Technical Appendix

Decarbonize DRCOG will reduce climate pollution, provide significant co-benefits, and spur market transformation in the DRCOG region's built environment, cutting greenhouse gas (GHG) emissions a cumulative **6,855,776 metric tons of carbon dioxide equivalent ($mtCO_2e$) by 2030 and 148,176,499 $mtCO_2e$ by 2050.** The Technical Appendix estimates GHG reductions for each Measure if implemented independently, then models a "Transformative Impact" scenario that estimates the combined effect of the Measures and Support Initiatives. Modeling support was provided by Lotus Engineering and Sustainability, LLC (Lotus), with additional contributions from Rewiring America. Emissions savings from Leveraged Funds are calculated separately to demonstrate the added impact of these commitments from the City of Boulder, Boulder County, and the City and County of Denver (Budget Narrative page 8).

Decarbonize DRCOG's calculations rely on two Excel-based models, described below and included in **GHGcalcs_DRCOG.xlsx**. The first model, developed by Rewiring America, estimates home and building level energy and GHG emission savings based on distinct energy improvement installations; this is used to calculate the individual impact of Measures 1: LIDAC Decarbonization, 2: Energy Advising, and 3: Rebates and Incentives, detailed in tabs **Measures 1-3 Calcs** and **Measures 1-3 EF and Constants**. The second model, developed by Lotus, calculates the effect of Measure 4 Policy Collaborative and total Transformative Impact by modeling ecosystem-wide impacts of increased efficiency and electrification in new and existing buildings; full details are found in tabs **Measure 4** and **TI** of the spreadsheet. The Lotus model used for *Decarbonize DRCOG* is derived from the model Lotus originally developed to calculate GHG emissions reductions potential in the Colorado Energy Office's (CEO) Priority Climate Action Plan (PCAP).[1] Co-pollutant reductions for all Measures are reported on page 10.

Summary of GHG Emission Reductions

Table 1: *Annual and Cumulative GHG Emission Reductions, by Measure*

Measure	Average Annual Emission Reductions ($mtCO_2e$)		Cumulative Emission Reductions ($mtCO_2e$)	
	2025-2030	2025-2050	2025-2030	2025-2050
1: LIDAC Decarbonization	849	830	12,204	94,955
Measure 1 Leveraged Funds	*302*	*28,448*	*4,337*	*33,747*
2: Energy Advisors	15,489	16,918	213,210	1,924,648
3: Rebates and Incentives	16,409	16,834	246,141	1,935,956
Measure 3 Leveraged Funds	*16,218*	*16,616*	*243,275*	*1,910,835*
4: Policy Collaborative	141,171	1,225,451	3,811,623	106,614,244
Transformative Impact	**253,918**	**1,703,178**	**6,855,776**	**148,176,499**

Table 2: *Cumulative GHG Savings from Reduction in Natural Gas Usage, by Greenhouse Gas and Measure*

Measure	CO_2 (metric tons)		CH_4 (metric tons)		N_2O (metric tons)	
	2025-2030	2025-2050	2025-2030	2025-2050	2025-2030	2025-2050
1: LIDAC Decarbonization	8,645	68,786	17	132	2	13
Measure 1 Leveraged Funds	*3,073*	*24,447*	*6*	*47*	*1*	*5*
2: Energy Advisors	209,580	1,733,691	403	3,334	40	333
3: Rebates and Incentives	191,726	1,469,902	369	2,827	37	283
Measure 3 Leveraged Funds	*192,353*	*1,474,708*	*370*	*2,836*	*37*	*284*
4: Policy Collaborative	2,467,019	78,729,467	4,744	151,402	474	15,140
Transformative Impact	**4,613,446**	**109,238,031**	**8,872**	**210,073**	**887**	**21,007**

[1] Colorado Priority Climate Action Plan. https://www.epa.gov/system/files/documents/2024-03/colorado-pcap.pdf Accessed March 2024

Modeling for Measures 1-3

GHG Reduction Measure Estimation Method

Rewiring America's method to calculate residential GHG reductions for Measures 1-3 is based on the modeled energy savings of specific efficiency and electrification improvements in single family and multifamily homes. The National Renewable Energy Laboratory (NREL) ResStock[2] dataset is used in partnership with EnergyPlus,[3] the Department of Energy's open-source building energy modeling tool, to model a 'blended average' single family home and multifamily unit, and the energy and emission savings each would realize by implementing specific energy improvements. Energy improvements modeled as part of Measure 1 are the installation of a heat pump dryer, heat pump water heater, induction range, medium efficiency heat pump (SEER 18, HSPF 10), and basic insulation. For Measures 2 and 3, improvements modeled are a heat pump water heater, medium efficiency heat pump, and basic insulation. By sampling from ResStock to get savings estimates at the Census tract level, savings in LIDAC vs. non-LIDAC tracts and ergo LIDAC vs. non-LIDAC households are calculated using CEJST[4] definitions. Annual energy savings per household are reported in kWh (electricity) and therms (natural gas and propane). Energy savings are converted into emission savings using the emission factors on pages 3-4.

Commercial emission savings were calculated per square foot, based on the Energy Information Administration's (EIA) Commercial Building Energy Consumption Survey (CBECS).[5] Emissions savings and cost per square foot were based on a blended rate of space and water heating upgrades across three building typologies: medium office, large hotel, and retail space. The number of clients served annually by Measure 2 was converted to square footage based on the average size of buildings in the region. The emission impact was calculated directly based on expected square footage served; $8M are anticipated to serve 4.1M square feet of commercial real estate over the grant period (Budget Narrative page 7).

Models, Tools, and Key Datasets Used

Models and tools used to develop the GHG emission reduction estimate include:

- Colorado Greenhouse Gas Pollution Reduction Roadmap;[6] modeling conducted by Energy & Environmental Economics (E3)
- Council of Environmental Quality Climate and Economic Justice Screening Tool (CEJST)
- EIA CBECS
- EIA Residential Energy Consumption Survey (RECS)[7]
- Energy Innovation and RMI's Colorado Energy Policy Simulator[8]
- EPA Emissions & Generation Resource Integrated Database (eGRID) 2022 RMPA region[9]
- EPA National Emissions Inventory (2020 inventory year)[10]
- NREL ResStock
- Rewiring America household savings model
- U.S. Census Bureau American Community Survey[11]
- U.S. Department of Energy EnergyPlus

Measure Implementation Assumptions

Total budget allocated for Measures 1, 2, and 3 from 2025-2030 is $108,633,321. Leveraged funds and in-kind staff time from the City and County of Denver, Boulder County, and the City of Boulder contribute

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[2] NREL ResStock Analysis Tool. https://www.nrel.gov/buildings/resstock.html Accessed March 2024
[3] DOE EnergyPlus. https://energyplus.net/ Accessed March 2024
[4] Climate and Economic Justice Screening Tool. https://screeningtool.geoplatform.gov/ Accessed March 2024
[5] EIA Commercial Buildings Energy Consumption Survey. https://www.eia.gov/consumption/commercial/ Accessed March 2024
[6] Colorado Greenhouse Gas Pollution Reduction Roadmap. https://drive.google.com/file/d/19pmqOzKV9ulXHHRyZz5egOBJWO0fPw-i/view Accessed March 2024
[7] EIA Residential Energy Consumption Survey. https://www.eia.gov/consumption/residential/ Accessed March 2024
[8] Energy Innovation and RMI Colorado Energy Policy Simulator. https://energypolicy.solutions/simulator/colorado/en Accessed March 2024
[9] EPA eGRID. https://www.epa.gov/system/files/documents/2024-01/egrid2022_summary_tables.pdf Accessed March 2024
[10] EPA National Emissions Inventory. https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei Accessed March 2024
[11] U.S. Census Bureau American Community Survey. https://www.census.gov/programs-surveys/acs Accessed March 2024

an added $73,258,343 across the same five-year period. See pages 8-9 of the Budget Narrative for cost estimate methodology for individual energy upgrades and additional program budget assumptions. Measures 1 and 2 are modeled as scaling up through Year 4 with decreased expenditures in Year 5 —a reflection of anticipated trends in existing programs. Rebates are modeled as evenly distributed across the duration of the program. Emission reductions realized by installation of new equipment are considered persistent through 2050 in comparison to emissions associated with prior appliances and building envelope status.

GHG Reduction Estimate Assumptions

See **GHGcalcs_DRCOG.xlsx** tab **Measure 1-3 Calcs** for full assumptions around kWh and therm reductions by efficiency and electrification upgrades and associated emission savings. Key assumptions:

Residential efficiency and electrification upgrade specifications:

- *Weatherization:* The modeled weatherization package includes attic floor insulation up to International Energy Conservation Code (IECC) Residential 2021 levels (R-60 for homes with R-38 insulation or less), general air sealing to achieve a 30% reduction in ACH50,[12] duct sealing to 10% leakage, and R-13 drill-and-fill insulation.[13]
- *Heat Pumps:* modeled performance is similar to a centrally-ducted SEER 18[14] and HSPF 10[15] heat pump with electric resistance backup. For homes with existing ductwork, heat pumps are sized using ACCA Manual S, which sizes heat pumps based on cooling load with an oversizing allowance to meet higher heating loads. For homes without ducts, the heat pumps modeled are ductless heat pumps sized to the larger of the cooling and heating load.

Commercial Building Assumptions

- High-level assumptions about baseline natural gas equipment efficiency and replacement equipment types were utilized.
- Additional electricity consumption from equipment electrification is included and energy savings from improved cooling efficiency are accounted for.
- Average size of a commercial building served by Measure 2 is assumed to be 20,000 square feet. This value is informed by the average size of commercial buildings in five urban/suburban communities in the region as reported by individual County Assessors' offices. This compares to the average size of a building subject to the City of Denver's Building Performance Standard at 120,000 sq ft. The 20,000 average from smaller urban centers is expected to be a conservative approach for savings calculations.
- The incentives in Measure 3 are calculated to cover 25% of the total upgrade cost.

Emission Factors

Electricity GHG emissions were modeled using blended emissions factors from Xcel Energy and a statewide average. Emissions from Xcel Energy, which account for 79% of regional electricity usage, are modeled based on public commitments and statutory requirements to reduce emissions 80% below 2005 levels by 2030 and 100% by 2050.[16] The remaining 21% of electricity use is represented by the state-wide average emission factors reported in the Colorado Greenhouse Pollution Reduction Roadmap, as utilized by Energy Innovation and RMI's Colorado Energy Policy Simulator. Methane and N_2O emission factors are based on EPA's eGRID.

[12] Air changes per hour at 50 pascals. A measure of air leakage in a building envelope. https://building-performance.org/bpa-journal/ach50-achnat/ Accessed March 2024

[13] Insulation is measured in terms of its heat trapping ability. This is noted by an R score. The higher the R-value, the more the insulation traps heat. https://www.energystar.gov/saveathome/seal_insulate/identify-problems-you-want-fix/diy-checks-inspections/insulation-r-values Accessed March 2024

[14] The Seasonal Energy Efficiency Ratio (SEER) 18 value is the second-highest energy efficiency rating a heat pump may be graded at. https://carbonswitch.com/what-is-a-seer-rating/ Accessed March 2024

[15] Heating Seasonal Performance Factor 10. HSPF 10.2 is the highest heating efficiency score for a heat pump. https://www.lennox.com/buyers-guide/guide-to-hvac/glossary/heating-seasonal-performance-factor-hspf Accessed March 2024

[16] Xcel Energy Carbon Reduction Plan. https://co.my.xcelenergy.com/s/our-commitment/carbon-reduction-plan Accessed March 2024

Rewiring America used the following emission factor values for non-electric on-site fuel consumption CO_2e emissions. These values are static and do not change over the life of the measured savings.

- Natural gas: 147.3 lb CO_2e/MMbtu (228.0 kg CO_2e/MWh)
- Propane: 177.8 lb CO_2e/MMbtu (182.3 kg CO_2e/MWh)

Emission factors include both the combustion and precombustion (e.g., methane leakage for natural gas) CO_2e emissions. These values are from Table 7.1.2(1) National Average Emissions Factors for Household Fuels from draft ANSI/RESNET/ICC 301 Standard for the Calculation and Labeling of the Energy Performance of Dwelling and Sleeping Units using an Energy Rating Index.[17]

The Intergovernmental Panel on Climate Change (IPCC)'s 5th Assessment Report's global warming potential values for methane (CH_4) and nitrous oxide (N_2O) were used to calculate $mtCO_2e$.

Reference Case Scenario

The reference case modeled by Rewiring America is like-for-like replacement of natural gas-fueled appliances with electricity-powered appliances in single family homes and multifamily units. Appliances include boilers/furnaces, water heaters, stoves, and dryers.

Measure Specific Activity Data

Table 3: *Number of Households and Commercial Square Footage Served by Measure and Leveraged Funds*

Program	*Decarbonize DRCOG* Direct Impact		
	Single Family served	Multi-family served	Commercial served
1: LIDAC Decarbonization	533 homes	1,067 units	-
Measure 1 Leveraged Funds	*155 homes*	*414 units*	-
2: Energy Advisors	23,800 homes	10,200 units	5,800 businesses
3: Rebates and Incentives	10,000 homes	16,000 units	4.1M sq ft
Measure 3 Leveraged Funds	*8,655 homes*	*17,837 units*	*7.3M sq ft*

Table 4: *Cumulative Electricity and Natural Gas Savings, by Measure*

Measure	Cumulative Electricity Savings (kWh)		Cumulative Natural Gas Savings (therms)	
	2025-2030	2025-2050	2025-2030	2025-2050
1: LIDAC Decarbonization	4,754,489	37,828,298	1,662,578	13,228,026
Measure 1 Leveraged Funds	*1,689,759*	*13,444,286*	*590,885*	*4,701,278*
2: Energy Advisors	13,282,823	109,371,330	40,303,931	333,402,075
3: Rebates and Incentives	17,356,215	133,064,314	36,870,444	282,673,403
Measure 3 Leveraged Funds	*31,394,591*	*240,691,864*	*36,991,005*	*283,597,708*

Modeling for Measure 4 and Transformative Impact

GHG Reduction Estimation Method

Emission reductions from Measure 4 and the Transformative Impact of the entirety of *Decarbonize DRCOG* were estimated based on the model Lotus initially developed to quantify impact of measure "LG Buildings 2: Adopt building energy codes and performance standards that exceed state requirements" in CEO's PCAP. Modeling for Measure 4 estimates its impact if implemented in isolation, without any other Measures or Support Initiatives. Transformative Impact estimates the sector-wide impact of all Measures and Support Initiatives working in concert, signifying the impact of the whole *Decarbonize DRCOG* program is greater than the sum of its parts.

[17] ANSI/RESNET/ICC 301-2022. https://www.resnet.us/wp-content/uploads/ANSIRESNETICC301-2022_resnetpblshd.pdf Accessed March 2024

Market-wide emission reductions from Measure 4 and *Decarbonize DRCOG*'s Transformative Impact are calculated as the outcome of three levers that accelerate building decarbonization: higher performance of newly constructed buildings (New Construction), electrification of existing buildings (Electrification), and energy efficiency improvements of existing buildings (Efficiency), all in comparison to a business-as-usual (BAU) baseline of 2018 or 2021 IECC performance. For New Construction and Electrification, jurisdictions are modeled as moving toward performance goals in three cohorts, labeled in the model as Tier A1 (first adopters), Tier A2 (second wave), and non-participating communities. For Efficiency, the Denver area is broken into two cohorts. Tier B1 comprises Boulder and Denver Counties, the two jurisdictions in the region that currently have a building performance standard more stringent than that required by the state. Tier B2 comprises for the rest of the DRCOG region.

See Table 5 for overview of assumptions used across Measure 4 and Transformative Impact modeling.

Emission Reductions from Higher Performance New Construction

New Construction emission reductions are calculated as the cumulative impact of constructing buildings above BAU energy code performance. The total square footage of new construction each year is derived from Google Environmental Insights Explorer[18] and Colorado State Demography Office county-level employment and population projections.[19] Total square footage incorporates the nine counties that are wholly within the DRCOG region (Adams, Arapahoe, Boulder, Broomfield, Clear Creek, Denver, Douglas, Gilpin, Jefferson) plus a population-based percentage of total annual growth expected in Weld County. Initial compliance is assumed at a rate of 50%; compliance increases over time as a result of Measure 4 as well as the Transformative Impact of *Decarbonize DRCOG*.

Square Footage of new construction producing GHG emission savings (SF) is calculated as:

SF = (Total DRCOG New Construction sq ft x *Compliance Rate)*

Emission reductions are calculated based on changes in total energy use between the baseline and high performance energy codes. BAU energy use – energy use intensity (EUI) per square foot by fuel type – is derived from the Pacific Northwest National Laboratory (PNNL) Prototype Building Models for the 2018 and 2021 IECC.[20] EUI values for non-residential properties represent a weighted average based on square footage of each building type in NREL's ComStock[21] dataset for Colorado; residential energy use is based on PNNL analysis for climate zone 5B. BAU energy use is then adjusted to account for expected equipment electrification even if no policy action is taken. The reduction in natural gas use and increase in electricity use due to this baseline electrification is included in BAU energy use. The BAU rate of electrification is derived from NREL's Electrification Futures Study.[22] Natural gas, propane, and electricity savings are calculated annually.

Emission reductions from electrification that would have already happened under a BAU scenario are excluded from calculating GHG impacts of *Decarbonize DRCOG*. Energy impact of this baseline electrification is captured in avoided natural gas usage and additional electricity consumption.

Reduction in natural gas usage due to baseline electrification:

BAU natural gas reduction = BAU sq ft x *% of BAU sq ft served by a heat pump* x *BAU natural gas EUI*

Increase in electricity consumption due to baseline electrification:

BAU electricity increase = BAU natural gas reduction x *fossil fuel appliance efficiency / heat pump COP*

Tier A1 communities are modeled as moving directly to zero-emission new construction performance in 2027 from a baseline of the 2021 IECC; Tier A2 communities have a period under "Electric Preferred"

[18] Google Environmental Insights Explorer. https://insights.sustainability.google/ Accessed March 2024
[19] Colorado State Demography Office. https://demography.dola.colorado.gov/ Accessed March 2024
[20] US DOE / PNNL Prototype Building Models. https://www.energycodes.gov/prototype-building-models Accessed March 2024
[21] NREL ComStock Analysis Tool. https://www.nrel.gov/buildings/comstock.html Accessed March 2024
[22] NREL Electrification Futures Study. https://www.nrel.gov/analysis/electrification-futures.html Accessed March 2024

performance between performing at a baseline of 2018 IECC and eventual zero-emission performance. Under zero-emission performance, new buildings are modeled as all-electric, with all electricity coming from renewable sources as opposed to the background utility emission factor.

Natural gas savings under zero-emission performance:

Zero-emission natural gas savings = baseline IECC natural gas usage – BAU natural gas reduction

Electricity consumption savings under zero-emission performance:

Zero-emission electricity savings = baseline IECC electricity usage + BAU electricity increase

For Tier A2, energy use changes compared to BAU during the 3 years (2027-2029) under the "Electric Preferred" code are modeled based on the performance pathway provisions in the 2022 Denver Energy Code. Non-residential energy targets are derived from Appendix SE: Site Energy from Denver's Commercial Code,[23] where target site energy usage is based on a percentage reduction in energy use from HVAC, service water heating, lighting, and refrigeration ("regulated loads"). Each building type is given a Building Performance Factor (BPF) for all-electric properties and mixed-fuel buildings that represents the needed energy reduction from regulated loads. *Decarbonize DRCOG* models a blended BPF and percentage of load that is regulated based on Colorado relative square footage of buildings types from NREL's ComStock database.

Tier A2 non-residential building energy use under "electric preferred" performance:

$$\text{Electric Preferred Performance} = \frac{[\ \text{Unregulated energy use} + (\text{BPF} \times \text{Regulated energy use})\ ]}{\text{2018 IECC baseline energy usage}}$$

Residential energy performance under the "electric preferred" is tied to the Denver Residential Total Building Performance Pathway 18% energy cost savings from baseline requirement for mixed-use homes; 5% energy cost savings for all-electric properties.[24]

Natural gas usage reductions and electricity use increases are considered persistent through 2050. Natural gas GHG emission rates per therm are held constant in alignment with ICLEI's US Community Protocol.[25] Emissions produced from electricity consumption are calculated based on a blended emission factor as described on page 3.

Emission Reductions from Electrification of Existing Buildings

Electrification of existing buildings was modeled as the replacement over time of fossil fuel and electric resistance appliances with electric heat pump alternatives. For non-residential buildings, end uses replaced are space heating (natural gas, propane, and electric resistance), space cooling, water heating (natural gas, propane, and electric resistance), and cooking (natural gas). Modeling for the residential sector in addition considered conversions from propane cooking and natural gas clothes dryers. Total square footage of non-residential and residential buildings within the DRCOG area that have fossil fuel appliances were calculated based on data from NREL's Electrification Futures Study and the Colorado Demography Office. The universe of buildings that could be electrified is held constant from 2024 through 2050, with the assumption that under the Measure 4 and Transformative Impact scenarios, a negligible amount of post-2025 new construction will be built with fossil fuel appliances.

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[23] Denver 2022 Denver Energy Code Fact Sheet - Appendix SE: Site Energy. https://denvergov.org/files/assets/public/v/1/climate-action/documents/hpbh/nze/2022-denver-energy-code-fact-sheets-c-appendix-se-site-energy.pdf Accessed March 2024

[24] Denver 2022 Denver Energy Code Residential Resources: 3. Residential Compliance Pathways. https://denvergov.org/Government/Agencies-Departments-Offices/Agencies-Departments-Offices-Directory/Climate-Action-Sustainability-Resiliency/Cutting-Denvers-Carbon-Pollution/High-Performance-Buildings-and-Homes/Net-Zero-Energy-Hub-Codes-and-Resources/Resources-for-New-Single-Family-Duplex-Townhomes/SFDT-Design-Phase-Resources/2022-Denver-Energy-Code-Resources-RES#section-3 Accessed March 2024

[25] ICLEI's U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions – Appendix C: Built Environment Emission Activities and Sources, Version 1.1. https://icleiusa.org/ghg-protocols/ Accessed March 2024

The model establishes a baseline replacement rate of 7% per year for all appliance types, replacing equipment roughly once every fifteen years, the standard lifespan for an air-source heat pump.[26] An elevated replacement rate of 10% per year is applied to the Transformative Impact scenario for years 2025-2030, under the assumption that the existence of advising services and rebate dollars will drive consumers to replace their appliances before end of life.

Square footage served by a given fuel type/end use pair (e.g. propane cooking) replaced each year:

Sq ft replaced = total existing sq ft retrofit rate (%) x *% sq ft served by fuel type/end use combo*

For each specific end use/fuel type pairing, the percentage of those replacements that results in electrification starts at the BAU expected heat pump/electric share in 2025 according to the NREL Electrification Futures Study (e.g. 9% for commercial heat pump space heating). The percentage of replacements that result in electrification increases linearly to meet the "Share of equipment replaced with heat pump electric equipment" target percentages and dates specified in Table 5. Once the square footage electrified for each fuel type/end use combination is established, avoided fossil fuel use and change in electricity use are calculated from EUIs sourced from NREL's ResStock for residential properties, and a weighted average of property types from EIA CBECS. Electrification upgrades are considered persistent through 2050.

Natural gas or propane reductions in a give year are calculated as:

Fossil fuel savings = (Square footage electrified this year x *EUI) + prior year's fossil fuel savings*

Additional electricity use from electrification in a given year is calculated as:

Additional electricity = (energy savings from appliances electrified this year x *efficiency of equipment being replaced / COP of electric replacement) + last year's additional electricity usage*

GHG emissions savings are then calculated from reduction in natural gas and associated pipeline leaks (0.3%), reduction in propane use, and net additional electricity use (including savings from electric resistance to heat pump conversions and additions from new air conditioning capabilities) plus additional GHG emissions from transmission and distribution losses (5%).[27]

Emission Reductions from Energy Efficiency of Existing Buildings

Energy efficiency savings calculations are modeled as if buildings down to 10,000 sq ft realized the EUI targets of Colorado's state building performance standard (BPS) (the Colorado BPS only applies to buildings 50,000 sq ft and larger).[28] The total existing square footage of buildings 10,000 to 49,999 sq ft in the DRCOG area is estimated based on County Assessor data, data from the state BPS program provided by CEO, and data from Google Environmental Insights Explorer. Boulder and Denver Counties, representing the two DRCOG jurisdictions that currently have building performance requirements, comprise Tier B1, with the assumption that buildings within these counties will realize efficiency gains at an accelerated pace compared to the rest of the DRCOG region.

The Colorado BPS established performance targets by building type to be reached by 2026 and 2030. A weighted average EUI target for non-residential buildings was calculated by mapping Colorado BPS EUIs onto NREL ComStock building stock data detailing relative frequency by building type. Residential performance goals were matched with the Colorado BPS target EUI for multifamily buildings. Average baseline EUIs were calculated using NREL ComStock for non-residential buildings and the EUI for a high-rise multifamily building in climate zone 5B built to 2012 IECC from PNNL prototype building models.

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[26] McDevitt, C. "How long do heat pumps last?" EnergySage. https://www.energysage.com/heat-pumps/how-long-do-heat-pumps-last/ Accessed March 2024

[27] Calculated using Colorado specific EIA data. https://www.eia.gov/electricity/state/colorado/ Accessed March 2024

[28] CEO Building Performance Colorado: Technical Resource Guide. https://drive.google.com/file/d/1qMA8936XohwGMbEq3OlOpnupU8Ay6lLz/view Accessed March 2024

For Measure 4 and Transformative Impact, dates were set for when buildings 10,000 to 49,000 sq ft in Tier B1 and Tier B2 communities would match the level of efficiency required for corresponding buildings 50,000+ sq ft in 2026 and 2030 under the state BPS. For example, under the Transformative Impact scenario, buildings in Tier B2 communities are modeled to meet CO BPS 2026-level efficiency in 2030 (Table 5). Efficiency improvements are modeled as a linear progression to performance target years. Total avoided energy (MMBtu) is calculated directly from the difference between initial 2024 EUI and the modeled EUI for years 2025-2050. Those energy savings are attributed across natural gas, propane, and electricity usage depending on a given fuel's percentage of total energy use in the BAU case.

Savings for each specific (sp.) fuel type (natural gas v. propane v. electricity):

Sp. fuel energy savings = total energy savings x *(BAU sp. fuel energy use / BAU all fuel energy use)*

Once natural gas therm reductions, propane gallon reductions, and electricity MWh reductions are established, these energy use savings are translated into emissions savings from reductions in natural gas use, natural gas leaks, propane use, electricity use, and electricity transmission and distribution losses using the same method as Electrification of Existing Buildings.

Models, Tools, and Key Datasets Used

- CEO Building Performance Standard Technical Resource Guide
- Colorado Demography Office - household and employment forecasts
- EIA CBECS 2018
- Energy Innovation and RMI's Colorado Energy Policy Simulator
- EPA Energy Star Heat Pump Equipment Criteria[29]
- Google Environmental Insights Explorer
- ICLEI U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions
- Lotus business as usual model for DRCOG's PCAP[30]
- NREL Building Energy Optimization Tool (BEopt)[31]
- NREL ComStock
- NREL Electrification Futures Study
- NREL ResStock
- PNNL's Prototype Building models for 2021 and 2018 IECC

Measure Implementation Assumptions

Tier 1 and Tier 2 participation rates are based on current adoption of IECC versions; currently 65% of DRCOG's population lies within a jurisdiction that has adopted the 2021 IECC, 30% are at the 2018 IECC, whereas the last 5% are 2015 or earlier. The existing status of building codes were utilized to designate two "tiers" of adoption; Tier 1. See Table 5 for key modeling inputs.

GHG Reduction Estimate Assumptions

Electricity emissions are calculated with the same method as Measure 1-3 (see pages 3). Measure 4 and Transformative Impact reductions were calculated using those projected emission factors, along with natural gas and propane emissions factors from EPA's Emission Factors for Greenhouse Gas Inventories.[32]

See **GHGcalcs_DRCOG.xlsx** tabs **Measure 4 Forecast Parameters**, **Measure 4 EF and Constants**, **TI Forecast Parameters**, and **TI EF and Constants** for full assumptions including emission factors, square footage forecasts, BAU forecasts of market share of appliance type (e.g. heat pump, natural gas) for given end uses (e.g. water heating), and BAU forecasted total energy consumption.

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[29] EPA Energy Star Heat Pump Equipment Criteria. https://www.energystar.gov/products/heating_cooling/heat_pumps_air_source/key_product_criteria Accessed March 2024

[30] DRCOG PCAP. https://drcog.org/sites/default/files/Final%20PCAP%20Document%20-%20Feb%202024.pdf Accessed March 2024

[31] NREL BEopt: Building Energy Optimization Tool. https://www.nrel.gov/buildings/beopt.html Accessed March 2024

[32] EPA Emission Factors for Greenhouse Gas Inventories. https://www.epa.gov/system/files/documents/2024-02/ghg-emission-factors-hub-2024.pdf Accessed March 2024

Table 5: *Transformative Impact and Building Policy Collaborative Modeling Assumptions*

Variable	Transformative Impact		Policy Collaborative Only	
POLICY AMBITION: New Construction + Electrification Tier A1: First Adopter Cohort / Tier A2: Second Wave	**Tier A1**	**Tier A2**	**Tier A1**	**Tier A2**
% of DRCOG population	65%	35%	65%	25%
Non-participating %	0%		10%	
NEW CONSTRUCTION	**Transformative Impact**		**Policy Collaborative Only**	
Baseline compliance rate	50%	50%	50%	50%
Code compliance rate target	95%	95%	75%	75%
Year code compliance target is achieved	2030	2030	2035	2035
Electric preferred performance target year	2025	2027	2025	2027
Zero emission performance target years	2027	2030	2027	2030
ELECTRIFICATION OF EXISTING BUILDING	**Transformative Impact**		**Policy Collaborative Only**	
Yearly replacement rate with rebates 2025-2030	10%	10%	7%	7%
Final year of electrification rebates	2030			
Target year 1	2030	2035	2030	2035
Target 1: Share of equipment replaced with electric equipment	75%	65%	50%	40%
Target year 2	2040	2040	2040	2040
Target 2: Share of equipment replaced with heat pump/ electric equipment	100%	100%	95%	95%
EFFICIENCY OF EXISTING BUILDINGS	**Transformative Impact**		**Policy Collaborative Only**	
POLICY AMBITION: Efficiency Tier B1: Denver+Boulder Counties/Tier B2: Rest of DRCOG	**Tier B1**	**Tier B2**	**Tier B1**	**Tier B2**
Target 1 Date	2028	2030	2030	2035
Target 2 Date	2040	2045	2050	2050
Include savings from existing State BPS (Y/N)	No		No	

Reference Case Scenario

The reference case building energy use data was taken from a GHG model developed by Lotus for DRCOG's PCAP to estimate building energy use for the DRCOG region from 2022 through 2050. Values were forecasted using a variety of parameters including population, economic growth, and climatic changes. The Lotus model borrows heavily from RMI's Energy Policy Simulator's BAU scenario. In the RMI's Simulator BAU scenario, it is assumed that there will be low-level electrification taking place in the market regardless of DRCOG's efforts, however there are no additional efficiency measures or accelerated code adoption occurring. The baseline scenario assumes that buildings required to meet the State of Colorado's BPS by law will do so on the timeline set in the law, and also incorporates provisions from the Inflation Reduction Act and the Infrastructure Investment and Jobs Act, though none directly impact baseline modeling for the buildings sector. These assumptions are checked against the modeled results from NREL's Electrification Futures Study.

Measure-Specific Activity Data

In 2050, there are roughly 7.5M mtCO_2e emissions remaining in the building energy use sector. These remaining emissions can be attributed to the following: remaining use of propane and stationary diesel in homes and backup generators, remaining use of natural gas in industrial facilities for industrial processes, and electricity use in buildings in the region not serviced by the utility Xcel Energy. About 65% of the emissions that remain are due to electricity use in buildings not receiving electricity from Xcel Energy, 33% of remaining emissions are from industrial natural gas use, and the remaining 2% of emissions come from propane and diesel use in buildings.

Table 6: *Cumulative Electricity and Natural Gas Savings, by Measure*

Measure	Cumulative Electricity Savings (kWh)		Cumulative Natural Gas Savings (therms)	
	2025-2030	2025-2050	2025-2030	2025-2050
4: Policy Collaborative	4,264,139	88,469,280	474,426,900	15,140,282,156
Transformative Impact	**7,055,410**	**150,757,479**	**887,201,252**	**21,007,313,721**

Co-Pollutant Reductions Estimates

Co-pollutant estimates are provided by Rewiring America for Measures 1-3. Lotus calculated co-pollutant savings for Measure 4 and Transformative Impact. The estimation of criteria air pollutants nitrous oxides, PM2.5, and volatile organic compounds (VOC) is based on energy consumption and air pollutant emission factor data from EPA's eGRID. For the estimation of criteria air pollutants (CAPs) only, Rewiring America forecast a cleaning grid based on NREL's Cambium scenario,[33] which projects a 95% decarbonized grid by 2050. Co-pollutant impacts from Measure 4 and Transformative Impact were estimated using co-pollutant emission factors for electricity and natural gas found in the US EPA's 2022 eGRID Emission Factors and the US EPA's AP-42 Chapter 1.4,[34] respectively.

Table 7: *All Measures Co-Pollutant Emissions Reduced (metric tons)*

Program	Co-pollutant Reductions 2025-2030 (mt)			Co-pollutant Reductions 2025-2050 (mt)		
	NO_x	PM2.5	VOC	NO_x	PM2.5	VOC
1: LIDAC Decarbonization	7.41	0.04	0.41	58.93	0.31	3.30
Measure 1 Leveraged Funds	*2.75*	*0.01*	*0.07*	*21.06*	*0.11*	*0.53*
2: Energy Advisors	159.22	0.66	9.14	1,311.06	5.43	75.30
3: Rebates and Incentives	142.79	0.54	8.25	1,094.72	4.17	63.23
Measure 3 Leveraged Funds	*134.61*	*0.56*	*7.73*	*949.81*	*4.28*	*59.27*
4: Policy Collaborative	3,813.97	211.91	114.03	102,277.87	6,155.92	3,638.90
Transformative Impact	**6,757.25**	**384.58**	**213.23**	**153,344.43**	**8,898.36**	**5,049.01**

[33] NREL Cambium. https://www.nrel.gov/analysis/cambium.html Accessed March 2024

[34] AP Fifth Edition Volume I. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-fifth-edition-volume-i-chapter-1-external-0. Accessed March 2024