

Acknowledgments

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¹Left this position during the work of the Climate Action Panel.

Acronyms

AFO	animal feeding operation
AFW	Agriculture, Forestry, and Waste Management [TWG]
ANL	Argonne National Laboratory
BACT	best available control technology
BAU	business-as-usual
BMP	best management practice
BRT	bus rapid transit
C	carbon
C&T	cap-and-trade
CAFO	confined animal feeding operation
CAP	Climate Action Panel
CC	Cross Cutting Issues [TWG]
CC&S	carbon dioxide capture and sequestration
CCLT	Colorado Coalition of Land Trusts
CCS	Center for Climate Strategies
CCX	Chicago Climate Exchange
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CE	cost-effectiveness
CH ₄	methane
CHP	combined heat and power
CO ₂	carbon dioxide
CO ₂ e/MMBtu	carbon dioxide equivalents per million metric British thermal units
Colorado I&F	Colorado Inventory & Forecast
CRP	Conservation Reserve Program
CSU	Colorado State University
DEQ	Department of Environmental Quality
DG	distributed generation
DOC	degradable organic carbon
DSM	demand-side management
EF	electricity emission factor
EIA	Energy Information Administration [US DOE]
ES	Energy Supply [TWG]
FERC	Federal Energy Regulatory Commission
FTE	full-time equivalent
gal	gallon
GHG	greenhouse gas
GOCO	Great Outdoors Colorado
GUTD	gear-up, throttle-down
ha	hectare
HFC	hydrofluorocarbons
HOV	high-occupancy vehicle [lanes]
IECC	International Energy Conservation Codes
IGCC	integrated gasification combined cycle

IOUs	Investor-owned utilities
IPCC	Intergovernmental Panel on Climate Change
kW	kilowatt
LF	landfill
LFG	landfill gas
LFGTE	landfill gas-to-energy
LMOP	Landfill Methane Outreach Program
MMgal/year	million gallons per year
MMt	million metric tons
MMtCO ₂ e	million metric tons of carbon dioxide equivalent
MMtCO ₂ e/kg N	million metric tons of carbon dioxide equivalent per kilogram of nitrogen
MOU	Memorandum of Understanding
MPO	metropolitan planning organization
MSW	municipal solid waste
Mt	metric ton
MtCO ₂ /ha-year	metric tons of carbon dioxide per hectare per year
MWh	megawatt-hour
N ₂ O	nitrous oxide
NASS	National Agriculture Statistics Service
NCSU	North Carolina State University
NPS	National Park Service
NPV	net present value
NRCS	Natural Resources Conservation Service
NREL	National Renewable Energy Laboratory [US DOE]
NRI	National Resources Inventory
NSPS/EG	New Source Performance Standards/Emissions Guidelines [US EPA]
NSR	New Source Review
PAYD	pay-as-you-drive
PAYT	pay-as-you-throw
PFC	perfluorocarbons
psi	pounds per square inch
PTO-hp	power take-off horsepower
PUC	[Colorado] Public Utilities Commission
PV	photo-voltaic
PWG	Policy Work Group
R&D	research and development
RCI	Residential, Commercial, and Industrial [TWG]
REA	Rural Electric Association
RECs	renewable energy credits
RFS	renewable fuels standard
RMCO	Rocky Mountain Climate Organization
RMFU	Rocky Mountain Farmer's Union
rpm	revolutions per minute
RPS	renewable portfolio standard
SBC	system benefits charge
SERA	Skumatz Economic Research Associates, Inc

SF ₆	sulfur hexafluoride
TLU	Transportation and Land Use [TWG]
TWG	Technical Work Group
UNFCC	United Nations Framework Convention on Climate Change
US	United States
US DOE	U.S. Department of Energy
US EPA	U.S. Environmental Protection Agency
USDA	US Department of Agriculture
USFS	US Forest Service
VMT	vehicle miles traveled
WArm	Waste Reduction Model (US EPA)
WGA	Western Governors' Association
WUI	wildland–urban interface

Executive Summary

Creation of the Colorado Climate Project

The Rocky Mountain Climate Organization (RMCO) undertook the Colorado Climate Project to bring Coloradans together to reduce the state's contribution and vulnerability to climate change. The project was inspired by and patterned after similar efforts undertaken by state governments around the country. Like many of those efforts, the Colorado Climate Project was carried out in partnership with the Center for Climate Strategies (CCS), which helped design the process and provided technical analyses for and facilitation services for this project, as CCS has done for state government advisory panels in several states.

RMCO's Project Directors of the Colorado Climate Project appointed a blue-ribbon Climate Action Panel (CAP) and charged them to develop recommendations for actions that can be taken in Colorado by the state government, local governments, water providers, the private sector, and individuals to reduce the state's contribution and vulnerability to a changed climate. This report is the culmination of the work of 116 Coloradans who worked as members of and alternates to the CAP and the six Policy Work Groups (PWGs) that supported the CAP.

Greenhouse Gas Emissions Inventory and Projections

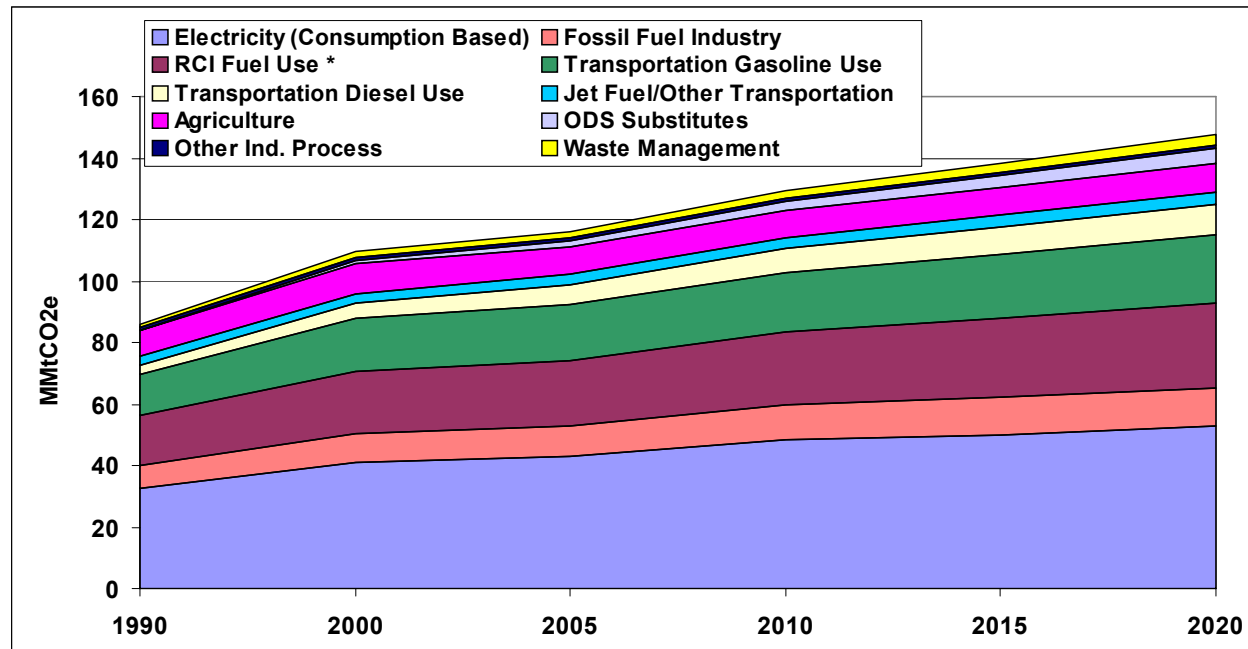
In January 2007, CCS prepared a preliminary draft greenhouse gas (GHG) emissions inventory and reference case projection for the Colorado Department of Public Health and Environment (CDPHE) that was separately provided to the CAP and its PWGs to assist them in understanding past, current, and possible future GHG emissions in Colorado, and thereby inform the policy development process. The preliminary draft *Inventory and Projections* was improved by incorporating comments provided by the CAP and PWGs. As shown in Figure ES-1, the *Inventory and Projections* revealed substantial emissions growth rates and related mitigation challenges. Colorado's gross emissions of GHGs grew by 35% between 1990 and 2005, slightly more than twice the national average of 16%. Colorado's emissions growth was driven largely by the growth of Colorado's population, as the state's emissions on a per-capita basis stayed essentially constant between 1990 and 2005. Under current law, Colorado's gross GHG emissions (not counting sequestration) are projected as rising fairly steeply to 147.5 million metric tons (MMt) of carbon dioxide equivalent (CO₂e) by 2020, or 71% over 1990 levels.

CAP Policy Recommendations

The CAP recommends 70 policy actions. Among those CAP members present and voting, sixty-one policy recommendations were approved unanimously; seven were approved by a super majority, with fewer than five votes against them; and two were approved by a simple majority. For each of 10 recommendations (four of which were among the recommendations not approved unanimously), at least one CAP member expressed qualifications but did not object to it. These expressions of qualifications, which CAP members called "yes but" votes, allowed members to express an objection or concern to some of the specific details of a policy recommendation or the supporting analysis considered by the CAP while supporting the overall concept of the policy. Explanations of both individual objections and qualifications are in the appendices to this report, in the detailed accounts of each CAP recommendation (except that the explanation for the one

objection to a water adaptation recommendation is in Chapter 8, where those recommendations are detailed).

Figure ES-1. Gross GHG emissions by sector, 1990–2020: historical and projected (consumption-based approach) business-as-usual base case



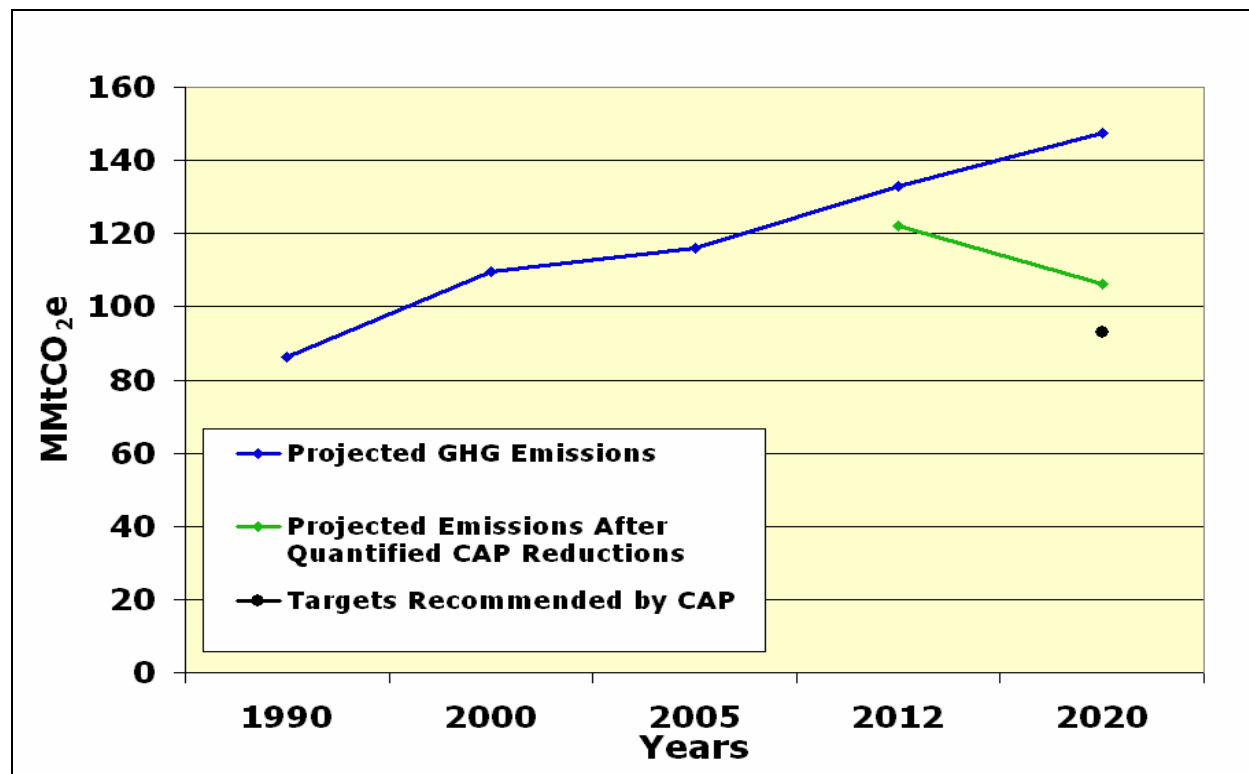
* RCI = direct fuel use in residential, commercial, and industrial sectors; ODS Substitutes = ozone depleting substances substitutes. Other Industrial Processes include process-related GHG emissions from cement, lime, and soda ash manufacturing; semiconductor manufacture; soda ash, limestone, and dolomite use; electricity transmission and distribution systems. Ozone Depleting Substance (ODS) substitutes (for hydrofluorocarbons, etc) are used in cooling and refrigeration equipment for industrial and commercial applications as well as for vehicle air conditioners.

Figure ES-2 and Table ES-1 present a summary of some of the recommendations.

Figure ES-2 presents:

- Actual (for 1990, 2000, and 2005) and projected (for 2012 and 2020) levels of Colorado’s gross GHG emissions on a consumption basis are shown by the blue line. (The consumption-based approach accounts for emissions associated with the generation of electricity in-state and imported from out-of-state to meet Colorado’s demand for electricity.)
- Projected emissions if all of the CAP’s 33 recommendations that were analyzed quantitatively with respect to its GHG reduction potential are completely implemented and the estimated reductions are fully achieved are shown by the green line. (Note that other CAP recommendations would have the effects of reducing emissions, but those reductions were not analyzed quantitatively and they are not reflected in the green line.)
- Projected emissions associated with the CAP’s recommendation that Colorado set a target to reduce its GHG emissions economy-wide in the vicinity of 20% below 2005 levels by 2020 are shown by the black dot.

Figure ES-2. Annual GHG emissions: reference case projections and CAP recommendations (consumption-basis, gross emissions)



The CAP approved 55 recommendations to reduce emissions, of which 33 were analyzed quantitatively to estimate their effects on emissions. The analyzed measures were estimated to have a cumulative effect of reducing emissions by about 41.3 MMtCO₂e in 2020, enough by themselves to achieve over three quarters of the reductions necessary to meet the 2020 goal. The 26 measures analyzed in terms of their cost-effectiveness were estimated to have a total net savings of about \$2.6 billion between now and 2020. That is because the most effective way to reduce emissions often is to improve energy efficiency, which both cuts emissions and saves money.

Table ES-1. Annual emissions: reference case projections, and impact of CAP recommendations (consumption-basis, gross emissions)

Greenhouse Gas (GHG) Emissions (MMtCO ₂ e)					
	1990	2000	2005	2012	2020
Actual/projected GHG emissions	86.1	109.6	116.1	132.8	147.5
Projected emissions compared to 2005				+14%	+27%
Total GHG reductions from 33 analyzed CAP recommendations				-10.6	-41.3
Projected emissions after above reductions				122.2	106.2
2020 target recommended by CAP					92.9
2020 target compared to actual/forecast				-20%	-30%

The CAP chose to recommend goals for emission reductions to be achieved by 2020 and 2050, mindful of scientists' conclusions that global GHG emissions have to be reduced substantially by

2050, compared to 2000 levels, in order to stabilize global temperatures, and that emission reductions in the next two to three decades will have a large impact on opportunities to achieve that kind of stabilization. Accordingly, the CAP recommends that the Governor of Colorado set goals for reducing GHG emissions in Colorado in the vicinity of a 20% reduction in GHG emissions by 2020 and an 80% reduction by 2050, both compared to 2005 levels on a gross emissions/consumption basis. The CAP believes the goals should guide actions in the state, but should not be a firm cap.

If the 2020 goal were achieved, Colorado's emissions in 2020 would be reduced 37% to 92.9 million metric tons of GHGs, compared to 147.5 MMtCO_{2e} projected under current law. The Colorado target would fall within the range of statewide emission goals already set by other western states, including Arizona (45% below projected emissions in 2020), Oregon (44%), New Mexico (33%), California (28%), and Washington (28%).

If adopted, the 33 recommendations for emission reductions that were analyzed quantitatively could achieve 75% of the 2020 goal chosen by the CAP. While the CAP's 22 other GHG mitigation recommendations were not readily quantifiable, many of them would likely achieve additional reductions. In addition, the CAP believes other reasonable measures to reduce emissions beyond those recommended by the panel are available now, and emerging technologies hold the potential to substantially reduce emissions even more.

The CAP also adopted 15 recommendations for adaptation to future climate changes. They include 14 policies that, together, outline a road map for dealing with the projected effects of climate change on the state's water supplies, which may well amount to Colorado's greatest vulnerability to climate change. Another recommendation is that the state government assess Colorado's particular vulnerabilities to climate change and develop specific adaptation plans.

Table ES-2 provides a summary by sector of the estimated cumulative impacts of implementing all of the CAP's recommendations. The table shows the estimated GHG reductions; costs or savings from each policy recommendation and, its cost-effectiveness (cost or savings per ton of reduction) upon which the cumulative impacts in Table ES-3 are based. Note that the cumulative impacts shown in Table ES-3 account for overlaps between policies by eliminating potential double counting of emission reductions and costs or cost savings.

Table ES-2. Summary by sector of estimated impacts of implementing all of the CAP recommendations

Cumulative Reductions and Costs/Savings	2012 GHG Reductions (MMtCO ₂ e)	2020 GHG Reductions (MMtCO ₂ e)	2007–2020 GHG Reductions (MMtCO ₂ e)	2007–2020 Costs (Savings) (Net Present Value Million \$)	2007–2020 Cost-Effectiveness (\$/tCO ₂ e)
	<i>From 33 recommendations analyzed for GHG reductions</i>			<i>From 26 recommendations analyzed for costs and cost savings</i>	
Residential Commercial and Industrial (RCI) Sector Total Adjusted for Overlaps	3.7 ¹	15.1 ¹	86.0 ¹	–\$153 ²	–\$2/ton ²
Energy Supply (ES) Sector Total Adjusted for Overlaps	3.0 ³	9.1 ³	58.8 ³	\$526 ⁴	\$10/ton ⁴
<i>Adjustments for Overlaps Between RCI and ES Recommendations</i>	<i>[–0.3]</i>	<i>[–2.0]</i>	<i>[–8.6]</i>	<i>[–\$10.0]</i>	
Transportation and Land Use (TLU) Sector Total Adjusted for Overlaps	2.1 ⁵	7.8 ⁵	46.7 ⁵	–\$3,185 ⁶	–\$141/ton ⁶
Agriculture, Forestry, and Waste Management (AFW) Sector Total Adjusted for Overlaps	2.2	11.5	66.0	\$252	\$4/ton
<i>Adjustments for Overlaps Between AFW and ES Recommendations</i>	<i>[–0.04]</i>	<i>[–0.21]</i>	<i>[–1.40]</i>	<i>[–\$0]</i>	<i>[–\$0/ton]</i>
Cross-Cutting (CC) Sector Total	N/A	N/A	N/A	N/A	N/A
Water Adaptation (WA) Sector Total	N/A	N/A	N/A	N/A	N/A
Totals	<i>From 33 recommendations analyzed for GHG reduction</i>			<i>From 26 recommendations analyzed for costs and cost savings</i>	
	10.7	41.3	247.5	–\$2,570	Not estimated

Notes: Negative numbers indicate cost savings. N/A = not available.

Table ES-3. Summary of CAP’s 70 policy recommendations by sector

Notes: Negative numbers indicate cost savings. The cost (savings) shown are calculated in terms of net present value in constant 2005 dollars using a 5% annual real discount rate for the period 2008 through 2020. Capital investments are represented in terms of levelized or amortized costs through 2020.

¹ Totals from all 9 RCI recommendations with estimated GHG reductions.

² Totals from only those 7 RCI recommendations with estimated costs/cost savings.

³ Totals from all 6 ES recommendations with estimated GHG reductions.

⁴ Totals from only those 5 ES recommendations with estimated costs/cost savings.

⁵ Totals from all 8 TLU recommendations with estimated GHG reductions.

⁶ Totals from only those 4 TLU recommendations with estimated costs/cost savings.

Residential, Commercial, and Industrial Policy Recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
RCI-1	Expand demand side management programs of all electric and gas utilities, ramped up to reduce energy use by 1% per year by 2013.	0.6	5.2	24	–\$853	–\$32/ton	Unanimous Consent (Several qualified approvals)
RCI-2	Revolving loans to reduce energy use in state and local government buildings.	0.2	0.5	3.7	–\$67	–\$18/ton	Super Majority (1 objection)
RCI-3	Upgrade the state's energy requirements for local building codes every 3 years, and improve enforcement of building codes.	0.3	2.7	13.0	N/A	N/A	Unanimous Consent
RCI-4 (total)	Targets and programs for beyond-code reductions in energy use in new government, residential, and commercial buildings.	1.0	2.4	20.4	\$1,550	\$76/ton	Unanimous Consent
	<i>Government subtotal:</i>	0.4	0.6	6.0	\$348	\$58/ton	
	<i>Commercial subtotal:</i>	0.5	1.4	11.2	\$1,219	\$109/ton	
	<i>Residential subtotal:</i>	0.2	0.4	3.2	–\$17	–\$5/ton	
RCI-5	Inverted electricity block rates for all residential and commercial consumers to fund utility energy efficiency programs.	1.6	6.7	38.2	–\$1,135	–\$30/ton	Majority (7 objections)
RCI-6	Low interest loans to fund energy efficiency retrofits for commercial and industrial buildings.	0.5	1.8	11.7	–\$334	–\$28/ton	Unanimous Consent (2 qualified approvals)
RCI-7	Electricity smart metering with time-of-use rates and in-home or in-office displays for all residential, commercial, and industrial consumers.	2.0	2.6	25.4	–\$844	–\$33/ton	Unanimous Consent
RCI-8	Tax credits for renewable energy systems in new and existing residential, commercial, and industrial buildings.	N/A	N/A	N/A	N/A	N/A	Unanimous Consent
RCI-9	Promote commercial and industrial combined heat and power (CHP) systems.	0.3	1.4	8.3	–\$25	–\$3/ton	Unanimous Consent
RCI-10	Statewide program for voluntary GHG reductions by businesses.	0.6	1.0	4.5	N/A	N/A	Unanimous Consent
RCI-11	Inverted electricity block rates for all residential and commercial consumers, recovering only cost of service.	N/A	N/A	N/A	N/A	N/A	Unanimous Consent
	RCI Sector GHG reduction total of 9 analyzed policies after adjusting for overlaps among policies	3.7	15	86	N/A	N/A	
	RCI Sector cost-effectiveness total of 7 analyzed policies with cost analysis after adjusting for overlaps among policies				–\$153	–\$2/ton	

Energy Supply Policy Recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
ES-1	Tax credits and incentives to finance renewable energy generation facilities.	Benefits are quantified in policy ES-2					Unanimous Consent
ES-2	Increase renewable portfolio standards to 30% for investor-owned electric utilities and 15% for municipal and co-op utilities, with no more than 85% of renewable energy from centralized wind power.	1.9	4.9	34	\$524	\$16/ton	Super Majority (3 objections) (1 qualified approval)
ES-3	Consider adoption of Xcel's clean energy portfolio standard on a state, regional, or national basis.	Non-specific policy was not quantified					Majority (9 objections)
ES-4	Require all electric utilities to plan cooperatively for electricity transmission infrastructure investments that support renewable resources.	Non-quantitative policy proposal analyzed					Unanimous Consent
ES-5	Consider applying a price to CO ₂ emissions (such as cap and trade or tax) on a state, regional, or national basis.	Non-specific policy not quantified					Super Majority (1 objection) (1 qualified approval)
ES-6	Assess a public benefit charge on all electric utility bills to fund renewable energy programs.	Policy not quantified					Super Majority (3 objections) (1 qualified approval)
ES-7	Adopt structural changes to facilitate large businesses and universities to invest in combined heat and power (CHP) and distributed generation (DG) systems.	0.4	1.1	7.3	\$110	\$15/ton	Unanimous Consent
ES-8	Work with neighboring states to form a regional CO ₂ transportation and sequestration collaborative.	Non-quantitative proposal not quantified					Unanimous Consent
ES-9	Low interest loans to Colorado companies and universities for research and development of carbon emissions reduction technology, funded at \$100M/yr through surcharge on all electricity bills.	R&D benefits not quantified					Unanimous Consent
ES-10	Evaluate and, if appropriate, seek funding for advanced fossil fuel generation with carbon capture demonstration project.	Non-specific policy not quantified					Unanimous Consent
ES-11	Statewide mapping and development of small hydro-power, geothermal, and biomass renewable power sources.	0.0	0.8	3.1	\$123	\$40/ton	Unanimous Consent
ES-12	Review costs and emission reduction potential of nuclear power.	Non-specific policy not quantified					Unanimous Consent
ES-13	Adopt policies to promote a 2% increase in efficiency of existing power generators by 2020.	Costs not quantified—savings ca. 1 MMtCO ₂ /yr by 2020					Unanimous Consent
ES-14	Reduce GHG emissions from oil and gas operations 35% by 2020.	0.8	2.6	16	\$12	\$0.8/ton	Unanimous Consent
ES-15	Establish a CO ₂ emissions performance standard of no more than 1,100 lbsCO ₂ /MWh for new non-peaking power plants and those older than 60 years.	0.5	2.3	13	–\$14	–\$1/ton	Super Majority (5 objections)

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
	Energy Supply Sector totals of 6 analyzed policies (including ES-13) after adjusting for overlaps among policies	3	9	59	N/A	N/A	
	Energy Supply Sector totals of 5 policies with cost estimates (not including ES-13) after adjusting for overlaps				\$526	\$10/ton	

Transportation and Land Use Policy Recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
TLU-1	Reduce light-duty vehicle miles traveled 2% by 2020 by promoting “smart growth” land use planning and development. Require that GHG emissions be considered in long-range transportation plans by 2010.	0.08	0.47	2.43	Less than \$0	Less than \$0/ton	Unanimous Consent
TLU-2	Incentives for the purchase of low-GHG vehicles. [An alternative if the TLU-6 clean car standards are not implemented.]	Quantified as part of TLU-6					Unanimous Consent
TLU-3	Reduce light-duty vehicle miles traveled 6% by 2020 by improving transit service quality and funding expansion of transit infrastructure.	0.17	0.97	5.09	N/A	N/A	Unanimous Consent
TLU-4	Reduce heavy-duty vehicle idling.	0.07	0.11	0.91	–\$123	–\$134/ton	Unanimous Consent
TLU-5	Adopt a low carbon fuels standard that will reduce carbon intensity of passenger vehicle fuels by 10% by 2020.	0.38	2.21	16.1	N/A	N/A	Unanimous Consent
TLU-6	Adopt California GHG emission standards for cars and trucks.	0.70	3.40	18.8	–\$1,880	–\$100/ton	Unanimous Consent
TLU-7	Expand transit use marketing and employer-sponsored transit fare programs.	Quantified as part of TLU–3					Unanimous Consent
TLU-8	Move toward basing motor vehicle insurance on the distances vehicles are driven.	0.32	0.94	7.19	Less than \$0	Less than \$0/ton	Unanimous Consent
TLU-9	Local parking management programs to encourage alternative travel choices and transit-oriented development.	0.03	0.03	0.34	–\$37	–\$110	Unanimous Consent
TLU-10	Require employers with more than 100 employees to offer commuter benefits programs.	0.42	0.45	4.77	–\$1,145	–\$240/ton	Unanimous Consent
TLU-11	Incorporate vehicle maintenance, operation, and transportation choice GHG reduction information in driver training and education.	Not quantified					Unanimous Consent
	TLU Sector GHG reduction total of 8 analyzed policies after adjusting for overlaps among policies	2.14	7.84	46.7	N/A	N/A	
	TLU Sector cost-effectiveness total of 4 analyzed policies with cost estimates after adjusting for overlaps among policies				–\$3,185	–\$141/ton	

Agriculture, Forestry, and Waste Management Policy Recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
AFW-1	Achieve no-till operation of half of croplands by 2020 and increase nitrogen fertilizer efficiency by 20%.	0.57	0.78	7.7	–\$57	–\$7/ton	Unanimous Consent
AFW-2	Implement methane capture and energy recovery on manure management projects on 80% of animal feeding operations by 2020.	0.01	0.32	1.8	\$66	\$36/ton	Unanimous Consent (1 qualified approval)
AFW-3	Reduce on-farm petro-diesel use 20% by 2020, and reduce electricity use from fossil fuels 40% through energy efficiency and on-site renewable sources generation.	0.14	0.64	3.8	–\$150	–\$40/ton	Unanimous Consent
AFW-4	Incentives for the production of biodiesel fuel from oilseed crops, waste vegetable oil, or other sources to offset 40% of fossil diesel fuel use by 2020.	0.02	0.22	1.1	\$13	\$12/ton	Unanimous Consent (3 qualified approvals)
AFW-5	Increase in-state ethanol production, using GHG-superior feedstocks and production methods, to 400 million gallons per year above BAU by 2020.	0.39	3.1	15	\$58	\$3/ton	Unanimous Consent (3 qualified approvals)
AFW-6	Preserve forest lands (line 1) and grasslands (line 2) to reduce the rate of conversion to developed uses by 25% by 2020.	0.10 0.05	0.24 0.14	1.7 1.0	\$44 \$31	\$26/ton \$32/ton	Unanimous Consent
AFW-7	Increase the use of biomass from forest health and fire risk treatment for energy production, using 20% of harvested wood by 2020.	0.08	0.20	1.4	–\$104	–\$75/ton	Unanimous Consent
AFW-8	Divert 75% of wastes from landfills by 2020 through source reduction, enhanced recycling, and composting programs.	0.48	4.6	24	\$311	\$13/ton	Unanimous Consent
AFW-9	Control or capture landfill methane to achieve 50% reduction from BAU by 2020.	0.33	1.2	7.5	–\$0.1	–\$0.02/ton	Unanimous Consent
AFW-10	Plant 3.4 million new trees statewide by 2020 through expanded urban forestry programs.	0.03	0.08	0.59	\$40	\$79/ton	Unanimous Consent (1 qualified approval)
	AFW Sector Total of Analyzed Policies After Adjusting for Overlaps	2.2	11.5	66	\$252	\$4 /ton	

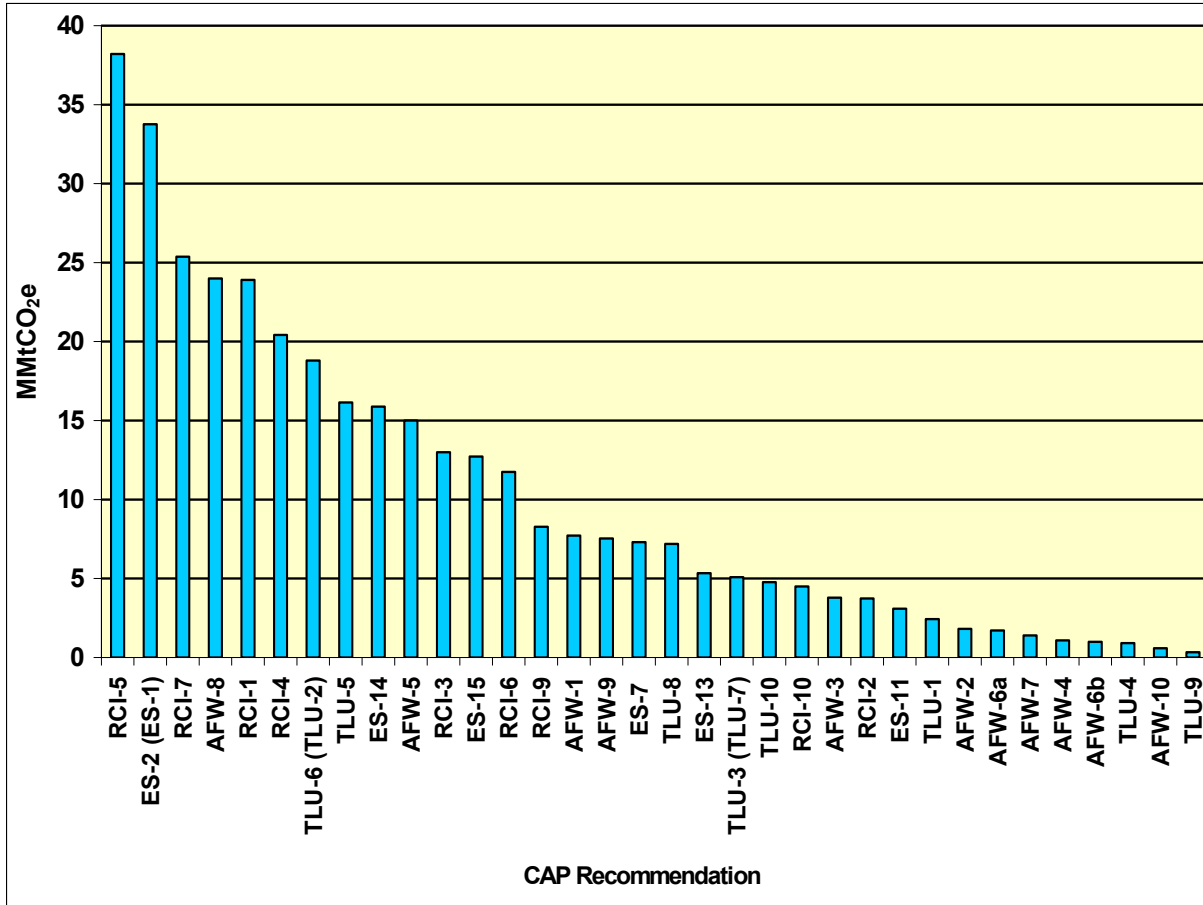
Cross-Cutting Issues Policy Recommendations

	Policy Recommendation	Analysis	Climate Action Panel Action
CC-1	Periodically update GHG inventories and forecasts.	<i>Not Quantified</i>	Unanimous Consent
CC-2	State development of annual GHG reporting protocols for all sources, including mandatory reporting for significant sources.	<i>Not Quantified</i>	Unanimous Consent
CC-3	State development of capacity to participate in the national <i>Climate Registry</i> to measure, track, and record emissions reductions.	<i>Not Quantified</i>	Unanimous Consent
CC-4	The governor should set statewide GHG reduction goals and targets to achieve in the vicinity of a 20% reduction by 2020 and 80% by 2050, both compared to 2005 levels.	<i>Not Quantified</i>	Super Majority (1 objection) (5 qualified approvals)
CC-5	Set state and local government reduction targets for their own GHG emissions; the state target should be at least an amount consistent with CC-4 levels.	<i>Not Quantified</i>	Unanimous Consent
CC-6	Promote adoption of comprehensive local government climate action plans.	<i>Not Quantified</i>	Unanimous Consent
CC-7	State and local government public education and outreach efforts to support GHG reduction programs, policies, and goals.	<i>Not Quantified</i>	Unanimous Consent
CC-8	A public-private partnership to seek funding for GHG reduction measures and development of a new energy economy in Colorado.	<i>Not Quantified</i>	Unanimous Consent
CC-9	State government assessment of vulnerabilities to climate change and development of adaptation plans.	<i>Not Quantified</i>	Unanimous Consent

Water Adaptation Policy Recommendations

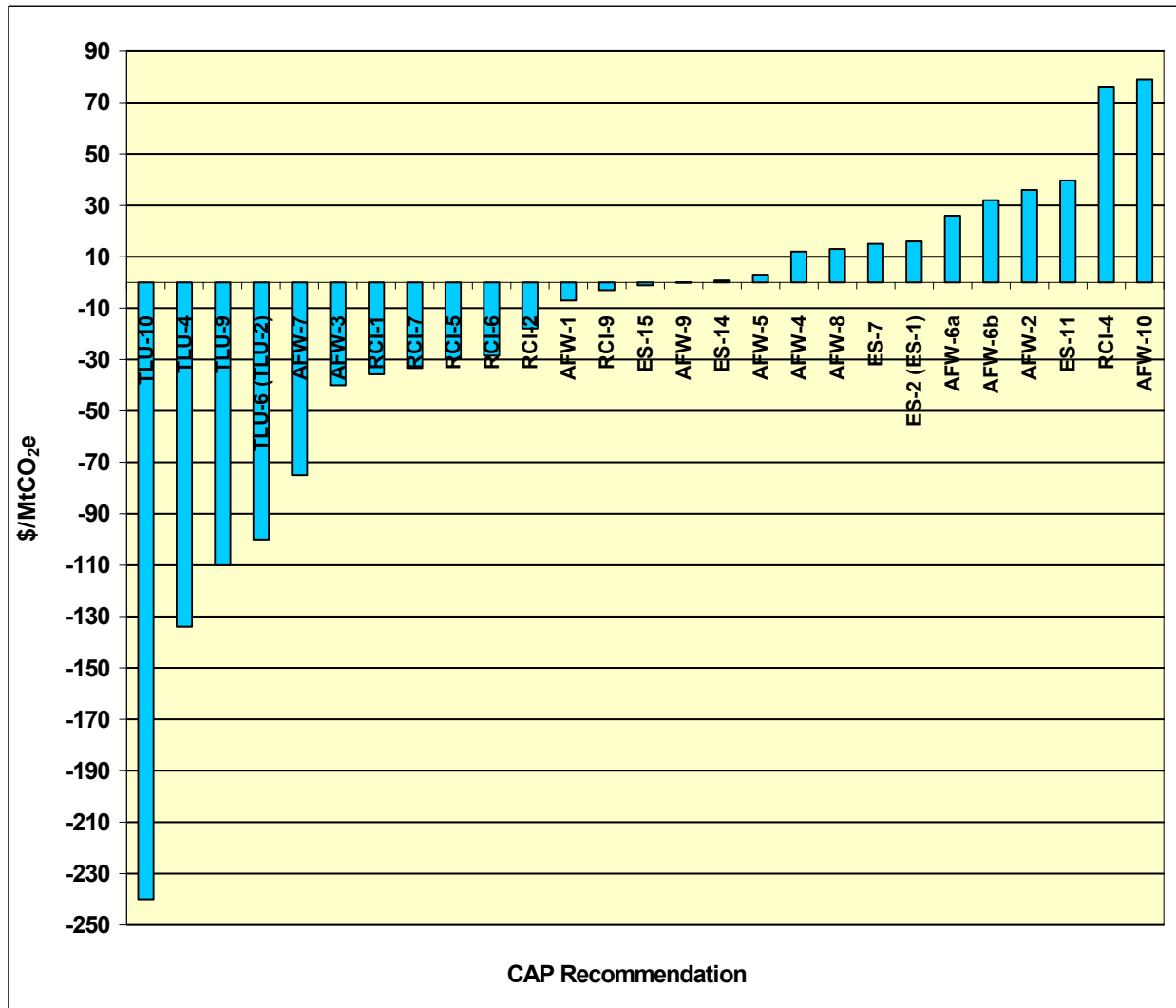
	Policy Recommendation	Analysis	Climate Action Panel Action
WA-1	Public officials exercise leadership in addressing climate change effects on water supplies.	<i>Not Quantified</i>	Unanimous Consent
WA-2	Water managers consider climate change in all water supply decisions.	<i>Not Quantified</i>	Unanimous Consent
WA-3	Climate change effects considered in the new Colorado Water Conservation Board study of Colorado River water availability.	<i>Not Quantified</i>	Unanimous Consent
WA-4	State government develop mechanisms for compact calls for each major river basin.	<i>Not Quantified</i>	Unanimous Consent
WA-5	Assessment of knowledge about climate change effects on Colorado's water resources. An assessment of data and data systems for understanding climate change.	<i>Not Quantified</i>	Unanimous Consent
WA-6	Cooperative development of information on climate change effects in each major river basin.	<i>Not Quantified</i>	Unanimous Consent
WA-7	Municipal water providers evaluate water conservation savings, best demand management practices, and the best uses of conserved water in their systems.	<i>Not Quantified</i>	Unanimous Consent
WA-8	Minimize effects of water-rights transfers on agricultural economies.	<i>Not Quantified</i>	Unanimous Consent
WA-9	Consider relationships between energy and water use.	<i>Not Quantified</i>	Unanimous Consent
WA-10	Information exchanges on effects of climate change on water resources.	<i>Not Quantified</i>	Unanimous Consent
WA-11	State government consider ways to reduce climate change effects on water-related recreation and tourism.	<i>Not Quantified</i>	Unanimous Consent
WA-12	State government consider ways to reduce climate change effects on the environment.	<i>Not Quantified</i>	Unanimous Consent
WA-13	Reduce use of groundwater for irrigation until recharges match discharges.	<i>Not Quantified</i>	Unanimous Consent
WA-14	Establish new Colorado Water Institute.	<i>Not Quantified</i>	Super Majority (1 objection)

Figure ES-3. CAP policy recommendations ranked by cumulative GHG reductions, 2007–2020



Note: Emission reductions for TLU-2 are included in the reductions for TLU-6, reductions for TLU-7 are included in the reductions for TLU-3, and reductions for ES-1 are included in the reductions for ES-2. For the purpose of counting the number of options for which emission reductions were quantified, each of the following are counted as one option: TLU-6 and TLU-2, TLU-3 and TLU-7, ES-2 and ES-1, and AFW-6a and AFW-6b.

Figure ES-4. CAP policy recommendations ranked by dollars per metric ton



Note: Negative values represent net cost savings and positive values represent net costs associated with the policy recommendation. Cost savings for TLU-2 are included in the cost savings for TLU-6, and costs for ES-1 are included with the costs for ES-2. For the purpose of counting the number of options for which costs or cost savings were quantified, each of the following are counted as one option: TLU-6 and TLU-2, ES-2 and ES-1, and AFW-6a and AFW-6b.

Chapter 1

Background and Overview

The Creation of the Colorado Climate Project

In June 2005, the Rocky Mountain Climate Organization (RMCO, www.rockymountainclimate.org) decided to undertake the Colorado Climate Project, to bring Coloradans together to reduce the state's contribution and vulnerability to climate change.¹ The project was inspired by and patterned after similar efforts undertaken by state governments around the country, including in particular efforts then underway in two western states, Arizona and New Mexico, soon followed by a third such effort in Montana. One key difference between the Colorado Climate Project and these state-government efforts is that this is the first effort of this kind undertaken by a non-profit organization. One key similarity between the Colorado Climate Project and many of the state-government efforts around the country is that this project was carried out as a partnership between RMCO and the Center for Climate Strategies (CCS, www.climatestrategies.us), which helped design the process and provided technical analyses for and facilitation services for this project, as CCS has done for state government advisory panels in several states. This is the first time that CCS has partnered with a nonprofit organization in helping to carry out a process to develop recommendations for state climate action.

Over the next year, RMCO entered into the partnership with CCS, obtained the agreement of key public and private officials to serve as Project Directors of the Colorado Climate Project, and secured initial funding for it. In August 2006, the Project Directors held a news conference to publicly launch the project. They announced that they would appoint a blue-ribbon Climate Action Panel (CAP) to develop recommendations on actions that could be taken by the state government, local governments, water providers, the private sector, and others to address climate change and its effects in Colorado. The Project Directors then appointed the members of the CAP and gave them the following mission:

The Climate Action Panel is charged to develop recommendations for actions that can be taken in Colorado to reduce the state's contribution and vulnerability to a changed climate. Those recommendations are to include goals that can be adopted consistent with the goal of an efficient, robust Colorado economy for statewide reductions in the amount of greenhouse gases (GHGs) emitted, actions that can be taken that would achieve those goals, and actions that can be taken to prepare for and reduce the possible adverse impacts of climate change in Colorado. The recommendations may also include actions that can be taken by Colorado as part of international, national or regional efforts that would reduce Colorado's contribution and vulnerability to climate change. The panel shall, to the extent reasonably possible with the best information available, consider the feasibility and costs or cost savings of possible goals and actions and develop goals and actions that may achieve additional benefits, including protecting and improving Colorado's economy, public health, and natural resources and avoid adverse economic or environmental impacts. In considering how goals

¹ RMCO is a three-year old nonprofit organization whose partners now include 16 local governments, Denver Water, 17 businesses, and 11 nonprofit organizations.

and actions may affect Colorado's economy, the panel shall take into account the effects of both action and inaction.

It is up to the members of the panel to determine which actions it recommends, with no recommendations predetermined. The panel shall work in an open process that allows for Coloradans not on the panel to observe the work of the panel and to submit in an appropriate manner comments for consideration by the members of the panel. A report with the recommendations of the panel is expected before the end of calendar year 2007.

This report is the culmination of the work of 116 Coloradans who worked as members of and alternates to the CAP and the six Policy Work Groups (PWGs) that supported the CAP.

Colorado GHG Emissions Inventory and Reference Case Projections

In January 2007, CCS prepared a preliminary draft greenhouse gas (GHG) emissions inventory and reference case projection for the Colorado Department of Public Health and Environment (CDPHE) through an effort of the Western Regional Air Partnership.² The draft report was separately provided to the CAP and its PWGs to assist them in understanding past, current, and possible future GHG emissions in Colorado, and thereby inform the policy development process. The CAP and the PWGs provided comments for improving the reference case projections. Subsequently, the inventory and reference case projection estimates (hereafter referred to as the *Inventory and Projections*) were revised to incorporate revisions approved by the CAP.³

The *Inventory and Projections* included detailed coverage of all economic sectors and GHGs in Colorado, including future emissions trends and assessment issues related to energy, economic, and population growth. The assessment included estimates of total statewide “gross emissions” (leaving aside carbon sequestration⁴) and “net emissions” (in which reductions due to sequestration are subtracted from gross emissions) on a production basis for all sources and a consumption basis for the electricity sector (see prior discussion under “Analysis of Policy Recommendations” in this chapter for an explanation of the production versus consumption approach). Further discussion of the issues involved in developing the inventory and reference case projections is summarized in Chapter 2 (Inventory and Projections of GHG Emissions) and discussed in detailed in the final report for the *Inventory and Projections*.

The *Inventory and Projections* revealed substantial emissions growth rates and related emission reduction (also called mitigation) challenges. Colorado's gross emissions of GHGs grew by 35%

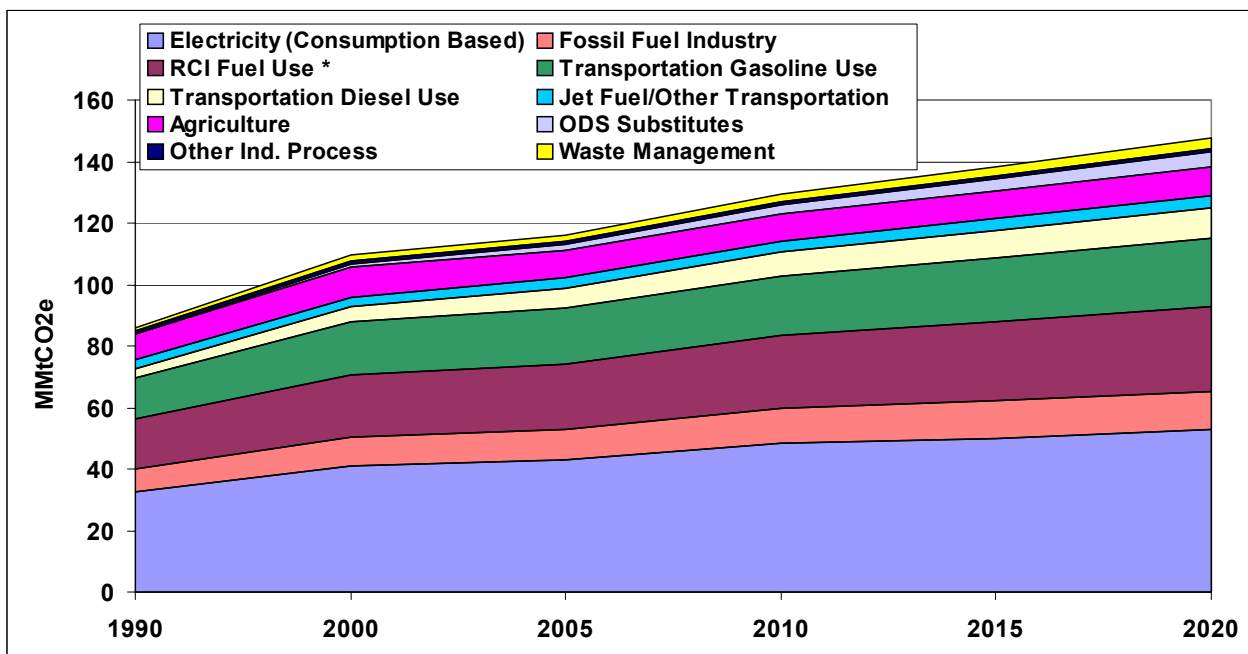
² *Draft Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020*, prepared by the Center for Climate Strategies for the Colorado Department of Public Health and Environment (CDPHE) through an effort of the Western Regional Air Partnership, January 2007.

³ *Final Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020*, prepared by the Center for Climate Strategies for the Climate Action Panel of the Colorado Climate Project, October 2007.

⁴ Sequestration refers to the storing of carbon in mines, brine strata, oceans, plants and soil. As trees and other plants grow they remove CO₂, the principal GHG, from the atmosphere transforming the carbon (C) through photosynthesis into cellulose, starch and sugars, thus sequestering it in their structures and roots. The oxygen (O₂) is released back into the atmosphere. Colorado's forests and agricultural lands are capable of sequestering much CO₂, as described in Chapter 6 (Agriculture, Forestry and Waste Management).

between 1990 and 2005, slightly more than twice the national average of 16%. Colorado's emissions growth was driven largely by the growth of Colorado's population, as the state's emissions on a per-capita basis stayed essentially constant between 1990 and 2005. Figure 1-1 shows the reference projections for Colorado's gross GHG emissions (not counting sequestration) as rising fairly steeply to 147.5 million metric tons (MMt) of carbon dioxide equivalent (CO₂e) by 2020, or 71% over 1990 levels. Figure 1-1 also provides the sectoral breakdown of forecasted GHG emissions. Using a net emissions basis – by accounting for sequestration in Colorado's forests and soil – would decrease the gross estimates by about 27 MMtCO₂e per year. On a net emissions/consumption-based basis, Colorado's GHG emissions are projected to grow by about 103% over 1990 levels (about 121 MMtCO₂e in 2020).

Figure 1-1. Gross GHG Emissions by Sector, 1990-2020: Historical and Projected (Consumption-based Approach) Business as Usual Base Case



* RCI = direct fuel use in residential, commercial, and industrial sectors; ODS Substitutes = ozone depleting substances substitutes. Other Industrial Processes include process-related GHG emissions from cement, lime, and soda ash manufacturing; semiconductor manufacture; soda ash, limestone, and dolomite use; electricity transmission and distribution systems; and, Ozone Depleting Substitutes (ODS) substitutes (for hydrofluorocarbons) used in cooling and refrigeration equipment for industrial and commercial applications as well as for vehicle air conditioners.

The inventory and projection of Colorado's GHG emissions provided several critical findings, including:

- As is common in many states, the electricity and transportation sectors are the two sectors with the largest emissions, and are expected to continue to grow faster than other sectors.
- Consumption of electricity is growing faster in Colorado than its population. In addition, there appears to be a trend toward an increasing reliance on natural gas and imported electricity. Vehicle-miles traveled (VMT) are also projected to grow faster than the state's

population. Freight traffic (resulting in increased diesel consumption) and increasing use of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) as substitutes for ozone-depleting substances (ODS) in refrigeration, air conditioning, and other applications is also increasing more rapidly than population.

While Colorado's emissions estimated growth rate (71% from 1990 to 2020 on a gross emissions/consumption basis) presents challenges, it also provides major opportunities. It is usually easier and cheaper to reduce emissions resulting from future population growth, by making initial choices on the technologies and infrastructure to support that growth, than it is to reduce emissions from an existing population, which can require revising technologies and infrastructure that are already in use. The CAP's recommendations document the opportunities for the state to reduce its GHG emissions while continuing its strong economic growth by being more energy efficient, using more renewable energy sources, and increasing the use of cleaner transportation modes, technologies, and fuels. The inventory and reference case projections are discussed in more detail in Chapter 2 of this report and the entire study appears in the final report for the *Inventory and Projections*.⁵

CAP Policy Recommendations

The CAP recommends 70 policy actions. Among those CAP members present and voting, sixty-one actions were approved unanimously; seven were approved by a super majority, with fewer than five votes against them; and two were approved by a simple majority. For each of 10 recommendations (four of which were among the recommendations not approved unanimously), at least one CAP member expressed qualifications but did not object to it. These expressions of qualifications, which CAP members called "yes but" votes, allowed members to express an objection or concern to some of the specific details of a policy recommendation or the supporting analysis considered by the CAP while supporting the overall concept of the policy. Explanations of both individual objections and qualifications are in the appendices to this report, in the detailed accounts of CAP recommendation (except that the explanation for the one objection to a water adaptation recommendation is in Chapter 8, where those recommendations are detailed).

Figure 1-2 below presents a summary of some of the recommendations. Table 1-1 provides the numeric estimates underlying Figure 1-2. In Figure 1-2:

- Actual (for 1990, 2000, and 2005) and projected (for 2012 and 2020) levels of Colorado's gross GHG emissions on a consumption basis are shown by the blue line. (The consumption-based approach accounts for emissions associated with the generation of electricity in-state and imported from out-of-state to meet Colorado's demand for electricity.)
- Projected emissions if all of the CAP's 33 recommendations that were analyzed quantitatively with respect to its GHG reduction potential are completely implemented and the estimated reductions are fully achieved are shown by the green line. (Note that other CAP

⁵ *Final Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020*, prepared by the Center for Climate Strategies for the Climate Action Panel of the Colorado Climate Project, October 2007, <http://www.coloradoclimate.org/>.

recommendations would have the effects of reducing emissions, but those reductions were not analyzed quantitatively and they are not reflected in the green line.)

- Projected emissions associated with the CAP’s recommendation that Colorado set a target to reduce its GHG emissions economy-wide in the vicinity of 20% below 2005 levels by 2020 are shown by the black dot.

Figure 1-2. Annual GHG Emissions: Reference Case Projections and CAP Recommendations (Consumption-Basis, Gross Emissions)

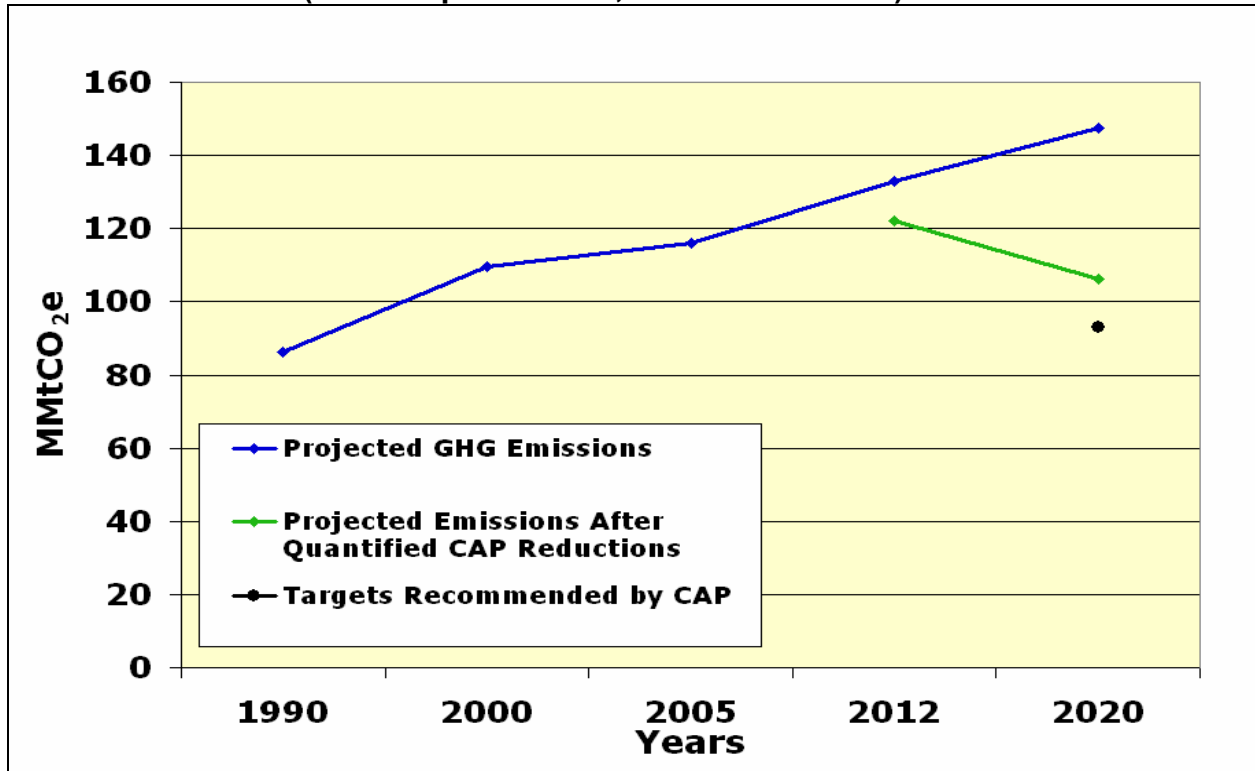


Table 1-1. Annual Emissions: Reference Case Projections, and Impact of CAP Recommendations (Consumption-Basis, Gross Emissions)

Greenhouse Gas (GHG) Emissions (millions metric tons of CO ₂ equivalent)					
	1990	2000	2005	2012	2020
Actual/projected GHG emissions	86.1	109.6	116.1	132.8	147.5
Projected emissions compared to 2005				+14%	+27%
Total GHG reductions from 33 analyzed CAP recommendations				-10.6	-41.3
Projected emissions after above reductions				122.2	106.2
2020 target recommended by CAP					92.9
2020 target compared to actual/forecast			-20%	-30%	-37%

The CAP approved 55 recommendations to reduce emissions, of which 33 were analyzed quantitatively to estimate their effects on emissions. The analyzed measures were estimated to have a cumulative effect of reducing emissions by about 41.3 MMtCO₂e in 2020, enough by themselves to achieve over three quarters of the reductions necessary to meet the 2020 goal. The 26 measures analyzed in terms of their cost effectiveness were estimated to have a total net savings of about \$2.6 billion between now and 2020. That is because the most effective way to reduce emissions often is to improve energy efficiency, which both cuts emissions and saves money.

The statewide goals and targets recommendation (CC-4) is an over-arching CAP recommendation. The Cross-Cutting (CC) PWG waited until the last stages of the project to develop the recommendation, which it proposed to the CAP and which the CAP approved, in order to be able to consider the GHG reduction policies that emerged from the other PWGs. Once the emissions reductions potentials and cost-effectiveness of the policies were quantified by the other groups, the CC PWG and in turn the CAP were able to gain a perspective on the scope of the overall reductions that are realistically attainable by 2020.

The CAP chose to recommend goals for emission reductions to be achieved by 2020 and 2050, mindful of scientists' conclusions that global GHG emissions have to be reduced substantially by 2050, compared to 2000 levels, in order to stabilize global temperatures, and that emission reductions in the next two to three decades will have a large impact on opportunities to achieve that kind of stabilization. Accordingly, the CAP recommends that the Governor of Colorado set goals for reducing GHG emissions in Colorado in the vicinity of a 20% reduction in GHG emissions by 2020 and an 80% reduction by 2050, both compared to 2005 levels on a gross emissions/consumption basis. The CAP believes the goals should guide actions in the state, but should not be a firm cap.

If the 2020 goal were achieved, Colorado's emissions in 2020 would be reduced 37% to 92.9 million metric tons of GHGs, compared to 147.5 MMtCO₂e projected under current law. The Colorado target would fall within the range of statewide emission goals already set by other western states, including Arizona (45% below projected emissions in 2020), Oregon (44%), New Mexico (33%), California (28%), and Washington (28%). Table 1-2 shows how the goals recommended by the CAP compare with the goals set by other states across the country.

If adopted, the 33 recommendations for emission reductions that were analyzed quantitatively could achieve 75 percent of the 2020 goal chosen by the CAP. While the CAP's 22 other GHG mitigation recommendations were not readily quantifiable, many of them would likely achieve additional reductions. In addition, the CAP believes other reasonable measures to reduce emissions beyond those recommended by the panel are available now, and emerging technologies hold the potential to substantially reduce emissions even more.

It should be noted that the CAP recommended that statewide goals be established to reduce gross emissions on a consumption basis to be consistent with the levels and framework of goals set by other states, including those in the West, that are implementing GHG reduction strategies. Since Colorado is a net importer of electricity, goals established on a consumption-based accounting approach provides Colorado with the opportunity to reach beyond its borders to reduce

Table 1-2. US State, Canadian Province, and Regional GHG Reduction Goals and Timelines

State, Province, or Region	GHG Reduction Goals and Timelines
Arizona	2000 level by 2020; 50% below 2000 level by 2040; WCI goal
British Columbia	See WCI goal
California	2000 level by 2010; 1990 level by 2020; 80% below 1990 level by 2050; WCI goal
Colorado - CAP Recommendations	20% below 2005 level by 2020; 80% below 2005 level by 2050
Connecticut	1990 level by 2010; 10% below 1990 level by 2020; 75% below 1990 level by 2050
Florida	2000 level by 2017; 1990 level by 2025; 80% below 1990 by 2050
Maine	1990 level by 2010; 10% below 1990 level by 2020; 75% below 1990 level by 2050
Manitoba	See WCI goal
Maryland	1990 level by 2020; 80% below 2006 level by 2050
Massachusetts	1990 level by 2010; 10% below 1990 level by 2020; 75% below 1990 level by 2050
Minnesota	15% below 2005 level by 2015; 30% below 2005 level by 2025; 80% below 2005 level by 2050
Montana	1990 level by 2020; 80% below 1990 level by 2050 (consumption & production basis)
NEG/ECP ⁶	1990 level by 2010; 10% below 1990 level by 2020; 75% below 1990 level by 2050
New Jersey	1990 level by 2020; 80% below 2006 level by 2050
New Mexico	2000 level by 2012; 10% below 2000 level by 2020; 75% below 2000 level by 2050; WCI goal
New York	5% below 1990 level by 2010
Ontario	6% below 1990 level by 2014
Oregon	10% below 1990 level by 2020; 75% below 1990 level by 2050; WCI goal
Rhode Island	1990 by 2010; 10% below 1990 level by 2020; 75% below 1990 level by 2050
Vermont	25% below 1990 level by 2012; 50% below 1990 level by 2028; 75% below 1990 level by 2050
Puget Sound, WA	1990 level by 2010; 10% below 1990 level by 2020; 75% below 1990 level by 2100
Rhode Island	1990 level by 2010; 10% below 1990 level by 2020; 75% below 1990 level by 2050
Vermont	25% below 1990 level by 2012; 50% below 1990 level by 2028; 75% below 1990 level by 2050
Utah	See WCI goal
Washington State	1990 level by 2020; 25% below 1990 level by 2035; 50% below 1990 level by 2050; WCI goal
WCI ⁷	15% below 2005 level by 2020 (applies to AZ, CA, NM, OR, UT, WA, British Columbia, Manitoba)

emissions associated with the generation of electricity by managing its own demand for electricity. It should be noted that Colorado could also consider establishing goals on a net emissions basis; however, as noted in Chapter 2, there are significant uncertainties associated

⁶ New England Governors/Eastern Canadian Premiers

⁷ Western Climate Initiative

with forest carbon sink estimates that should be addressed before setting goals based on a net emissions basis.⁸

In addition to the 55 policy recommendations to reduce GHG emissions, the CAP adopted 15 recommendations for adaptation to future climate changes. They include 14 policies that together outline a road map for dealing with the projected effects of climate change on the state's water supplies. This may well be Colorado's greatest vulnerability to climate change. Another recommendation is that the state government assess Colorado's particular vulnerabilities to climate change and develop specific adaptation plans.

Table 1-3 provides a summary by sector of the estimated cumulative impacts of implementing all of the CAP's recommendations. Table 1-4 shows the estimated GHG reductions, costs or savings from each policy recommendation and, its cost effectiveness (cost or savings per ton of reduction) upon which the cumulative impacts in Table 1-3 are based. Note that the cumulative impacts shown in Table 1-3 account for overlaps between policies by eliminating potential double counting of emission reductions and costs or cost savings. Chapters 3 through 7 and the Appendices provide detailed descriptions and analysis of GHG reductions, costs or cost savings, additional impacts, feasibility, etc. for each policy developed by the six PWGs for each sector.

In order for the CAP recommended policies to yield the levels of estimated emission reductions and cost savings shown in Table 1-3, the policies must be implemented in a timely, aggressive, and thorough manner. In some cases, the actions recommended by the CAP are precise, concrete steps. In other cases, the recommendations are more general, and work must be done to develop precise, concrete steps to achieve goals recommended by the CAP. In the latter case, the additional work to identify precise, concrete actions is needed before they can be implemented. While there are considerable benefits to both the environment and to consumers from implementation of the policy recommendations, careful, comprehensive, and detailed planning and implementation, as well as consistent support, of these policies will be required if these benefits are to be achieved. It should be noted that the CAP's policy recommendations complement the numerous other climate-related efforts underway in Colorado outlined at the end of this chapter, underscoring the potential co-benefits of their implementation.

⁸ The standing forest carbon sink estimates in states like Colorado with a large amount of unproductive forest area (e.g. Pinyon-Juniper forests) are highly uncertain (with potential for over-estimation of the sink). This is because these types of forest were not well represented in earlier US Forest Service surveys. Since they are now being inventoried, it is anticipated that future inventories will reduce the amount of uncertainty. See Appendix H of the separate report Final Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020, for a discussion of uncertainties associated with the estimates for this sector.

Table 1-3. Summary by Sector of Estimated Impacts of Implementing All of the CAP Recommendations

Cumulative Reductions and Costs/Savings	2012 GHG Reductions (MMtCO ₂ e)	2020 GHG Reductions (MMtCO ₂ e)	2007-2020 GHG Reductions (MMtCO ₂ e)	2007–2020 Costs (Savings) (Net Present Value Million \$)	2007-2020 Cost-Effectiveness (\$/tCO ₂ e)
	<i>From 33 recommendations analyzed for GHG reductions:</i>			<i>From 26 recommendations analyzed for costs & cost savings:</i>	
Residential Commercial and Industrial (RCI) Sector Total Adjusted for Overlaps	3.7 ⁹	15.1 ⁹	86.0 ⁹	-\$ 153 ¹⁰	-\$ 2/ton ¹⁰
Energy Supply (ES) Sector Total Adjusted for Overlaps	3.0 ¹¹	9.1 ¹¹	58.8 ¹¹	\$ 526 ¹²	\$ 10/ton ¹²
<i>Adjustments for Overlaps Between RCI and ES Recommendations</i>	<i>[-0.3]</i>	<i>[-2.0]</i>	<i>[-8.6]</i>	<i>[-\$ 10.0]</i>	
Transportation and Land Use (TLU) Sector Total Adjusted for Overlaps	2.1 ¹³	7.8 ¹³	46.7 ¹³	-\$ 3,185 ¹⁴	-\$ 141/ton ¹⁴
Agriculture, Forestry, and Waste Management (AFW) Sector Total Adjusted for Overlaps	2.2	11.5	66.0	\$ 252	\$ 4/ton
<i>Adjustments for Overlaps Between AFW and ES Recommendations</i>	<i>[-0.04]</i>	<i>[-0.21]</i>	<i>[-1.40]</i>	<i>[-\$ 0]</i>	<i>[-\$ 0/ton]</i>
Cross-Cutting (CC) Sector Total	N/A	N/A	N/A	N/A	N/A
Water Adaptation (WA) Sector Total	N/A	N/A	N/A	N/A	N/A
TOTALS	<i>From 33 recommendations analyzed for GHG reduction:</i>			<i>From 26 recommendations analyzed For costs & cost savings:</i>	
	10.7	41.3	247.5	-\$ 2,570	Not estimated

Notes: Negative numbers indicate cost savings. N/A = Not available.

⁹ Totals from all 9 RCI recommendations with estimated GHG reductions.

¹⁰ Totals from only those 7 RCI recommendations with estimated costs/cost savings.

¹¹ Totals from all 6 ES recommendations with estimated GHG reductions.

¹² Totals from only those 5 ES recommendations with estimated costs/cost savings.

¹³ Totals from all 8 TLU recommendations with estimated GHG reductions.

¹⁴ Totals from only those 4 TLU recommendations with estimated costs/cost savings.

Table 1-4. Summary of CAP’s 70 policy recommendations by sector

Notes: Negative numbers indicate cost savings. The cost (savings) shown are calculated in terms of net present value in constant 2005 dollars using a 5% annual real discount rate for the period 2008 through 2020. Capital investments are represented in terms of levelized or amortized costs through 2020.

Residential, Commercial, and Industrial Policy Recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
RCI-1	Expand demand side management programs of all electric and gas utilities, ramped up to reduce energy use by 1% per year by 2013.	0.6	5.2	24	–\$853	–\$32/ton	Unanimous Consent (Several qualified approvals)
RCI-2	Revolving loans to reduce energy use in state and local government buildings.	0.2	0.5	3.7	–\$67	–\$18/ton	Super Majority (1 objection)
RCI-3	Upgrade the state’s energy requirements for local building codes every 3 years, and improve enforcement of building codes.	0.3	2.7	13.0	N/A	N/A	Unanimous Consent
RCI-4 (total)	Targets and programs for beyond-code reductions in energy use in new government, residential, and commercial buildings.	1.0	2.4	20.4	\$1,550	\$76/ton	Unanimous Consent
	<i>Government subtotal:</i>	<i>0.4</i>	<i>0.6</i>	<i>6.0</i>	<i>\$348</i>	<i>\$58/ton</i>	
	<i>Commercial subtotal:</i>	<i>0.5</i>	<i>1.4</i>	<i>11.2</i>	<i>\$1,219</i>	<i>\$109/ton</i>	
	<i>Residential subtotal:</i>	<i>0.2</i>	<i>0.4</i>	<i>3.2</i>	<i>–\$17</i>	<i>–\$5/ton</i>	
RCI-5	Inverted electricity block rates for all residential and commercial consumers to fund utility energy efficiency programs.	1.6	6.7	38.2	–\$1,135	–\$30/ton	Majority (7 objections)
RCI-6	Low interest loans to fund energy efficiency retrofits for commercial and industrial buildings.	0.5	1.8	11.7	–\$334	–\$28/ton	Unanimous Consent (2 qualified approvals)
RCI-7	Electricity smart metering with time-of-use rates and in-home or in-office displays for all residential, commercial, and industrial consumers.	2.0	2.6	25.4	–\$844	–\$33/ton	Unanimous Consent
RCI-8	Tax credits for renewable energy systems in new and existing residential, commercial, and industrial buildings.	N/A	N/A	N/A	N/A	N/A	Unanimous Consent
RCI-9	Promote commercial and industrial combined heat and power (CHP) systems.	0.3	1.4	8.3	–\$25	–\$3/ton	Unanimous Consent
RCI-10	Statewide program for voluntary GHG reductions by businesses.	0.6	1.0	4.5	N/A	N/A	Unanimous Consent
RCI-11	Inverted electricity block rates for all residential and commercial consumers, recovering only cost of service.	N/A	N/A	N/A	N/A	N/A	Unanimous Consent
	RCI Sector GHG reduction total of 9 analyzed policies after adjusting for overlaps among policies	3.7	15	86	N/A	N/A	
	RCI Sector cost-effectiveness total of 7 analyzed policies with cost analysis after adjusting for overlaps among policies				–\$153	–\$2/ton	

Energy Supply Policy Recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
ES-1	Tax credits and incentives to finance renewable energy generation facilities.	Benefits are quantified in policy ES-2					Unanimous Consent
ES-2	Increase renewable portfolio standards to 30% for investor-owned electric utilities and 15% for municipal and co-op utilities, with no more than 85% of renewable energy from centralized wind power.	1.9	4.9	34	\$524	\$16/ton	Super Majority (3 objections) (1 qualified approval)
ES-3	Consider adoption of Xcel's clean energy portfolio standard on a state, regional, or national basis.	Non-specific policy was not quantified					Majority (9 objections)
ES-4	Require all electric utilities to plan cooperatively for electricity transmission infrastructure investments that support renewable resources.	Non-quantitative policy proposal analyzed					Unanimous Consent
ES-5	Consider applying a price to CO ₂ emissions (such as cap and trade or tax) on a state, regional, or national basis.	Non-specific policy not quantified					Super Majority (1 objection) (1 qualified approval)
ES-6	Assess a public benefit charge on all electric utility bills to fund renewable energy programs.	Policy not quantified					Super Majority (3 objections) (1 qualified approval)
ES-7	Adopt structural changes to facilitate large businesses and universities to invest in combined heat and power (CHP) and distributed generation (DG) systems.	0.4	1.1	7.3	\$110	\$15/ton	Unanimous Consent
ES-8	Work with neighboring states to form a regional CO ₂ transportation and sequestration collaborative.	Non-quantitative proposal not quantified					Unanimous Consent
ES-9	Low interest loans to Colorado companies and universities for research and development of carbon emissions reduction technology, funded at \$100M/yr through surcharge on all electricity bills.	R&D benefits not quantified					Unanimous Consent
ES-10	Evaluate and, if appropriate, seek funding for advanced fossil fuel generation with carbon capture demonstration project.	Non-specific policy not quantified					Unanimous Consent
ES-11	Statewide mapping and development of small hydro-power, geothermal, and biomass renewable power sources.	0.0	0.8	3.1	\$123	\$40/ton	Unanimous Consent
ES-12	Review costs and emission reduction potential of nuclear power.	Non-specific policy not quantified					Unanimous Consent
ES-13	Adopt policies to promote a 2% increase in efficiency of existing power generators by 2020.	Costs not quantified—savings ca. 1 MMtCO ₂ /yr by 2020					Unanimous Consent
ES-14	Reduce GHG emissions from oil and gas operations 35% by 2020.	0.8	2.6	16	\$12	\$0.8/ton	Unanimous Consent
ES-15	Establish a CO ₂ emissions performance standard of no more than 1,100 lbsCO ₂ /MWh for new non-peaking power plants and those older than 60 years.	0.5	2.3	13	–\$14	–\$1/ton	Super Majority (5 objections)

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
	Energy Supply Sector totals of 6 analyzed policies (including ES-13) after adjusting for overlaps among policies	3	9	59	N/A	N/A	
	Energy Supply Sector totals of 5 policies with cost estimates (not including ES-13) after adjusting for overlaps				\$526	\$10/ton	

Transportation and Land Use Policy Recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
TLU-1	Reduce light-duty vehicle miles traveled 2% by 2020 by promoting “smart growth” land use planning and development. Require that GHG emissions be considered in long-range transportation plans by 2010.	0.08	0.47	2.43	Less than \$0	Less than \$0/ton	Unanimous Consent
TLU-2	Incentives for the purchase of low-GHG vehicles. [An alternative if the TLU-6 clean car standards are not implemented.]	Quantified as part of TLU-6					Unanimous Consent
TLU-3	Reduce light-duty vehicle miles traveled 6% by 2020 by improving transit service quality and funding expansion of transit infrastructure.	0.17	0.97	5.09	N/A	N/A	Unanimous Consent
TLU-4	Reduce heavy-duty vehicle idling.	0.07	0.11	0.91	–\$123	–\$134/ton	Unanimous Consent
TLU-5	Adopt a low carbon fuels standard that will reduce carbon intensity of passenger vehicle fuels by 10% by 2020.	0.38	2.21	16.1	N/A	N/A	Unanimous Consent
TLU-6	Adopt California GHG emission standards for cars and trucks.	0.70	3.40	18.8	–\$1,880	–\$100/ton	Unanimous Consent
TLU-7	Expand transit use marketing and employer-sponsored transit fare programs.	Quantified as part of TLU–3					Unanimous Consent
TLU-8	Move toward basing motor vehicle insurance on the distances vehicles are driven.	0.32	0.94	7.19	Less than \$0	Less than \$0/ton	Unanimous Consent
TLU-9	Local parking management programs to encourage alternative travel choices and transit-oriented development.	0.03	0.03	0.34	–\$37	–\$110	Unanimous Consent
TLU-10	Require employers with more than 100 employees to offer commuter benefits programs.	0.42	0.45	4.77	–\$1,145	–\$240/ton	Unanimous Consent
TLU-11	Incorporate vehicle maintenance, operation, and transportation choice GHG reduction information in driver training and education.	Not quantified					Unanimous Consent
	TLU Sector GHG reduction total of 8 analyzed policies after adjusting for overlaps among policies	2.14	7.84	46.7	N/A	N/A	
	TLU Sector cost-effectiveness total of 4 analyzed policies with cost estimates after adjusting for overlaps among policies				–\$3,185	–\$141/ton	

Agriculture, Forestry, and Waste Management Policy Recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
AFW-1	Achieve no-till operation of half of croplands by 2020 and increase nitrogen fertilizer efficiency by 20%.	0.57	0.78	7.7	–\$57	–\$7/ton	Unanimous Consent
AFW-2	Implement methane capture and energy recovery on manure management projects on 80% of animal feeding operations by 2020.	0.01	0.32	1.8	\$66	\$36/ton	Unanimous Consent (1 qualified approval)
AFW-3	Reduce on-farm petro-diesel use 20% by 2020, and reduce electricity use from fossil fuels 40% through energy efficiency and on-site renewable sources generation.	0.14	0.64	3.8	–\$150	–\$40/ton	Unanimous Consent
AFW-4	Incentives for the production of biodiesel fuel from oilseed crops, waste vegetable oil, or other sources to offset 40% of fossil diesel fuel use by 2020.	0.02	0.22	1.1	\$13	\$12/ton	Unanimous Consent (3 qualified approvals)
AFW-5	Increase in-state ethanol production, using GHG-superior feedstocks and production methods, to 400 million gallons per year above BAU by 2020.	0.39	3.1	15	\$58	\$3/ton	Unanimous Consent (3 qualified approvals)
AFW-6	Preserve forest lands (line 1) and grasslands (line 2) to reduce the rate of conversion to developed uses by 25% by 2020.	0.10 0.05	0.24 0.14	1.7 1.0	\$44 \$31	\$26/ton \$32/ton	Unanimous Consent
AFW-7	Increase the use of biomass from forest health and fire risk treatment for energy production, using 20% of harvested wood by 2020.	0.08	0.20	1.4	–\$104	–\$75/ton	Unanimous Consent
AFW-8	Divert 75% of wastes from landfills by 2020 through source reduction, enhanced recycling, and composting programs.	0.48	4.6	24	\$311	\$13/ton	Unanimous Consent
AFW-9	Control or capture landfill methane to achieve 50% reduction from BAU by 2020.	0.33	1.2	7.5	–\$0.1	–\$0.02/ton	Unanimous Consent
AFW-10	Plant 3.4 million new trees statewide by 2020 through expanded urban forestry programs.	0.03	0.08	0.59	\$40	\$79/ton	Unanimous Consent (1 qualified approval)
	AFW Sector Total of Analyzed Policies After Adjusting for Overlaps	2.2	11.5	66	\$252	\$4 /ton	

Cross-Cutting Issues Policy Recommendations

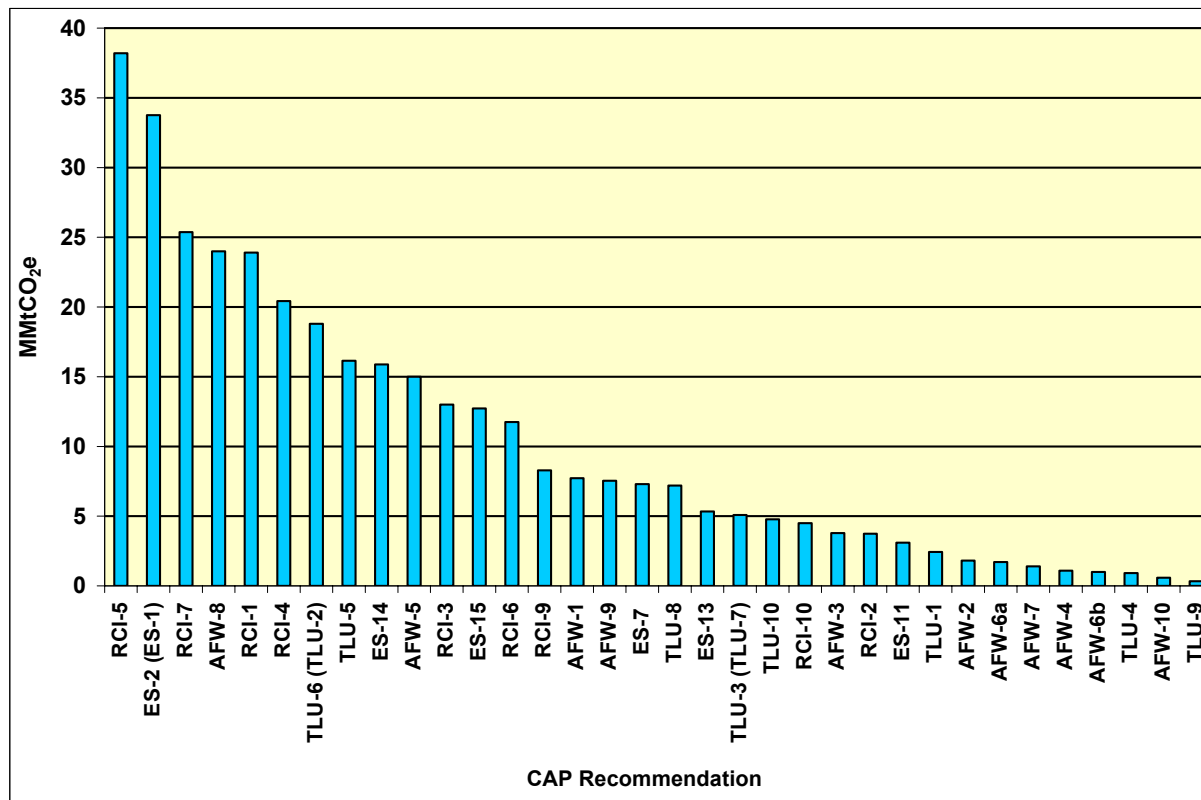
	Policy Recommendation	Analysis	Climate Action Panel Action
CC-1	Periodically update GHG inventories and forecasts.	<i>Not Quantified</i>	Unanimous Consent
CC-2	State development of annual GHG reporting protocols for all sources, including mandatory reporting for significant sources.	<i>Not Quantified</i>	Unanimous Consent
CC-3	State development of capacity to participate in the national <i>Climate Registry</i> to measure, track, and record emissions reductions.	<i>Not Quantified</i>	Unanimous Consent
CC-4	The governor should set statewide GHG reduction goals and targets to achieve in the vicinity of a 20% reduction by 2020 and 80% by 2050, both compared to 2005 levels.	<i>Not Quantified</i>	Super Majority (1 objection) (5 qualified approvals)
CC-5	Set state and local government reduction targets for their own GHG emissions; the state target should be at least an amount consistent with CC-4 levels.	<i>Not Quantified</i>	Unanimous Consent
CC-6	Promote adoption of comprehensive local government climate action plans.	<i>Not Quantified</i>	Unanimous Consent
CC-7	State and local government public education and outreach efforts to support GHG reduction programs, policies, and goals.	<i>Not Quantified</i>	Unanimous Consent
CC-8	A public-private partnership to seek funding for GHG reduction measures and development of a new energy economy in Colorado.	<i>Not Quantified</i>	Unanimous Consent
CC-9	State government assessment of vulnerabilities to climate change and development of adaptation plans.	<i>Not Quantified</i>	Unanimous Consent

Water Adaptation Policy Recommendations

	Policy Recommendation	Analysis	Climate Action Panel Action
WA-1	Public officials exercise leadership in addressing climate change effects on water supplies.	<i>Not Quantified</i>	Unanimous Consent
WA-2	Water managers consider climate change in all water supply decisions.	<i>Not Quantified</i>	Unanimous Consent
WA-3	Climate change effects considered in the new Colorado Water Conservation Board study of Colorado River water availability.	<i>Not Quantified</i>	Unanimous Consent
WA-4	State government develop mechanisms for compact calls for each major river basin.	<i>Not Quantified</i>	Unanimous Consent
WA-5	Assessment of knowledge about climate change effects on Colorado's water resources. An assessment of data and data systems for understanding climate change.	<i>Not Quantified</i>	Unanimous Consent
WA-6	Cooperative development of information on climate change effects in each major river basin.	<i>Not Quantified</i>	Unanimous Consent
WA-7	Municipal water providers evaluate water conservation savings, best demand management practices, and the best uses of conserved water in their systems.	<i>Not Quantified</i>	Unanimous Consent
WA-8	Minimize effects of water-rights transfers on agricultural economies.	<i>Not Quantified</i>	Unanimous Consent
WA-9	Consider relationships between energy and water use.	<i>Not Quantified</i>	Unanimous Consent
WA-10	Information exchanges on effects of climate change on water resources.	<i>Not Quantified</i>	Unanimous Consent
WA-11	State government consider ways to reduce climate change effects on water-related recreation and tourism.	<i>Not Quantified</i>	Unanimous Consent
WA-12	State government consider ways to reduce climate change effects on the environment.	<i>Not Quantified</i>	Unanimous Consent
WA-13	Reduce use of groundwater for irrigation until recharges match discharges.	<i>Not Quantified</i>	Unanimous Consent
WA-14	Establish new Colorado Water Institute.	<i>Not Quantified</i>	Super Majority (1 objection)

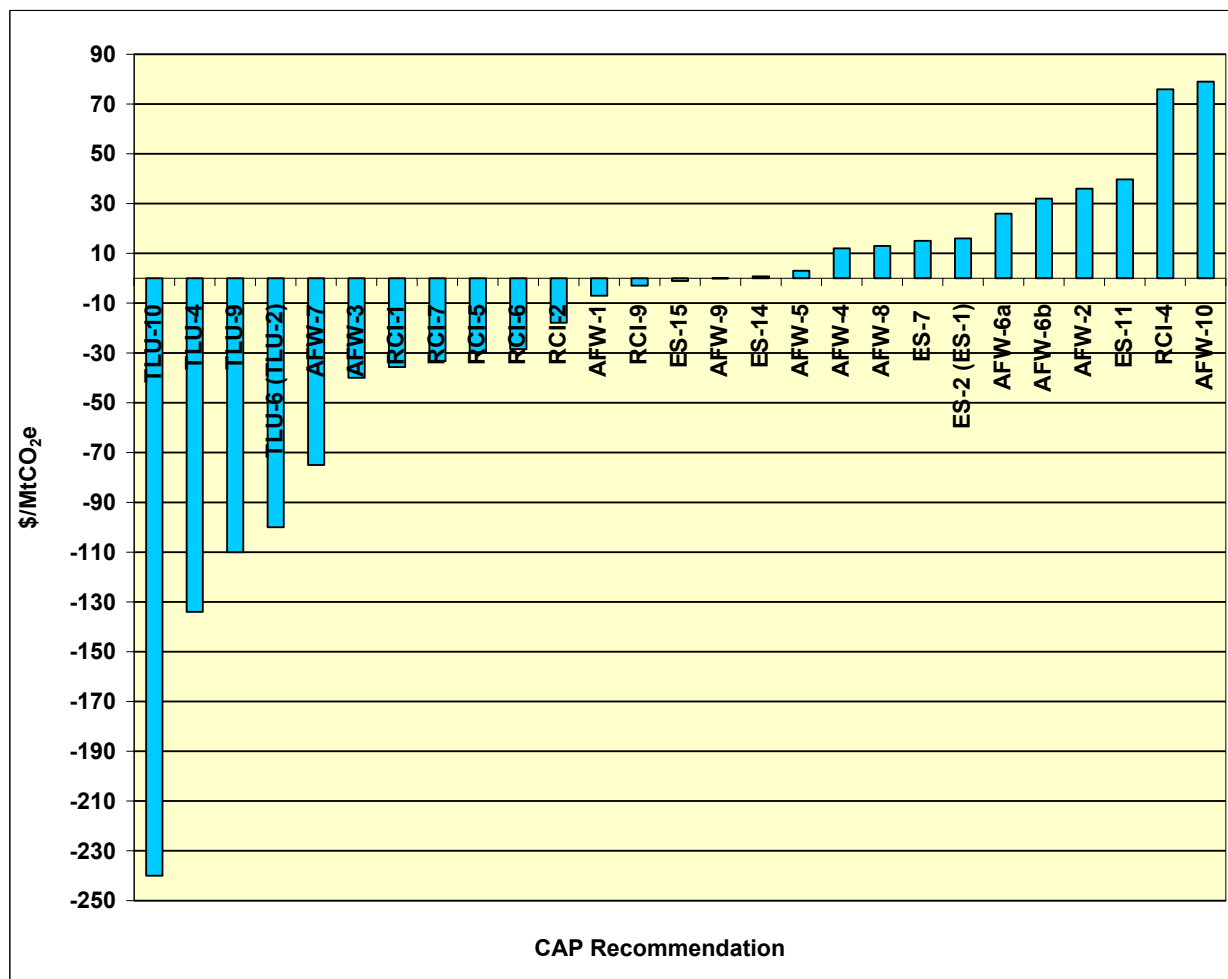
As explained above, the CAP considered the estimates of the GHG reductions that could be achieved by 33 of its recommendations, and the costs (or cost savings) of 26 of those 33. Having these analyses was very helpful to the CAP, but the CAP was mindful that these are estimates. There can be a large imprecision in the GHG reductions associated with various policy recommendations. Figure 1-3 presents the estimated tons of reductions for each policy recommendation for which estimates were available, expressed as a cumulative figure for the period 2007-2020. In addition to the imprecision in GHG reductions achieved by each policy recommendation, there are also uncertainties in the exact cost (or cost savings) per ton of reduction achieved. Figure 1-4 presents the estimated dollars per ton cost (or cost savings, depicted as a negative number) for each policy recommendation for which cost estimates were available. This measure is calculated by dividing the net present value of the cost of the policy recommendation by the cumulative GHG reductions, all for the period 2007-2020. In some cases, there is a wide variation in the cost effectiveness of the policy recommendations depending on the assumptions used in the analysis.

Figure 1-3. CAP Policy Recommendations Ranked by Cumulative GHG Reductions, 2007-2020



Note: Emission reductions for TLU-2 are included in the reductions for TLU-6, reductions for TLU-7 are included in the reductions for TLU-3, and reductions for ES-1 are included in the reductions for ES-2. For the purpose of counting the number of options for which emission reductions were quantified, each of the following are counted as one option: TLU-6 & 2; TLU-3 & 7; ES-2 & 1; and AFW-6a & 6b.

Figure 1-4. CAP Policy Recommendations Ranked by Dollars per Metric Ton



Note: Negative values represent net cost savings and positive values represent net costs associated with the policy recommendation. Cost savings for TLU-2 are included in the cost savings for TLU-6, and costs for ES-1 are included with the costs for ES-2. For the purpose of counting the number of options for which costs or cost savings were quantified, each of the following are counted as one option: TLU-6 & 2; ES-2 & 1; and AFW-6a & 6b.

Recent Policy Developments

In the year that the CAP has been working on the development of this report, the Colorado state government, local governments, and others have taken many actions that will make it quicker and easier for the state to reduce its contribution and vulnerability to climate change. These recent actions include the enactment of bills by the Colorado General Assembly in 2007 that:

- Strengthen the state’s renewable portfolio standard, first adopted by the voters of Colorado in 2004, requiring utilities to obtain a certain percentage of their electricity from renewable sources.

- Direct natural gas utilities to implement energy-efficiency programs.
- Direct rural electric cooperatives to enable customers to use net metering.
- Require local governments who have building codes to adopt and update to international energy conservation codes at a minimum.
- Require electric utilities to identify areas where transmission capacity lags behind generating capacity, including renewable sources.
- Created the Renewable Energy and Infrastructure Authority to provide loans and grants for transmission lines to serve renewable energy sources.
- Created a Clean Energy Fund for programs and grants administered by the Governor's Energy Office.
- Establish a pilot grants program for forest restoration projects.

Other significant actions in 2007 include:

- The issuance by Governor Bill Ritter of an executive order to reduce GHGs from state government operations.
- A decision by the Colorado State Government to participate in *The Climate Registry* and to participate as an observer in the development of the Western Climate Initiative.
- Actions by several local governments around the state to reduce local GHG emissions.
- A heightened awareness of potential climate change impacts on the state's water supplies and new efforts by water providers to consider what must be done to meet our water needs in a changed future.

The CAP Process

The CAP first met on November 20, 2006, and met a total of seven times, with the final decisional meeting held on September 12, 2007, and a final meeting for review of this report on October 25, 2007. In all, over 50 meetings and teleconference calls of the CAP and the six supporting PWGs were held to identify and analyze various potential policy actions in advance of the CAP's September 12, 2007, final decisional meeting.

The six PWGs considered information and potential recommendations in the following sectors:

- Energy Supply (ES)
- Residential, Commercial, Industrial (RCI)
- Transportation and Land Use (TLU)
- Agriculture, Forestry, and Waste Management (AFW)
- Cross-Cutting Issues (CC)

- Water Adaptation (WA)

CCS provided facilitation and technical assistance to the first five of those and RMCO played a similar role with respect to the Water Adaptation group. The PWGs consisted of CAP members as well as individuals not on the CAP with interest and expertise in the issues being addressed by each PWG (see Appendix B for a listing of the members of each PWG). The PWGs served as advisors to the CAP and brought forth initial recommendations on priority policy recommendations for analysis, then developed draft proposals on the design characteristics and quantification of the proposed policy recommendations. Where members of a PWG did not fully agree upon recommendations to the CAP, the summary of their efforts was reported to the CAP for their further consideration and actions. The CAP then made its decisions after reviewing the PWGs' proposals.

The CAP process involved a model of informed self-determination through a facilitated, stepwise, consensus-building approach. Under the oversight of RMCO, the process was conducted by CCS, an independent, expert facilitation and technical analysis team. It was based on procedures that CCS consultants have used in a number of other state climate change planning initiatives since 2000, but adapted specifically for Colorado. The CAP process sought, but did not mandate consensus, and it explicitly documented the level of CAP support for some policies and key findings established through a voting process established in advance.

The 70 policy recommendations (out of over 300 potential options considered) adopted by the CAP and presented in this report underwent two levels of screening by the CAP. First, a potential policy recommendation being considered by a PWG was not accepted as a "priority for analysis" and fleshed out for full analysis unless it had a super majority of support from CAP members present at the decisional meetings (with a "super majority" defined as five objections or less by CAP members attending a meeting). Second, after the analyses were conducted, only policy recommendations that received at least majority support (defined as less than half of those present objecting) from CAP members present at the decisional meetings were adopted by the CAP and included in this report.

In total, of the 70 policy recommendations adopted by the CAP, 62 were approved unanimously, six were approved by a super majority, and two were approved by a simple majority of the CAP.

The PWGs' recommendations to the CAP were documented and presented to the CAP at each CAP meeting. All of the CAP and PWG meetings were open to the public and all materials for and summaries of the CAP and PWG meetings were posted on the Colorado Climate Project website.

Analysis of Policy Recommendations

With CCS providing facilitation and technical analysis, the five PWGs other than the Water Adaptation group submitted recommendations for policies for CAP consideration using a "policy option template" conveying the following key information:

- Policy option description
- Policy option design (goals, timing, parties involved)
- Implementation mechanisms

- Related policies / programs in place
- Type(s) of GHG reductions
- Estimated GHG Savings and Costs per metric ton (Mt) of CO₂e
- Key uncertainties
- Additional benefits and costs
- Feasibility issues
- Status of group approval
- Level of group support
- Barriers to consensus

In its deliberations, the CAP modified and embraced various policy recommendations. The final versions for each sector, conforming to the policy option templates, appear in Appendices E through I (and Chapter 8 for Water Adaptation) and constitute the most detailed record of decision of the CAP. Appendix D presents a description of the methods used for quantification of the 33 policy recommendations that were analyzed quantitatively. Three key methods are summarized here:

- *Estimates of GHG reductions.* Using the projection of future GHG emissions (see below) as a starting point, 33 policy recommendations were analyzed by CCS to estimate GHG reductions attributable to each policy in the individual years of 2012 and 2020, and cumulative reductions over the time period 2007-2020. The CCS estimates were prepared in accordance with guidance by the appropriate PWG and the CAP, which later reviewed the estimates and in some cases directed that they be revised with respect to such elements as goals, data sources, and methodology. Many policies were estimated to affect the quantity or type of fossil fuel combusted; others affected methane (CH₄) or CO₂ sequestered. Among the many assumptions involved in this task was selection of the appropriate GHG accounting framework, namely, the choice between taking a “production-based” approach versus a “consumption-based” approach to various sectors of the economy.¹⁵ The CAP took a “production-based” approach in all sectors except the electricity sector, in both forecasting emissions and in estimating the GHG impacts of policies. This issue, along with other GHG estimation issues (e.g., analysis of overlapping or interacting policy impacts), are discussed in detail in Appendix D (Methods for Quantification).
- *Estimates of costs / cost savings.* The analyses of 26 policy recommendations included estimates of the cost of those policies, both in terms of a net costs or cost savings from 2007-

¹⁵ A production-based approach estimates GHG emissions associated with goods and services produced within the state, and a consumption-based approach estimates GHG emissions associated with goods and services consumed within the state. In some sectors of the economy, these two approaches may not result in significantly different numbers, however, the power sector is notable in that it is responsible for large quantities of GHG emissions, and states often produce more or less electricity than they consume (with the remainder attributable to power exports or imports). Colorado imports electric power and must account for the emissions this consumption creates, even though they are not produced in-state.

2020 and a dollars-per-ton cost (i.e., cost-effectiveness).¹⁶ (The other seven policy recommendations that were analyzed with respect to their GHG reductions were of such a nature that their costs or cost savings could not be readily estimated.) The approach used was similar to a conventional cost-benefit framework but had some important differences:

— *Discounted and “Levelized” Costs.* Fairly standard approaches were taken here. The “net present value” of costs was calculated by applying a real discount rate of 5%. Dollars-per-ton estimates were derived as a “levelized” cost per ton, dividing the “present value cost” by the cumulative GHG reduction measured in tons. As was the case with GHG reductions, the period 2007-2020 was analyzed.

— *Benefits vs. costs.* The principal benefit of the CAP policy recommendations is reduced GHG emissions and these were quantified simply as metric tons. There was no attempt to monetize the benefit of these reductions in atmospheric concentration (e.g., health benefits). Many policies did create easily monetized non-GHG benefits (e.g., fuel savings and electricity savings). In these cases, monetized benefits were subtracted from monetized costs, resulting in net costs. These net costs could be positive or negative; negative costs indicated that the policy saved money or produced “cost savings.”

— *Direct vs. Indirect Effects.* Cost estimates were based on “direct effects” (i.e., those borne by the entities implementing the policy).¹⁷ Implementing entities could be: individuals, companies, and/or government agencies, etc. In contrast, conventional cost-benefit analysis takes the “societal perspective” and tallies every conceivable impact on every entity in society (and quantifies these wherever possible).

Colorado vs. National/Global perspective. Cost estimates were based on implementing entities in Colorado, not on a broader societal perspective (national or global). One implication of this is that national taxes or subsidies that affect actions in Colorado were considered as external to the analysis. For example, while the federal Production Tax Credit was taken into account in reducing the cost of renewable resources in Colorado, the cost of this program to taxpayers nationally was not considered.

¹⁶ The analysis addressed the costs / cost savings of each policy recommendation and, with the exception of a few recommendations that address rate structures, did not attempt to estimate specific price changes or utility rate changes that might result from implementation of a policy.

¹⁷ “Additional benefits and costs” were defined as those borne by entities other than those implementing the policy recommendation. These indirect effects were quantified on a case-by-case basis depending on magnitude, importance, need and availability of data.

Chapter 2

Inventory and Projections of GHG Emissions

Introduction

This chapter presents a summary of Colorado’s anthropogenic greenhouse gas (GHG) emissions and sinks (carbon storage) from 1990 to 2020. The Center for Climate Strategies (CCS) prepared a preliminary draft GHG emissions inventory and reference case projection for the Colorado Department of Public Health and Environment (CDPHE) through an effort of the Western Regional Air Partnership.¹ The preliminary draft report was provided to the Climate Action Panel (CAP) (and its Policy Work Groups [PWGs]) of the Colorado Climate Project to assist the CAP in understanding past, current, and possible future GHG emissions in Colorado, and thereby inform the policy option development process. The CAP and the PWGs provided comments for improving the reference case projections. Subsequently, the inventory and reference case projection estimates were revised to incorporate revisions approved by the CAP. The information presented in this chapter reflects the information presented in the final inventory and reference case projections report (hereafter referred to as the *Inventory and Projections*).²

Historical GHG emissions estimates (1990 through 2005)³ were developed using a set of generally accepted principles and guidelines for state GHG emissions inventories, relying to the extent possible on Colorado-specific data and inputs. The reference case projections (2006–2020) are based on a compilation of various existing Colorado and regional projections of electricity generation, fuel use, and other GHG-emitting activities, along with a set of simple, transparent assumptions described in the appendixes of the *Inventory and Projections* report.

The *Inventory and Projections* report covers the six types of gases included in the U.S. Greenhouse Gas Inventory: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). Emissions of these GHGs are presented using a common metric, CO₂ equivalence (CO₂e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential- (GWP-) weighted basis.

It is important to note that the emissions estimates for the electricity sector reflect the *GHG emissions associated with the electricity sources used to meet Colorado’s demands*, corresponding to a consumption-based approach to emissions accounting. Another way to look at electricity emissions is to consider the *GHG emissions produced by electricity generation facilities in Colorado*. This report covers both methods of accounting for emissions, but for consistency, all total results are reported as *consumption-based*.

¹ *Draft Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020*, prepared by the Center for Climate Strategies for the Colorado Department of Public Health and Environment (CDPHE) through an effort of the Western Regional Air Partnership, January 2007.

² *Final Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020*, prepared by the Center for Climate Strategies for the Climate Action Panel of the Colorado Climate Project, October 2007.

³ The last year of available historical data varies by sector; ranging from 2000 to 2005.

Colorado GHG Emissions: Sources and Trends

Table 2-1 provides a summary of GHG emissions estimated for Colorado by sector for the years 1990, 2000, 2005, 2010, and 2020. As shown in this table, Colorado is estimated to be a net source of GHG emissions, but with significant sinks of GHG emissions due to the forestry sector and agricultural soils. We note that there are significant uncertainties associated with forest carbon sink estimates.⁴ In the sections below, we discuss GHG emission sources (positive, or *gross*, emissions) and sinks (negative emissions) separately in order to identify trends, projections, and uncertainties clearly.

Table 2-1. Colorado historical and reference case GHG emissions, consumption-based by sector

(Million Metric Tons CO₂e)	1990	2000	2005	2010	2020
Energy	75.4	96.0	102.2	114.1	129.1
Electricity use (consumption)	32.7	40.9	42.9	48.2	52.6
Transportation fuel use	19.0	25.5	28.0	30.6	36.2
Fossil fuel industry	7.5	9.3	10.1	11.8	12.3
RCI fuel use [†]	16.3	20.2	21.2	23.6	27.9
Other	10.7	13.6	13.9	15.2	18.4
Industrial processes	0.8	2.1	2.9	3.8	5.9
Agriculture	8.7	9.6	8.9	8.9	9.1
Waste management	1.2	1.9	2.1	2.5	3.5
Gross emissions	86.1	109.6	116.1	129.3	147.5
<i>change relative to 1990</i>		27%	35%	50%	71%
<i>change relative to 2000</i>			6%	18%	35%
Forestry	-24.7	-24.7	-24.7	-24.7	-24.7
Agricultural soils	-2.0	-2.0	-2.0	-2.0	-2.0
Net emissions (incl. sinks)	59.4	82.9	89.4	102.6	120.8
<i>change relative to 1990</i>		39%	50%	73%	103%
<i>change relative to 2000</i>			8%	24%	46%
Per capita gross emissions	26.1	25.3	24.6	24.8	21.7
Per capita net emissions	18.0	19.1	18.9	19.7	17.8

* Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

† RCI = residential, commercial, and industrial fuel use. Totals reflect emissions associated with the direct use of natural gas, oil, coal, and wood for all years and avoided emissions associated with recent demand-side management initiatives from 2007 through 2020.

The next section of this chapter provides a summary of the historical emissions (1990 through 2005) followed by a summary of the reference case projection year emissions (2006 through

⁴ The standing forest carbon sink estimates in states like CO with a large amount of unproductive forest area (e.g. Pinyon-Juniper forests) are highly uncertain (with potential for over-estimation of the sink). This is because these types of forest were not well represented in earlier US Forest Service surveys. Since they are now being inventoried, it is anticipated that future inventories will reduce the amount of uncertainty. See Appendix H of the report Final Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020, for a discussion of uncertainties associated with the estimates for this sector.

2020), and key uncertainties and next steps. We also provide an overview of the general methodology, principles, and guidelines followed for preparing the inventories.

Historical Emissions

Overview

In 2005, on a gross emissions consumption basis (i.e., excluding carbon sinks), Colorado accounted for approximately 116 million metric tons (MMt) of CO₂e emissions, an amount equal to 1.6% of total United States (US) gross GHG emissions. On a net emissions basis (i.e., including carbon sinks), Colorado accounted for approximately 89 MMtCO₂e of emissions in 2005, an amount equal to 1.4% of total US net GHG emissions.⁵ Colorado's GHG emissions are rising more quickly than those of the nation as a whole.⁶ From 1990 to 2005, Colorado's gross GHG emissions were up 35% while national gross emissions rose by 16% during this period. Much of Colorado's emissions growth can be attributed to its population growth. From 1990 to 2005, Colorado's population grew by 43% as compared with a national population growth of 19%.

Figure 2-1 illustrates the state's emissions per capita and per unit of economic output. Colorado's per capita emission rate is slightly more than the national average of 25 MtCO₂e/year. Between 1990 and 2005, per capita emissions in Colorado and national per capita emissions have changed relatively little. Economic growth exceeded emissions growth in Colorado throughout the 1990–2005 period. From 1990 to 2005, emissions per unit of gross product dropped by 40% nationally, and by 54% in Colorado.

Electricity use and transportation are the state's principle GHG emissions sources. Together, the combustion of fossil fuels for electricity generation and in the transportation sector accounted for 60% of Colorado's *gross* GHG emissions in 2000, as shown in Figure 2-2. The remaining use of fossil fuels—natural gas, oil products, and coal—in the residential, commercial, and industrial (RCI) sectors, plus the emissions from fossil fuel production, constituted another 28% of total state emissions.

Agricultural activities such as manure management, fertilizer use, and livestock (enteric fermentation) result in CH₄ and N₂O emissions that account for another 9% of state GHG emissions. Industrial process emissions comprise about 2% of state GHG emissions in 2000, and these emissions are rising rapidly due to the increasing use of HFCs and PFCs as substitutes for ozone-depleting chlorofluorocarbons.⁷ Other industrial processes emissions result from cement

⁵ National emissions from *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2005*, April 2007, US EPA #430-R-07-002, (<http://www.epa.gov/climatechange/emissions/usinventoryreport.html>).

⁶ *Gross* emissions estimates only include those sources with positive emissions. Carbon sequestration in soils and vegetation is included in *net* emissions estimates. All emissions reported in this section for Colorado reflect consumption-based accounting (including emissions from electricity imports). On a national basis, little difference exists between *production-based* and *consumption-based* accounting for GHG emissions because net electricity imports are less than 1% of national electricity generation.

⁷ Chlorofluorocarbons (CFCs) are also potent GHGs; however they are not included in GHG estimates because of concerns related to implementation of the Montreal Protocol. See Appendix J in the *Inventory and Projections* report for Colorado.

and lime manufacturing; PFC use in semiconductor manufacture; CO₂ released during soda ash, limestone, and dolomite use; and SF₆ released from transformers used in electricity transmission and distribution systems. Landfills and wastewater management facilities produce CH₄ and N₂O emissions accounting for the remaining 2% of the state's gross GHG emissions in 2000.

Figure 2-1. Colorado and US gross GHG emissions, per capita and per unit gross product

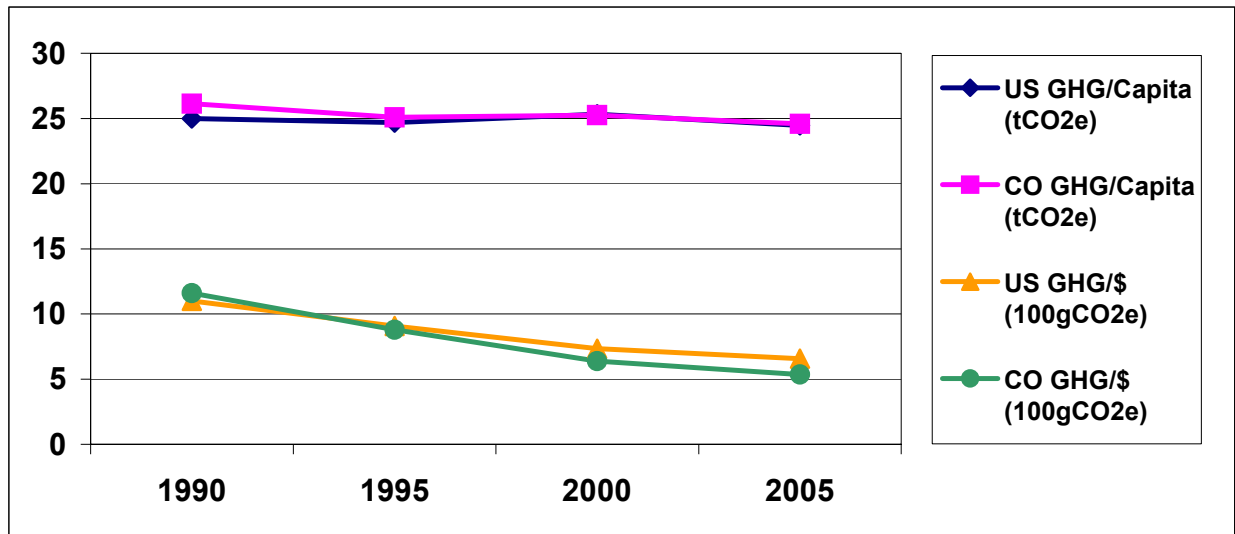
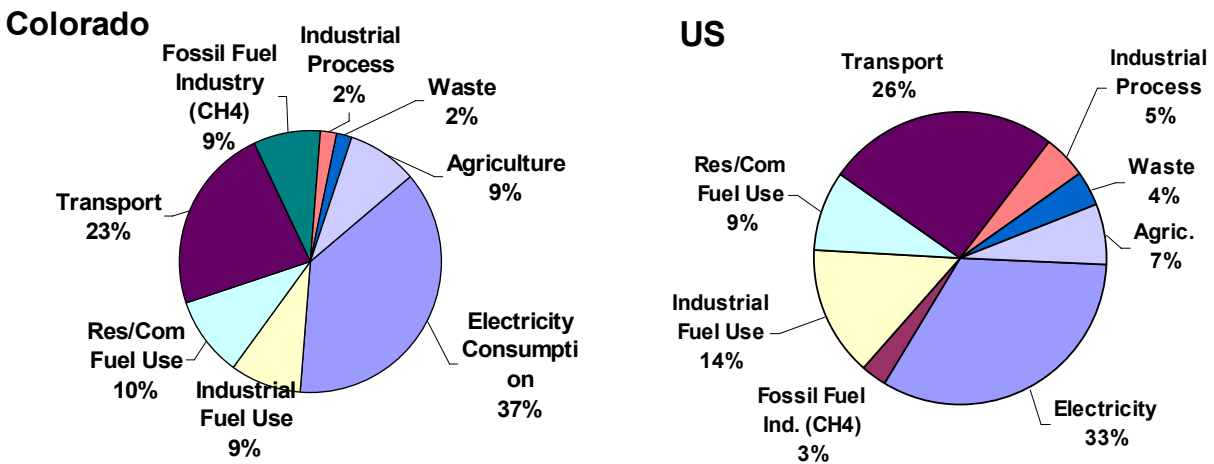


Figure 2-2. Gross GHG emissions by sector, 2000, Colorado and United States



Based on data from the early 1980s through 2004, Colorado's forests are estimated to be net sinks, accounting for -24.7 MMtCO₂ of GHG emissions (the negative value indicates a net sequestration of CO₂ from the atmosphere). Also, agricultural soils are estimated to sequester an additional -2.0 MMtCO₂. With these GHG sinks, Colorado's net emissions were 59.4 MMtCO₂ in 1990. Due to a lack of information to estimate future trends, these sinks were estimated to remain constant throughout the forecast period from 2005 through 2020. Thus, with the increase

in GHG emission sources, by 2020, the net emissions in Colorado are estimated to increase to about 121 MMtCO₂e.

Emissions of aerosols, particularly “black carbon” (BC) from fossil fuel combustion, could have significant climate impacts through their effects on radiative forcing.⁸ Estimates of these aerosol emissions on a CO₂e basis were developed for Colorado based on 2002 and 2018 data from the Western Regional Air Partnership. The results were a total of 6.75 MMtCO₂e, which is the midpoint of a range of estimated emissions (4.3–9.2 MMtCO₂e) in 2002. Based on an assessment of the primary contributors, it is estimated that BC emissions will decrease substantially by 2018 after new engine and fuel standards take effect in the onroad and nonroad diesel engine sectors (decrease of about 4.0 MMtCO₂e). These estimates are not incorporated into the totals shown in Table 2-1 because a global warming potential for BC has not yet been assigned by the Intergovernmental Panel on Climate Change (IPCC). By including BC emission estimates in the inventory, however, additional opportunities for reducing climate impacts can be identified as the scientific knowledge related to BC emissions improves.

A Closer Look at the Two Major Sources: Electricity and Transportation

As shown in Figure 2-2, electricity consumption accounted for about 37% of Colorado’s gross GHG emissions in 2000 (about 40.9 MMtCO₂e), which was higher than the national average share of emissions from electricity consumption (33%).⁹ The GHG emissions associated with Colorado’s electricity sector increased by 8.2 MMtCO₂e between 1990 and 2000, accounting for about 35% of the state’s net growth in gross GHG emissions in this time period. In 2000, emissions associated with Colorado’s electricity consumption were slightly higher than those associated with electricity production (38.7 MMtCO₂e). The higher level for consumption-based emissions reflects GHG emissions associated with net imports of electricity to meet the state’s electricity demand.¹⁰ See Chapter 4 for additional information.

While we estimate both the emissions from electricity production and consumption, unless otherwise indicated, tables, figures, and totals in this report reflect electricity consumption emissions. The consumption-based approach can better reflect the emissions (and emissions reductions) associated with activities occurring in the state, particularly with respect to electricity use (and efficiency improvements) and is particularly useful for policy making. Under this approach, emissions associated with electricity imported from other states would need to be covered in those states’ accounts in order to avoid double counting or exclusions. (Indeed,

⁸ Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC, 1996). Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth), <http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm>.

⁹ For the US as a whole, there is relatively little difference between the emissions from electricity use and emissions from electricity production, as the US imports only about 1% of its electricity, and exports far less. Colorado’s situation is different, since it is a net electricity importer.

¹⁰ Estimating the emissions associated with electricity use requires an understanding of the electricity sources (both in-state and out-of-state) used by utilities to meet consumer demand. The current estimate reflects some very simple assumptions, as described in the *Inventory and Projections* report.

Arizona, California, Oregon, New Mexico, and Washington are currently considering such an approach.)

Like electricity emissions, GHG emissions from transportation fuel use have risen steadily from 1990 through 2000 at an average rate of slightly under 3% annually. In 2002, onroad gasoline vehicles accounted for about 66% of transportation GHG emissions. Onroad diesel vehicles accounted for another 20% of emissions, and air travel for roughly 11%. Rail, marine gasoline, and other sources (natural gas- and liquefied petroleum gas- (LPG-) fueled-vehicles and used in transport applications) accounted for the remaining 2% of transportation emissions. As the result of Colorado’s population and economic growth and an increase in total vehicle miles traveled (VMT) during the 1990s, onroad gasoline use grew 32% between 1990 and 2002. Meanwhile, onroad diesel use rose 151% during that period, suggesting an even more rapid growth in freight movement within or across the state. Aviation fuel use grew by 16% from 1990 to 2002.

Reference Case Projections

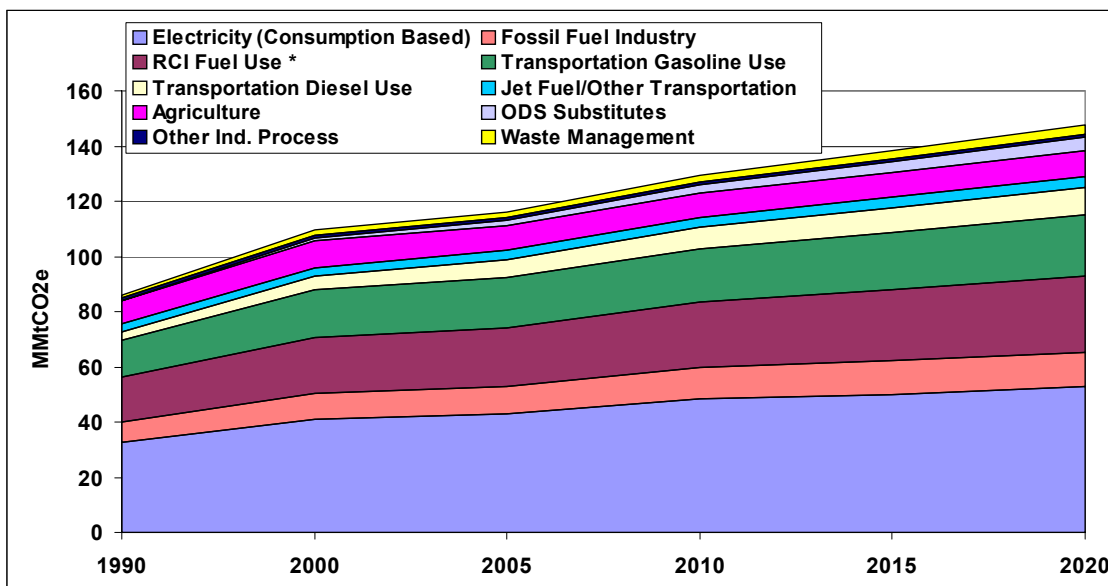
Relying on a variety of sources for projections of electricity and fuel use, as noted below and in the *Inventory and Projections* report, a simple reference case projection of GHG emissions through 2020 was developed. Table 2-2 shows key annual growth rates used to project emissions for Colorado and provides historical growth rates for comparison. As illustrated in Figure 2-3 and shown numerically in Table 2-1, under the reference case projections, Colorado gross GHG emissions continue to grow steadily, climbing to approximately 148 MMtCO_{2e} by 2020, 71% above 1990 levels. Overall, the average annual projected rate of emissions growth in Colorado is 1.6% per year from 2005 to 2020. Demand for electricity is projected to be the largest contributor to future emissions growth accounting for about 36% of total gross GHG emissions in 2020, followed by emissions associated with transportation (25%), RCI fossil fuel use (19%), and fossil fuel production (8%) (see Figure 2-4).

Table 2-2. Key annual growth rates for Colorado, historical and projected

	1990–2005	2005–2020	Sources
Population*	2.4%	1.8%	Colorado State Demography Office
Employment*			Colorado Department of Labor and Employment website, based on analysis by the US Bureau of Labor Statistics.
Goods	1.0%	2.7%	
Services	2.8%	2.8%	
Electricity sales	3.0%	2.1%	US DOE Energy Information Administration (EIA) data for 1990-2004 (3.0% growth is mix of increased residential and commercial electricity sales countered by a decrease in industrial sales). The growth rate for 2005-2020 is based on electricity sales forecasts developed for the energy supply sector, and includes state legislation passed in 2007 establishing new requirements for Colorado’s renewable portfolio standard and for demand-side management programs.
Vehicle miles traveled	3.1%	2.1%	Federal Highway Administration, Highway Statistic; Metropolitan Planning Organizations and CDPHE

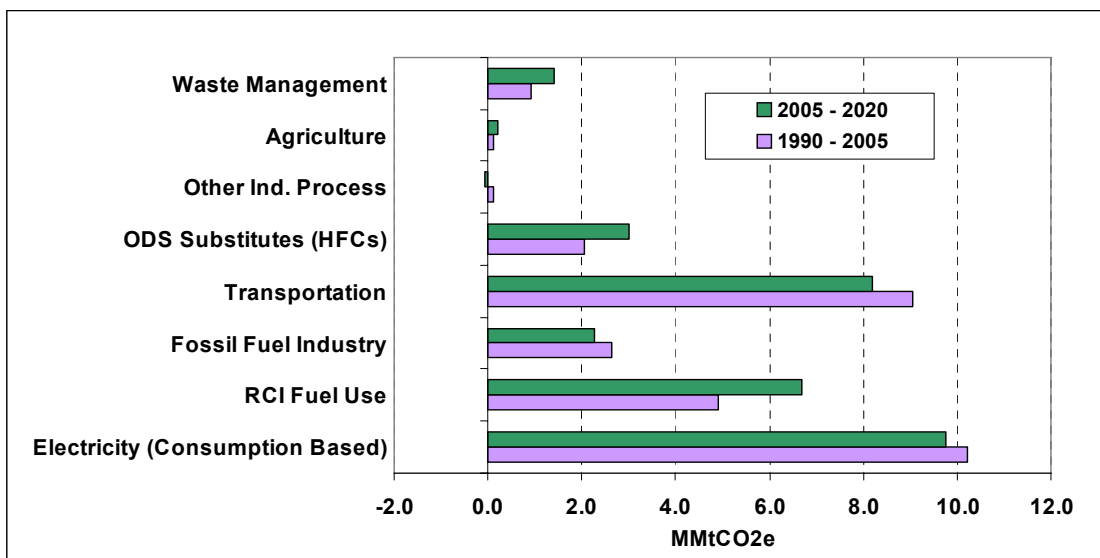
* For the RCI fuel consumption sectors, population and employment projections for Colorado were used together with US DOE EIA’s Annual Energy Outlook 2006 (AEO2006) projections of changes in fuel use for the EIA’s Mountain region on a per capita basis for the residential sector and on a per employee basis for the commercial and industrial sectors. For instance, growth in Colorado’s residential natural gas use is calculated as the Colorado population growth times the change in per capita natural gas use for the Mountain region.

Figure 2-3. Colorado gross GHG emissions by sector, 1990–2020: historical and projected under reference case assumptions



* RCI = direct fuel use in residential, commercial, and industrial sectors; ODS Substitutes = ozone depleting substances substitutes. Other Industrial Processes include process-related GHG emissions from cement and lime manufacturing; semiconductor manufacture; soda ash, limestone, and dolomite use; and electricity transmission and distribution systems.

Figure 2-4. Sector contributions to emissions growth in Colorado, 1990–2020: historic and reference case projections



* RCI = direct fuel use in residential, commercial, and industrial sectors; ODS Substitutes = ozone depleting substances substitutes; HFC = hydrofluorocarbons.

CAP Revisions

The following identifies the revisions that the CAP made to the inventory and reference case projections thus explaining the differences between this report and the initial assessment completed during January 2007:

- Energy Supply: Lowered emissions to account for changes in reference case assumptions associated with Colorado's renewable portfolio standard (RPS), which was amended upward in 2007 by the state legislature's passage of House Bill (HB) 07-1281 (Renewable Energy Standards):
 - Investor-Owned Utilities (IOUs) to provide 20% renewable energy by 2020
 - Non-IOUs (e.g., municipal utilities and rural electric cooperatives) to provide 10% renewable energy by 2020
 - Incentives for in-state generation, community-based projects, and solar energy
- RCI: Reduced energy consumption in the reference case projections associated with the passage of HB 07-1146 (Energy Conservation Building Codes) in 2007. This bill requires local governments who have building codes to adopt energy efficiency codes for certain buildings.¹¹ Reduction in emissions is accounted for under the RPS adjustment to avoid double counting of emission reductions.
- RCI: Reduced energy consumption in the reference case projections associated with the passage of HB 07-1037 (legislation recently passed requiring that public electric and gas utilities implement demand-side management programs)¹² and Xcel's demand side management commitments under a recent legal settlement, both of which have the effect of limiting demand growth relative to what it would have been in the absence of these factors.¹³
- Waste Management: Revisions to municipal solid waste (MSW) to reflect revisions the US Environmental Protection Agency made to the methods for calculating emissions in US EPA's State Greenhouse Gas Inventory Tool (SGIT; i.e., change was from use of regression equations to LANDGEM model equation):
 - 1990 emissions decrease from 1.6 to 0.8 MMtCO₂e
 - 2020 emissions decrease from 5.7 to 2.7 MMtCO₂e
- Forestry: Removed forest soil organic carbon emissions sink as recommended by the United States Forest Service (USFS). Relative to the January 2007 report, this change removed 7.1 MMtCO₂e of emissions from the forest sink pool for 1990 through 2020.

Key Uncertainties

Some data uncertainties exist in this inventory, and particularly in the reference case projections. Key tasks for future refinement of this inventory and projection include review and revision of key drivers, such as the electricity and transportation fuel use growth rates that will be major determinants of Colorado's future GHG emissions (see Table 2-2). These growth rates are driven

¹¹ <http://www.statebillinfo.com/sbi/index.cfm?fuseaction=Bills.View&billnum=HB07-1146>.

¹² <http://www.statebillinfo.com/sbi/index.cfm?fuseaction=Bills.View&billnum=HB07-1037>.

¹³ Comprehensive Settlement Agreement, docket 04A-214E, 04A-215E, and 04A-216E, issued December 3, 2004, available at <http://www.xcelenergy.com/docs/corpcomm/SettlementAgreementFinalDraftclean20041203.pdf>

by uncertain economic, demographic, and land use trends (including growth patterns and transportation system impacts), all of which deserve closer review and discussion.

Perhaps the variable with the most important implications for GHG emissions is the type and number of power plants that will be built in Colorado between now and 2020. The assumptions on VMT and air travel growth also have large impacts on projected GHG emissions growth in the state. Finally, uncertainty remains on estimates for historic and projected GHG sinks from forestry, which can greatly affect the net GHG emissions attributed to Colorado.

Chapter 3

Residential, Commercial, and Industrial Sectors

Overview of GHG Emissions

The residential, commercial, and industrial (RCI) sectors are between them the third largest direct source of gross greenhouse gas (GHG) emissions in Colorado, if emissions from the generation of the electricity they consume are not included. Direct use of oil, natural gas, coal, and wood in the RCI sectors accounted for an estimated 21.2 million metric tons (MMt) of carbon dioxide equivalent (CO₂e) (18%) of gross GHG emissions in 2005.¹ Energy-related direct emissions result principally from the on-site combustion of natural gas, with smaller contributions by on-site combustion of coal and oil. The release of CO₂ and fluorinated gases (hydrofluorocarbons [HFCs], perfluorocarbons [PFCs]) during industrial processing, the use of sulfur hexafluoride (SF₆) in the utility industry, and the leakage of HFCs from refrigeration and related equipment accounted for an additional 2.9 MMtCO₂e in 2005. Including industrial process emissions, the RCI sectors are directly responsible for about one-fifth of Colorado's current gross GHG emissions (24.0 MMtCO₂e in 2005).

Considering only the direct emissions that occur within buildings and industries, however, ignores the fact that nearly all electricity sold in the state is consumed as the result of residential, commercial, and industrial activity. If the emissions associated with producing the electricity consumed in Colorado are considered, RCI activities are associated with over half (about 55%) of the state's gross GHG emissions.² The State's future GHG emissions therefore will depend heavily on future trends in the consumption of electricity and other fuels in these sectors. Figure 3-1 shows historical and projected RCI GHG emissions by fuel and source, and illustrates the large fraction of RCI emissions associated with electricity use. RCI emissions associated with electricity and natural gas use are expected to rise by roughly 35% between 2005 and 2020, from around 60 MMtCO₂e in 2005 to about 80 MMtCO₂e in 2020.

Key Challenges and Opportunities

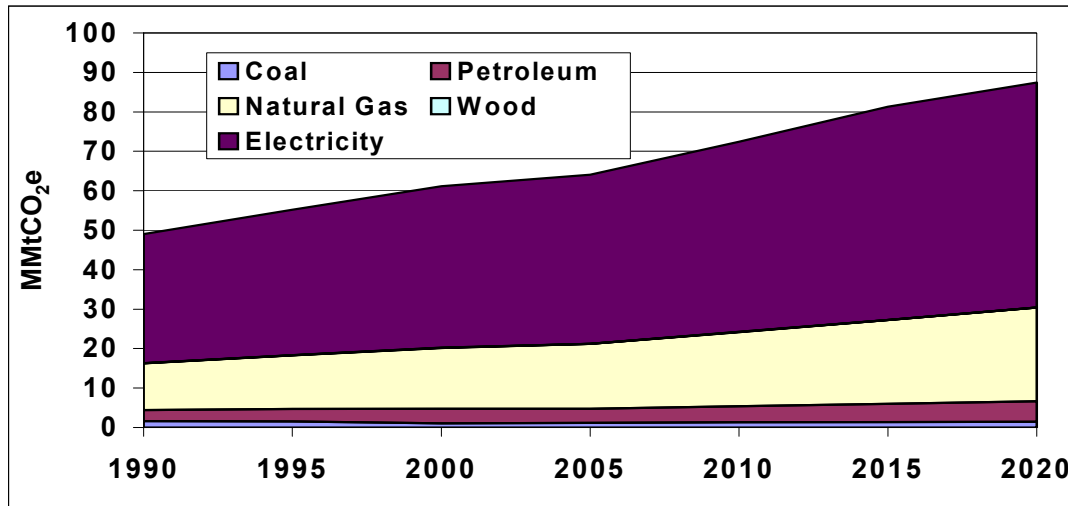
The principal means to reduce RCI emissions include improving energy efficiency, substituting electricity and natural gas with lower-emission energy resources (such as solar water heating, passive solar heating, and geothermal heat pumps), and various strategies to decrease the emissions associated with electricity production (see Chapter 4, Energy Supply). The state's relatively limited pursuit of energy efficiency until recent years offers abundant opportunities to reduce emissions through programs and initiatives to improve the efficiency of buildings, appliances, and industrial practices. At the same time, Colorado faces high growth in population (relative to the national average) and new construction, underscoring the importance of

¹ Emissions estimates from wood combustion include only nitrous oxide (N₂O) and methane (CH₄). Carbon dioxide emissions from biomass combustion are assumed to be "net zero", consistent with US EPA and Intergovernmental Panel on Climate Change (IPCC) methodologies, and any net loss of carbon stocks due to biomass fuel use should be accounted for in the land use and forestry analysis.

² Gross emissions here denote GHG emissions from activities in Colorado, adjusted for exports of electricity, oil, and gas, but not including consideration of estimated "sinks" of GHGs in the forestry and land-use sectors.

integrating energy efficient design principles into buildings that will contribute GHG emissions for many years to come, while still reducing the carbon footprint of the existing stock.

Figure 3-1. Historical and projected residential, commercial, and industrial (RCI) GHG emissions from fuel consumption in Colorado, 1990 to 2020



Colorado has already taken important steps in this direction. Two recently-passed pieces of legislation are particularly relevant for the RCI sectors: HB07-1146 and HB07-1037. HB07-1146 requires Colorado jurisdictions with building codes to adopt the 2003 IECC standard. HB07-1037 directs gas and electric investor-owned utilities (IOUs) to implement additional or new energy efficiency programs. This law requires electric companies to reduce a certain amount of energy consumption and peak demand by 2018. The energy and demand reduction for electric IOUs are set equal to 5% of the energy consumption and peak in 2006. HB07-1037 also requires gas companies to spend 0.5 % of their annual revenue on energy efficiency programs. Aside from these recent legislative actions, Xcel Energy has committed to implementing expanded and new demand-side management (DSM) under a recent legal settlement. These actions indicate growing momentum for improving energy efficiency and reducing GHG emissions.

There are significant opportunities to reduce GHG emissions growth attributable to the RCI sectors in Colorado, including updating building codes on a regular basis, expanding DSM efforts in areas with pre-existing programs and implementing DSM in areas that do not, and promoting beyond code building practices. The Climate Action Panel (CAP) has also identified significant opportunities to reduce GHG emissions through policies addressing electricity production such as tapping into Colorado’s bountiful wind and solar resources (these are detailed in Chapter 4).

Overview of Policy Recommendations and Estimated Impacts

The CAP recommends a set of 11 policies for the RCI sector that offer the potential for significant GHG emission reductions in the state. The GHG emissions reduction for nine of these policies were quantified, and the costs per ton of GHG avoided were quantified for seven. The nine policy recommendations with estimates for potential avoided GHG emissions could lead to emissions savings from reference case projections of:

- 15 MMtCO₂e per year by 2020, and
- cumulative savings of over 86 MMtCO₂e from 2007 through 2020.³

The seven recommended policies for which costs were quantified could result in net cost savings of over \$150 million through the year 2020 on a net present value (NPV) basis.⁴ The weighted average cost of these policies is a net savings of \$2 per MMtCO₂e.

Among the CAP members present and voting, nine recommendations were accepted by unanimous consent, one by super majority (5 or fewer objections) and one by simple majority. These recommendations and results are summarized in Table 3.1. For each of two recommendations (RCI-1 and RCI-6), at least one CAP member expressed qualifications about support for the recommendation, but did not object to it.

The explanations of the objections and the qualified votes of approval are included in the detailed policy recommendations in Appendix E.

Recommended policies RCI-1, 2, 3, 4, 5, 6, 7, and 11 are all focused on DSM, but are distinguished by their different approaches, their focus on varied types of energy use, or the specific energy users they target. RCI-1 and RCI-5 involve implementing general DSM programs on a widespread basis. In contrast, RCI-2 targets state and local government buildings, and RCI-6 focuses on existing commercial and industrial buildings. RCI-4 covers the government, residential, and commercial sectors but focuses on incorporating energy efficiency into the design of new buildings. RCI-7 implements a specific technology (smart meters coupled with time-of-use rates) to increase awareness of energy consumption in the private sector. The goal of RCI-11 is to build an incentive for reducing energy use into electricity rates without collecting additional revenues.

Both RCI-8 and RCI-9 involve energy production at the site of use. RCI-8 involves promoting renewable energy systems, and RCI-9 focuses on increased implementation of combined heat and power in the state. Recommended policy RCI-10 provides free technical assistance to businesses for reducing carbon emissions in several areas, including renewable energy, energy efficiency, water, transportation, and solid waste.

Policies RCI-1, 2, 5, 6, 7, 8, 9, 10, and 11, as well as commercial and residential components of RCI-4, are all structured to provide incentives for energy efficiency or other measures to reduce GHG emissions. RCI-3 (building codes) and the government component of RCI-4 involve mandatory implementation of measures to reduce energy consumption.

³ Note that these savings figures were calculated relative to a baseline that does not include emission savings from recent actions such as HB07-1037 and a recent Xcel settlement, discussed in the text. However, the reference case forecast does include the effect of these actions. Note also that the emissions savings and costs of a number of the policy recommendations were not quantified.

⁴ The net cost savings, based on fuel expenditures, operations, maintenance, and administrative costs, and amortized, incremental equipment costs, are shown in constant 2005 dollars. All NPV analyses here use a 5% real discount rate.

Table 3-1. Summary list of RCI policy recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
RCI-1	Expand demand side management programs of all electric and gas utilities, ramped up to reduce energy use by 1% per year by 2013.	0.6	5.2	24	–\$853	–\$32/ton	Unanimous Consent (Several qualified approvals)
RCI-2	Revolving loans to reduce energy use in state and local government buildings.	0.2	0.5	3.7	–\$67	–\$18/ton	Super Majority (1 objection)
RCI-3	Upgrade the state’s energy requirements for local building codes every 3 years, and improve enforcement of building codes.	0.3	2.7	13.0	N/A	N/A	Unanimous Consent
RCI-4 (total)	Targets and programs for beyond-code reductions in energy use in new government, residential, and commercial buildings.	1.0	2.4	20.4	\$1,550	\$76/ton	Unanimous Consent
	<i>Government subtotal:</i>	<i>0.4</i>	<i>0.6</i>	<i>6.0</i>	<i>\$348</i>	<i>\$58/ton</i>	
	<i>Commercial subtotal:</i>	<i>0.5</i>	<i>1.4</i>	<i>11.2</i>	<i>\$1,219</i>	<i>\$109/ton</i>	
	<i>Residential subtotal:</i>	<i>0.2</i>	<i>0.4</i>	<i>3.2</i>	<i>–\$17</i>	<i>–\$5/ton</i>	
RCI-5	Inverted electricity block rates for all residential and commercial consumers to fund utility energy efficiency programs.	1.6	6.7	38.2	–\$1,135	–\$30/ton	Majority (7 objections)
RCI-6	Low interest loans to fund energy efficiency retrofits for commercial and industrial buildings.	0.5	1.8	11.7	–\$334	–\$28/ton	Unanimous Consent (2 qualified approvals)
RCI-7	Electricity smart metering with time-of-use rates and in-home or in-office displays for all residential, commercial, and industrial consumers.	2.0	2.6	25.4	–\$844	–\$33/ton	Unanimous Consent
RCI-8	Tax credits for renewable energy systems in new and existing residential, commercial, and industrial buildings.	N/A	N/A	N/A	N/A	N/A	Unanimous Consent
RCI-9	Promote commercial and industrial combined heat and power (CHP) systems.	0.3	1.4	8.3	–\$25	–\$3/ton	Unanimous Consent
RCI-10	Statewide program for voluntary GHG reductions by businesses.	0.6	1.0	4.5	N/A	N/A	Unanimous Consent
RCI-11	Inverted electricity block rates for all residential and commercial consumers, recovering only cost of service.	N/A	N/A	N/A	N/A	N/A	Unanimous Consent
	Sector GHG reduction total of 9 analyzed policies after adjusting for overlaps among policies	3.7	15	86	N/A	N/A	
	Sector cost-effectiveness total of 7 analyzed policies with cost analysis after adjusting for overlaps among policies				–\$153	–\$2 /ton	

GHG = greenhouse gas; MMtCO₂e = million metric tons of carbon dioxide equivalent; MWh = megawatt hours.

Negative cost numbers indicate cost savings.

The cost (savings) shown are calculated in terms of net present value in constant 2005 dollars, using a 5% annual real discount rate for the period 2008 through 2020. Capital investments are represented in terms of levelized or amortized costs through 2020.

There is overlap in the expected emissions reduction and cost among some of the policies within the RCI sector. Many of the policies in the RCI sector affect similar types of energy use, although some policies (such as RCI-1) are defined by their usage reduction goals, while others (such as RCI-2, financing for energy efficiency improvements in state and local government buildings) are defined by addressing a specific type of energy use. Overlaps are expected to occur where policies have no specific funding mechanisms that would set them apart from other measures to reduce energy use. RCI-5, for example, which involves increasing block rates set to generate revenue to support aggressive DSM, is expected to subsume the electricity component of RCI-1 which is defined solely in terms of a usage reduction goal. In contrast, natural gas savings targets (part of RCI-1), financing for government building efficiency improvements (RCI-2), incentives for incorporating beyond-code energy efficient design in new government, residential, and commercial buildings (RCI-4), and financing retrofits for commercial and industrial buildings (RCI-6) each have dedicated funding sources and thus do not overlap. Encouraging implementation of combined heat and power (CHP) systems (RCI-9) is not a DSM program so it does not overlap with the various DSM policies. Implementing the Climate Wise program statewide (RCI-10) is self-funded and is expected to have much of its impact on non-electricity energy consumption. Similarly, RCI-3 focuses on building efficiency codes for new structures and is unlikely to overlap with other policy options.

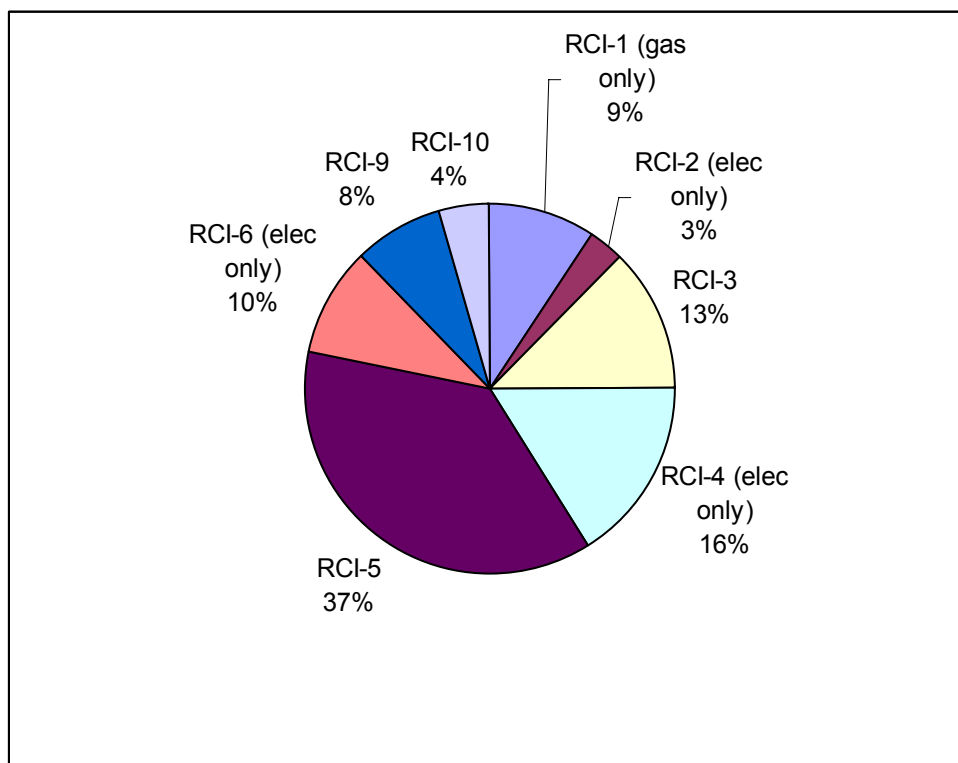
Between sectors, the recommended policies for the RCI sectors decrease overall electricity demand and thereby reduce the impact of the renewable portfolio standard (RPS) recommended under ES-2. ES-2 requires that a certain percentage of electricity sales come from renewable sources (see chapter 4). RCI-8 may also overlap with ES-2 and provide no incremental benefit, as new renewable energy sources on buildings would qualify towards this policy option.

See Appendix D, Methods of Quantification, for additional description of overlaps among sectors and of analyses of the cumulative GHG reductions from the combined effects of the CAP policy recommendations that were quantified.

The CAP policy recommendations described briefly here, and in more detail in Appendix E, result not only in significant emissions and costs savings, but offer a host of additional benefits as well. These benefits include reduction in spending on energy by homeowners and businesses; reduced risk of power shortages, energy price increases, and price volatility; and improved public health as a result of reduced pollutant emissions by power plants.

Figure 3-2 shows the breakdown of impacts of the recommended RCI policies, taken together, in terms of avoided GHG emissions (2007–2020).

Figure 3-2. Percent of avoided greenhouse gas emissions by policy



Residential, Commercial, and Industrial Policy Descriptions

The RCI sectors include emissions reduction opportunities related to improving energy use efficiency and using lower GHG energy sources.

RCI-1 Expanded Energy Efficiency and Demand Side Management

The CAP recommends, by unanimous vote of those members present and voting, with several votes of qualified approval, that Colorado increase the efficiency of electricity and natural gas use in the state through increased investment in DSM programs. Energy efficiency is the lowest cost resource for reductions in electricity and natural gas use by the residential, commercial and industrial sectors. Improving energy efficiency is a “win-win” strategy—it saves consumers and businesses money; it reduces the need for costly and controversial new power plants; it cuts pollution emissions when less fuel is burned in a home, commercial building, factory, or power plant; and it lowers energy imports. There is a long track record of cost effective energy efficiency initiatives, typically called DSM, at the local, state and regional levels in areas around the country. There is vast potential for improving the energy efficiency of homes, appliances, businesses and industry in Colorado.

The goal of this policy is to bring the total demand reduction of two recent DSM actions (House Bill 07-1037, enacted in 2007, and a commitment to additional DSM action by Xcel Energy as

part of a legal settlement) plus new, additional DSM activities in the state to a 1% reduction per year by 2013, and continuing at that rate through 2020. In the year 2020, about one-third of the goal of this policy would be achieved by those two recent actions and about two-thirds by the new actions contemplated to achieve the goal. The policy would apply to the entire state's gas and electric producers, suppliers, and customers. Because some rural cooperatives or municipal utilities do not have existing DSM programs, a five year ramp-in is recommended to allow time to establish infrastructure.

RCI-2 Energy Efficiency in Buildings Owned by State and Local Governments

Revolving loan funds are proven and effective tools for promoting energy efficiency in state and local government facilities. This policy would facilitate investment by public agencies in energy efficiency improvements by providing zero interest loans. Utility cost savings would provide cash flow for repayment of principle, so that the cost of the program would be limited to interest payments and loan administration. In addition to saving energy dollars, participating governments will demonstrate leadership in conservation principles.

The CAP recommends, by supermajority vote of those present and voting, with one objection, the use of a revolving fund providing zero-interest loans to achieve a 20% reduction in energy use by buildings owned by state and local governments, including schools. Measures would be implemented in stages over a five-year period.

RCI-3 Strengthening and Enforcement of Building Codes

Stronger building energy codes can be a very effective way to eliminate the least efficient energy approaches in new or renovated buildings. The International Energy Conservation Codes (IECC), updated every three years through an exhaustive consensus process involving a large number of code officials and building experts, have become a widely accepted standard. Many Colorado jurisdictions have adopted the 2003 IECC standard, and more will do so as a result of legislation (HB07-1146) recently signed by the Governor. The IECC must be enforced, however, and enforcement can be spotty in many building jurisdictions. Building code jurisdictions need to be encouraged to enforce the IECC with training, technical support and education. Enforcement is a critical element in the success of any code, but it may be particularly important for the success of policies that must be undertaken during planning and construction, such as RCI-4.

The CAP recommends, by unanimous vote of those members present and voting, a gradual increase in energy efficiency code for new construction in Colorado following the progress of the IECC, backed up by strong, consistent enforcement measures.

RCI-4 Planning and Design

The CAP recommends, by unanimous vote of those members present and voting, aggressively pursuing energy conservation through attention to building design, to ensure that the next generation of buildings in Colorado produces much lower GHG emissions per unit of utility. The CAP suggests a policy of mandating building design to a very high efficiency standard for

government-owned buildings, and aggressively encouraging voluntary efforts to design residential homes and non-government commercial buildings to very high efficiency standards. Specifically, this policy would:

- Mandate that of all new construction and major renovations of government-owned buildings, including schools and publicly-owned hospitals, 30% reduce energy consumption 37% consistent with LEED™ Gold and the other 70% reduce energy consumption 30% consistent with LEED Silver.
- Encourage voluntary efforts to attain a 15% reduction in energy consumption by new residential homes consistent with the Energy Star “high performing” standard (see HPH100.org for definition). The goal is to reach 70% of new residential units.
- Promote voluntary efforts to achieve a 50% to 70% reduction in energy consumption (with increasing in stringency over time) through the design of new commercial buildings. The goal is to reach 70% of new commercial buildings.

Property tax credits can be leveraged for promoting voluntary residential and commercial efforts. Other approaches should be considered to gain participation by state and local governments.

RCI-5 Inverted Block Rates to Fund Energy Efficiency

The CAP recommends, by majority vote of those members present and voting (with seven objections), use of a tiered, increasing surcharge on electricity rates to simultaneously provide a source of funding for energy efficiency and a financial incentive to adhere to high energy efficiency (low energy intensity) standards. Unlike a traditional public benefits charge, the surcharge would grow with increasing use above target levels, and high efficiency consumers would pay no surcharge.

The CAP recommends that these rates be applied to the Residential and Commercial sectors, statewide (consistent with the implementation mechanisms established by HB07-1037, but municipal utilities and cooperatives would have the alternative of participating in a System Benefits Charge.) Under this policy, proceeds above cost-of-service recovery would be used to fund residential and commercial energy efficiency programs. It is suggested that surcharge energy use thresholds be consistent with recent utility experience with inverted block rates, e.g., Southern California Edison’s Residential Baseline Allocation.

RCI-6 Retrofitting Existing Buildings for Energy Efficiency

Existing commercial and industrial buildings account for roughly 20% of GHG emissions. Because many buildings are extremely inefficient, small efficiency upgrades can result in dramatic reductions in GHG emissions in addition to economic savings. Energy efficiency upgrades can yield significant cost savings to participating businesses, improving competitiveness of businesses and the state. Providing incentives for energy efficiency upgrades can stimulate local business development in energy performance analysis and energy efficiency, as well as reducing GHG emissions and other air pollution.

The CAP recommends, by unanimous vote of those members present and voting, with two votes of qualified approval, that the state provide short-term, low- or no-interest loans to businesses to offset the initial costs of energy efficiency improvements in existing privately owned (e.g., non-municipal) commercial, industrial, and institutional buildings. This policy would seek to reach 5% of buildings per year by 2017, with each participant reducing energy use per square foot by 25% over five years. It could also create low- or no-interest loans to energy service companies who contract with commercial and industrial clients to implement energy-savings measures.

RCI-7 Pricing and Purchasing

Providing electricity consumers with timely, accessible feedback on energy use and cost information can result in reductions in energy use of 4% to 15%. Additionally, smart metering can save operating and maintenance expense to electric utilities and their customers by 1) reducing labor cost due to remote meter reading, 2) enabling better outage management, and 3) providing more accurate meter reading and consumption forecasting.

The CAP recommends, by unanimous vote of those members present and voting, further investigation into implementing smart metering in Colorado, combined with time-of-use rate schedules and in-home displays, to enable electricity consumers to better manage energy use. Specifically, the CAP recommends:

- A legislatively-prescribed Colorado Public Utilities Commission study of a mandatory investor-owned utility program combining advanced metering infrastructure, time-of-use electricity rates, and end-user energy displays. The study would weigh the energy cost savings, peak reduction benefits, and GHG benefits against the cost of the program. Costs would be considered from both the customer and the utility perspective. The study would use Colorado-specific assumptions to determine the most cost-effective technologies and programs to apply by customer class, and
- Based upon the results of the study, adoption of mandatory time-of-use rates for all commercial and industrial customers, as well as residential customers, and
- Installation of advanced metering infrastructure with two way communications (smart meters), and
- Installation of end-user energy displays with hourly usage, pricing, and GHG emissions display capabilities, and
- Allowing full recovery for the costs of the program through the utility ratemaking process if the program is proven cost-effective.

RCI-8 Renewable Energy Systems on New and Existing Buildings

Renewable energy, when combined with energy efficiency measures, can dramatically lower CO₂ emissions from energy production required to heat, light, cool, and otherwise power new and existing residential, commercial, and industrial buildings. Efforts to promote the installation of active and passive renewable energy systems, such as passive solar heating and cooling, domestic solar hot water, and wind, will complement many other efforts being recommended by the CAP.

The CAP recommends, by unanimous vote of those members present and voting, that the state promote wider use of active and passive renewable energy systems on all buildings through education and financial incentives in the form of tax credits to businesses, homeowners, and residential rental property owners who install proven and reliable renewable energy systems.

Systems to be included in the mix of renewable energy technologies include passive solar heating, solar hot water, concentrated solar thermal, photo-voltaic solar (PV) on buildings not already covered by the existing RPS, and geothermal (ground-source heat pumps), and possibly other emerging technologies. The CAP recommends that the proposed tax incentives be awarded only to individuals and businesses that have significantly reduced energy consumption prior to or concurrent with system installation.

The policy design includes an educational campaign to assist individuals and businesses in understanding the renewable energy options and requirements of the program. In addition, short-term, low-interest loans from the state and/or tax credits will be available to businesses, and tax credits will be available to homeowners and residential rental property owners, for energy-efficiency upgrades (to enlarge the pool of homeowners, residential property owners, and businesses eligible to take advantage of the renewable energy system tax credit).

RCI-9 Energy Delivery

Combined heat and power (CHP) refers to any system that simultaneously or sequentially generates electric energy and utilizes the thermal energy that is normally wasted. Western Governors' Association (WGA) analysis shows that CHP is an affordable, efficient, clean, and reliable piece of the puzzle for meeting the Western region's energy needs while substantially reducing carbon emissions. The recovered thermal energy can be used for space heating, hot water, steam, air conditioning, water cooling, product drying, or for nearly any other thermal energy need. The end result is significantly more efficient than generating electric and thermal energy separately. In fact, many CHP systems are capable an overall efficiency of more than 80%—double that of conventional systems.

CHP faces barriers to widespread adoption, including inadequate information, institutional barriers, high transaction costs for small projects, high financing costs because of lender unfamiliarity and perceived risk, “split incentives” between building owners and tenants, and utility-related policies like interconnection requirements, high standby rates, and exit fees.

The CAP recommends, by unanimous vote of those members present and voting, further study by the Governor's Energy Office into in-state CHP potential, and implementation of WGA's recommendations with the goal of facilitating the development of 50% of the economic CHP potential.

RCI-10 Implementing Climate Wise Statewide

The CAP recommends, by unanimous vote of those members present and voting, implementing a state-wide, voluntary business program featuring free technical assistance and continuous support as a means for reducing carbon emissions through reductions in energy, water,

transportation, and solid waste, emulating the success of Fort Collins’ “Climate Wise” program. In addition to supporting local businesses and stimulating economic development, the Climate Wise model seeks to facilitate business participation in other programs, thus resulting in additional indirect emissions reductions. The policy complements many of the energy efficiency, waste-diversion, and transportation policies being recommended by the CAP and would implement a state-wide clearinghouse to provide support for start-up of similar outreach, technical assistance, and recognition programs as requested by cities, counties, or agencies state-wide. This program may ultimately be linked to existing and future efforts managed by the Governor’s Energy Office.

RCI-11 Cost of Service Inverted Block Rates

The CAP recommends, by unanimous vote of those members present and voting, that the state consider implementing increasing block rates that would solely be structured to recover cost of service, as in traditional ratemaking. Such a policy might encourage greater levels of energy efficiency based on a price elasticity effect. In contrast to RCI-5, this policy would provide no excess funds to specifically promote energy efficiency programs.

Chapter 4

Energy Supply

Overview of GHG Emissions

Greenhouse gas (GHG) emissions from the Energy Supply (ES) sector in Colorado primarily include emissions from electricity generation, with a lesser contribution from the production and distribution of natural gas. Total emissions from the sector comprise a substantial share of the State's overall GHG emissions (approximately 42% of gross emissions in 2000). Overall, by 2020 ES emissions are expected to increase from 2005 levels by approximately 25% on a production basis, from roughly 40 million metric tons (MMt) of carbon dioxide equivalent (CO₂e) in 2005, to about 50 MMtCO₂e in 2020. On a consumption basis, total GHG emissions to meet the state's electricity demand rise from about 43 MMtCO₂e in 2005 to about 53 MMtCO₂e in 2020. The higher emissions total under the consumption-based approach reflects that Colorado is a net importer of electricity (see also Figure 4-1).¹ Figure 4-2 shows the electricity generation resource mix upon which the emissions inventory and reference case projections are based.

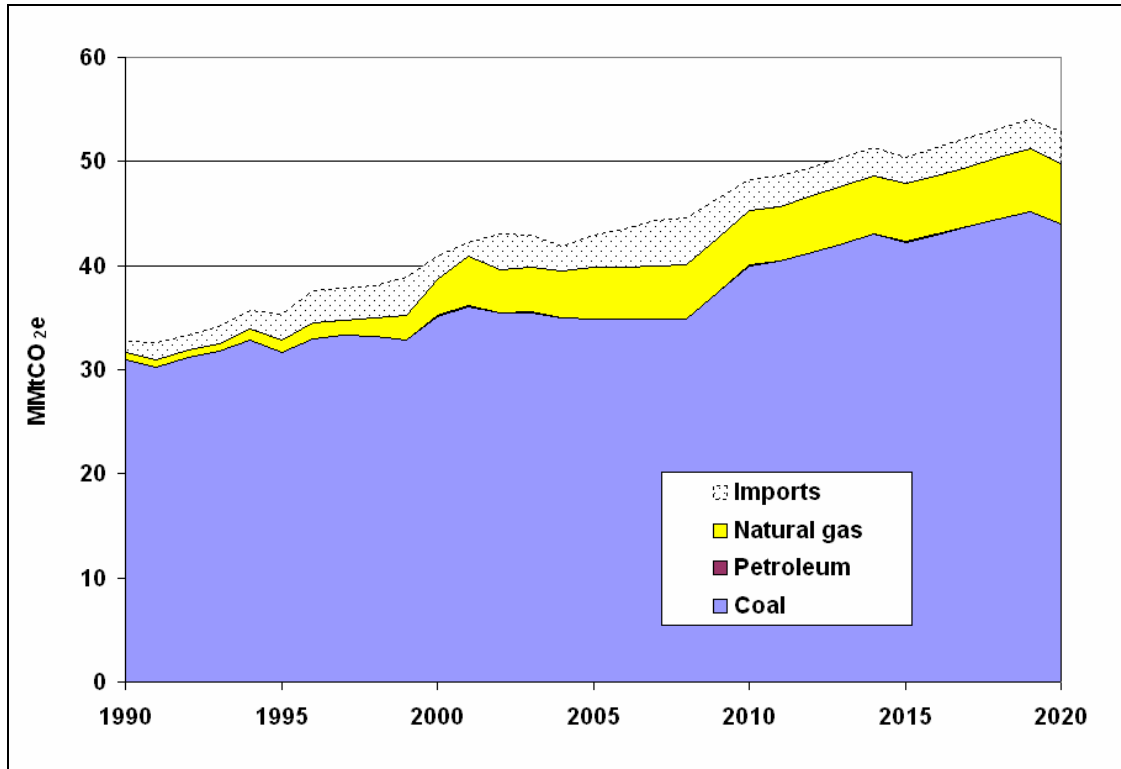
Key Challenges and Opportunities

There are significant opportunities to reduce GHG emissions growth attributable to energy production and supply in Colorado, including diminishing the carbon intensity of electrical generation through greater use of renewable energy options and recapture of waste energy through combined heat and power and other technologies. Opportunities exist for natural gas producers and processors to reduce methane (CH₄) venting, leaks, or combustion and at the same time to enable more product to come to the market, producing a genuine win-win situation. Significant opportunities to reduce GHG emissions through policies addressing electricity consumption also exist and can often provide cost savings. The Climate Action Panel (CAP) has identified several demand-side management, energy efficiency, and conservation measures in the Residential, Commercial, and Industrial Sector, which are detailed in Chapter 3.

Colorado has plentiful renewable energy resource potential in the form of solar and wind energy, unexploited hydropower resources, and possibly untapped geothermal potential. Bringing this resource potential to where electricity is needed presents a challenge to be addressed through coordinated planning of transmission infrastructure for renewables, one of the policies recommended by the CAP in the ES area. Colorado is already a national leader in the strength of its existing Renewable Portfolio Standard (RPS), which mandates that a certain percentage of delivered energy in the state must come from renewable resources. The CAP recommends that Colorado do even better in this crucial and promising area.

¹ Accounting for electricity emissions on a production basis considers the GHG emissions produced by electricity generation facilities in Colorado. This perspective is useful because the state may have different policies it can use to influence electricity suppliers within the state than those outside of the state. Emissions estimates provided elsewhere in this report (including the inventory and forecast) reflect the GHG emissions associated with the electricity sources used to meet Colorado's demands, corresponding to a consumption-based approach. The consumption-based approach can better reflect the emissions (and emissions reductions) associated with activities occurring in the state, particularly with respect to electricity use (and efficiency improvements).

Figure 4-1. Historical and projected GHG emissions from the electric sector, Colorado, 1990 to 2020



Overview of Policy Recommendations and Estimated Impacts

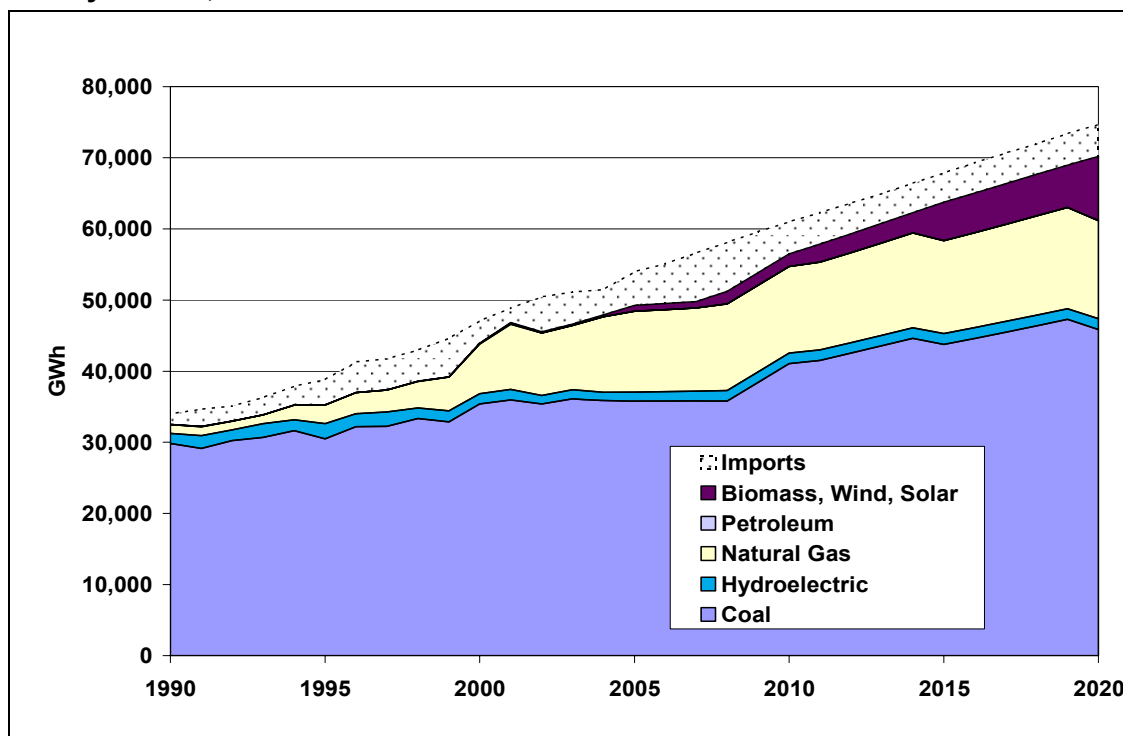
The CAP recommends a set of 15 policies for the Energy Supply sector that offer the potential for significant GHG emission reductions in the state. Six of these have been quantified to estimate the potential for avoided GHG emissions. These six policy recommendations could lead to emissions reductions of

- 9 MMtCO₂e per year by 2020, and
- 59 MMtCO₂e cumulative savings from 2007 through 2020.

Five of the recommended policies have been quantified to estimate the total costs and cost per ton of GHG avoided. For these five policies, the net cost is estimated at \$526 million through the year 2020 on a net present value (NPV) basis.² The weighted average cost of the policy recommendations for which quantitative estimates of both costs and savings were prepared is \$10 per MMtCO₂e.

² The net cost savings are based on fuel expenditures, operations, maintenance, and administrative costs, and amortized, incremental equipment costs. All NPV analyses here use a 4% real discount rate.

Figure 4-2. Historical and projected electricity generation to meet Colorado electricity demand by source, 1990 to 2020



Among the CAP members present and voting, ten recommendations were accepted by unanimous consent, four by super majority (5 or fewer objections) and one by simple majority. These recommendations and results are summarized in Table 4.1. For each of three recommendations (ES-2, ES-5, and ES-6), at least one CAP member expressed qualifications about support for the recommendation, but did not object to it. The explanations of the objections and the qualified votes of approval are included in the detailed policy recommendations in Appendix F.

Recommended policies ES-1, ES-2, ES-3, ES-6, and ES-11 are initiatives that would lead to increased reliance on renewable energy resources in the state, although ES-3 could be implemented on a state, regional, or national level.

Policy ES-4 would direct the state’s energy suppliers to coordinate their efforts to improve transmission infrastructure to support renewable resources. Policy ES-5 addresses applying a price to CO₂ emissions through either a cap-and-trade mechanism or a carbon tax, although neither mechanism is endorsed. Policy ES-7 includes measures to increase the use of highly efficient combined heat and power (CHP), also known as cogeneration, as well as distributed renewable energy resources. Policies ES-8 and ES-10 are both designed to promote carbon capture and permanent sequestration, while Policy ES-9 is designed to provide more general support for emissions reduction technology research and development.

Table 4-1. Summary list of energy supply policy recommendations

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
ES-1	Tax credits and incentives to finance renewable energy generation facilities.	Benefits are quantified in policy ES-2.					Unanimous Consent
ES-2	Increase renewable portfolio standards to 30% for investor-owned electric utilities and 15% for municipal and co-op utilities, with no more than 85% of renewable energy from centralized wind power.	1.9	4.9	34	\$524	\$16/ton	Super Majority (3 objections) (1 qualified approval)
ES-3	Consider adoption of Xcel's clean energy portfolio standard on a state, regional, or national basis.	Non-specific policy was not quantified					Majority (9 objections)
ES-4	Require all electric utilities to plan cooperatively for electricity transmission infrastructure investments that support renewable resources.	Non-quantitative policy proposal analyzed					Unanimous Consent
ES-5	Consider applying a price to CO ₂ emissions (such as cap and trade or tax) on a state, regional, or national basis.	Non-specific policy not quantified					Super Majority (1 objection) (1 qualified approval)
ES-6	Assess a public benefit charge on all electric utility bills to fund renewable energy programs.	Policy not quantified					Super Majority (3 objections) (1 qualified approval)
ES-7	Adopt structural changes to facilitate large businesses and universities to invest in combined heat and power (CHP) and distributed generation (DG) systems.	0.4	1.1	7.3	\$110	\$15/ton	Unanimous Consent
ES-8	Work with neighboring states to form a regional CO ₂ transportation and sequestration collaborative.	Non-quantitative proposal not quantified					Unanimous Consent
ES-9	Low interest loans to Colorado companies and universities for research and development of carbon emissions reduction technology, funded at \$100M/yr through surcharge on all electricity bills.	R&D benefits not quantified					Unanimous Consent
ES-10	Evaluate and, if appropriate, seek funding for advanced fossil fuel generation with carbon capture demonstration project.	Non-specific policy not quantified					Unanimous Consent
ES-11	Statewide mapping & development of small hydro-power, geothermal, and biomass renewable power sources.	0.0	0.8	3.1	\$123	\$40/ton	Unanimous Consent
ES-12	Review costs and emission reduction potential of nuclear power.	Non-specific policy not quantified					Unanimous Consent
ES-13	Adopt policies to promote a 2% increase in efficiency of existing power generators by 2020.	Costs not quantified – savings ca. 1 MMtCO ₂ /year by 2020					Unanimous Consent
ES-14	Reduce GHG emissions from oil and gas operations 35% by 2020.	0.8	2.6	16	\$12	\$0.8/ton	Unanimous Consent
ES-15	Establish a CO ₂ emissions performance standard of no more than 1,100 lbsCO ₂ /MWh for new non-peaking power plants and those older than 60 years.	0.5	2.3	13	–\$14	–\$1/ton	Super Majority (5 objections)
	Sector totals of 6 analyzed policies (including ES-13) after adjusting for overlaps among policies	3	9	59	N/A	N/A	
	Sector totals of 5 policies with cost estimates (not including ES-13) after adjusting for overlaps				\$526	\$10/ton	

GHG = greenhouse gas; MMtCO₂e = million metric tons of carbon dioxide equivalents; MWh = megawatt-hours.

Negative cost numbers indicate cost savings. The cost (savings) shown are calculated in terms of net present value in constant 2005 dollars, using a 5% annual real discount rate for the period 2008 through 2020. Capital investments are represented in terms of levelized or amortized costs through 2020.

Policy ES-12 supports a review of the costs and emissions reduction potential of new nuclear power in the state, although it does not contain a specific recommendation in this regard. Policy ES-13 supports an increase in the efficiency of existing generators in the state, while Policy ES-15 places a strict limit on the emission rates of any new generators either built in or supplying electricity to Colorado. Policy ES-14 addresses reduction of CH₄ leakage in gas operations in the state.

There is overlap in the expected emissions reduction and cost among some of the policies within the ES sector, as well as between policies in the ES, RCI, and AFW sectors. The aggressive RPS recommended under ES-2 overlaps with other policies that promote development of renewable energy technologies that would qualify for credit under the same RPS. These policies include small hydro and other small renewables (ES-11), the distributed generation (DG) component of ES-6, and the landfill CH₄ energy program (AFW-10, discussed in chapter 6). Because of this overlap, these other renewable energy policies would not actually add to the total amount of renewable energy generated in the state if implemented along with the stronger RPS initiative.

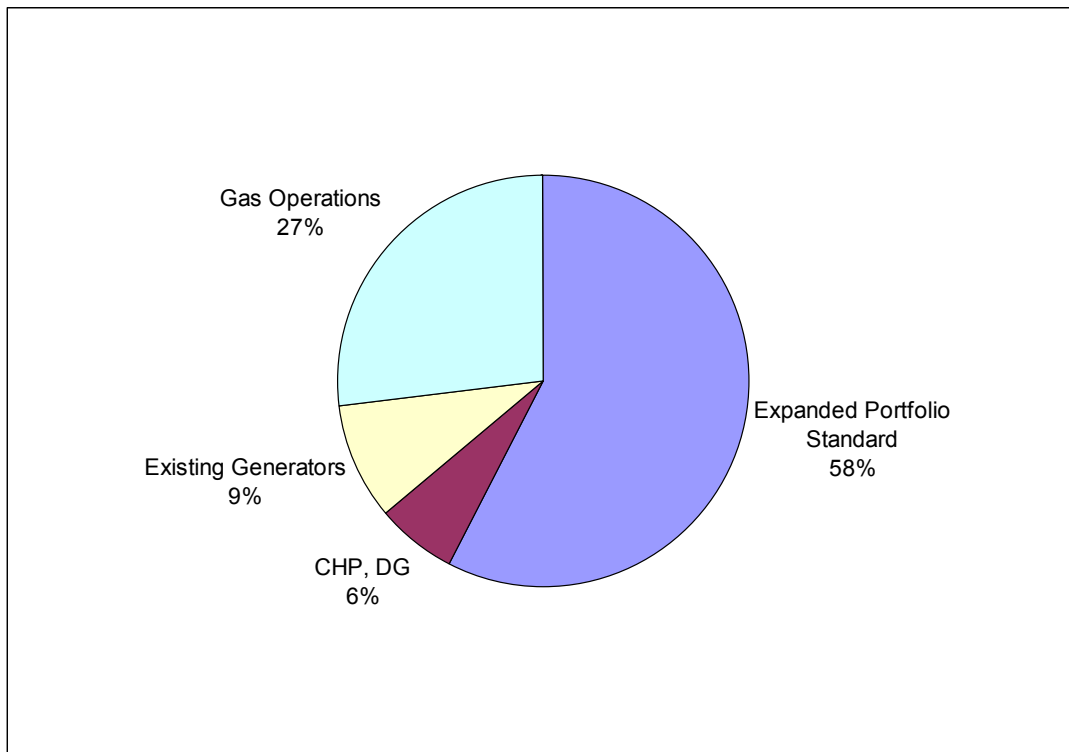
Similarly, the recommended policies for the RCI sectors (see chapter 3) decrease overall electricity demand and thereby reduce the impact of the RPS, which is designed to serve a certain percentage of electricity sales from renewable sources. Because new base load generation would not be needed in the state through 2020 if the RPS is implemented, emissions standards for new base load generation (ES-15) would have no incremental effect on total emissions.

See Appendix D, Methods of Quantification, for additional description of overlaps among sectors and of analyses of the cumulative GHG reductions from the combined effects of the CAP policy recommendations that were quantified.

Of the policies analyzed quantitatively, we find that the aggregate avoided emissions during the period 2007 through 2020 would be 59 MMtCO₂e, or 8.5% of the baseline GHG emissions from energy supply over this period, if all of the ES policies were implemented together. We estimate that the total cost of these policies would be \$526 million dollars (net present value) over this same period, leading to an average cost of about \$10 per ton of CO₂e avoided through these policies.

Figure 4-3 shows the breakdown of impacts of the recommended Energy Supply policies, taken together, in terms of avoided GHG emissions (2007–2020). The strengthened portfolio standards have the biggest impact, by replacing existing fossil-fired generation with carbon-free renewable resources. Second largest is improved natural gas operations, which has a large impact partly because the Global Warming Potential (GWP) of CH₄ is much higher than that of CO₂. Improvements in the efficiency of existing generators and expanded use of CHP and distributed generation also play significant roles. Interestingly, efficiency standards for new generators have no impact during this period when all of the policies are considered simultaneously. The reason for this is that with the aggressive portfolio standard, there is no requirement for any new base load fossil resources during this period.

Figure 4-3. Percent of avoided greenhouse gas emissions by policy



Energy Supply Sector Policy Descriptions

The Energy Supply sector includes emissions mitigation opportunities related to electricity generation and gas production. Electrical energy recommendations include increased reliance on renewable energy resources, improvements in the efficiency and emissions intensity of existing and new generators, measures that would support carbon capture and sequestration for existing generators, and consideration of both a price on CO₂ emissions and construction of nuclear facilities. Also considered are increased use of Combined Heat and Power (CHP) and distributed renewable resources at customer sites. The recommendation for mitigation of emissions associated with gas production is to reduce the leakage associated with the extraction, transportation, and processing of natural gas.

ES-1 Renewable Energy Incentives

Resource maps of renewable energy in Colorado developed by the Department of Energy's National Renewable Energy Laboratories (NREL), based in Golden, Colorado, show that Colorado is well-endowed with renewable resources. Wind is prevalent in the northeast and southeast corners of the state. Biomass is available in the northeast. Photovoltaics can be deployed throughout the state. Concentrating solar power can be tapped in the San Luis Valley. Deep geothermal resources exist in the southern portion of the state. Solar and wind alone may have the potential to produce 100 times the electricity currently used in Colorado, even after

reasonable filters are applied. However, renewables are generally more costly than today's conventional energy supplies. Financial incentives can greatly accelerate the deployment of renewables and allow time for learning curves, economies of scale, and R&D to lower their costs.

Mechanisms include an investment tax credit, an energy production tax credit, tax incentives, and incentives to help support financing of projects. Production tax credits are generally preferred by renewable energy providers that can produce electricity at under about 10 cents per kWh (wind and geothermal), whereas investment tax credits are generally preferred for more expensive technologies (e.g., concentrating solar power). Key to the success of these incentives is that they be guaranteed for a period of at least 5 years to allow time to raise financing and build projects.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado implement financing and/or tax incentives such as these for the first 2,000 megawatts (MW) of renewable resources developed to help meet the renewable energy goals outlined in Policy Recommendation ES-2

ES-2 Renewable Portfolio Standards

A Renewable Portfolio Standard (RPS) is a requirement that utilities must supply a certain percentage of electricity from an eligible renewable energy source(s). For example, an RPS of 5% would mean that for every 100 kWh that a utility supplies, 5 kWh must be generated from renewable resources. About 20 states currently have an RPS, including Colorado. Colorado's current RPS requires investor-owned utilities (IOUs) to provide 20% renewable energy by 2020 and other load serving entities, such as rural electric cooperatives and municipal utilities, to provide 10%, also by 2020. In some states, utilities can also meet their RPS by purchasing certificates from eligible energy projects, typically referred to as Renewable Energy Credits (RECs).

The CAP recommends, by supermajority of those members present and voting (with three objections), and with one qualified vote of approval, that Colorado increase its renewable requirement to 30% for IOUs and 15% for other load serving entities by 2020. The CAP further recommends that the requirement may be satisfied in part through the purchase of RECs following the guidelines of the existing Colorado RPS, except that in-state RECs would be weighted equally to out-of-state RECs.

ES-3 Clean Energy Portfolio Standards

A Clean Energy Portfolio Standard is a variant on the RPS that is more broadly defined to include energy efficiency, clean coal, new nuclear resources, and carbon offsets, as well as renewable energy. This particular policy is based on a proposal by Xcel Energy for a nationwide portfolio standard.

The CAP recommends by simple majority of those members present and voting (with nine objections), that Colorado consider adoption of Xcel’s proposed “clean energy portfolio standard” on a state, regional, or national basis.

ES-4 Transmission Infrastructure for Renewables

Colorado SB 100 provides that utilities regulated by the Public Utilities Commission are required to file maps of generation resource areas that need transmission, and transmission plans to serve those areas, for approval by the PUC by October 31 of each odd-numbered year. This changes the goal of transmission planning and investments by requiring planning and investment for transmission to serve resource areas, rather than for single generators as had been the case in the past. This will break the “chicken and egg” dilemma for new renewable energy projects in the state, where transmission to serve potential wind-power resources could not be built without generators to serve, but no wind project developer could develop a project in an area without transmission already in place.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado amend SP 100 to require joint planning and cooperation by all Colorado utilities and to design “expandable” transmission to serve renewable energy resource zones.

ES-5 Cost for CO₂ Emissions (Cap-and-Trade or Tax)

Establishing a cost for CO₂ emissions is an alternative, and complementary, GHG-control method relative to direct regulations such as energy efficiency standards. The concept is to internalize the cost of emissions in the cost of producing energy, allowing the marketplace find the most efficient reductions. Pricing CO₂ emissions has two primary effects. First, it increases the cost of carbon-based energy to encourage conservation and energy efficiency. Second, it provides an economic advantage to non-carbon-based or lower emissions energy technologies.

There are two basic approaches: cap-and-trade (C&T) and carbon taxes. The cap and trade approach has largely been based on the success of the C&T system for acid rain in the United States. A cap is placed on total GHG emissions, with each unit of emissions represented by a permit that can be traded to find the lowest cost compliance. Typically the caps begin somewhat high (close to current emissions levels) and ratchet down on a pre-determined schedule.

Under the carbon tax approach, the government collects a tax per unit of GHG emissions. The tax collection can be done either upstream (e.g., wellhead, power plant) or downstream (e.g., gas pump, electricity bill). A carbon tax can be designed to be net revenue neutral. That is, the carbon tax revenue collected would be offset dollar-for-dollar by a reduction of some other tax. The revenue offset can be designed to mitigate impact on lower income or vulnerable ratepayers without negating the incentive for conservation.

Hybrid schemes are possible, such as a tax and trade system where an entity facing a large tax liability could offset their taxes through investments in reducing the GHG footprint of another with no or low liability.

The CAP recommends, by super majority of those present and voting (with one objection), and with one qualified vote of approval, that Colorado consider applying a price to carbon emissions (such as cap and trade or a tax) on a state, regional or national basis.

ES-6 Public Benefit Charge Funds

A system benefits charge (SBC) is a small monthly fee assessed on utility bills. The money that is collected is used to fund “public benefits,” which typically include low-income weatherization programs, appliance efficiency rebates, renewable energy rebates, energy efficiency programs, and demand-side management programs. More than twenty states currently assess such charges under a variety of names, including system and public benefits charge, wires charge, access charge, universal service charge and distribution charge. Natural gas utilities can also collect such funds, and a bill to require this has been introduced in the Colorado legislature in past sessions. The current proposal is focused on using SBC funds to support renewable energy development.

The CAP recommends, by super majority of those members present and voting (with three objections), and with one qualified vote of approval, that Colorado impose a \$0.2 cents/kWh or 0.4 cents/kWh public benefits charge, with the funds collected to be spent on new renewable energy resources.

ES-7 Incentives for Combined Heat and Power and Distributed Generation

Financial incentives for combined heat and power (CHP) and distributed generation (DG) can include 1) direct subsidies for purchasing/selling systems given to the buyer/seller, 2) tax credits or exemptions for purchasing/selling systems given to the buyer/seller, 3) tax credits or exemptions for operating systems, 4) feed-in tariff, which is a direct payment to CHP/DG owners for each kWh of electricity or Btu of heat generated from a qualifying system, and 5) tax credits for each kWh or Btu generated from a qualifying system.

Barriers to these resources include inadequate information, institutional barriers, high transaction costs for small projects, high financing costs because of lender unfamiliarity and perceived risk, “split incentives” between building owners and tenants, and utility-related policies like interconnection requirements, high standby rates, and exit fees. The lack of Standard Offer or long-term contracts, payments at avoided cost levels, and lack of recognition of the value of reduced carbon emissions also creates obstacles to widespread implementation. In addition, the availability of net metering would substantially increase the value of certain kinds of DG resources, as any excess energy produced could effectively be sold to the grid at the retail price to offset the cost of purchasing power when additional energy is needed.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado adopt structural changes to facilitate the growth of CHP and distributed generation to 1% each of total fossil fuel generation in the state by 2020.

ES-8 CO₂ Capture and Transport Infrastructure

Carbon dioxide capture and sequestration (CC&S) may represent one future option to significantly reduce the CO₂ emissions associated with electricity generation. One barrier to implementation of CC&S on a wide scale is the absence of a pipeline infrastructure to carry CO₂ to suitable sequestration sites. Another barrier is regulatory uncertainty in key areas such as ownership of underground sequestration resources, regulations, and long-term liability against CO₂ leakage. There are also uncertainties and concerns over potential adverse environmental impacts of carbon storage.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado work with neighboring states and the Western Governors' Association (WGA) to analyze options for a regional CO₂ transportation and sequestration collaborative. The CAP further recommends that Colorado create a workshop process resulting in a written report by state agencies to address various regulatory and environmental uncertainties associated with CC&S.

ES-9 Research and Development for Carbon Emissions Reducing Generating Technology

Research and development (R&D) funding can be targeted toward a particular technology or group of technologies as part of a state program with a mission to build an industry around that technology in the state and/or to set the stage for adoption of the technology for use in the state. For example, an agency could be established to help develop and deploy energy storage technologies. R&D funding can be made available to any renewable or other advanced technology through an open bidding procedure (driven by bids received rather than by a focused strategy to develop a particular technology). Funding can also be given for demonstration projects to help commercialize technologies that have already been developed but are not yet in widespread use.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado create a fund to make low-interest loans to Colorado research companies & universities to support the development of carbon emissions reducing technology. The CAP recommends that this be funded through a 0.2 cents per kWh charge on all electricity sold in the state.

ES-10 Promote Advanced Fossil Fuel Generation with Carbon Capture, Including IGCC

Advanced fossil fuel generation technologies, in combination with CC&S, may offer one option to reduce the CO₂ emissions associated with fossil-fuel based electricity generation. While coal-based generation is the largest source of CO₂ emissions in the state, CC&S may provide a cost-effective pathway to reduce carbon emissions from coal power plants while continuing to rely on an abundant, domestic source of energy. Coal generation with CC&S could be based on integrated gasification combined cycle (IGCC) technology, pulverized coal technology, or some other approach yet to be determined.

The CAP recommends, by unanimous vote of those members present and voting, that the governor and the legislature of Colorado evaluate and, if appropriate, seek funding for a

demonstration project using advanced fossil fuel generation with carbon capture and sequestration.

ES-11 Small New Hydro and Efficiency Improvements at Existing Hydro, Identifying Other Small Renewables and Removing Barriers

Currently, existing hydroelectric plants in Colorado produce about 1,200 GWh of electric energy per year. This energy is produced from plants built in the early 1920s and before as well as relatively newer units. Older plants present opportunities for improvements in efficiency and production including more efficient turbines, upgraded generator windings and replacement of mechanical controls with solid state equipment. The improvement in efficiency and plant production can range from 1%–2% to as high as 25%–30%.

In addition, several studies have suggested there may be 1,000 MW or more of hydroelectric potential in Colorado at existing dams and water impoundments, diversions and conveyance structures.

These facilities are generally owned and operated by entities without expertise in power production. Also, the generation potential of each site is usually small and often overlooked by power providers. In fact, all small renewable resources face barriers similar to these: the site owner rarely has experience in power generation, and power production per site is relatively small, making it more difficult to justify the investment in feasibility studies and other up-front costs.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado expand SB-91 to initiate statewide mapping of the unexploited potential of small hydropower, geothermal, and biomass resources. The CAP further recommends that institutional barriers to the exploitation of these resources be addressed, with the goal of adding 50 MW of such new, small renewable resources to the state's generation mix each year beginning in 2014. Finally, the CAP recommends that a transfer of oversight from the Federal Energy Regulatory Commission (FERC) to state authorities be considered in order to streamline the permitting process for these resources.

ES-12 Nuclear Energy

In 2005, electricity generation accounted for 37% of Colorado's gross GHG emissions on a consumption basis, or about 43 MMtCO₂e. Of that, coal-fired plants emit 35 MMtCO₂e. Since nuclear plants also produce base load power, they are potentially a direct replacement for coal-fired plants.

By unanimous vote of those members present and voting, the CAP recommends that the state initiate a review of the costs and emissions reduction potential of nuclear energy resources.

ES-13 Efficiency Improvements for Existing Generators, including Heat Recovery

Making efficiency improvements at existing generation stations has a number of benefits such as: offsetting the rising cost of fuel, reducing overall emissions and improving plant reliability. This can be done through improvements in both the combustion and steam cycles, as well as with waste heat recovery.

Efficiency improvements at existing generating stations may be hampered by federal regulation, lawsuits and uncertainty. New Source Review (NSR) and New Source Performance Standard (NSPS) regulations need to be clarified and should encourage, not discourage, efficiency improvements such as turbine upgrades, motor, pump, fan and drive improvements, control system upgrades and recovery of waste heat.

Efficiency improvements at existing generating stations may also be hampered by lack of regulatory cost recovery certainty for regulated investor-owned utilities under the jurisdiction of the Colorado Public Utilities Commission (PUC). Public policy could specifically encourage the PUC to allow for the recovery of costs for efficiency improvements at existing generators.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado adopt policies that would lead to a 2% overall improvement in the efficiency of the existing generation fleet.

ES-14 Oil and Gas Operations

There are a number of ways in which GHG emissions in the oil and gas industry, particularly CO₂ and CH₄, can be mitigated. Methane is a potent GHG, so any leaks during production, processing, and transportation/distribution should be addressed. Eliminating these leaks can be economically beneficial because it prevents the waste of valuable product.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado require reductions in CH₄ leakage from gas operations to 35% below 2004 levels by 2020.

ES-15 CO₂ Emissions Standards for Power Plants

A CO₂ emissions performance standard is an emissions standard requiring that all new non-peaking power plants located in Colorado or serving Colorado electricity customers have CO₂ emission no greater than a threshold amount of CO₂ per megawatt-hour (MWh) produced. In addition, to ensure that power providers have the necessary incentives to invest in new low-CO₂ emitting facilities rather than continue to operate aging high-CO₂ emitting plants the standard would also apply to existing facilities once they reach 60 years of age. The allowable emissions per MWh standard is based on the level of emissions of a new efficient natural gas plant.

The CAP recommends by super majority of those members present and voting (with five objections), that Colorado adopt an emissions standard of 1,100 pounds of CO₂ per MWh

produced for all new base load power plants constructed in or serving power to the state, and that this standard also apply to all plants 60 years old or older.

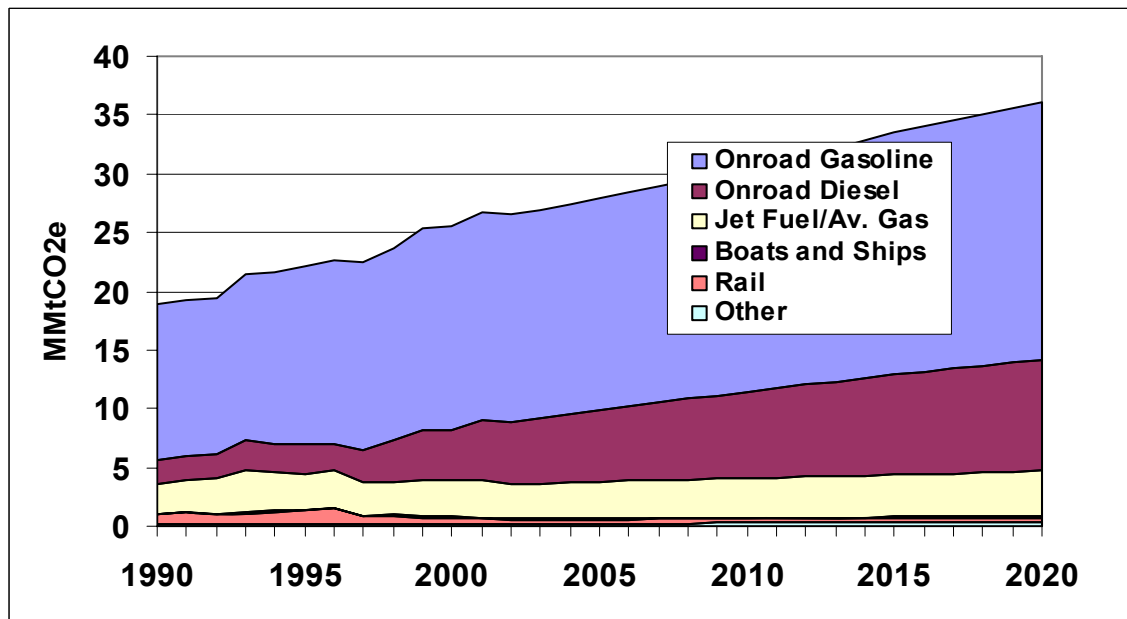
Chapter 5 Transportation and Land Use

Overview of GHG Emissions

The Transportation and Land Use (TLU) sector is a major source of greenhouse gas (GHG) emissions in Colorado, currently accounting for about 24% of the State’s gross GHG emissions in 2005. The transportation technologies and fuels used are key determinants of those emissions, along with population, economic growth, and various land use policies that all affect the demand for transportation services. Colorado GHG emissions from the TLU sector totaled 28 million metric tons of carbon dioxide equivalent (MMtCO₂e) in 2005.

Figure 5-1 shows historical and projected transportation sector GHG emissions by fuel and source, illustrating rapid growth. Total transportation emissions are expected to nearly double between 1990 and 2020, reaching 36.2 MMtCO₂e in 2020 under the reference case projection. Growth in vehicle miles traveled (VMT) will account for most of the increase. VMT from gasoline-fired vehicles is projected to grow by 34% between 2005 and 2020, while VMT from diesel vehicles is projected to grow 68%, largely due to growth in freight movement.

Figure 5-1. Historical and projected GHG emissions from the transportation sector, Colorado, 1990 to 2020



Key Challenges and Opportunities

The principal means to reduce transportation emissions include improving vehicle fuel efficiency, substituting gasoline and diesel with lower-carbon fuels, reducing vehicle travel, and improving the efficiency of transportation system operations. The first three approaches are particularly important areas for policy development at present.

In Colorado and in the nation as a whole, vehicle fuel efficiency has improved little since the late 1980s, yet many studies have documented the potential for substantial increases in efficiency while maintaining vehicle size and performance. Opinions differ on the extent to which vehicle fuel efficiency can be increased in the near term and the impacts of mandated efficiency standards on automakers. Increases in federal fuel economy standards are likely in the near future, but the scale of increase is unknown.

The use of alternative fuels with lower per-mile GHG emissions is growing in Colorado, and larger market penetration is possible. Conventional gasoline- and diesel-fired vehicles can use low level blends of biofuels. Alternative technology vehicles can also use higher level biofuel blends, as well as other types of alternative fuels such as natural gas, electricity, and hydrogen. The type of fuel and its origin are crucial determinants of impacts on GHG emissions, as some alternative fuels have relatively little life-cycle GHG benefit. Currently, the most prevalent biofuel in Colorado is corn-based ethanol, which has minimal GHG benefit from a life-cycle perspective. Ethanol from cellulosic feedstocks can achieve much larger GHG reductions, but the production of such fuels is not yet commercially viable. Fuel distribution infrastructure is also a constraining factor for wide distribution of many alternative fuels.

The reduction of per capita VMT is a critical component of mitigating GHG emissions from the transportation sector. Expanded use of smart growth land use patterns can contribute substantially to this goal by reducing trip length and encourage the use of transit, ridesharing, bicycling, and walking. A variety of pricing policies and incentive packages can also help to reduce VMT. Some localities in Colorado have taken steps to increase transit options and encourage smart growth. The development of better planning methods and regulations and the increase of funding in support of alternative modes of transportation will be key mechanisms to achieve these goals.

Overview of Policy Recommendations and Estimated Impacts

The CAP recommends a set of 11 policy recommendations for the TLU sector that offer the potential for major economic benefits and emissions savings. All 11 recommendations were adopted by unanimous consent of the CAP members present and voting. These policy recommendations could lead to emissions reductions of

- 7.8 MMtCO₂e per year by 2020,
- 47 MMtCO₂e cumulative savings from 2007 through 2020, and
- \$3.2 billion net cost savings to the Colorado economy through the year 2020 on a net present value (NPV) basis.¹

The weighted average cost of the policy recommendations for which quantitative estimates of both costs and savings were prepared is -\$141 per ton of CO₂e.

¹ The net cost savings are based on fuel expenditures, operations, maintenance, and administrative costs, and amortized, incremental equipment costs. All NPV analyses here use a 5% real discount rate.

The estimated impacts of the individual policies are shown in Table 5-1. The CAP policy recommendations are described briefly here and in more detail in Appendix G of this report. The recommendations not only result in significant emissions and costs savings, but offer a host of additional benefits as well.

Table 5-1. CAP-recommended policies and results for the transportation and land use sector

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
TLU-1	Reduce light-duty vehicle miles traveled 2% by 2020 by promoting “smart growth” land use planning and development. Require that GHG emissions be considered in long-range transportation plans by 2010.	0.08	0.47	2.43	Less than \$0	Less than \$0/ton	Unanimous Consent
TLU-2	Incentives for the purchase of low-GHG vehicles. [An alternative if the TLU-6 clean car standards are not implemented.]	Quantified as part of TLU-6					Unanimous Consent
TLU-3	Reduce light-duty vehicle miles traveled 6% by 2020 by improving transit service quality and funding expansion of transit infrastructure.	0.17	0.97	5.09	N/A	N/A	Unanimous Consent
TLU-4	Reduce heavy-duty vehicle idling.	0.07	0.11	0.91	–\$123	–\$134/ton	Unanimous Consent
TLU-5	Adopt a low carbon fuels standard that will reduce carbon intensity of passenger vehicle fuels by 10% by 2020.	0.38	2.21	16.1	N/A	N/A	Unanimous Consent
TLU-6	Adopt California GHG emission standards for cars and trucks.	0.70	3.40	18.8	–\$1,880	–\$100/ton	Unanimous Consent
TLU-7	Expand transit use marketing and employer-sponsored transit fare programs.	Quantified as part of TLU-3					Unanimous Consent
TLU-8	Move toward basing motor vehicle insurance on the distances vehicles are driven.	0.32	0.94	7.19	Less than \$0	Less than \$0/ton	Unanimous Consent
TLU-9	Local parking management programs to encourage alternative travel choices and transit-oriented development.	0.03	0.03	0.34	–\$37	–\$110	Unanimous Consent
TLU-10	Require employers with more than 100 employees to offer commuter benefits programs.	0.42	0.45	4.77	–\$1,145	–\$240/ton	Unanimous Consent
TLU-11	Incorporate vehicle maintenance, operation, and transportation choice GHG reduction information in driver training and education.	Not quantified					Unanimous Consent
	Sector GHG reduction total of 8 analyzed policies after adjusting for overlaps among policies	2.14	7.84	46.7	N/A	N/A	
	Sector cost-effectiveness total of 4 analyzed policies with cost estimates after adjusting for overlaps among policies				–\$3,185	–\$141/ton	

GHG = greenhouse gas; N/A = not applicable.

* Cumulative Net Present Value and Cost-Effectiveness values reflect options 4, 6, 9, and 10 only. Cumulative Net Present Value and Cost-effectiveness values for all options cannot be quantified.

Negative cost numbers indicate cost *savings*. The cost (savings) shown are calculated as in terms of net present value in constant 2005 dollars using a 5% annual real discount rate for the period 2008 through 2020. Capital investments are represented in terms of levelized or amortized costs through 2020.

These benefits include reduced local air pollution, more livable, healthy communities, and economic development and job growth. In order for the TLU policies recommended by the CAP to yield the levels of savings described here, the policies should be implemented in a timely, aggressive, and thorough manner.

Technology is an important component of the recommended policies. The State Clean Car program (TLU-6) would result in the largest GHG reduction of any single TLU policy recommendations. However, before Colorado or any other state can adopt it, U.S. EPA must grant a waiver approving the original California GHG standards for new vehicles. If for any reason Colorado is not able to implement the Clean Car Program, other technology-based policies could play a larger role. For example, the policies to be studied under the Incentives for Purchase and Operation of Low-GHG Vehicles (TLU-2) could improve fuel efficiency through a multi-state “feebate” program. Such a program would be revenue-neutral, assessing a fee on relatively high emissions/low fuel economy vehicles and offering a rebate or tax credit on low emissions/high fuel economy vehicles. A multi-state approach to feebates is recommended because of the drawbacks of Colorado, or any other state, acting alone in this area.

Other policies can promote technological improvements in the heavy-duty diesel fleet. TLU-4, Heavy-Duty Vehicle Idle Reduction, would limit unnecessary idling by heavy-duty trucks and buses and would promote technological alternatives to extended idling. Less idling means less fuel consumed and fewer GHG emissions.

Colorado can achieve greater alternative fuel use through a combination of voluntary and mandatory measures. A Low Carbon Fuel Standard (TLU-5) can increase the use of alternative transportation fuels that result in lower GHG emissions. The policies recommended in Chapter 6 (AFW-4 and AFW-5) can promote in-state production of these fuels through methods with lower lifecycle GHG emissions. The Low Carbon Fuel Standard would also promote the use of vehicles powered by electricity or hydrogen. When produced from renewable sources, these fuels can dramatically reduce GHG emissions.

A number of policies would work together to reduce VMT by increasing the viability of alternative modes of travel and providing incentives to use alternative modes. These policies will require increased coordination between state government, local government, and businesses in many cases. Smart Growth and Related Planning (TLU-1) presents the greatest institutional challenge. The promotion of more compact and mixed-use development patterns requires significant reform in local planning practices. Yet implementation of this policy is essential to make travel by walking, bicycling, and transit more feasible. In fact, transit use is on the rise nationwide and can be increased in many areas. TLU-3 (Improve and Expand Transit Service) and TLU-7 (Transit Marketing, Promotion, and Pricing Incentives) involve a policy package for the improvement, expansion, and promotion of public transit in Colorado. Commuter Benefits Programs (TLU-10), offered by employers to their employees, also promote use of transit as well as other alternatives to driving to work.

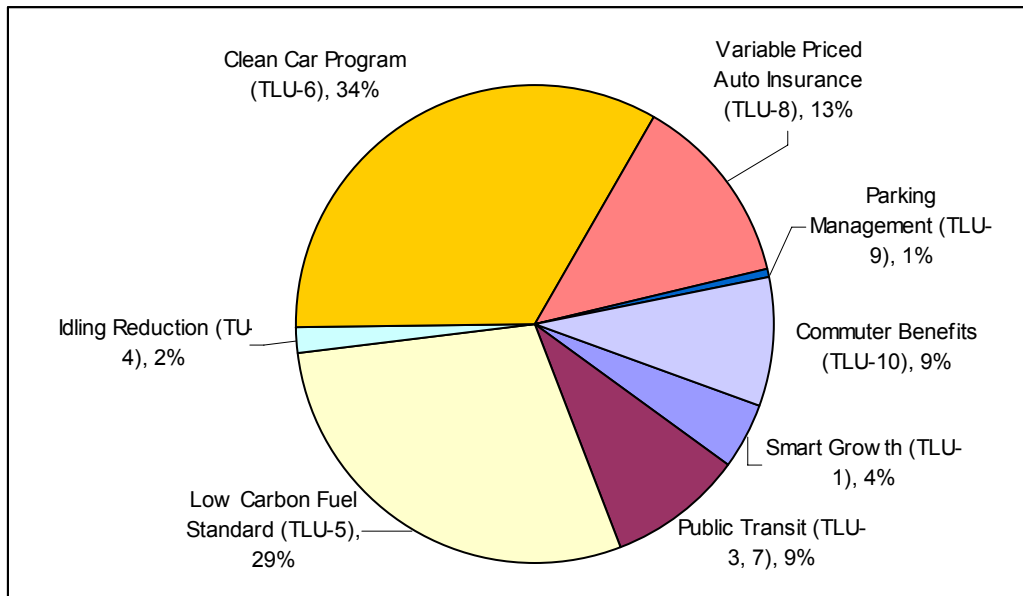
Other policies would change the price or perceived convenience of driving. Variable Priced Automobile Insurance (TLU-8) and Parking Management (TLU-9) increase the attractiveness of alternative modes relative to driving. Together these policies address the built environment, transportation infrastructure, and the behavior of individuals to reduce per capita VMT.

Finally, driver and consumer education provides users of the transportation system with the information they need to make choices that results in lower GHG emissions. TLU-11 would develop a curriculum to be incorporated into all driver training programs to promote voluntary reductions of fuel use and GHG emissions.

There is overlap in the expected emissions reductions among some of the policies within the TLU sector, so the GHG reductions resulting from individual stand-alone policies are not purely additive. In particular, policies that reduce VMT will erode the GHG benefits of policies that improve vehicle fuel economy or reduce fuel carbon intensity (TLU 5 and 6). It was assumed that there is no overlap among the policies that affect VMT (TLU-1, 3/7, 8, 9, and 10), so the VMT effects of these policies were summed to arrive at an adjusted statewide VMT (by vehicle class and urban/rural designation). Using the adjusted VMT, statewide fuel use and GHG emissions were calculated, and this result was reduced by the impacts of TLU-5 and TLU-6. TLU-4 affects only heavy-duty vehicles and therefore has no overlap with other policies. There is no overlap between TLU policies and those from the other sectors. More detail on the calculation of net cumulative impacts is included in Appendices D and G.

Figure 5-2 illustrates the distribution of total (2007-2020) emission reductions by policy recommendation. The Clean Car program (TLU-6) and Low Carbon Fuel Standard (TLU-5) account for the largest shares of emission reduction, together making up 63% of the total reductions from the recommended TLU policies. Variable priced auto insurance (TLU-8), commuter benefits programs (TLU-10), and public transit improvement and expansion (TLU 3/7) each contribute approximately 10% to the total TLU reductions. The other policy recommendations contribute smaller shares.

Figure 5-2. Percent of avoided greenhouse gas emissions by policy



Transportation and Land Use Sector Policy Recommendations

The TLU sector includes emissions and mitigation opportunities related to vehicle technologies, fuel choices, public transit options, and demand for transportation services.

TLU-1 Smart Growth and Related Planning

The CAP recommends, by unanimous vote of those members present and voting, that Colorado implement land use planning, development, and analysis that supports protection of natural and cultural resources, strengthens communities, creates more compact development, and reduces growth in driving and emissions. Specific policies and strategies to be considered and undertaken include the following:

- Provide incentives to developers for density and mixed use.
- Improve techniques for estimating reductions in vehicle trip generation for land uses with mixed use developments.
- Include reductions in estimated traffic generation as a result of intelligently located development.
- Implement a concurrency management system or adequate public facilities requirement.
- Encourage the use of intergovernmental agreements to implement urban growth boundaries.
- Provide a means for local governments to share local sales tax proceeds.
- Implement inter-jurisdictional planning and/or regional review of local plans.
- Program infrastructure investments so as to encourage and reward compact development.
- Undertake local planning for local street patterns prior to development.
- Increase property owners' awareness of conservation easements in Colorado.
- Promote brownfield development through rebates of property taxes to offset cleanup costs.
- Increase funding for a Conservation/ Land Protection Fund.

Together, these Smart Growth policies reduce GHG emissions by giving municipalities the tools needed to shift development patterns and reduce vehicle trips and total vehicle miles traveled.

In addition, the CAP recommends that the Colorado Department of Transportation (CDOT) and metropolitan planning organizations (MPOs) quantify and report GHG emissions from long-range transportation plans by 2010, provided that financial and technical assistance is provided as needed.

TLU-2 Incentives for Purchase and Operation of Low-GHG Vehicles

The CAP recommends, by unanimous vote of those members present and voting, that Colorado further study, develop and/or maintain policies and programs that encourage the purchase of low GHG emission vehicles. These policies include

- Performing a multi-state study of the feasibility and effectiveness of a regional feebate system;
- Continuing the current income tax credit program for hybrid, alternative fuel, and low-emission vehicles so that it continues in its present form beyond 2010; and
- Maintaining current preferential state-controlled infrastructure (high-occupancy vehicle (HOV) lanes) access for alternative fuel vehicles (natural gas, propane, 100% electric) with possible provision of “green license plates” to designate alternative fuel vehicles.

Additionally, the CAP recommends, by unanimous vote of those members present and voting, that tax-funded, non-tax paying entities (state and local governments) be required to purchase the lowest GHG vehicle suitable for their usage. Together, these incentives could change the vehicle fleet technology mix through a combination of demand- and supply-side changes.

TLU-3 Improve and Expand Transit Service

The CAP recommends, by unanimous vote of those members present and voting, that Colorado make improvements to existing transit service and expand current transit routes to reach more of the state’s population. The provision of better and more extensive transit service can shift passenger transportation from single-occupant vehicles to public transit, thereby reducing emissions. This recommendation involves a number of actions to be undertaken by state government, local government, and transit agencies. Transit investments that encourage greater use of public transportation may include

- Improving service frequency on selected existing transit routes,
- Supporting and encouraging improvements in intercity bus service,
- Reducing travel times on selected existing transit routes (e.g., signal prioritization, exclusive lanes),
- Improving service quality on selected existing transit routes (safety, cleanliness, and improvements to shelters/stations), and
- Expanding transit service and infrastructure (commuter rail, light rail, bus, bus rapid transit [BRT]).

TLU-3 also works in conjunction with TLU-7 (Transit Marketing, Promotion, and Pricing Incentives) to reduce VMT growth. TLU-3 is the service and infrastructure component of an overall strategy to increase the mode share of public transit.

TLU-4 Heavy-Duty Vehicle Idle Reduction

The CAP recommends, by unanimous vote of those members present and voting, that Colorado develop and implement a statewide regulation banning extended idling by heavy-duty vehicles. This regulation would reduce idling from diesel and gasoline heavy-duty vehicles, buses, and other vehicles. In addition to the regulation, the policy would promote and expand the use of technologies that reduce heavy-duty vehicle idling. These technologies include truck stop electrification stations as well as vehicle equipment modifications such as auxiliary power units, direct fired heaters, and automatic engine shut down/startup system controls.

The CAP also recommends, by unanimous vote of those members present and voting, that Colorado create programs aimed at increasing voluntary adoption of idling reduction technologies. Components of such programs would include:

- Collaborative outreach and education timed with the implementation and enforcement of a statewide anti-idling regulation
- Conducting pilot projects and demonstrations to evaluate the effectiveness of various idle reduction technologies
- Seeking funding from federal and other sources for such programs.

TLU-5 Low Carbon Fuels Standard

The CAP recommends, by unanimous vote of those members present and voting, that Colorado promote greater use of low-carbon transportation fuels by adopting a “Low Carbon Fuels Standard.” The Low Carbon Fuel Standard would require all transportation fuel providers in Colorado to ensure the mix of fuel they sell into the Colorado market meets, on average, a declining standard for GHG emissions measured in CO₂ equivalent gram per unit of fuel energy sold. Low carbon fuels could include biodiesel, ethanol from cellulosic feedstocks, hydrogen, compressed natural gas, liquefied petroleum gas, and electricity. The program does not mandate that any particular fuel be used to meet the performance standard.

Related elements of this strategy include:

- Fuel Quality Standards
- State Government Fleet ‘Leadership’ Programs for adoption of Low Carbon Fuels
- Low Carbon Fuel Infrastructure Development

The CAP recommends that the Low Carbon Fuel Standard require a reduction in the carbon intensity of passenger vehicle fuels sold in-state by at least 10% by 2020. The standard would be measured in CO₂e grams per unit of fuel energy sold, calculated on a lifecycle basis in order to include emissions from fuel production. Fuel providers (defined as refiners, importers, and blenders of passenger vehicle fuels) would need to demonstrate compliance with the standard.

TLU-6 Clean Car Program for Autos and other Light-Duty Vehicles

The CAP recommends, by unanimous vote of those members present and voting, that Colorado adopt the State Clean Car Program in order to reduce GHG emissions from new light-duty vehicles. Under the current federal law, states have the option of choosing between the federal standard for air pollution emissions and the California standard. This policy assumed the California standards, which must still be approved by US EPA, would take effect in Colorado beginning with Model Year 2011 (calendar year 2010). Other Clean Car Program elements can include standards requiring reductions in smog- and soot-forming pollutants and promoting introduction of very low-emitting technologies into new vehicles.

In 2005, California finalized a set of GHG standards for new light-duty vehicles, to be phased in from 2009 to 2016. The regulations are estimated to result in an average reduction of GHGs from new cars and light trucks of about 22% in 2012 and about 30% in 2016, compared to today's vehicles. States that already have adopted or stated an intention to adopt the Clean Car Program standards include, at least, Arizona, California, Connecticut, Florida, Maine, Massachusetts, Montana, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Utah, Vermont, and Washington.

TLU-7 Transit Marketing, Promotion, and Pricing Incentives

The CAP recommends, by unanimous vote of those members present and voting, that Colorado promote greater use of public transit and a reduction in automobile travel through various forms of marketing and pricing incentives. Travel patterns are affected by public knowledge and attitudes; therefore marketing becomes an important tool in order to increase transit usage. Instead of merely advertising its availability, transit marketing could be an ongoing dialogue between community partners and transit agencies to develop programs in metropolitan areas.

Complementing policy recommendations TLU-3 and TLU-10, TLU-7 would increase the use of transit service by expanding employer-provided transit benefit programs that encourage commuting by transit. Public transit can be made more affordable by offering other price incentives, such as group discounts or discounted pricing for multi-modal purchases. The state would also work with transit agencies to develop and implement new transit marketing programs in metropolitan areas.

TLU-8 Variable Priced Automobile Insurance

The CAP recommends, by unanimous vote of those members present and voting, that Colorado take steps to promote provision of a variable priced automobile insurance. Variable priced insurance transfers some of the fixed cost of annual auto insurance premiums to a variable basis, thereby providing an incentive for vehicle owners to drive less. One form of this concept is "pay-at-the-pump insurance," whereby insurance premiums are paid as a fuel tax surcharge. Another form is Pay-As-You-Drive (PAYD) insurance, whereby a portion of vehicle insurance payments is assessed on a per-mile basis. Benefits of variable priced insurance include emissions

reductions, increased safety (through decreased driving) and fairer distribution of costs (by tracking the portion of individuals' risk associated with miles driven).

The CAP recommends that Colorado change insurance regulations to allow private companies to offer a variable priced insurance option. Additionally, the CAP recommends that Colorado initiate and promote a pilot program of PAYD. Assuming a pilot program is successful, market penetration could increase to 50% by 2020. This could happen either through competitive market pressure (increasing numbers of companies offer it in order to stay competitive) or through a change in state policy mandating insurance companies to offer PAYD at some point after it has been proven to work.

TLU-9 Parking Management

The CAP recommends, by unanimous vote of those members present and voting, that Colorado encourage innovative parking management by local governments as a way to reduce automobile use and encourage infill and transit-oriented development. The location, supply, and pricing of parking can have a major impact on travel decisions, including choice of mode. Parking management refers to policies and programs that result in more efficient use of parking resources. Managing parking by restricting parking availability or encouraging market rate pricing can encourage more transit usage, ridesharing, bicycling, and walking. Reducing requirements for parking supply can also encourage infill and transit-oriented development by lowering the cost of such projects.

TLU-10 Commuter Benefits Programs

The CAP recommends, by unanimous vote of those members present and voting, that Colorado promote commuter benefits programs by employers. Employers can significantly reduce automobile travel by their employees by offering amenities such as free or low cost transit passes, strong telework programs, carpool matching and vanpool subsidies, guaranteed ride home services, parking cash-out, and facilities for bicyclists.

State and local government agencies can offer these programs to their employees and can encourage private employers to offer such programs. Commuter benefits programs could also be part of a larger Colorado corporate climate challenge. The CAP recommends that Colorado adopt an employee trip reduction act and require large employers to participate in an employee trip reduction program. The goal of this policy recommendation is that, by 2010, all employers in Colorado served by a transportation authority or district with more than 100 employees will offer a commuter benefits program.

TLU-11 Driver and Consumer Education

The CAP recommends, by unanimous vote of those members present and voting, that Colorado develop and implement a driver and consumer education curriculum on energy efficient driving behaviors. Drivers will voluntarily reduce fuel use and GHG emissions from their activities when they have the information necessary to make proper decisions.

A driver and consumer education curriculum would address improved vehicle maintenance, improved vehicle operation and improved transportation choice. This curriculum would be a requirement for all driver training programs with questions pertinent to training included on the written/driving portion of private and commercial driver licensing tests. Currently, driver training programs in Utah and Arizona incorporate this type of curriculum in classroom settings.

This policy would also involve a state marketing program for fuel efficient replacement tires and energy efficient driving practices and devices, and training for state and municipal fleet operators.

Chapter 6

Agriculture, Forestry, and Waste Management

Overview of GHG Emissions

The agriculture and waste management sectors together are directly responsible for about 9% of Colorado's current GHG emissions in 2005. For agriculture, gross emissions were 9.6 million metric tons (MMt) of carbon dioxide equivalent (CO₂e) in 2000 (8.8% of Total Gross Emissions). Agricultural emissions include methane (CH₄) and nitrous oxide (N₂O) emissions from enteric fermentation, manure management, agriculture soils and agriculture residue burning. As shown in Figure 6-1, emissions from agricultural soils and enteric fermentation in cattle account for the largest portions of agricultural emissions. The agricultural soils category includes N₂O emissions resulting from activities that increase nitrogen in the soil, including fertilizer (synthetic, organic and livestock) application and production of nitrogen fixing crops. The evaluation of emissions from the agriculture sector includes a study of the net soil carbon flux.¹ Carbon dioxide is either emitted or sequestered as a result of agricultural practices. Net carbon fluxes from agricultural soils have been estimated by researchers at the Natural Resources Ecology Laboratory at Colorado State University, and are reported in the United States (US) Inventory of Greenhouse Gas Emissions and Sinks² and the US Agriculture and Forestry Greenhouse Gas Inventory. For Colorado, Table 6-1 below shows a summary of the latest estimates available from the USDA.³ These data show that changes in agricultural practices are estimated to result in a net sink of -2.0 MMtCO₂e/year in Colorado. Since data are not yet available from USDA to make a determination of whether the emissions are increasing or decreasing, the net sink of -2.0 MMtCO₂e/year is assumed to remain constant.

Although manure management and enteric fermentation comprise a significant portion of the gross agriculture emissions, the contribution of these sources to the total gross agriculture emissions is not projected to increase substantially through 2020. GHG emissions from agricultural burning are estimated to contribute a very small amount to the agricultural sector emissions. Figure 6-1 shows that little growth is expected in emissions from the agricultural sector beyond 2005.

Forestland emissions refer to the net CO₂ flux from forested lands in Colorado, which account for about 34% of the state's land area. As shown in Table 6-2, US Forest Service (USFS) data

¹ "Flux" refers to both emissions of CO₂ to the atmosphere and removal (sinks) of CO₂ from the atmosphere.

² US Inventory of Greenhouse Gas Emissions and Sinks: 1990–2004 (and earlier editions), US Environmental Protection Agency, Report # 430-R-06-002, April 2006. Available at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

³ *US Agriculture and Forestry Greenhouse Gas Inventory: 1990–2001*. Global Change Program Office, Office of the Chief Economist, US Department of Agriculture. Technical Bulletin No. 1907. 164 pp. March 2004. http://www.usda.gov/oce/global_change/gg_inventory.htm; the data are in Appendix B table B-11. The table contains two separate IPCC categories: "carbon stock fluxes in mineral soils" and "cultivation of organic soils." The latter is shown in the second to last column of Table F1. The sum of the first nine columns is equivalent to the mineral soils category.

suggest that Colorado forests and the use of forest products sequestered on average nearly 25 MMtCO₂e per year from 1983 to 1997. An accounting of forest carbon flux is done within several carbon pools: live trees; dead-standing trees; live understory; forest floor; coarse woody debris; forest soil organic carbon; landfills; and harvested wood products. The data show an accumulation of carbon in each of the forest carbon pools during this period, except for the harvested wood products and landfilled forestry waste pools.⁴ These rates of sequestration are assumed to remain constant through 2020. Note that based on the recommendations of the USFS, carbon storage estimates for the forest soil organic carbon pool are not included in the statewide totals because of the considerable uncertainty associated with the estimates.

Figure 6-2 shows estimated historical and projected emissions from the management and treatment of solid wastes and wastewater. Emissions from waste management consist largely of CH₄ emitted from landfills, while emissions from wastewater treatment include both CH₄ and N₂O. In 2000, the waste management sector accounted for 1.7% of total gross emissions in Colorado. Overall, the sector accounts for 2.1 MMtCO₂e in 2005. By 2020, emissions are expected to grow to 3.5 MMtCO₂e/year. The growth in emissions is driven largely by the solid waste management sector, in particular uncontrolled landfills. In 2005, over 45% of the emissions were contributed by the uncontrolled landfills sector. By 2020, the contribution from these sites is expected to be over 50% of the sector totals.

The largest contribution to emissions from the waste management sector comes from landfills (LFs), which fall into one of four categories in Colorado Inventory & Forecast: uncontrolled LFs, flared LFs, Industrial LFs, and landfill gas-to-energy (LFGTE) LFs. Also considered is municipal solid waste (MSW) combustion. However, the Colorado Department of Public Health and the Environment (CDPHE) indicated that no MSW combustion took place between 1990 and 2005. Growth rates for landfill emissions in both controlled and uncontrolled landfill categories were estimated by using the historic (1995–2005) growth rates.⁵

GHG emissions (N₂O and CH₄) from municipal and industrial wastewater treatment were also estimated. Due to data availability, only emissions from meat and poultry processing in the industrial wastewater treatment sector were estimated (and these emissions were held constant at 2005 levels for the forecast). Only about 2% of the emissions were contributed by the industrial wastewater treatment sector in 2005. In 2005, about 13% of the waste management sector emissions were contributed by municipal wastewater treatment systems. By 2020, the contributions from municipal wastewater treatment are expected to remain about the same (at about 11% of the waste management sector emissions).

Overall, gross GHG emissions in the agricultural sector were estimated at 8.9 MMtCO₂e in 2005 and are expected to grow to 9.1 MMtCO₂e by 2020 (an increase of 2.2%). For forestry, the CO₂

⁴ This is not to say that the dead carbon pools (e.g., standing dead, forest floor) are sequestering carbon directly from the atmosphere. These pools accumulate carbon from trees/biomass that transition from a live carbon pool to a dead carbon pool.

⁵ The period from 1995 to 2005 was used since there were a large number of landfill closures during the period from 1987 to 1995 (which could have affected waste management practices). Hence, the post-1995 period is thought to be most representative of waste emplacement rates in the future and subsequent emissions.

sink of -25 MMtCO₂ was forecasted to remain constant through 2020 (due to significant uncertainties surrounding future development patterns, wildfire activity, and near-term effects of climate change and their impacts on forest size and health). For waste management, 2005 emissions were estimated to be 2.1 MMtCO₂e, and these were forecasted to grow to 3.5 MMtCO₂e by 2020 (an increase of 67%).

Figure 6-1. Historical and projected GHG Emissions from the agriculture sector, Colorado, 1990 to 2020

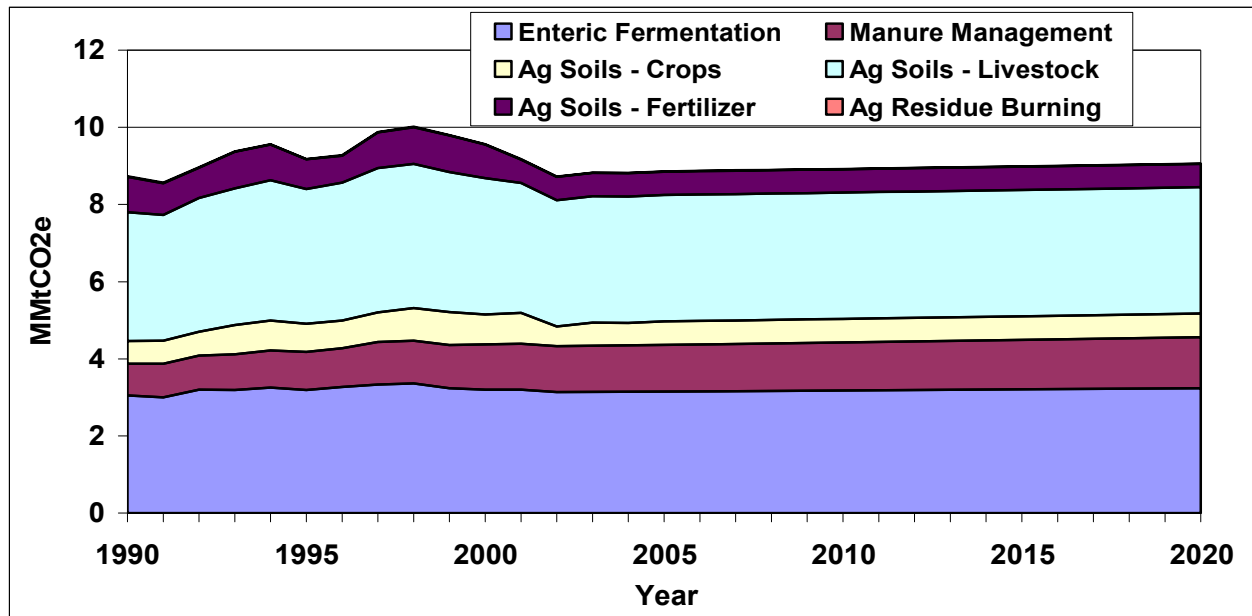


Table 6-1. GHG emissions from soil carbon changes due to cultivation practices (MMtCO₂e)

Changes in Cropland			Changes in Hayland				Other			Total ⁴
Plowout of grassland to annual cropland ¹	Cropland management	Other cropland ²	Cropland converted to hayland ³	Hayland management	Cropland converted to grazing land ³	Grazing land management	CRP	Manure application	Cultivation of organic soils	Net soil carbon emissions
0.77	-0.15	0.00	-0.55	-0.04	-0.26	0.00	-1.25	-0.53	0.00	-2.00

Based on USDA 1997 estimates. Parentheses indicate net sequestration.

¹ Losses from annual cropping systems due to plow-out of pastures, rangeland, hayland, set-aside lands, and perennial/horticultural cropland (annual cropping systems on mineral soils, e.g., corn, soybean, cotton, and wheat).

² Perennial/horticultural cropland and rice cultivation.

³ Gains in soil carbon sequestration due to land conversions from annual cropland into hay or grazing land.

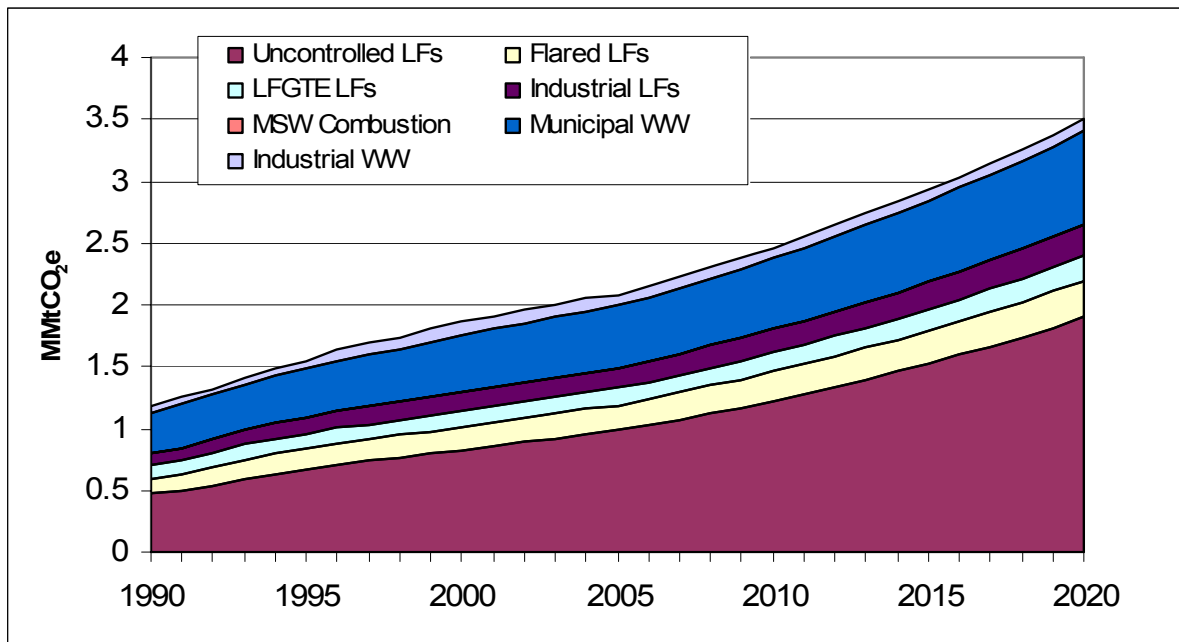
⁴ Total does not include change in soil organic carbon storage on federal lands, including those that were previously under private ownership, and does not include carbon storage due to sewage sludge applications

Table 6-2. GHG emissions (sinks) from forestry

Forest Carbon Pool	1990–2020* MMtCO ₂ e/year
Live and dead-standing trees and understory	-17.7
Forest floor and coarse woody debris	-6.2
Soils	-7.1
Wood products and landfills	-0.8
Total	-31.8

*Based on USFS data from 1987–1997. Flux held constant for the rest of the inventory and forecast period.

Figure 6-2. Estimated historical and projected emissions from waste and wastewater management in Colorado



Key Challenges and Opportunities

Opportunities for GHG mitigation in the AFW sector involve measures that can reduce emissions within the sector or reduce emissions in other sectors. For example, production of liquid biofuels can offset emissions in the transportation or RCI sectors, while biomass energy can reduce emissions in the energy supply or RCI sectors.

In the agricultural sector, the implementation mechanisms for the CAP recommendations should focus on methods that avoid conflict with potential future market-based GHG reduction programs. These include GHG credits that could be generated in the agricultural sector through renewable fuels projects, soil carbon projects, and possibly other project types. New regulations that mandate emission reductions or specific agricultural practices could limit Colorado agriculture from taking part in emerging carbon markets. Implementation mechanisms that are incentive- and education-based can avoid these conflicts.

Production of renewable fuels, such as ethanol or biodiesel from crops, crop residue, forestry residue or MSW, can produce significant reductions when they are used to offset consumption of fossil fuels (gasoline and diesel fuels in the transportation sector). This is particularly true when these fuels are produced using processes and/or feedstocks that emit much lower GHG emissions than those from conventional sources (e.g., conventional corn-based ethanol and soybean-based biodiesel). For ethanol, this means the benefits are dependent on developing in-state production capacity that achieves benefits above the levels of existing and planned (business-as-usual [BAU]) starch-based production. GHG-superior feedstocks/processes could include cellulosic hydrolysis, biomass gasification combined with biofuels production, or alternative starch-based production (fermentation processes fueled by renewable fuels). For biodiesel, the analysis focuses on the incremental benefits of in-state production derived from in-state lower carbon content feedstocks (vegetable oil and algal oil) compared to the importation of out of state feedstock supplies (soybean oil).

Funding and/or incentives will be needed to support the development of biofuels production capacity, including research and development (for production processes and feedstocks) and scale-up of production facilities. In addition to vegetable oil, sufficient planning is needed to promote in-state production for the other primary feedstock to biodiesel (methanol or ethanol).

Agricultural crop management programs that incentivize growers to improve crop management practices can result in gains in soil carbon sequestration and reductions in additions of the nutrients that produce N₂O emissions as well as in emissions from fossil fuel combustion used during application. On-farm energy efficiency programs to reduce fossil fuel and electricity use can also provide significant GHG reductions. Improving the availability of information to farm operators is crucial for the success of these policies. Additionally, some of the strategies that require initial capital investments may prove difficult to implement if financing and/or incentives are not made available.

Source reduction, enhanced recycling and composting reduces future landfill CH₄ emissions potential, while source reduction and recycling reduces emissions associated with the manufacturing of products and packaging from raw materials, as well as their distribution. While the reduction benefits from the goal of 75% less materials being landfilled is relatively ambitious, it is attainable, as evidenced by the results of aggressive programs nationwide. A broad suite of implementation mechanisms will be needed to achieve this goal, which include education and public involvement; economic support; technical research and assistance; legislative actions; and state “lead by example” actions.

By protecting high carbon value forested lands and grasslands from conversion to developed uses, the carbon in above-ground biomass and below-ground soil organic carbon can be maintained and additional emissions of CO₂e to the atmosphere can be avoided. To achieve these reductions, the state will need to work closely with local planning agencies, land owners, and non-governmental organizations to identify lands suitable for acquisition/conservation easements and funding mechanisms. A related challenge is that there is limited capacity within the state for crop production to support biofuels feedstock production without the use of cropland that is currently enrolled in the federal Conservation Reserve Program.

Expanded use of biomass energy from residue removed from forested areas during treatments to reduce fire risk can achieve GHG benefits by offsetting fossil fuel consumption (either to produce electricity or heat). Success can be achieved through close cooperation between Colorado, federal agencies (USFS), and private industry to identify biomass resources and effective end uses for the resource.

The recommendation for significant expansion of urban tree planting and maintenance programs in the state could achieve higher levels of carbon sequestration in the urban forest, as well as provide energy savings in residential and commercial buildings (e.g. from shading and wind protection). Attaining the goal of 4.4 million trees planted by 2020 will require a commitment from municipalities and promotion by the state.

Overview of Policy Recommendations and Estimated Impacts

The CAP adopted by unanimous consent of those present and voting a set of ten policy recommendations for the AFW sector that offer the potential for major economic benefits and emissions savings. For each of four recommendations (AFW-2, AFW-4, AFW-5, and AFW-10), at least one CAP member expressed qualifications about support for the recommendation, but did not object to it. The explanations of the qualified votes of approval are included in the detailed policy recommendations in Appendix H.

The total GHG reductions from reference case projections are estimated to be 11.5 MMtCO_{2e} per year by 2020, a cumulative savings of 66 MMtCO_{2e} from 2007 to 2020. The net present value of the costs is approximately \$252 million over the same period.⁶ The weighted average cost of saved carbon from the policies for which quantitative estimates of both costs and savings were prepared was \$4 per metric ton of CO₂ equivalent.

The estimated impacts of the individual recommended policies are shown in Table 6-3. This summarizes the effects of the AFW policies within the AFW sectors, but it should be noted that these policies achieve emission reductions not only from the AFW source sectors, but in other source sectors as well (e.g., transportation sector due to consumption of biofuels produced; energy supply or RCI from biomass energy production).

Improving agricultural crop management methods (AFW-1) has been estimated to result in significant benefits by 2020 (0.78 MMtCO_{2e}/year). Improved cultivation methods can provide increases in soil carbon, reductions in nutrient-related emissions, and will reduce all GHG emissions that result from the combustion of fossil fuels in farm equipment. This final reduction is captured under AFW-1, rather than AFW-3 (Reductions in On-Farm Energy Use).

AFW-3 examines on-farm energy efficiency measures. The GHG benefit associated with the implementation of policy AFW-3 is estimated to be 0.64 MMtCO_{2e} in 2020. This policy also has significant cost savings due to more efficient farming practices.

⁶ The net cost savings are based on fuel expenditures, operations, maintenance, and administrative costs, and amortized, incremental equipment costs. All NPV analyses here use a 5% real discount rate.

Table 6-3. CAP-recommended policies and results for the agriculture, forestry, and waste management sectors

	Policy Recommendation	GHG Reductions (MMtCO ₂ e)			Costs (Savings) 2007–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Climate Action Panel Action
		2012	2020	Total 2007–2020			
AFW-1	Achieve no-till operation of half of croplands by 2020 and increase nitrogen fertilizer efficiency by 20%.	0.57	0.78	7.7	–\$57	–\$7/ton	Unanimous Consent
AFW-2	Implement methane capture and energy recovery on manure management projects on 80% of animal feeding operations by 2020.	0.01	0.32	1.8	\$66	\$36/ton	Unanimous Consent (1 qualified approval)
AFW-3	Reduce on-farm petro-diesel use 20% by 2020, and reduce electricity use from fossil fuels 40% through energy efficiency and on-site renewable sources generation.	0.14	0.64	3.8	–\$150	–\$40/ton	Unanimous Consent
AFW-4	Incentives for the production of biodiesel fuel from oilseed crops, waste vegetable oil, or other sources to offset 40% of fossil diesel fuel use by 2020.	0.02	0.22	1.1	\$13	\$12/ton	Unanimous Consent (3 qualified approvals)
AFW-5	Increase in-state ethanol production, using GHG-superior feedstocks and production methods, to 400 million gallons per year above BAU by 2020.	0.39	3.1	15	\$58	\$3/ton	Unanimous Consent (3 qualified approvals)
AFW-6	Preserve forest lands (line 1) and grasslands (line 2) to reduce the rate of conversion to developed uses by 25% by 2020.	0.10 0.05	0.24 0.14	1.7 1.0	\$44 \$31	\$26/ton \$32/ton	Unanimous Consent
AFW-7	Increase the use of biomass from forest health and fire risk treatment for energy production, using 20% of harvested wood by 2020.	0.08	0.20	1.4	–\$104	–\$75/ton	Unanimous Consent
AFW-8	Divert 75% of wastes from landfills by 2020 through source reduction, enhanced recycling, and composting programs.	0.48	4.6	24	\$311	\$13/ton	Unanimous Consent
AFW-9	Control or capture landfill methane to achieve 50% reduction from BAU by 2020.	0.33	1.2	7.5	–\$0.1	–\$0.02/ton	Unanimous Consent
AFW-10	Plant 3.4 million new trees statewide by 2020 through expanded urban forestry programs.	0.03	0.08	0.59	\$40	\$79/ton	Unanimous Consent (1 qualified approval)
	Sector Total of Analyzed Policies After Adjusting for Overlaps	2.2	11.5	66	\$252	\$4/ton	

Negative numbers indicate cost savings.

The cost (savings) shown are calculated as in terms of net present value in constant 2005 dollars using a 5% annual real discount rate for the period 2008 through 2020. Capital investments are represented in terms of levelized or amortized costs through 2020.

Control and utilization of methane is addressed in two policies. Methane can be collected from manure management through the use of anaerobic digesters or other technology (AFW-2). Collection and utilization of CH₄ from landfills (AFW-9) reduces GHG emissions directly from control of CH₄ emissions and indirectly by offsetting fossil fuel use. The CH₄ captured in either policy can then be used to create electricity, steam, or heat to offset fossil fuel use.

Production of ethanol and biodiesel were found to offer substantial GHG reduction potential with an estimated 2020 reduction of 3.32 MMtCO₂e (combined benefit of AFW-4 and AFW-5). This is the benefit from in-state production using Colorado grown feedstocks and GHG-superior production methods (superior to current conventional methods of biofuel production). The benefit is incremental to the benefit achieved via the renewable fuels standard incorporated in TLU Policy 5 (Low Carbon Fuels Standard).

Combining the GHG benefits from the grasslands and forested land preservation policies (AFW-6), 0.38 MMtCO₂e/year in GHG emissions are estimated to be saved in 2020. Also in the forestry sector is AFW-7, which recommends the utilization for energy of biomass feedstocks from forest treatment projects (to reduce fire risk), resulting in a significant potential for GHG benefits (0.2 MMtCO₂e/year by 2020).

In the waste management sector, the CAP is recommending a strong goal for solid waste diversion: 75% overall reduction in landfilling through source reduction, recycling and composting by 2020 (AFW-8). The resulting 4.6 MMtCO₂e per year reduction by 2020 makes this one of the most effective CAP recommendations for GHG reductions.

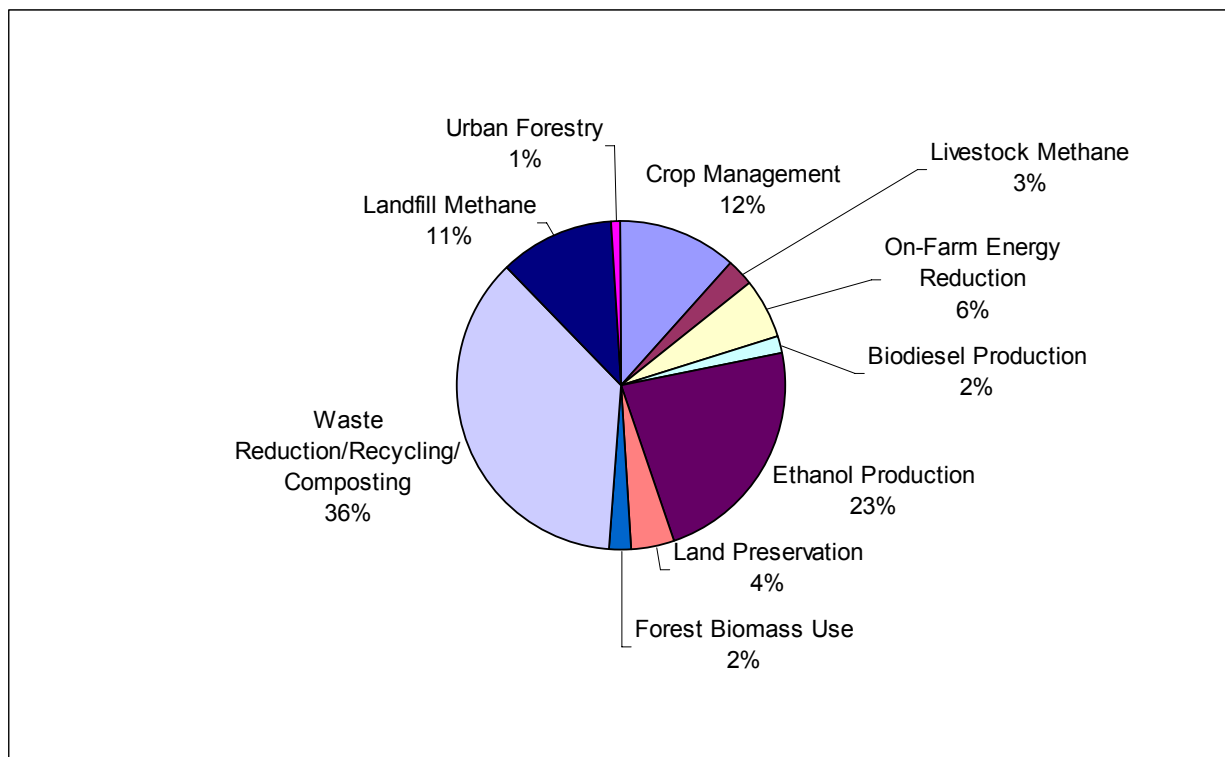
There is overlap in the expected emissions reduction and cost between AFW-9 and ES-2 (Increase renewable portfolio standards) and the quantification of the emission reductions and costs for AFW-9 account for this overlap to eliminate potential double counting. See Appendix D, Methods of Quantification, for additional description of overlaps among sectors and of analyses of the cumulative GHG reductions from the combined effects of the CAP policy recommendations that were quantified.

The CAP policy recommendations described briefly here (and in more detail in Appendix H to this report) result not only in significant emissions savings, but offer a host of additional benefits as well. These benefits include (but are by no means limited to): 1) Support of Colorado agricultural producers in the production of biofuels crops, development of new markets for agricultural byproducts, and training/outreach covering energy production and energy efficiency; 2) Creation of jobs in the biomass energy and liquid biofuels feedstock/production industries; 3) Healthier forests with lower fire risk through the development of markets for forestry residue; and 4) Lower air and water pollution from implementation of several policies in both the agriculture and waste management sector.

Figure 6-3 shows the breakdown of the emission reductions (2007–2020) anticipated from the recommended actions in the AFW sector. The greatest emission reductions achieved (36%) come from implementation of enhanced waste management programs. Under AFW-8, these programs cover source reduction, recycling, and composting. It is important to note that these emission reductions are lifecycle GHG reductions that occur both within and outside of Colorado (resulting from lower energy use and GHG emissions to create, transport, and dispose of new products and packaging that are avoided through source reduction and recycling). In-state production of ethanol using technologies and feedstocks (e.g., cellulosic hydrolysis) that have superior GHG benefits to conventional starch-based ethanol production is also estimated to produce substantial benefits during the policy period. Improvements to crop management that result in higher levels of carbon sequestration in soils and lower amounts of nutrients applied will provide 12% of the total AFW GHG reductions through 2020. Finally, landfill methane

collection and control/use will provide another substantial portion of the overall AFW sector benefit (11%). As with the livestock methane under AFW-2, the reductions under AFW-9 come not only from control of the methane emitted by landfills, but also utilization of this methane as an energy source.

Figure 6-3. Percent of avoided greenhouse gas emissions by policy



Agriculture Forestry and Waste Management Sector Policy Descriptions

The Agriculture, Forestry, and Waste Management Sectors include emissions and mitigation opportunities related to use of biomass energy, protection and enhancement of forest and grassland carbon sinks, control of agricultural CH₄ emissions, production of renewable fuels, methods to increase soil carbon, and source reduction/recycling/composting programs.

AFW-1 Agricultural Crop Management

The amount of carbon (C) stored in the soil can be increased by crop management practices that increase C inputs to soil and/or reduce soil organic matter decomposition rates. Adoption of conservation tillage, in particular no-till, can increase soil C stocks. Reducing mechanical soil disturbance reduces the oxidation of soil carbon compounds and allows more stable aggregates to form. Other benefits of conservation tillage include reduced wind and water erosion, improved

soil structure and crop water use, reduced fuel consumption, and improved wildlife habitat. On non-irrigated cropland, increased cropping frequency to reduce or eliminate summer fallow goes hand in hand with adopting no-till practices. Application of biochar (i.e., stable organic residues from biomass pyrolysis) to soils is a potential practice to capture and sequester atmospheric CO₂.

Improved nutrient management (i.e., better timing, application rates based on soil testing, advanced fertilizer formulations, etc.) of both fertilizer and manure can increase nutrient use efficiency and reduce addition rates, thereby reducing N₂O emissions and potentially fossil fuel use. For some production systems, organic farming practices result in lower net GHG emissions.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado achieve 50% no-till cultivation and increase nitrogen fertilizer efficiency by 20% by 2020.

AFW-2 Manure Management and Energy Programs

The CH₄ emissions inherent from the anaerobic decomposition process of manure and other wastes may be captured and used as an energy source. Methane and N₂O emissions can occur at several different places in the manure management process. Management techniques can also reduce GHG emissions and, with energy recovery, offset fossil-based energy. This policy covers producer incentives to adopt programs to increase the number of CH₄ capture and energy recovery projects or other manure management techniques that reduce CH₄ and N₂O emissions.

The CAP recommends, by unanimous vote of those members present and voting, with one qualified vote of approval, that by 2020 Colorado implement manure management and energy utilization programs on 80% of all animal feeding operations where the application of such technology is feasible and cost-effective.

AFW-3 Reductions in On-Farm Fossil Energy Use

This policy seeks to develop and implement cost-effective programs for renewable energy (solar thermal, solar photovoltaic or PV electricity) and energy efficiency technologies for farmers and ranchers. Reductions in fossil fuel consumption reduce emissions of CO₂, CH₄, and N₂O.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado achieve a 40% reduction of on-farm grid-based electricity use and a 20% reduction in petro-diesel use by 2020.

AFW-4 Biodiesel Production

Provide incentives for the production of biodiesel from oilseed crops, waste vegetable oil, or other sources. Biodiesel use will offset diesel fuel derived from petroleum and will lead to decreased fossil fuel-based CO₂ emissions. This policy emphasizes the supply of biodiesel, accounting for the incremental benefit of using in-state, GHG-superior feedstocks (superior to the conventional national soybean oil feedstock).

The CAP recommends, by unanimous vote of those members present and voting, with three qualified votes of approval, that Colorado produce enough biodiesel using in-state GHG-superior feedstocks to offset 20% of the State's diesel fuel demand by 2020. Recognizing limitations on the amount of cropland that can be devoted to oilseed crops, the assessment of the policy benefits included the need to develop and commercially deploy advanced technologies for feedstock production (e.g. algal oil).

AFW-5 Ethanol Production

Trees, crops and other plants convert atmospheric carbon to carbohydrate or fiber stocks that can be converted to liquid fuels, such ethanol. The use of these renewable, biological fuels can offset fossil fuel use and reduce associated net CO₂ emissions. Production incentives for the conversion of crops, forest sources, animal waste and other sources to ethanol through existing or new technologies can increase the level of ethanol use in future markets. In-state production of ethanol using GHG-superior feedstocks and processes (e.g., cellulosic technologies) offer the highest GHG benefits and complement policies to increase ethanol consumption as part of a low carbon fuels standard (e.g., TLU-5).

The CAP recommends, by unanimous vote of those members present and voting, with three qualified votes of approval, that Colorado increase in-state ethanol fuel output to 400 million gallons per year above business-as-usual (BAU) by 2020. Adoption and deployment of these methods to produce ethanol using GHG-superior methods (superior to conventional corn-based ethanol) will position Colorado's biofuel industry to better meet the fuel needs associated with emerging low carbon fuel standards in the state and region.

AFW-6 Preserve Lands with Carbon Storage Value

The CAP recommends, by unanimous vote of those members present and voting, that the rate at which high carbon lands (i.e., existing grassland and forested land) are converted to developed uses be reduced by 25% by 2020. The carbon stored in soils and aboveground biomass is typically higher in these lands than in developed land uses. Each year, developed areas also typically sequester less CO₂ than high carbon lands. Policies are needed to protect working farms and forests from unwise and unplanned development. Indirectly, this policy also supports important policies in the transportation and land use sector by promoting more efficient development patterns (e.g., TLU-1).

Another element of this policy is to reduce the rate at which permanent grassland in the USDA Conservation Reserve Program is converted to cultivated cropland. Soil carbon stored in retired agricultural land that has been maintained as grassland is reversed when lands are put back to cultivation, resulting in net carbon emissions. Since these *potential* emissions were not included in the reference case forecast of GHG emissions, the benefits for this policy element were not quantified.

The CAP discussed that infestations by mountain pine beetles could affect the extent to which Colorado's forested lands store carbon in the future, but did not have sufficient data to be able to analyze that possible effect.

AFW-7&8 Forest Health and Biomass Feedstocks for Energy Production

A specific focus of this policy is on the potential synergistic objectives of forest fire risk management and bioenergy production. Forest management methods that decrease wildfire risk to communities remove biomass from forests to reduce biomass density or dead/diseased trees. The biomass harvested is typically of low economic value and therefore generally is underutilized (e.g. burned on-site or left to decompose). This policy proposes using this biomass as a feedstock for energy production to yield GHG reduction benefits. Woody biomass feedstocks may also come from other types of forest health management programs such as pest and disease prevention.

Based on data availability, the analysis of this policy focused on forest fire risk mitigation in communities at risk of wildfires in the wildland-urban interface (WUI) of the Front Range Region of Colorado (although the recommended goals apply statewide). The focus on WUI areas was chosen in part because of the significant potential benefits, in terms of avoided costs and other losses, from preventing wildfires in communities. Also, the best available information is for this region of Colorado.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado increase the use of biomass from fire risk treatments to produce energy (specifically institutional heating) to 20% of harvested wood by 2020.

AFW-9 Source Reduction, Enhanced Recycling and Composting Programs

Solid waste that is normally buried in landfills generates CH₄ through decomposition processes. By preventing this source of CH₄, GHG emissions are reduced. Waste can be diverted through a variety of actions including composting, source reduction, recycling, and re-use. Alternatives to landfilling unprocessed organic material (food wastes, agricultural wastes, biosolids, lawn & garden wastes, or other organic materials) include composting and anaerobic digestion. Both alternatives reduce net GHG emissions and anaerobic digestion can also provide a source of renewable energy (CH₄). Source reduction and recycling also reduce product life cycle GHG emissions, including extraction and processing of raw materials, product & packaging manufacture, transport, and final disposal.

The CAP recommends, by unanimous vote of those members present and voting, that through the implementation of additional recycling, organic composting, and source reduction programs, Colorado divert 75% of waste from landfilling by 2020.

AFW-10 Landfill Methane Reduction Programs

Provide incentives that will result in an increase in the recovery of landfill CH₄ for use as an energy source. Increasing the recovery of landfill CH₄ will reduce emissions of this GHG and

will offset the use of fossil fuels for commercial/industrial heat/steam generation or electricity production.

The CAP recommends, by unanimous vote of those members present and voting, with one qualified vote of approval, that Colorado implement controls or waste management practices at municipal solid waste landfills such that 50% of the CH₄ emissions that would be generated under business as usual conditions are avoided by 2020.

AFW-11 Urban Forestry Programs

Urban forest enhancement and management offers a potentially cost effective mechanism to reduce energy use and to store/sequester carbon. Strategic planting of trees to shade houses and air conditioning units can yield energy savings of 15% to 50% on cooling costs.⁷ Planting of shade trees can reduce summer cooling costs, with only marginal increases in winter heating costs, particularly in mild climates. In addition, depending on local conditions, tree planting can reduce wind-speed and further reduce energy costs. This policy seeks to expand existing urban tree planting and maintenance programs, such as Denver's Tree Initiative.⁸

The CAP recommends, by unanimous vote of those members present and voting, that Colorado expand urban tree planting and maintenance programs statewide, such that 3.4 million new trees are planted by 2025.

⁷ Cooling Our Cities, US Environmental Protection Agency PM-221.

⁸ More information on this program can be found at: <http://www.greenprintdenver.org/trees/index.php>

Chapter 7

Cross-Cutting Issues

Overview of Cross-Cutting Issues

Some issues relating to climate policy cut across multiple or all sectors. The Climate Action Panel (CAP) addressed such issues explicitly in a separate policy work group as “cross-cutting” issues rather than assigning them to any individual sector. Cross-cutting recommendations typically encourage, enable, or otherwise support emissions mitigation activities and/or other climate actions. The types of policies considered for this sector are not readily quantifiable in terms of greenhouse gas (GHG) reductions and cost-effectiveness calculations. Nonetheless, if successfully implemented, they would likely contribute to GHG emission reductions and enhance the economic benefits described for each of the 33 quantified policy recommendations that were quantified. Those recommendations are described in Chapters 3–6.

The Cross-Cutting Issues Policy Work Group (CC PWG) developed recommendations for each of nine policies (see Table 7-1) that were then reviewed, revised, and ultimately adopted by the CAP. Eight of the recommendations are focused on GHG emissions reduction; the ninth addresses adaptation to the changes expected from the effects of gases that will remain in the atmosphere for decades.

The statewide goals and targets recommendation (CC-4) is the over-arching CAP recommendation. The CC PWG waited until the last stages of the project to develop the recommendation, in order to be able to consider the GHG reduction policies that emerged from the other policy work groups. Once the emissions reductions potentials and cost-effectiveness of the policies were quantified by the other groups, the CC PWG and in turn the CAP were able to gain a perspective on the scope of the overall reductions that are realistically attainable by 2020.

The CAP chose to recommend goals for emission reductions to be achieved by 2020 and 2050 goals, mindful of scientists’ conclusions that global GHG emissions have to be reduced substantially by 2050, compared to 2000 levels, in order to stabilize global temperatures, and that emission reductions in the next two to three decades will have a large impact on opportunities to achieve that kind of stabilization. Accordingly, the CAP recommends that the Governor of Colorado set goals for reducing GHG emissions in Colorado in the vicinity of a 20% reduction in GHG emissions by 2020 and an 80% reduction by 2050, both compared to 2005 levels. The CAP believes the goals should guide actions in the state, but should not be a firm cap.

Eight of the recommendations were adopted unanimously by the CAP members present and voting. The ninth, CC-4, was adopted by a super-majority, with one objection. Five CAP members expressed qualifications about their support for CC-4, but did not object to it. The explanations of the objection and qualified votes of approval are included in the detailed policy recommendation in Appendix I.

Table 7-1. CAP policy recommendations and results for cross-cutting issues

	Policy Recommendation	Analysis	Climate Action Panel Action
CC-1	Periodically update GHG inventories and forecasts.	<i>Not Quantified</i>	Unanimous Consent
CC-2	State development of annual GHG reporting protocols for all sources, including mandatory reporting for significant sources.	<i>Not Quantified</i>	Unanimous Consent
CC-3	State development of capacity to participate in the national <i>Climate Registry</i> to measure, track, and record emissions reductions.	<i>Not Quantified</i>	Unanimous Consent
CC-4	The governor should set statewide GHG reduction goals and targets to achieve in the vicinity of a 20% reduction by 2020 and 80% by 2050, both compared to 2005 levels.	<i>Not Quantified</i>	Super Majority (1 objection) (5 qualified approvals)
CC-5	Set state and local government reduction targets for their own GHG emissions; the state target should be at least an amount consistent with CC-4 levels.	<i>Not Quantified</i>	Unanimous Consent
CC-6	Promote adoption of comprehensive local government climate action plans.	<i>Not Quantified</i>	Unanimous Consent
CC-7	State and local government public education and outreach efforts to support GHG reduction programs, policies, and goals.	<i>Not Quantified</i>	Unanimous Consent
CC-8	A public-private partnership to seek funding for GHG reduction measures and development of a new energy economy in Colorado.	<i>Not Quantified</i>	Unanimous Consent
CC-9	State government assessment of vulnerabilities to climate change and development of adaptation plans.	<i>Not Quantified</i>	Unanimous Consent

Key Challenges and Opportunities

Recognizing factors such as Colorado’s growth rate, its diverse economy characterized by an entrepreneurial spirit, extraordinary renewable energy resources, universities and agencies rich with talented experts, and overall emissions reduction feasibility, the CAP identified GHG reduction goals that are aggressive, yet achievable. If the 2020 goal were achieved, Colorado’s emissions in 2020 would be reduced 37% to 93 million metric tons of GHGs, compared to 147 under current law. The Colorado target would fall well within the range of statewide emission goals already set by other western states, including Arizona (45% below projected emissions in 2020), Oregon (44%), New Mexico (33%), California (28%), and Washington (28%).

If adopted, the 33 recommendations for emission reductions that were analyzed quantitatively could achieve 75 percent of the 2020 goal chosen by the CAP. While the CAP’s 22 other GHG mitigation recommendations were not readily quantifiable, many of them would likely achieve additional reductions. In addition, other reasonable measures to reduce emissions beyond those recommended by the panel are available now, and emerging technologies hold the potential to substantially reduce emissions even more.

Further reductions might also be realized from a regional approach of states acting cooperatively on reduction strategies. Currently, Colorado is an official observer in the Western Regional Climate Initiative, which was formed to meet regional challenges raised by climate change. Its members, six US states and two Canadian provinces, have set a region-wide GHG reduction goal of 15% below 2005 levels by 2020.

Establishing a GHG inventory and forecasting function within state government is key to the accomplishment of the targets. GHG reporting and registry programs will be more effective if applied on a broad regional or national basis, rather than state by state.

Any regional or national effort involves reconciling the interests and perspectives of the member states, each of which are at much different stages of the learning curve with respect to these and other climate actions. The State of Colorado has joined the effort to develop a national GHG registry through *The Climate Registry*.¹ Being a charter state in this effort should help ensure that Colorado's needs and priorities are addressed in the course of *The Climate Registry*'s development.

The CAP further recommends that Colorado state government and local governments should lead-by-example by reducing their own GHG emissions by at least an amount consistent with the statewide emission reduction goals. The CAP sees a strong role for state government, local government associations (such as Colorado Counties, Colorado Municipal League, and regional Councils of Governments), and RMCO and other non-governmental organizations in promoting GHG reduction initiatives.

Ultimately, public education and outreach will be the foundation for the long-term success of many efforts to reduce GHGs. The CAP recommends that one or more organizations in Colorado, such as state agencies and/or non-governmental organizations, implement a statewide program to encourage and structure voluntary individual actions to reduce GHG emissions.

Another CAP recommendation could achieve GHG reductions while also strengthening Colorado's new energy economy. Envisioned is a state-sponsored clearinghouse to link investment capital and philanthropic funding with business interests entrepreneurs, and researchers pursuing GHG reduction technologies and solutions. As a result, Colorado's ability to identify and secure early business opportunities associated with climate change may be enhanced, increasing its global competitive advantage while creating jobs.

Even if Colorado plays a lead role in both reducing its GHG emissions and helping to bring about reductions elsewhere, it will still face the challenge of living with changes in its climate and a multitude of predicted impacts. The changes Colorado will face in the long term will be more manageable if it begins now to reduce emissions, but now is also the time to begin preparing to deal with the changes that are already underway and likely to become more dramatic. Recognizing that these adaptation efforts are urgent and essential, the CAP recommends that state government conduct a comprehensive assessment of Colorado's vulnerabilities to the effects of climate change and take the lead in developing statewide action plans to prepare for and deal with the most potentially serious categories of adverse climate-change impacts likely in Colorado.

¹ The Climate Registry (<http://www.theclimateresistry.org/>) is a collaboration between states, provinces and tribes aimed at developing and managing a common GHG emissions reporting system with high integrity that is capable of supporting various GHG emission reporting and reduction policies for its member states and tribes and reporting entities. It will provide an accurate, complete, consistent, transparent and verified set of GHG emissions data from reporting entities, supported by a robust accounting and verification infrastructure. As of October 2007, over 40 US states, several Tribal Authorities, two Canadian Provinces, and one Mexico state have joined *The Climate Registry*.

Overview of Policy Recommendations

Following are summaries of each of the nine cross-cutting issue policy recommendations. Detailed descriptions of the individual Cross-Cutting Issues policy recommendations as presented to and approved by the CAP can be found in Appendix I.

Cross-Cutting Issues Policy Recommendation Descriptions

CC-1 GHG Inventories and Forecasts

Greenhouse gas emissions inventories and forecasts are essential for understanding the magnitude of all emission sources and sinks (both anthropogenic and natural), the relative contribution of various types of emission sources and sinks to total emissions, and the factors that affect trends over time. Inventories and forecasts help to inform state leaders and the public on statewide trends, opportunities for mitigating emissions or enhancing sinks, and verifying GHG reductions associated with implementation of action plan initiatives. Responsibility for preparing inventories and forecasts GHG emission sources and sinks often resides with the environmental agency, which typically has the expertise needed to systematically compile information on GHG sources and sinks using established methods and data sources. Inventory and forecast efforts should be on-going over time reflecting improvements to the accuracy and completeness of data collected.

The CAP recommends, by unanimous vote of those members present and voting, that the state institute a formal GHG inventory and forecast function within the Colorado Department of Public Health and Environment (CDPHE) as soon as possible. The CDPHE should develop a periodic, consistent, and complete inventory of emission sources and sinks and an accompanying forecast of future GHG emission that:

- Is in at least 5- and 10-year increments extending at least 20 years into the future.
- Reflects projected growth as well as the implementation of scheduled mitigation options.
- Provides a basis for documenting and illuminating trends in state GHG emissions.
- Is developed with a consistent protocol for preparing the inventory and forecast and for treatment of uncertainties in forecasts.
- Includes all natural and man-made emissions sources and sinks (both anthropogenic and natural) generated within the boundaries of the state (i.e., a production-based inventory approach) as well as emissions associated with energy imported and consumed in the state (i.e., a consumption-based inventory approach).

CC-2 State Greenhouse Gas Reporting

Greenhouse gas reporting reflects the measurement and reporting of GHG emissions to support tracking and management of emissions. GHG reporting can help sources identify emission reduction opportunities and reduce risks associated with possible future GHG mandates by moving “up the learning curve.” Tracking and reporting of GHG emissions can also help in the construction of periodic state GHG inventories. GHG reporting is typically a precursor for sources to participate in GHG reduction programs, opportunities for recognition, and a GHG emission reduction registry, as well as to secure “baseline protection” (i.e., credit for early reductions). Further, collaboration with other states in the development of a GHG reporting program could influence the development of GHG reporting practices throughout the region and nation and build consistency and reciprocity with other state or regional GHG reporting programs.

Accordingly, the CAP recommends, by unanimous vote of those members present and voting, that Colorado develop and implement GHG reporting opportunities for all sources as soon as possible. Mandatory reporting should be required for significant sources as determined by the CDPHE. Subject to consistently rigorous quantification, opportunity to voluntarily report GHG emissions should be open to all sources (e.g., combustion, processes, vehicles, etc.). The GHG reporting framework should include:

- Phase-in by sectors as rigorous, standardized quantification protocols, base data, and tools become available, and as responsible parties become clear.
- Annual reporting on a calendar-year basis for all six traditional GHGs and, to the extent possible, for black carbon.

Consistency with federal, regional, and other states’ GHG reporting programs and quantification protocols in order to maximize consistency and reciprocity with federal, regional, and other states’ GHG reporting programs.

- GHG verification through self-certification and CDPHE spot-checks.
- Appropriate public transparency of reported emissions.

CC-3 State Greenhouse Gas Registry

A GHG registry enables measurement and recording of GHG emissions reductions in a central repository with a “transaction ledger” capacity to support tracking, management, and “ownership” of emission reductions. Registries can help encourage sources to undertake GHG reduction efforts, enable potential recognition for such actions, baseline protection, and/or the crediting of actions by implementing programs and parties in relation to possible emissions reduction goals. Registries can also provide a mechanism for regional, multi-state, and cross-border cooperation. Subject to appropriately rigorous quantification, registration of GHG reductions should not be constrained to particular sectors, sources, or approaches so as to encourage GHG mitigation activities from all quarters.

The State of Colorado has joined the effort to develop a national GHG registry through *The Climate Registry*. Being a charter state in this effort should help ensure that Colorado's needs and priorities are addressed in the course of *The Climate Registry*'s development.

To the extent that Colorado's needs may not be fully met by *The Climate Registry*, the CAP recommends, by unanimous vote of those members present and voting, that Colorado consider developing supplemental or ancillary registry capacity or opportunity as soon as possible.

CC-4 Statewide GHG Reduction Goals and Targets

The overarching purpose of the CAP stakeholder effort is to develop recommendations for actions that can be taken in Colorado to reduce the state's contribution and vulnerability to a changed climate. The GHG reduction goals or targets recommended by the CAP are meant to be consistent with the parallel goal of an efficient, robust Colorado economy. Within this framework, a statewide goal or target can provide vision and direction, as well as a basis for implementation of CAP policy recommendations and regular periodic assessments of progress toward reaching the statewide goal.

Scientists have concluded (1) that global GHG emissions may have to be reduced by 50 to 85% by 2050, compared to 2000 levels, to stabilize global temperature increases at no more than about 4°F, a level that some scientists have suggested represents a threshold of dangerous interference with the global climate; and (2) that emission reductions in the next two to three decades will have a large impact on opportunities to achieve that kind of climate stabilization.²

Consistent with these scientific conclusions, the CAP recommends, by super-majority of those members present and voting (with one objection), and with five qualified votes of approval, that the Governor of Colorado should set goals for the reduction of GHG emissions in Colorado. The CAP believes the goals should be in the vicinity of a 20% reduction in GHG emissions by 2020 and an 80% reduction by 2050, both compared to 2005 levels. The CAP believes the goals should guide actions in the state, but should not be a firm cap. The CAP believes these kinds of goals are realistic because (1) the panel's recommendations that have been analyzed quantitatively would achieve most of the emission reductions that would be needed to meet such a 2020 goal; (2) other panel recommendations that were not analyzed quantitatively would lead to additional reductions; and (3) other reasonable measures to reduce emissions beyond those recommended by the panel are available now, and more will become available in the future.

CC-5 State and Local Government GHG Emissions (Lead-by-Example)

State and local government is responsible for providing a multitude of services for the public that are delivered through diverse operations and result in wide-ranging GHG emission activities. State and local governments can take the lead in demonstrating that reductions in GHG

² See "Summary for Policy Makers" in R. Bosch, R. Dave, and L. Meyer (eds), *Climate change 2007: Mitigation: Contribution of Working group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge, United Kingdom, and New York, NY, 2007), especially pages 22-23.

emissions can be achieved by analyzing their own current operations, identifying significant GHG sources, and implementing changes in technology, procedures, behavior, operations, and the services provided. State and local governments can also encourage and/or incent GHG reductions by others in a variety of ways.

The CAP recommends, by unanimous vote of those members present and voting, that state and local governments establish GHG reduction targets for their own GHG emissions. Colorado state agencies should reduce emissions by at least an amount consistent with the statewide emission reduction goals established under CC-4. The state's efforts to lead-by-example in reducing its own GHG emissions should start immediately. The state should report annually to reflect its progress in reducing GHG emissions, preferably based on the performance of individual agencies and departments. A multi-agency group should oversee the on-going climate efforts of the government's agencies or departments, review their performance, and provide direction, guidance, resources, shared approaches, and recognition to agencies or departments and their employees that are working to reduce the government's GHG emissions. The CAP recommends that local agencies use this model for monitoring and reporting progress on reducing their own GHG emissions.

CC-6 Comprehensive Local Government Climate Action Plans

A number of local governments in Colorado have already taken the initiative to address climate change in their communities. Aspen, Boulder, Denver, Fort Collins, Telluride, and Frisco are just a few examples of local communities that are establishing GHG reduction goals and developing plans to reduce GHG emissions. Additionally, several communities are partners of the RMCO, and many have signed the Mayors Climate Protection Agreement. The CAP strongly encourages all local communities in Colorado to develop such plans. Additionally, the CAP sees a strong role for state government, local government associations (such as Colorado Counties, Colorado Municipal League, and regional Councils of Governments), RMCO, and other non-governmental organizations in promoting GHG reduction initiatives by local governments and in serving as a clearinghouse for local government initiatives. State government, local government associations, RMCO and others could help spread the successful actions and efforts of some local jurisdictions broadly to others through several means, such as workshops and conferences, a website clearinghouse, education and outreach to public and municipal officials, recognizing local government GHG emission reduction achievements, etc.

The CAP recommends, by unanimous vote of those members present and voting, that Colorado promote adoption of community climate action plans by all local governments to set and achieve local GHG reductions and to help achieve state GHG reduction goals. To the extent possible, these plans should:

- Be used to stimulate equivalent GHG reduction initiatives by the private sector and non-governmental entities in each community. These
- Include adaptation-oriented strategies.
- Include an assessment of opportunities for reducing GHG emissions by element at the community scale.

- Specific goals or targets and a timeline for the emissions reductions.
- Consideration of urban planning processes, land use management activities, transportation management planning, management of municipal power and water utilities, and waste management.

CC-7 Public Education and Outreach

Public education and outreach can provide significant GHG emission reduction through direct individual action, as well as broad public support for other GHG emissions reduction programs, policies, or goals. Broad awareness of climate change issues and effects (including co-benefits, such as clean air and public health) is necessary to engage citizens in actions to reduce GHG emissions. Ultimately, public education and outreach will be the foundation for the long-term success of all the mitigation actions proposed by the CAP as well as those which may evolve in the future.

The CAP recommends, by unanimous vote of those members present and voting, that the state and local communities establish pro-active public education and outreach capabilities, using them to target education and outreach activities to at least six specific audiences: policymakers (legislators, regulators, executive branch, agencies); (2) younger generations; (3) community leaders and community-based organizations (e.g., institutions, municipalities, service clubs, social and affinity groups, non-governmental organizations, etc.); (4) general public; (5) industrial and economic sectors; and (6) particular sectors (users of public lands, forest industry, farmers, ranchers, etc.). Attached to Appendix I is a set of recommended strategies specific to each of these audiences.

The CAP further recommends that one or more organizations in Colorado (e.g., state agency and/or non-governmental organization) implement a statewide program to encourage and structure voluntary individual actions to reduce GHG emissions. Such a program might be called “Colorado Climate Keepers” and echo models in other states and local communities. Public education and outreach efforts should commence as rapidly as possible, and should include a coordinated effort between state government, local governments, RMCO, water districts, metropolitan districts, fire protection districts, regional Councils of Governments, and others.

CC-8 Establish a Pro-active Public-Private Partnership to Seek Investment Capital and Philanthropic Funding for Reducing GHG Emissions and Supporting Development of the New Energy Economy in Colorado

The intent of this policy recommendation is to encourage and facilitate the involvement of funding and investment sources, business interests, and entrepreneurs in pursuing business opportunities associated with GHG reductions and global warming solutions as quickly and as significantly as possible. The creation of this clearinghouse-like entity may make it possible to match technology developers and other climate solution entrepreneurs with necessary financing more effectively and expeditiously. In addition, this clearinghouse-like entity should also assist in matching funding sources with research and development efforts as well as to support successful scale-up and commercialization of new products and services. As a result, Colorado’s

ability to identify and secure early business opportunities associated with climate change may be enhanced, increasing its global competitive advantage and job creation within the state.

Potential funding sources include philanthropic organizations, high net worth individuals, or others interested in supporting innovative, environmentally effective market solutions. Although technology entrepreneurs are often cited as offering potential global warming solutions, equally progressive solutions may lie in the fields of law, accounting, marketing, production, and even government relations and lobbying. Further, some funding under this policy recommendation could address – but not exclusively target – implementation of other CAP policy recommendations.

The CAP recommends, by unanimous vote of those members present and voting, that the state (together with local governments as desired) establish a clearinghouse to seek investment capital and philanthropic funding for reducing GHG emissions and supporting development of the new energy economy in Colorado. This clearinghouse should be established with a small office and staff to execute its purposes and functions.

CC-9 Vulnerability and Adaptation

Even if Colorado plays a lead role in both reducing its GHG emissions and helping to bring about reductions elsewhere, it will still face changes in its climate and a multitude of impacts. Greenhouse gases have long atmospheric life-times, and Colorado will face additional warming and related changes from GHGs that have already been emitted, let alone from those that will be emitted in the future. The changes Colorado will face in the long term will be more manageable if it begins now to reduce emissions, but now is also the time to begin preparing to deal with the changes that are already underway and likely to become more dramatic. Undertaking these adaptation efforts is urgent and essential to developing an effective and comprehensive action plan that will ensure that Colorado remains such a special place to live.

The CAP recommends, by unanimous vote of those members present and voting, that state government conduct a comprehensive assessment of Colorado's vulnerabilities to the effects of climate change. However, without awaiting the results of the vulnerability assessment, state government should take the lead immediately, with appropriate involvement by local governments, other governmental entities, affected businesses, colleges and universities, nongovernmental organizations, and others, in launching efforts to develop statewide action plans to prepare for and deal with the most potentially serious categories of adverse climate-change impacts likely in Colorado. In some cases, local action plans undertaken by local governments would also be appropriate.

Among the categories of climate-change impacts likely in Colorado for which statewide, and perhaps also local, action plans are needed include: (1) effects on water quantity and water quality, which in turn are likely to affect every aspect of life in Colorado (*see the separate recommendations in Chapter 8 of this report on those issues*); (2) increases in heat-related deaths and illnesses; (3) increases in air pollution and its effects on mortality and health; (4) potential increases in diseases; (5) increases in the length of wildfire seasons and of the frequency and severity of wildfires; (6) increases in severe weather; (7) effects on agriculture stemming from

changes in water supplies and availability and the effects of increased temperatures on livestock and crops; (8) a reduction of skiing and other snow-dependent outdoor recreation and tourism, along with the jobs, business income, and tax revenues derived from them; (9) increased warm-season congestion on transportation corridors to and in Colorado's mountains; (10) changes in ecosystems, such the substantial loss of lodgepole pines and other trees now occurring across the mountains as a result of bark beetle infestations caused by, among other things, a reduction in extreme cold temperatures that have historically served as a natural check on beetle populations; and (11) effects on opportunities for recreational fishing (as higher temperatures push streams beyond their ability to support cold-water fish populations) and hunting (particularly for waterfowl).

Chapter 8

Water Adaptation

Overview of Effects of GHG Emissions on Water Resources

The consensus of the scientific community is that warming caused by greenhouse gas (GHG) emissions resulting from a wide variety of human endeavors will likely have significant effects on water supplies and availability in many parts of the world, including the American West. A 2007 report of the Intergovernmental Panel on Climate Change (IPCC) on the basic science of climate change states:

Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. With regards to snow, ice and frozen ground (including permafrost), there is high confidence that natural systems are affected. . . Based on growing evidence, there is high confidence that the following types of hydrological systems are being affected around the world:

- increased run-off and earlier spring peak discharges in many glacier- and snow-fed rivers;
- warming of lakes and rivers in many regions, with effects on thermal structure and water-quality...

In the course of the century, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges . . . Warming in western mountains [in North America] is projected to cause decreased snowpack, more winter flooding, and reduced summer flows, exacerbating competition for over-allocated water resources...¹

A second IPCC report in 2007 on the impacts of climate change states:

The impacts of climate change on freshwater systems and their management are mainly due to the observed and projected increases in temperature, evaporation, sea level and precipitation variability (very high confidence). More than one-sixth of the world's population live in glacier- or snowmelt-fed river basins and will be affected by a decrease in water volume stored in glaciers and snowpack, an increase in the ratio of winter to annual flows, and possibly a reduction in low flows caused by decreased glacier extent or melt-season snow water storage. . . Increased precipitation intensity and variability is projected to increase the risk of floods and droughts in many areas. . .

Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater (high confidence). Many of these areas (e.g., Mediterranean Basin, western USA, southern Africa, north-eastern Brazil, southern and eastern Australia) will suffer a decrease in water resources due to climate change. . .

Higher water temperatures, increased precipitation intensity and longer periods of low flows are likely to exacerbate many forms of water pollution, with impacts on ecosystems, human health, and water system reliability and operating costs (high confidence). . .

Climate change affects the function and operation of existing water infrastructure as well as water management practices (very high confidence). Adverse effects of climate on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanization. Globally, water demand will grow in the coming decades, primarily due to population growth and increased affluence. Regionally, large changes in irrigation water demand as a result of climate change are likely. Current water management practices are very likely to be inadequate to reduce the negative

¹ Intergovernmental Panel on Climate Change, "Summary for Policymakers." In: M. Parry et al., *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge, UK, 2007), 7-22, 2, 3, 7, 12. Footnotes and internal references omitted.

impacts of climate change on water-supply reliability, flood risk, health, energy and aquatic ecosystems. Improved incorporation of current climate variability into water-related management is likely to make adaptation to future climate change easier.

Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions (e.g., Caribbean, Canada, Australia, Netherlands, UK, USA, Germany) that recognize the uncertainty of projected hydrological changes (very high confidence). Since the IPCC Third Assessment, uncertainties have been evaluated and their interpretation has improved, and new methods (e.g., ensemble-based approaches) are being developed for their characterization. Nevertheless, quantitative projections of changes in precipitation, river flows and water levels at the river-basin scale remain uncertain.²

[In North America:]

- Projected warming in the western mountains by the mid-21st century is very likely to cause large decreases in snowpack, earlier snow melt, more winter rain events, increased peak winter flows and flooding, and reduced summer flows.
- Reduced water supplies coupled with increases in demand are likely to exacerbate competition for over-allocated water resources.³

The American Water Works Association, the primary trade group of water management professionals, has concluded, “global warming is a fact and water managers need to plan accordingly.”⁴

The projected effects of climate change on Colorado’s water supplies and water quality include

- **Reduced snowpack and streamflow.** Most water used in Colorado comes from streamflow that originates as snowmelt. There is a consensus of climate model projections that warming will continue in Colorado, leading to more winter precipitation falling as rain and less as snow, lesser snowpack accumulation, earlier runoff, and more evaporation. Computer models are still unclear on what changes may occur in this region with respect to the total amount and timing of precipitation. However, studies indicate that a substantial increase in precipitation would be needed to offset the reduction in streamflow from more evaporation caused by warmer temperatures.
- **More drought.** The frequency, duration, and severity of droughts are projected to increase, further reducing water supplies and making water use restrictions more likely.
- **Earlier snowmelt.** Warmer weather is expected to melt mountain snowpack earlier. An early melt potentially increases evaporative losses, reduces summer streamflow, and disrupts established patterns of the timing of water capture and use under existing water rights.
- **Intense precipitation.** Precipitation is expected to be more concentrated or intense, potentially making the capture and storage of water more difficult. Increases in flooding are projected, with risks to lives, property, water quality, and the environment.
- **Increased water needs.** The growing season is expected to be longer and warmer. This will increase the water requirements of some crops and other plants. Irrigation of landscapes

² M. Parry et al., “Technical Summary,” in *Change 2007: Impacts, Adaptation and Vulnerability*, 23-78, 35-36. Internal references omitted.

³ Parry et al., “Technical Summary,” 62. Internal references omitted.

⁴ American Water Works Association Public Advisory Forum, “Committee Report: Climate Change and Water Resources,” *Journal AWWA*, vol. 89, issue 11, Nov. 1997, 107-110, 107.

accounts for roughly half the municipal water use along the urban Front Range. Increases in water use in other sectors, particularly agricultural uses with senior water rights, could reduce the supplies available to others, including municipal providers, with more junior water rights. Water use for cooling buildings and other weather-dependent uses could increase with an increase in temperature.

- **Degraded water quality.** Water quality is projected to degrade because of reduced streamflow, increases in forest fires and subsequent runoff of sediment, higher stream temperatures, and other factors. This potentially will increase water supply maintenance and treatment costs. Sedimentation in water supply systems is expected to increase, and this could decrease water storage capacity and increase maintenance costs.
- **Interstate compact calls.** Reduced streamflow and increased water use could increase the contention over interstate allocations, which are based on “normal” precipitation and streamflow expectations.
- **Secondary impacts.** A number of important secondary impacts have the potential to affect water management, such as more forest fires, which can lead to increased runoff causing sedimentation of reservoirs, as well as outbreaks of forest pests, which may affect total runoff and runoff timing.

Several climate change studies have investigated possible effects on future flows of the Colorado River, the state’s largest source of surface water, which is used not only on Colorado’s Western Slope but is also diverted for use in cities and farms east of the Continental Divide (and, overall, supplies water to more than 30 million people in seven states). The studies consistently project that climate changes will lead to Colorado River flows being reduced below those seen from 1905 to 2000. Recent studies project reductions in river flows ranging from a very significant reduction of up to 50% by Hoerling and Eischeid to 11% by Christensen and Lettenmaier. For the Colorado River, any reduction would be significant. Similar studies have not yet been conducted with respect to other river systems in Colorado.

Many of these predicted impacts have already begun to be observed across the West. These changes are projected to have far-reaching effects in Colorado.

It likely will be harder to meet our water needs in the future. Phase 1 of the Colorado Water Conservation Board’s Statewide Water Supply Initiative projected that even with some additional conservation measures and no change in the climate, there could be a net increase in demand of 630,000 acre-feet of water per year to meet just the municipal and industrial needs of the population projected to live in the state in 2030. This illustrates how the combined pressures of population growth and climate change will be doubly challenging.

Water engineering and management will need to change. They have generally been based on assumptions that the future will look like the past. Reservoir design, flood planning, and municipal yield are but three of the critical water management areas where good engineering practice has dictated the use of historical hydrology in planning. As the globe warms, past assumptions about municipal yield, supply, demand, flood control, and other water management issues based on historical hydrology will become less valid.

Agriculture consumes a significant majority of the water used in Colorado, so if climate change produces a more restricted water supply over the long term, it will have a commensurately greater impact on agricultural water consumption than on consumption by others in the state. In the event of shortages, there likely will be transfers of water from agricultural uses to other uses, such as for municipal and industrial purposes.

The combination of changes in water availability and the application of the legal regimes governing water uses may affect both individual water users and the state as a whole. Changes in runoff timing could affect whether holders of water rights have water when they need it. For example, more water could be available earlier in the spring and less in late spring and summer than in the past. State or regional water shortages may trigger the application of interstate compact requirements that could lead to additional water restrictions in Colorado.

All in all, the projected effects on water supplies and quality represent what may well be Colorado's greatest vulnerability to climate change.

References

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N. Christensen and D. Lettenmaier, "A Multimodel Ensemble Approach to Assessment of Climate Change Impacts on the Hydrology and Water Resources of the Colorado River Basin," *Hydrology and Earth System Sciences*, 11:1417–1434 (2007).

M. Parry et al., *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

B. Udall and G. Bates, "Climatic and Hydrologic Trends in the Western U.S.: A Review of Recent Peer-Reviewed Research," in *Western Water Assessment, Intermountain West Climate Summary*, pp. 2–8 (January 2007).

Water Adaptation Policy Recommendations

The Climate Action Panel’s 14 water adaptation recommendations are the first comprehensive set of actions assembled to guide water providers and others in preparing for the predicted effects of climate change on Colorado’s water resources. Thirteen were adopted by unanimous consent and one by a super majority (5 objections or fewer) of the CAP members present and voting.

Table 8-1. CAP policy recommendations for water adaptation

	Policy Recommendation	Analysis	CAP Action
WA-1	Public officials exercise leadership in addressing climate change effects on water supplies.	<i>Not quantified</i>	Unanimous Consent
WA-2	Water managers consider climate change in all water supply decisions.	<i>Not quantified</i>	Unanimous Consent
WA-3	Climate change effects considered in the new Colorado Water Conservation Board study of Colorado River water availability.	<i>Not quantified</i>	Unanimous Consent
WA-4	State government develop mechanisms for compact calls for each major river basin.	<i>Not quantified</i>	Unanimous Consent
WA-5	Assessment of knowledge about climate change effects on Colorado’s water resources. An assessment of data and data systems for understanding climate change.	<i>Not quantified</i>	Unanimous Consent
WA-6	Cooperative development of information on climate change effects in each major river basin.	<i>Not quantified</i>	Unanimous Consent
WA-7	Municipal water providers evaluate water conservation savings, best demand management practices, and the best uses of conserved water in their systems.	<i>Not quantified</i>	Unanimous Consent
WA-8	Minimize effects of water-rights transfers on agricultural economies.	<i>Not quantified</i>	Unanimous Consent
WA-9	Consider relationships between energy and water use.	<i>Not quantified</i>	Unanimous Consent
WA-10	Information exchanges on effects of climate change on water resources.	<i>Not quantified</i>	Unanimous Consent
WA-11	State government consider ways to reduce climate change effects on water-related recreation and tourism.	<i>Not quantified</i>	Unanimous Consent
WA-12	State government consider ways to reduce climate change effects on the environment.	<i>Not quantified</i>	Unanimous Consent
WA-13	Reduce use of groundwater for irrigation until recharges match discharges.	<i>Not quantified</i>	Unanimous Consent
WA-14	Establish new Colorado Water Institute.	<i>Not quantified</i>	Super Majority (1 objection)

WA-1 Need for Leadership

CAP Recommendation

- Federal, state, and local public officials in Colorado who have general responsibility for the health, safety, and welfare of the citizens of the state, or a particular responsibility for meeting the consumptive and non-consumptive water needs of Coloradans, should exercise leadership in addressing the identified causes of, and adapting to the impacts of, climate change on water supplies. Even if GHG emissions are reduced, scientists believe that our climate is likely to change enough to significantly impact current flow regimes. These effects could pose substantial risks to the economic, social and environmental well-being of the state. Accordingly, our public officials should give a high priority to identifying and

implementing actions designed to respond, in a responsible and coordinated manner, to the potential adverse effects of climate change on our water resources and the full range of beneficial uses associated therewith. Key public officials to whom this recommendation apply include our elected representatives to Congress, the Governor and other officials in the executive branch of state government, members of the Colorado General Assembly, elected and appointed officials in local governments, water providers, and officials in public colleges, universities, and research institutions.

Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-2 Consideration of Climate Change in Water Decisions

CAP Recommendations

- All Colorado water managers should investigate the vulnerabilities to climate change of the water supply systems they manage and determine how they will continue to meet future water needs in light of those vulnerabilities. As they plan changes in future water supply systems and operate current ones, water providers should no longer assume the future will necessarily be like the past. Most water supply planning in Colorado is based on the hydrology of the recent past. New plans should consider both the substantial variations in regional climate now understood to have occurred in the more distant past and the potential climate changes and their effects. Colorado water managers should also
 - Assess the vulnerability of their supplies and systems to climate change effects;
 - Identify and preserve adaptation options;
 - Apply risk management and adaptive management;
 - Explore phased approaches to adjust with climate changes;
 - Consider increasing water system reliability, diversity, and flexibility;
 - Use “no-regrets” planning of actions that would produce benefits even if the climate does not change as now projected; and
 - Create and participate in regional efforts to model and analyze the impacts of climate change.
- Water suppliers should carefully consider the appropriate roles under a changed climate of
 - **Reuse.** A reduction in the water available for first use within a municipal system could also reduce water available for reuse, including use in water recycling systems, river exchanges, and augmentation plans. Municipal sources from non-tributary groundwater wells and from water rights that were transferred from very senior agricultural rights may not see a reduction in water available for the first use and reuses. Some municipal water rights cannot be reused. Suppliers should analyze their system vulnerability.
 - **Conservation.** See recommendation WA-7, below.
 - **Storage.** The value of new or enlarged storage in reducing the impacts of climate change on municipal water supplies is being debated in the West. Some believe that reduced streamflow would mean there would no longer be additional water available for storage in new or enlarged reservoirs. Others believe new storage could play a role along with

other measures to smooth out what could become even more variable supplies and the effects of more intense precipitation events. Reservoirs could also continue to help redistribute the timing and location of available streamflow to the time and place of societal and environmental needs.

- **Conjunctive use.** Water suppliers should consider the value of storing surface water flows in underground aquifers where feasible and when there are excess water supplies, for subsequent use during drier years.
- The state government should provide assistance to water providers that do not have the resources needed to consider the effects of climate change on the water supply systems they manage to help them do so.

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Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-3 Colorado River Water Availability

The 2007 version of the Colorado Water Conservation Board (CWCB) annual project authorization bill (SB-2007-122) directed the CWCB to evaluate how much remaining Colorado River water the State of Colorado has to develop. Section 15 of that law states:

(1) In addition to any other appropriation, there is hereby appropriated, out of any moneys in the Colorado water conservation board construction fund not otherwise appropriated, to the department of natural resources, for allocation to the Colorado water conservation board, for the fiscal year beginning July 1, 2007, the sum of five hundred thousand dollars (\$500,000), or so much thereof as may be necessary, for the board to evaluate water availability in the Colorado river basin and its tributaries. The board shall work in full consultation with, and with the active involvement of, the basin roundtables. The study shall consider current and potential future in-basin consumptive and non-consumptive needs. The board, in consultation with the basin roundtables, shall recommend whether additional study or phases of study should be undertaken.

This is an essential public policy question. Under 2005 legislation, HB-2005-1177, the State of Colorado is engaged in a broad public effort to take a comprehensive evaluation of Colorado's future water needs and identify solutions to meet the identified needs. Through the HB-1177 process and the companion Statewide Water Supply Initiative (SWSI) process, a number of new

projects have been proposed in the future. These projects range in size from small local projects to improve water use efficiency to large multistate, multi-billion dollar projects that would convey water as far away as Flaming Gorge Reservoir to the Colorado Front Range.

Determining how much Colorado River water is available to Colorado under various federal statutes, state statutes, interstate compacts, and international treaties (commonly referred to as the “Law of the River”) is going to be a complicated and difficult endeavor. The issue is complicated by the potential impacts of climate change. For decades, Colorado water officials have assumed that the state could develop at least 3.0 million acre-feet per year. However, this conclusion is based on the assumption that in the future, the Colorado River flows will be similar to the most recent past (1905–2000). Scientific studies, however, project that Colorado River flows will actually be reduced as a consequence of climate change.

CAP Recommendation

- To ensure that the new Colorado River water supply study is complete, relevant, widely accepted, and useful for future decision making, the state government should ensure that the potential effects of climate change are considered in the study.

Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-4 Interstate Compacts

Interstate compacts to which Colorado is a party apportion among our state and other states the right to make beneficial consumptive use of interstate rivers and related water supplies. Several compacts, including the Republican River Compact and the Rio Grande Compact, contain mechanisms to adjust Colorado’s apportionment based on climatic conditions. Others, such as the Colorado River Compact, contain requirements for delivery to downstream states of at least specified minimum amounts of water, causing Colorado (and in the case of the Colorado River, other upper basin states) to bear a greater share of any significant shortage. In the case of the Colorado River, therefore, the operation of the compact can serve to increase Colorado’s vulnerability to climate change–driven water shortages.

Although it is a popular topic of discussion, the idea of renegotiating interstate compacts is not particularly realistic or appealing. All of the signatory states to compacts in the western United States are suffering from varying degrees of water shortage and will be adversely affected by water shortages brought about by climate change. Each signatory state would have a similar goal in any compact negotiation, namely to acquire a greater share of the available supply for its citizens.

CAP Recommendations

- Colorado should not assume that interstate compacts can or will be renegotiated to reduce the effects that climate change may have on the amount of water available for use in the state. Planning based upon assumed changes in compacts would likely lead to nothing but frustration and disappointment.

- The state government should develop for each major river basin where one does not now exist a mechanism to deal with potential compact calls should they occur for any reason.

Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-5 Climate, Hydrologic, and Climate-Impact Assessment and Data

Understanding and adapting to the effects of climate change on water supplies will require good information on what changes are occurring with respect to such key elements as temperatures, precipitation, snowpack, the timing of snowmelt, and streamflows.

A single document summarizing the current state of that scientific knowledge would help water providers, public officials, and others in Colorado identify and take appropriate actions to adapt to the changes that are already underway and that may be coming.

In addition, the data collection systems that currently exist to gather this information were not designed to track changes in climate, and so may be incomplete to meet today's needs. Many of the programs for collecting and disseminating these data have deteriorated or have been diverted over the last quarter-century, with the result that many long-term climate and streamflow records have been interrupted.

CAP Recommendations

- The state government, the University of Colorado, Colorado State University, RMCO, or another entity should arrange for a report to be prepared by scientists from key relevant institutions in the state expressing the current state of scientific knowledge about climate change and its possible effects on Colorado's water resources. The report should be designed to be useful to water providers, public officials, and the general public.
- A task force appointed by the state government, with participation by invited federal agencies and research organizations, should assess the data and data systems that are needed to enable water suppliers and others in Colorado to understand and adapt to the possible effects of climate change on water supplies and water quality in the state, and identify gaps in current data and data systems.
- The state government and water users should support additional data collection with an emphasis on preserving and extending long-term records.
- Colorado's representatives in Congress, our state and local governments, and water providers should support re-definition of agency priorities and, where necessary, increases in federal funding for collection and assessment of key data related to the potential effects of climate change on the state's water supplies.

Level of Group Support

Unanimous consent of those CAP members present and voting.

Climate change will impact water supply by changing the amount and timing of streamflows and the amount and timing of water requirements for agricultural, industrial, non-consumptive and municipal uses. A water supplier requires estimates of future water use to plan its own system and operations, but also to understand how competing water rights will affect its water supply.

The nature of future water supply conditions can be estimated based on projections of future climate conditions from climate models, but such estimates require that the models' output be translated into projected streamflows and water requirements at relevant locations. Because current climate models use large grids (with a typical grid cell covering one fourth of Colorado), model results must be mapped to a finer level of detail prior to translation to streamflows.

Several scientific studies have made projections of the possible effects of climate change on water supplies in the Colorado River basin, but these studies are at scales too large for local water supply planning. The state's other river basins have not been studied even at large scales. Some larger water providers have conducted studies to begin to estimate the potential impact of climate change on their systems.

Making estimates of future water supply conditions presents a number of technical challenges:

- **Scale/Translation.** For the near future, climate model data will be available at scales that are far too large for planning and decision making by water suppliers and users. Until climate projections become available in appropriate scales, planners will require some method of mapping large-scale climate projections to scales appropriate for planning purposes. Planners also require that climate projections be translated into streamflows. Many techniques are currently available to re-map and translate climate projections, and new techniques are becoming available. These can be broadly categorized as process-oriented or statistical techniques.
- **Water rights response.** Almost all water supply models in Colorado rely on historical records of water rights yields, calls, or both. Climate-change induced changes in streamflows and water use will affect the yield of individual water rights and the pattern of calls. Historical water-rights yields and calls can no longer be depended on to represent future conditions.
- **Uncertainty.** Projections of future climate contain much uncertainty, arising from projections of future policy and economic responses (which are necessary to estimate future GHG concentrations) and from simulations of future climate responses. Further uncertainty is introduced by re-mapping and translation methods.

Collecting the data and constructing and running the models necessary to project future streamflows is a substantial effort. Many smaller municipalities and most individual agricultural users will not have the resources to make these assessments. Further, virtually every productive watershed in the state is shared by many water users, so if water users make independent assessments, the result will be much duplication of effort.

CAP Recommendations

- The state government, water providers, and others should cooperate in
 - Developing information from climate models on the possible effects of climate change on consumptive and non-consumptive water supplies in each of the state's major river basins.
 - Developing common practical tools and databases for re-mapping and translation of climate model outputs. These tools should allow for flexibility on the part of water providers to choose from a variety of approaches to assessing climate change effects.
 - Setting up and maintaining a clearinghouse of up-to-date climate projection data.
 - Undertaking demonstration projects to assess the feasibility of making basin-wide assessments of water rights yields and call patterns in support of the individual water-supply modeling of water providers.

Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-7 Water Conservation

Decreasing river flows and lake and reservoir levels that are the expected by-product of climate change will provide great interest in and opportunities to step up water conservation throughout Colorado.

Role of the state government. While the bulk of conservation work needs to be carried out by individual water providers and water users throughout Colorado, state agencies can play an important role by providing funding and technical assistance and helping shape regional and state-wide education and message development.

Planning. State laws require conservation planning by water providers, but those laws have not been enforced. Recent additions to state laws require conservation planning and conservation goal-setting by water suppliers obtaining state funding for water-related activities. Substantial state funding to assist with conservation and drought planning is available in the form of planning and implementation grants from the Colorado Water Conservation Board.

Municipal water supplier dilemma. Water conservation is favored by many water suppliers as a cost-effective means to decrease the need for new water development. The risk of a drying climate poses a new dilemma for water suppliers. Do the suppliers use the water saved from conservation to 1) supply new population growth, 2) reserve some or all of the saving to protect against shrinking supplies, or 3) set aside some savings for environmental purposes such as improving river habitat? If the supplier uses the savings exclusively to supply growth in its service area, water efficiency is increased but more people become dependent on the same supply of water. If that supply shrinks, the additional savings needed to provide for the essential human uses in that supplier's service area might substantially impact landscapes and businesses within the service area. Water suppliers need to recognize that the choices are very case-specific and a given volume of saving can usually only be used for one choice. The saved water probably

cannot do double duty. Water suppliers should carefully consider the risks and potential tradeoffs of this dilemma.

With respect to the conservation of agricultural water, see recommendation WA-9, below.

CAP Recommendations

- Municipal water providers should determine the potential for water conservation saving in their municipal water system. Providers should consider measures that are cost-effective for both the utility and customers and that accomplish significant water savings. Evaluations should address all customer segments, particularly those that demand the greatest volume of water or place the greatest burden on the water system in terms of peak use.
- Municipal water providers should determine the best use of conservation savings such as reserving the savings for adaptation to climate change, using the savings to supply new growth, or using the savings for environmental purposes.
- For municipal water providers reserving the saving for adaptation to climate change, it is recommended that the following conservation methods be considered and implemented where appropriate. These methods should also serve well for providers using conservation savings for purposes other than adaptation to climate change.
 - Specific demand management measures for municipal water providers include
 - Rate structures that reward conservation and provide incentive to avoid water waste,
 - Rebate programs that encourage customers (both residential and business) to install high-efficiency water fixtures (e.g., toilets and clothes washers),
 - City ordinances and utility programs that encourage efficient irrigation,
 - Business and residential audits that identify property-specific water issues and educate the customer on how to curb demand,
 - Education programs that deliver a consistent conservation message to all,
 - Water loss reduction programs that decrease treatment costs and plant capacity needs, and
 - Using non-potable water supplies for landscape or other appropriate water use whenever possible and metering this use, just as is done for treated water.
 - Because irrigation of municipal landscapes accounts for roughly half of total annual municipal water use, it deserves special attention. Outdoor water conservation measures for municipal water providers include
 - Incentives and requirements to amend the soil before planting new landscapes.
 - Encouraging Xeriscape to boost the prevalence of water-saving landscapes. For new development, consider limiting the amount of turf as a percentage of total landscaped area. For existing development consider turf removal incentives for both residential and commercial customers. Landscape changes may lower owners' maintenance costs.
 - Increasing efficiency by changing watering habits (decreasing the numbers of watering days per week and lowering the amount of time per sprinkler zone).

- Irrigation improvements, including rain sensors (that turn off sprinkler systems during rain) and more efficient sprinkler head placement and water pressure.
- New development and redevelopment measures. There is a special opportunity for additional conservation savings in new developments and redeveloped properties. State and local governments should consider requiring or providing incentives to residential and commercial developers and builders to use state-of-the-art conservation practices. Water providers may not have the authority to require such practices but they can work with state and local governments in recommending the conservation practices and may have opportunities to provide incentives.
- Ongoing evaluation by municipal water providers. Water providers should evaluate the actual impacts of conservation on system yields and reliability through model runs and reasonable assumptions about technological and behavior savings that may be expected from customers before and after the implementation of conservation measures. Mechanisms must be devised and applied to effectively and accurately monitor and to report to the state government for its use in water supply planning program information on savings in order to evaluate this impact.

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Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-8 Agriculture

Agriculture consumes a significant majority of the water resources apportioned to the state by interstate compact, and the state rights supporting that water use are generally the most senior in Colorado. If climate change produces a more restricted water supply over the long term, there will be a movement of water use from lower intensity uses such as agriculture to higher intensity uses, such as municipal supplies. Consequently, climate change will have a commensurately greater impact on irrigated agriculture in the state. Because of the close relationship between agricultural production and water consumption, it will be necessary to develop strategies that trade some measure of increased productivity for a known amount of actual conservation.

However, it is unreasonable to assume that increased efficiencies in agriculture will necessarily result in a long-term quantity of “saved” water that can be made available to municipalities. The opportunity to reuse water saved by efficiency improvements may be limited by downstream water rights and interstate compacts that depend on return flows. Additionally, the reality is that

if water supplies become scarcer, the law of economics will lead to the amount of land in irrigated agriculture being reduced in order to provide supplies to municipalities.

There could be an important role for increased agricultural efficiency in providing supplies for non-consumptive uses. Water that is not released from storage or not diverted from streams because of increased efficiency in agriculture could be used to better manage in-stream flows to the benefit of non-consumptive uses. Realizing this potential will require operating agreements and possibly changes in the law.

CAP Recommendations

The state government, agricultural water users and municipal water users should

- Try to develop operating arrangements (such as fallowing/leasing programs) that minimize the disruption of agricultural economies as water is transferred from agriculture to municipal uses, while not unduly hindering the operation of Colorado’s important market in water and water rights.
- Develop operating agreements, funding sources and, if necessary, legislation to allow agreements among willing parties to undertake efficiency improvements in agriculture for the benefit of non-consumptive uses.

Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-9 Energy and Water

Water and energy are inextricably linked. Drinking water requires energy for water treatment, distribution, heating, and wastewater treatment. Energy production requires water for cooling of thermal plants or water for generating hydropower. The strong connection between water and energy provides opportunities to reduce GHGs and reduce water supply vulnerabilities by conserving water and by examining increasing hydropower generation. On the other hand, both energy production and water supplies may be impacted by reductions in water availability.

Thermal power production—principally to cool steam at fossil fuel plants—requires large amounts of water. In 2000, fossil fuel plants in Colorado withdrew 20 billion gallons (just over 61,000 acre-feet), consuming 500 gallons per megawatt-hour generated. Increased source water temperatures may require additional water diversions for the same cooling effect. But for those thermal generation plants that use dry cooling systems, water consumption would not be impacted.

Proposed new sources of energy including ethanol and oil-shale production also have large water requirements. New demands should be evaluated in terms of relative production efficiencies and in the case of oil shale development potential impacts to junior users of the Colorado River. Ethanol production with corn grown in Colorado requires approximately 1000 gallons of water per gallon of ethanol produced, if you include water used to grow the corn. Oil shale production uses roughly 200 gallons of water for each barrel of oil, such that a full production scenario for Colorado of one million barrels of oil daily is projected to require somewhere between 180 and

270 million gallons per day (or 200,000–300,000 acre-feet per year) for retorting the shale and related power needs.

Many new proposed water supply projects in Colorado involve moving water over significant distances because of the scarcity of undeveloped water near population centers. Unallocated water is usually far downstream or even across mountain ranges from the anticipated point of use. In these cases, Colorado’s geography may impose potentially significant pumping requirements, with the potential for significant increased GHG emissions.

Hydropower can provide energy without consuming water and without generating carbon. However, some hydropower facilities in the United States have resulted in adverse environmental effects, including blocked fish passage, a decrease in sediment transport, and water quality impacts. New hydropower as an energy solution to climate change requires a close examination of environmental impacts. Possibilities include new hydropower facilities, improving the efficiency of existing plants, and examining whether existing water storage and conveyance facilities may have hydropower additions.

Colorado’s geography provides for a unique synergy between water providers and energy generation through the use of hydroelectric power. Communities, especially front-range water providers, may have ideal attributes for development of small hydroelectric projects at existing facilities—significant volumes of water flowing from higher elevations to water treatment facilities at lower elevations. But climate change or drought conditions could pose challenges to hydropower generation located in snowmelt-dominated basins as water supplies decrease.

CAP Recommendations

- The state government and utilities should evaluate cooling technologies on all new electricity generating facilities. Closed-loop recycling and dry cooling use much less water than once-through cooling. Wind and solar generating facilities use no water and should continue to be promoted, while recognizing their limitations for base load generation.
- Public education campaigns about climate change in Colorado should include efforts to
 - Make visible and understood the links among water conservation, energy conservation, and carbon dioxide and
 - Encourage both energy and water conservation.
- Water providers and others should consider the GHG emissions to result from new water projects and activities. The state government should provide guidance on limiting such emissions and should encourage alternatives that minimize them.

References

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Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-10 Information Exchanges

Climate change presents complex policy, planning, and operational issues to water users, water managers, and appointed and elected officials. Planning for adaptation requires an understanding of the potential impacts of climate change, of the probabilities that particular impacts will occur, and of the range of potential technical and policy responses to those impacts. While there is no shortage of information about climate change, much of that information exists at two extremes: academic journal articles, research reports, and policy analyses; or articles in the popular press (not to mention the entertainment industry). It is difficult and inefficient for water resource managers to use the academic resources, but the reliability of the information in the popular press is doubtful.

Likewise, the sophistication of water-dependant organizations in Colorado covers a very wide range. Large organizations, such as large utilities or large water conservancy districts, have their own technical staff, while a small town or a small mutual ditch might have only a part-time manager or maintenance person.

For these reasons, it will be difficult to convey information about climate change to the broad spectrum of water users throughout the state. On the other hand, Colorado is blessed with exceptional technical, research, and educational resources in the fields of climate, water resources, and policy.

CAP Recommendations

- The state government, education and research institutions, appropriate nonprofit organizations, or other entities should develop, publish, and circulate at least one publication (or set of related publications) using either traditional or electronic media that addresses an audience of water resources professionals, managers, and policy makers. Such a publication should translate research products to useful practice- and policy-oriented information. In order to be authoritative, such a publication will need some degree of peer review.
- The state government, education and research institutions, appropriate nonprofit organizations, and/or other entities should
 - Provide practice-oriented information about climate change;
 - Host information exchanges among water management organizations, at both the policy and technical level, where they can trade experiences, successes, and failures;
 - Conduct research oriented toward practical issues of water resources management and policy in the face of climate change; and
 - Provide opportunities for training and education in specific, practice-oriented topics related to climate change.

- The state government, water provider organizations, education and research institutions, appropriate nonprofit organizations, and/or other entities should encourage and facilitate cooperative working relationships among water provider organizations in order to facilitate joint adaptive responses.
- The state government, water provider organizations, education and research institutions, appropriate nonprofit organizations, and other entities should develop training and education opportunities for elected officials with respect to climate change in Colorado and ways to reduce the state’s contributions and vulnerabilities to it, including with respect to climate change effects on water quantity and quality in the state.

Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-11 Recreation and Tourism

The effects of climate change on Colorado’s snow and water resources are likely to have a wide range of impacts on the opportunities for recreation and tourism in the state and the industries that support them. These impacts threaten to decrease the intrinsic and economic value of resources that currently bring enjoyment to millions of residents and add billions of dollars to the State’s economy.

The impact of climate change will be felt on several recreational and tourism areas, such as

- **Fishing.** Scientists project that warmer trout streams will eliminate or reduce trout populations in many, perhaps most, streams in the West where they are now found. Lower summer flows may make trout more susceptible to disease and angling pressure. Angling and related activities are estimated to bring hundreds of millions of dollars annually to Colorado’s economy.
- **Skiing.** Scientists project that less snow and warmer temperatures likely will mean shorter ski seasons and fewer days of champagne powder.
- **Rafting and Boating.** Earlier and quicker spring runoff could change the timing of and shorten the prime season for river running. (Rafting provided an estimated \$135 million economic benefit to the state in 2006.) Lakes and reservoirs could have decreased water levels in summer, which would affect boating.
- **Hunting.** Scientists project that climate change could lead to fewer wetlands, which could leave fewer nesting ponds for ducks and geese and fewer hunting spots in the fall. Vegetation changes may affect elk and deer food supply at different elevations.
- **Camping, Hiking, and Biking.** Projected further increases in forest fires could mean more forest closures and campfire restrictions. The aesthetic value of streams could decrease if summer flows drop.

CAP Recommendations

- State government agencies, with invited participation by federal agencies, should undertake studies to evaluate possible impacts of climate change on recreation and tourism in Colorado.

Responsible state agencies include the Division of Wildlife, Colorado State Parks, Water Quality Control Division, Air Pollution Control Commission, and Colorado Water Conservation Board. Responsible federal agencies include the Forest Service, Bureau of Land Management, Fish and Wildlife Service, Corps of Engineers, Department of Agriculture, and Environmental Protection Agency.

- The potential impact of climate change on outdoor recreation and tourism underscores how essential it is for natural resource management agencies to take advantage of their responsibilities and relationships with the public to set an example in decreasing GHG emissions while at the same time preparing for impacts on Colorado's valuable waterways. Government agencies and businesses managing and providing outdoor recreation and tourism opportunities and services should take visible actions to reduce emissions that might affect climate change, to adapt to the effects of climate change, and to educate the public on the risks of climate change and actions that can be taken to reduce it and respond to it.
- The Colorado Water Conservation Board should evaluate its instream flow program for any changes needed in its administration to reflect the effects of climate change on the purposes for which the program was established.
- The state government, with invited participation by appropriate federal agencies and others, should investigate habitat protection and enhancement needs for terrestrial and aquatic species particularly vulnerable to climate change.

References

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Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-12 Water Quality and the Environment

Climate change can have significant impacts on the water quality of our rivers and lakes and the associated aquatic ecosystems.

Climate-driven increases in water temperature, seasonal decreases in flow, and changes in the intensity and duration of precipitation events can all influence water quality standards and designated beneficial uses. Potential impacts include

- Increased pollutant runoff from more frequent and severe rainfall events;
- Periodic drought-related low flows below aquatic life needs;
- Loss of anticipated dilution flows;
- Channel reconfiguration and sediment transport through flooding;

- Reduced dissolved oxygen levels in bodies of water;
- A loss of, or change in, biodiversity;
- An increase in forest fires and accompanying runoff concerns;
- Reduced populations of cold water fish such as trout;
- Reduction in aquatic and riparian biodiversity; and
- Additional pressure on threatened and endangered species, including four fish species native to the Colorado River and its main tributaries, because of changes in stream flows, increases in water temperature, and degradation of other habitat elements.

Climate-induced hydrologic modifications may similarly affect the implementation of water quality regulatory programs, such as compliance with wet-weather mandates (combined sewer overflow and stormwater best management practices); the establishment of permit effluent limitations based on “low flow” averages; and the listing of water bodies as impaired under Section 303(d) of the Clean Water Act due to increased pollutant loadings, elevated temperature, or the mere loss of flows. Water resource allocation decisions designed to adapt to changes in water availability will also hold implications for water quality. For example, there may be a tendency to expand reuse programs, necessitating additional protective reuse regulations, or to adopt enhanced treatment techniques, such as reverse osmosis, with attendant brine disposal concerns.

Climate change may also have broad effects on natural ecosystems, including those where snow cover and streamflows are dominant features. In fact, the Intergovernmental Panel on Climate Change says that such effects are already being observed around the world from factors such as reduced snow cover and increased temperature of water bodies. Section WA-12 on recreation and tourism mentions the potential effects of climate change on trout and angling. Threatened and endangered aquatic species (including four fish species native to the Colorado River and its tributaries which are vulnerable to changes in stream flows and other stresses) may potentially be adversely affected by climate change. Riparian areas, including wetlands may be at risk, particularly if there is an extended and deeper low flow period. Increases in forest pests, disease, and fire would lead to more runoff of sediments into streams and lakes, worsening water quality and harming aquatic ecosystems. Some invasive plant species may soak up more water, further reducing runoff.

CAP Recommendations

- The state government and others, with invited participation by the federal government, should undertake additional data gathering and research on water quality impacts related to climate change, along with a reexamination of certain regulatory programs under both the Clean Water Act and the Safe Drinking Water Act. EPA and certain states have commenced an examination of these issues, and their efforts should be utilized in the development of a response strategy.
- The state government should consider ways to enhance protection of aquatic and riparian ecosystems. They should consider methods of further reducing stressors on ecosystems, protecting core habitat areas, increasing the size and extent of fish populations, and monitoring aquatic and riparian ecosystems to quickly detect any deterioration in their health.

References

EPA Web site on Climate Change, <http://www.epa.gov/climatechange/>

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Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-13 Groundwater

The tributary groundwater supplies in the state are expected to respond to the effects of climate change in a manner very similar to that of the surface stream systems to which they are connected. As the surface stream flows diminish, their ability to replenish groundwater systems declines commensurately; as surface irrigation supplies diminish, the ability of those irrigation systems to recharge the groundwater declines; and as “conservation” and improved efficiency in agricultural irrigation practices increase in response to climate change, there is a resulting loss in return flows to the groundwater systems.

Nontributary groundwater systems, such as the Denver Basin, are believed to be relatively immune to the effects of climate change. On the other hand, they are effectively non-replenishing from natural sources and, as tributary systems are affected by climate change, the temptation to continue to rely upon them and mine the water within them will increase, hastening their ultimate elimination as viable sources of water supply.

CAP Recommendation

- Colorado should reduce the use of groundwater for irrigation supplies in groundwater-dependent basins including the South Platte, the Republican, the Arkansas, and the Rio Grande until recharges match discharges from pumping, natural losses, and the obligations to neighboring states under our compacts.

Level of Group Support

Unanimous consent of those CAP members present and voting.

WA-14 Colorado Water Institute

Water is the key natural resource for economic development in the state. The management of this resource is done within a complex environmental and legal framework. Many demands are put on this resource, and in recent times, due to climate variability, the water system has been stressed. Climate change has the potential to further stress the water supply and quality. Better integrated planning for the management of water and policy decisions is needed that better

utilizes the expertise in fundamental and applied research in climate and water resource management and technology. While many groups within the state deal with water issues, those groups are fragmented, often redundant, and individually under-funded. As a result, we are not reaching our full potential in addressing climate and water adaptation strategies

Other states (such as Arizona and California) have developed new models for approaching water management activities. These new approaches

- Are partnerships of select state and federal agencies, research universities that have expertise in water, and the governor's office;
- Have a strong mandate for the development of sound water management and conservation practices;
- Explicitly examine the impacts of climate change and adaptation strategies for water resource management;
- Examine the interface between water and energy;
- Incorporate the latest research into decision-modeling;
- Provide evaluation and assessment of water-adaptation strategies and implementation plans;
- Provide policy analysis;
- Actively participate in policy development, including participation in drought task forces and other water-related task forces (e.g., watershed management groups);
- Interface with federal agencies, particularly the Bureau of Land Management, Forest Service, Bureau of Reclamation, and National Oceanic and Atmospheric Administration;
- Provide education and training for a variety of constituencies;
- Develop enhanced information for stakeholders; and
- Provide a Web-based clearinghouse for information needs and resources for water management.

CAP Recommendation

- A Colorado Water Institute (CWI) should be formed. It should be a consortium and partnership of state research universities (such as Colorado School of Mines, Colorado State University, and the University of Colorado-Boulder); state agencies (such as the Division of Water Resources, the Department of Public Health and Environment, the Colorado Water Conservation Board, the Office of Economic Development and International Trade); federal agencies (such as the National Oceanic and Atmospheric Administration's Earth System Research Laboratory and the National Weather Service's Regional Office); other relevant institutions (such as the National Center for Atmospheric Research); and the governor's office. The CWI should not be a state agency. The formation of such an institute may require the reallocation of resources in current water activities and organizations that are supported by the state. The benefits would be a more visible, integrated, and collaborative approach to planning, adaptation, and management of water resources within the state that includes the

impacts of climate variability and climate change. Many of the recommendations in this report would be incorporated as part of the mission of the CWI.

Level of Group Support

Super majority of those CAP members present and voting. One CAP member objected on the grounds that the existing Colorado Water Resources Research Institute should carry out these recommended actions rather than a new entity.