrial market.
- 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.
- 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.





Transportation

- Continue to support strategies and develop new strategies to reduce GHG emissions, reduce the growth of VMT and alleviate congestion, as laid out in the Colorado Resiliency Framework and the CDOT Air Quality Action Plan.
- Support new technology, fiber optics, and planning process considerations to reduce GHG emissions by improving traffic operations for improved safety, mobility and reliability.
- 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.
- The CDOT's Division of Aeronautics will continue to work with the Federal Aviation Administration and local airport sponsors to ensure airport infrastructure, facilities and equipment minimize aviation's impact on our climate, and are adaptable to climate change effects, to the extent practicable.
- The CDOT's Division of Transit and Rail will seek to improve statewide transit connectivity by sponsoring and providing grants for regional and interregional bus services. The Division will monitor this goal by tracking the number of miles of regional, interregional, and inter-city passenger service. Increased transit opportunities can reduce single-occupant vehicle travel and reduce GHG emissions.
- The CDOT's Division of Transit and Rail will continue to support local transit agencies by providing grants to rural and small urban transit providers for operational costs and bus purchases. The Division will track ridership in these areas with the goal that transit ridership will increase by 1.5 percent every year. Increased transit opportunities can reduce single-occupant vehicle travel and reduce GHG emissions.
- 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.
- Encourage local, state, and federal entities to assess climate-related risks to transportation systems and take action to improve their resilience.
- The CDOT will continue the development of a process to assess hazards, manage asset inventories, identify areas of high risk, utilize those findings in the design and planning of projects, and establishment of maintenance needs.
- Ensure a robust emergency management program to deal with the immediate consequences of transportation disruption.
- Improve communication, data sharing, and collaboration between local, state, and federal entities related to climate change mitigation and adaptation programs and activities for transportation.
- 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 low 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.

Tourism

- Partner with federal, regional and local agencies and entities 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 preparedness and post disaster strategies.

Ecosystems

- 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.
- Maintain current data in the Colorado Wildfire Risk Assessment Portal, so that homeowners and others can accurately assess the level of risk associated with their communities, and to best inform insurance companies, emergency personnel, and local governments.
- Encourage forest management on private, state and other lands to help capture and store carbon, reduce wildfire and insect/disease risk, improve wildlife habitat, and achieve other forest management objectives. Recommended management actions may include emphasizing tree diversity, reducing woody fuel loads, helping forests regenerate after fire and other disturbance, and landscape-scale forest restoration projects.
- Promote the utilization of Colorado wood products to improve markets that enable forest management actions.
- Implement conservation targets and management actions in the updated State Wildlife Action Plan approved by the U.S. Fish and Wildlife Service.
- 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 evaluate how future water-supply projections will impact aquatic habitat.
- Develop strategies to reduce impacts of climate change in aquatic systems through stream-habitat improvement and connectivity

Partnerships

- Promote safe, resilient, and sustainable communities by providing holistic data, information, and best practices to support local decision making in areas such as addressing vulnerabilities, risk, economic stability, development patterns, housing affordability and availability, transportation, resource conservation, and avoidance of development in high-hazard areas.
- Develop a resilience and climate adaptation financing toolkit for communities to identify opportunities to implement resilience actions.
- Provide guidance for incorporating climate related risks into community planning efforts, including long-range, capital improvement, and emergency plans.
- Develop interactive analytic and data visualization tools that enable communities and regions to assess vulnerability and prioritize climate resilience actions.
- Through guidance, resources, and technical assistance, strengthen the ability of local communities to incorporate resilience and adaptation into various programs, plans, and land use policies.
- Build resilience and adaptation criteria into appropriate state grant, loan, and asset management programs and develop guidance for local governments.

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 and meet the goals set forth by the Executive order D2017-015, 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
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

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Thank You

We would like to thank those stakeholders who provided feedback on the Climate Plan during our public comment period. All comments received were addressed and a summary spreadsheet of those comments can be found online.

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