February 28, 2020

Colorado's Climate Action Plan Emission Targets: Illustrative Strategies and GHG Abatement Potentials

On May 30, 2019, Colorado Governor Jared Polis signed House Bill 19-1261, the Climate Action Plan, into law.[1] This legislation amends Colorado's Air Pollution Prevention and Control Act and commits the state to economy-wide greenhouse gas (GHG) emission reduction goals of 26 percent below 2005 levels by 2025, 50 percent by 2030, and 90 percent by 2050.[2] The Act also requires the Colorado Air Quality Control Commission (AQCC) to develop implementing regulations consistent with these targets.[3] Further revisions through Senate Bill 19-096[4] to Colorado's Act require the Air Quality Control Commission to, by July 1, 2020 "propose rules to implement measures that would cost-effectively allow the state to meet its greenhouse gas emission reduction goals."[5]

Meeting these goals will require significant emission reductions across Colorado's economy including in the electric, transportation, residential, commercial, and industrial sectors. This analysis reviews the statutory emission reduction goals in the context of Colorado's historic and projected emissions through 2030 under a business-as-usual (BAU) scenario. It then evaluates potential emission reductions from a range of illustrative sector-specific strategies to inform discussions on the potential scale of GHG emission reductions that could be expected depending on the breadth and ambition of each illustrative strategy.[6]

In addition to using MJB&A's proprietary STEP Tool,[7] this analysis also draws from previous analyses and projections of Colorado's economy-wide GHG emissions by Evolved Energy Research[8] and the Rhodium Group.[9] It is important to note that the abatement strategies considered in this paper are neither exhaustive, prescriptive, nor exclusive in nature. Rather, they constitute a set of illustrative strategies that may be deployed to drive GHG emission reductions across different sectors of the state's economy. Some abatement strategies could be implemented through regulatory change resulting in enforceable emission reductions; other strategies could require several policy changes.

This analysis aims to illustrate the relative scales of potential reductions from pursuing various abatement strategies under the stated assumptions and scopes of applicability for each. Magnitudes of emission reductions

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1 State of Colorado, Seventy-Second General Assembly, "Concerning the Reduction of Greenhouse Gas Pollution, and in Connection Therewith, Establishing Statewide Greenhouse Gas Pollution Reduction Goals and Making an Appropriation." (May 13, 2019), available at: https://leg.colorado.gov/sites/default/files/documents/2019A/bills/2019a_1261_rr2.pdf (accessed December 12, 2020).

2 C.R.S. § 25-7-102(2)(g).

3 C.R.S. § 25-7-105(1)(e)(II).

4 State of Colorado, "Concerning the Collection of Greenhouse Gas Emissions Data to Facilitate the Implementation of Measures That Would Most Cost-Effectively Allow the State to Meet Its Greenhouse Gas Emissions Reduction Goals, And, in Connection Therewith, Making an Appropriation." (May 30, 2019), available at: https://leg.colorado.gov/sites/default/files/2019a_096_signed.pdf (accessed December 4, 2020)

5 C.R.S. § 25-7-140(2)(a)(III).

6 MJB&A undertook this analysis on behalf of the Environmental Defense Fund (EDF) with additional input from Western Resource Advocates.

7 M.J. Bradley & Associates, STate Emission Pathways (STEP) Tool, available at: https://mjbradley.com/mjb_form/STEP-tool. The STEP Tool is a spreadsheet-based multi-sector model that allows users to analyze state and regional energy use and their CO_2 emission trajectories under a range of economy-wide policy scenarios. The STEP Tool does not try to reach any equilibrium condition or optimize the system for any variables.

8 Evolved Energy Research, Colorado Near-Term Policy Advising, February 19, 2019. Evolved Energy Research notes limitations to their analysis driven by compressed timelines. These limitations include lack of calibration to existing state-level energy demands and equipment stocks and the need to consider the long-term role and impact of each abatement strategy when assessing its relative importance. https://www.edf.org/sites/default/files/documents/EER%20-ColoradoNearTermPolicy.pdf (accessed February 11, 2020).

9 Rhodium Group U.S. Climate Service data (2019).

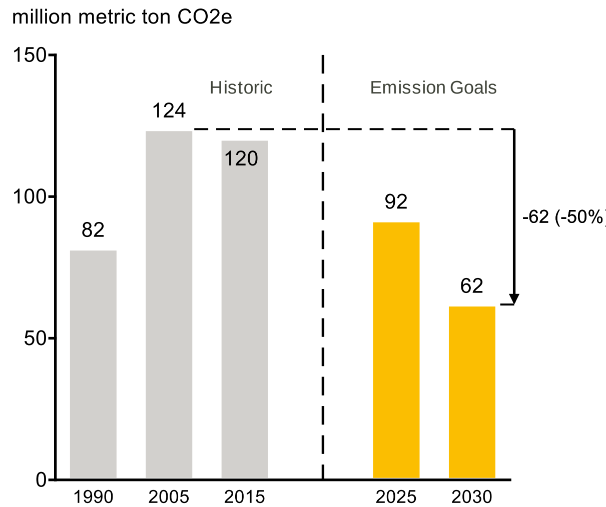
This paper was originally published on February 18, 2020. It was modified on February 28, 2020, to include a call-out box on page 4.

and gaps illustrated in this paper may vary significantly under different sets of assumptions. Additionally, this paper did not undertake, nor does it reflect, any economic analyses or cost assessments associated with the individual measures.

Historic Emissions and Midterm Targets

Colorado's newly adopted law requires the state to reduce economy-wide GHG emissions by 26 percent from 2005 levels by 2025, 50 percent by 2030, and by 90 percent by 2050—with an additional requirement for the state to "strive" for net-zero emissions by 2050.[10] These goals are broadly in line with emission pathway characteristics that would be required to limit global warming to 1.5 degrees Celsius according to the IPCC—about 45 percent from 2010 levels by 2030 (Colorado's GHG emissions for 2005 and 2010 differed by less than one percent) and net zero by 2050.[11] Neighboring states have adopted similar GHG reduction targets recently—both New Mexico's climate Executive Order[12] and Nevada's Senate Bill 254[13] commit the states to a 45 percent reduction goal below 2005 levels by 2030. Additionally, the state of Washington's proposed 2020 budget calls for legislation that would update the state's emission reduction targets for 2030 to similar levels.[14]

Figure 1: Historic Economy-wide Emissions v. Mid-term Targets



In absolute terms, in order to comply with the statutory emission reduction targets, Colorado must secure 58 million metric tons of GHG emission reductions in 2030 relative to the state's net economy-wide emissions of 120 million metric tons in 2015 (the most recent year for which comprehensive data are available; see Figure 1).[15] Note, however, that the statute allows the state to coordinate with other jurisdictions in securing these emission reductions provided such programs "[…] are of sufficient rigor to ensure the integrity of the reductions in greenhouse gas emissions […]".[16]

Colorado's emission target translates into a reduction trajectory that implies an average annual decline rate of about 4.9 percent (of 2021 levels) between 2021 and 2030, which is in the range—three to five percent—of the targets in California and Oregon (based on the state's proposed GHG budget) as well as New Mexico and Nevada. The relative consistency of the GHG targets and implied trajectories across many states may also facilitate the

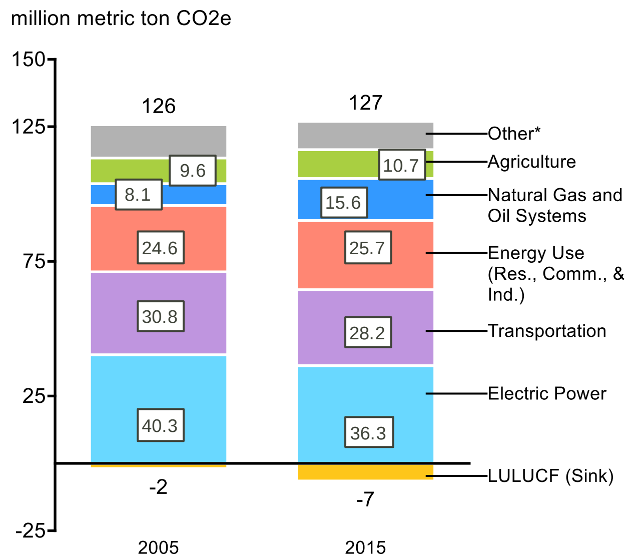
10 C.R.S. §25-7-102(2)(g).
11 International Panel on Climate Change, "Global Warming of 1.5°C," (October 2018), available at: https://www.ipcc.ch/sr15/ (accessed January 10, 2020).
12 State of New Mexico, "Executive Order On Addressing Climate and Energy Waste Prevention," (Executive Order 2019-003), available at: https://www.governor.state.nm.us/wp-content/uploads/2019/01/EO_2019-003.pdf (accessed February 10, 2020).
13 State of Nevada, "An Act Relating to Greenhouse Gas Emissions; Requiring the State Department of Conservation and Natural Resources to Issue an Annual Report Concerning Greenhouse Gas Emissions in this State; and Providing Other matter Properly Relating thereto," (June 5, 2019), available at: https://legiscan.com/NV/bill/SB254/2019/ (accessed January 10, 2020).
14 State of Washington, Office of Financial Management, "Highlights of Gov Inslee's proposed 2020 budget," available at: https://ofm.wa.gov/sites/default/files/public/budget/statebudget/highlights/budget20/2020_CarbonEmissions.pdf (accessed January 31, 2020).
15 State of Colorado, Department of Public Health & Environment, "Colorado Greenhouse Gas Inventory 2019 Including Projections to 2020 & 2030," (December, 2019), available at: https://www.colorado.gov/pacific/cdphe/colorado-greenhouse-gas-reports (accessed December 12, 2020).
16 C.R.S. § 25-7-105(1)(e)(V).

consideration of interstate collaboration or even joining or developing multi-jurisdictional programs to achieve the required reductions, an option that Colorado's new statute expressly provides.[17]

Historic Emissions

In 2015, Colorado's net GHG emissions were an estimated 120 million metric tons—slightly lower than in 2005.[18] Electric sector emissions represented 29 percent of Colorado's economy-wide GHG emissions, transportation 22 percent, industrial 15 percent, residential and commercial 9 percent, with mining, natural gas, and oil operations representing 14 percent. Agriculture and municipal solid waste made up the remaining 12 percent of state-wide emissions in 2015 (see Figure 2).

Figure 2: Composition of Economy-wide Emissions



*Coal mining & abandoned mines, industrial processes, waste management

While Colorado's total economy-wide GHG emissions have remained largely flat between 2005 and 2015—up one percent (down three percent net of sinks) over the decade, this relative lack of change in headline emission numbers masks larger intersectoral changes. Emissions from both the electric and transportation sectors, which constitute the two largest sources and account for the majority of Colorado's GHG emissions, declined by 9-10 percent during this period (see Figure 2). By contrast, emissions from natural gas and oil systems nearly doubled from 8.1 million metric tons in 2005 to 15.6 million metric tons in 2015, accounting for over 12 percent of total emissions in that year, largely due to the growth of hydraulic fracturing and development of other technology innovations.[19] Shares of emissions from other sectors including from residential and commercial buildings saw smaller changes.

The extent to which each sector reduces emissions to meet Colorado's goals will depend on a host of factors including the overall composition of Colorado's economy-wide GHG emissions, relative size of each sector's share, market dynamics, and the availability of cost-efficient abatements in each sector. Additionally, the emission reductions achieved will be affected by the type of policies implemented (e.g., whether Colorado chooses to deploy market-based mechanisms, command and control measures, or a combination of policies) and whether the state elects to use its authority under the statute to coordinate with other states to secure such reductions.

Projected Emissions Under Current State Policies (Business-as-Usual)

Colorado's 2019 (released December 2019) GHG inventory report (last historic data year: 2015),[20] which also includes emission projections through 2030, indicates that net overall GHG emissions in the state will decline to 118 million metric tons in 2030.[21] The report, however, notes that its projections, which are apportioned using a

17 C.R.S. § 25-7-105(1)(e)(V).

18 See note 15. For non-CO_2 emissions this analysis uses global warming potential (GWP) values from the IPCC 4th Assessment Report, consistent with the approach U.S. EPA takes in developing its Greenhouse Gas Inventory (also used by Colorado DPHE for the state's GHG inventory) and usage by Rhodium Group U.S. Climate Service. Note that IPCC's 5th Assessment report includes updated, higher GWP values for some non-CO_2 emissions including methane.

19 The natural gas and oil sector includes estimated fugitive methane emissions from the extraction and production of natural gas and oil, and carbon dioxide emissions from the venting and flaring of natural gas. See also note 18 regarding assumed global warming potential values.

20 See note 15.

21 Assumes land use and forestry (LULUCF) related sequestration of 4.2 million metric tons calculated based on an averaging of historic sequestration levels in Colorado since 1990.

national model, may not fully reflect the emission benefits associated with all state policies and initiatives, particularly electric and oil and gas sector emission control strategies that Colorado has adopted. A review by MJB&A of more recent data from the Rhodium Group's U.S. Climate Service suggests a slightly lower projected total of 108 million metric tons in 2030 (hereinafter "adjusted RHG BAU").[22]

Colorado SB 19-236: CO_2 Emission Reductions from Electricity Sales to Utility Customers

The adjusted RHG BAU projections account for the requirement that utilities with more than half a million customers in Colorado reduce CO_2 emissions associated with electricity sales by 80 percent in 2030 relative to 2005 levels (see footnote 29). Only one utility—Public Service Company of Colorado (PSCo)—had more than 500,000 customers in Colorado in 2018. Based on PSCo's disclosures, an 80 percent reduction, if realized fully within the state of Colorado as assumed in this analysis (see footnote 28 for other key assumptions), would result in about 25 million metric tons of **gross** CO_2 emission reductions from PSCo's retail sales in 2030 relative to 2005 levels, or, if there were no offsetting emission increases elsewhere in the economy, about 40 percent of the **net** 62 million metric tons of economy-wide emission reductions Colorado needs in 2030 relative to 2005 levels. However, under adjusted RHG BAU **gross** emission reduction requirements are higher than the **net** 62 million metric tons as CO_2 emissions from other sources in Colorado's economy are projected to rise through 2030 (see Figure 5 and footnote 30).

Adjusted RHG Business-As-Usual

This analysis uses the *adjusted RHG BAU* as a starting point. In general, the adjusted RHG BAU projections factor in most existing federal and state policies "on the books" as of December 2019. They include Colorado's adoption of zero-emission vehicle amendments to Colorado's Low Emission Automobile Regulation[23] as well as the retirement of nine coal-fired electric generating units in Colorado that have already announced to retire: Comanche 1 (2023), Comanche 2 (2026), Craig 1 (2025), Craig 2 (2030),[24] Craig 3 (2030),[25] and all four units at Nucla, which just closed in 2019. In addition to these planned retirements, the RHG-NEMS model[26] retires one additional coal-

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22 MJB&A analysis using Rhodium Group U.S. Climate Service projections (2019), which are based on a modified version of the U.S. Energy Information Administration's (EIA) National Energy Modeling System (NEMS) model ("RHG-NEMS"). The EIA uses NEMS for its yearly Annual Energy Outlook projections. NEMS is an energy-economic equilibrium model that produces optimized projections of supply, demand, and prices of energy products in future years subject to macroeconomic factors, energy market dynamics and resource availability inputs, and other assumptions. MJB&A made additional adjustments to RHG-NEMS BAU projections to reflect announced electric sector generating unit retirements and other changes since June 2019. RHG-NEMS BAU projections also include average LULUCF related sequestration of 1.9 million metric tons in 2030. See also note 26 for additional notes on electric sector modeling. For additional detail on methodology, data sources, and assumptions used in RHG-NEMS BAU, see https://rhg.com/wp-content/uploads/2019/07/RHG_USCS_TS2019_WebTechAppendix.pdf (accessed February 13, 2020).

23 State of Colorado, Department of Public Health and Environment, Air Quality Control Commission, Regulation Number 20, "Colorado Low Emission Automobile Regulation," (September 30, 2019), available at: https://drive.google.com/file/d/1LmJQHfKUkzg6HuAKDZ0xzDO4MJMchxxA/view (accessed January 24, 2020).

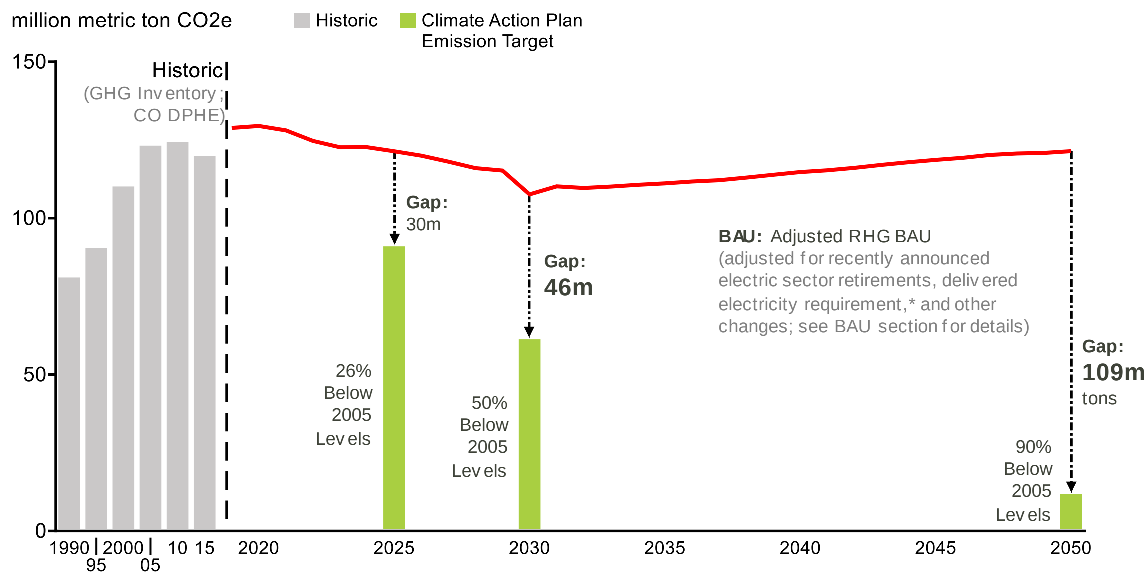
24 Tri-State Generation and Transmission, the operator of the Craig Station, has announced plans to retire Craig units 2 and 3 by 2030. However, PacifiCorp, one of the co-owners of Craig Unit 2, indicated in its Integrated Resource Plan that it intends to exit Craig Unit 2 in 2026. See PacifiCorp, 2019 Integrated Resource Plan, Volume 1, October 18, 2019, available at: https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/integrated-resource-plan/2019_IRP_Volume_I.pdf (accessed February 11, 2020).

25 Tri-State Generation and Transmission Association, Inc., United States Securities and Exchange Commission Form 8-K filing, January 8, 2020, available at: https://tristatestaging.coopwebbuilder3.com/sites/tristatestaging/files/PDF/2020%20SEC%20filings/Tri-State_8K-01082020%20-%2001-09-2020.pdf (accessed February 11, 2020).

26 Electric sector modeling within the RHG-NEMS model is carried out by the RHG-NEMS electricity market module (EMM). The EMM is a cost optimization module that uses least cost dispatch of generating resources to minimize total cost of electricity production, subject to operational and regulatory constraints. As a result, EMM projections, which are included in *adjusted RHG BAU*, are sensitive to a range of inputs including coal and natural gas prices, renewable and storage technology costs, and other macroeconomic variables. Projected electricity generation levels of different fuel types (i.e., coal, natural gas, renewables, etc.) and, therefore, GHG emission projections, may differ significantly depending on the underlying assumptions. For details of assumptions used in *the adjusted RHG BAU* projections see https://rhg.com/wp-content/uploads/2019/07/RHG_USCS_TS2019_WebTechAppendix.pdf; for methodology and details

fired unit—Rawhide 1 in 2023[27]—as a result of finding it uneconomic. Using several simplifying assumptions,[28] for illustrative purposes the adjusted RHG BAU also factors in estimated potential emission reductions associated with the requirement, codified in Colorado SB 19-236,[29] that utilities with more than half a million customers in Colorado reduce emissions associated with delivered electricity by 80 percent in 2030, relative to 2005 levels (see also call-out box on previous page).[30] Furthermore, the adjusted RHG BAU projections assume that U.S. EPA's Significant New Alternatives Policy (SNAP) rules 20 and 21[31] regulating the use of hydrofluorocarbons (HFC) remain vacated and the Kigali Amendment[32] is not adopted. New oil and gas control measures adopted by Colorado AQCC in December 2019 are also not included.[33]

Figure 3: Projected Economy-wide Emissions Reductions Required



*Illustrative estimates for Colorado's delivered electricity emission reduction requirement assume that emission reductions come from reduced output at in-state coal-fired power plants with zero-emitting resources replacing lost output for the most part. It is beyond the scope of this paper to estimate with any degree of accuracy the actual sources of abatement that a utility may use for compliance, which would depend on regional electricity grid dynamics.

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of the EMM framework see https://www.eia.gov/outlooks/aeo/nems/documentation/electricity/pdf/m068(2018).pdf (both accessed February 13, 2020).

27 Note that a higher degree of uncertainty may be associated with modeled outcomes at the electric generating unit level. Smaller units of economic activity (e.g., an electric generating unit as opposed to the entire electric sector) often tend to be more sensitive to changes in modeling assumptions and inputs than higher level projections (e.g.: state, regional or national results).

28 To estimate potential emission reductions in Colorado associated with this requirement, this analysis makes a few simplifying assumptions: all emission reductions are due to reduced output at coal-fired power plants; the power plants are located within the state of Colorado; and zero-emitting generating resources make up the replacement output for the most part. Note, however, that because the focus of the requirement is delivered electricity, it is beyond the scope of this paper to estimate with any degree of accuracy the actual sources of abatement that a utility may use for compliance, which would depend on regional electricity grid dynamics.

29 C.R.S. § 40-2-125.5(3)(I).

30 See EIA File 861 and Xcel Energy Corporate Responsibility Report (May 2019), available at: https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Corporate%20Responsibility%20Report/CRR-Performance-Summary.pdf (accessed February 11, 2020).

31 See Federal Register Volume 80, No. 138 (July 20, 2015) and Volume 81, No. 1231 (December 1, 2016).

32 Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer, October 15, 2016, https://treaties.un.org/doc/Publication/MTDSG/Volume%20II/Chapter%20XXVII/XXVII-2-f.en.pdf (accessed January 24, 2020).

33 Colorado Air Pollution Control Division has estimated that the GHG emission reductions from implementation of the December 2019 oil and gas control measures will be modest at 125,000 metric tons of CO_2e per year (see note 44). These reductions are included under the abatement measures considered for the oil and gas sector in this paper.

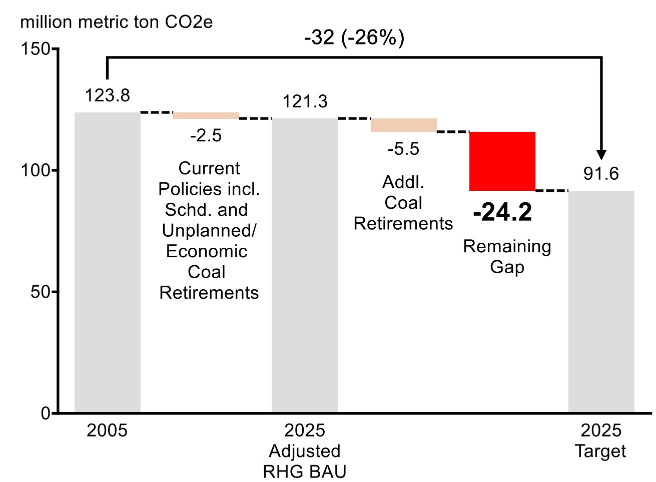
Despite some differences in their outlooks, Colorado Department of Public Health and Environment (CDPHE) (released December 2019) and the adjusted RHG BAU projections are broadly in agreement. Both sets of projections also show that under current policies, virtually all of the abatements through 2030 are projected to come from the electric and transportation sectors, with the electric sector accounting for an overwhelming majority of those reductions. As such, for the sake of simplicity, throughout this analysis the adjusted RHG BAU emission projections form the basis for all illustrations of emission reduction gaps.

The adjusted RHG BAU projections suggest that under current policies and relative to 2005 levels, Colorado's net economy-wide GHG emissions will decline by 2 million (2 percent) and 16 million metric tons (13 percent) in 2025 and 2030, respectively. However, as Figure 1 illustrates, in order to meet its statutory targets Colorado needs to achieve, from the same baseline, total emission reductions of 32 million and 62 million metric tons in 2025 and 2030, respectively. In other words, the adjusted RHG BAU projections outlined above indicate that Colorado will have an economy-wide emission reduction gap of about 30 million metric tons in 2025 and 46 million metric tons in 2030 (see Figure 3).

Potential Options to Meet the 2025 Goal

While the primary focus of this analysis is Colorado's potential GHG emissions gap in 2030, the state must also comply with a more near-term target in 2025—26 percent or 32 million metric tons below 2005 levels by 2025.

Figure 4: Economy-wide Emission Reductions in 2025



Given the short five-year timeframe to achieve these reductions and acknowledging that many strategies take time to deploy and ramp up to secure reductions, the state may prioritize sectors that can offer achievable emission reductions in that timeframe. Consequently, and similar to other states, Colorado may look to announced retirements by power plants as one option. However, the adjusted RHG BAU projections, which factor in announced power plant retirements in Colorado (six units at three plants through 2025—Comanche 1, Craig 1, and all four Nucla units), suggest that already scheduled retirements in the electric sector may yield only a small share of the required reductions by 2025. As illustrated in Figure 3, after accounting for these retirements (plus other unplanned retirements, i.e., coal plants that have not yet announced their retirement, but which were found to be uneconomic by the RHG-NEMS model), Colorado would still face a potential emission gap of 30 million metric tons in 2025.

Table 1: Electric sector assumptions and potential abatement levels in 2025

Coal EGU Retirements (MW)				**Replacement Electricity Mix** (% zero-emitting: % NGCC)	**Est. Emission Reduction** (rel. to BAU; $mmtCO_2e$)
Already Announced	Based on economics under *adjusted RHG BAU*	Additional Considered	Total		
852 Comanche 1 (325) Craig 1 (427) Nucla 1-4 (100)	280 Rawhide 1 (280)	953 Comanche 2 (335) Craig 2 (410) Drake 6,7 (208)	2,085	100:0	5.5

Even an accelerated retirement schedule for several additional coal-fired power plants (i.e., Craig 2, Comanche 2, and two units at the Martin Drake plant[34]) would not close Colorado's estimated emissions gap in 2025. Under

[34] Comanche 2 is scheduled to retire in 2026; while Craig 2 is anticipated to close in 2030, the unit may close earlier—see note 24 for additional details. Units 6 and 7 at the Martin Drake plant in Colorado are slated to be decommissioned no later than 2035, but the two units are relatively small in size (both are smaller than 150 MW in size) and about 50 years

the adjusted RHG BAU projections, in 2025 these four units together emitted 5.5 million metric tons of CO_2, less than 20 percent of the potential emission gap Colorado faces in that year (see Figure 4).

Potential Options to Meet the 2030 Goal

With an additional five years for the 2030 goal, Colorado may be able to consider a wider range of potential abatement strategies to reduce its emission reduction gap of 46 million metric tons in 2030. Table 2 outlines a set of strategies and several targeted policies that could take place in the different sectors of the state's economy.

As noted in the beginning, this paper does not attempt to evaluate *all* potential sources of greenhouse gas emissions, but explores a number of emission reduction strategies to illustrate the potential scale of the emission reductions that could become available under the right incentives or regulatory requirements for the power and oil and gas sectors as well as potential emission reductions under certain assumptions from electrification, alternate fuel use, and more efficient use of energy across Colorado's economy in the transportation, residential, and commercial sectors.

However, this is not an exhaustive list of abatement strategies to meet Colorado's goals. For example, carbon capture and storage (CCS) at CO_2-intensive industrial plants or efficiency improvement programs for industrial users of energy, strategies not considered in this paper, could yield additional emission reductions under the right incentive or policy framework. CCS technology is already being evaluated for application at a cement manufacturing plant in Colorado to sequester up to 0.7 million metric tons per year.[35] Another example of an abatement strategy that this analysis did not assess is land use, land-use change, and forestry (LULUCF) activities that increase the removal of GHGs from the atmosphere (in terrestrial sinks), which may potentially mitigate up to 14 million metric tons per year of GHG emissions in Colorado,[36] depending on the policies implemented.

Electricity Emission Rates

In order to show potential maximum emission reductions from abatement measures under the scopes considered (e.g., coal-fired power plant closures, electrification of vehicles and buildings, etc.), unless otherwise indicated, this analysis assumes for illustrative purposes that zero-emitting electricity sources meet replacement and incremental electricity demands. Potential emission reductions would be lower if fossil generation is used to meet any part of such electricity demands.

Power Sector

In the power sector, the retirement of all of Colorado's existing coal-fired power plants by 2030 and the replacement of the lost output with zero-emitting generation would offer Colorado the greatest emission reductions, relative to changes in other sectors listed in Table 2, in tonnage terms—7.4 million metric tons.[37] Doing so would reduce emissions associated with Colorado's in-state electricity generation to just over 9 million metric tons in 2030, nearly 80 percent below 2005 levels.

The two main assumptions above—elimination of coal from the electric sector and the sole use of zero-emitting resources in their place—are ambitious and not necessarily required, but they are generally consistent with

old. Colorado Springs Utilities, owner of the units, has considered retiring the units earlier. See https://www.csu.org/pages/martin-drake-r.aspx.

35 Svante, LafargeHolcim, Oxy Low Carbon Ventures and Total launch study for commercial-scale carbon capture and end-use at U.S. plant, January 6, 2020, available at: https://svanteinc.com/svante-lafargeholcim-oxy-low-carbon-ventures-and-total-launch-study-for-commercial-scale-carbon-capture-and-end-use-at-u-s-plant/ (accessed February 11, 2020).

36 See J.E. Fargione et al., 2018, Natural climate solutions for the United States. Science advances, 4(11), p.eaat1869; and U.S. State Mapper Tool, Nature4Climate, https://nature4climate.org/u-s-carbon-mapper/ (accessed February 6, 2020). Nature4Climate is a multi-organization initiative of the United Nations Development Programme, The Nature Conservancy, World Business Council for Sustainable Development, World Resources Institute, and several other organizations.

37 Based on the amount of CO_2 emissions associated with coal-fired electric generation in 2030 under adjusted RHG BAU.

Table 2: Potential abatement measures and associated emission reductions in 2030 in Colorado (relative to BAU)

IMPORTANT: In order to illustrate potential maximum emission reductions from coal-fired power plant closures and electrification of vehicles and buildings under the scopes considered, unless otherwise indicated, this analysis assumes zero-emitting electricity sources to meet all replacement and incremental electricity demands; potential emission reductions would be lower than illustrated in this paper if fossil generation is used to meet any part of such electricity demands. Furthermore, total emission reduction required for compliance is based on adjusted RHG BAU, which factors in estimated reductions due to Colorado's delivered electricity emission reduction requirement based on certain simplifying assumptions: emission reductions come from reduced output at in-state coal-fired power plants and zero-emitting generation replaces lost output for the most part. It is beyond the scope of this paper to estimate with any degree of accuracy the actual sources of abatement that a utility may use for compliance, which would depend on regional electricity grid dynamics.

Abatement Measure/Sector	**Description**	**Potential GHG Reduction in 2030** *(rel. to BAU; million metric ton CO_2e)*	**Incremental / Replacement Electricity mix** (% zero-emitting: % NGCC)	**Additional Notes**
Power Sector	All coal-fired generating capacity in Colorado retires by 2030	6.8	80:20	A range of emission reductions could result depending on the timing of coal retirements and the potential emissions associated with replacement generation. See also "IMPORTANT" note above.
		7.4	100:0	
Oil and Gas Methane Leakage	Adopt additional elements of SB 19-181 including continuous monitoring for oil and gas operations and requirements to use zero bleed pneumatic devices	up to 5.0	NA	Based on EDF's estimate of the implementation of SB 19-181, including the initial updates already finalized in December 2019. No implementing regulations have been proposed regarding continuous monitoring, use of zero bleed pneumatic devices, and other aspects of SB 19-181.
Electrification of Light Duty Vehicles	0.94 million electric light duty vehicles by 2030; no emissions averaging	2.4	100:0	Based on Colorado's adopted goal of 940,000 electric vehicles on the road by 2030 (see footnote 46)
Low Carbon Fuel Standard (LCFS)	20 percent reduction by 2030 in carbon intensity of fuels used; potential GHG reductions count only medium- and heavy-duty vehicle fuel substitution related reductions	1.9	NA	The Colorado Energy Office is currently studying a state LCFS, but no regulations have been proposed. This paper assumes Colorado adopts a 2030 LCFS target similar to California's; and roughly half of the required credits come from credit generating abatement measures deployed elsewhere in the economy (e.g., LDV electrification, heating fuel substitution, etc.)
Electrification and Alternate Fuel Use in Homes and Businesses	Direct natural gas use in residential and commercial buildings: 15 percent electrified (see footnote 57) and 10 percent substituted with renewable natural gas by 2030 (see footnote 55)	2.1	100:0	Discussions are currently ongoing among stakeholders regarding whether and to what extent electrification opportunities can reduce emissions in the state; however, there are no state policies requiring these reductions or levels of electrification and renewable natural gas use assumed in this paper
	Direct natural gas use in residential and commercial buildings: 20 percent electrified by 2030 (based on High scenario from footnote 57)			
Building Codes	0.75-1 percent of annual energy efficiency savings in residential and commercial buildings through 2030	0.3	NA	HB 19-1260 directs local jurisdictions to apply recent international energy conservation codes; this paper assumes that roughly one-third of the potential maximum energy savings is realized by 2030 in Colorado
Hydrofluorocarbons (HFC)	Implementation of Kigali amendment in Colorado	1.7	NA	Colorado APCD has proposed regulation modeled after U.S. EPA's SNAP rules 20 and 21 (both vacated by federal courts), which cover partial HFC use; Kigali amendment covers all HFC use
Total emission reduction from all abatement sources considered		**20.2-20.8**		Range reflects different power sector scenarios
Total emission reduction required for compliance with Climate Action Plan		*45.8*		Based on adjusted RHG BAU (see BAU section for details)
Emission reduction compliance gap		**25.0-25.6**		

Colorado's recently unveiled roadmap to achieve 100 percent renewable electricity by 2040.[38] If an 80/20 mix of zero-emitting and natural gas-fired generation replaced the lost output instead, the potential abatement in 2030 would be slightly lower at 6.8 million metric tons.[39]

Oil and Gas Sector

Colorado's next single largest potential source of abatement considered in this paper is methane leakage reduction in the oil and gas sector. In 2014, the Colorado AQCC adopted new rules to regulate methane emissions from the oil and gas sector.[40] Most of the requirements under these rules, including leak detection and repair (LDAR) for wells and pipelines, were phased in starting in 2015 and are incorporated into the BAU projection. On April 16, 2019, Colorado's governor signed SB 19-181,[41] which directs the AQCC to review current LDAR rules to "[…] consider whether to adopt more stringent rules and to adopt rules to minimize emissions of methane […]."[42] On December 19, 2019, the AQCC revised portions of the existing oil and gas control measures, including LDAR requirements for some well production facilities and control of emissions from storage tanks. The Air Pollution Control Division (APCD) projects these measures will reduce methane emissions by about 5,000 tons (125,000 tons in CO_2e terms[43]) per year.[44] The AQCC further directed the APCD to propose regulations to adopt additional elements of SB 19-181 including continuous monitoring for oil and gas operations and requirements to use zero bleed pneumatic devices. While the specifics of the regulation must be proposed for comment before being finalized, and the magnitude of potential emission reductions will depend on the details of the regulations, some stakeholders have developed estimates of the scale and scope of the potential emission reductions. For example, EDF has estimated that implementation of SB 19-181, including the initial updates already finalized in December 2019, could reduce GHG emissions from the sector by 4 million to 5 million metric tons of CO_2e in 2030.[45]

Electrification of Light Duty Vehicles

Colorado has a goal of 940,000 electric vehicles on the road by 2030 and recently adopted its zero emission vehicle program under section 177 of the Clean Air Act.[46] Assuming the state achieves this target, zero-emitting

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38 State of Colorado, Office of the Governor, "Roadmap to 100% Renewable Energy by 2040 and bold Climate Action", (May 2019), available at: https://drive.google.com/file/d/0B7w3bkFgg92dMkpxY3VsNk5nVGZGOHJGRUV5VnJwQ1U4VWtF/view (accessed January 10, 2020).

39 Assumes average NGCC and coal-fired generation CO_2 emission rates in Colorado of 906 and 2,325 lb/MWh, respectively, based on MJB&A analysis of EIA File 923 (2017) data.

40 State of Colorado, Department of Public Health and Environment, Oil & Gas Compliance and Recordkeeping, available at: https://www.colorado.gov/pacific/cdphe/air/oil-and-gas-compliance.

41 State of Colorado, Seventy-Second General Assembly, "Concerning the Additional Public Welfare Protections Regarding the Conduct of Oil and Gas Operations, and, in Connection Therewith, Making an Appropriation." (signed April 16, 2019), available at: https://leg.colorado.gov/sites/default/files/2019a_181_signed.pdf (accessed January 24, 2020).

42 Ibid.

43 Based on a 100-year time horizon global warming potential of 25 for methane. See note 18 for more details.

44 State of Colorado, Department of Public Health & Environment Air Pollution Control Division, "Colorado Air Quality Control Commission's 2019 Revisions to Regulation Number 7 – Oil and Gas Emissions and Regulation Number 3 – Permitting and APENs Fact Sheet." (January 8, 2020), available at: https://drive.google.com/file/d/1b0qXRpFOFayO1r3qF4bdFpG9NPukGJfP/view.

45 Environmental Defense Fund, EDF Statement from Matt Garrington, State Campaigns Manager, Energy, "Colorado Adopts Stronger Rules to Protect Health and Climate from Oil and Gas Pollution," December 19, 2019, available at: https://www.edf.org/media/colorado-adopts-stronger-rules-protect-health-and-climate-oil-and-gas-pollution (accessed January 10, 2020).

46 State of Colorado, "Executive Order On Supporting a Transition to Zero Emission Vehicles," (Executive Order 2019-002), January 17, 2019, available at https://www.colorado.gov/governor/sites/default/files/inline-files/b_2019-002_supporting_a_transition_to_zero_emissions_vehicles.pdf and State of Colorado, Department of Public Health and Environment, Air Quality Control Commissions, Colorado Low Emission Automobile Regulation, September 30, 2019, available at: https://drive.google.com/file/d/1LmJQHfKUkzg6HuAKDZ0xzDO4MJMchxxA/view (accessed January 24, 2020).

electricity is used to meet the incremental electricity demand—an ambitious assumption that maximizes potential emission reductions, and no ZEV emission averaging under vehicle standards happens, analysis using the MJB&A STEP Tool[47] suggests that Colorado's GHG emissions could be reduced by an estimated 2.4 million metric tons in 2030.

For comparison, modeling by Evolved Energy Research with somewhat different assumptions (one million electric light duty vehicles, 30 percent of medium- and heavy-duty vehicles electrified by 2030, and a mix of natural gas-fired generation and renewable resources used to satisfy incremental electricity demand) shows a smaller emission reduction outcome at one million metric tons in 2030.[48]

Low Carbon Fuel Standard (LCFS): Medium- and Heavy-Duty Vehicles

In September 2019, the Colorado Energy Office started the process of studying a state LCFS, beginning with a life-cycle analysis of potential strategies including the feasibility of an LCFS to reduce emissions from the transportation sector.[49] LCFS programs are designed to drive reductions in overall carbon intensity of fuels used in one or more sectors of the economy. In general, under an LCFS program, fuel providers must lower the carbon intensity of their fuels to comply with the targets. Fuels below the stipulated target generate credits, and fuels with carbon intensities above the target must acquire credits to demonstrate compliance. Because LCFS programs tend to rely on market mechanisms to identify—and develop—the most efficient fuel compliance options, with credits trading on market exchanges, it is not possible to outline in this paper any definitive compliance pathways. For example, nearly 750 pathways involving more than a dozen alternative fuels have been certified in California under the state's LCFS program.[50]

However, for illustrative purposes and to provide a sense of the magnitude of emission reductions Colorado could potentially achieve under an LCFS program that is broadly similar to California's, this paper assumes that Colorado adopts a target carbon intensity of 20 percent below 2010 levels by 2030.[51] It further assumes that roughly half of the credits the state will need for compliance will come from medium- and heavy-duty vehicles using alternative fuels (e.g., renewable and bio diesel) in lieu of diesel, a share that is consistent with projections of illustrative fuel mixes that could meet California's LCFS in 2030.[52] Under these assumptions, analysis using the MJB&A STEP Tool suggests that transportation sector GHG emissions in Colorado could decline by an additional estimated 1.9 million metric tons in 2030.[53]

Note that potential LCFS credits generated due to electrification and fuel substitution in other sectors of Colorado's economy, which are among the abatement sources considered in sections of this paper, could provide the remaining credits (or more) required for compliance, but these LCFS credits are not quantified or considered in this paper. Further, since emission reductions associated with such credit generating abatement activities are already accounted for in their respective sections, to reduce the likelihood of any double counting, only emission reductions associated with alternative fuel use by medium- and heavy-duty vehicles are counted under LCFS in

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47 See note 7.

48 See note 8. Emission reductions associated with an individual measure may also depend on the order in which it is applied in certain models. For example, if electrification of light-duty vehicles to a certain target level follows (within the model) an LCFS program and any electrification of light duty vehicles that happen prior to the application of the electrification measure is attributed to the LCFS program, then emission reductions attributed to the electrification measure may be significantly smaller than if the order of applying the two measures were reversed.

49 See Colorado Energy Office solicitation for documented quote (DQ) to conduct a Low Carbon Fuel Standard (LCFS) Feasibility Study, September 11, 2019, DQ1 EFAA 2020-185.

50 See State of California, Air Resource Board, LCFS Pathway Certified Carbon Intensities, January 27, 2020, available at: https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm and https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/current-pathways_all.xlsx (accessed February 5, 2020).

51 California Air Resources Board, "Low Carbon Fuel Standard", (2018), available at: https://ww3.arb.ca.gov/fuels/lcfs/background/basics-notes.pdf (accessed February 7, 2020).

52 California Air Resources Board, "Staff Report: Initial Statement of Reasons for the Proposed Amendments to the Low Carbon Fuel Standard Regulation," (2018).

53 See note 7.

this section. Evolved Energy Research's modeling of a similar LCFS target for Colorado projects higher emission reductions at 5 million metric tons, due in part to the inclusion of GHG abatements associated with carbon intensity reduction of gasoline, a fuel that is primarily consumed by light-duty vehicles.[54]

Electrification and Alternate Fuel Use in Homes and Businesses
While there are currently no state policies requiring electrification or use of alternate fuels in homes and businesses, stakeholders and policymakers in Colorado have begun to consider potential opportunities for emission reductions in the state's buildings sector. A recently introduced bill—Colorado HB 20-1018—would require large natural gas utilities in the state to meet a procurement target of at least 10 percent renewable natural gas by 2030.[55] Similar electrification related bills may also be under consideration by state legislators.[56] Assuming 15 percent[57] of direct natural gas use in the residential and commercial sectors is electrified[58] and the increased electricity demand is met with zero-emitting electricity—a relatively ambitious assumption—analysis using MJB&A's STEP Tool[59] suggests that Colorado would be able to cut its GHG emissions in 2030 by 1.6 million metric tons. If we further assume that another 10 percent of direct natural gas use is converted to renewable natural gas by 2030, analysis using the same STEP Tool results in another 0.6 million metric tons of GHG reductions by that year. A similar level of additional reduction—0.5 million metric tons—may also be achieved by increasing electrification levels by 5 percentage points to 20 percent in lieu of renewable natural gas use.

Evolved Energy Research's modeling, which restricts electrification to residential buildings only and assumes a mix of natural gas-fired generation and renewable resources for incremental electricity demand (this paper assumes zero-emitting electricity in most cases), suggests lower emission reductions at approximately 0.5 million metric tons.[60]

Building Codes
In the residential and commercial sectors, a recently adopted law—Colorado HB 19-1260[61]—directs local jurisdictions to apply one of three most recent international energy conservation codes (IECC) upon updating any building code. The IECC code revisions from 2015 and 2018 are only slightly more energy efficient than those from 2012;[62] therefore, regardless of which one of the three most recent IECC codes is selected, the resulting energy efficiency impact will likely be very similar—roughly around 30 percent relative to IECC 2006 or

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54 See note 48.
55 State of Colorado, Seventy-Second General Assembly, "Concerning Adoption of a Renewable Natural Gas Standard." (introduced January 8, 2020), available at: https://leg.colorado.gov/sites/default/files/documents/2020A/bills/2020a_1018_01.pdf (accessed February 10, 2020)
56 Cost, comfort emphasized as building electrification takes off in Colorado, Energy News Network, November 18, 2019, available at: https://energynews.us/2019/11/18/west/cost-comfort-emphasized-as-building-electrification-takes-off-in-colorado/ (accessed February 11, 2020).
57 Based on midpoint of Medium and High scenarios included in National Renewable Energy Laboratory, 2018. Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. Golden, CO. NREL/TP-6A20-71500. Available at: https://www.nrel.gov/docs/fy18osti/71500.pdf (accessed January 30, 2020). Midpoint calculated for 2030 by MJB&A using visual estimates of sub sectoral charts provided in Figure 6.5 on page 53
58 Assumes the use of air source heat pumps.
59 See note 7.
60 See note 8.
61 State of Colorado, Seventy-Second General Assembly, "Concerning an Update to the Minimum Energy Code for the Construction of Buildings" (signed May 03, 2019), available at: https://leg.colorado.gov/sites/default/files/2019a_1260_signed.pdf (accessed January 30, 2020).
62 See Federal Register Volume 84, No. 237 (December 10, 2019) and Volume 80, No. 112 (June 11, 2015).

earlier.[63] Consequently, given that the current code in Colorado is 2003 IECC,[64] the adoption of any of the three most recent IECC codes would roughly produce about 30 percent energy savings for individual buildings and homes in Colorado that are compliant with earlier standards.

In order to translate these estimated savings into state level sectoral energy use impacts in 2030, this paper assumes that by 2030 only about one-third of the maximum estimated energy savings due to the newer codes, or about 10 percent, will be realized in Colorado. It assumes so for two reasons—buildings and individual jurisdictions are likely to adopt the newer IECC codes gradually over time, while at the same time some of the existing building stock in the state may already be compliant with the newer codes. On this basis, this paper calculates that average annual energy efficiency savings of 0.75-1 percent through 2030 in Colorado's buildings sector would approximate this level of efficiency savings in 2030.[65]

Using the estimated annual energy efficiency savings rates as inputs, analysis using MJB&A's STEP Tool estimates that Colorado's GHG emissions could fall by an additional 0.3 million metric tons in 2030 due to the adoption of the more updated building codes.[66]

Hydrofluorocarbons (HFC)

In February 2020, the Colorado APCD proposed new regulation to phase out the use of HFCs for certain end-uses in the state.[67] HFCs, a class of highly potent GHGs with global warming potential values in the hundreds and thousands, are increasingly employed as replacements for ozone-depleting substances in uses such as refrigeration and air-conditioning equipment, aerosol sprays, insulation of buildings, and fire extinguishing systems.

The Colorado APCD modeled the draft HFC rule after U.S. EPA's SNAP rules 20 and 21,[68] which sought to reduce HFC use in the U.S. in certain end-use sectors, but were invalidated by the courts.[69] An initial analysis of the draft rule estimates GHG emission reductions of about 1.2 million metric tons in 2030.[70]

The SNAP rules, however, are relatively limited in scope—according to an analysis by the California Air Resources Board (CARB) they would affect less than half of all HFC emissions in that state.[71] By comparison, the Kigali Amendment,[72] an international agreement that aims to reduce the use of HFCs by 85 percent relative to

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63 See Pacific Northwest National Laboratory, Energy and Energy Cost Savings Analysis of the IECC for Commercial Buildings, August 2013, and Cost-Effectiveness Analysis of the 2009 and 2012 IECC Residential Provisions – Technical Support Document, April 2013. This paper assumes the energy saving and cost savings follow each other closely.

64 U.S. Department of Energy, Building Energy Codes Program, Colorado, available at: https://www.energycodes.gov/adoption/states/colorado (accessed January 31, 2020).

65 For context, U.S. EIA's Annual Energy Outlook projections (2019), which do not assume the adoption of any of the newer IECC codes, suggest national average annual energy efficiency savings of 0.5 and 0.8 percent for the commercial and residential sectors, respectively. See https://www.eia.gov/outlooks/aeo/ (accessed January 19, 2020).

66 See note 7.

67 State of Colorado, Department of Public Health and Environment, Colorado Greenhouse Gas Reporting and Emission Reduction Requirements (February 2020), available at: https://drive.google.com/drive/folders/1irIUGWl4j4BOkkq4J1g54hscK7ov_BS8 (accessed February 14, 2020).

68 See January 16-17, 2020, Stakeholder Meeting Handout, available at: https://drive.google.com/a/state.co.us/file/d/1jfQWU2YKcmtCao0qpw26Tkk4GJJUfT4n (accessed January 29, 2020) and note 31.

69 See, *Mexichem Fluor, Inc. v. EPA*, 866 F.3d 451 (D.C. Cir. 2017) and *Mexichem Fluor, Inc. v. EPA*, 760 Fed. Appx. 6 (D.C. Cir. 2019).

70 State of Colorado, Department of Public Health and Environment, Initial Economic Impact Analysis. Proposed AQCC Regulation Number 22: Colorado Greenhouse Gas Reporting and Emission Reduction Requirements (February 2020), available at https://drive.google.com/drive/folders/1irIUGWl4j4BOkkq4J1g54hscK7ov_BS8 (accessed February 14, 2020).

71 California Air Resources Board, Potential Impact of the Kigali Amendment on California HFC Emissions, December 15, 2017, https://ww3.arb.ca.gov/cc/shortlived/carb-potential-impact-of-the-kigali-amendment-on-hfc-emissions-final-dec-15-2017.pdf (accessed February 11, 2020).

72 See note 32.

a 2011-13 baseline by 2036,[73] applies to all HFC use across the economy. Consequently, its adoption is likely to result in higher GHG emission reductions. Analysis using the RHG NEMS model indicates that adoption of a HFC phase-down schedule in Colorado that is similar to that of the Kigali Amendment would produce about 1.7 million metric tons of GHG emission reductions in 2030.[74]

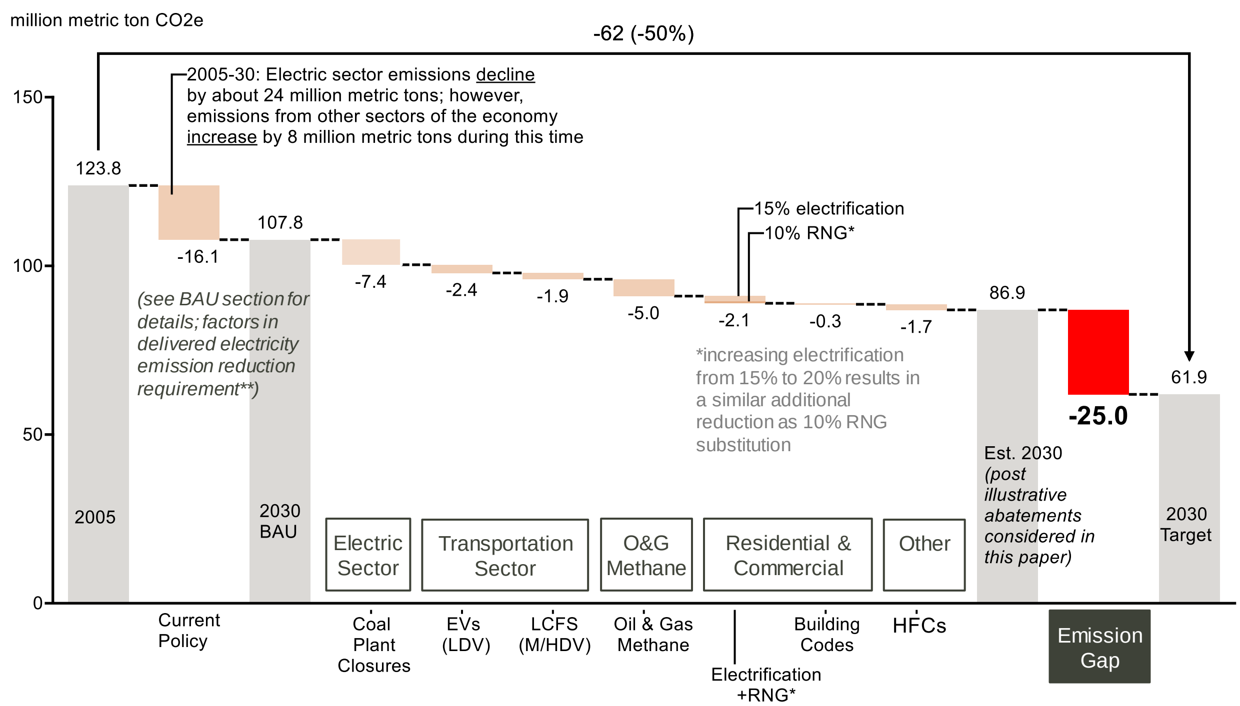
Conclusions

Based on current policies, under the adjusted RHG BAU projections, Colorado's economy-wide GHG emissions in 2030 would be about 108 million metric tons. Relative to this level of projected emissions in 2030, Colorado must secure 46 million metric tons of GHG emission reductions to meet its statutory target under the Climate Action Plan.

The abatement strategies considered in this paper, under the assumptions discussed above, could result in about 21 million metric tons of total GHG emission reductions in 2030, leaving the state a potential emission gap of 25 million metric tons in that year. Figure 5 illustrates the emission reductions as well as the estimated gap to achieve Colorado's 2030 statutory target.

It is important to note that this analysis is illustrative in nature and, as noted throughout, there are some limitations. First, it did not undertake any equilibrium modeling of Colorado's economy with dynamic interaction between the different sectors, which may result in emission reduction estimates that are different from those shown in this paper. Second, it did not assess *all* potential sources of abatement or policy mechanisms (e.g., market-based mechanisms, command and control mechanisms, multi-sector or multi-jurisdictional programs, etc.) that may be available to the state. And, finally, for the abatement strategies that this paper did consider, the

Figure 5: Abatement Sources and Associated Economy-wide Emission Reductions in Colorado in 2030



**Illustrative estimates for Colorado's delivered electricity emission reduction requirement assume that emission reductions come from reduced output at in-state coal-fired power plants with zero-emitting resources replacing lost output for the most part. It is beyond the scope of this paper to estimate with any degree of accuracy the actual sources of abatement that a utility may use for compliance, which would depend on regional electricity grid dynamics.

[73] Developed country schedule under the Kigali Amendment; see also note 32.
[74] See notes 9 and 22.

associated potential emission reductions are sensitive to underlying assumptions, levels of stringencies, and policy architectures adopted for each.

That said, the potential scale of the emissions gap illustrated in this paper—even considering some high-ambition sectoral assumptions—along with frameworks that incentivize or require additional emission reductions would be among the factors that Colorado's AQCC may consider as it evaluates various options to meet the state's statutory emission reductions targets.

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