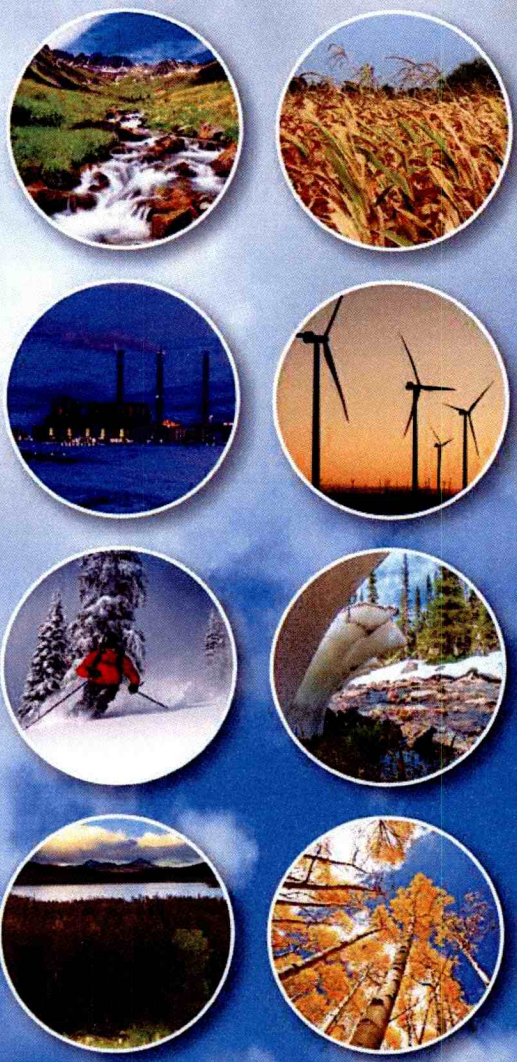

COLORADO **CLIMATE PLAN**

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 2.5°F to 5°F 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://www.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.

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

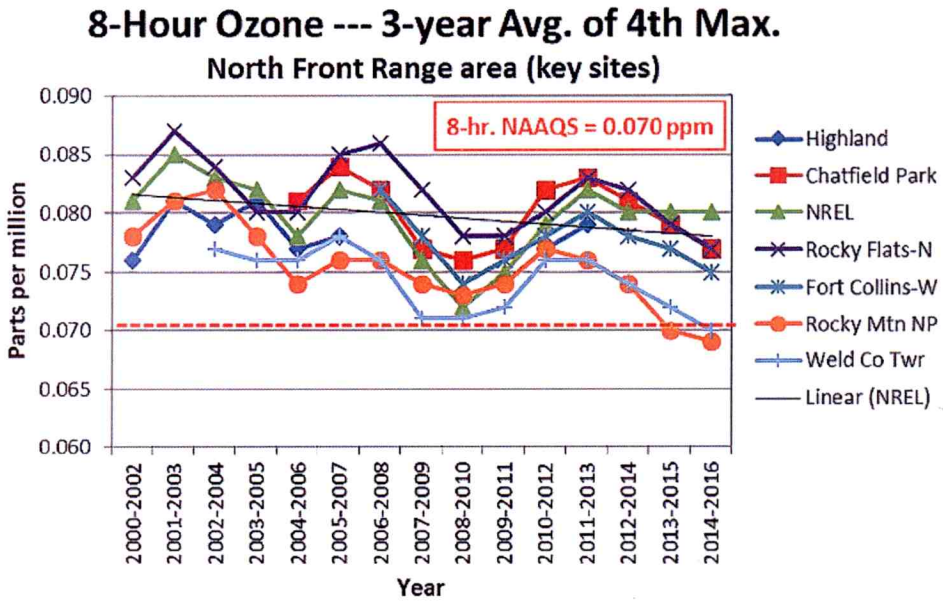
3.1.1 OZONE

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.[7] 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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[4] U.S. Environmental Protection Agency, *Endangerment and Cause or Contribute Findings*, 75-76; Howard H. Chang et al., "Impact of Climate Change on Ambient Ozone Level and Mortality in Southeastern United States," *International Journal of Environmental Research and Public Health* 7 (2010): 2866-2880, https://facultas.wordpress.com/2010/07/19/impact-of-climate-change-on-ambient-ozone-level-and-mortality-in-southeastern-united-states/; USGCRP Climate and Health Assessment, *supra* note 1, 73.
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[41] Environmental Public Health Tracking Network, *supra* note 39.

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:"

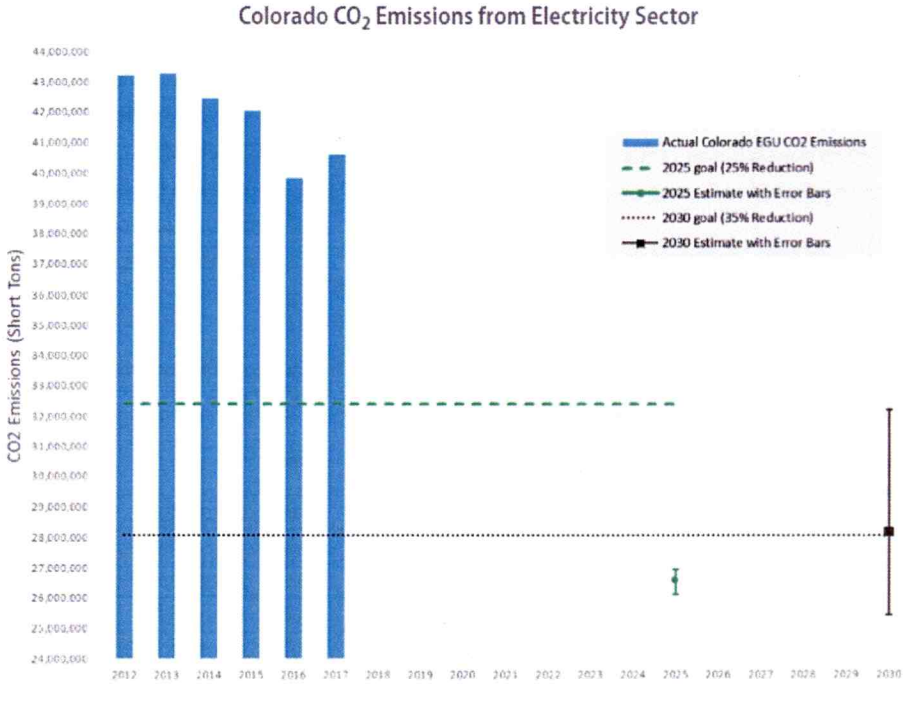
- Reduce GHG emissions statewide by more than 26 percent by 2025, as compared to 2005 levels;
- A 25 percent reduction in CO_2 emissions from the electricity sector by 2025, as compared to 2012 levels;
- A 35 percent reduction in CO_2 emissions from the electricity sector by 2030, as compared to 2012 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.

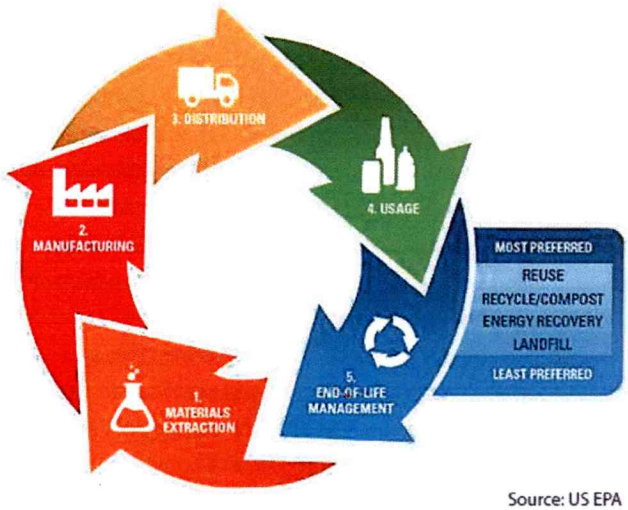
Since 2007, Colorado has tracked GHG emission reductions resulting from the amount and types of materials that are recycled and composted each year. In 2016, 1.8 million metric tons of CO_2 emissions were avoided through recycling and composting efforts in Colorado. This is equivalent to the annual emissions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

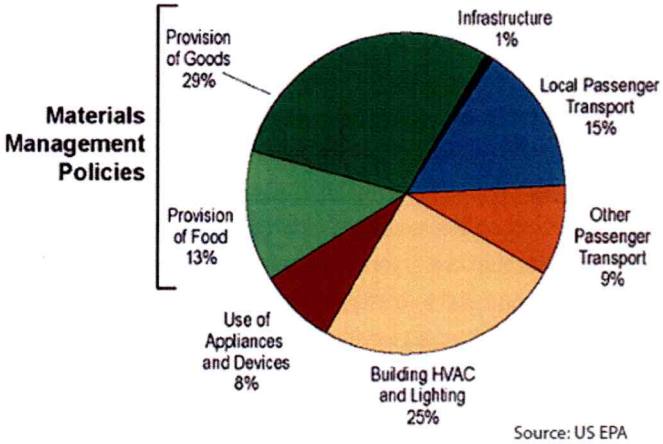
Sustainable Material Management's Life-cycle Perspective



Source: US EPA

Figure 4-3

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



Source: US EPA

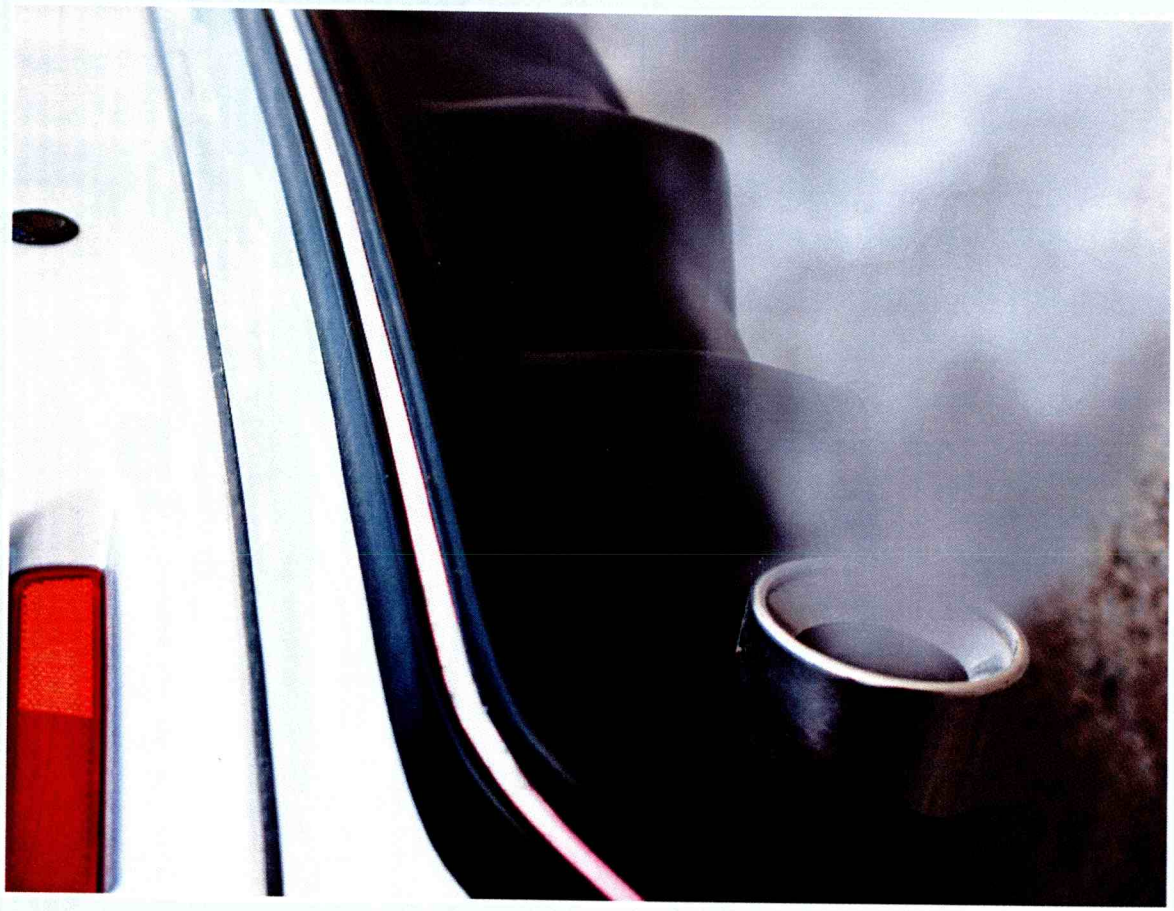
4.5 LOCAL GOVERNMENT TARGETS AND INITIATIVES

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.

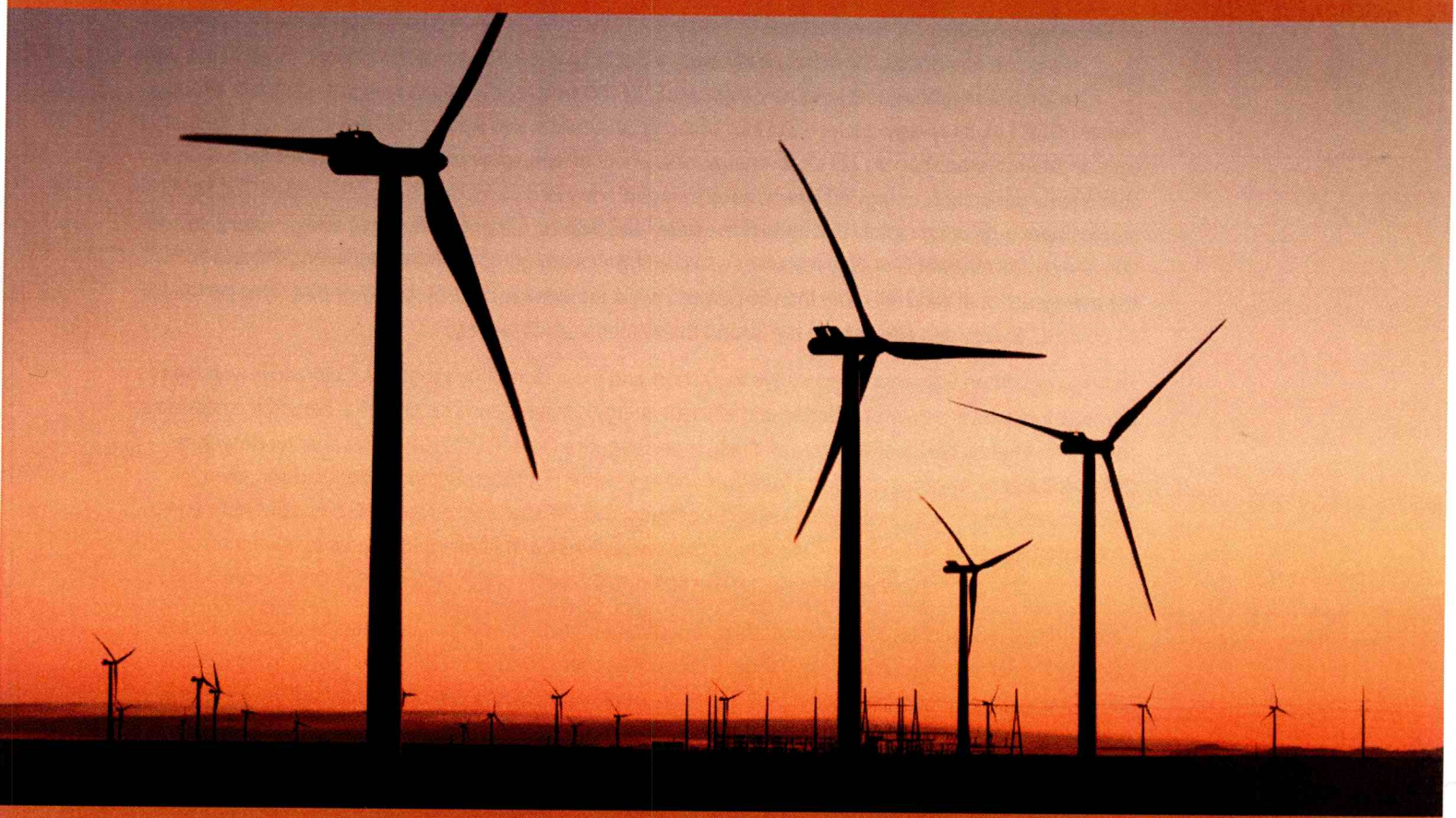
4.6 STRATEGIES AND POLICY RECOMMENDATIONS

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.

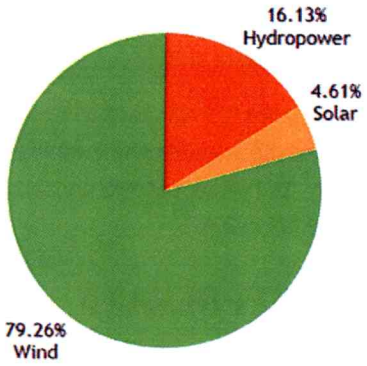
Through bipartisan legislation, responsible regulation, and groundbreaking programs, Colorado is working to promote innovative energy production and efficient energy consumption practices that benefit the economic and environmental health of the state and help meet Executive Order D 2017-015.[5] This 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

CO Renewable Generation by Source (2016)

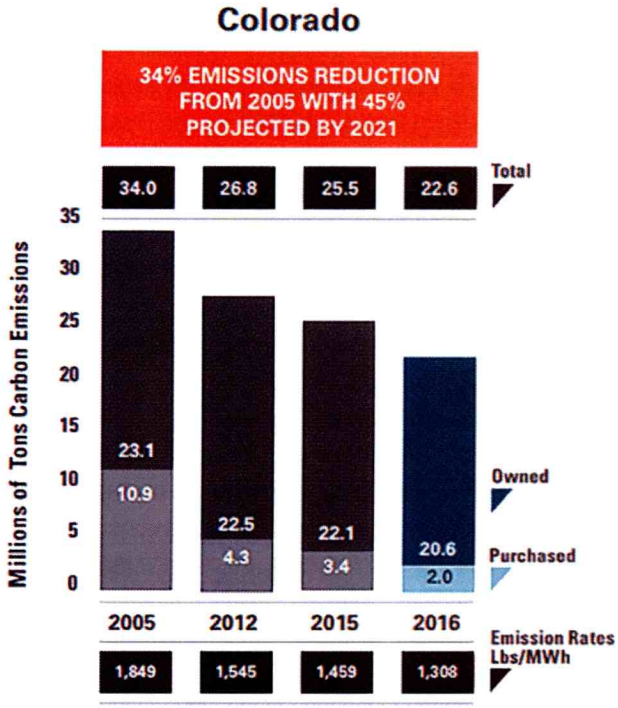


Source: Energy Information Administration

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]

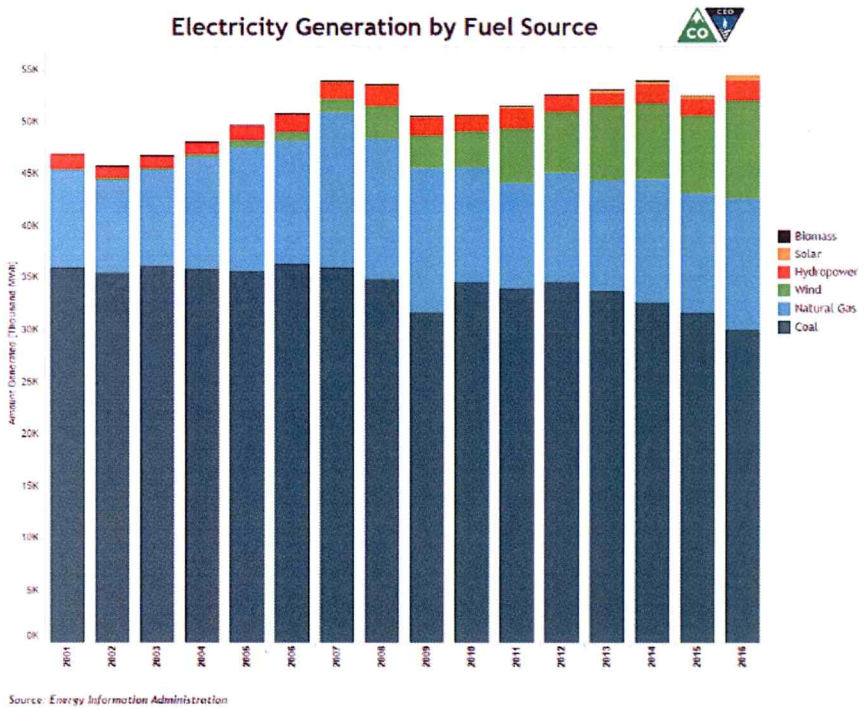
Since 2004 when Colorado's RES was passed into law by voters, Colorado has increased the amount of renewable energy in the state (Figure 5-3) from 0.54 percent of total annual electricity generated to 21.8 percent in 2016.[22]

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

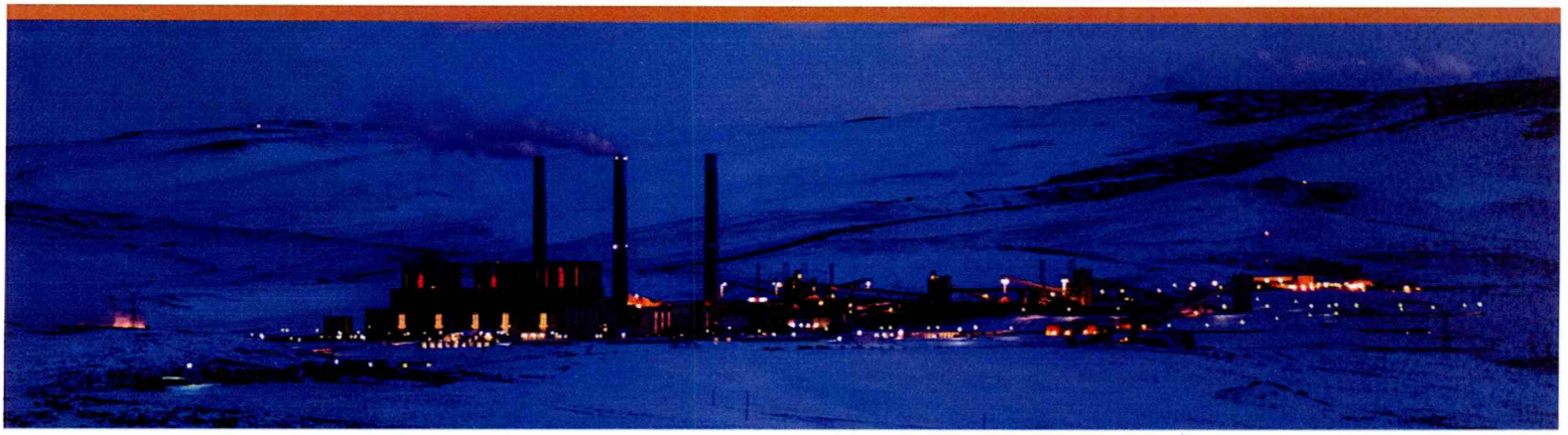
	2009	2010	2011	2012	2013	2014	2015	2016	TOTAL
Xcel Energy									
Energy Savings (MWh)	219,611	252,014	311,643	400,676	384,230	391,615	405,703	410,499	**2,775,991**
Demand Savings (MW)	59.8	67.4	75.7	90.6	81.0	81.0	82.9	88.5	**627**
Black Hills Energy									
Energy Savings (MWh)		4,554	17,296	18,561	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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[11] "State Solar Policy, Colorado Solar," Solar Energy Industries Association, accessed January 18, 2018, https://www.seia.org/state-solar-policy/colorado-solar.
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[13] Ibid.
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[31] U.S. Energy Information Administration, Electricity Data Browser, accessed September 2017, https://www.eia.gov/electricity/data/browser/.
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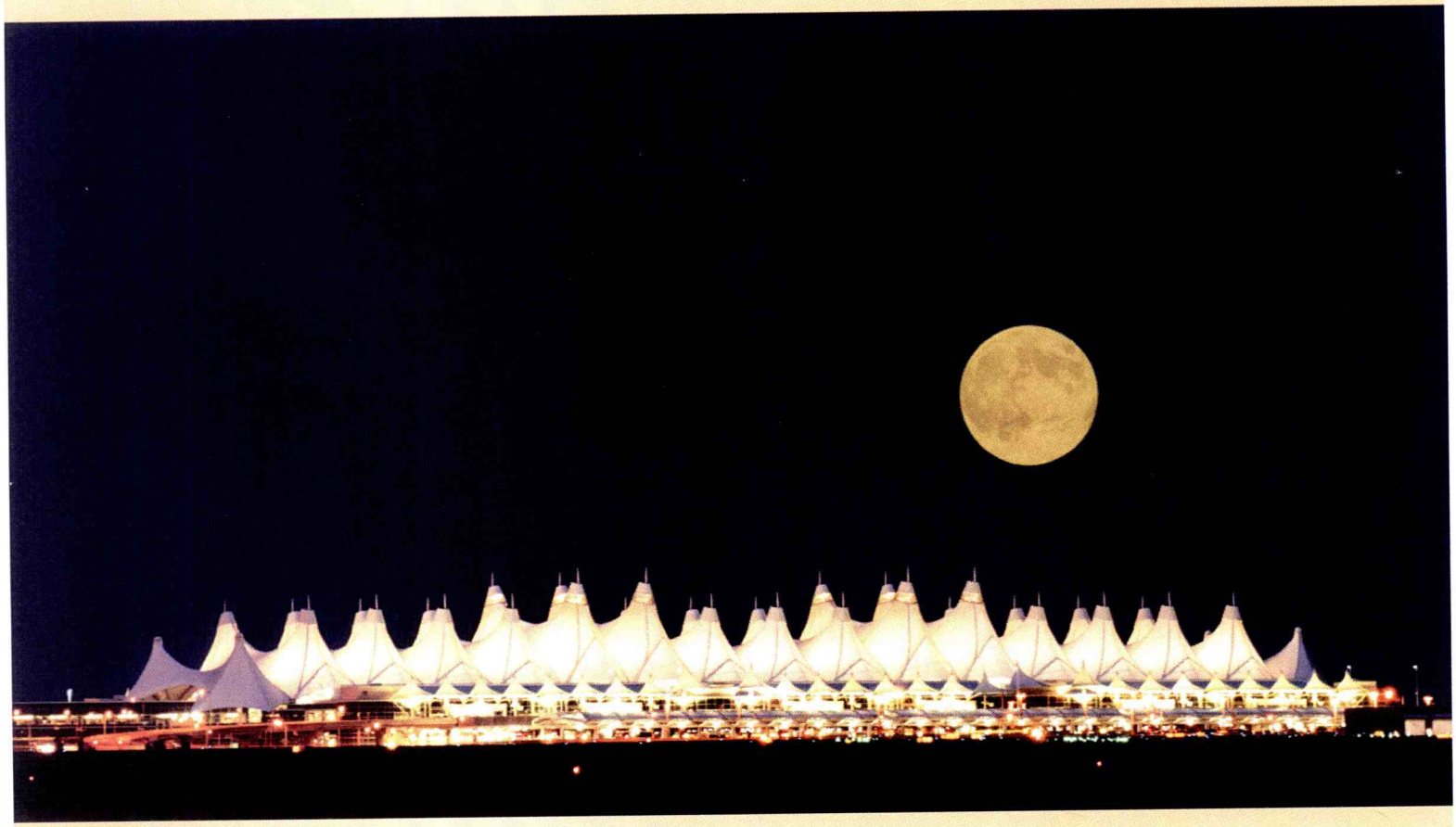


6

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:

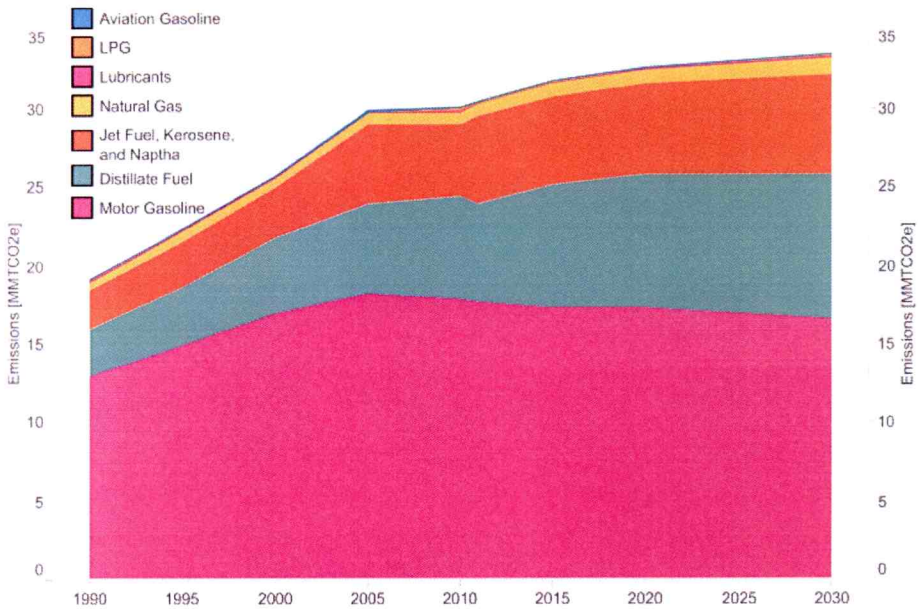
1. The sensitivity of road, rail, and airport infrastructure to the physical effects of extreme heat and heavy precipitation; and,
2. The sensitivity of travel behavior and safety to impaired visibility and traction from wildfires and precipitation events.[2]

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.

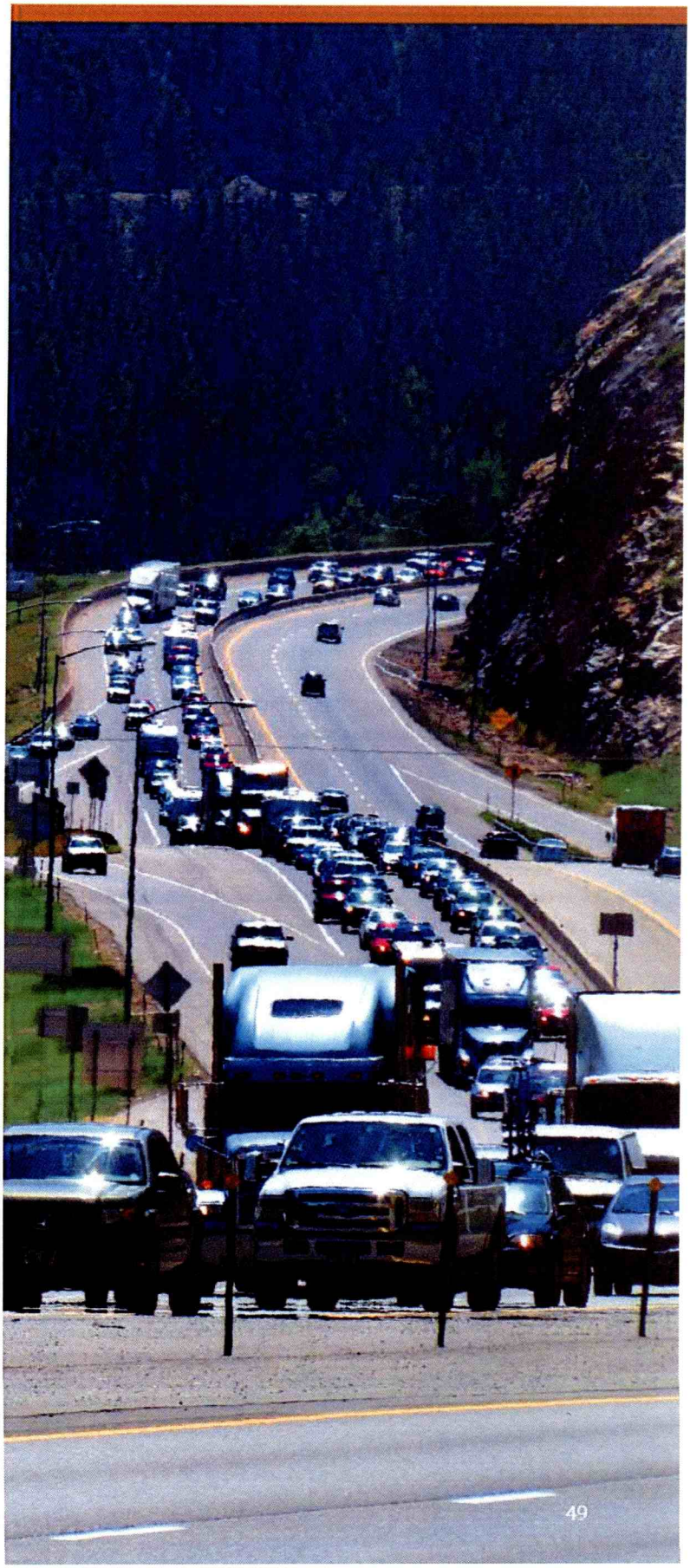
Increased peak streamflow could affect scour rates and influence the size requirement for bridges and culverts.

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]