

COLORADO

ASSESSING THE COSTS OF CLIMATE CHANGE

CLIMATE TRENDS IN COLORADO

During the last 50 years, Colorado has experienced rising temperatures, increased precipitation, and altered surface water flow as a result of climate change. The state on the whole has warmed faster than the U.S. average, with more dramatic temperature increases seen at higher altitudes. Lower altitudes, including the state's eastern plains, also are seeing higher temperatures.^{1,2,3} The average annual temperature at Fort Collins, located at 5,000 feet, has increased by 4.1° F, while the temperature in the Arkansas River Valley—located at a much lower elevation—has increased by only 0.5° F.^{4, 5} As climate change continues during the next 100 years, Colorado is likely to see higher temperatures and more precipitation in some regions, while water resources are likely to become less secure.^{6,7} At the highest elevations, winter and summer temperatures may increase by 5° F to 6° F, while spring and fall temperatures could increase by 3° F to 4° F.

OVERVIEW

In the coming decades, a changing climate could impact Colorado's economy. The most recent climate modeling predicts a warmer and drier environment for much of Colorado. These changes could be more pronounced if global emissions of greenhouse gases are not reduced. Tourism, forestry, water resources and human health may be affected in a variety of ways and could result in more than \$1 billion in losses. Since state economies are directly linked to the economies of neighboring states and regions, policymakers may wish to consider both state and regional policies.

Seasonal temperature changes and overall increased precipitation, less of which is falling as snow, have led to less snow pack and earlier spring thaw on average for the Rocky Mountains.^{8,9,10} Precipitation in the state's higher altitudes increased by 5 percent to 20 percent during last century, but the eastern plains have seen slightly lower precipitation levels.^{11,12}

During the next century, winter precipitation could increase by 20 percent to 70 percent, with high altitudes receiving the largest boost.¹³ This could alter the seasonal flow patterns of major rivers that originate in the Rocky Mountains, intensifying summer droughts in downstream areas.^{14,15} The arid weather and longer growing seasons caused by warmer weather are expected to increase the risk of drought and forest fires.

ECONOMIC IMPACTS

Tourism

Colorado's tourism sector could see significant economic losses from climate change. As the nation's favored skiing and snowboarding destination—with 23 percent of the market share and an estimated \$2 billion in annual revenue—the Colorado economy thrives on national and international tourism.

If global greenhouse gas emissions continue at the current rate, the snow line—or the elevation above which snow and ice cover the ground throughout the year—could increase by as much as 1,312 feet, and the snow season could end 30 days earlier.¹⁶ A shortened ski season and less ski-able area could affect the state's ski industry. A typical ski resort must remain open for 105 days to meet the average industry profit margin of 6.5 percent to 7 percent, so the length of the season is critical. If a shortened ski season leads to a 1 percent



annual decrease in the number of tourists at Colorado ski resorts, the total economic effects would include losses of more than \$375 million and more than 4,500 jobs by 2017.

The 2006 Colorado College State of the Rockies Report Card highlights the significant losses predicted in snow pack for the state (see Table 1).

Table 1. Projected Loss in Snow Pack by 2085 With no Greenhouse Gas Reductions.

Resort	Loss in Snow Pack
Telluride	82 percent
Vail and Beaver Creek	57 percent
Winter Park	54 percent
Breckenridge and Copper Mountain	50 percent

If adequate snow pack for skiing in Colorado becomes less reliable, the ski and real estate industry could suffer. Just a 1 percent annual decrease in the amount of tourists visiting Colorado's ski resorts could produce a loss of more than \$375 million and 4,500 jobs by 2017.¹⁷ The ski industry also is linked to Colorado's \$42.17 billion (2007) insurance, real estate and leasing sector because so many tourists, vacationers and homeowners want to buy or rent homes or condos near the resorts.¹⁸ Real estate sector profits may decrease in conjunction with loss of winter recreation opportunities in Colorado.

Tourists also enjoy Colorado's national and state parks, forests and recreational areas for various outdoor activities. The state has 41 wilderness areas, 28 recreational trails, and countless acres of state and federal public land that attract campers, climbers, hikers, bikers and fishermen. In 2006, nearly 27 million tourists spent a total of \$9.15 billion in Colorado, supporting 112,000 jobs and generating \$1.8 billion in payroll revenue.^{19, 20, 21, 22} It is possible that other seasonal activities, such as whitewater rafting, hiking, and camping, may do well under a scenario of longer seasons and higher minimum temperatures.²³

Natural Resources

Natural resources play a critical role in Colorado's economic and cultural identity. Today, Colorado's natural resources sectors account for 2 percent of the state's workforce, or about 63,000 jobs, and \$2.12 (2007) billion in revenue.^{24,25} Changes in temperature and precipitation could affect forest health, biodiversity (the number of different species) and water availability.



Forests are likely the single most threatened natural resource, since foreign and native pests and diseases, as well as forest fires, tend to

thrive in a warmer climate. Warmer temperatures and longer seasons have encouraged population growth among species such as the western spruce budworm, the piñon ips beetle and the mountain pine beetle. The most severe damage has been caused by the mountain pine beetle, which benefits from longer summers and warmer winters that no longer are cold enough to kill it. The beetle killed 1.2 million acres of alpine trees in 2004 and has destroyed 1.5 million acres of lodgepole pine since 1996.^{26,27} The cost of forest thinning and management involved with cleaning up beetle-infested trees on ski resorts and other private land runs about \$100 per tree—Vail Ski Resort cut down 2,000 trees at a cost of \$200,000 in 2008.²⁸ Summit County, home to a number of popular resorts and tourist activities, estimates that it costs roughly \$2,000 per acre to thin infected trees. Beetles infected roughly 500,000 acres in 2007 alone, and full thinning of these forests would have cost \$1 billion.^{29,30}

Thinning of infected forests is critical partly because dead trees are hazardous fuel for wildfires—a worsening problem in Colorado and the entire western United States. The 2002 Hayman Fire—Colorado's largest in history—burned 138,000 acres and 133 homes; total cost to put out the fire was \$39 million.³¹ Based on more recent wildfire activity (California's fall 2007 fires), a conservative estimate for the average damage cost per acre burned is approximately \$2,500.³² Since 2000, the median acreage of private land burned by wildfires is 9,127 acres in Colorado; the median annual cost of private land damage is around \$22.8 million.³³ These devastating fires could become more common as warmer summer temperatures create drought-like conditions and as destructive forest pests create more fuel. If the median annual forest fire damage on private land increases by 2 percent each year for the next 10 years, total costs could reach nearly \$8 million per year by 2019.³⁴

Biodiversity in Colorado could be threatened as species native to Colorado's unique climate regions die out in warmer temperatures. The elevation of dense alpine forests could shift upwards by 350 feet for each degree increase.³⁵ Drought from warmer summer temperatures could inhibit close clustering of trees and affect formation of forests.³⁶

Cold-water fish such as trout, which have historically prospered in the Rocky Mountains, will suffer from an increase in water temperatures.^{37,38} Western Trout populations may decline by as much as 64 percent as a result of climate change.³⁹ Large animals such as deer and moose may benefit from warmer temperatures at high altitudes where they prefer to graze, while other animals such as bears may migrate north to colder climates.⁴⁰ A wide range of smaller scale dynamics will occur during the next century as insects and pests that typically cannot survive in cold, high-altitude areas infiltrate the region and alter the entire food web. As Colorado's ecosystems become less familiar, state revenue from fishing, hunting, and sightseeing could decrease. (Fishing and hunting contribute \$1 billion annually to the state's economy.⁴¹)

Although Colorado generally has plentiful water resources—five major western rivers originate in the state—complex water rights, warmer temperatures and population growth could more than offset its advantageous position in the coming century. An estimated 75 percent of the yearly water flow for the major rivers of the Rockies comes from spring snowmelt. Nonetheless, with the possibility of snow packs decreasing by as much as 80 percent in parts of Colorado and melting occurring earlier in the season, late summer and fall water stress could become a regular occurrence in the state.⁴² Surface water represents 85 percent of the western supply. This supply is forecast to decline due to increased evaporation caused by warmer temperatures. This may lead to an increased risk of water shortages in the coming decades, which could impose high economic costs. In 2002, when Colorado's reservoir shortage was at 48 percent of average levels, the state lost an estimated \$1 billion dollars in revenue because of the drought's effect on tourism and agriculture.⁴³

Agriculture

The value of all agricultural goods in Colorado in 2002 was \$4.5 billion. Crops accounted for about 25 percent of the total value, and livestock and poultry goods accounted for the remainder. The sector as a whole is not likely to benefit from climate change. The combination of more arid temperatures and reduced water availability on both the eastern plains and the western slope are forecast to decrease productivity for grains by 8 percent to 33 percent, although hay yields may increase.⁴⁴ These same conditions are likely to negatively affect livestock and poultry operations.

The effect of higher temperatures on dairy operations, for example, could cause industry losses of \$28 million annually, since higher temperatures could cause a decrease in milk production. If dairy production decreases by just 10 percent in Colorado due to heat stress on the animals, the dairy industry could lose an estimated \$28 million. Related sectors could then lose roughly \$30 million and 520 jobs.⁴⁵ Colorado's eastern plains, which have been prime real estate for livestock grazing in the past, may no longer be suitable if a temperature increase of 3° F to 4° F occurs; ranchers may respond by shifting grazing activity north to Wyoming and east to Nebraska.⁴⁶

Health

Health risks may increase as a result of warming summer temperatures and increased water contamination. Ground-level ozone could increase in Denver and other larger cities due to warmer summer temperatures, which can lead to an increase in asthma attacks and other respiratory disorders.⁴⁷ Temperature increases in cities and developed regions could be higher than surrounding areas, since buildings and pavements absorb and store heat. These urban heat islands can be 7° F to 10° F warmer than nearby suburbs, where more greenery dissipates heat. As summer temperatures rise during the next century, cooling

costs also could increase. Vulnerable populations such as the poor and the elderly may be disproportionately affected by the higher temperatures and increased energy costs in Denver and other cities.

Higher temperatures increase evaporation, which reduces supply of and increases demand for drinking water and irrigation. Reduced water supplies also can lead to a higher concentration of bacteria, pesticides and other unwanted contaminants, exposing the population to potentially unhealthy conditions. Moreover, warmer water and longer seasons could facilitate the growth of algae and harmful bacteria that could cause fish kills and general water contamination.

CONCLUSION

Colorado's greatest challenge is likely to be adapting to climate change along its mountain corridor, where the most significant economic and ecological impacts could occur. The state's tourism, natural resources and agriculture industries are most vulnerable, so policymakers may want to encourage more research on the localized effects of climate change and steps these industries can take to adapt. Policymakers also may wish to encourage more research on the effects that climate change poses to alpine forests and ecosystems and promote creation of management plans that take these changes into account.

Due to the growing population on Colorado's Front Range and other water-constrained areas it become more important to determine the effects of climate change on water resources and encourage prudent water management. Exploring the possible effects of climate change on water supply may encourage water management plans that can adapt to both worst- and best-case scenarios and help avoid water shortages.

MISSING INFORMATION AND DATA GAPS

Colorado is a geographically and topographically complex state with a great deal of variance between areas, resulting in many sub-climates. The variance within the state was accounted for as best as possible by avoiding generalities where they did not apply. More precise data could be gathered on Colorado's sub-climates to gain the clearest picture of how climate change could affect the state. Overall, this study is subject to the uncertainties inherent in measuring global climate change and climate change itself and attempts to reflect this to the best possible extent through use of scenarios and ranges of confidence intervals. Quantifying the economic effects of climate change deserves significantly more focus, since this paper and much of the literature on the topic primarily qualify the potential impacts.





NOTES

1. U.S. Environmental Protection Agency (U.S. EPA), *Climate Change and Colorado* (Washington, D.C.: U.S. EPA, Climate and Policy Assessment Division, 1997), www.epa.gov/globalwarmingimpacts.
2. U.S. Global Change Research Program (U.S. GCRP), *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, "Chapter 8: Potential Consequences of Climate Variability and Change for the Western United States," Eds. Joel B. Smith, Richard Richels, and Barbara Miller (Washington, D.C.: U.S. GCRP, 2000), www.usgcrp.gov/usgcrp/Library/nationalassessment/08West.pdf.
3. NOAA Satellite and Information Service. *Colorado Climate Summary* (2008), www.ncdc.noaa.gov/oa/climate/research/cag3/co.html.
4. U.S. EPA, *Climate Change and Colorado*.
5. U.S. GCRP, *Climate Change Impacts on the United State*.
6. Ibid.
7. U.S. EPA, *Climate Change and Colorado*.
8. U.S. GCRP, *Climate Change Impacts on the United State*.
9. Intergovernmental Panel on Climate Change (IPCC), Chapter 11: Regional Climate Projections; Section 11.5: North America. Working Group I: The physical science basis of Climate Change. (Cambridge: Cambridge University Press, 2007), ipcc.wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch11.pdf
10. U.S. EPA, *Climate Change and Colorado*.
11. U.S. GCRP, *Climate Change Impacts on the United State*.
12. U.S. EPA, *Climate Change and Colorado*.
13. Ibid.
14. U.S. GCRP, *Climate Change Impacts on the United State*.
15. IPCC, 2007.
16. P. Woodford, F. Quartarone, W.W. Berg, and J.C. Erickson, *Climate Change and Colorado: A Technical Assessment* (Denver, Colo.: Colorado Department of Public Health and Environment, 1998), www.cdph.state.co.us/ap/down/climatechange.pdf.
17. Colorado Office of Economic Development and International Trade, *Colorado Data Book* (Denver: COED&IT, 2006), www.state.co.us/oed/business-development/colorado-data-book.cfm.
18. U.S. GCRP, *Climate Change Impacts on the United State*.
19. The Colorado Tourist Office, *The Important Role and Mission of the Colorado Tourism Office* (Denver: CTO, 2008), www.colorado.com/data/docs/ambassador/FY08TourismBenefitsBrochure.pdf.
20. Bureau of Labor Statistics, *Consumer Price Indexes: Inflation Calculator* (Washington, D.C.: BLS, 2008), www.bls.gov/cpi/.
21. Ibid.
22. U.S. Global Change Research Program, *Climate Change Impacts on the United States*.
23. Colorado Office of Economic Development and International Trade, *Colorado Data Book*.
24. Bureau of Labor Statistics, 2008.
25. Colorado Forest Advisory Board, *Report on the Health of Colorado's Forests 2004* (Denver: CFAB, 2005), csfs.colostate.edu/library/pdfs/fhr/o4fhr.pdf.
26. Todd Hartman, "Deaths of Trees Catastrophic: Lodgepole die-off imperils recreation, supplies of water," *Rocky Mountain News*, Jan. 15, 2008, www.rockymountainnews.com/news/2008/jan/15/beetle-infestation-get-much-worse/.
27. David O. Williams, "Ski Towns Scramble to Cope With Mountain Pine Beetle Epidemic," *Colorado Confidential*, April 11, 2008, coloradoconfidential.com/showDiary.do;jsessionid=B7F01C6A14D0FB3815FC8F1E8B568FD1?diaryId=3663.
28. Ibid.
29. Timothy Hurst, "Pine Beetles Cross the Continental Divide," Jan. 22, 2008, sustainablog.org/2008/01/22/pine-beetles-cross-the-continental-divide-part-i/.
30. Colorado Forest Advisory Board, *Report on the Health of Colorado's Forests 2004*.
31. National Public Radio, "Cost of California Wildfires is More Than \$1 Billion," Oct. 24, 2007, www.npr.org/templates/story/story.php?storyId=15603441.
32. Colorado State Forest Service, *Wildfire: Historical Wildfire Statistics for Colorado* (CSFS, 2007), <http://csfs.colostate.edu/wildfire.htm>.
33. Regional Economic Studies Institute, calculations using modified IMPLAN™ economic model from the Regional Economic Studies Institute (RESI) of Towson University, 2008.
34. U.S. EPA, *Climate Change and Colorado*.
35. Ibid.
36. U.S. Global Change Research Program, *Climate Change Impacts on the United States*.
37. Woodford et al., *Climate Change and Colorado: A Technical Assessment*.
38. Jack Williams, Senior Scientist, Trout Unlimited, Testimony Before Subcommittee of Water and Power, Energy and Natural Resources Committee, U.S. Senate, June 6, 2007, www.livingrivers.org/pdfs/CongressionalTestimony/WilliamsTestimony.pdf.
39. U.S. Global Change Research Program, *Climate Change Impacts on the United States*.
40. Colorado Office of Economic Development and International Trade, *Colorado Data Book*.
41. Colorado College, *State of the Rockies Report Card* (Colorado College, 2006), www.coloradocollege.edu/StateoftheRockies/06ReportCard.html.
42. Colorado State University, "Final 2002 Drought Update: Wet Weather Brings Relief, but Drought Far From Over – State Needs to Prepare for More Years of Drought," *News and Information* (Nov. 12, 2002), www.newsinfo.colostate.edu/index.asp?page=news_item_display&news_item_id=1341676038.
43. U.S. EPA, *Climate Change and Colorado*.
44. Regional Economic Studies Institute, calculations using modified IMPLAN™ economic model from the Regional Economic Studies Institute (RESI) of Towson University, 2008.
45. U.S. Global Change Research Program, *Climate Change Impacts on the United States*.
46. U.S. EPA, *Climate Change and Colorado*.

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