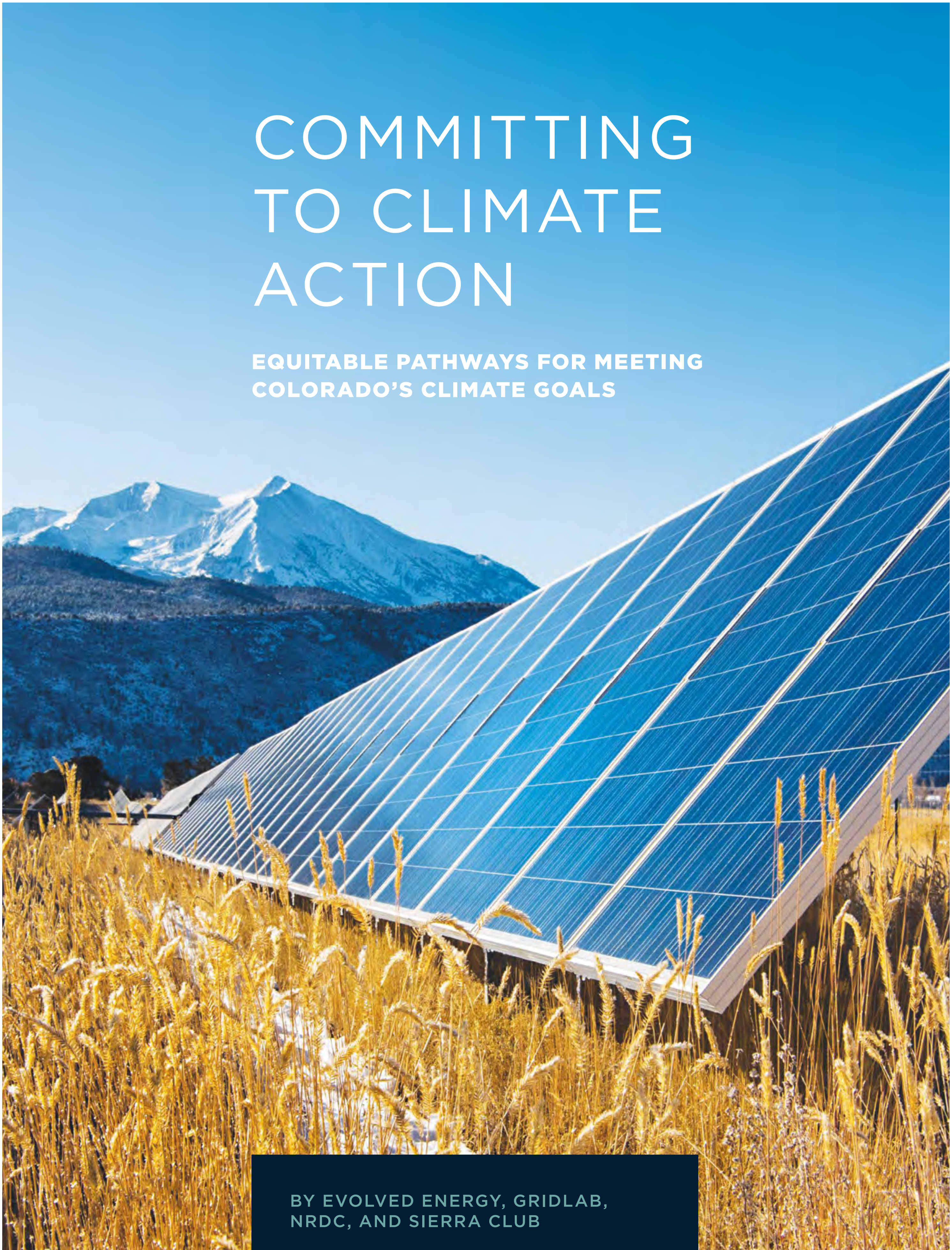

# COMMITTING TO CLIMATE ACTION

## EQUITABLE PATHWAYS FOR MEETING COLORADO'S CLIMATE GOALS

BY EVOLVED ENERGY, GRIDLAB, NRDC, AND SIERRA CLUB

SEPTEMBER 2020

# ACKNOWLEDGMENTS


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| **About Evolved Energy** | Evolved Energy Research was founded to address key energy sector questions accelerated by policy goals and new technology development. |
| **About GridLab** | GridLab provides technical grid expertise to enhance policy decision-making and to ensure a rapid transition to a reliable, cost effective, and low carbon future. |
| **About NRDC** | The Natural Resources Defense Council is an international nonprofit environmental organization that, since 1970, has worked to protect the world's natural resources, public health, and the environment. |
| **About PSE Healthy Energy** | Physicians, Scientists, and Engineers (PSE) for Healthy Energy is a multidisciplinary, nonprofit research institute that studies the way energy production and use impact public health and the environment. |
| **About Sierra Club** | Sierra Club is a grassroots environmental organization dedicated to defending everyone's right to a healthy world. |
| **Photos** | Multiple images in this report are courtesy of NREL |

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# GLOSSARY OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **AQCC** | Air Quality Control Commission |
| **CDOT** | Colorado Department of Transportation |
| **CDPHE** | Colorado Department of Public Health and Environment |
| **CEO** | Colorado Energy Office |
| **$CO_2$** | carbon dioxide |
| **$CO_2e$** | carbon dioxide equivalents |
| **GHG** | greenhouse gas |
| **MMT** | million metric tons |
| **$NO_x$** | nitrogen oxides |
| **OGCC** | Oil & Gas Conservation Commission |
| **PM** | particulate matter |
| **PUC** | Public Utilities Commission |
| **$SO_2$** | sulfur dioxide |
| **VOC** | volatile organic compounds |

# EXECUTIVE SUMMARY

The Colorado Legislature passed a law (HB 19-1261) in 2019 to reduce greenhouse gas (GHG) pollution 26 percent by 2025 and 50 percent by 2030 compared to 2005 levels of emissions. The state is not currently on track to meet these goals for 2025 and 2030. This report details pathways for the state to reduce its GHG emissions while ensuring that the benefits of a cleaner Colorado are shared amongst all communities.

Through this analysis, we envision a better future for all, one in which every community benefits from clean air and water, every household avoids enormous suffering from worsening wildfires, droughts, and floods, every family can affordably heat their home in the winter, and every Coloradan across the state goes to work to build a clean, efficient, and just energy system.

Decades of inequitable resource placement and access have burdened communities of color and low-income communities with disproportionate exposure to pollution. Our analysis shows that meeting the climate goals results in significant reductions in pollution harmful to human health. However, as we decarbonize, disparities may remain in the distribution of pollution across communities and access to clean energy solutions. A transition to a cleaner Colorado must ensure that GHG reduction policies address these systemic injustices instead of perpetuating the current inequities in access to clean energy and distribution of air pollution and energy burden. Early and ongoing engagement with historically underserved and environmentally overburdened communities throughout the decarbonization process will help identify strategies to ensure clean energy benefits accrue to all Coloradans.

This Executive Summary contains two parts. Part I, the "Summary Modeling Results," explains the key energy system modeling findings conducted by Evolved Energy Research and discusses the level of emission reductions, infrastructure upgrades, and operation changes needed from each sector of the economy. Part I also discusses the analysis that Physicians, Scientists, and Engineers for Healthy Energy (PSE) conducted on the equity implications of GHG reduction pathways. Part II, the "Outline of Policy Recommendations," summarizes the specific policies that, taken together, can provide the emissions reductions we need in each sector. The details of each policy recommendation are included later in the report.

## PART I: SUMMARY MODELING RESULTS

### ELECTRIC SECTOR

#### DECARBONIZE THE ELECTRIC SECTOR AT LEAST 90 PERCENT AND OPTIMALLY 98 TO 99 PERCENT BY 2030

In our Core decarbonization scenario, the electricity sector almost completely decarbonizes by 2030, and all coal units retire by 2025. Some gas units remain, but they operate very infrequently (generating only 2 percent of electricity in 2030), mostly during sustained periods of low renewable output. The decarbonized electricity system relies on large amounts of wind and solar, new energy storage, strategic use of flexible loads, and coordination with other states in the region. This rapid transition to clean electricity is not only necessary to reduce pollution from the power sector itself but also to enable reductions in emissions from transportation, buildings, and industry through electrification.

In addition to *deeply* decarbonizing, the state should prioritize decarbonizing the electric sector *as quickly as possible*, within reliability and cost constraints. **With existing policies, Colorado is not building renewables and storage fast enough and will not achieve the required electric sector emission reductions to meet its climate goals.**

Our modeling shows that it would be cheaper and more feasible to achieve the state's climate goals with much higher reductions from the electric sector—98 to 99 percent by 2030. **If Colorado does not decarbonize the electric sector by 98 to 99 percent by 2030, then other sectors will have to make up the difference by electrifying transportation, upgrading buildings, and transitioning away from fossil fuel use even more quickly—including solutions with other downsides, such as additional expense and pollution from biofuel combustion.** The scenario in which the power sector delays deep decarbonization is more expensive than any other scenario we analyzed, including a scenario that entirely eliminates fossil fuels from the economy by 2050.

### PRIORITIZE EMISSION REDUCTIONS IN COMMUNITIES WITH HIGH POLLUTION BURDENS

Our analysis shows the overwhelming majority of fossil fuel power plants in Colorado are located in communities with higher-than-median poverty rates, higher percentage of population that are people of color, or both. Rapidly retiring and cutting utilization of these power plants, as is required to meet the climate goals, will result in significant reductions in harmful air pollution. State policymakers and utilities should consult with local communities living near fossil fuel power plants to determine how to prioritize retirement of, or pollution reductions from, power plants located in communities with high pollution burdens.

### EXPAND ENERGY EFFICIENCY PROGRAMS, PARTICULARLY FOR LOW-INCOME CUSTOMERS

All pathways for meeting the climate goals involve significant increases in energy efficiency measures to reduce energy demand and reduce pressure on the electricity system. In addition, our analysis shows that people with lower incomes spend a higher share of their income on electricity than higher-income households. One way to address the high energy burden that low-income customers face is to expand energy efficiency programs to reach more low-income customers. Doing so is a win-win strategy, because energy efficiency programs both lower customers' energy bills and reduce emissions.

## TRANSPORTATION

### ACCELERATE ELECTRIFICATION OF VEHICLES

In the scenarios in which Colorado meets its climate targets, electric vehicles make up at least 27 percent of new car sales and 8 percent of new light truck sales by 2025 and 66 percent of new car sales and 40 percent of new light truck sales by 2030. By 2035 or soon thereafter, nearly all car and light truck sales should be electric. However, as of 2018, fewer than 2 percent of total vehicle sales in Colorado were battery electric vehicles or plug-in hybrid electric vehicles. **With existing policy, the state is not on a trajectory to decarbonize the transportation sector at the pace required to meet the 2030 climate goal.**

**Colorado must rapidly electrify cars and light trucks and transition to zero-emission vehicles for medium- and heavy-duty applications to meet its climate goals.** The fleet of medium- and heavy-duty vehicles must transition away from gasoline and diesel-powered vehicles, though on a slightly later timeline: zero-emission vehicles will have to make up at least 21 percent of new medium- and heavy-duty trucks by 2030 and close to 100 percent by 2040. The substantial gap between current levels and future targets, coupled with the challenge of decarbonizing large stocks of vehicles, means that state policymakers must move quickly. Over the long term, electrifying personal vehicles can save Coloradans money because electric vehicles are more efficient and have lower operating and maintenance costs than gasoline-powered vehicles.

Reductions in transportation energy demand and vehicle electrification makes the transportation system significantly less energy intensive and plays an important role in meeting the climate goals. Moreover, infrastructure and planning to shift from vehicle use to public transit, walking, and cycling will reduce energy demand even further.

### PRIORITIZE REDUCTIONS IN PARTICULATE MATTER POLLUTION FROM TRANSPORTATION IN COMMUNITIES WITH HIGH AIR POLLUTION

Meeting the climate goals will result in significant reduction in harmful air pollution. However, our analysis indicates that medium- and heavy-duty trucks, which primarily run on diesel today, will likely decarbonize at a slower rate than passenger vehicles, resulting in a slower rate of decline for particulate matter (PM) emissions, including both $PM_{10}$ and $PM_{2.5}$, than for other air pollutants, such as $NO_x$ and $SO_2$. Moreover, in certain high-traffic areas, particularly urban areas near interstate highways and certain rural areas with heavy diesel truck traffic, PM emissions may actually increase between 2020 and 2030 even while overall GHG emissions from transportation decline. Low-income people and people of color are more likely to live in areas with more air pollution from diesel trucks. The state needs to take steps to prevent these communities

from facing continued disproportionate pollution impacts by investing in electric charging infrastructure along urban interstate highway corridors; rerouting diesel truck traffic away from heavily populated areas, where feasible; electrifying heavy-duty trucks; and reducing vehicle miles traveled through public transportation.

## BUILDINGS

### ACCELERATE ELECTRIFICATION AND IMPROVEMENTS IN ENERGY EFFICIENCY

Our analysis shows that emissions from the buildings sector must decrease by at least 9 to 14 percent from 2005 levels to meet the 2030 climate goals. Accelerated electrification in space heating, hot water heating, and cooking, along with energy efficiency, are necessary to provide these reductions. **Absent new policy, the state will not achieve the level of building electrification and efficiency required to meet the climate goals and risks increasing building sector emissions.**

One pathway to meeting the climate goals would require at least 55 percent of new homes to be all electric by 2025 and all new homes to be all electric by 2030 or soon thereafter. In this scenario, 2 to 3 percent of non-electric space heaters and 4 to 5 percent of non-electric water heaters in existing homes must be replaced with electric heat pumps each year.

Commercial buildings must follow a similar trajectory. By 2025, 12 percent of commercial space heater sales and 4 percent of commercial water heater sales must be electric, including replacement of appliances in existing buildings and new appliances for new buildings. By 2030, 36 percent of space heater sales and 30 percent of water heater sales are electric in all scenarios meeting the climate goals. Similar to the challenge of vehicle stock turnover, there is no time to waste. Transformative electrification of stocks of space heaters and water heaters will take time, and the state must accelerate adoption immediately.

The state's building stock must also become significantly more efficient. Adoption of highly efficient, electric appliances must accelerate, with efficient options comprising about 80 percent of appliance sales by 2030. A growing portion of new buildings must be built with highly efficient shells, and the state must retrofit at least 1 to 2 percent of existing homes per year in the next decade to reach energy savings necessary to reach the state's targets.

### PRIORITIZE BUILDING ELECTRIFICATION AND EFFICIENCY PROGRAMS FOR AREAS WITH HIGH ENERGY BURDENS

Our analysis shows that Colorado residents in rural areas spend a higher portion of their income on heating, cooling, and cooking than residents of other parts of the state, on average. Many low-income households in urban areas also have high residential energy burdens. Increased energy efficiency and electrification can reduce residential energy burdens, so the state should prioritize building electrification programs in these rural and urbans areas with the highest energy burdens.

In addition to reducing GHG emissions and lowering energy burdens, energy efficiency measures and building electrification can also reduce harmful air pollutants generated at home. The primary air pollutants generated at home are $NO_x$ from burning gas and $PM_{2.5}$ from burning wood. Energy efficiency and electrification can reduce these dangerous emissions and thereby improve both indoor and outdoor air quality.

## OIL AND GAS

### REDUCE METHANE AND $CO_2$ EMISSIONS FROM OIL & GAS PRODUCTION

Meeting the climate goals requires significant cuts in methane emissions from oil and gas production, processing, and transportation. **Colorado must reduce methane emissions from the oil and gas production sector by at least 54 percent by 2030 relative to 2005 levels to meet the state's climate goals.**

Methane emissions can be reduced by decreasing the rate of methane leakage, decreasing production, or a combination of the two approaches. In our modeling, the oil and gas sector achieves the required methane emission reductions by reducing the methane leakage rate by 57 percent from the current leakage rate and by reducing overall output 25 percent relative to 2019 production levels.

This report also recommends modest near-term reductions in oil and gas production for two reasons. First, oil and gas production in Colorado has increased dramatically since 2005. Increases to oil and gas production will necessitate even greater reductions in the methane leakage rate and make it even more difficult to achieve the overall level of methane reductions needed from the oil and gas sector. Second, our modeling indicates that Colorado can achieve its climate goals only if it significantly reduces use of oil and gas (e.g., the use of gasoline and diesel in transportation, the burning of gas for electricity and heat, etc.). Given that GHGs are global pollutants, Colorado wants other states and countries to adopt similar policies to make similar reductions in GHG emissions. **It is inconsistent for the state to chart pathways to address climate-warming pollution while simultaneously proposing to expand oil and gas production for export to other states and countries (as shown in the state's Roadmap).** Our recommendation that oil and gas production decline 25 percent by 2030 relative to 2019 levels is in line with the overall decline in oil and gas use of 30 percent by 2030 that Colorado needs to achieve to meet its climate goals.

In addition, our analysis shows that industrial point sources—including oil and gas wells and other infrastructure—are more highly concentrated in locations with higher numbers of people of color. Expansion of oil and gas production will exacerbate pollution exposure for these communities. Adopting larger setback requirements can help protect communities from the health impacts of oil and gas development. In addition, state policymakers should consider the cumulative pollution impacts from oil and gas development and other pollution sources on communities in the permitting process and prioritize health protections for communities that have high overall levels of air pollution.

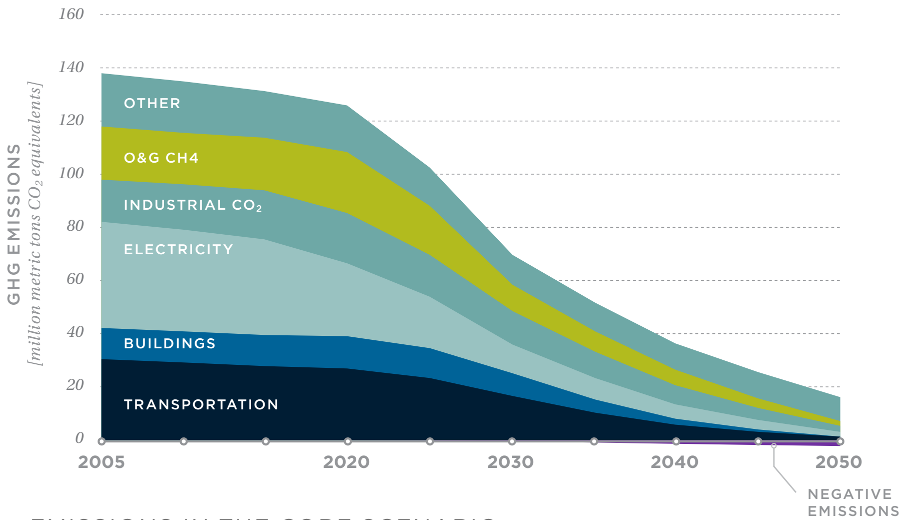
## COMPARISON WITH THE STATE'S ROADMAP

Multiple state agencies, coordinated by the Colorado Energy Office, were tasked with developing a "Roadmap" of possible actions to reduce greenhouse gas pollution in line with HB-1261. The state's modeling in the "Roadmap" study differs in a few important ways from Evolved and PSE's modeling, as explained in more depth in the body of the report, but below is a high-level comparison between the two trajectories for emissions reductions and the measures to achieve those emission reductions.

**FIGURE ES-1.** GHG EMISSIONS: ROADMAP'S "HB-1261 ACTION SCENARIO" VS. EVOLVED'S "CORE SCENARIO"

*The Roadmap and Evolved's analysis show similar trajectories for total net GHG emissions, as these trajectories are defined by the HB-1261 targets. The net-negative transportation emissions in 2050 are the result of a small amount of biofuels with carbon capture and sequestration. Negative emissions represent captured and sequestered $CO_2$. The "Other" category includes agricultural emissions, other methane emissions, and hydrofluorocarbons (powerful greenhouse gases primarily used for cooling and refrigeration).*

EMISSIONS IN THE CO GHG ROADMAP




EMISSIONS IN THE CORE SCENARIO

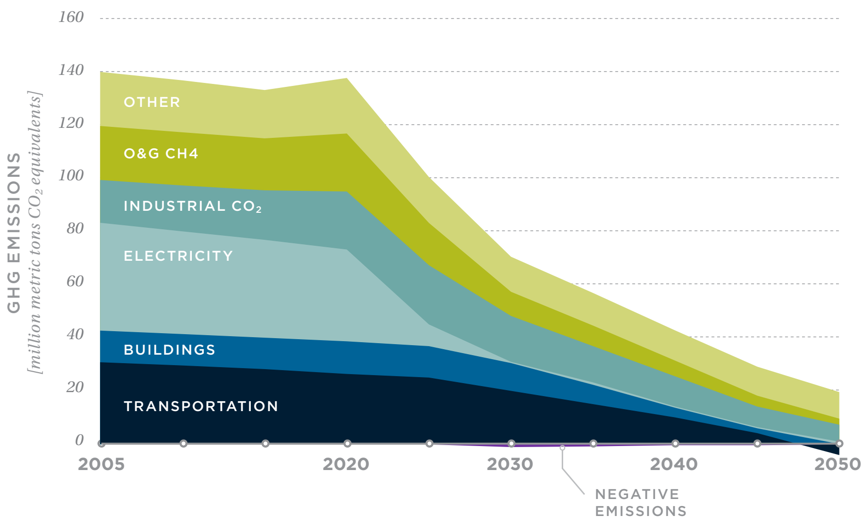


**TABLE ES-1.** COMPARISON OF SECTOR-SPECIFIC MEASURES IN THE STATE'S ROADMAP STUDY AND EVOLVED'S THREE SCENARIOS

| SECTOR | MEASURES/ METRICS BY 2030 | ROADMAP/ E3 ANALYSIS | EVOLVED, CORE SCENARIO | EVOLVED, LOW DEMAND SCENARIO | EVOLVED, SLOW ELECTRICITY SCENARIO |
|---|---|---|---|---|---|
| **Electricity** | GHG reductions (relative to 2005) | 80% | 98% | 99% | 67% |
| **Transportation** | % of on-road vehicles that are zero-emission: | | | | |
| | Light-duty | 22% | 16% | 16% | 22% |
| | Buses | 35% | 16% | 16% | 16% |
| | Medium & heavy duty | 16% | 4% | 4% | 9% |
| | Reduction in vehicle miles traveled, light-duty (relative to Reference) | 3% | 0% | 7% | 0% |
| **Buildings** | % of buildings with high-efficiency shells | 19% | 13% | 25% | 13% |
| | % of appliances that are high efficiency | 30-35% | 19-38% | 19-38% | 19-39% |
| | % of space & water heaters that are electric | 27% | 21-28% | 21-28% | 42-50% |
| | Total demand reduction (from 2020) | 7% | 1% | 4% | 6% |
| **Industry** | Reduction in final energy demand from EE (from 2015 baseline) | 20% | 5%[1] | 5% | 5% |
| | Electrification of non-process energy demand | 100% | <5% | <5% | <5% |
| | Electrification of process energy demand | 57% | <10% | <10% | <10% |
| **Oil and Gas** | Methane leakage rate reduction (from 2019) | 75% | 57% | 57% | 57% |
| | Production Levels | +50% | -25% | -25% | -25% |
| | Electrification of vehicles and equipment | 100% | 0% | 0% | 0% |
| **Low-Carbon Fuels** | Ethanol blend for motor gasoline | 15% | 7.63% | 14% | 14% |
| | Biodiesel blend for diesel | 20% | N/A% | N/A% | N/A% |
| | Renewable diesel blend for transp. diesel | 52% | 14% | 4.5% | 77% |
| | Renewable gas blend | 2% | 0% | 0% | 0% |
| | Hydrogen blend for pipeline gas | 7% | .7% | .1% | 1.1% |
| **In-State Geologic Sequestration** | Carbon capture & sequestration | 1.7 MMT $CO_2$ | 1 MMT $CO_2$ | 0 | 1.5 MMT $CO_2$ |
| **Imported Biofuels** | Net $CO_2$ captured during biofuel production | | 1.4 MMT | 0 | 6 MMT $CO_2$ |

1 Our industrial energy efficiency gains only apply to non-heavy industries, and the electrification energy increases apply to all industries except oil and gas extraction and refineries.

## PART II: OUTLINE OF POLICY RECOMMENDATIONS

*Note: the Policy Recommendations section of the report provides details for each of the policies mentioned below. This table is intended only as a summary of the key policy recommendations.*

**TABLE ES-2.** SUMMARY POLICY RECOMMENDATIONS

| SECTOR | RECOMMENDATION | AGENCY | EQUITY CONSIDERATIONS | PAGES |
|---|---|---|---|---|
| **All Sectors** | Implement HB 19-1261's mandate to solicit input from disproportionately impacted communities | AQCC | Prioritize ongoing community input and create a required mechanism to use that input when enforcing this Act | p 111 |
| **Electric** | Require each electric utility to reduce its $CO_2$[2] emissions at least 75 percent by 2025 and at least 90 percent by 2030 | AQCC | Prioritize retirement of coal and gas units in communities with disproportionately high pollution burdens, and consult with the community itself | pp 108-111 |
| | Maximize energy efficiency programs, targeting savings levels of at least 1-2% of annual sales | PUC | Increase the budget for, and better tailor programs for, low-income customers, especially customers in rental housing | pp 111-113 |
| | Create transition plans for workers affected by the transition away from fossil fuels | PUC, Office of Just Transition | Collaborate with impacted communities, workers, and unions to create plans for local capacity for planning and dislocated worker wages and benefits | pp 114-115 |
| **Transportation** | Adopt a clean medium- and heavy-duty truck rules as soon as the waiver is in place | AQCC, CDOT | Prioritize decarbonization and rerouting/rail options for trucks in communities with high air pollution | pp 116-117 |
| | Significantly increase investment in EV charging infrastructure, particularly utility-side make-ready models | PUC, CDOT, cities | Create specific targets and incentives for low-income residents (e.g., EV charging for multi-family housing, etc.) | pp 117-118 |
| | Support low- and zero-emission vehicle sales by working to reinstate the waiver for CA and other states to adopt LEV/ZEV rules, support a strong CA update to LEV/ZEV rules, and adopt updated LEV/ZEV rules in 2022 | AQCC | Create specific targets and incentives for low-income communities, communities of color, and communities with high air pollution levels | pp 118-119 |

2 HB 19-1261 sets statewide GHG emission goals. Carbon dioxide emissions account for the overwhelming majority of the GHGs that are directly emitted by electric generators. Thus, this section focuses on $CO_2$ emission reductions. There are upstream emissions of other GHGs associated with electricity production, primarily methane emissions from oil & gas production and coal mining. Methane emissions are addressed in a separate section on fossil fuel production.

| SECTOR | RECOMMENDATION | AGENCY | EQUITY CONSIDERATIONS | PAGES |
|---|---|---|---|---|
| **Transportation** | Index the gas tax to the Consumer Price Index and total fuel consumption | Legislature | Create financial assistance programs to aid in the adoption of LEVs/ZEVs for low- and moderate- income families | p 119 |
| | Support affordable, electrified transit, walkable cities, and bike investments | CDOT, Cities | Create a community input mechanism to prioritize which projects are funded and implemented and set aside specific funds for affordable public transit in rural communities | p 120 |
| | Adopt a low carbon fuel standard | AQCC, CDOT, CEO | Avoid encouraging the use of biomass feedstocks with lower environmental standards | pp 120-121 |
| **Buildings** | For new buildings, adopt the 2021 IECC building code and start the process for developing a building code requiring all new residential buildings to be all-electric by 2031 at the latest | AQCC | Include carve outs for the creation of all-electric affordable housing | pp 122-123 |
| | Eliminate restrictions on fuel-switching in utility energy efficiency programs to allow for expanded electrification | PUC | Prioritize investments in electrifying low income, multi-family, rural, and modular homes | p 123 |
| | Maximize building electrification programs offered by investor-owned utilities and co-ops through a PUC docket | PUC, AQCC | Tailored incentives, financing mechanisms, and programs are carved out for moderate- to low-income residents in electrification programs | pp 124-125 |
| | Adopt an existing building energy performance standard for 2025 and 2030. The standards should enable building emissions to be at or below 11.7 MMT $CO_2e$ in 2025 and 10.5 MMT $CO_2e$ in 2030. | AQCC, legislature | Community stakeholders should be actively engaged in planning and implementing building electrification programs so they do not unintentionally harm vulnerable populations | pp 125-126 |

| SECTOR | RECOMMENDATION | AGENCY | EQUITY CONSIDERATIONS | PAGES |
|---|---|---|---|---|
| **Oil & Gas** | Adopt a mass-based limit on total methane emissions from the oil & gas sector of 15.8 MMT $CO_2$e for 2025 and 9.2 MMT $CO_2$e for 2030 | AQCC | | pp 126-127 |
| | Implement SB 19-181 by adopting rules to minimize methane emissions to protect public health | AQCC, OGCC | Establish setbacks that protect schools and homes, particularly in lowincome and people of color communities | p 127 |
| | Include in all new oil and gas permits provisions for reopening or revoking the permit if oil and gas methane emissions exceed the 2025 and/or 2030 emission limits | AQCC, OGCC | Significant funding for inspections and enforcement | pp 127-128 |
| | Reduce overall oil and gas production by approximately 25% by 2030 relative to 2019 levels | OGCC | Prioritize any reductions in output from wells closest to vulnerable populations (e.g., schools, etc.) And prepare and plan for workforce implications | pp 128-129 |
| **Industrial** | Adopt a rule to require zero-emission technologies for equipment used in oil and gas production | AQCC | | p 130 |
| | Enact a 'buy clean' provision to incentivize publicly purchased industrial products to be increasingly low emissions | AQCC, Legislature | | p 131 |

# INTRODUCTION

The climate crisis is harming families, communities, and businesses across Colorado. This report outlines pathways for the state to take effective climate action and achieve the statewide reductions in GHG emissions required by Colorado's landmark 2019 law, HB-1261, and analyzes the health and equity implications of different decarbonization pathways. The report also includes policy recommendations to turn the modeling into reality.

Our analysis sought to answer the following questions: What technological, infrastructure, and operational changes must the energy and industrial system make to achieve the state's climate goals? What are the tradeoffs from key decisions, such as the extent of demand reduction measures, the ambition of power sector emissions reduction targets, and the fate of oil and gas production? What policies are required to put the state on track to meet its goals? And what are the equity and pollution impacts for communities in the state?

We set out to envision a better future for Colorado, one in which every community benefits from clean air, reduced warming avoids enormous suffering from worsening wildfires, drought, and floods, no Coloradan has to worry about whether they will be able to afford to keep the lights on in their home, policymakers care for and protect the workers who have run our energy system for so long, and people across the state go to work in clean energy jobs to build a clean, efficient, and just energy system.

Recognizing that the Colorado Energy Office is developing its own Roadmap and has hired E3 to provide analysis for achieving the GHG reductions required by HB-1261, this report aims to provide additional technical insights, present alternative pathways to those in the state's analysis, and emphasize the equity and health implications of decarbonization pathways.

Macroeconomic and jobs analysis is not within the scope of this report. Several recent analyses (e.g., Rewiring America, 2035 Report) demonstrate significant employment benefits of swift, deep decarbonization, as the process of upgrading our transportation, buildings, industrial, and electricity infrastructure will require millions more clean energy workers across the country.

According to the Intergovernmental Panel on Climate Change, the consensus among climate scientists is that the world must cut carbon dioxide emissions in half by 2030 and to net zero by 2050 at the latest in order to have a chance of limiting the most catastrophic effects of climate change. What we do to transform our economy over the next decade—from local and state government policy to international cooperation—is instrumental to the future of our state, country, and world.

The impacts of the climate crisis are already here in Colorado. Coloradans have seen an increase in deadly, polluting, and expensive wildfires, extended drought conditions, and more frequent 100-year flooding events due to a warming climate. In 2018 alone, the wildfire season cost state and local governments over 145 million dollars. It is critical that we do our part to address climate change to protect our natural spaces, farmlands, and communities at risk of climate disasters.

Thankfully, Colorado is positioning itself as a leader in climate action and renewable energy. Governor Jared Polis was elected on a platform of getting the state to 100 percent renewable energy by 2040. In 2019, Governor Polis signed into law HB-1261, which requires the state to reduce economy-wide GHG emissions 26 percent by 2025, 50 percent by 2030, and 90 percent by 2050 relative to 2005 emission levels. Meeting these goals will require swift and transformative action across all sectors of the economy. To make a plan for Colorado to meet its future climate goals, we must first understand where we are starting.

**Colorado is projected to emit approximately 128 million metric tons of $CO_2$ equivalents in 2020, with electricity, transportation, and fossil fuel extraction making up the bulk of emissions.**

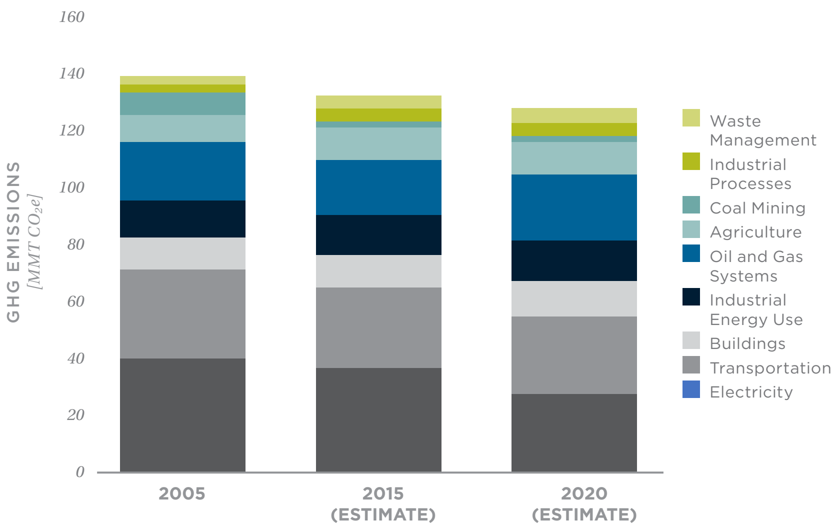
Colorado's annual GHG emissions totaled about 139 million metric tons of $CO_2$ equivalents (MMT $CO_2$e) in 2005, according to the state's Roadmap Analysis.[3] Since then, the state's annual emissions have declined slightly, reaching 132 MMT in 2015 and approximately 128 MMT this year, according to the state's projections. The reductions to date are the result of substantial clean energy growth in the electricity sector and a slight decline in transportation emissions. To achieve the goals in HB-1261, Colorado must cut about 25 MMT $CO_2$e by 2025, 58 MMT by 2030, and 113 MMT by 2050. The required 2030 reductions are equivalent to slightly more than the total current emissions from the electricity and transportation sectors combined—no small feat. Electricity generation, transportation, and the production and processing of oil and

3 The 2005 baseline is based on the state's estimates in the document entitled "CO GHG Roadmap Assumptions & Results_2020-06-18." We reognize that the state may update the methodology used for these estimates, resulting in changes to the baseline emissions value, but we anticipate that these changes will have a small impact.

gas are the state's largest sources of climate-warming pollution, together comprising 63 percent of the total greenhouse gas emissions. Industrial energy use is the next largest source at 11 percent, followed by buildings at 10 percent, as Figure 1 below indicates.

**FIGURE 1.** COLORADO GHG EMISSIONS BY SECTOR IN 2005, 2015, AND 2020

*GHG emissions have been declining in Colorado since 2005, but much more rapid decarbonization will be needed to reach the state's 2025, 2030, and 2050 goals. Data source: Colorado GHG Roadmap.*




**Colorado's energy and industrial systems emit harmful pollution across the state, and low-income communities and communities of color bear the brunt of the impacts.**

Colorado's existing energy, industrial, and fossil fuel infrastructure emits health-damaging pollution in communities across the state. These emissions include criteria air pollutants such as fine particulate matter ($PM_{2.5}$), sulfur dioxide ($SO_2$), and nitrogen oxides ($NO_x$), as well as hazardous air pollutants such as benzene and mercury. These pollutants contribute to a wide range of health impacts, including cardiovascular and respiratory problems, adverse birth outcomes, asthma, cancer, and premature death. Children, the elderly, and those with underlying health conditions are particularly vulnerable to these health impacts. Some of these pollutants are unique to certain fuels or processes; for example, mercury and sulfur dioxide emissions are associated primarily with coal combustion. Other pollutants such as fine particulate matter and nitrogen oxides (a precursor for ozone and secondary fine particulate matter formation) are produced from fossil fuel and biomass combustion. Pollution health impacts are often highest for those living near or downwind from the source of pollution, but pollutants also have broad regional impacts many miles from the emission source. Figure 2 below shows how the emissions of fine particulate matter, nitrogen oxides, and sulfur dioxide compare with carbon dioxide emissions across sectors in 2017.

Air pollution varies by sector and fuel, and the pollution reductions and associated health impacts from decarbonization will depend on the distribution of reductions between sectors and the fuels that phase out first.

**FIGURE 2.** $CO_2$ AND PRIMARY CRITERIA POLLUTANT EMISSIONS BY SECTOR IN 2017

*Reducing $CO_2$ emissions in different sectors and from different fuels will have different impacts on co-pollutant emission reductions, both on the type of pollutants and where they are emitted. Data sources: U.S. EPA; U.S. EIA; U.S. Census Bureau; Evolved modeling.*


Some pollutants, such as $SO_2$ which largely comes from coal plants, are primarily emitted in rural parts of Colorado. Other pollutants, such as $NO_x$, are higher in urban areas. However, as shown in Figure 3, $NO_x$ pollution occurs statewide, and the secondary formation of ozone and particulate matter from instate $NO_x$ pollution affects even broader regions throughout the state and beyond. Figure 3 shows a map of $NO_x$ point sources and annual $NO_x$ emissions across all sectors, indicating which counties contain sources of $NO_x$ emissions and which have the highest total $NO_x$ emissions. Figure 4 shows major point sources overlaid on a Demographic Index (described in the Methodology section) that characterizes census tracts by the socioeconomic vulnerability of their populations.

Roadways, industrial point sources, and power plants overlap with places that have higher $NO_x$ emissions, illustrated by the darker red counties in Figure 3, and many of these sources are located in communities with high cumulative socioeconomic vulnerability, as shown in Figure 4. Emissions are notably high in the Denver area, where point sources are concentrated and which is out of attainment for federal ozone standards.

Regional criteria pollutant emission reductions—and legacy pollution in 2050—will vary under different decarbonization pathways depending on the rate at which different sectors and regions adopt cleaner energy technologies.

**FIGURE 3.** ANNUAL $NO_X$ EMISSIONS IN 2017 AND MAP OF $NO_X$ POINT SOURCES

*Darker red areas indicate counties with high $NO_x$ emissions. Denver and the surrounding counties have high $NO_x$ emissions, as do some rural counties in the northwest part of the state. Oil and gas wells, industrial point sources, and power plants are predominantly located in counties with high $NO_x$ emissions. Because of data limitations, some decentralized sources of pollution, such as oil and gas wells, are not included in the estimates of total $NO_x$ emissions—meaning $NO_x$ pollution may be even more geographically distributed throughout Colorado than pictured here. Data sources: EIA NEI 2017 commercial and industrial data, National Highway Administration, Modeling using ACS + RECS data, EIA power plant data.*

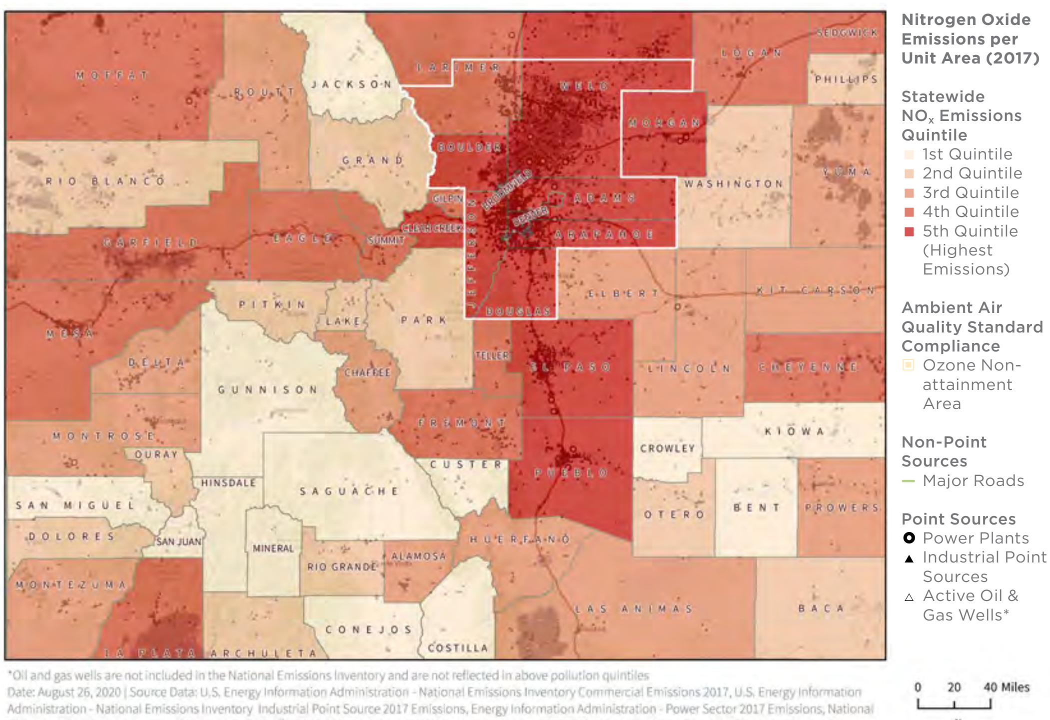
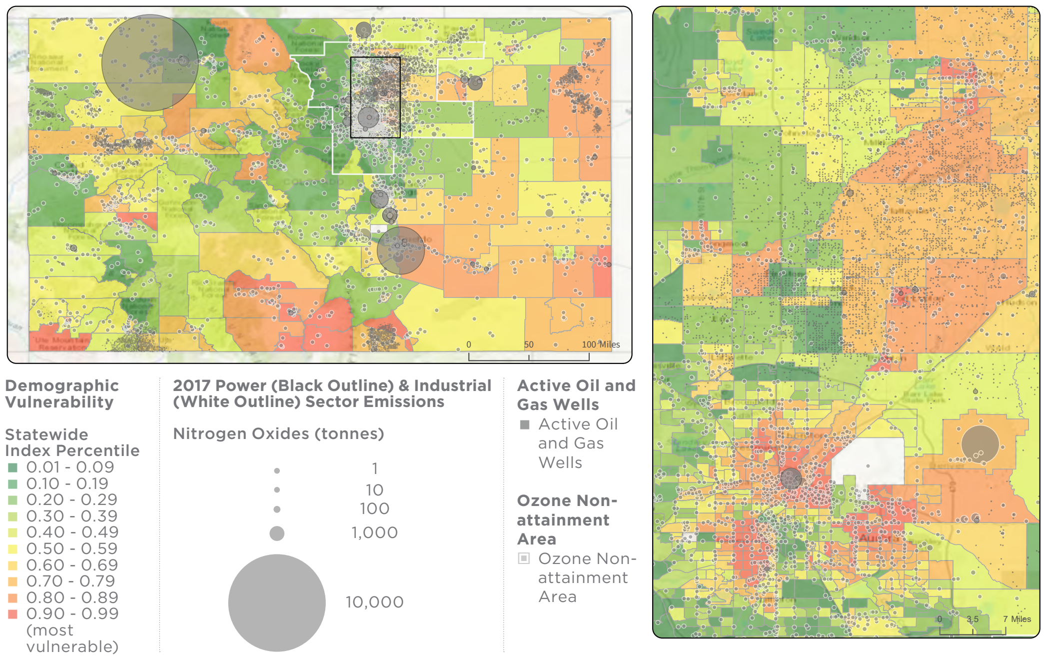


**FIGURE 4.** POLLUTION POINT SOURCES OVERLAYED WITH SOCIOECONOMIC VULNERABILITY

*Major point sources of pollution, except for coal plants, are concentrated in the highly populated Denver area, including in areas where populations have high cumulative socioeconomic vulnerability as reflected in the Demographic Index. This Index, described in the Methodology section, includes indicators for minority, low-income, linguistically isolated, low educational attainment, very young, and elderly populations. Many sources in rural communities are also located in places with high socioeconomic vulnerability, though some major sources are not.*




Date: August 21, 2020. Source Data: U.S. Environmental Protection Agency - EJ Screen, Energy Information Administration - National Emissions Inventory 2017, Energy Information Administration - Power Generation Facilities, Drilling Info - Active Oil and Gas Wells

**Distributed clean energy adoption and the resulting energy cost savings have not been distributed equitably.**

While clean energy has grown in Colorado, distributed energy resources such as rooftop solar have not been adopted equally across all income levels and communities. As of June 2020, Colorado has a considerable amount of distributed solar photovoltaic capacity, approximately 410 MW. The highest-earning Coloradans (top 20 percent of households by income) have adopted rooftop solar systems at 16 times the rate of the lowest-earning households (bottom 20 percent).

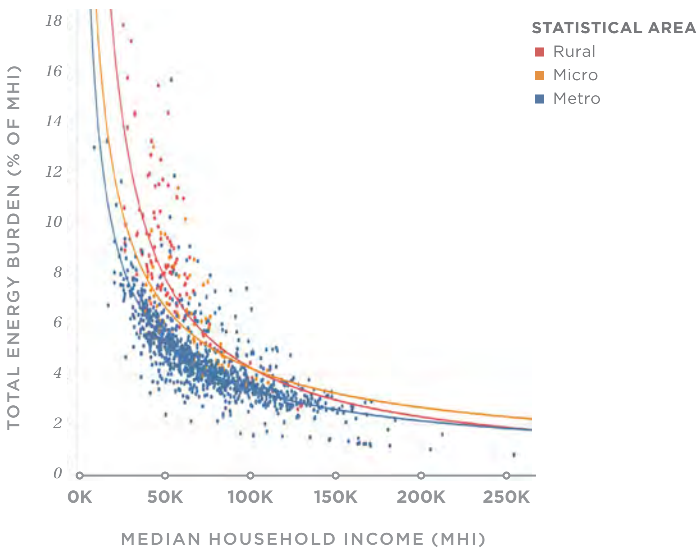
Adoption of electric vehicles has followed a similar pattern in Colorado, with households in the top 20 percent of zip codes by income adopting electric vehicles at eight times the rate of households in lowest-income zip codes (bottom 20 percent). Energy efficiency faces similar barriers of high upfront costs. Adoption of all of these distributed energy resources is more challenging for people who rent their homes, especially in the absence of programs and financing models that target low-income customers.

The lowest-income households therefore have little access to the direct long-term savings provided by these distributed energy technologies and associated policies, like net metering subsidies. These trends suggest that we should not expect further growth to be equitable without policies that explicitly try to expand access to clean energy technologies to Coloradans who cannot currently afford them.

Moreover, low-income households and those in disadvantaged communities could benefit substantially from cost-saving clean technologies. Figure 5 below plots the combined energy burden from housing and transportation by census tract where the x-axis shows an increase in income from left to right and the y-axis shows an increase in burden from bottom to top. Low-income households pay a disproportionate share of their income on energy and transportation costs. Low-income households stand to benefit from clean energy measures that reduce overall system costs as well as energy burdens. These measures can come in the form of facilitating greater access to consumer-adopted clean energy measures and ensuring that utilities adopt cost-effective and clean resource portfolios.

**FIGURE 5.** AVERAGE ENERGY BURDEN FOR RESIDENTIAL & TRANSPORTATION ENERGY COSTS BY CENSUS TRACT (2017)

*Energy burden rises exponentially as income declines, on average. Residents of rural areas tend to have a higher energy burden than residents in urban and micro (suburban) areas.*




While many clean energy technologies are economically inaccessible to low-income Coloradans, in part due to high up-front costs, their lifetime economic savings could help reduce bills for some of Colorado's lowest-income households. Vulnerable populations may also benefit from the resilience provided by energy storage and more consistent heating and cooling in the face of cold winters or climate-driven heat waves as provided by efficiency and electrification upgrades.

Energy burdens are highest for low-income households even though these households do not have the highest carbon footprints—higher-income households tend to have more cars, drive more, and use more energy to support larger houses. Policies focused primarily on high-carbon-footprint households will therefore miss those who might realize the greatest economic benefits from clean energy. As policymakers work to accelerate clean energy growth, they should consider the existing inequities in clean energy adoption and craft policies to ensure equitable access to the benefits of a clean transition going forward.

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**Colorado faces interlocking economic and environmental crises, and addressing them requires interlocking solutions.**

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While developing its plan to address the climate crisis, Colorado is facing the staggering public health and economic effects of the coronavirus pandemic,

which are compounding the effects of underinvestment, systemic racism, and structural inequality. These conditions existed before the pandemic and will be further exacerbated by the effects of climate change. The ongoing crisis has left more than 300,000 Coloradans unemployed (over 10 percent of the workforce). As the crisis continues, hundreds of thousands of Coloradans are losing income and accumulating debt. By one estimate, 420,000 Coloradans are at risk of being evicted and facing the harsh long-term consequences—homelessness, poverty, food insecurity, and lack of access to credit to recover. Evictions affect low-income people and communities of color the most.

The social, economic, and racial context is inseparable from our understanding of pathways to address climate change and policies to effectively realize these pathways. As we show in this report, meeting the state's climate goals requires a transformation of every sector of the economy, including upgrading the homes and vehicles of millions of Coloradans. Policy solutions that upgrade our energy infrastructure without also addressing the inequitable systems that have caused worsening economic inequality, rising debt, and the affordable housing shortage will lead to a clean economy that replicates or exacerbates existing disparities.

The arguments in this report are based on modeling and analysis from Evolved Energy Research (Evolved) and Physicians, Scientists, and Engineers for Healthy Energy (PSE). Evolved conducted energy system modeling to chart energy system pathways consistent with the HB-1261 targets. PSE then used the energy system modeling results, combined with other historical data, to analyze the health and equity implications of decarbonization pathways. This section describes the key components of the methodology. The forthcoming technical appendix includes more details on methodology and assumptions.

## ENERGY SYSTEM MODELING

Evolved modeled the energy system using two tools: EnergyPATHWAYS and the Regional Investment and Operations (RIO) platform.

EnergyPATHWAYS is a bottom-up energy sector scenario planning tool. It performs a full accounting of all energy, cost, and carbon flows in the economy and can be used to represent both current fossil-based energy systems as well as transformed, low-carbon energy systems. The tool represents infrastructure that produces, converts, stores, delivers, or consumes energy with a robust set of technology options. It includes detailed representations of existing infrastructure (e.g., power plants, refineries, equipment stock in buildings, vehicle stock) and options for new infrastructure and resources. We used EnergyPATHWAYS to produce demand-side scenarios based on input assumptions for technology stock turnover under each policy scenario we considered. The model produces results for fuel and electricity demand based on these assumptions.

Evolved paired EnergyPATHWAYS with RIO, an energy system planning tool that is specifically designed to study deeply decarbonized energy systems, which will work very differently from today's system. RIO finds the least-cost set of investments and operational strategies for the energy supply system, considering future policy, fuel pricing, technology pricing, and demand-side flexibility. The platform represents investment and operation decisions in the electricity sector and fuel production for direct use. RIO also captures the time variability of electricity supply and demand with high resolution, which is important for characterizing systems with significant variable renewable energy generation. We used RIO to optimize energy supply decisions based on the demand-side results generated from EnergyPATHWAYS and considering an emissions constraint for each state.

Both models rely on input assumptions for fuel price forecasts, technology costs, and technology performance characteristics. We chose these assumptions based on reputable and commonly used sources, detailed in the technical appendix.

Our assumptions on biofuels availability are of particular importance to the modeling results. Biomass feedstocks carry climate and ecological risks, and only a subset of feedstocks are appropriate to use as environmentally sustainable and climate-friendly solutions. For this reason, Evolved's analysis restricts biomass availability to a subset of feedstocks with lower risks. This mix excludes high-risk feedstocks, such as forest biomass. In total, 430 million dry tons per year of sustainable biomass feedstocks are available in the model. Given this limited supply, and the attractiveness of carbon capture on biofuels facilities, some biofuels from this biomass are considered negative emissions. Biofuels can be imported or made in-state using the Fischer-Tropsch process (for diesel and jet fuel replacements), pyrolysis (for heavy fuel oil and solid fuel replacements), and bio-hydrogen and cellulosic ethanol (for gasoline replacement) conversion technologies. As noted elsewhere in the report, policymakers must ensure that all biofuels used to cut emissions are produced using sustainable biomass that is independently certified to the Roundtable on Sustainable Biomaterials (RSB) or equivalent standard.

## SCENARIO DESCRIPTIONS

Evolved modeled several scenarios for comparison. At the heart of the analysis is a comparison between business-as-usual and a future in which the state acts appropriately to meet the HB-1261 targets. This central comparison is between two scenarios:

### REFERENCE

Scenario that represents business as usual for comparison with the decarbonization scenarios. No emissions reductions are required, and Colorado does not meet its HB-1261 goals.

### CORE

Decarbonization case on which the other scenarios are built. Includes a mix of achievable but aggressive demand-side transformation paired with rapid electricity decarbonization to achieve 2030 goals, and the model selects the most cost-effective energy supply (fuel production and electricity) portfolio for achieving the emission reduction goals in HB-1261. The 2050 goals are achieved with almost complete electrification of on-road transportation, heating, and the limited deployment of low-carbon fuels.

The Core scenario represents the central decarbonization scenario on which Evolved built three other scenarios in which the state achieves the HB-1261 targets. These three scenarios maintain most aspects of the Core scenario while changing a small number of key assumptions to understand the importance of relevant decisions.

### SLOW ELECTRICITY

Decarbonization scenario to assess the costs of delay in power sector emissions reductions. Includes delayed closure of coal plants that do not have confirmed retirement dates. Requires accelerated electrification past what some might consider achievable in the 2030 timeframe to make up for smaller emission reductions in the power sector. By 2050, scenario outcomes converge with the Core scenari

### LOW DEMAND

Decarbonization scenario to assess the benefits of measures to reduce demand, beyond the energy efficiency included in the Core scenario. Includes reduced demand for energy services due to increased energy efficiency measures, retrofits of existing homes, and buildout of public transit infrastructure, alongside reduced heavy-duty vehicle and aviation use.

### FOSSIL FREE

Decarbonization scenario that focuses on a full transition to zero fossil fuel production and use across the country by 2050. Emphasis is on the infrastructure necessary to support such a future and implications for siting, economic development, and the pace of expansion of clean electricity. Constraints through 2030 are identical to the Core scenario. This scenario has a more limiting 2050 constraint (no fossil fuel use) than the HB-1261 targets and requires greater ambition from the energy and industrial system. Therefore, it is not an “apples-to-apples” comparison with the other scenarios but rather a scenario that provides insight into pathways to even deeper decarbonization of the economy.

Information on the assumptions and methodology used in the energy system modeling for each scenario are below in Table 1 and 2, with more details available in the forthcoming technical appendix. The italicized portions below signify areas that differ from the core case.

**TABLE 1.** MODELING ASSUMPTIONS FOR ALL SCENARIOS

### REFERENCE (BAU)

Scenario that represents business as usual for comparison with the decarbonization scenarios. No emissions reductions are required, and Colorado does not meet its HB-1261 goals.

| | |
|---|---|
| **Economy-Wide** | No economy-wide emissions restriction (the state does not achieve HB-1261 goals) |
| **Electricity** | Coal plants that have firm retirement commitments retire on time. |
| **Transportation** | Minimal electrification. Vehicle use grows by 38 percent and aviation increases by 89 percent by 2050 from today's levels. |
| **Buildings** | Minimal new electrification and minimal efficiency improvements. |
| **Oil & Gas** | No restrictions. |
| **Other Industry** | Minimal efficiency and electrification. |

### CORE

Decarbonization case on which the other scenarios are built. Includes a mix of achievable but aggressive demand-side transformation paired with rapid electricity decarbonization to achieve 2030 goals. 2050 goals are achieved with almost complete electrification of on-road transportation, heating, and the limited deployment of low-carbon fuels.

| | |
|---|---|
| **Economy-Wide** | Energy and industrial $CO_2$ emissions are required to decline in line with HB-1261 targets. |
| **Electricity** | Coal plants that have firm retirement commitments retire on time or earlier if cost effective. Generation mix is optimized based on cost and economy-wide emissions constraints. |
| **Transportation** | Vehicle electrification accelerates at the optimal pace to meet HB-1261 targets, based on Evolved's analysis. Vehicle miles travelled increase by 38 percent and aviation miles increases by 89 percent by 2050 from today's levels due to growth not offset by efficiency. |
| **Buildings** | Building electrification accelerates at the optimal pace to meet HB-1261 targets, based on Evolved's analysis. Adoption of efficient appliances and building shells accelerates. |
| **Oil & Gas** | O&G production declines by 25 percent by 2030 and 75 percent by 2050. Methane leakage rates decline by 57 percent by 2030 and 71 percent by 2050, compared to today's levels. |
| **Other Industry** | Energy efficiency measures lead to a 5 percent decrease in energy demand from 2015 levels by 2030. Modest electrification of industrial processes. |

## SLOW ELECTRICITY

Decarbonization scenario to assess the costs of delay in power sector emissions reductions. Includes delayed closure of coal plants that do not have confirmed retirement dates. Requires accelerated electrification past what some might consider achievable in the 2030 timeframe. By 2050, scenario outcomes converge with the Core scenario.

| | |
|---|---|
| **Economy-Wide** | Energy and industrial $CO_2$ emissions are required to decline in line with HB-1261 targets. |
| **Electricity** | *Coal-fired generators without a firm retirement date must stay online through 2035.* |
| **Transportation** | *Electric vehicles make up 100 percent of sales five years earlier than in the Core scenario.* Vehicle miles travelled increase by 38 percent and aviation miles increases by 89 percent by 2050 from today's levels due to growth not offset by efficiency. |
| **Buildings** | *Electric appliances make up 100 percent of sales five years earlier than in the Core scenario.* Adoption of efficient appliances and building shells accelerates. |
| **Oil & Gas** | O&G production declines by 25 percent by 2030 and 75 percent by 2050. Methane leakage rates decline by 57 percent by 2030 and 71 percent by 2050, compared to today's levels. |
| **Other Industry** | Energy efficiency measures lead to a 5 percent decrease in energy demand from 2015 levels by 2030. Modest electrification of industrial processes. |

## LOW DEMAND

Decarbonization scenario to assess the benefits of measures to reduce demand, beyond the energy efficiency included in the Core scenario. Includes reduced demand for energy services, particularly in transport and through aggressive building energy efficiency.

| | |
|---|---|
| **Economy-Wide** | Energy and industrial $CO_2$ emissions are required to decline in line with HB-1261 targets. |
| **Electricity** | Coal plants that have firm retirement commitments retire on time or earlier if cost effective. Generation mix is optimized based on cost and economy-wide emissions constraints. |
| **Transportation** | Vehicle electrification accelerates at the optimal pace to meet HB-1261 targets, based on Evolved's analysis. Transportation energy demand is lower than in the Core case. *Light-duty vehicle miles travelled decline by 10 percent, heavy-duty VMT increases by 10 percent, and aviation miles increase by 50 percent by 2050, compared to today's levels.* |
| **Buildings** | Building electrification accelerates at the optimal pace to meet HB-1261 targets, based on Evolved's analysis. *Building energy demand drops even further than in the Core scenario. All existing residential buildings are retrofitted by 2050.* |
| **Oil & Gas** | O&G production declines by 25 percent by 2030 and 75 percent by 2050. Methane leakage rates decline by 57 percent by 2030 and 71 percent by 2050, compared to today's levels. |
| **Other Industry** | Energy efficiency measures lead to a 5 percent decrease in energy demand from 2015 levels by 2030. Modest electrification of industrial processes. |

### FOSSIL FREE

Decarbonization scenario that focuses on a full transition to zero fossil fuel production and use across the country by 2050. Emphasis is on the infrastructure necessary to support such a future and implications for siting, economic development, and the pace of expansion of clean electricity. Constraints through 2030 are identical to the Core scenario.

| | |
|---|---|
| **Economy-Wide** | Energy and industrial $CO_2$ emissions are required to decline in line with HB-1261 targets *and fossil fuel use declines to zero by 2050.* |
| **Electricity** | Coal plants that have firm retirement commitments retire on time or earlier if cost effective. Generation mix is optimized based on cost and economy-wide emissions constraints. |
| **Transportation** | Vehicle electrification accelerates at the optimal pace to meet HB-1261 targets, based on Evolved's analysis. Vehicle miles travelled increase by 38 percent and aviation miles increases by 89 percent by 2050 from today's levels due to growth not offset by efficiency. |
| **Buildings** | Building electrification accelerates at the optimal pace to meet HB-1261 targets, based on Evolved's analysis. Adoption of efficient appliances and building shells accelerates. |
| **Oil & Gas** | O&G production declines by 25 percent by 2030 *and completely phases out by 2050.* Methane leakage rates decline by 57 percent by 2030. |
| **Other Industry** | Energy efficiency measures lead to a 5 percent decrease in energy demand from 2015 levels by 2030. Modest electrification of industrial processes. |

## NON ENERGY EMISSIONS

Evolved's modeling focused on energy and industrial emissions, but HB-1261 covers economy-wide emissions, which extend beyond the energy and industrial systems and include non-energy agricultural emissions, other methane sources, and hydrofluorocarbons. The required reductions in energy and industrial $CO_2$ emissions (and oil and gas methane emissions) are dependent on assumptions for future changes in these non-energy emissions. Our analysis assumes that the reductions in other non-energy emissions are very similar to the reductions specified in the state's Roadmap. In our analysis, these emissions decline to 35 percent below 2005 levels by 2030 and 52 percent below 2050 levels. Reductions in these emissions are not certain, and the technical pathways and policies required to achieve these reductions are out of the scope of this report, though these issues are important for the state to achieve the HB-1261 goals.

## HEALTH AND EQUITY ANALYSIS

PSE analyzed the health, equity, and distributional implications of the scenarios. This report summarizes some of the key findings of PSE's analysis. The full results of PSE's health and equity analysis will be published separately.

PSE's analysis covered:

- The relationship between socioeconomic and demographic indicators across the state and energy system impacts and trends;
- The historical distribution of health-damaging fossil fuel air pollutant emissions;
- Modeled changes in these air pollutant emissions under the five scenarios and the geographic distribution of those changes;
- HIstorical trends in energy costs, energy burdens, and access to clean energy technologies;
- Modeled adoption of clean energy technologies, changes to energy costs, and the energy burden and equity implications of these changes.

PSE analyzed the characteristics of populations across Colorado using a mix of data aggregated from the U.S. Census and from the U.S. Environmental Protection Agency's environmental justice screening tool EJSCREEN. EJSCREEN includes census block group information on a set of demographic and environmental indicators, including:[4]

1. **Minority:** Non-white population fraction;
2. **Low-income:** Population in households below double the federal poverty level;
3. **Linguistic isolation:** Population living in households where no one over 14 speaks English as a primary language and all adults speak English less than "very well;"
4. **Educational attainment:** Fraction of adults with less than high school education;
5. **Children:** Population fraction under age five;
6. **Elderly:** Population fraction over 64.

To identify populations uniquely vulnerable to pollution due to cumulative socioeconomic burdens or who might particularly benefit from the economic savings and resilience benefits of cleaner energy technology, PSE created a set of indices to reflect a combination of demographic indicators. This Demographic Index was calculated by first averaging the percentiles for each of the six listed demographic indicators. This raw value was then assigned a statewide percentile by comparing census tracts across the state. This percentile value is the Demographic Index.

Air pollutant emission and energy consumption data were aggregated from numerous sources, primarily including federal datasets from the U.S. Environmental Protection Agency (EPA), U.S. Energy Information Administration (EIA), U.S. Bureau of Transportation Statistics (BTS), U.S.

4 Descriptions and data years for EJSCREEN indicators are provided in the "Technical Documentation for EJSCREEN," available at: www.epa.gov/ejscreen/technical-documentation-ejscreen

Federal Highway Administration (FHWA), and the U.S. Census. Census tract energy use for the residential sector was estimated using a regression model based on EIA Residential Energy Consumption Survey data and U.S. Census American Community Survey household data. Residential emissions were calculated by applying EPA AP-42 and California Air Resources Board (CARB) emission factors. Transportation emissions were calculated by applying EPA MOVES emission factors to vehicle travel and vehicle class data from the FHWA and the Colorado Department of Public Health and the Environment. Household transportation energy burdens were calculated using BTS and FHWA data. Full data sources and methods will be detailed in the forthcoming report from PSE.

## COMPARISON WITH ROADMAP METHODOLOGY

The Colorado Energy Office and other state agencies are developing a Roadmap of possible actions to reduce greenhouse gas pollution in line with HB-1261 and hired E3 to conduct modeling for the Roadmap.

The methodology and assumptions that Evolved and E3 used are similar, but differ in a few important ways:

- Both Evolved's and E3's analyses use a pathways model (EnergyPATHWAYS and PATHWAYS) to develop economy-wide energy demand scenarios. The pathways models provide energy demand projections based on assumptions about stock turnover and technology adoption in the end-use sectors (e.g., adoption rates of electric vehicles). Evolved's model then determines levels of sector emissions reductions through RIO's optimization. RIO develops cost-optimal investments for energy supply, combining elements of electricity sector capacity expansion and production cost modeling to represent the power sector and analyzing biomass, synthetic electric fuel production, and direct air capture deployment in the other sectors. In place of RIO, E3's modeling pairs its pathways model with the additional modeling platform, RESOLVE, which is an electricity sector capacity expansion modeling tool. RESOLVE is limited to the power sector and does not cover fuel supply in the other sectors. As a result, the state's analysis includes baked-in assumptions for biofuel and synthetic fuel adoption and assigns greater emissions reductions to the end-use sectors with these assumptions than occurs in RIO with our cost, performance, and availability assumptions.
- We explore four scenarios that all reach the state's targets. The state modeled one scenario that reaches the emission reduction targets, Colorado Climate Action Plan Scenario (HB-1261).
- The Roadmap models Colorado. Evolved's model covers the full western region, which means the model balances the electricity and fuel supply systems across the west, rather than treating Colorado as an island. Moreover, Evolved's analysis included all state clean energy and emissions

targets in the surrounding western region, which affects demand for clean electricity and fuel, some of which is produced in Colorado and exported.

- The Roadmap assumes that the methane leakage rate declines 75 percent by 2030 and 90 percent by 2050. By contrast, our model assumes that the methane leakage rate declines 57 percent by 2030 and 71 percent by 2050 in line with recent studies. The Roadmap also assumes a 41 percent increase in gas production and an 86 percent increase in oil production by 2030 from 2019 levels, while our analysis assumes a 25 percent decrease in oil and gas production by 2030.

Finally, the health and equity work that PSE conducted is largely outside of the scope of E3's analysis.

**Our analysis shows that it is feasible for Colorado to meet its climate targets with modest increases—and potentially even savings—in energy system costs and significant reductions in health-damaging pollution.** Doing so requires a significant buildout of renewable energy resources, rapid retirement of all coal plants, accelerated adoption of highly efficient and electric technologies in buildings and vehicles, and the development of infrastructure to produce and transport clean fuels between Colorado and other western states. In accelerating the clean energy transition, policymakers must consider equity implications and engage communities in decision-making processes from the beginning.

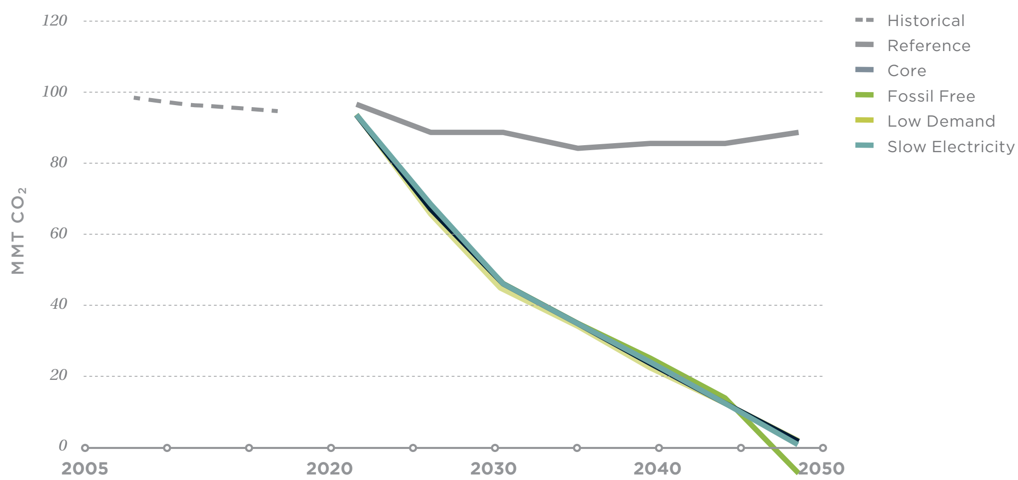
**All decarbonization scenarios require steep declines in energy and industrial $CO_2$ emissions.**

All four decarbonization scenarios meet the state's climate goals and hence follow similar economy-wide $CO_2$ emissions reduction trajectories, with the greatest variation in the last years of the analysis (2045 to 2050), as seen in Figure 6 below.

The Fossil Free scenario is more ambitious than the others because elimination of fossil fuels from the economy results in greater emissions reductions than the 90 percent reduction specified in HB-1261. In fact, this scenario leads to net negative energy and industrial $CO_2$ emissions because eliminating fossil fuel use brings $CO_2$ emissions to essentially zero and imported biofuels with carbon capture and sequestration are net carbon sinks.

**FIGURE 6.** ENERGY AND INDUSTRIAL $CO_2$ EMISSIONS IN ALL MODELED SCENARIOS

*The four decarbonization scenarios show significant cuts in $CO_2$ emissions compared to today's levels. In the Reference case, emissions do not change significantly from today's levels.The Fossil Free scenario has the lowest emissions in 2050 because fossil fuels are eliminated from the economy in this case.*




The Core scenario shows a pathway for Colorado to meet its climate goals at modest cost, and the Low Demand scenario shows a pathway with net savings, as shown in Figures 7 and 8. Keeping costs low requires the electricity sector to decarbonize swiftly. Hesitation in the power sector leads to much more expensive pathways for decarbonization, as shown by the Slow Electricity case.

**Colorado can achieve its climate goals at modest cost —and potentially even with savings—compared to business as usual.**

In the Core scenario, the total annual system cost is 2 percent higher than the Reference case in 2025, 10 percent higher in 2030, and only 1 percent higher in 2050. The cost above the Reference case peaks in the 2030s when the level of investment in energy demand infrastructure is greatest and then declines in the 2040s as some of the more efficient demand infrastructure starts to pay for itself. At its peak, the incremental annual cost of the Core scenario is only 0.4 percent of the state's 2019 gross domestic product.[5] The Core scenario results show that $6 billion of public and private investment through 2030 could transform the energy system to meet the 2030 goal and set the state on a pathway for deep decarbonization. These costs calculations do not consider the benefits of decarbonization, including the avoided damages of disasters fueled by climate change and reduced health impacts from pollution cuts.

5 Colorado's GDP was $353B in 2019, according to the U.S. Bureau of Economic Analysis. Even with a severe decline in economic activity due to COVID, the modeled incremental costs will still be far less than 1 percent of current state GDP.

The Slow Electricity scenario is the most expensive pathway, demonstrating the high costs of a slow pace of decarbonizing the power sector. This scenario has the highest costs in the next decade, as it does not take advantage of cost-effective emissions reduction opportunities in the power sector and instead must invest in more demand-side measures and low-carbon fuels. As we show later on, the most cost-effective pathway to meet the climate goals requires swift decarbonization—98 to 99 percent reductions by 2030—of the power sector.

The Low Demand scenario, which has the highest levels of energy efficiency and demand reductions, has the lowest overall costs of the four modeled scenarios. Costs in this scenario peak at 5 percent above the Reference case in 2030 and decline to 8 percent below the Reference case by 2050 as a result of investments that reduce energy use. This cost trajectory shows the cost effectiveness of energy efficiency and other demand reduction measures.

The cost of the Fossil Free scenario rises significantly in 2050 because of the need for large quantities of synthetic substitutes for petroleum based products. Importantly, the Fossil Free scenario is inherently more ambitious than the other decarbonization scenarios, as it requires greater GHG emissions reductions and replacement of fossil-based products outside of the energy system. Even so, **the cumulative cost over the next 30 years of entirely eliminating fossil fuels from the economy is less than that of the Slow Electricity case**, illustrating the enormous expense the state faces if the power sector does not move swiftly.

**FIGURE 7.** TOTAL ANNUAL PER-CAPITA SYSTEM COSTS FOR THE MODELED SCENARIOS

*Costs for a given year include total capital investments that year, combined with the operating, maintenance, and fuel costs of the energy and industrial system incurred that year, divided by the state population. In the Core scenario, the average annual system cost is about $200 per person higher than in the Reference case in 2030. The Slow Electricity scenario shows the greatest costs in the next decade because of the need for increased reductions in the transportation, buildings, and industrial sectors. The Low Demand scenario has the lowest costs because of reduced energy use and hence avoided infrastructure and fuel costs.*

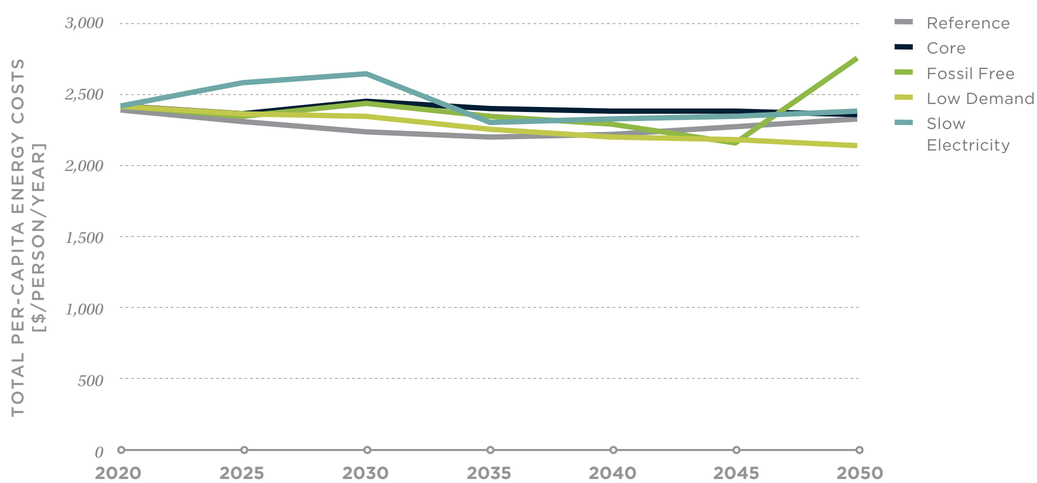
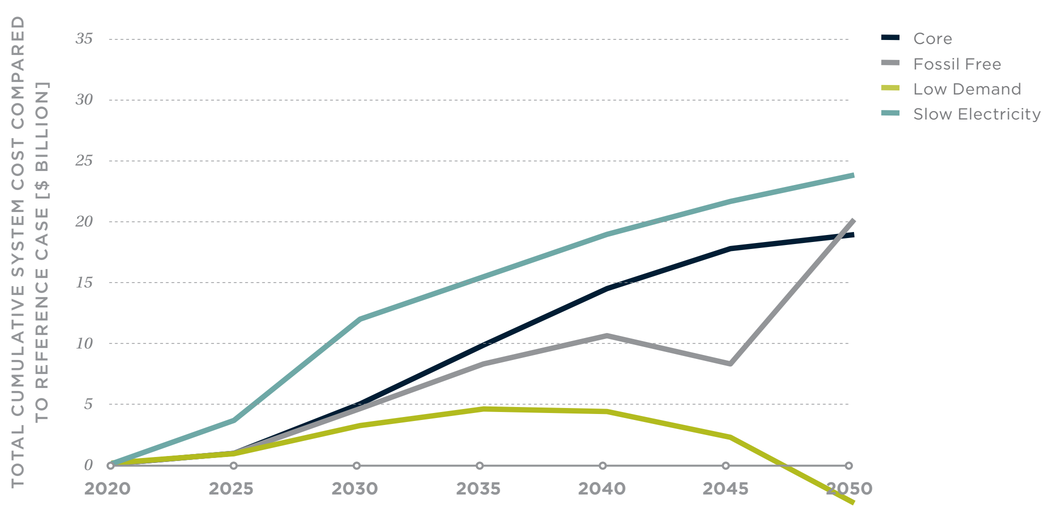



**FIGURE 8.** TOTAL CUMULATIVE SYSTEM COSTS COMPARED TO REFERENCE CASE

*Cumulative costs include the sum of total system costs from 2020 to a given year, minus equivalent costs for the Reference case. In the Core scenario, the cumulative cost of meeting the 2030 target is $6 billion, incurred over the next decade. The Low Demand scenario cuts this total cost to $4 billion by 2030 and results in cumulative net savings by 2050.*



The state's Roadmap is less ambitious on power sector decarbonization and instead includes more aggressive reductions in the other sectors.

Different modeling approaches, assumptions, and priorities led to different results in the Roadmap analysis and Evolved's analysis. While the central takeaway—the need for rapid action across all areas of the economy to meet the 2030 target—is the same, the studies are distinct in the distribution of emission reductions between sectors and some of the strategies for achieving these reductions. Most notably, the Roadmap study shows significantly slower electricity sector decarbonization by 2030 than Evolved's analysis. Table 2 summarizes the major difference in results.

**TABLE 2.** COMPARISON OF THE STATE'S ROADMAP AND EVOLVED'S ANALYSIS OF EMISSIONS REDUCTIONS, BY SECTOR, TO ACHIEVE THE HB 19-1261 GHG REDUCTION TARGETS

| SECTOR | MEASURES/ METRICS BY 2030 | ROADMAP/ E3 ANALYSIS | EVOLVED, CORE SCENARIO | EVOLVED, LOW DEMAND SCENARIO | EVOLVED, SLOW ELECTRICITY SCENARIO |
|---|---|---|---|---|---|
| **Electricity** | GHG reductions (relative to 2005) | 80% | 98% | 99% | 67% |
| **Transportation** | % of on-road vehicles that are zero-emission: | | | | |
| | Light-duty | 22% | 16% | 16% | 22% |
| | Buses | 35% | 16% | 16% | 16% |
| | Medium & heavy duty | 16% | 4% | 4% | 9% |
| | Reduction in vehicle miles traveled, light-duty (relative to Reference) | 3% | 0% | 7% | 0% |
| **Buildings** | % of buildings with high-efficiency shells | 19% | 13% | 25% | 13% |
| | % of appliances that are high efficiency | 30-35% | 19-38% | 19-38% | 19-39% |
| | % of space & water heaters that are electric | 27% | 21-28% | 21-28% | 42-50% |
| | Total demand reduction (from 2020) | 7% | 1% | 4% | 6% |
| **Industry** | Reduction in final energy demand from EE (from 2015 baseline) | 20% | 5%[6] | 5% | 5% |
| | Electrification of non-process energy demand | 100% | <5% | <5% | <5% |
| | Electrification of process energy demand | 57% | <10% | <10% | <10% |
| **Oil and Gas** | Methane leakage rate reduction (from 2019) | 75% | 57% | 57% | 57% |
| | Production Levels | +50% | -25% | -25% | -25% |
| | Electrification of vehicles and equipment | 100% | 0% | 0% | 0% |
| **Low-Carbon Fuels** | Ethanol blend for motor gasoline | 15% | 7.63% | 14% | 14% |
| | Biodiesel blend for diesel | 20% | N/A% | N/A% | N/A% |
| | Renewable diesel blend for transp. diesel | 52% | 14% | 4.5% | 77% |
| | Renewable gas blend | 2% | 0% | 0% | 0% |
| | Hydrogen blend for pipeline gas | 7% | .7% | .1% | 1.1% |
| **In-State Geologic Sequestration** | Carbon capture & sequestration | 1.7 MMT $CO_2$ | 1 MMT $CO_2$ | 0 | 1.5 MMT $CO_2$ |
| **Imported Biofuels** | Net $CO_2$ captured during biofuel production | | 1.4 MMT | 0 | 6 MMT $CO_2$ |

6 Our industrial energy efficiency gains only apply to non-heavy industries, and the electrification energy increases apply to all industries except oil and gas extraction and refineries.

## ELECTRICITY

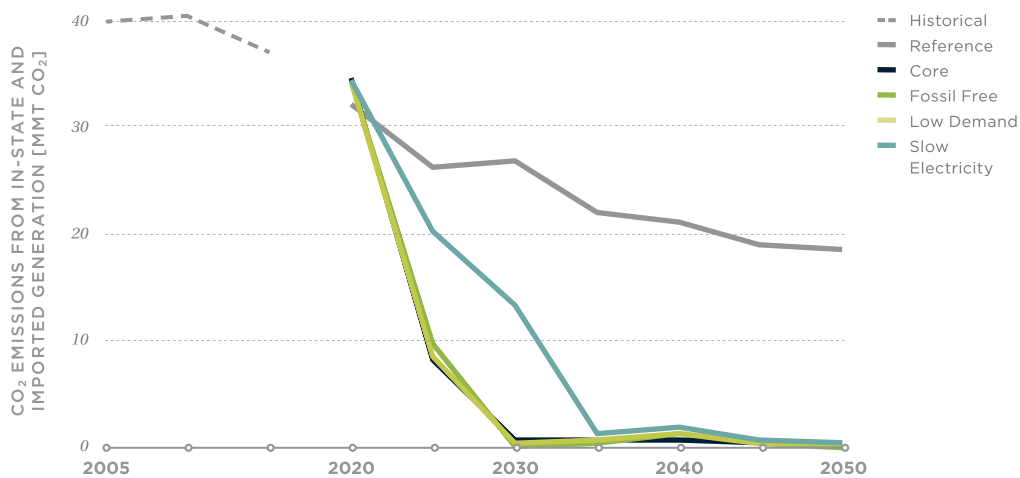
The biggest single takeaway from our modeling effort is the urgent need for the electricity sector to decarbonize as quickly as possible. Our model shows this is essential for two main reasons: some of the cheapest carbon reductions come from the electricity sector, and decarbonization of the electricity sector is necessary for using electrification to decarbonize other sectors such as buildings and transportation. Specifically, the state's utilities should promptly retire their remaining coal-fired power plants, minimize the operation of gas plants, maximize energy efficiency (covered in detail in the Buildings section), and rapidly build out wind, solar, and storage to nearly eliminate carbon pollution from electricity generation within the next ten years. Colorado should also work to further integrate its electricity system with other western states that are likely to develop renewable resources for economic reasons (e.g., Wyoming, Montana) and for economic and policy reasons (e.g., New Mexico). An integrated western grid will lead to more cost-effective emission reductions in Colorado's electricity sector.

**The electric sector reduces $CO_2$ emissions to 98 to 99 percent below 2005 levels by 2030 in the lowest-cost decarbonization scenarios.**

Our modeling suggests that the most cost-effective way to reduce statewide emissions 50 percent by 2030 is to maximize emissions reductions from the power sector. The Core and Low Demand scenarios reduce electric-sector carbon emissions by 98 to 99 percent by 2030 relative to 2005. Even more pressing is that to reach the 2025 goal of a 26 percent reduction in statewide emissions, the electric sector must reduce its carbon emissions 80 percent by 2025. Figure 9 below shows these steep reductions in emissions. These emission reductions translate into essentially a 72 percent renewable portfolio standard for 2025 and 98 percent renewable portfolio standard for 2030. In comparison, the state's largest utilities, Xcel Energy and Tri-State Generation and Transmission, aspire to reduce their carbon dioxide emissions 80 percent and 70 percent by 2030, respectively. These targets, along with Xcel's goal of net zero emissions by 2050, are promising, but our analysis suggests the power sector must move faster to unlock the least-cost pathway to meet the economy-wide goals. Moreover, many coal units are slated to retire after 2025, and several coal units are slated to operate well past 2030, including the state's largest coal unit, Comanche 3, which is scheduled to run through 2070. Accelerating coal unit retirements so that all coal units close no later than 2025 would be one of the most cost-effective, and largest, sources of $CO_2$ reductions.

**FIGURE 9.** $CO_2$ EMISSIONS FROM THE ELECTRICITY SECTOR FOR ALL MODELED SCENARIOS

*All scenarios other than the Reference case reduce $CO_2$ emissions to meet the state's economy-wide targets, but the Slow Electricity case results in more overall $CO_2$ emissions along the way.*




Developing and operating an electricity system with such low carbon emissions intensity is an unprecedented but necessary endeavor. In addition to requiring rapid buildout of renewable energy capacity, this level of decarbonization requires rigorous planning, significant new policy, and coordination across sectors and states to ensure a reliable electricity system. Several studies (e.g., 2035 Report) have documented the feasibility of cutting electric sector emissions 90 percent by the 2030 to 2035 timeframe while maintaining reliability and affordable rates. Others have examined pathways to round out the last 10 percent, without raising electricity rates, using strategies like combustion of clean hydrogen in gas turbines. One of Colorado's largest electric utilities, Platte River Power Authority, already has a goal of becoming carbon neutral by 2030.

More utilities should follow PRPA's and CSU's lead in examining portfolios that achieve 90 to 100 percent carbon reductions by 2030. In the meantime, **a 90 percent carbon reduction by 2030 relative to 2005 levels should be the *minimum* target for Colorado's electric sector.** If state policy aims for 90 percent reductions in lieu of greater cuts, then policymakers must ensure that other sectors make up the gap through faster electrification and greater demand reductions.

In setting policies for the electric sector, the Air Quality Control Commission (AQCC) can maintain a reliable grid by laying out a process for resolving any reliability concerns posed by regulations and creating a role for the Colorado Public Utilities Commission (PUC) to assist in reviewing any utility-specific plans presented to the AQCC for meeting GHG reduction targets. The PUC has long regulated electric utilities under its jurisdiction with a focus on maintaining reliability standards, and the AQCC should involve the PUC in any AQCC rulemakings or actions that review utility plans to reduce GHG emissions.

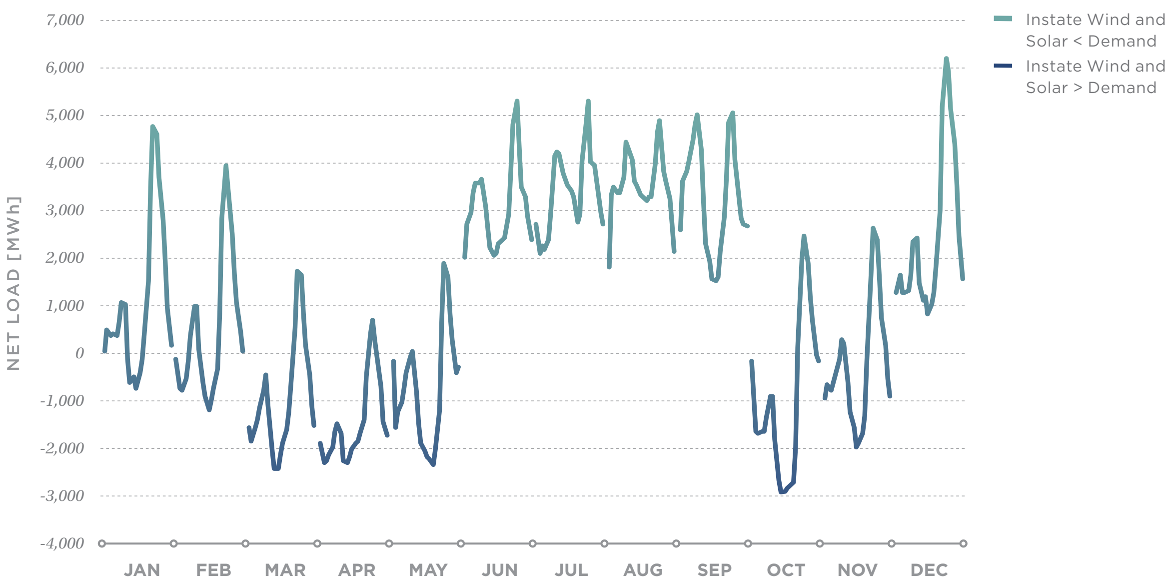
The principal economic challenge to achieving emissions reductions from the electric sector of greater than 80 percent is solving the seasonal balancing problem, which occurs when renewable generation persistently over-generates relative to demand in one season and under-generates relative to demand in other seasons. Our modeling illustrates these balancing challenges based on the demand profiles and projected generating resource mix. In 2030, under-generation occurs primarily in the summer, with low wind production and high loads (due to air conditioning), though some under-generation also occurs in winter months as a result of increased electrification of heating (water- and space-heating). Over-generation occurs in the shoulder months (spring and fall) with high wind generation and low demand.

The seasonal balancing challenge is apparent in the variation in net load over the course of the year. Net load is total electricity demand minus generation from variable renewable energy resources (almost entirely wind and solar in Colorado). Average net loads by hour of the day for each month are shown below in Figure 10. Net-load deficits (shown here as positive in green) must be met with resources other than instate wind and solar. Net-load surpluses (shown in blue) must be curtailed, exported, shifted with energy storage or flexible load, or used productively (in applications like steam production or electric fuel production). In addition to showing the seasonal pattern, Figure 10 also illustrates the hourly variations in net load that also require balancing.

**FIGURE 10.** NET LOAD DEFICITS BY MONTH IN 2030 IN THE CORE SCENARIO

*Net load is total electricity demand minus generation from variable renewable energy resources. The line is blue when net load is negative and green when positive. In-state wind and solar is often insufficient to meet demand in the summer and winter but generates excess electricity in the spring and fall.*

COLORADO'S ELECTRICITY $CO_2$ EMISSIONS



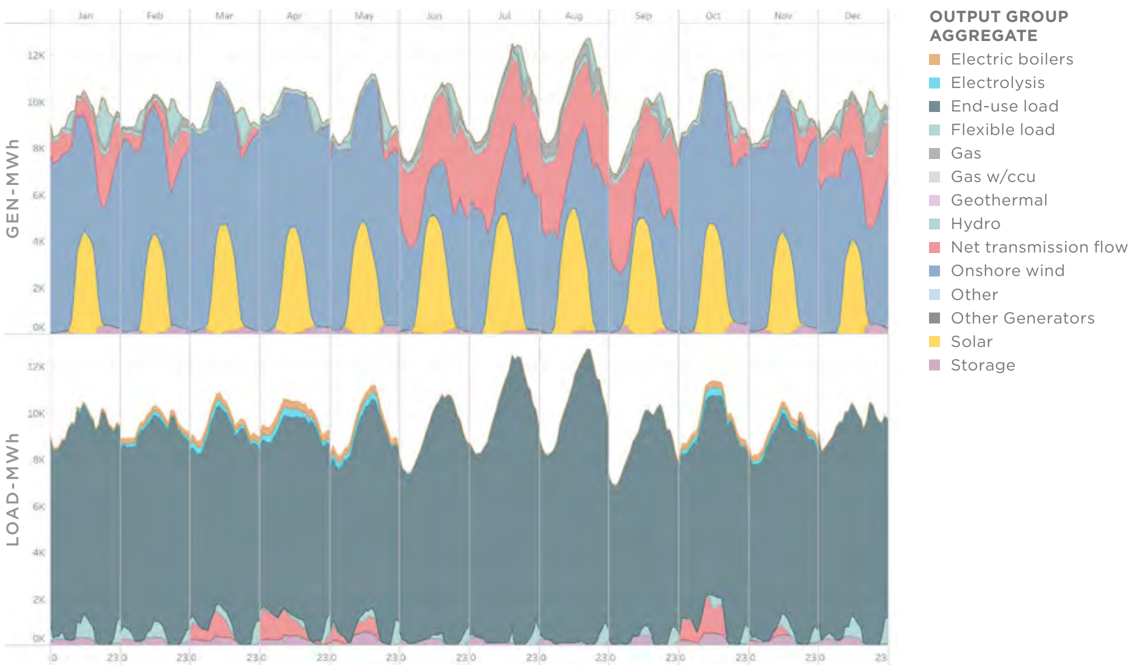

Several technically feasible, cost-effective solutions are available to address seasonal and daily imbalances between renewable generation and energy demand. The modeled electricity system addresses these imbalances and maintains reliability through an all-of-the above approach that relies on storage, greater grid integration (enabling imports and exports with other states), and some gas capacity, as shown in Figure 11.

- In the winter and summer, the state imports electricity primarily from Wyoming and New Mexico. These imports all must be wind or solar to be counted as zero-carbon resources for Colorado's emissions accounting in the model. However, the model does not require all of the production from these plants to be imported to Colorado at all times of the year. Instead, it tends to import seasonally, with wind production from these states split between Colorado and other states in varying distributions throughout the year. This strategy presupposes coordination and contractual structures that may not exist today, but the economic benefits are obvious and significant, which informs the modeled outcome. The importance of this strategy illustrates the necessity to engage in more integrated planning across the west, including firm contracts to ensure imports are available when needed.

- Colorado exports excess renewable energy generation in the spring and fall to other states that would otherwise be running thermal power plants.
- Flexible loads in the form of electrolysis and electric boilers are used to soak up excess renewables in the spring and fall. These loads operate to avoid curtailment when transmission export opportunities are not available. The hydrogen produced from electrolysis can then be used as a fuel in other sectors.
- Gas capacity is maintained for use in periods where there is not available renewable generation either in state or out of state. However, the model runs the gas units significantly less than today to provide this seasonal balancing function. In the Core case, combined cycle units operate with a capacity factor of less than 4 percent and combustion turbines operate with a capacity factor of approximately 1 percent. To the extent that gas units are needed to run to address sub-hourly conditions on the grid, ensure local reliability, or provide an inertial function (all things not captured within the model framework), then there may be greater output from gas units than is optimized in the model. However, other resources, such as energy storage, can provide these services. Even if gas plants are used for these functions, the additional gas generation is likely to be small and we would expect utilization rates to remain low.
- Energy storage and flexible building and transportation loads—including appliances and EVs that can shift demand a few hours earlier or later—help balance daily supply and demand fluctuations in the seasons that have lower renewable energy output.

**FIGURE 11.** BALANCING ELECTRICITY SUPPLY AND DEMAND IN 2030 IN THE CORE SCENARIO

*These charts show the electricity supply portfolio and the sources of electricity demand by hour for a typical day in each month. All year, Colorado gets a significant quantity of electricity from instate renewables. In the summer months, the state relies most heavily on electricity imports to supplement instate renewables. The state also uses flexible load and storage to balance supply and demand in these months and a small amount of gas generation to fill in the gaps. In the spring and fall, the state exports some renewables and turns on electrolysis facilities to produce hydrogen with excess renewables, shown in the load chart.*




If the power sector does not meet the needed emission reductions quickly enough, as in the Slow Electricity scenario, then the other sectors must decarbonize even more quickly. In the Slow Electricity scenario, Colorado's electricity sector only sees a 67 percent reduction in emissions by 2030 relative to 2005 levels, which makes it much more difficult to meet the goal of reducing economy-wide emissions 50 percent by 2030. As a result, the transportation, buildings, and industrial sectors will have to cut emissions even more quickly to offset the lingering emissions from power plants, which is difficult when constrained by stock turnover. Some of the strategies for faster reductions, especially in the transportation and industrial sectors, are more costly, require a potentially unachievable pace of transformation, and carry other downsides, like the local air pollution, sustainability, and availability challenges of biofuels.

WHAT THE SLOW ELECTRICITY SCENARIO REQUIRES FROM THE OTHER SECTORS VS CORE SCENARIO

| | |
|---|---|
| **Transportation** | Almost 450,000 more electric light-duty vehicles and 6,000 medium- and heavy-duty vehicles on the road than in the Core scenario by 2030. In addition, biofuels must replace even more fossil fuels (especially diesel), composing 18 percent of total transportation energy demand in 2030, compared to 7 percent in the Core scenario. Moreover, these additional biofuels must be produced using carbon capture and storage to balance out the emissions. |
| **Buildings** | 375,000 more homes are all electric than in the Core scenario by 2030. |
| **Industry** | Biofuels make up 14 percent of industrial energy demand, compared to only 6 percent in the Core scenario. |

**Colorado needs to eliminate the use of coal to serve electricity customers by 2025; delaying retirements to 2030 will make it more difficult to meet the state's economy-wide targets.**

In each of the four decarbonization scenarios that Evolved modeled, Colorado's fossil fuel generation declines, driven by coal plant retirements and steep declines in gas use. **In the Core scenario, all coal units retire by 2025.** This scenario shows coal generating only 2 percent of the state's electricity at the end of 2024, then dropping to zero for 2025 and beyond. Figure 12 below underscores the sharp and rapid drop in coal capacity in the Core, Fossil Free, and Low Demand scenarios compared to the Slow Electricity and Reference scenarios.

**State policymakers and the state's utilities must speed up coal retirements.** The model shows that the most cost-effective path is to retire all coal before 2025. If all coal units are not retired by 2025, they must be retired as soon after 2025 as possible and state policymakers must ensure that other sectors make up the emissions difference. If the state's coal plants are not all retired before 2030, it will be much harder and more expensive to achieve the 2030 statewide goal because other costlier and more difficult reductions will need to take place in the buildings, transportation, and fossil fuel sectors. The Slow Electricity case illustrates this point as it is the most expensive scenario—even more expensive than the Fossil Free case—warning of the serious cost implications of slow electric decarbonization.

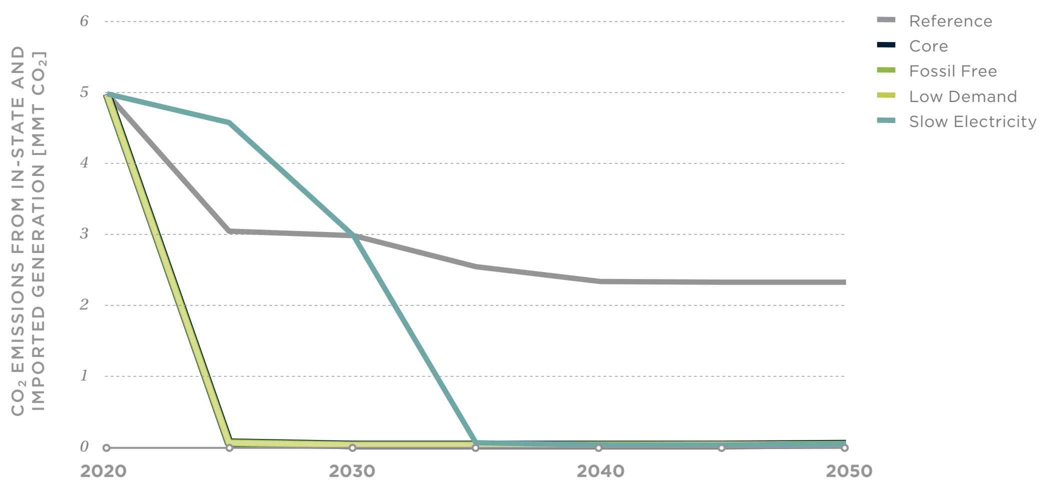
Similarly, gas utilization must drop significantly to meet the climate goals. The Core scenario projects gas generation will provide 26 percent of the state's electricity in 2025, then drop sharply to 2 percent of electricity in 2030, and finally reach only 1 percent in 2050. Again, this trend is in stark contrast with the Reference scenario where fossil fuels could still generate 63 percent of the state's electricity in 2025, 69 percent of the state's electricity in 2030, and

37 percent of the state's electricity in 2050. Our results show that the current path of the electric sector is insufficient and strong new policy drivers will be necessary to accelerate decarbonization in the electricity sector to reach the state's climate goals. The Low Demand and Fossil Free scenarios show almost identical declines in coal plants and gas use.

In the Slow Electricity scenario, coal generation remains high in 2030, while gas generation is lower than in the other decarbonization cases. The remaining coal generation displaces generation from gas and a small amount of renewable energy.

**FIGURE 12.** COAL CAPACITY FOR ALL MODELED SCENARIOS

*In the Core, Fossil Free, and Low Demand scenarios, coal capacity drops to near zero by 2025. In the Slow Electricity Sector, coal capacity remains online for longer and drops to zero by 2035.*



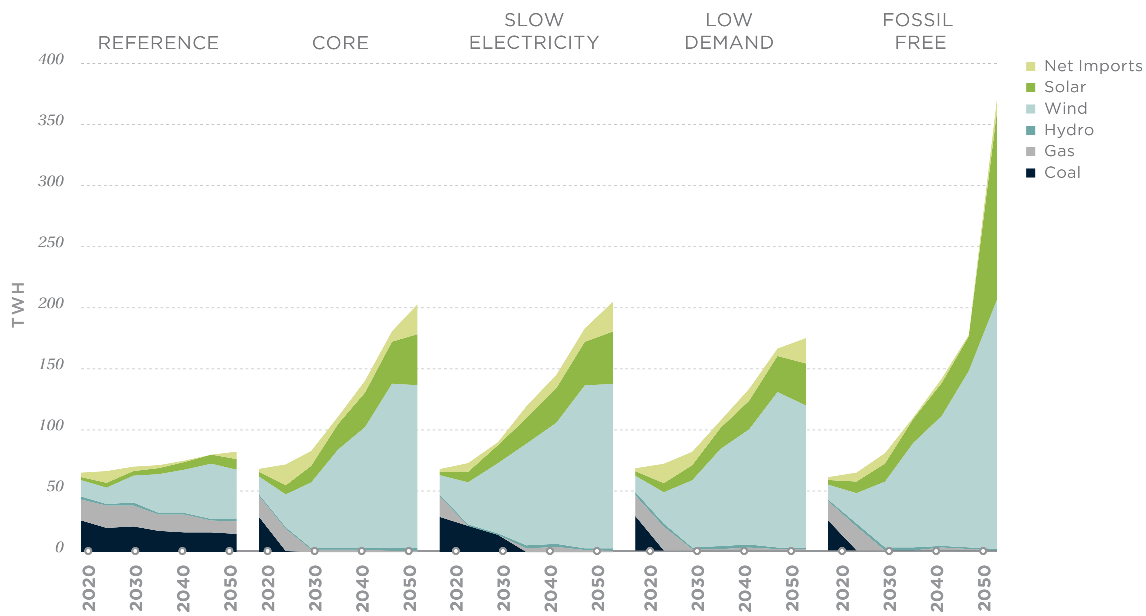

**Colorado will need 6 GW of new wind capacity and 4 GW of new solar capacity by 2030.**

While coal- and gas-fired power plants still dominate today's generation mix in Colorado, the future decarbonized grid looks very different. Each decarbonization scenario we modeled shows a marked shift in electricity generation to reach the state's economy-wide goals. Wind energy grows to represent the largest share of electricity in the state, solar output increases, and imports of clean energy elsewhere in the region grow to fill in the rest.

All of the decarbonization scenarios project considerable growth in the electricity system. Compared to today's levels, total electricity generation at least doubles by 2050 because of the significant electrification of buildings and vehicles required to decarbonize the other sectors. Figure 13 below displays the large jump in electricity generation and each resource's contribution across the modeled scenarios between now and 2050. The level of electricity growth shown here is still less than it would be without energy efficiency measures, discussed in more detail in the Buildings section of the report. Without the level of efficiency represented in all the decarbonization cases, the challenge of decarbonizing the grid would be even greater.

**FIGURE 13.** ELECTRICITY GENERATION FOR ALL MODELED SCENARIOS

*In the Core, Slow Electricity, and Low Demand Scenarios, electricity output increases three- to four-fold between 2020 and 2050, with most of that increase occurring after 2030. Coal and gas generation, which presently dominates the grid, decline to near zero in the Core, Low Demand, and Fossil Free scenarios. Instate wind generation expands dramatically in all scenarios to become the largest source of electricity. Solar generation grows to become a significant player in the decarbonized grid, and imports fill in the rest of the portfolio.*




Renewable energy growth (and total electricity generation) is greatest in the Fossil Free scenario by 2050, as shown in the right-hand graph in Figure 13. Whereas the other scenarios allow a small budget for fossil fuel for hard-to-decarbonize sectors (e.g., jet fuel for aviation), the Fossil Free scenario requires the state (and the nation) to produce carbon-neutral fuels from non-fossil inputs. Moreover, this scenario also requires replacement of all petrochemicals and other fossil-fuel-based products with renewable, synthetic substitutes. As a result, electricity supports an even greater share of the economy through production of synthetic fuels that can directly replace refined fossil fuels. Further reductions in energy demand (such as those included in the Low Demand scenario) and product demand (such as plastics recycling) would reduce the need for renewable energy growth, especially if those demand reductions were targeted at hard-to-decarbonize sectors like aviation.

The state must begin building vast amounts of new renewable energy and corresponding new transmission right away to replace fossil fuels and meet growing electricity demand. Colorado currently has almost 4 gigawatts (GW) of wind capacity and slightly more than 1 GW of solar capacity. **In the Core scenario, wind and solar collectively add 13 GW of new capacity in the 2020s, more than tripling the existing wind and solar capacity.** By 2030, about 97 percent of in-state electricity generation must come from renewables. When you factor in imports, renewable energy meets 98 percent of the state's electricity demand in 2030. In the 2030s, the state must add another 17 GW of new renewable capacity followed by an additional 14 GW in the 2040s.

All together, in the Core scenario, Colorado needs 28 GW of new wind and 16 GW of new solar by 2050—more than seven times as much wind capacity and almost 15 times as much solar capacity as is currently on the system. That is the equivalent of adding 0.9 GW of new wind (one fourth of the current wind capacity) and 0.5 GW of new solar (half of the current solar capacity) each year through 2050. Table 3 below outlines the growth in wind and solar capacity in the Core and Reference scenarios between now and 2050 and highlights the total renewable capacity difference between the Reference and Core scenarios by 2050: a whopping 35 GW of renewables.

**TABLE 3.** WIND AND SOLAR CAPACITY IN THE CORE AND REFERENCE SCENARIOS

*While both the Core and Reference scenarios see an increase in wind and solar capacity, the Core scenario sees over three times more renewables built between now and 2050.*

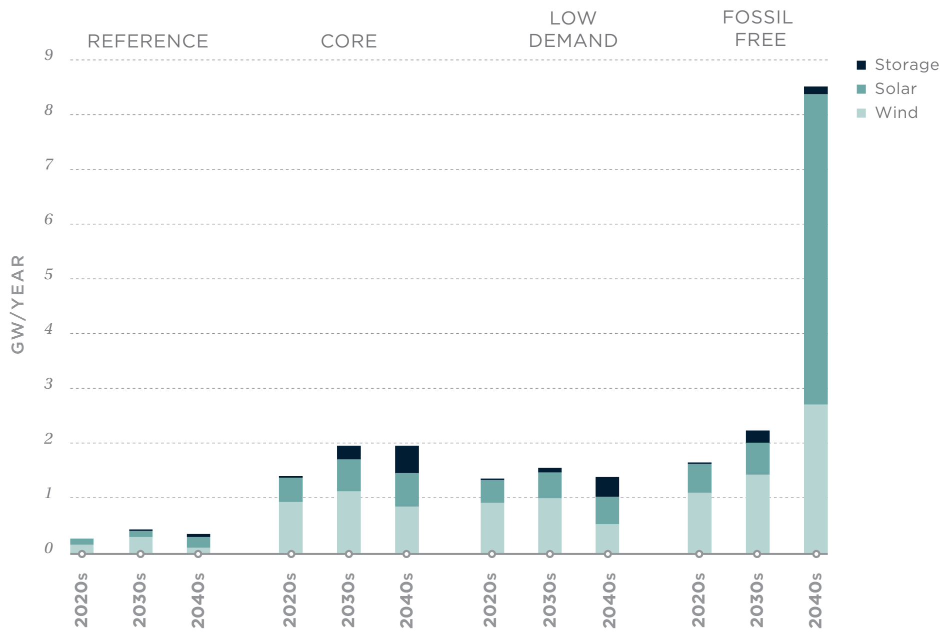
| | | 2025 | 2030 | 2050 |
|---|---|---|---|---|
| **Core** | Wind | 7.6 | 13.5 | 32.7 |
| | Solar | 3.3 | 6.0 | 17.7 |
| | Total Renewable | 10.9 | 19.5 | 50.4 |
| **Reference** | Wind | 4.6 | 6.3 | 10.5 |
| | Solar | 1.8 | 2.3 | 5.3 |
| | Total Renewable | 6.4 | 8.6 | 15.8 |

The additional efficiency and demand reduction measures in the Low Demand scenario reduce the need for renewable energy buildout by about 0.2 GW per year, compared to the Core case. That is a 15 percent reduction in the amount that the sector needs to build. Conversely, in the Fossil Free scenario, renewable energy builds more than double compared to the Core case, with the greatest increase in the 2040s.

Energy storage also plays an important role in decarbonizing the grid. Figure 14 below showcases the contribution of storage on top of new power plant capacity in the Reference, Core, Low Demand, and Fossil Free scenarios. While distributed solar and storage are not options in the model's optimization, ensuring that some solar and storage is distributed will help harden the grid and increase resilience in the face of wildfires and other emergencies.

**FIGURE 14.** NEW POWER PLANT CAPACITY IN SELECT MODELED SCENARIOS

*Construction of new wind, solar, and storage must accelerate significantly to meet the climate goals. Demand reduction and efficiency measures in the Low Demand case reduce the necessary amount of new capacity. The Fossil Free scenario requires significantly more new renewable energy and storage to provide electricity to produce synthetic fuels and products to replace all fossil fuels.*




**Deep decarbonization of the electricity sector drives significant reductions in pollutants harmful to human health.**

The decarbonization scenarios all reduce harmful air pollution from the electricity system, with the Slow Electricity scenario showing the smallest reductions. The magnitude of the benefits of air pollution reductions, including their impact on low-income communities, communities of color, and overburdened communities, will depend on the order in which the plants retire or reduce utilization.

Air pollution from coal declines rapidly in the Core scenario, and pollution from gas power increases slowly by 2025 before declining to close to zero by 2030. Figure 15 demonstrates the overall downward trajectory in electricity air pollution in the Reference, Core, and Slow Electricity scenarios. In the Slow

Electricity scenario, air pollution from coal remains high in 2030 because the state keeps several coal-fired power plants online.

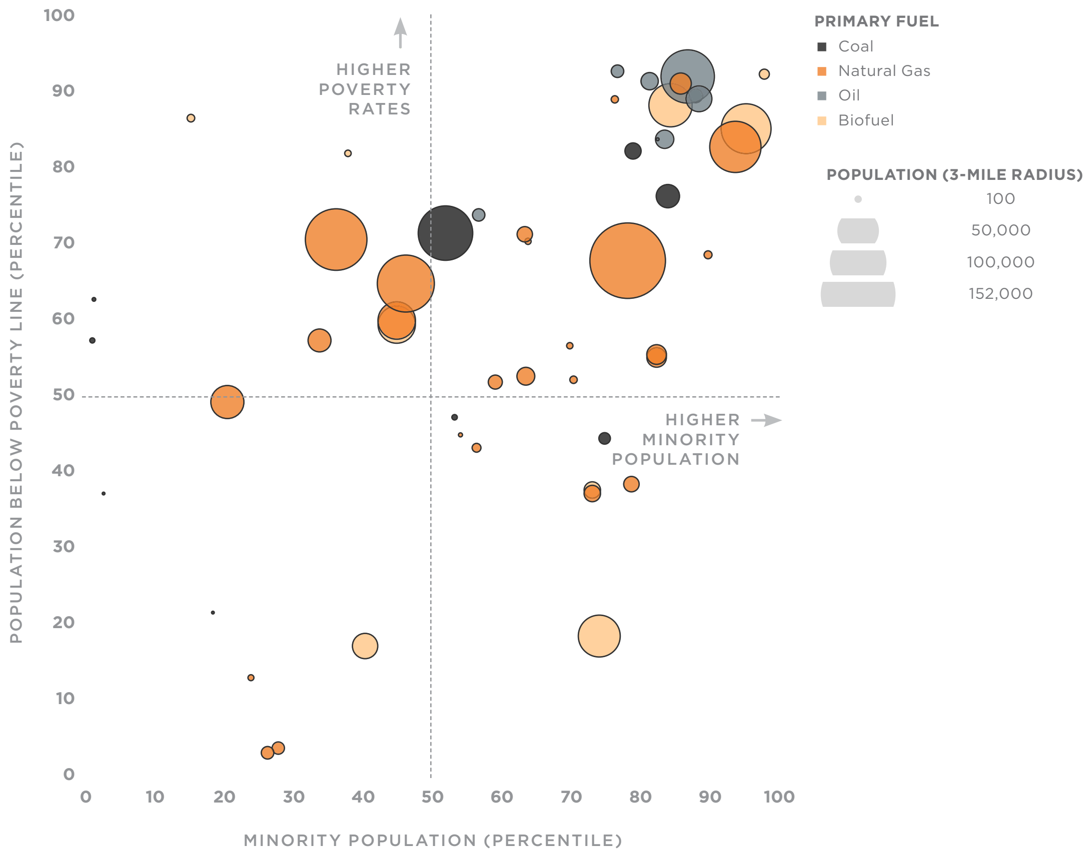
**FIGURE 15.** ELECTRIC SECTOR POLLUTION IN THE REFERENCE, CORE, AND SLOW ELECTRICITY SCENARIOS, 2020-2030

*Pollution remains high in the Slow Electricity scenario due to ongoing operation of coal units. In the Core case, emissions from coal drop to zero by 2025 because all coal retires by 2025, and emissions from gas then drop significantly between 2025 and 2030.*


Colorado's electricity sector pollution sources are disproportionately located in low-income communities and communities of color. As shown in Figure 16 below, two thirds of the state's fossil fuel power plants are located in communities with higher-than-median low-income populations, and two thirds are located in communities with higher-than-median census-defined minority populations, with many located in both. Figure 16 plots the distribution of plants among low-income communities and communities of color. The top half of the plot shows higher levels of populations below the poverty line and the right half of the plot shows higher levels of minority populations. The concentration of circles (fossil fuel plants) in the top and top right of the plot illustrates the prevalence of fossil fuel power plants in areas with more low-income and minority populations.

**FIGURE 16.** POVERTY RATES AND PERCENT MINORITY POPULATIONS WITHIN A 3-MILE RADIUS OF POWER PLANTS

*Most power plants are located in communities with higher-than-median low-income populations and/or higher-than-median census-defined minority populations. Data sources: U.S. Census Bureau; U.S. EIA.*

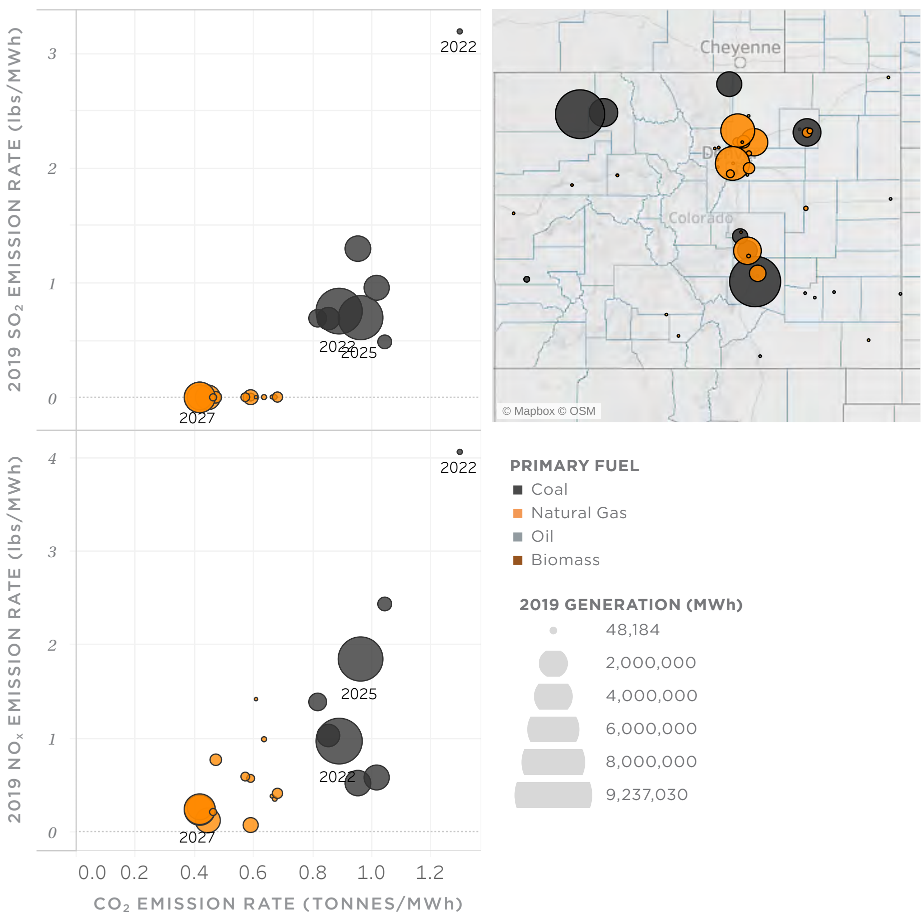



It is essential to understand how policy pathways will affect emissions of different air pollutants in these communities. Electricity-system $SO_2$, $NO_x$, and mercury (Hg) pollution drop to near zero by 2030 in the Core, Low Demand, and Fossil Free scenarios. By contrast, in the Slow Electricity scenario, the power sector achieves only a 45 percent reduction in $SO_2$, 61 percent reduction in $NO_x$, and 48 percent reduction in Hg, due to the lingering coal-fired electricity. Prioritizing retirement of the most polluting plants—especially if the state achieves slower power sector progress—is important to ensure pollution reductions.

Not all plants have the same pollution impact, even within the same fuel class. There is wide variation in air pollution emissions intensity among Colorado's coal- and gas-fired power plants, in part due to differences in technology vintage and air pollutant control technologies. This variation, combined with variation in plant location, means that different plants have different impacts on public health. Figure 17 below shows $CO_2$, $NO_x$, and $SO_2$ emissions from power plants in 2019 alongside a map of power plants across the state. Reducing emissions first from plants with high emissions rates, beginning with coal facilities, will reduce pollution more rapidly. Another trend is that many of Colorado's gas plants are located in and around the Denver area, whereas the state's coal plants are in communities outside of Denver.

**FIGURE 17.** $CO_2$, $NO_x$, AND $SO_2$ EMISSIONS FROM POWER PLANTS AND MAP OF POWER PLANTS

*Coal plants show some variation in $SO_2$ emission rates, and $SO_2$ intensities are not well correlated with $CO_2$ intensity. Gas plants emit very little to no $SO_2$. Both coal and gas show significant variation in $NO_x$ emissions rates, which again are not well correlated with $CO_2$ emissions rates. Eliminating a ton of $CO_2$ leads to reducing more health-harming co-pollutants from some plants than from others. The years shown on the charts represent the planned retirement for plants whose owners have committed to closing the plant.*



Differences in air pollution intensity of coal plants are important for policy decisions particularly if the power sector emissions do not decline as quickly as in the Core scenario. If power sector decarbonization follows the pace of the Slow Electricity scenario, air pollutant emissions could meaningfully vary depending on the timing and sequencing of coal unit retirements. Prioritizing the retirement of coal plants with high sulfur dioxide emission rates, for example, could reduce 2030 emissions by roughly 15 percent, or more than 730 tons. The differences are less of an issue for coal if the state succeeds in eliminating nearly all coal power by 2025 to meet its climate goals.

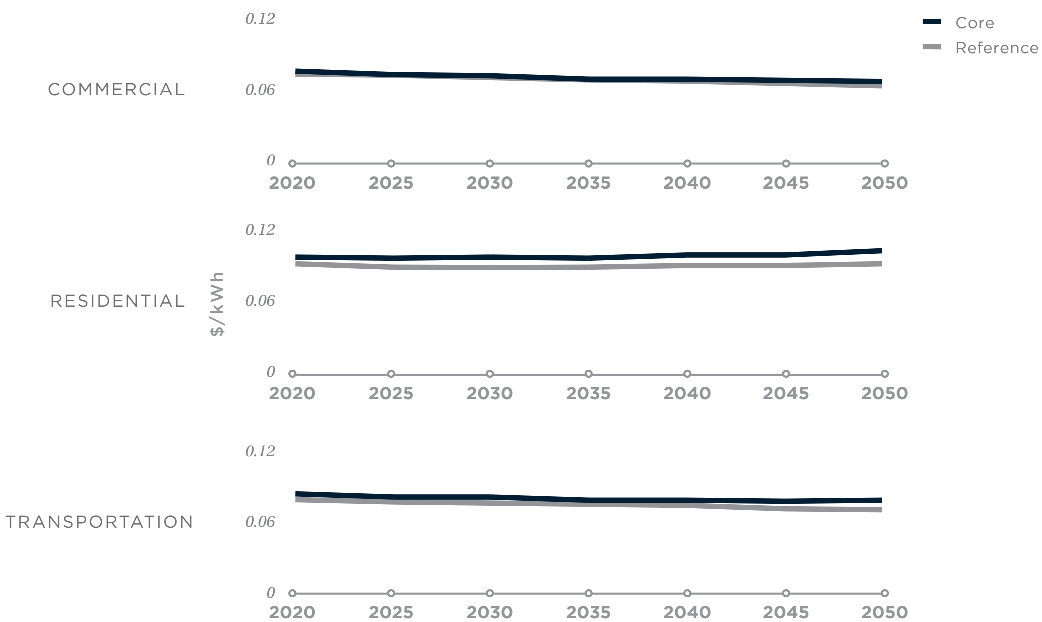
Our modeling suggests that some gas-fired power may remain in 2030 and generate a small amount of electricity, even if the state meets its climate goals. Many of Colorado's gas plants are located in low-income communities, communities of color, and areas that already face high levels of pollution burden, including many in the federal ozone nonattainment area around Denver (Figure 4 illustrates this trend earlier in the report). Decisions about which, if any, gas plants remain online past 2030 will influence the extent to which these communities continue to face disproportionate burdens from fuel infrastructure.

**The state can achieve the required transformation of the electricity system without large increases in average retail electricity costs.**

Retail costs stay stable throughout the modeled time period, with little difference between the Core and Reference cases, as shown in Figure 18. The average electricity costs do not account for the variation in the bills that individual consumers pay, including consumers' energy burden (i.e., the share of income devoted to energy costs).

**FIGURE 18.** AVERAGE ELECTRICITY COSTS IN THE REFERENCE AND CORE CASES

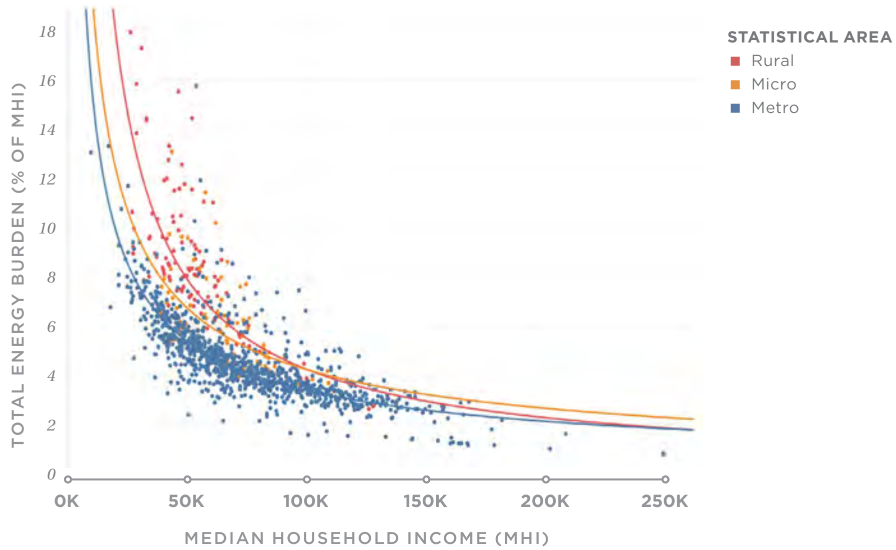
*The cost of electricity for commercial buildings, residential buildings, and transportation (electric vehicles) remains stable through 2050, with little difference between the Reference and Core scenarios.*




Many households pay more than 10 percent of their income on energy expenses, and low-income and rural households tend to be worse off, as shown in Figure 19. Under the decarbonization scenarios, certain Coloradans will continue to face high energy burdens without additional policy, reinforcing the notion that reducing $CO_2$ emissions from the electric sector is not, by itself, sufficient to address the inequities in the state. State policymakers must intentionally adopt targeted policies to ensure that electricity is affordable for all Coloradans.

**FIGURE 19.** AVERAGE ENERGY BURDEN FOR RESIDENTIAL & TRANSPORTATION ENERGY COSTS BY CENSUS TRACT (2017)

*Energy burden rises exponentially as income declines, on average. Residents of rural areas tend to have a higher energy burden than residents in urban and suburban areas. The dots indicate census tracts. Total energy burden is based on average energy use (at home and for transportation) per household by census tract, retail electricity costs, and median household income by census tract.*




## TRANSPORTATION

Colorado must build out a highly efficient and decarbonized transportation system to meet its near- and long-term climate goals. The transportation sector must shift from an inefficient system dominated by fossil fuels to a lower-consumption system powered primarily by clean electricity, supplemented by smaller amounts of green hydrogen, electrically produced fuels, and biofuels. Electrification of the vehicle fleet is the primary transportation decarbonization strategy in the near term. Transportation electrification has the potential to save people money on fuel costs, push down electricity rates (for example, by absorbing excess renewable generation that might otherwise have to be curtailed), and curb air pollution. Likewise, if done right, investments in public transit, rail, and smart urban design, such as those represented in the Low Demand scenario, can increase mobility and create safer, healthier, and more accessible transportation systems.

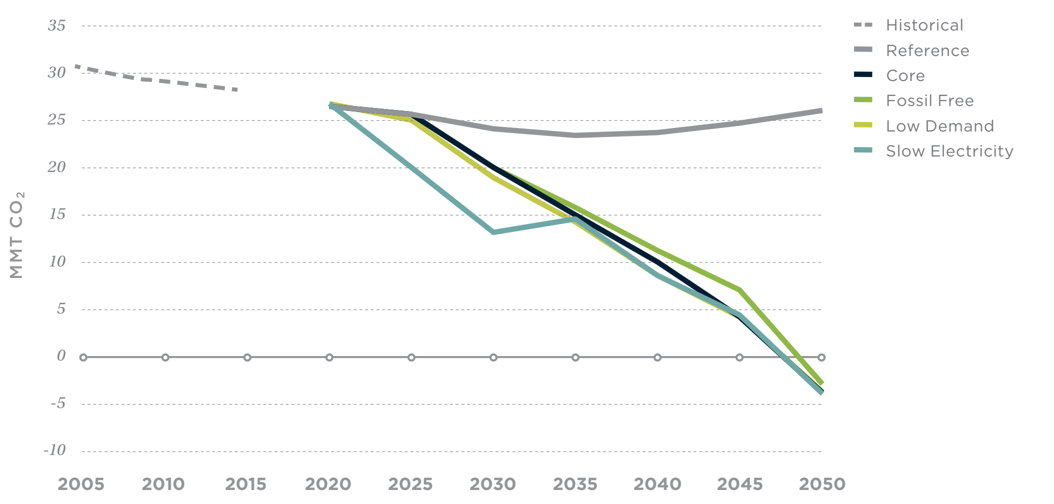
**Transportation $CO_2$ emissions must drop by at least 35 percent by 2030.**

Our modeling shows that transportation-related $CO_2$ emissions must drop 18 percent by 2025 and 35 percent by 2030, relative to 2005 levels. That is equivalent to a 30 percent reduction from 2017 levels by 2030. Emissions must then decline even more rapidly from 2030 to 2050, becoming net negative[7] by 2050 to meet the midcentury target. In our decarbonization pathways, electrification, low-carbon fuels, and efficiency drive these emissions reductions. Increased transit, walking, and biking also play a significant role in the Low Demand scenario.

If the power sector does not achieve the level of reductions that occur in the Core scenario, the transportation sector needs to decarbonize even more quickly. In the Slow Electricity scenario, transportation emissions plummet down to 35 percent below 2005 levels by 2025—reaching this level five years earlier than in the Core Scenario—and 57 percent by 2030, nearly double the level in the Core scenario. Figure 20 below shows the large emissions gap that the transportation sector must fill through 2030 to make up for additional $CO_2$ from the power sector in the Slow Electricity case, compared to the Core, Fossil Free, and Low Demand scenarios.

**FIGURE 20.** $CO_2$ EMISSIONS FROM THE TRANSPORTATION SECTOR IN ALL MODELED SCENARIOS

*Transportation emissions drop to at least 18 percent below 2005 levels by 2025 and 35 percent below 2005 levels by 2030 in the Core, Fossil Free, and Low Demand scenarios. The reductions in the next five years are small, as electric vehicle adoption is slowly accelerating. In the Slow Electricity scenario, steep reductions begin immediately, and emissions drop to 35 percent below 2005 levels by 2025 and 57 percent below 2005 levels by 2030.*




7 Emissions are net-negative due to the use of imported biofuels produced with carbon capture and storage.

**Electric vehicle sales must make up the majority of new light-duty vehicle sales by 2030.**

Electrification is a key pillar of transportation decarbonization, and the state must quickly electrify the vehicle fleet to meet the near- and long-term economy-wide goals. This result was consistent across all the scenarios analyzed.

The market for light-duty vehicles must shift rapidly for Colorado to meet its climate goals. In scenarios where the state meets its targets, electric vehicles make up at least 27 percent of new car sales and 8 percent of new light truck sales by 2025 and 66 percent of new car sales and 40 percent of new light truck sales by 2030. By 2035 or soon after, nearly all new cars and light trucks should be electric. If the power sector decarbonizes more slowly than we recommend, as demonstrated in our Slow Electricity scenario, then EV sales must accelerate even more quickly, reaching 39 percent of new car and 14 percent of new light truck sales by 2025 and 85 percent of new car and 71 percent of new truck sales by 2030.

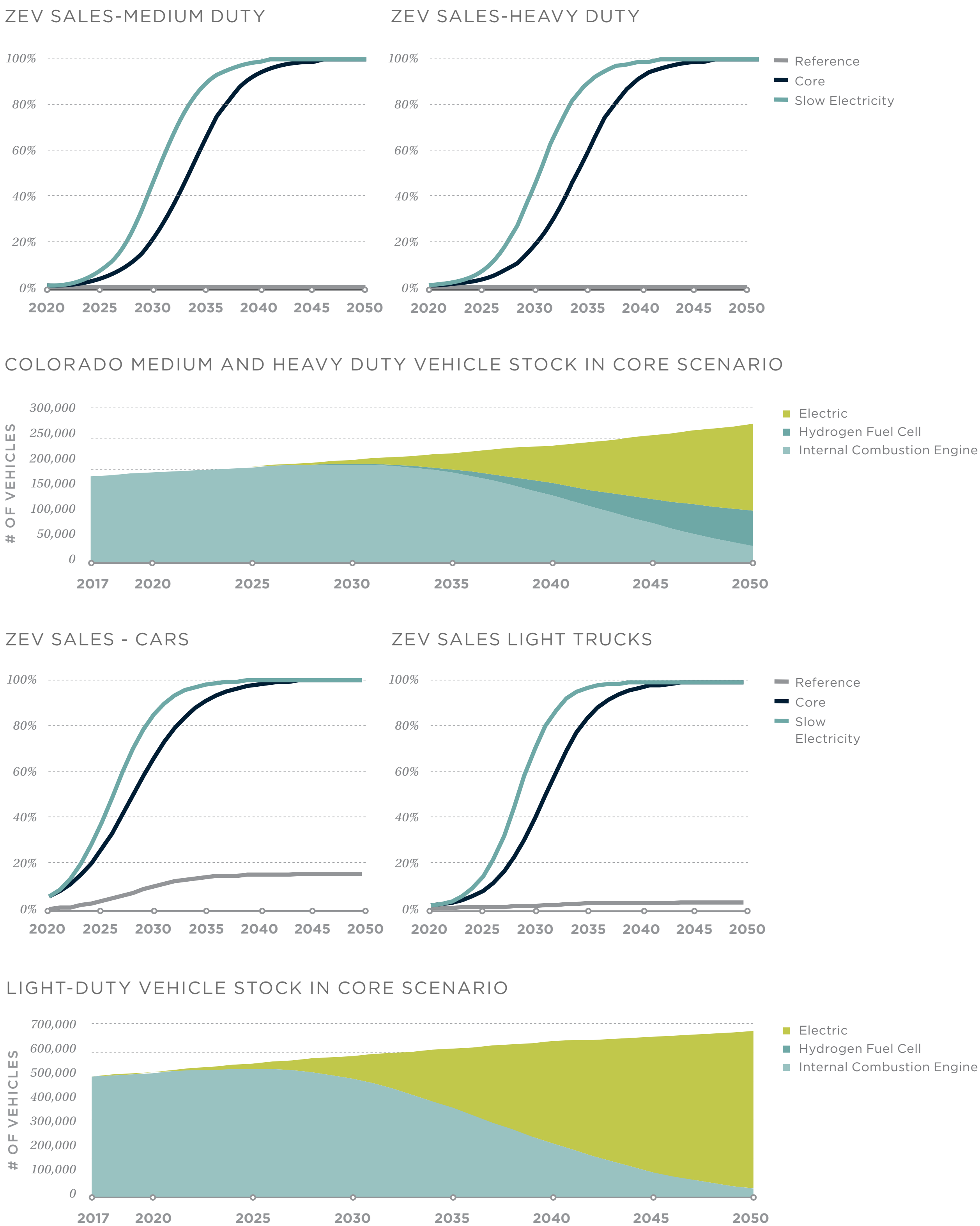
In the Core scenario, increased adoption of EVs leads to at least 220,000 electric cars and light trucks on the road by 2025 and 900,000 on the road by 2030. Because EVs dominate the new vehicle market starting in the 2030s, vehicle stock will turn over quickly in the 2040s as a growing share of people buy EVs when replacing their old cars. As a result, 95 percent of on-road light-duty vehicles are electric by 2050.

The fleet of medium- and heavy-duty vehicles must also electrify, though on a slightly later timeline. To meet the state's targets, electric vehicles and hydrogen fuel cell vehicles make up at least 21 percent of new medium- and heavy-duty trucks by 2030 and close to 100 percent by 2040. To reach the 2025 emissions goal and develop the technology and infrastructure to meet the 2030 target, clean truck adoption should grow in the next five years, reaching 4 percent of new sales by 2025. In our scenarios, hydrogen fuel cell vehicles play a modest role in the 2030s and a larger role in 2040s, with double or triple the number of medium- and heavy-duty trucks powered by batteries compared to being powered by hydrogen fuel cells. In the Slow Electricity scenario, EVs must make up almost 50 percent of new trucks by 2030 to help make up for greater emissions in the power sector. Figure 21 below compares electric vehicles growth as a percentage of all new vehicle sales from now to 2050 between the Reference, Core, and Slow Electricity scenarios as well as the shift in vehicle stock composition.

Electric and fuel cell options for heavy-duty trucks are currently limited by high costs and limitations in performance, especially for long-haul trucks, which is why adoption is slow until the 2030s, by when the technologies are expected to have improved.

**FIGURE 21.** ZERO-EMISSION VEHICLES AS A PERCENTAGE OF ALL SALES IN THE REFERENCE, CORE, AND SLOW ELECTRICITY CASES

*Adoption of zero-emission vehicles must accelerate rapidly in the late 2020s and 2030s to meet the climate goals. In the Slow Electricity scenario, adoption must grow significantly in the next few years so that zero-emission technologies make up a significant share of new vehicles by 2030.*



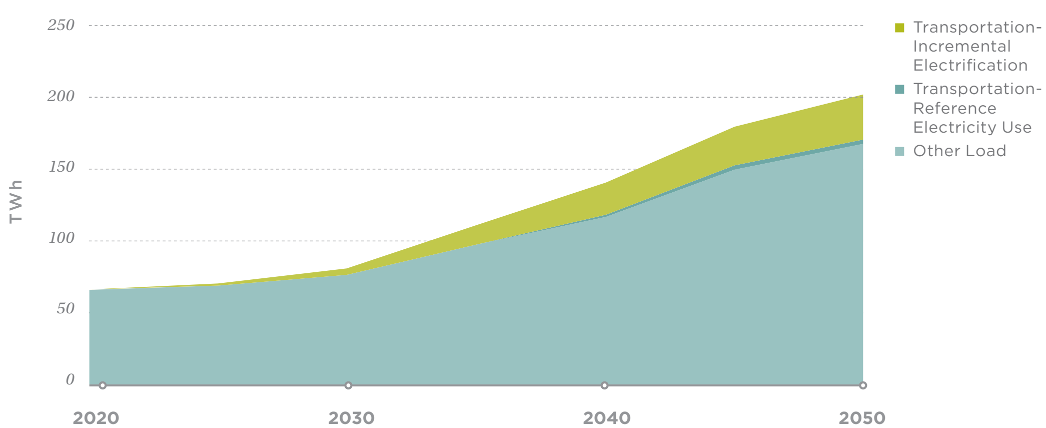
**Transportation electrification adds 5 TWh—equal to 6 percent of total load—to the electric sector by 2030.**

Transportation electrification contributes to growth in electricity demand in all modeled scenarios. Figure 22 below shows how in the Core scenario, newly electrified vehicles increase electricity demand by 5 TWh by 2030, or about 6 percent of total electricity use. By 2050, the transportation sector uses 31 TWh of electricity, roughly 16 percent of total electricity load in 2050.

In our decarbonization scenarios, Colorado takes advantage of flexibility in operation of electric vehicles to help reliably meet load in a deeply decarbonized electricity system. In the Core, Slow Electricity, and Fossil Free scenarios, we assume that 50 percent of light-duty vehicle load can shift up to eight hours, 50 percent of medium-duty vehicle load can shift up to three hours, and 25 percent of heavy-duty vehicle load can shift up to three hours. That means, for example, that 50 percent of the electricity required to charge electric cars can shift a few hours later in the evening to avoid the late afternoon peak in demand. Enabling this load flexibility requires policy solutions, including strategic rate structures, to incentivize energy use to improve grid operation.

**FIGURE 22.** INCREMENTAL ELECTRICITY LOAD FROM TRANSPORTATION ELECTRIFICATION

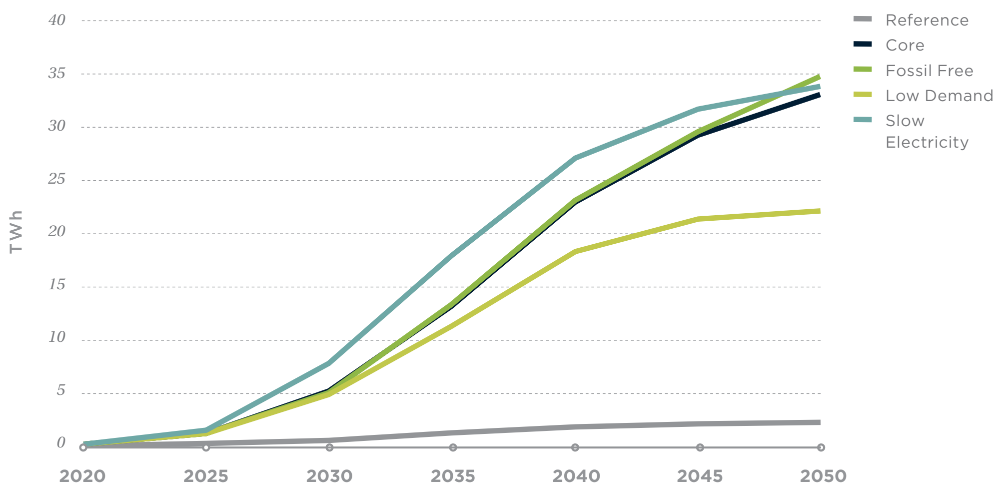
*Though transportation electrification adds electricity demand, it only represents a small share of load through 2030. By 2050, transportation makes up a more significant share of total load. The load from transportation in the Reference case (the dark green wedge) is very small.*



Efficiency and demand-reduction measures (including managing the times that electric vehicles are charged to maximize charging during off-peak hours and/or during periods of excess renewable generation) can reduce the impact of electrification on the electricity system. In the Low Demand scenario, reductions in vehicle use result in 7 percent less electricity growth from transportation by 2030 and 33 percent less by 2050. The Low Demand scenario also maximizes load flexibility from electric vehicles, allowing 100 percent of LDVs and MDVs and 50 percent of HDVs to shift load. The demand reduction measures and additional load flexibility help reduce the amount of new wind and solar power plants that need to be built. Figure 23 below displays the growth paths of electricity load attributable to transportation electrification across all the scenarios.

**FIGURE 23.** ELECTRICITY LOAD FROM TRANSPORTATION ELECTRIFICATION ACROSS ALL MODELED SCENARIOS

*Electricity load for transportation grows considerably in all decarbonization cases. The Slow Electricity scenario grows the fastest in the near term. In the Low Demand scenario, demand reduction measures reduce the incremental load from electrification.*




**The state must decarbonize the remaining transportation fossil fuel use by 2050.**

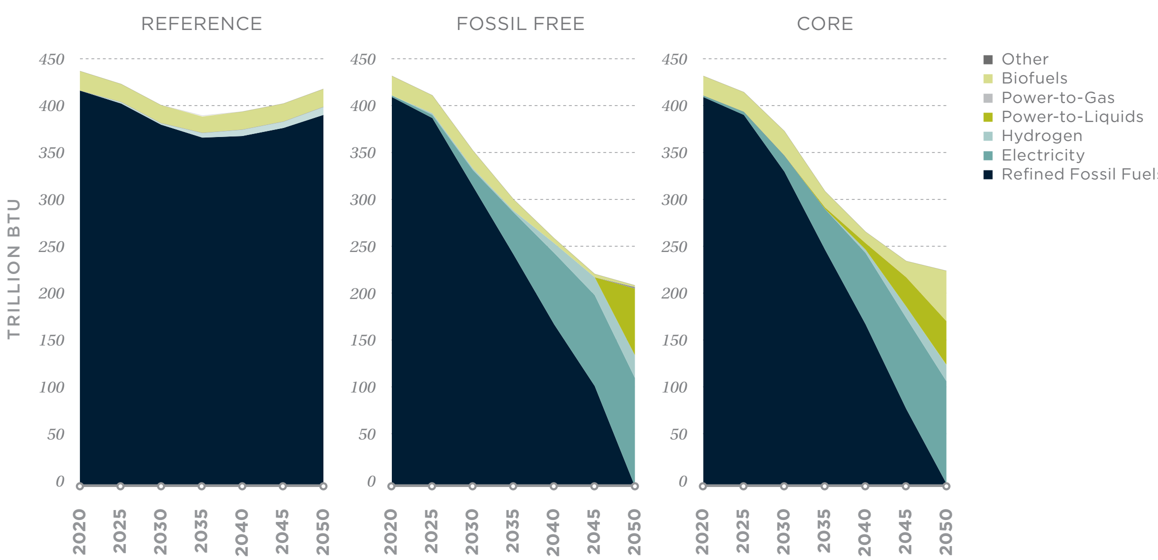
Electrification of the vehicle fleet accounts for a significant portion of the transportation sector transformation, but the sector also requires carbon-neutral fuels to meet the energy demand that will be difficult or impossible to electrify. Some medium- and heavy-duty trucking applications will likely remain difficult to meet with electric or hydrogen fuel cell vehicles, and some air travel is likely to remain impossible to directly electrify. Decarbonizing these transportation applications requires the buildout of infrastructure to produce and use carbon-neutral or low-carbon fuels.

Our analysis found that the state can decarbonize the remaining fossil fuel use with biofuels and synthetic fuels produced with green hydrogen, captured $CO_2$, and clean electricity. These synthetic fuels are called “power-to-gas” and “power-to-liquids.” In the Core scenario, the transportation sector decarbonizes mainly with electricity, hydrogen, and biofuels, only relying on a small amount of synthetic fuels. In the Fossil Free scenario, the available biomass sources are needed for other hard-to-decarbonize sectors (e.g. replacement feedstocks for petrochemical products) so the transportation sector requires a greater quantity of synthetic fuels. Notably, combustion of biofuels still produce harmful air pollution—especially particulate matter and nitrogen oxides—and should therefore be used sparingly, and emissions from biofuels should be minimized and mitigated near vulnerable populations. Figure 24 below shows the types of fuels used for transportation and the increasing portion of non-fossil fuels.

In our modeling, all biofuels are produced with sustainable biomass feedstocks. For the state to credibly reduce emissions using biofuels and avoid harm to ecosystems, policymakers must ensure that all biofuels are produced with biomass that is independently certified to the Roundtable on Sustainable Biomaterials (RSB) or equivalent standard.

**FIGURE 24.** TYPES OF FUEL USED FOR TRANSPORTATION IN THE REFERENCE, FOSSIL FREE, AND CORE CASES

*Transportation energy use, currently dominated by refined fossil fuels, must shift dramatically to meet the state’s climate goals. Electricity grows to become the largest energy source, and biofuels, synthetic fuels, and hydrogen fill in the rest. Synthetic fuels make up a greater share of fuel use in the Fossil Free scenario, in which the limited supply of sustainable biomass is needed for other hard-to-decarbonize sectors.*



**The transportation system must become much more efficient, especially with demand reduction investments.**

Investments to reduce transportation service demand can substantially affect the amount of clean energy production required to meet the climate goals. A decarbonized transportation sector would use significantly less energy than the present system, even as service demand (e.g. vehicle miles traveled) increases. As a result, the modeled 2050 transportation sector uses less than half the energy of today's system in the scenarios where the state meets its climate targets.

The demand reduction investments in the Low Demand scenario lead to even lower energy use, reducing the infrastructure necessary to produce electricity and synthetic fuels for transportation. In the Low Demand scenario, Coloradans rely more on public transit, walking, and biking and less on personal vehicles. As a result, it uses 64 percent less energy in 2050 than today's system.

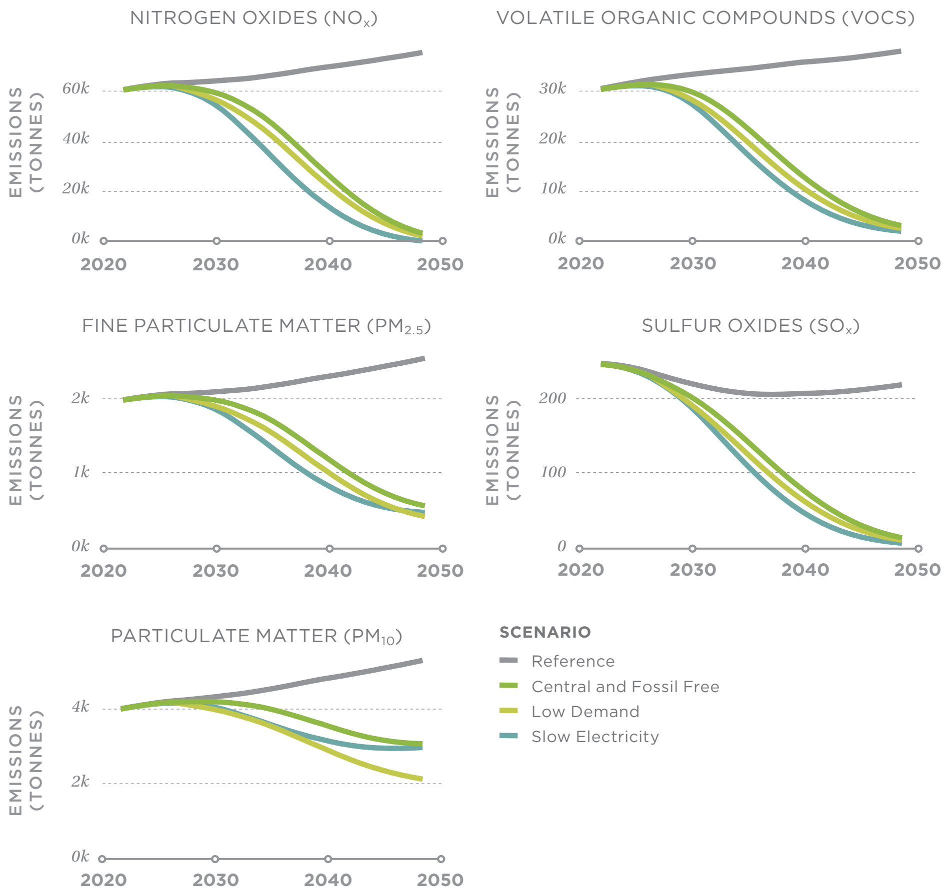
**Meeting the climate goals will cut harmful pollution, but the remaining pollution will still be inequitably distributed without targeted policies.**

In the Low Demand scenario, light-duty vehicle miles traveled is 7 percent lower than the Core scenario in 2030 and 35 percent lower in 2050. Heavy-duty vehicle miles traveled is 4 percent lower in 2030 and 20 percent lower in 2050. As a result, the Low Demand transportation system uses 33 percent less electricity and 25 percent less synthetic fuel than in the Core scenario in 2050.

The decarbonization scenarios all reduce health-damaging air pollution from the transportation sector. While the Reference case projects increases in pollution through 2050, the decarbonization scenarios show substantial cuts from the Reference case and a decline to near-zero emissions by 2050 for all pollutants except $PM_{10}$. Substantial $PM_{10}$ emissions remain from tire and brake wear from vehicle use. In the Core scenario, $PM_{2.5}$ emissions from vehicles decline by 1 percent from 2020 to 2030, ending up 7 percent lower than the Reference case in 2030. Similarly, $NO_x$ emissions decline by 3 percent from 2020 to 2030 and are 9 percent lower than the Reference case in 2030. $NO_x$ pollution declines most rapidly in the Slow Electricity scenario because of faster electrification, while PM10 drops fastest in the Low Demand scenario because of reduced miles travelled.

**FIGURE 25.** AIR POLLUTION FROM ON-ROAD VEHICLES IN ALL MODELED SCENARIOS

*Air pollution from on-road vehicles decline significantly in all scenarios compared to the Reference case. Unlike other pollutants, $PM_{10}$ emissions are not reduced to near-zero in 2050. Electric vehicles still produce $PM_{10}$ due to tire and brake wear, as well as the resuspension of dust and other particulate matter on road surfaces.*

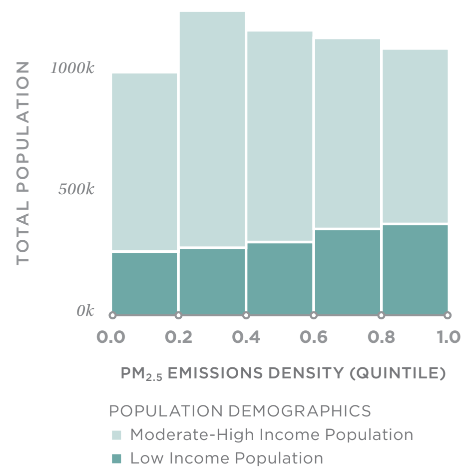



Pollution from the transportation sector is inequitably distributed, and these inequities are likely to remain in place even with reductions in total pollution. For example, $NO_x$ emissions from on-road vehicles across Colorado are higher in communities with a higher fraction of low-income people, people of color, and linguistically-isolated populations, as shown in Figure 26 below.

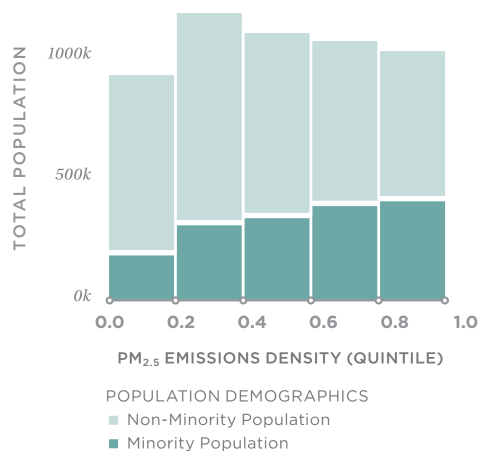
**FIGURE 26.** 2017 $PM_{2.5}$ EMISSIONS FROM TRANSPORTATION BY INCOME AND MINORITY PERCENTAGE

*These charts show the ranking of census tracts by $PM_{2.5}$ emissions from vehicles, alongside population and percentage of the population that are low-income or a racial minority. The bar on the far right represents the 20 percent of census tracts with the highest emissions, and the left-most bar represents the 20 percent with the lowest emissions. The darker teal portion of the bar represents the population that is either low-income or a racial minority. The dark teal portion is larger on the right-hand side of the charts, meaning transportation-related $PM_{2.5}$ emissions are more dense in census tracts with higher census-defined minority and low-income populations. This trend is true for all criteria air pollutants we analyzed ($NO_x$, $PM_{2.5}$, $PM_{10}$, CO) as well as VOCs (criteria air pollutant precursors).*

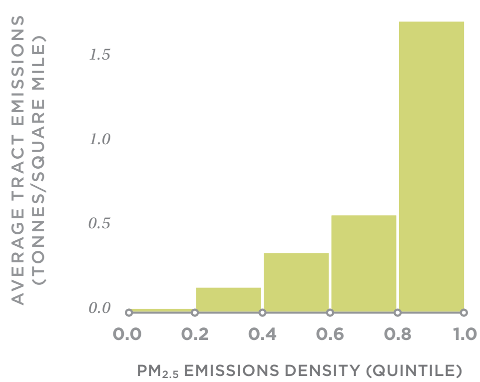
BASELINE $PM_{2.5}$ EMISSIONS DENSITY AND LOW INCOME POPULATIONS




BASELINE $PM_{2.5}$ EMISSIONS DENSITY AND MINORITY POPULATIONS




AVERAGE TRACT $PM_{2.5}$ EMISSIONS DENSITY



While the Core scenario reduces total statewide criteria air pollutant emissions compared to the Reference case and today's levels, emissions still increase in certain areas of the state from 2020 to 2030. Vehicle miles travelled increases in all scenarios except the Low Demand scenario, which will lead to increased pollution without sufficient adoption of zero-emission vehicles. Because heavy-duty and medium-duty trucks electrify more slowly than light-duty vehicles, $PM_{2.5}$ emissions increase from 2020 to 2030 in rural areas where heavy-duty and medium-duty trucks make up a larger fraction of vehicle miles traveled. Urban areas that are in close proximity to interstate highways also see an increase in $PM_{2.5}$ from 2020 to 2030 in the Core scenario, as depicted in Figures 27 and 28 below. Along these same interstate corridors, residual $NO_x$ and $PM_{2.5}$ emissions remain in 2050 in the Core scenario due to the use of biodiesel for medium- and heavy-duty vehicles.

As the communities living in close proximity to urban interstate highways tend to have a higher percentage of low-income households and people of color, the increase in criteria air pollutant emissions over this time period and residual emissions in 2050 mean that pollution will continue to disproportionately burden these communities without policies to specifically address this issue. Although the projected increase in pollutant emissions, lingering emissions levels, and associated inequities are worse in the Reference scenario than in the Core case, the results suggest that achieving the state climate targets alone will not ensure equitable outcomes or guarantee the elimination of harmful pollution for all Coloradans.

**FIGURE 27.** PERCENT CHANGE IN $PM_{2.5}$ EMISSIONS FROM ON-ROAD VEHICLES FROM 2020 TO 2030 IN CORE CASE

*Transportation-related $PM_{2.5}$ emissions increase in many rural areas from 2020 to 2030. This is largely due to medium and heavy-duty trucks, which electrify at slower rates than light-duty vehicles while vehicle use increases. Some areas that experience increases, especially in eastern Colorado, have high socioeconomic vulnerability, as shown by high scores on the Demographic Index. The increases in emissions are smaller than those in the Reference case. Data Sources: FHWA 2018 Highway Performance Monitoring System, EPA MOVES 2014a, Argonne National Laboratory 2019 AFLEET Tool, U.S. Census Bureau American Community Survey (ACS) 2014-2018 5-Year Estimates.*

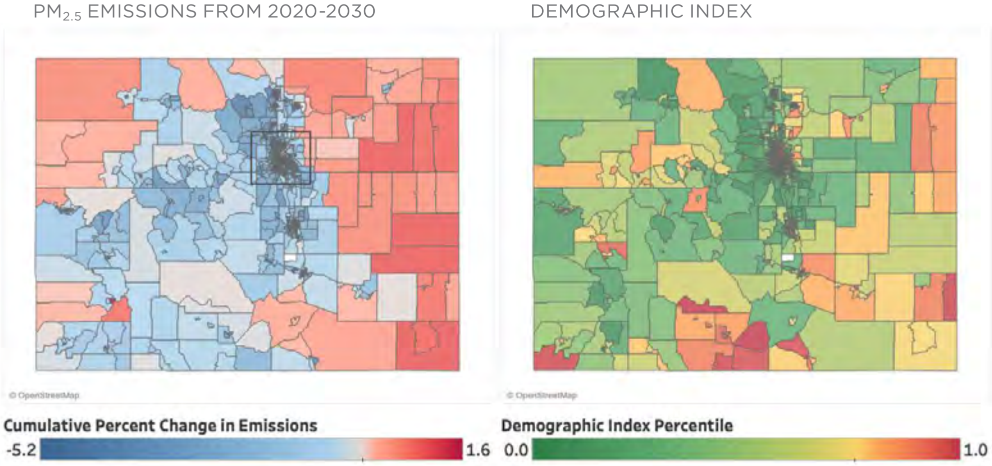
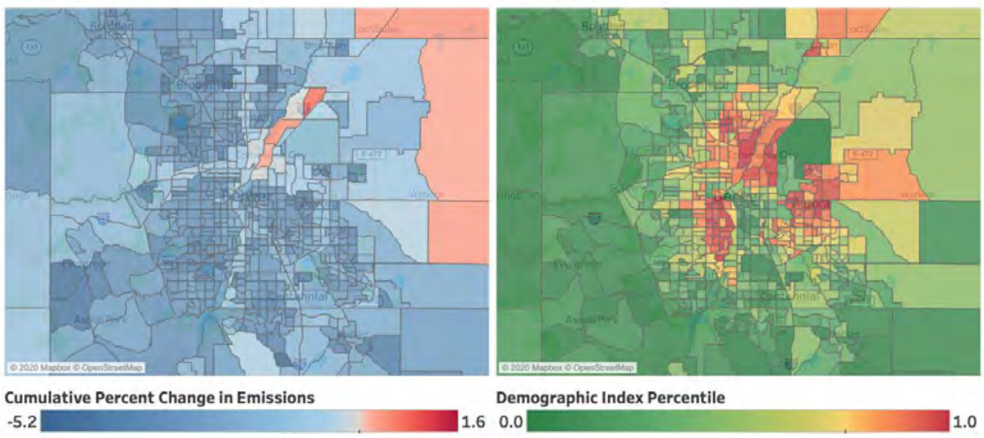


**FIGURE 28.** PERCENTAGE CHANGE IN $PM_{2.5}$ EMISSIONS FROM ON-ROAD VEHICLES IN CORE CASE IN THE DENVER METRO REGION

*Transportation-related $PM_{2.5}$ emissions increase in some areas on the outskirts of Denver between 2020 and 2030, as well as in several urban areas near interstate highways, areas that have higher-than-median populations of color and are also near highly polluting industrial point sources. The increases shown here for the Core scenario are smaller than those in the Reference case. Data Sources: FHWA 2018 HPMS, EPA MOVES 2014a, Argonne National Laboratory 2019 AFLEET Tool, U.S. Census Bureau American Community Survey (ACS) 2014-2018 5-Year Estimates.*

$PM_{2.5}$ EMISSIONS FROM 2020-2030

DEMOGRAPHIC INDEX




In the Low Demand scenario, criteria air pollutant emissions from vehicles decline in all regions of the state from 2020 to 2030, due to investment in public transit and other measures that reduce vehicle miles traveled across vehicle classes. In this scenario, as in the other decarbonization scenarios, pollution from biodiesel-powered trucks persists in 2050, albeit at a lower level than in the Core scenario.

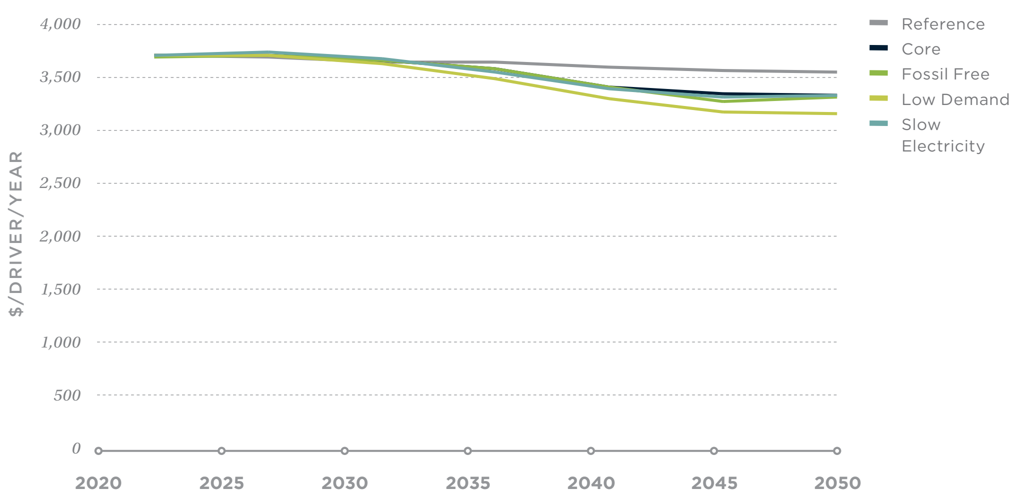
Prioritizing investment in electric charging infrastructure along urban interstate highway corridors, rerouting heavy-duty and medium-duty trucks to less populated areas, electrifying heavy-duty trucks and equipment serving warehouses and industrial sites, replacing some heavy-duty freight with rail, and incorporating certain measures from the Low Demand scenario could help to address equity issues associated with the increase in $PM_{2.5}$ emissions from 2020 to 2030 in the Core scenario.

The average Coloradan would spend less money on transportation in a decarbonized world, but policies are needed to ensure the economic benefits are more equitably distributed.

Colorado can decarbonize the transportation sector while cutting personal transportation costs for the average driver. As seen in Figure 29 below, in the scenarios where the state meets its climate goals, the per capita cost of personal travel declines 1 to 2 percent by 2030 and 10 to 16 percent by 2050. This includes all personal energy and vehicle costs as well as the energy costs for passenger rail and aviation (a much smaller component of costs). Transportation costs remain very close to the Reference case through 2030 and then 6 to 12 percent below the Reference case by 2050. The cost reductions come primarily from reduced fuel use, because the per-mile cost to power an electric vehicle is lower than the per-mile cost to power an internal combustion engine vehicle.

**FIGURE 29.** ANNUAL AVERAGE PERSONAL TRANSPORTATION COSTS IN ALL MODELED SCENARIOS

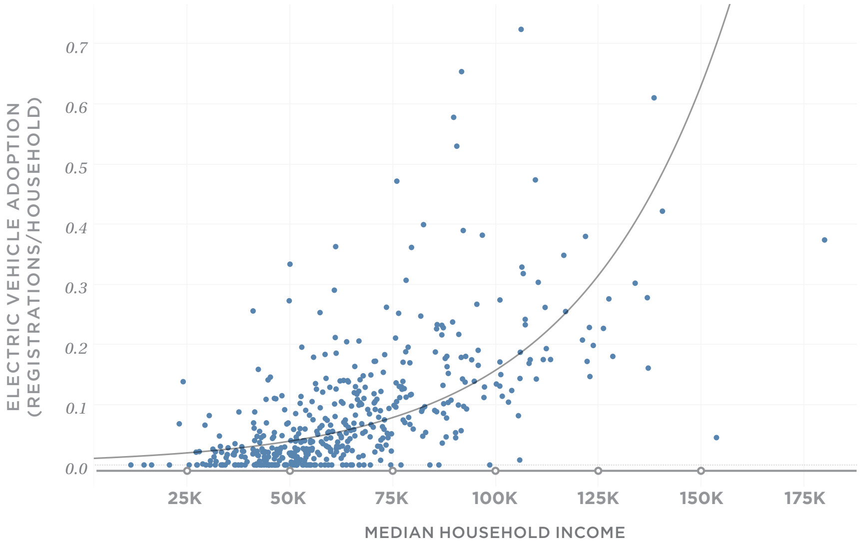
*Transportation costs do not change significantly through 2035, after which costs decline in the decarbonization cases, ending up 6 to 12 percent lower than the Reference case by 2050.*




While the reduction in average transportation costs is promising, these cost numbers do not represent the variation in costs between households, and do not convey the cost burden that these expenditures represent for households of different income levels. Access to these cost savings requires drivers to be able to purchase an electric vehicle and have access to vehicle charging. Figure 30 below shows the Colorado electric vehicle adoption rate by zip code median household income. The current distribution of EV registrations in Colorado suggests that, in the absence of additional government policies, EV adoption will likely continue to occur faster among higher-income households and low-and moderate-income households will be less likely to buy an EV in the near term, which could deepen the inequitable distribution of the savings from EVs.

**FIGURE 30.** COLORADO ELECTRIC VEHICLE ADOPTION BY MEDIAN HOUSEHOLD INCOME OF ZIP CODE

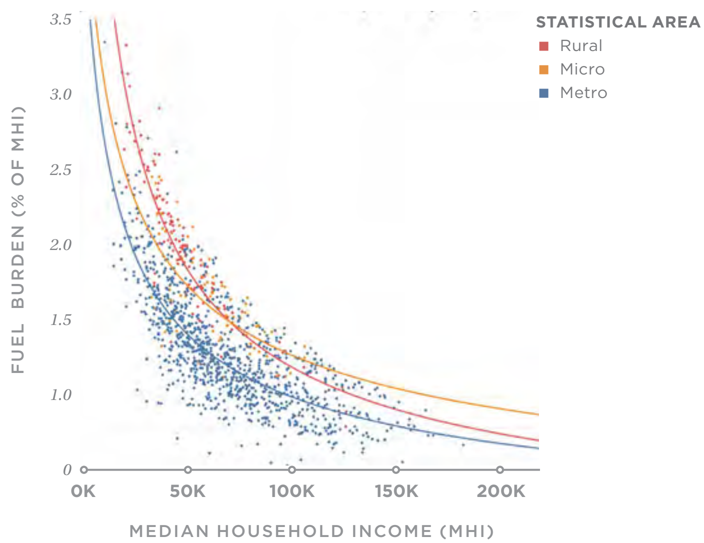
*Zip codes with higher median household incomes have higher rates of electric vehicle adoption (EV registrations per household). Data sources: Colorado Energy Office (CEO) 2020 EV Registrations, U.S. Census Bureau American Community Survey (ACS) 2014-2018 5-Year Estimates.*




Even if EVs are adopted equitably across households, lower-income households will spend a greater fraction of their annual income on transportation fuel costs in each of the scenarios, much as they currently do today. Figure 31 below illustrates this by showing how on average, the percentage of household income that is spent on transportation fuel from weekday travel increases exponentially as household income declines.

**FIGURE 31.** ENERGY BURDEN FROM TRANSPORTATION COSTS IN 2017

*The percentage of household income that is spent on transportation fuel from weekday travel increases exponentially as household income declines, on average. Each dot represents a census tract. Fuel burden is based on average weekday travel by census tract, average fuel economy and fuel costs, and median household income by census tract.*




Given that higher-income households typically have more access to and greater rates of ownership of cars than lower-income households, many low-income households would especially benefit from policies which support the build-out of public transit and walkable communities. In addition, policy measures that incentivize electrification by penalizing people that continue to use gasoline vehicles can exacerbate the differences in energy burdens between households that can afford EVs and those that cannot.

## BUILDINGS

Colorado must create a highly electric and efficient building sector to meet its climate goals. Doing so requires shifting from fossil fuels to clean electricity to heat our homes and offices, ensuring that new buildings are made with highly efficient shells, increasing adoption of efficient appliances, and upgrading the existing building stock. Colorado's residential building stock is expected to expand considerably in the coming years, so policies and technologies must address both new and existing buildings. Making the required changes to the state's building sector will also cut health-damaging pollutants, though additional planning and policies are needed to ensure that all Coloradans, including those who rent or live in mobile homes, can afford and access building upgrades. While these changes to the building sector can be accomplished without significantly increasing total costs, the high energy burden that many Coloradans face will persist without targeted policies to address these inequities.

**Emissions from buildings must drop 10 to 33 percent by 2030 and sharply decline to zero by 2050.**

In our modeling, Colorado's buildings sector contributes modest emissions reductions to meet the 2025 and 2030 climate goals and much deeper reductions to meet the 2050 target. Building sector emissions are expected to increase absent new policy, so the state must reverse this trend if it is to meet its climate goals. Our Core scenario shows that emissions from the buildings sector must decrease by 10 to 13 percent from 2005 levels by 2030 to meet the near term climate goals, assuming that the power sector decarbonizes quickly. If the power sector moves more slowly, as in the Slow Electricity scenario, then emissions from buildings must decline much more rapidly, achieving a 9 percent reduction by 2025 and a 33 percent reduction by 2030, compared to 2005 levels. Figures 32 and 33 outline $CO_2$ emission reductions from residential and commercial buildings respectively and highlight the gap between the Core scenario and Slow Electricity scenarios.

**FIGURE 32.** $CO_2$ EMISSIONS FROM RESIDENTIAL BUILDINGS IN ALL MODELED SCENARIOS

*$CO_2$ emissions from homes are expected to rise absent new policy. In the decarbonization scenarios, this trend reverses and residential buildings achieve modest reductions by 2030 and deep reductions by 2050. The Slow Electricity scenario requires much more rapid decarbonization by 2030.*

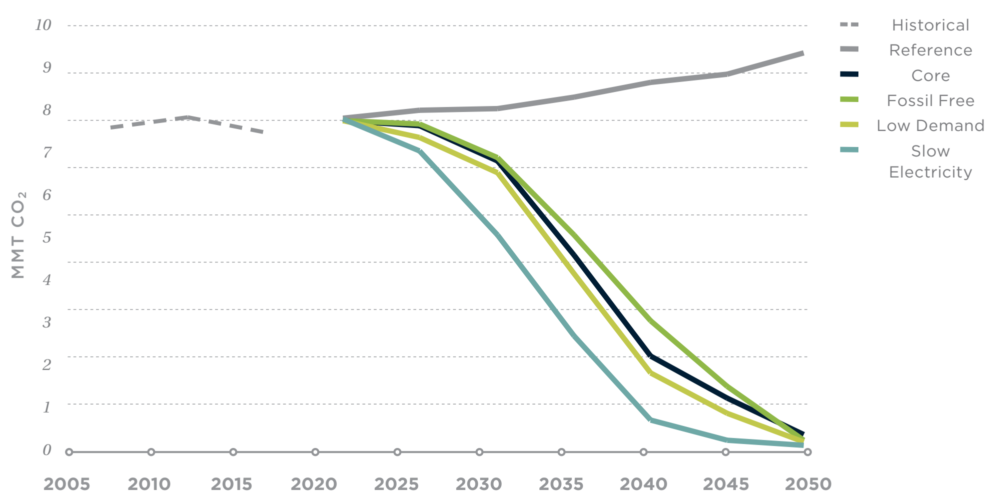
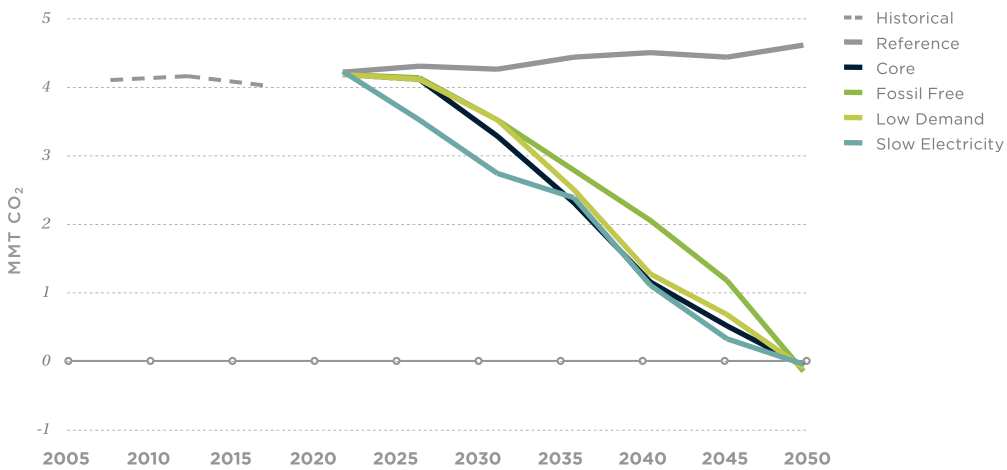


**FIGURE 33.** $CO_2$ EMISSIONS FROM COMMERCIAL BUILDINGS IN ALL MODELED SCENARIOS

*In the decarbonization scenarios, the commercial building sector achieves modest $CO_2$ emission reductions by 2030 and deep reductions by 2050. The Slow Electricity scenario requires much more rapid decarbonization by 2030.*




**Meeting the climate goals requires replacing fossil-fuel-fired heating and cooking systems with highly efficient electric appliances.**

Electrification is a key strategy to decarbonize Colorado's building sector. While today's building stock relies significantly on direct use of gas, wood, and heating oil, building energy use must shift almost entirely to electricity by 2050. Getting there requires dramatically increased adoption of electric heat pumps for space and water heating and electric ranges for cooking.

Adoption of electric appliances must grow rapidly to meet the near-term targets and ensure that the building stock fully transforms in time to meet the 2050 requirement. Figure 34 below showcases the percentage of new residential and commercial appliances that are electric in the Core, Slow Electricity, and Reference Cases. In the Core scenario, we see electric space heaters in residential buildings must make up 49 percent of new sales by 2030 and 95 percent by 2040 to meet the state's targets. Residential water heaters must follow a similar trajectory, with electric appliances making up 47 percent of new sales by 2030 and 99 percent by 2040. These adoption curves for the Core scenario require only addressing new appliances and appliances to replace burned-out old appliances—this scenario does not require retiring existing appliances earlier than planned. However, if adoption does not ramp up quickly, meeting the climate goals will require early retirement of appliances that have not exceeded their useful life.

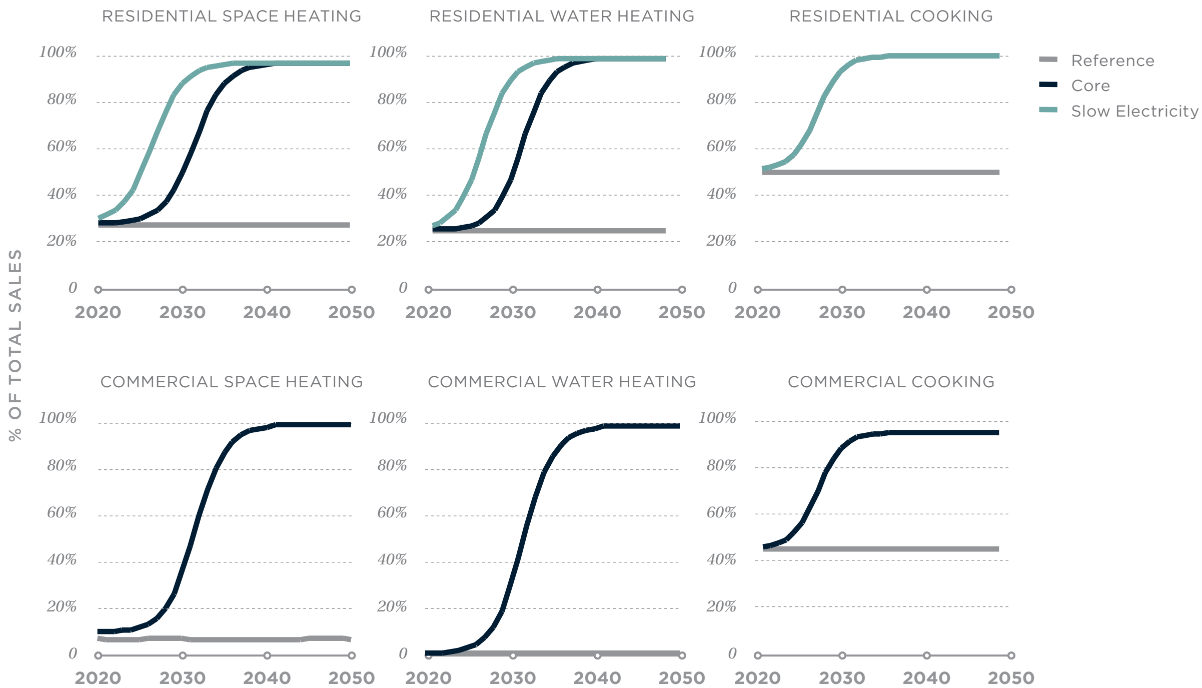
**This level of electrification is the equivalent of requiring *all* new homes to be all electric by 2031 and then replacing 2 to 3 percent of non-electric space heaters and 4 to 5 percent of non-electric water heaters with electric heat pumps in existing homes each year through 2040.** Note that these numbers represent only one way to get to emissions reductions necessary from the buildings sector; for example, an alternative would be to accelerate retrofits of existing buildings prior to 2030, which would likely be more costly, but in which case fewer new homes would need to be all-electric.

Figure 34 also shows that the Slow Electricity scenario requires the same pace, but starts sooner in the space and water heating market to make up for the lower reductions in the electricity sector. In the Slow Electricity scenario, electric appliances must make up 87 percent of new sales by 2030 for space heating and 90 percent for water heating. That's the equivalent of ensuring that all new homes have electric space and water heating by 2026 and thereafter replacing 2 to 3 percent of non-electric space heaters and 4 to 5 percent of non-electric water heaters with electric ones each year. We assumed that residential buildings, rather than commercial ones, help make up for reduced emissions from the power sector because residential emissions are significantly greater and therefore have greater potential for reductions.

Commercial buildings must follow a similar trajectory. By 2025, 12 percent of new commercial space heater sales, 4 percent of new commercial water heater sales, and 58 percent of new commercial stove sales must be electric. By 2030, 36 percent of space heater sales, 30 percent of water heater sales, and 91 percent of stove sales are electric in all scenarios in which the state meets its climate goals. By comparison, about 6 percent of commercial space heater sales, 2 percent of commercial water heater sales, and 46 percent of commercial stove sales are electric today.

**FIGURE 34.** PERCENTAGE OF NEW RESIDENTIAL AND COMMERCIAL APPLIANCES THAT ARE ELECTRIC IN THE CORE, SLOW ELECTRICITY, AND REFERENCE CASES

*Adoption of electric heat pumps must accelerate dramatically over the next 10 to 15 years for the state to meet its climate goals. In the Slow Electricity case, the adoption curve is even steeper to enable deeper cuts to emissions by 2030.*

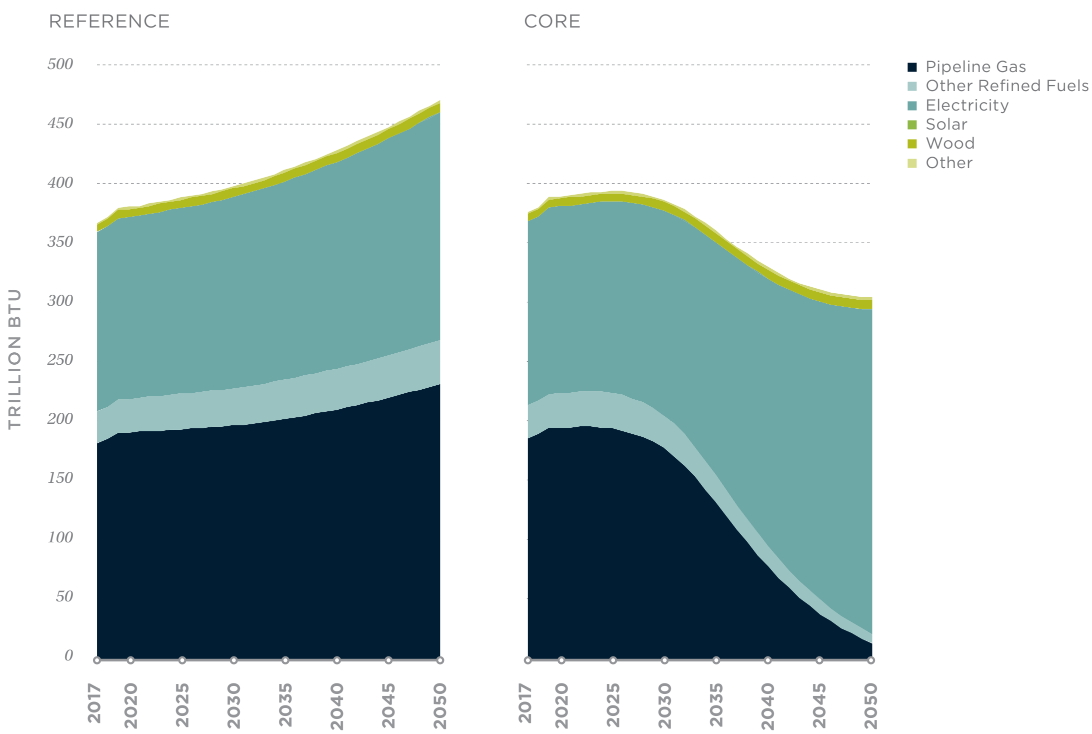



As a result of these shifts, electricity must meet a growing share of building energy demand, while fossil fuel use in buildings declines. Figure 35 shows that by 2050, only a small amount of fossil fuel and wood use remains in the Core scenario compared to the Reference scenario. The total building energy use also declines, as a result of the energy efficiency measures described below and the fact that efficient electric appliances use much less energy to provide the same services.

In our decarbonization scenarios, Colorado takes advantage of flexibility in operation of these newly electrified loads to help reliably meet load in a deeply decarbonized electricity system. In the Core, Slow Electricity, and Fossil Free scenarios, we assume that 50 percent of residential space heating and air conditioning load can shift one hour forward or backward and 50 percent of water heating load can shift two hours forward or backward. We also assume 50 percent of commercial space heating load can shift one hour forward or backward. That means, for example, that 50 percent of the electricity required to cool Colorado homes in the summer can shift a few hours earlier in the day to soak up the extra solar generation during that time period and reduce demand in the evening. The Low Demand scenario maximizes load flexibility from buildings, allowing 100 percent of space and water heating to shift. Enabling this load flexibility requires policy solutions to incentivize energy use to improve grid operation.

**FIGURE 35.** FUEL TYPES USED TO MEET BUILDING ENERGY DEMAND IN THE CORE AND REFERENCE CASES

*In the Core scenario, electricity grows to provide the vast majority of building energy use, a marked shift from the current system, which relies significantly on fossil gas. Total energy use declines significantly because of efficiency measures and the greater efficiency of electric appliances.*

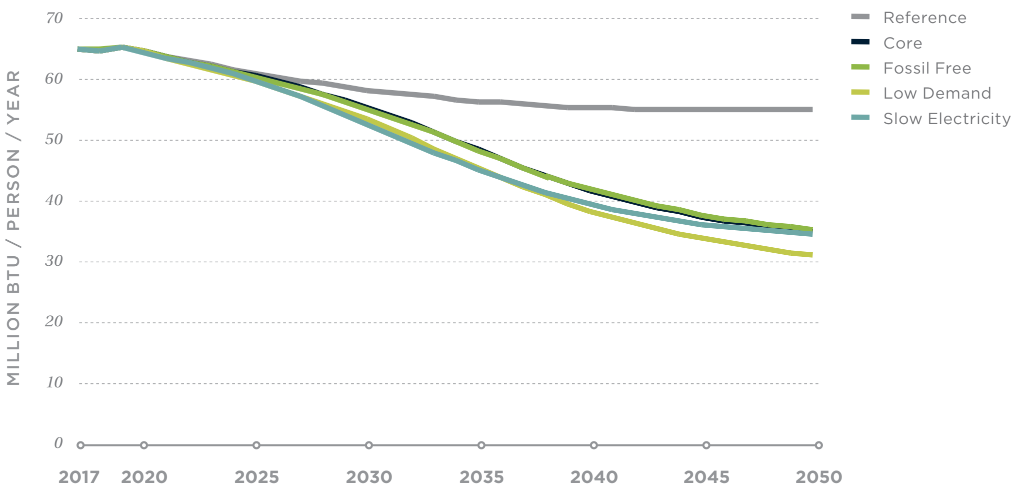



**The state must ensure that new buildings are efficient and existing buildings are upgraded.**

Making the building stock more efficient is critical to meet the state's climate goals. Figure 36 shows that building energy use is 5 percent lower in the Core scenario than in the Reference case in 2030 and 37 percent lower in 2050, thanks to energy efficiency measures. In the Low Demand scenario, the savings are even greater: 9 percent lower than in the Reference case in 2030 and 44 percent lower in 2050. These savings reduce the amount of new clean energy and new electricity distribution infrastructure that is necessary to meet the climate goals. Moreover, they create healthier, safer, and more comfortable buildings for all Coloradans, when complementary equitable policies are put in place.

**FIGURE 36.** AVERAGE PER-CAPITA ENERGY USE FROM BUILDINGS IN ALL MODELED SCENARIOS

*Per-capita energy use declines from today's levels and from the Reference case in all decarbonization scenarios, thanks to efficiency measures.*

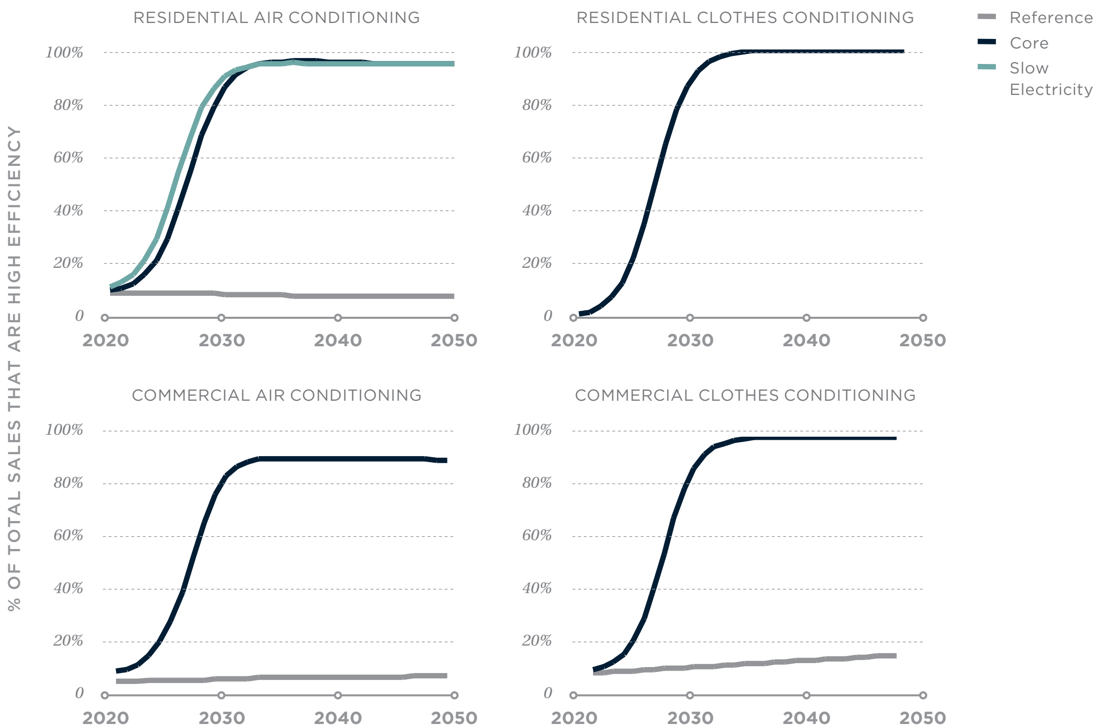



The building energy savings come from three major categories: 1) adoption of highly efficient appliances, 2) ensuring that new buildings have highly efficient envelopes, and 3) upgrading existing buildings to minimize energy losses.

As discussed in the previous section, the market for space heating, water heating, and cooking appliances needs to move rapidly toward highly efficient, electric options. For other energy-using appliances—such as air conditioning, refrigeration, and clothes washers and dryers—the existing stock is already mostly electric. For these appliances, the core strategy is to transform the market such that highly efficient (and electric) options are the norm and eventually take up the whole market. High efficiency technology does not currently have high deployment in the marketplace, but Figure 37 below shows that in order to meet Colorado's climate goals, adoption of high efficiency appliances must grow to more than 80 percent of new sales by 2030.

**FIGURE 37.** PERCENTAGE OF NEW RESIDENTIAL AND COMMERCIAL APPLIANCE THAT ARE HIGH EFFICIENCY IN THE CORE, SLOW ELECTRICITY, AND REFERENCE CASES

*Adoption of energy efficient appliances must rise dramatically in the next ten years for the state to meet its climate goals.*




In addition to replacing the appliance stock with efficient, electric equipment, Colorado must also ensure that new buildings have highly efficient envelopes. Colorado's residential building stock is expected to grow 16 percent by 2030 and 45 percent by 2050, based on projections from the 2019 Annual Energy Outlook from the U.S. Department of Energy. High construction rates make the new construction opportunity a must win in Colorado and ensuring new homes are highly efficient will curb the added energy demand from building growth.

Retrofitting existing buildings to improve building envelope efficiency is also part of the solution. These retrofits should include a package of upgrades[8] to make the whole building more efficient, such as improved insulation, air sealing, windows and doors, and air ducts. In the Core scenario, Colorado retrofits 28,000 homes per year in the mid 2020s, 51,000 homes per year in 2030, and about 70,000 homes every year through 2050. That is equal to upgrading 1 to 2 percent of existing homes per year in the 2020s and 2 to 2.5 percent per year in the 2030s and 2040s.

The Low Demand scenario includes an even larger retrofit program to upgrade all existing buildings by 2050. Doing so requires a retrofit rate of 67,000 homes

8 The upgrades described here are designed for a Maine context, but the specifications are applicable to Colorado, as well.

per year through the early 2030s, 120,000 homes per year through 2040, and 140,000 every year in the 2040s. That represents 2.7 percent of homes per year in the 2020s, a little more than 4 percent per year in the 2030s, and 4.5 percent per year in the 2040s. Figures 38 and 39 illustrate the scale of residential building upgrades required in the Core and Low Demand scenarios.

**FIGURE 38.** TOTAL NUMBER OF RESIDENTIAL BUILDINGS WITH ENERGY EFFICIENT BUILDING SHELLS

*In the Core scenario, a substantial portion of the building stock has energy efficient building shells by 2050, driven both by adoption of efficient shells for new buildings and retrofits of existing buildings. The Low Demand scenario includes a more significant retrofit program to upgrade every residential building with an efficient shell by 2050.*

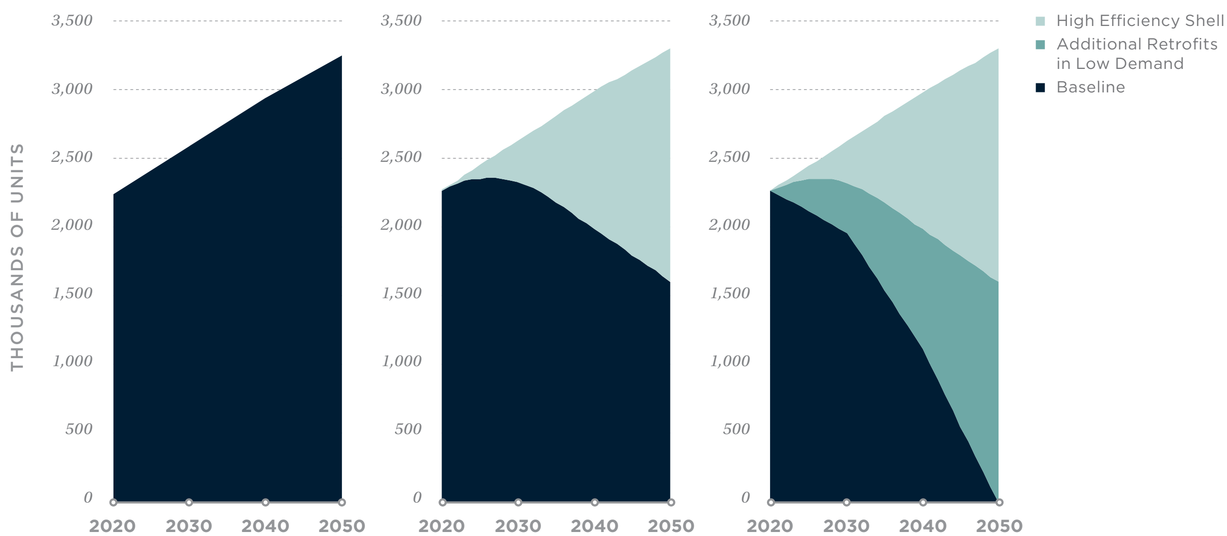
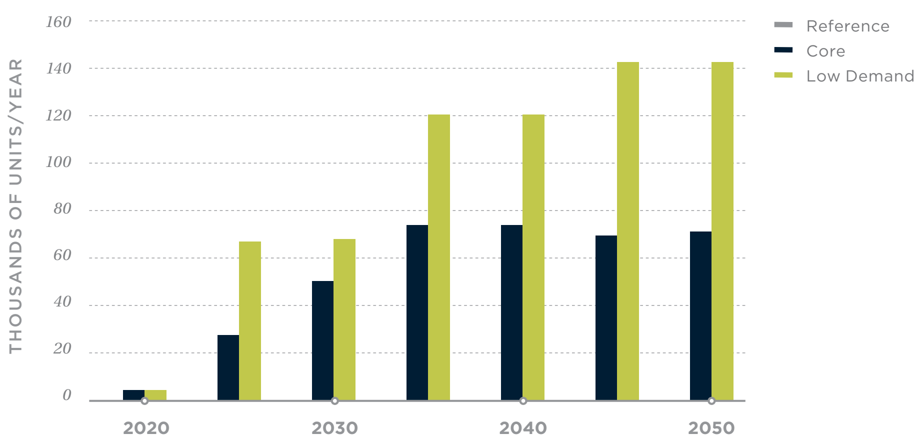



**FIGURE 39.** ANNUAL NUMBER OF RESIDENTIAL BUILDING RETROFITS

*The Core scenario (and the other decarbonization scenarios) requires a significant retrofit program for residential buildings. The Low Demand scenario includes a much larger retrofit program, especially in the 2030s and 2040s.*

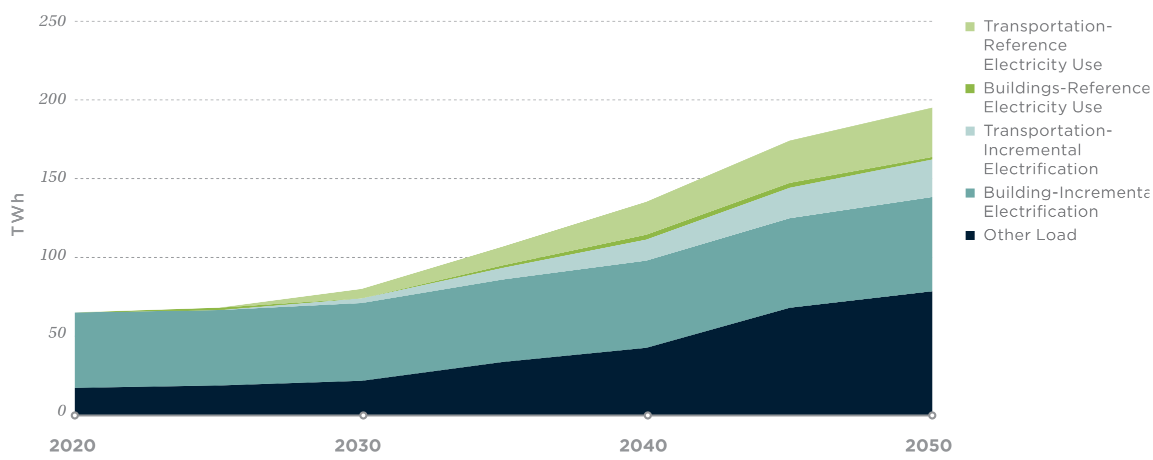


**Incremental building electrification adds 2 TWh (3 percent of total load) to the electricity system by 2030 and 24 TWh (12 percent of total load) by 2050, but efficiency measures reduce the impact.**

Electrifying buildings at the rate required to meet the state climate goals contributes to growth in electricity demand. In the Core scenario, building electricity use grows by 5 TWh from today's levels by 2030, with 2 of those TWh coming from additional electrification beyond business-as-usual. That represents a 10 percent increase from today's electricity use in buildings. Figure 40 shows that by 2050, building electricity demand grows to 84 TWh, a 74 percent increase from today's levels.

**FIGURE 40.** INCREMENTAL LOAD FROM BUILDING AND TRANSPORTATION ELECTRIFICATION IN THE CORE CASE

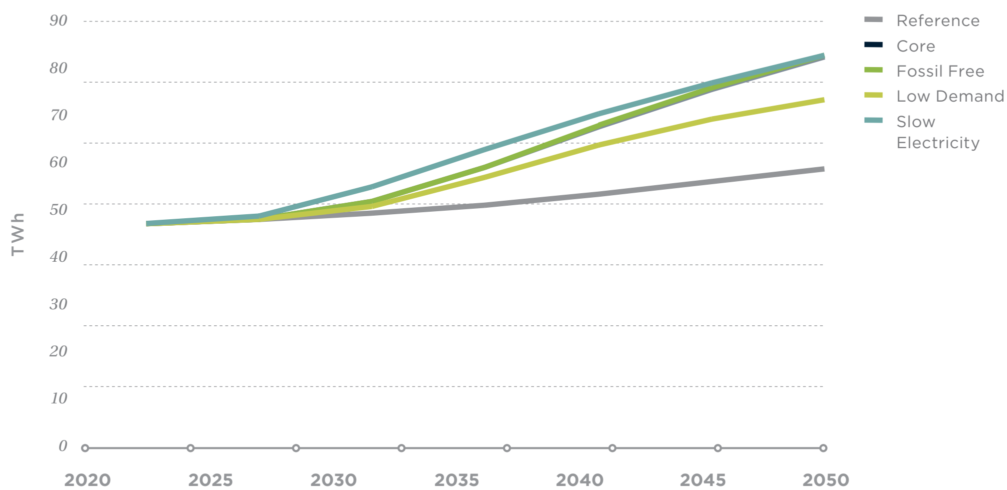
*Buildings represent the vast majority of electricity demand today. In the Core scenario, building electricity demand grows as more buildings electrify. Electricity demand for the transportation and industrial sectors also grows considerably, so that buildings make up a much smaller share of load in 2050.*




Additional investment in energy efficiency can reduce growth in electricity demand. Figure 41 showcases that the Low Demand scenario results in 20 percent less electricity growth than in the Core scenario by 2030 and 25 percent less by 2050.

**FIGURE 41.** INCREMENTAL LOAD FROM BUILDING ELECTRIFICATION IN ALL MODELED SCENARIOS

*All decarbonization scenarios result in increases to electricity load from incremental electrification. Demand reduction measures in the Low Demand scenario reduce the quantity of added load.*




**While overall pollution will decrease if the state achieves its climate goals, dangerous pollution from biomass will persist unless specifically addressed.**

Burning fossil fuels and biomass in homes produces health-harming pollutants. Decarbonizing buildings through efficiency and electrification will significantly cut pollution, but some pollution will remain without specific policies to address it.

The major pollutants from home energy use are $PM_{2.5}$ and $NO_x$. Buildings are a major source of PM2.5 pollution, exceeding $PM_{2.5}$ emissions from power plants and vehicles in Colorado. Residential $PM_{2.5}$ emissions are most substantial in rural areas (largely due to biomass burning), especially where wood is burned for home heating. About 40,000 households in Colorado currently use wood as a primary heat source. A fraction of $PM_{2.5}$ emitted from wood burning may remain indoors, posing a significant health hazard to Colorado residents that use wood for heating, primarily in rural areas

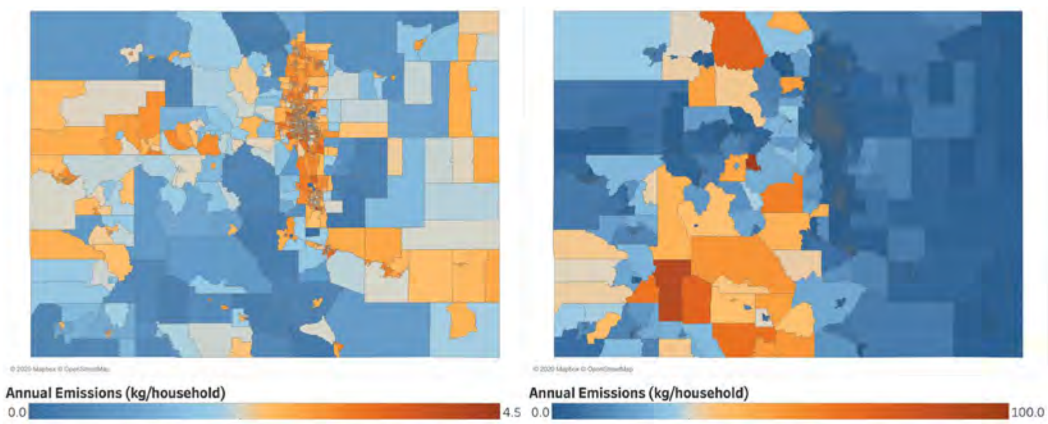
Buildings are a smaller but still significant source of $NO_x$ pollution. Residential $NO_x$ emissions are highest in urban areas (largely due to natural gas use). Though $NO_x$ emissions from transportation, power plants, and industrial facilities are much greater than those from buildings, some residential $NO_x$ emissions are indoors and have a greater direct impact on human health. Figure 42 shows the distribution of $PM_{2.5}$ and $NO_x$ emissions across the state.

**FIGURE 42.** $NO_x$ FROM RESIDENTIAL GAS COMBUSTION AND $PM_{2.5}$ EMISSIONS FROM BIOMASS COMBUSTION

*$NO_x$ emissions from gas use are highest in urban areas, though some rural areas also have high levels of $NO_x$ pollution.*

RESIDENTIAL $NO_x$ EMISSIONS FROM NATURAL GAS (2017 BASELINE)

RESIDENTIAL $PM_{2.5}$ EMISSIONS FROM BIOMASS (2017 BASELINE)

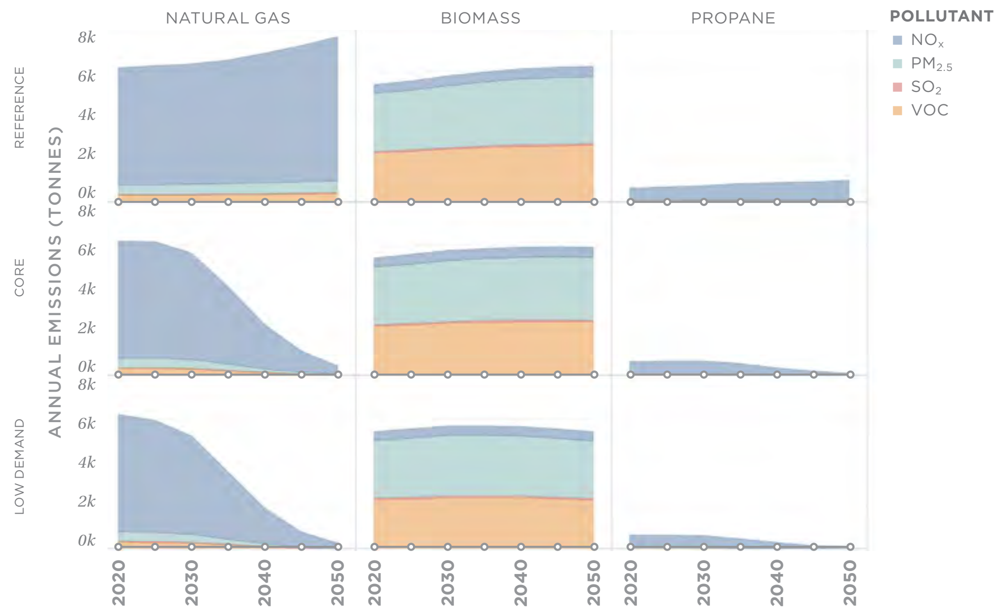



The Core and Low Demand scenarios significantly cut $NO_x$ pollution compared to today's levels and the Reference case. However, these scenarios do not reduce the high levels of $PM_{2.5}$ and VOC pollution from continued use of wood for space heating, as shown in Figure 43. Our modeling assumes no changes to wood burning. Reducing the use of wood for home heating—such as by switching to electric heat pumps and investing in more efficient building shells—would reduce particulate matter emissions and improve health outcomes.

Efficiency is also key to reducing fuel use and GHG emissions, but efficiency upgrades that seal buildings without proper ventilation can exacerbate health impacts, so it is important to couple efficiency measures with proper ventilation. Electrification reduces these dangerous emissions and thereby improves indoor and outdoor air quality and health outcomes. Efficiency can also help maintain comfortable indoor temperatures and protect vulnerable populations from both cold snaps and heat waves.

**FIGURE 43.** AIR POLLUTANT EMISSIONS BY FUEL TYPE FROM RESIDENTIAL SOURCES

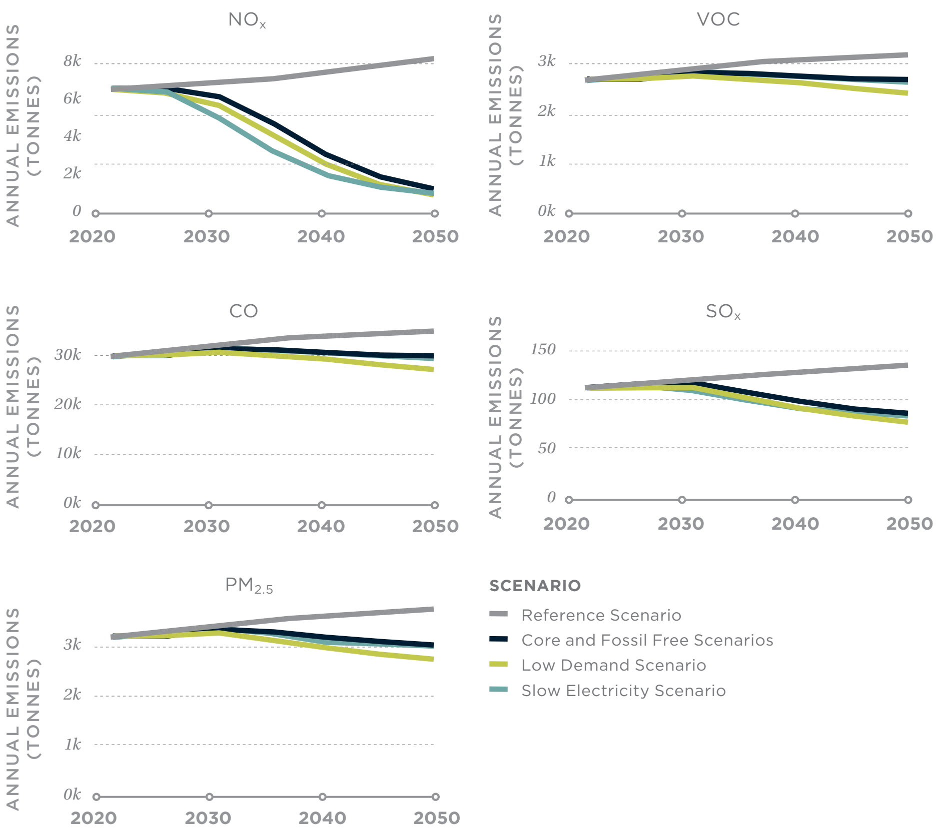
*Total pollution increases in the Reference scenario. In the Core and Low Demand scenarios, $NO_x$ pollution declines significantly due to reduced gas use, but $PM_{2.5}$ and VOC pollution remains high because of continued use of biomass as a primary home heat source for many households.*




The decarbonization scenarios also cut other harmful pollutants (including carbon monoxide and sulfur dioxide) from buildings, though the greatest reductions are to $NO_x$ pollution. Figure 44 shows $NO_x$ emissions decreasing substantially compared to the Reference scenario but emissions of other pollutants decreasing only slightly due to the continued use of biomass (e.g., wood) in residential heating.

**FIGURE 44.** AIR POLLUTION FROM RESIDENTIAL SOURCES IN ALL MODELED SCENARIOS

*Air pollution emissions of all categories decline in all decarbonization scenarios compared to the Reference case.*

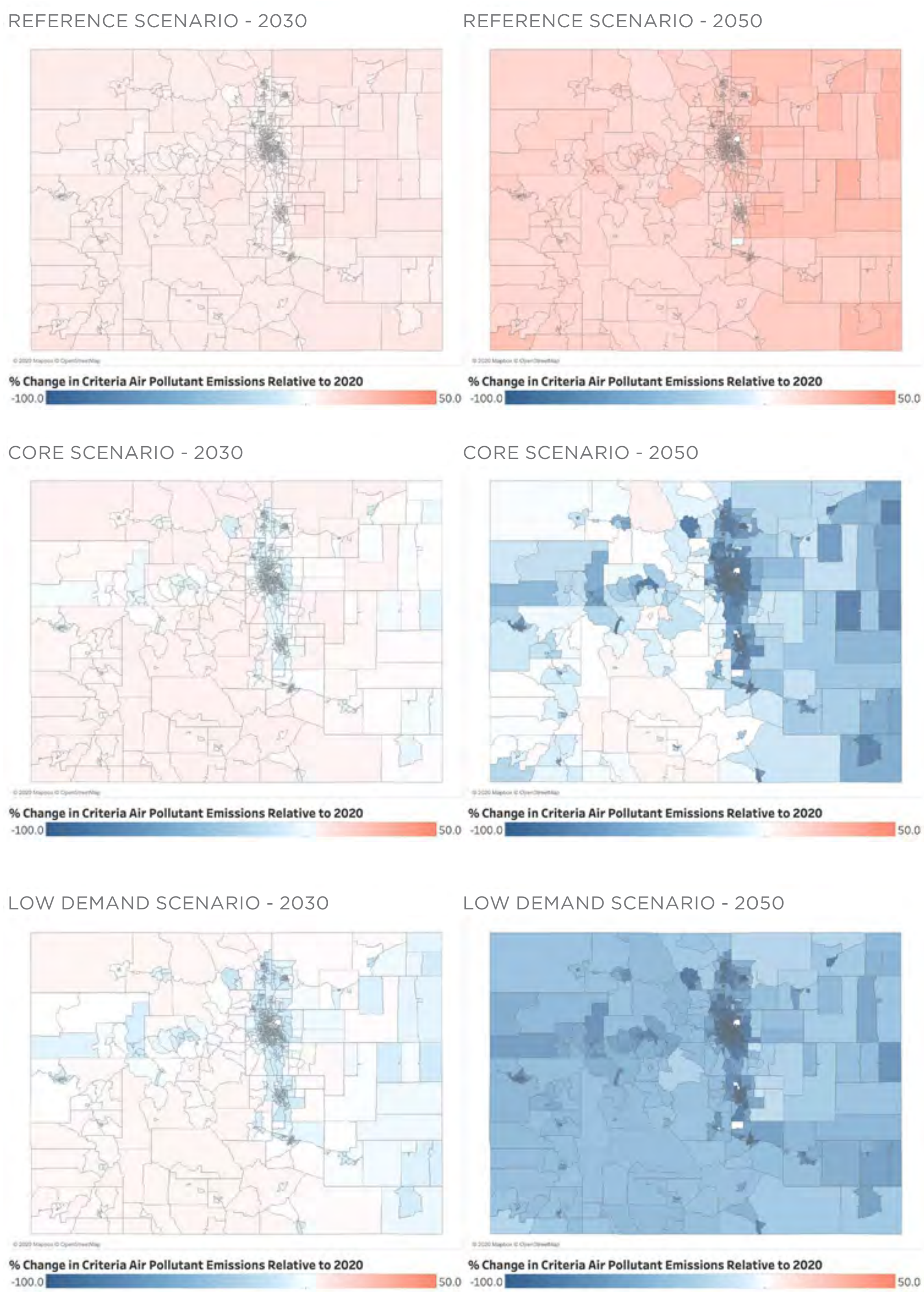



**Decarbonization will reduce total pollution from residential buildings, but some communities will still experience pollution increases without targeted policies to ensure reductions.**

Residential pollution will grow across Colorado if the state continues business-as-usual. In the Reference case, air pollution increases in all parts of Colorado through 2050. The Core scenario reverses this trend and reduces statewide pollution, but some communities still experience increases in pollutant emissions from present levels through 2030. Residential pollution also increases in some rural communities through 2050 due to continued use of wood for heating. The Low Demand scenario avoids these increases and ensures emissions reductions across the state through additional measures to reduce fuel use. In the Low Demand case, emissions increase through 2030 for some rural areas but then drop below current levels by 2050 across the state. Figure 45 shows these trends.

**FIGURE 45.** PERCENTAGE CHANGE RELATIVE TO 2020 LEVELS IN RESIDENTIAL $NO_X$, $PM_{2.5}$, $SO_2$, AND VOC EMISSIONS (CRITERIA POLLUTANTS)

*Air pollutant emissions from residential buildings increase across the state in the Reference case. Air pollutant emissions increase from present levels for some rural communities, even with the decarbonization measures in the Core scenario. The Low Demand scenario ensures a reduction in pollutant emissions from present levels for all census tracts by 2050.*



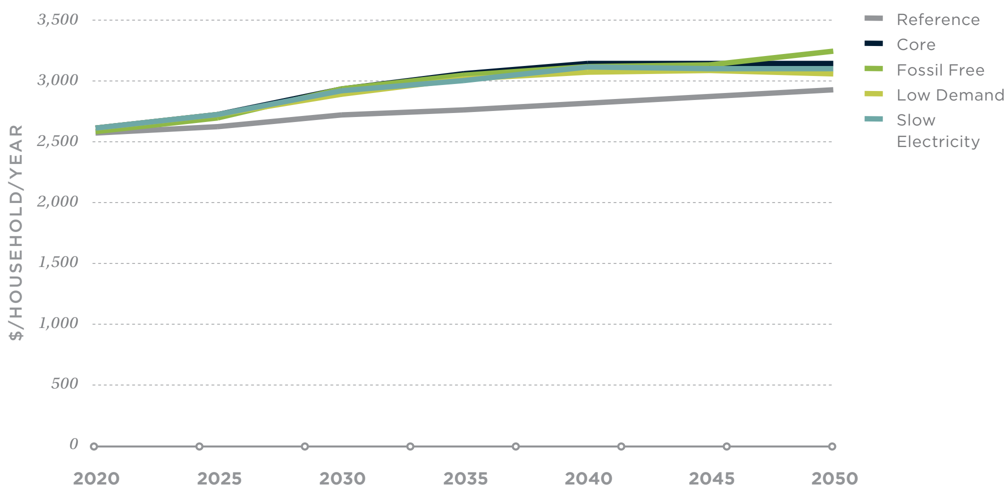
**The state can meet its emissions targets with only slight increases in home energy costs. Targeted policies will be needed to address disparities in energy burdens.**

The decarbonization cases result in slight increases in building energy costs for Coloradan households. Even though the increases are small, low-income people already pay a disproportionate amount of their income on energy costs, and decarbonization could perpetuate these inequities without targeted policies.

In the decarbonization scenarios, building energy costs are about 7 percent higher than the Reference case in 2030 and 2050, as shown in Figure 46. These costs include the cost of energy used within residential buildings (e.g., electricity and fuel), as well as the capital and installation costs of energy-using appliances and the costs of building shell upgrades.

**FIGURE 46.** AVERAGE PER-HOUSEHOLD COST FOR RESIDENTIAL ENERGY NEEDS

*The decarbonization scenarios result in modest increases in residential energy costs per household. The costs in this figure include the costs of electricity, fuel, purchase and installation of energy-using appliances, and building shell upgrades.*

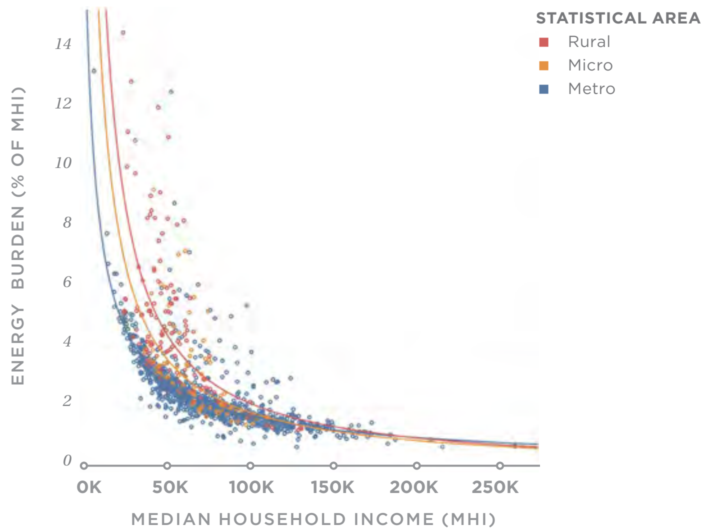



Today, many households spend more than 5 percent of their income on energy for their homes, and some households (especially in rural areas) have to spend 10 to 15 percent of their incomes for home energy use. Energy burden rises exponentially as income decreases, and rural households tend to have higher energy burdens. Energy efficiency reduces energy consumption thereby reducing energy bills and decreasing energy burdens. However, low-income families, particularly in multifamily homes, are often least likely to participate in efficiency programs and have efficiency upgrades because of unique issues like dispersed or complex building ownership, split financial incentives between the building owner and tenants, lack of financing, and lack of awareness of options.

And yet, it is low-income households who would often benefit most from the reduction in energy-related expenses, the decrease in energy waste, and the improved health benefits provided through energy efficiency.

**FIGURE 47.** BASELINE RESIDENTIAL ENERGY BURDEN IN 2017

*Energy burden rises exponentially as income decreases. Energy burden is calculated from median household fuel and electricity consumption for home energy use by census tract, average cost of fuel and electricity, and median household income by census tract.*




Areas with high energy burden also overlap to some extent with communities that rank high on the Demographic Index, particularly for census tracts in southern and eastern Colorado, as shown in Figure 48. Energy burden is particularly high in southwestern Colorado. While the Denver area has lower energy burden than rural parts of the state, the parts of Denver with higher energy burden also have high Demographic Indices, as shown in Figure 49. These types of maps can be used to screen for census tracts that have both high energy burdens and high cumulative socioeconomic burdens.

**FIGURE 48.** BASELINE SPATIAL DISTRIBUTION OF ENERGY BURDENS AND DEMOGRAPHIC INDEX IN 2017

*Many rural areas with high energy burden also have high concentrations of low-income and linguistically isolated populations and people of color, represented by a high score in the Demographic Index, especially in southern Colorado.*

RESIDENTIAL ENERGY BURDEN (2017) DEMOGRAPHIC INDEX (2017)

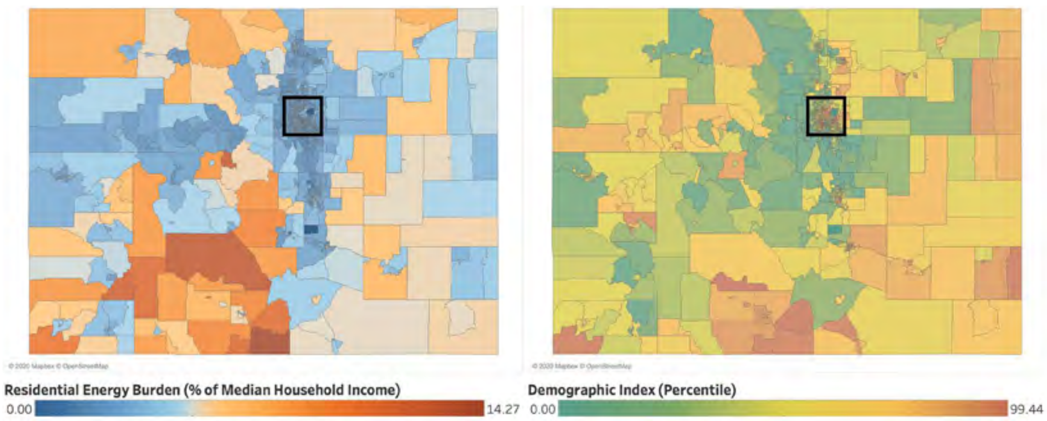
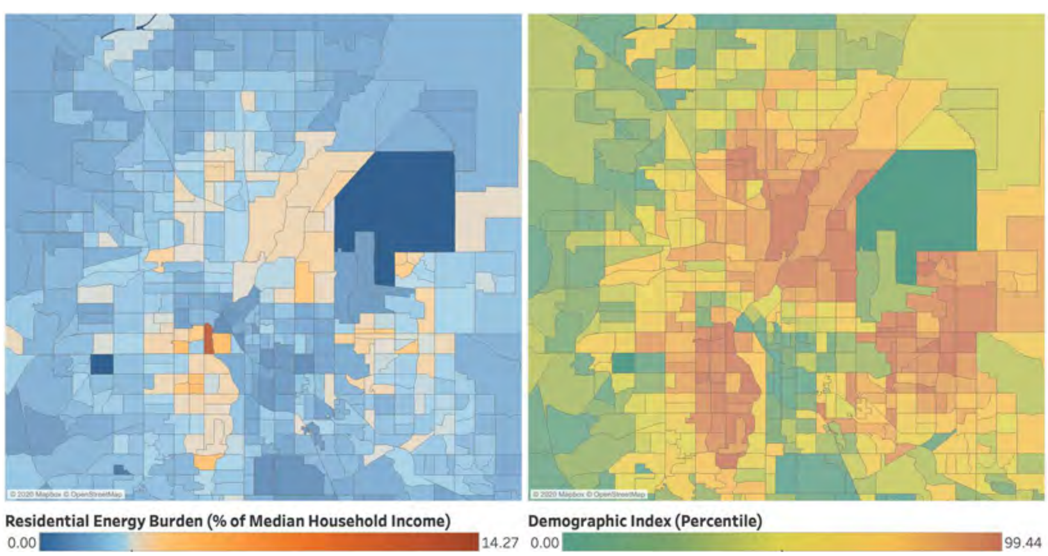



**FIGURE 49.** BASELINE ENERGY BURDEN AND DEMOGRAPHIC INDEX IN THE DENVER METRO AREA IN 2017

*Though most census tracts in Denver have lower energy burden than other parts of the state, the areas with relatively high energy burden also rank highly on the demographic index.*

RESIDENTIAL ENERGY BURDEN, DENVER AREA (2017) DEMOGRAPHIC INDEX, DENVER AREA (2017)



Average energy burden remains similar to today's levels in most of the decarbonization scenarios, as shown in Figures 50 and 51. The Low Demand scenario results in lower energy burdens compared to other scenarios. Rural areas see the highest increase in energy burdens in the Reference case, and all four decarbonization scenarios mitigate these increases in energy burden for rural communities.

**FIGURE 50.** ENERGY BURDEN IN ALL MODELED SCENARIOS

*Average energy burden remains similar to today's levels in metropolitan and micropolitan areas in all scenarios. Burden in rural areas increases in the Reference case, and the decarbonization scenarios mitigate these increases.*

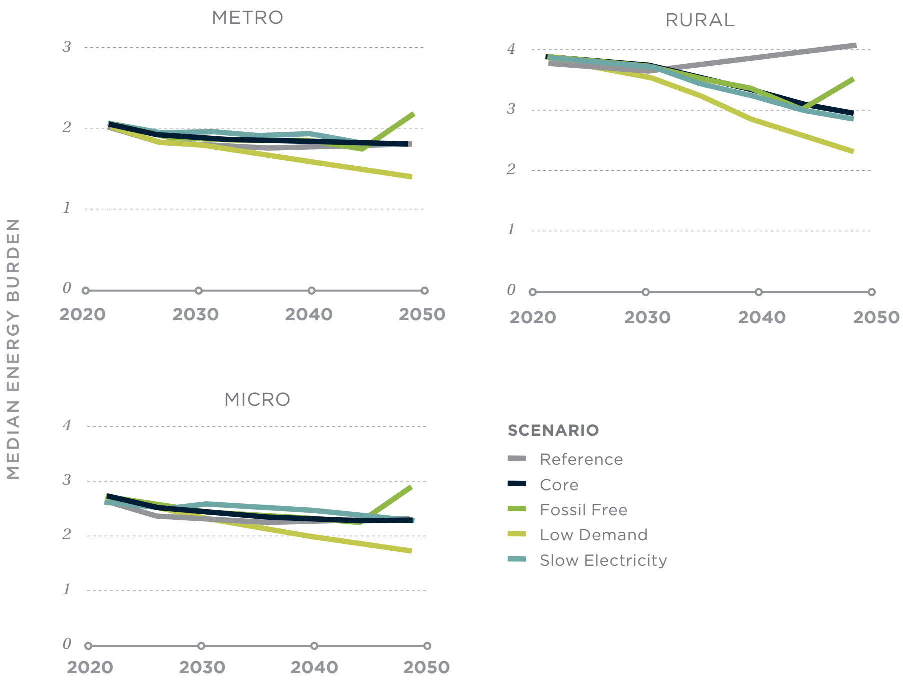
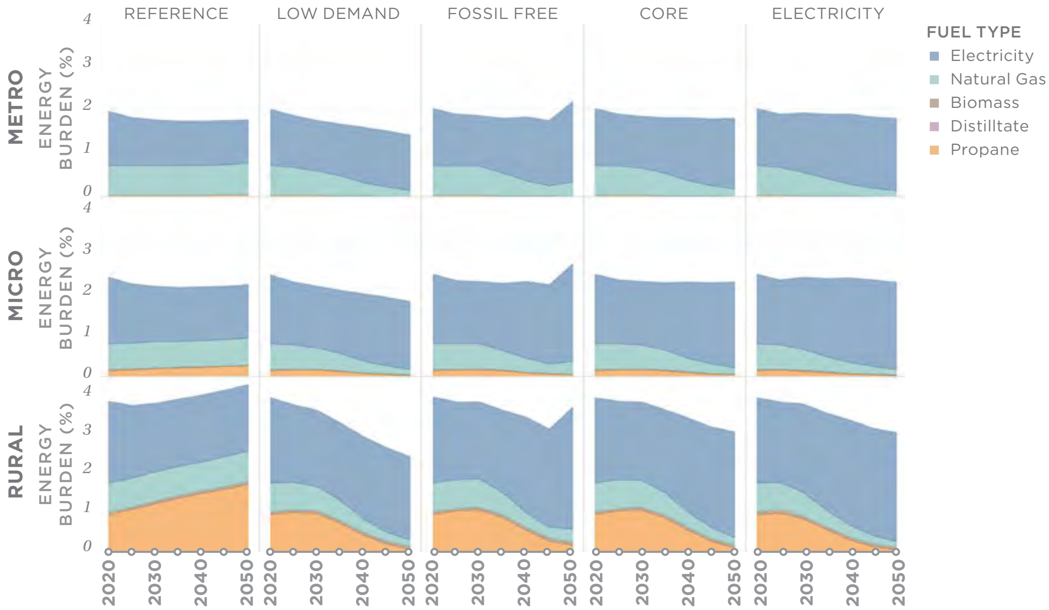



**FIGURE 51.** RESIDENTIAL ENERGY BURDEN BY MODELED SCENARIO AND FUEL TYPE

*Households in rural areas spend more on propane than households in metropolitan and micropolitan (suburban) areas. Propane expenditures decline in the decarbonization scenarios as electricity replaces propane appliances.*




## OIL & GAS PRODUCTION

To achieve the climate goals, Colorado must ensure substantial reductions in oil and gas (O&G) methane emissions. The state must cut O&G methane about 57 percent from pre-pandemic levels (54 percent from 2005 levels) by 2030 and at least 89 percent from pre-pandemic levels (88 percent from 2005 levels) by 2050.

Upstream methane emissions O&G are the largest source of the state's industrial greenhouse gas emissions, and they have grown significantly over the past 15 years due to large increases in production. O&G methane made up 14 percent of the state's total GHG emissions in 2005. According to pre-pandemic estimates, today's O&G methane emissions represent 18 percent of total GHGs emitted in Colorado.

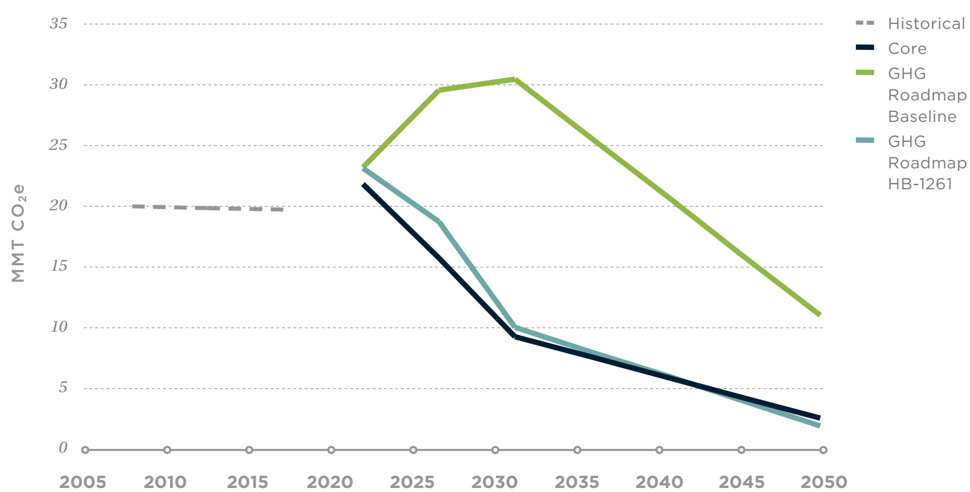
The core strategies to reduce O&G methane are to reduce the rate of leakage from the extraction, processing, transmission, and distribution of oil and gas and to reduce total O&G production. Colorado should pursue a combination of these strategies.

Colorado must reduce oil and gas methane emissions 57 percent by 2030 and at least 89 percent by 2050 from present levels.

O&G methane emissions must drop sharply in the next 10 years and steadily decrease through 2050. This is a significant departure from business as usual, in which O&G methane emissions climb over the next decade, peaking 52 percent higher than 2005 levels, and then decline through 2050. Figure 52 shows that O&G methane emissions in our Core scenario are very similar to the methane projections in the HB-1261 Action scenario of the GHG Roadmap. However, the Roadmap and our analysis show different technical pathways for achieving these reductions.

**FIGURE 52.** OIL AND GAS METHANE EMISSIONS IN GHG ROADMAP AND CORE SCENARIO

*The GHG Roadmap baseline shows an initial, substantial rise in methane emissions and never reaches the level of emissions reduction as the Roadmap's HB-1261 scenario and our Core scenario.*



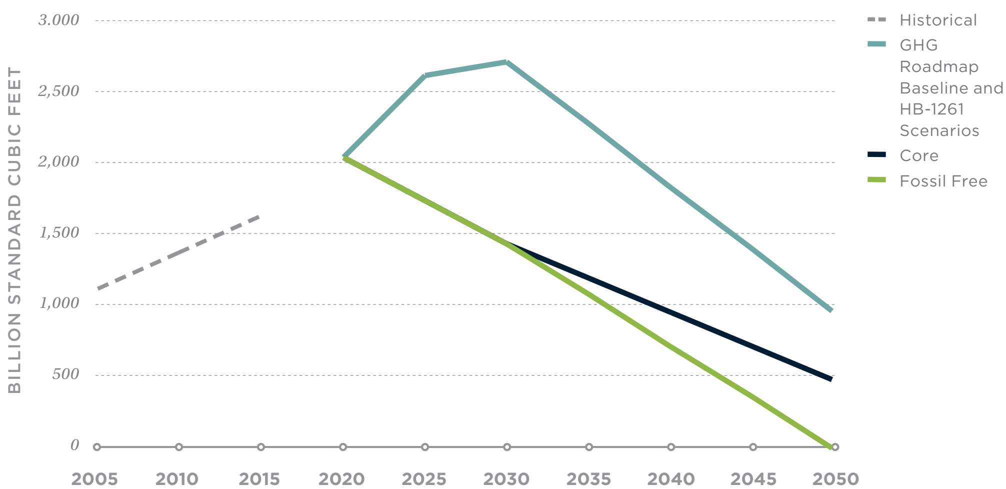

In Evolved's analysis, the reduction in oil and gas emissions is achieved through both a decrease in oil and gas production and a reduction in methane leakage rates. In the Core scenario, O&G output drops 25 percent from 2019 levels by 2030 and 75 percent by 2050, as shown in Figure 53. In the Fossil Free scenario, output drops to zero by 2050.

By contrast, the GHG Roadmap argues that the state can substantially increase production (by 41 percent for gas and 86 percent for oil between 2020 and 2030) and still achieve the necessary methane reductions. However, the state's analysis is counting on unprecedented reductions in methane leakage, as shown in Figure 54. The GHG Roadmap assumes the leakage rate drops from 2.4 percent today to 0.6 percent in 2030 and 0.3 percent in 2050. In our analysis, the leakage rate drops to 1 percent in 2030 and 0.7 percent in 2050, based on the EPA's Global Non-$CO_2$ Greenhouse Gas Emission Projections & Mitigation: 2015-2050.

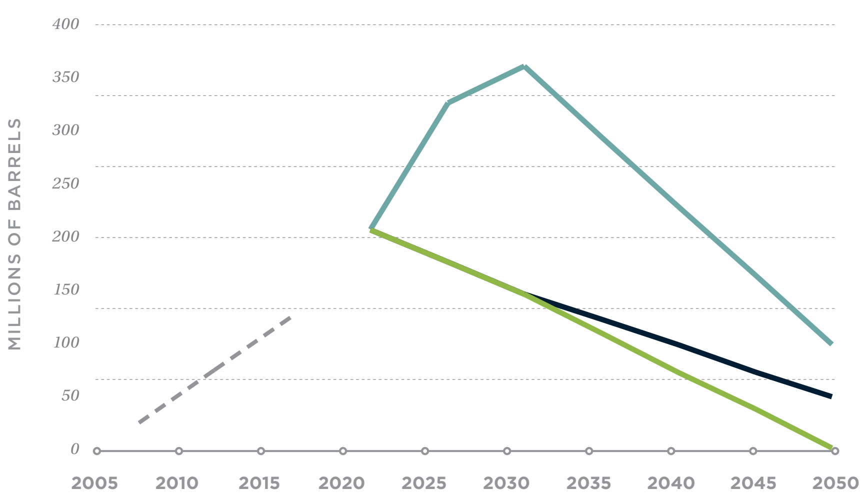
**FIGURE 53.** OIL & GAS PRODUCTION IN THE GHG ROADMAP AND OUR ANALYSIS

*Both the Roadmap Baseline and HB-1261 scenarios show a significant increase in oil and gas production and maintain higher overall levels of production between now and 2050, in sharp contrast with our Core and Fossil Free scenarios.*

GAS PRODUCTION



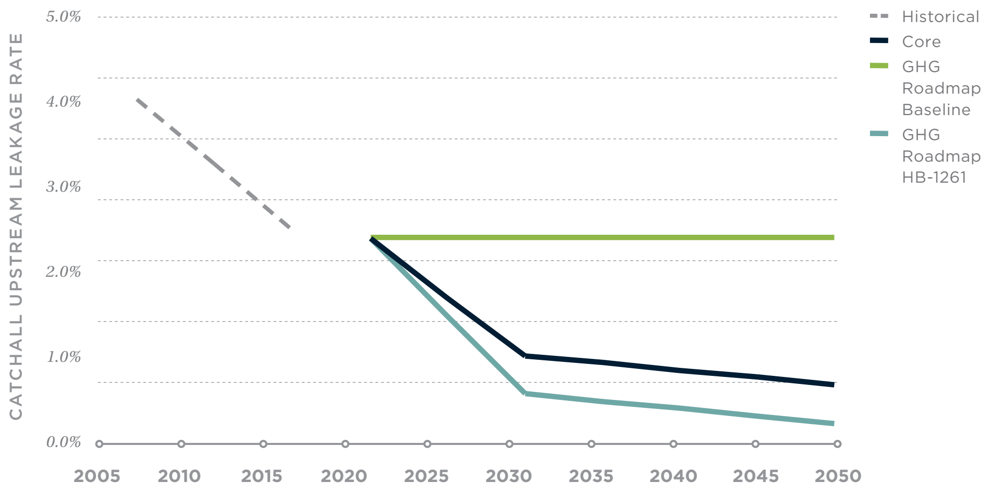

OIL PRODUCTION



While we would welcome Colorado's O&G industry achieving the levels of reductions in leakage rates assumed by the GHG Roadmap, we are concerned that the leakage rate reductions in the Roadmap may not occur without significant new regulations and resources devoted to monitoring and enforcement. In addition, expansion in the oil and gas industry means more pollution will remain in Coloradan communities.

**FIGURE 54.** METHANE LEAKAGE FROM OIL AND GAS PRODUCTION IN GHG ROADMAP AND OUR ANALYSIS

*The Roadmap HB-1261 scenario is dependent on more aggressive methane leakage rates than our analysis.*




By contrast, our modeling shows a steep decline in instate O&G production is necessary to meet the HB-1261 targets. Colorado should ensure modest reductions in O&G production by 2030 and steeper reductions through 2050 both as part of a strategy to reduce methane emissions and to be consistent with instate emissions reductions and reduced oil and gas use throughout the west. By assuming that oil and gas production continues to expand significantly, the Roadmap envisions a future in which the state cuts emissions from in-state demand, only to export a growing amount of fossil fuels for combustion elsewhere. We believe an approach that combines leakage rate reductions with production decreases is more consistent with the necessary reductions in O&G use to ensure emissions reductions across the country. A 25 percent reduction in oil and gas production is comparable to the reduction in oil and gas use that occurs across the western states in the Core scenario.

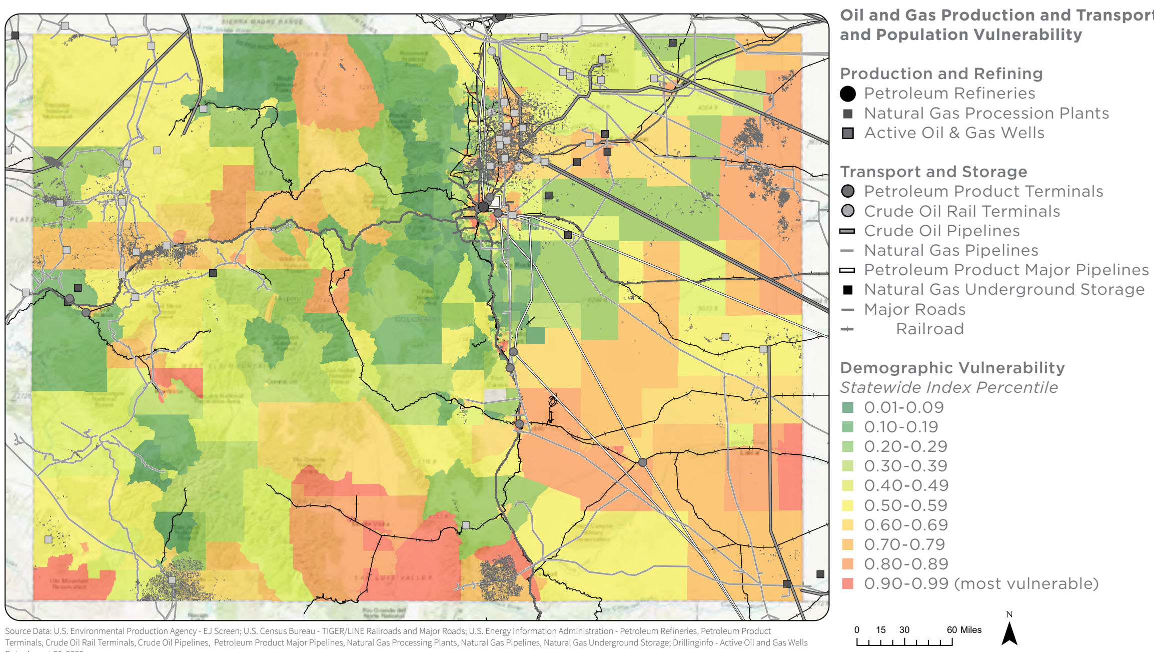
Strategies to reduce production must ensure protection and economic support for communities that are dependent on fossil fuel extraction and processing. By acknowledging the need for production declines to avoid the worst climate impacts and planning ahead for this future, the state can more readily and fully support these communities and work with them to find adequate solutions.

**Expanded production will exacerbate pollution harmful to human health.**

Pathways to cutting GHG emissions while leaving oil and gas production in place will continue to produce harmful co-pollutants, such as benzene. Oil and gas production can also contribute to water contamination and limit water access to local populations. Certain measures, such as set-backs, can help limit these impacts, but even with these measures, expanded production will continue to have pollution impacts on the state's rural communities.

**FIGURE 55.** OIL AND GAS PRODUCTION AND TRANSPORT OVERLAYED WITH DEMOGRAPHIC INDEX

*Petroleum refineries, gas processing plants, active oil and gas wells, and transport and storage infrastructure overlap considerably with higher vulnerability populations.*




Source Data: U.S. Environmental Production Agency - EJ Screen; U.S. Census Bureau - TIGER/LINE Railroads and Major Roads; U.S. Energy Information Administration - Petroleum Refineries, Petroleum Product Terminals, Crude Oil Rail Terminals, Crude Oil Pipelines, Petroleum Product Major Pipelines, Natural Gas Processing Plants, Natural Gas Pipelines, Natural Gas Underground Storage; Drillinginfo - Active Oil and Gas Wells
Date: August 20, 2020

## INDUSTRIAL ENERGY USE AND PROCESSES

The state must cut industrial $CO_2$ emissions by at least 27 percent from today's levels (still 6 percent higher than 2005 levels) by 2030 and 72 percent from today's levels (58 percent from 2005 levels) by 2050. These reductions should come from decreased fossil fuel production (which reduces energy use), alongside energy efficiency, electrification, and adoption of low-carbon fuels.

Industrial $CO_2$ emissions made up 11 percent of the state's total GHG emissions in 2005, with industrial energy use accounting for most $CO_2$ from the industrial sector and process emissions (emissions not associated with energy use) making up the rest. Industrial $CO_2$ pollution has grown in the past 15 years, comprising about 15 percent of the state's total GHG emissions today. These emissions include $CO_2$ produced from the non-electricity energy supply for all industrial sectors, including oil and gas production and processing, as well as $CO_2$ released in industrial processes (e.g. $CO_2$ as a byproduct of chemical processes used to produce cement). They do not include methane leakage from oil and gas, which are discussed in the previous section.

**Colorado's industrial energy use is dominated by oil and gas production, but manufacturing, construction, agriculture, and several other industries also are significant energy users.**

Colorado has a diverse industrial sector, so specific strategies to decarbonize industrial energy use will vary based on the specific subsector in question. Oil and gas production, processing, and refining use more energy than any other sector by far. These activities account for about half of all industrial energy use. The next largest subsectors by energy use are manufacturing, construction, agriculture, mining, and food and beverage production, as shown in Figure 56.

The manufacturing subsector includes several major industries. The largest manufacturing subsectors by energy use are chemicals, iron and steel, and cement and lime. Figure 57 shows the distribution of energy use by manufacturing subsector.

All industrial subsectors rely heavily on fossil fuels for energy supply. The oil and gas industry relies almost entirely on burning gas for energy. Construction and agriculture both use substantial diesel fuel, along with other energy sources. Electricity is an important energy source for manufacturing and mining, in particular. Figure 58 breaks down fuel use by subsector.

**FIGURE 56.** DISTRIBUTION OF INDUSTRIAL ENERGY USE BY SUBSECTOR

*This chart shows 2018 industrial energy use by subsector as a percentage of the total across the industrial sector. The oil and gas industry uses the most energy by far, composing more than 40 percent of all industrial energy use. Data source: Evolved downscaling of EPA data.*

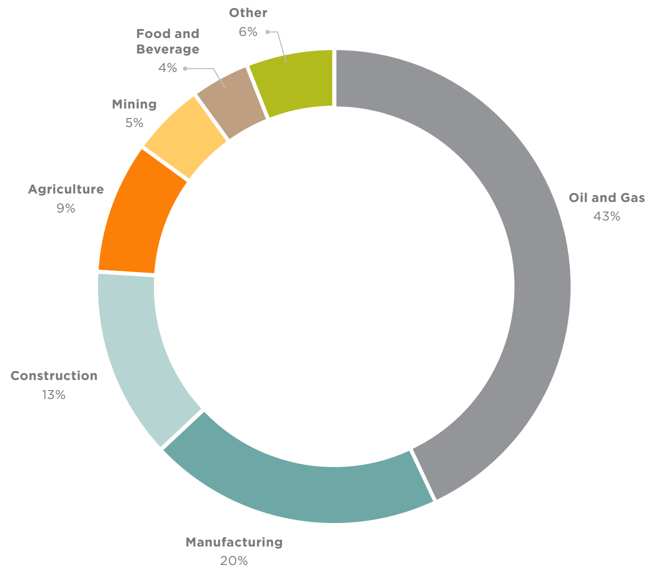



**FIGURE 57.** DISTRIBUTION OF INDUSTRIAL ENERGY USE AMONG MANUFACTURING SUBSECTORS

*This chart is a more detailed display of energy use within the manufacturing category, the dark teal bar shown in Figure 56. The data represent 2018 energy use for the manufacturing subsectors as a percentage of the total energy use across manufacturing in Colorado. Chemicals, iron and steel, and cement and lime are the three largest industries by energy use. These data are approximations, due to data limitations. Data source: Evolved downscaling of EPA data.*

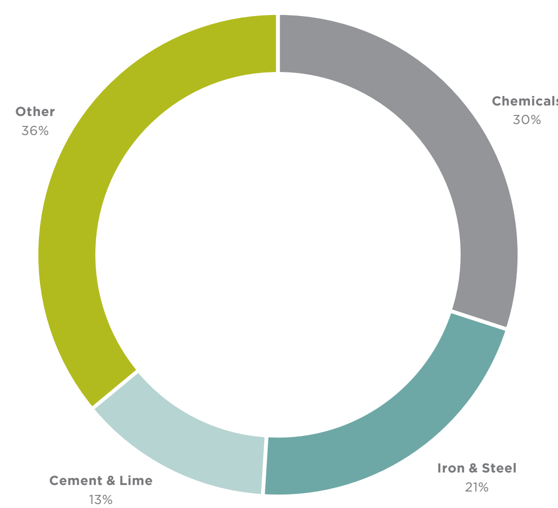
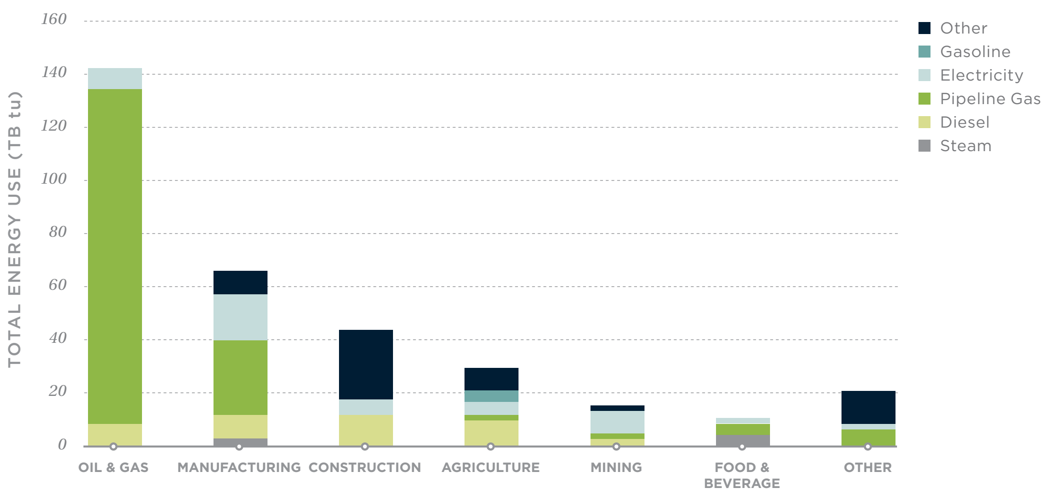


**FIGURE 58.** DISTRIBUTION OF FUEL USE ACROSS INDUSTRIAL SUBSECTORS IN COLORADO

*This chart shows a breakdown of 2018 industrial fuel use by subsector. Across all subsectors, fossil fuels dominate industrial energy use. Data Source: Evolved downscaling of EPA data.*

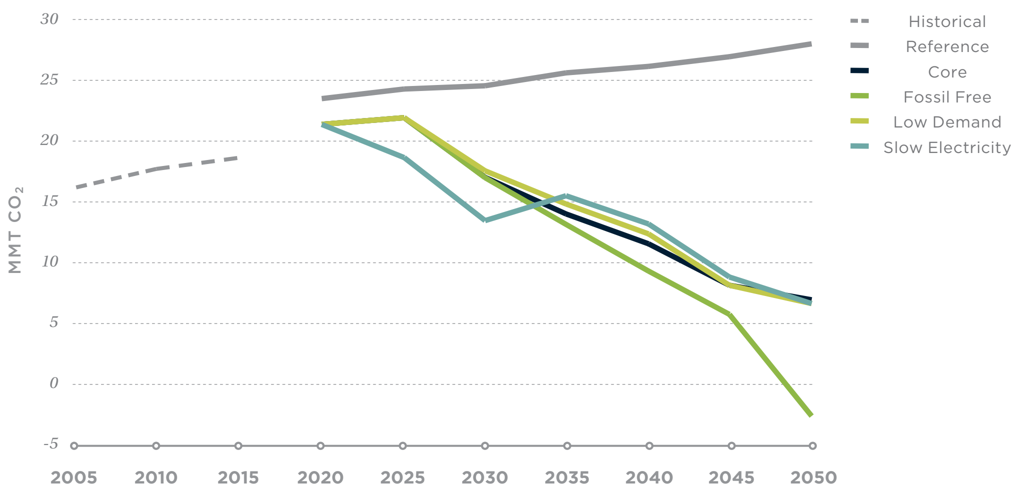



**Colorado must cut $CO_2$ emissions from the industrial sector by 27 percent by 2030 and 72 percent by 2050 from today's levels.**

Reductions in $CO_2$ emissions from industrial energy use are necessary for Colorado to meet the climate goals. In the Core scenario, industrial $CO_2$ emissions drop to about 17 MMT $CO_2$ (27 percent lower than today's levels and 5 percent higher than 2005 levels) by 2030 and 7 MMT $CO_2$ (72 percent lower than today's levels and 58 percent lower than 2005 levels) by 2050, as shown in Figure 59. The Slow Electricity scenario requires even greater reductions in the next ten years, reaching 13 MMT $CO_2$, 43 percent below today's levels and 17 percent below 2005 levels. These additional cuts help offset slower progress in the power sector, though at a greater cost than if the power sector moves as quickly as in the Core scenario. The Fossil Free scenario achieves even greater cuts to industrial $CO_2$ emissions by 2050, as industrial facilities replace all fossil fuel use and petroleum-based feedstocks with synthetic fuels, biofuels, and biomass or synthetic feedstocks.

**FIGURE 59.** $CO_2$ EMISSIONS FROM THE INDUSTRIAL SECTOR IN ALL MODELED SCENARIOS

*The Core, Fossil Free, and Low Demand scenarios show a largely similar reduction path between now and 2050, with the Fossil Free scenario ultimately achieving net negative emissions from biofuels with carbon capture and sequestration. The Slow Electricity scenario makes even greater reductions in the next ten years to offset the slower progress in the power sector.*




**The industrial sector must become more energy efficient and replace fossil fuel use with electricity, synthetic fuels, and biofuels.**

To achieve the required reductions in $CO_2$ emissions, Colorado must upgrade its industrial facilities with more efficient technologies and practices and replace fossil fuel use with alternative zero- or low-carbon energy sources.

In the Core scenario, industrial energy demand drops to 24 percent below today's levels by 2050. That's 45 percent below the Reference case, in which industrial energy demand continues to climb. These reductions come from less oil and gas production (which means less energy used to operate oil and gas production and processing facilities), combined with more efficient practices across the industrial sector.

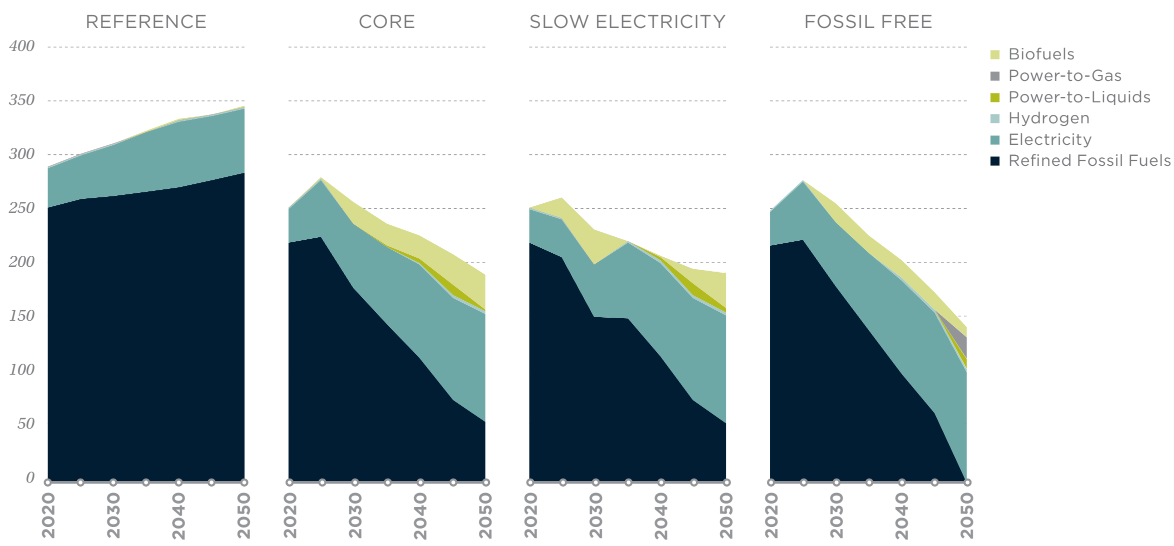
Direct use of fossil fuels (burning fuels on site to meet energy demand) currently supplies 87 percent of industrial energy use, and only 12 percent comes from electricity, as shown in Figure 60. In the Core scenario, electricity use grows to comprise 23 percent of energy demand by 2030 and 52 percent by 2050. Biofuels, which play a trivial role in today's industrial system, also supply a growing share of energy demand, reaching 8 percent by 2030 and 17 percent by 2050. These fuels replace current uses of diesel in industry. The Slow Electricity scenario relies more heavily on biofuels to achieve the greater reductions necessary by 2030. Biofuels make up 14 percent of industrial energy demand by 2030.

While the other decarbonization cases allow for some fossil fuel use to remain in 2050, the Fossil Free scenario requires the industrial system to fully rely on electricity, biofuels, and synthetic fuels. In this case, electricity supplies 71 percent of energy, synthetic fuels supply 20 percent, biofuels provide 6 percent, and hydrogen fills in the remaining 2 percent. The Fossil Fuel scenario also has greater reductions in total energy demand, in part due to even less oil and gas production in 2050.

In our modeling, all biofuels are produced with sustainable biomass feedstocks. For the state to credibly reduce emissions using biofuels and avoid harm to ecosystems, policymakers must ensure that all biofuels are produced with biomass that is independently certified to the Roundtable on Sustainable Biomaterials (RSB) or equivalent standard.

**FIGURE 60.** INDUSTRIAL FUEL USE IN MODELED SCENARIOS

*The Core, Slow Electricity, and Fossil Free cases all drastically reduce overall levels of fuel use and the portion of fossil fuel use, while increasing the portion of electricity between now and 2050 compared to the Reference case.*

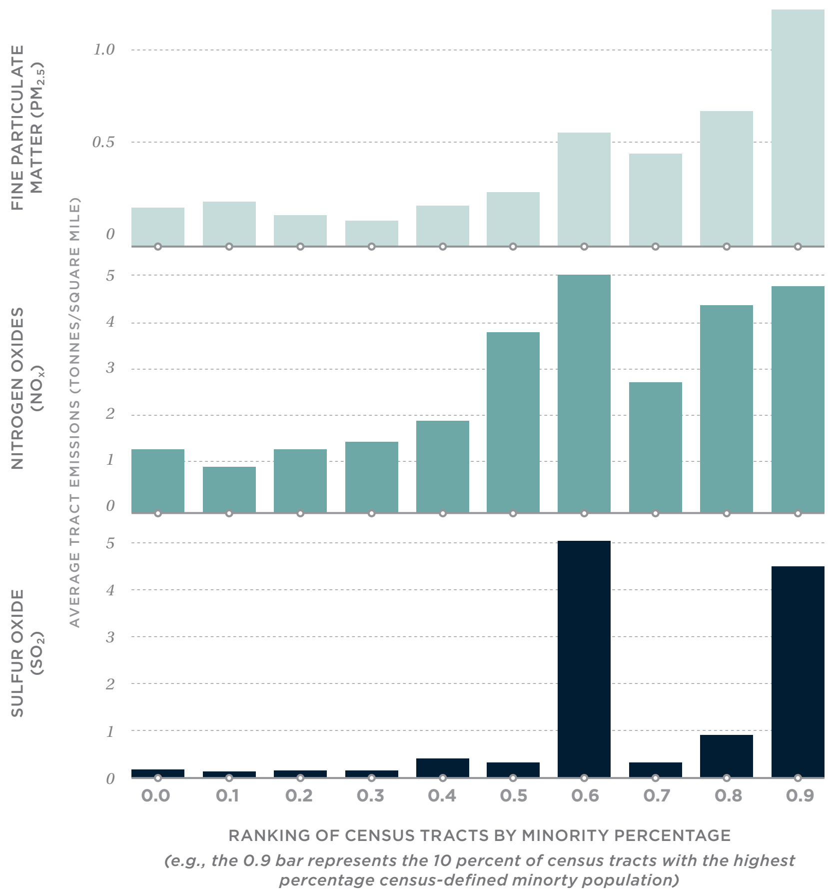



**Decarbonizing industrial energy use will help reduce harmful air pollution.**

Industrial facilities, including oil and gas infrastructure, release harmful air pollution through industrial processes and fossil fuel use for energy. Existing industrial pollution is concentrated in communities of color and low-income communities (e.g., Figure 61). Replacing fossil fuel use in industry will help reduce emissions in overburdened communities. However, burning biofuels and synthetic fuels still releases harmful air pollution, so some industrial pollution will remain, even in the Fossil Free scenario.

**FIGURE 61.** BASELINE AIR POLLUTION BY MINORITY POPULATION OF CENSUS TRACT

*Air emissions from industrial point sources are more highly concentrated in areas of the state with higher census-defined minority populations. The figure shows the average emissions density among census tracts with nonzero industrial point source emissions in each minority decile bracket. These data include all point sources from the National Emissions Inventory, excluding power plants, and major oil and gas extraction, transport, refining, and export infrastructure. The data do not include individual oil and gas production wells. Data Sources: EPA 2017 National Emissions Inventory (NEI), 2019 EPA Environmental Justice Screening and Mapping Tool (EJSCREEN), U.S. Census Bureau American Community Survey (ACS) 2014-2018 5-Year Estimates.*



The policy recommendations listed below are informed by Evolved's energy system modeling and PSE Health Energy's equity analyses. They are broken down by sector and include specific complementary recommendations for addressing equity.

While each equity recommendation is tailored to the specific sectors, four broad themes emerged from the equity analysis as a whole:

- First, pollution sources are not spread evenly across the state and tend to be concentrated in low-income communities and communities of color. Thus, policies are needed to prioritize pollution reductions in communities with the heaviest pollution burdens.
- Second, there is unequal support for the access to, and adoption of, clean energy technologies, particularly distributed energy resources such as energy efficiency, rooftop solar, and electric vehicles. We must take steps to ensure that all communities have access to, and benefit from, clean technologies.
- Third, some Coloradans have very high energy burdens, spending large shares of their income on electricity and transportation. Reducing GHGs will not, by itself, address these energy burdens, and thus complementary policies are needed to make energy and transportation more affordable.
- Fourth, we need more demographic data and analyses of affordability and access to clean technologies. Relatedly, policymakers have a duty to ensure that communities disproportionately affected by pollution are included in the process of devising and implementing policy solutions, that their rules decrease harmful air pollution and co-pollutants in disproportionately impacted communities, and that they provide ongoing tracking of emission sources.[9] Currently, there is no explicit direction in the statute for how to do so, so mechanisms for collecting, sharing, and requiring the use of the communities' input is needed.

Finally, an important consideration for the implementation of all policies will be funding. Policies that can secure robust funding particularly for low-income programs and programs for people of color, enable revenue generation, and staff the personnel needed can be the difference between successful or unsuccessful implementation. One barrier that will need to be addressed for sufficient funding is Colorado's Taxpayer's Bill of Right (TABOR) amendment, which prohibits state and local governments from raising tax rates and spending revenues collected under existing tax rates without voter approval if revenues grow faster than the rate of inflation and population growth.

9 Section 25-7-105(1)(e)(III), C.R.S. 2019

## ELECTRIC SECTOR POLICIES

**2025 Electric Sector Milestones for reducing statewide GHG emissions 26 percent in the Core Scenario:**

- Electric sector $CO_2$ emissions decline by at least 80 percent by 2025 relative to 2005 levels
- Absolute $CO_2$ emission budget for 2025: 8 MMT $CO_2$
- This is functionally equivalent to a 72 percent RPS standard for 2025

**2030 Electric Sector Milestones for reducing statewide GHG emissions 50 percent in the Core Scenario:**

- Electric sector $CO_2$ emissions decline by 98 to 99 percent by 2030 relative to 2005 levels
- Absolute $CO_2$ emissions budget for 2030: approximately 0.6 MMT $CO_2$
- This is functionally equivalent to a 98 percent RPS standard for 2030

### THE IMPORTANCE OF ACHIEVING RAPID AND DEEP DECARBONIZATION OF THE ELECTRIC SECTOR

Our modeling indicates that reductions in the electric sector are some of the lowest-cost GHG emission reductions on a dollar-per-ton basis compared to measures for reducing GHG emissions from all other sectors. As a result, the least cost option is to maximize reductions from the electric sector. If close to complete decarbonization by 2030 does not occur, other sectors have to pick up the slack and the state's climate goals will be much more expensive to achieve.

The Slow Electricity scenario illustrates how if Colorado's electric sector does not rapidly decarbonize by 2030, meeting the economy-wide 2030 target will be more expensive, more difficult, and have more negative consequences. The costs in the Slow Electricity scenario are higher overall than the Core decarbonization case in both 2025 and 2030 and have higher cumulatives cost than any other scenario. Furthermore, the Slow Electricity Scenario leaves high levels of health-damaging air pollutant emissions on the grid in 2030.

The pace of electric sector decarbonization is also critical because it affects the magnitude of emission reductions achieved in sectors that are electrified, e.g., transportation and buildings. Thus, the benefits of electrifying vehicles and buildings increase as the electric grid decarbonizes.

## RECOMMENDATION 1: ADOPT A CARBON EMISSIONS RULE FOR ELECTRIC UTILITIES

**Relevant Agency:** AQCC

**Recommendation Details:** The AQCC should issue a rule requiring each utility to do the following:

1. Reduce $CO_2$ emissions 80 percent by 2025;
2. Reduce $CO_2$ emissions by at least 90 percent by 2030;
3. Submit a plan to the AQCC with mass-based $CO_2$ emission limits for each of their $CO_2$-emitting generating units, with such limits becoming legally enforceable if the AQCC approves the plan as reducing emissions 75 percent by 2025 and 90 percent by 2030;
4. Include in the emissions calculations and budget the $CO_2$ emissions associated with electricity imported into Colorado to serve Colorado customers;
5. Include in the emissions calculations and budget any $CO_2$ emissions associated with electrification of other sectors;
6. Retire Renewable Energy Credits (RECs) in the year generated and avoid double-counting of RECs for compliance with both HB-1261 and other states' emission targets;
7. Prioritize emission reductions in communities with high pollution burdens, to maximize reductions in harmful co-pollutants such as $SO_2$, $NO_x$, and PM; and
8. Ensure remaining gas generation is not located in frontline communities.

### 1 & 2: Set Carbon Reduction Targets for All Electric Utilities

In our Core Decarbonization scenario, the modeling results show that the electric sector reduces its $CO_2$ emissions 75 percent by 2025 as part of the state achieving the 26 percent reduction in GHG emissions by 2025, and shows that the electric sector reduces $CO_2$ emissions 98 percent by 2030 to achieve the 50 percent reduction in statewide GHGs by 2030. This translates to a $CO_2$ emission budget for the electric sector of approximately 10 million metric tons in 2025 and 0.8 million metric tons in 2030.

The statewide GHG reduction targets in HB-1261 are science-based targets: they are based on the Intergovernmental Panel on Climate Change's recommendation for reducing GHG emissions to avoid the worst impacts of climate change. By contrast, the 80 percent by 2030 target in a CEP has no basis in scientific studies or in any analyses of the reductions needed to achieve the statewide targets. Our results show that it is unlikely we can reduce statewide emissions by 50 percent by 2030 if the electric sector as a whole reduces its $CO_2$ emissions by only 75 or 80 percent by 2030.

We recognize that HB-1261 essentially precludes the AQCC from requiring additional emission reductions from a utility under HB-1261 if it has an approved CEP and the AQCC has made certain findings regarding the CEP. Nonetheless, issuing the rule we recommend for the electric sector can drive emission reductions for utilities that choose not to submit a CEP.

The AQCC should coordinate its electric sector rule under HB-1261 with other rulemakings to encourage and/or require utilities to take steps to reduce their $CO_2$ emissions 75 percent by 2025 and 98 to 99 percent by 2030. The AQCC proposed to address both regional haze and HB-1261 requirements in a single rulemaking this fall, and this represents an opportunity to ensure that certain power plants reduce their $CO_2$ emissions consistent with the statewide targets in HB-1261.

### 3. Translate the Emission Reductions Into Enforceable Emission Limits

We recommend that the AQCC approve legally-enforceable emission limits for each $CO_2$-emitting facility of each electric utility. The AQCC should do this for both utilities that submit a Clean Energy Plan and those that do not.

The AQCC should require that, within six months of the AQCC adopting a final electric sector rule, a utility must either submit a Clean Energy Plan to the PUC or submit a plan to the AQCC for meeting the emission limits listed above, i.e., 75 percent reduction by 2025 and at least 90 percent by 2030. A plan submitted to the AQCC should include annual, mass-based $CO_2$ limits for each generating unit, and such $CO_2$ limits would become legally enforceable after AQCC approval of a plan.

Any electric-sector rule should describe how the AQCC will verify the emissions a utility actually emits under a CEP and whether the utility's actual emissions result in a 75 percent and 80 percent reduction in emissions by 2030 (the statutory targets for a CEP). We recommend that the AQCC adopt a rule that the projected 2030 emissions in a CEP that is approved and verified to meet the statutory requirements become enforceable, mass-based $CO_2$ emission limits for each generating unit covered by the CEP. This rule should also specify the process and standards for dealing with a utility that does not achieve the minimum emission reductions required by a CEP (i.e., a 75 percent or 80 percent reduction in emissions by 2030).

Ensuring that electric utilities' plans are legally enforceable is critical to implementing HB-1261, because it is possible that utilities will retain some gas-fired generators through 2030. Thus, utilities will have fossil-fuel generators that, if run at sufficiently high capacity factors, could cause the utilities to exceed the emission reductions promised in CEPs. Absent a mechanism for monitoring and enforcing emissions from electric utilities, there is no guarantee that a utility will run its generating units to stay below the emission reductions promised in a plan.

4. **Count Emissions Associated with Imported Electricity Toward Each Utility's Emission Budget**

It is our understanding that the state's Roadmap Study is not counting GHG emissions associated with electricity that is imported into Colorado to serve Colorado customers. This raises concerns given that one of the state's largest electric utilities, Tri-State, serves Colorado customers with significant amounts of electricity from coal-fired power plants located outside Colorado, including Laramie River Station in Wyoming, Springerville in Arizona, and coal units owned by Basin Electric Power Cooperative. According to Tri-State, under a business-as-usual trajectory, Tri-State's out-of-state power plants would emit roughly 2.5 million tons of $CO_2$ in 2025 and 2.9 million tons of CO2 in 2030 to generate electricity to serve Colorado customers.

Ignoring emissions associated with imported electricity is problematic for many reasons. It results in undercounting the total emissions associated with providing electricity to Colorado customers. It also incentivizes Colorado utilities to outsource electricity production, and the associated pollution thereof, to other states, creating an inequitable pollution burden shift to non-Coloradans.

In its rulemaking, the AQCC should ensure that the required level of emission reductions is calculated based on including emissions associated with electricity imported to serve Colorado customers.

5. **Count Emissions Associated with Electrification in Each Utility's Emission Budget**

Our analysis indicates that in order to meet the statewide GHG reduction targets, we must both decarbonize the electric sector rapidly and electrify the transportation and buildings sectors. There have been proposals to allow electric utilities, in the context of a Clean Energy Plan, to subtract the emissions due to electrification from their emission target. This proposal would make it harder to achieve the targets in HB-1261, because to meet the targets, the electric sector must almost completely decarbonize by 2030. Thus, if the electric sector achieves the level of decarbonization that our study indicates is needed, the incremental emissions from electrification would be negligible. The bottom line is that the AQCC should not be adjusting electric utilities' baseline or allowable emissions to subtract emissions from electrification, which is incompatible with the scale of reductions needed from both the electric sector and other sectors.

6. **Ensure No Double-Counting of Renewable Energy Credits**

Colorado's Clean Energy Plans and any other electric sector decarbonization requirements should require the contemporaneous retirement of renewable energy certificates (RECs) to ensure the renewable energy used to cut carbon by Colorado utilities are not also counted toward compliance with renewable energy portfolio standards in other states.

### 7 & 8. Require Utilities to Prioritize Emission Reductions in Communities With High Pollution Burdens

HB-1261 requires the AQCC to identify disproportionately impacted communities[10] and, in issuing rules to achieve the emission reduction targets, consider "pollution abatement opportunities in disproportionately impacted communities."[11] The AQCC should implement these statutory obligations by requiring each utility to prioritize emission reductions in disproportionately impacted communities and to consult with disproportionately impacted communities when creating their resource plans. Given that the generating units that emit $CO_2$ also emit harmful "conventional" pollutants, our recommendation can help reduce "conventional" pollution from the remaining fossil fuel plants and ensure that the fossil fuel plants that remain operating are not located in frontline communities, which typically experience multiple environmental burdens and are more vulnerable to the impacts of pollution. The PUC also has an important role to play in ensuring that utilities prioritize retirement and/or reductions in use of fossil fuel plants in communities with disproportionate pollution burdens. Specifically, the PUC should make this an important goal in utilities' resource plans.

## RECOMMENDATION 2: INCREASE ENERGY EFFICIENCY SAVINGS TARGETS FOR UTILITIES

**Relevant Agency:** PUC

**Recommendation Details:**

In proceedings for Xcel and Black Hills, the PUC should ensure the following:

1. Increase the energy efficiency savings target, budget, and measure incentives,
2. Specifically, increase the residential savings target, budget, and measure incentives for low-income and low-income multifamily customers, and
3. Target customers with high energy burdens, high pollution burden, and those having difficulty paying their bills.

### 1. Expand cost-effective energy efficiency programs

Energy efficiency is often the most cost effective way to serve a customer's electricity needs, even before the inclusion of non-energy benefits. Studies have shown energy efficiency programs ranging from 2 to 5 cents per kWh with an average of 2.8 cents per kWh, making their cost about one half to one third the levelized cost of alternative new electricity resource options, such as gas plants.

10 Section 25-7-105(1)(e)(III), C.R.S. 2019
11 Section 25-7-105(1)(e)(VI), C.R.S. 2019

Colorado has two electric investor-owned utilities that submit demand-side management programs (DSM) to the PUC for review and approval: Xcel and Black Hills. Xcel is the state's largest electric utility, serving more than 1.4 million customers and delivering more than half of the electricity used in the state. The Commission should set the expectation that utilities like Xcel and Black Hills must be maximizing their energy efficiency programs to capture nearly all, if not all, cost-effective energy efficiency. This translates into expanded budgets for these programs, increased incentive offerings, pursuit of whole building envelope measures beyond lighting, and tailored program design to help increase participation. Beyond Xcel and Black Hills, the Commission should push Tri-State to work with its members to increase incentives, measures offered, delivery options, and overall participation in energy efficiency programs. Collectively, the state is currently achieving 1.07 percent demand savings per year, but other states have been able to reach nearly three percent savings. The PUC should expect and encourage utilities to maximize energy efficiency savings.

To complement maximizing energy efficiency, demand-side management plans must also provide ways to increase flexible load and demand response services. In a future decarbonized electricity system, flexible electricity loads will be more important than ever to help integrate renewable resources and ensure a reliable electricity system. Moreover, load flexibility will be critical for cost-effective electrification so as to avoid costly pressure on the electricity grid.

### 2 & 3. Expand energy efficiency programs for low-income customers

Households with the highest energy burdens also tend to be the households with the lowest carbon footprints. This means the households that pay the highest shares of their incomes for electricity tend to be the households using the least electricity and fossil fuels and emitting the least carbon.

The implication for climate policy is that focusing solely on reducing carbon will not, by itself, reduce the energy burden for families with the highest energy burdens. Instead, complementary policies are needed that specifically alleviate the disproportionate energy burdens borne by some households.

Energy efficiency programs specifically targeted at low-income customers can be one of these complementary policies and would be especially timely since the recession caused by the coronavirus pandemic has resulted in a staggering increase in the number of customers who are behind on their electricity bills. For example, in July, Xcel reported that slightly more than 130,000 residential customers have a past-due electric bill.[12]

While the pandemic has increased the number of utility customers behind on their bills and at risk of disconnection, electricity affordability was a problem

12 Comments of Public Service Company of Colorado at 21, Proceeding No. 20M-0267EG (July 10, 2020).

for many households before the pandemic, and it will likely remain a problem after the current economic crisis related to the pandemic. By reducing customers' energy usage and hence bills, energy efficiency programs can help make electricity more affordable in the long run for customers who are currently struggling to pay their bills. Data from Xcel also show that low-income energy efficiency programs have the highest cost-to-benefit ratio of any energy efficiency programs, saving roughly three dollars for every dollar that is spent.[13]

We recommend that the PUC require utilities to develop and implement programs that would target energy efficiency services for customers who are behind on their bills and may be at risk of having their electric service disconnected.

We also recommend that the PUC approve significantly-expanded energy efficiency programs for both single-family and multifamily low-income customers, and that these programs be designed to overcome the many barriers that low-income customers typically face such as split incentives for renters, upfront costs, and cumbersome and confusing processes. Considerations should include adopting utility performance metrics that encourage continued program evolution toward delivering more comprehensive, whole-building savings and electrification, direct financial and technical assistance (as opposed to tax credits) for the installation of energy-efficiency solutions in low-income homes, increasing eligibility opportunities for low-income/income qualified programs, creating a health and safety program to address health and structural issues preventing energy efficiency projects, increased incentives and streamlined processes for building owners, and making the delivery of programs as simple as possible.

### RECOMMENDATION 3: EXPAND LOW-INCOME CUSTOMERS' ACCESS TO DISTRIBUTED SOLAR AND STORAGE

**Agencies:** PUC, AQCC, legislature

**Recommendation Details:** Colorado's low-income households lag behind in access to rooftop solar: the households with the 20 percent lowest incomes represent only 3 percent of all rooftop solar installations, while the households in the top 20 percent income bracket represent 49 percent. The benefits of rooftop solar include cost savings and consistent bills, and yet the lowest-income households, which have the highest energy burdens, rarely access these benefits. Some reasons for this include the upfront costs to install rooftop solar and the fact that lower-income households are more likely to rent than to own their home. Along with increased access to solar, coupling solar with storage will be increasingly important to provide resilience as climate-induced heat

13 *See, e.g.,* [cite to Xcel filing in 2021-2022 DSM plan].

waves lead to dangerously high temperatures and may lead to outages induced by wildfires or other natural disasters and weather events.

Explicit policies are needed to provide access to capital or otherwise target funds and projects toward these households (e.g., carve-outs, enhanced financing, educational outreach across multiple languages, working with landlords and property management companies). In consultation with the PUC, the AQCC should work with disproportionately impacted communities and low-income communities on how to increase access to residential solar and storage. HB-1261 already requires the AQCC to solicit input from disproportionately impacted communities when adopting policies to implement the statute. We believe that discussions around increasing low-income customers' access to residential solar and storage should be part of the AQCC's engagement with disproportionately impacted communities (which is required by HB 19-1261). It would also behoove the AQCC to explore ways in which to couple complementary policies and processes such as electrification and EV outreach to streamline the process and capitalize on as many clean energy improvements all at once.

We also believe that the PUC could play a role by opening an investigation into barriers to low-income customers' adoption of residential solar and storage and making outreach to low-income customers a part of such an investigation. The PUC could also improve low-income customers' ability to take advantage of the community solar gardens offerings. The PUC should require utilities to increase community solar garden capacity either reserved or prioritized for low-income subscribers and direct utilities to increase marketing to low-income customers of community solar garden offerings.

Examples of programs working to address customer access to clean energy technologies include California's SGIP program which includes an equity and equity resiliency budget, the Single Family Affordable Homes Program, the Solar on Multifamily Affordable Housing, and New York's MW Block program.

### RECOMMENDATION 4: CREATE TRANSITION PLANS FOR WORKERS AFFECTED BY THE TRANSITION AWAY FROM FOSSIL FUELS

**Agencies:** PUC, Office of Just Transition

**Recommendation Details:** Our modeling indicates that retiring all coal plants in Colorado by 2025 is a key element of the most cost-effective path to meet Colorado's climate goals. Coal plants have been providing jobs and funding for state and local government needs including overall state budget as well as local schools, roads, sewers, and bridges. A just and equitable transition of workers will need to include at a minimum local capacity for planning, dislocated worker wages and benefits, and the implementation of transition plans in collaboration with those affected by this transition, including those representing impacted communities, workers, and labor unions. The opportunity for new jobs, as well as the economic development and diversification that comes with building a clean regional economy are abundant and should be central to state decision making to ensure that Colorado's workforce reaps the benefits. Funding and coordinating with Colorado's Office of Just Transition will be key to ensuring a fair and equitable transition to a cleaner economy.

## TRANSPORTATION RECOMMENDATIONS

**2025 Transportation Milestones for reducing statewide GHG emissions 26 percent in the Core Scenario:**

- Percentage reduction needed by 2025 relative to 2005 levels: 18 percent
- Absolute $CO_2$ emissions budget for 2025: 25 MMT $CO_2$
- Electric cars as a percentage of all new car sales: 27 percent
- Electric light-duty trucks as a percentage of all new light-duty truck sales: 8 percent
- Number of electric cars and light-duty trucks on the road: 220,000

**2030 Transportation Milestones for reducing statewide GHG emissions 50 percent in the Core Scenario:**

- Percentage reduction needed by 2030 relative to 2005 levels: 35 percent
- Absolute $CO_2$ emissions budget for 2030: 20 MMT $CO_2$
- Electric cars as a percentage of all new car sales: at least 66 percent
- Electric light-duty trucks as a percentage of all new light-duty truck sales: 40 percent
- Number of electric cars and light-duty trucks on the road: at least 900,000 according to our model and at least 940,000 to reach the state's goal
- Reduction in light-duty vehicle miles travelled from Reference case (modeled in Low Demand scenario only): 7 percent

### RECOMMENDATION 1: ADOPT CLEAN MEDIUM- AND HEAVY-DUTY TRUCK RULES

**Relevant Agencies:** CDPHE, CDOT, CEO

**Recommendation Details:** Under the Clean Air Act, Colorado is able to adopt California's Advanced Clean Truck (ACT) and Omnibus rules by reference, which would require truck makers to sell an increasing number of clean, zero-emission trucks in place of dirty diesel and gasoline.

Earlier this year, CDPHE, CDOT, and CEO took a step in the right direction by signing a multi-state Memorandum of Understanding to work collaboratively to advance the market for electric trucks and buses. As a result, there will be a public process to work with industry and community stakeholders to develop a broad set of strategies to reduce emissions from heavy-duty vehicles. It will be important to develop a broad-based coalition and partnership—including labor, environmental justice, utility, EV industry, and consumer advocates—to support strong standards for commercial trucks including a clean medium rulemaking coupled with a Heavy-Duty "Omnibus" rule. Complementary measures must simultaneously be adopted on clean trucks and buses including charging infrastructure policies and incentives. The AQCC together with CDPHE should develop the rulemaking with input and coordination with the Governor's office, CDOT, and the CEO.

**ACT:** A Colorado Advanced Clean Truck rule would require manufacturers who sell trucks in the state to ensure that, on average, 30 to 50 percent of new commercial truck sales are zero emissions by 2030 (depending on the weight class) and reaching 40 to 80 percent by 2035. Compliance is determined based on manufacturers generating credits for selling electric trucks and using those credits to meet their overall credit requirement. The state and stakeholders will need to work to defend against proposals that result in a weak Colorado program relative to California's and work to ensure that only zero-emission vehicles offered for sale in Colorado generate compliance credits.

With regard to data collection, fleet reporting requirements will supply invaluable information on truck operations, providing vital insight for informing future policies. It should be noted that the ACT rule's reporting threshold is currently structured for California's larger truck market. If possible, it will need to be adjusted downward for Colorado's smaller on-road truck fleet to provide appropriate granularity.

Finally, it is important that Colorado quickly adopt California's Advanced Clean Truck rule to capitalize on the associated benefits as soon as possible. If the timeline is stalled and further delayed by manufacturer lead time requirements, additional compliance model years could be missed.

**Heavy-Duty Omnibus Rule:** California adopted new criteria pollutant standards from heavy-duty conventional, internal combustion engine trucks. Reducing truck emissions by a similar order of magnitude in Colorado will result in significant public health benefits. This rulemaking is a complementary standard to an ACT rule in Colorado and should ideally be pursued simultaneously by the AQCC and CDPHE.

**Complementary Policies:** Paired with the ACT and Omnibus rule, the state should support the development of a robust market for zero-emission medium- and heavy-duty vehicles through complementary strategies such as a fleet purchase requirement, infrastructure investments, and incentives for technology adoption.

**Equity Considerations:** These combined rulemakings will reduce harmful fossil fuel emissions in communities throughout the state. However, communities near highways or industrial hubs—which are predominantly communities of color and low-income communities—have for years disproportionately suffered from air pollution from diesel trucks. Negative impacts in these areas could be addressed by: prioritizing electrification infrastructure to replace trucks along polluted urban highways; supporting the electrification of heavy-duty trucks and equipment at warehouses and industrial facilities in overburdened communities; relocating bus terminals and yards away from already overburdened communities; and limiting the amount of time buses and trucks can idle.

### RECOMMENDATION 2: FACILITATE INVESTMENT IN EV CHARGING INFRASTRUCTURE

**Relevant Agencies:** PUC

**Recommendation Details:** The Public Utilities Commission should direct investor-owned utilities to propose new tariffs that allow them to design, install, and maintain electrical infrastructure and all associated work on the utility side of the meter for all transportation electrification customers outside of single-family homes. In many jurisdictions, these investments are referred to as "utility-side make-ready infrastructure." In this model, the utility can own, install, and maintain the utility side of the make-ready system. Equipment covered includes the transformer and conductor, as well as the trenching, repaving, and conduit to the utility meter. The only elements not covered are the customer-side make-ready and actual charging station.

Make-ready infrastructure can reduce a major barrier to widespread transportation electrification at a scale that has the potential to put significant downward pressure on rates and remove a significant and non-controversial issue from individual utility program applications that must be litigated repeatedly. It can also level the playing field between participants in utility infrastructure programs and customers not covered by these programs, improve certainty for independent market participants, and provide a foundation upon which other utility or state programs can facilitate the build out of transportation electrification infrastructure.

This utility-side make-ready requirement would be layered on top of last year's SB 77, which directed utilities to file applications for programs and investments that could include make-ready infrastructure. This tariff would be additive by making the provision of necessary electrical distribution infrastructure on the utility side of the meter the normal course of utility business. The tariff would obviate the need to litigate the same issue multiple times in the applications SB 77 contemplates and provide support to all customers instead of only to customers participating in utility infrastructure programs, as is the case now, thereby leveling the playing field. The tariff would also take hundreds of thousands of dollars out of the costs of installing charging stations for electric vehicles of all types at a typical site, providing a foundation of support upon which independent firms, state programs, and targeted utility programs can build out the charging network Colorado needs to meet its air quality and climate goals.

**Equity Considerations:** The PUC should ensure programs are created to enable access for multifamily as well as low-income buildings. Outside of homes, the PUC should also prioritize investment in smart charging capabilities and EV charging infrastructure along urban interstate highway corridors and frequently visited locations such as grocery stores, libraries, and hospitals.

### RECOMMENDATION 3: SUPPORT ADOPTION OF ZEV STANDARDS FOR 2026 TO 2035

**Relevant Agencies:** AQCC, CDOT, CEO

**Recommendation Details:** The Low Emission Vehicle and Zero Emission Vehicle (LEV/ZEV) programs and goals created over the last few years in Colorado were critical first steps to reach the levels of electric vehicles we need by 2030, but more work remains. LEV/ZEV programs require automakers to increasingly sell electric cars and trucks and have been adopted by multiple states across the country. Colorado will need to work with all the other LEV/ZEV states to ensure that the waiver allowing California, and thereby allowing other states, to pursue more ambitious standards is reinstated. Once reinstated, all states must ensure the rule is extended beyond 2025 and that the level of ZEV sales sufficient to reach state goals.

Strong 2026 to 2035 ZEV standards will be considered for adoption in California by the end of 2021 and Colorado decision makers will have an opportunity to adopt these standards in 2022. In preparation for the adoption of and alignment with California's standards, there should be a push for at least a 50 percent sales target by 2030 and virtually 100 percent sales by 2035 (including plug-in hybrids in addition to battery electric vehicles). Ensuring that the technical feasibility, economic, equity, consumer market, and environmental studies and analysis occur in 2021 (with stakeholder engagement) will also be important in laying the groundwork for adoption by CDPHE in 2022.

**Equity Considerations:** A key priority for decision makers should be to ensure that adoption of the ZEV standards will ultimately reduce transportation costs, particularly for low-income families and communities of color, and will expand access to zero emission vehicles, as well as other forms of clean mobility. In addition to overcoming the incremental upfront costs, policies must reform EV incentives in Colorado to increasingly be income-based and focused on accessibility over time. Simultaneously, decision makers must also ensure that charging infrastructure programs prioritize investments in underserved communities and communities of color.

### RECOMMENDATION 4: REFORM THE GAS TAX

**Relevant Agencies:** Legislature, DMV

**Recommendation Details:** We recommend that the legislature pass a new bill to revise the tax on gasoline in order to remove disincentives for electric vehicle adoption and create a simple, efficient, and stable source of transportation funding. Fuel-based taxation that encourages reduced fuel consumption and improved efficiency better corresponds with the "user pays" principle, appropriately placing a price on pollution. Beginning in 2022, and every year thereafter, state and local motor-fuel taxes should be indexed to the Consumer Price Index and total fuel consumption. The Colorado Department of Motor Vehicles should be tasked with assessing annual fees on alternative fuel vehicles not otherwise subject to motor-fuel taxes based on the following formula: ($/gallon state motor fuel tax) * (1/the US EPA's miles per gallon equivalent rating of the vehicle in question) * (annual miles driven by the vehicle as reported to the DMV or, in the case of a plug-in hybrid electric vehicle, the estimated number of reported annual miles reported to the DMV that were driven on electricity).

**Equity Considerations:** From a pollution standpoint, improving fuel economy disproportionately benefits low- and moderate-income households because currently they bear disproportionately high effects of air pollution. However, low-income households may only benefit financially if they can actually afford more efficient cars. If not, those driving older, inefficient vehicles may end up locked into paying increasing amounts for transportation. This risk makes accessibility to cleaner and all-electric vehicles even more important. Until electric vehicles are truly accessible to all and adoption rates are higher among low- and moderate-income families, financial assistance programs will be necessary to ensure that low- and moderate-income households can afford more efficient vehicles.

## RECOMMENDATION 5: INVEST IN PUBLIC TRANSIT OPTIONS

**Relevant Agencies:** CDOT, City Governments

**Recommendation Details:** Recognizing that vehicle electrification alone is insufficient to reach ambitious climate goals, state and local governments must implement innovative programs that increase low-carbon transportation choices over single-occupant vehicles, such as high-quality transit and widespread access to walk- and bike-friendly communities. Plans to use state funding, policies, and coordination/planning capacity to reduce vehicle use and associated emissions will be critical to ensure we reach our targets. Local and state transportation funds should prioritize low-carbon mobility options through greenhouse gas performance/vehicle-miles traveled planning and spending criteria and also use funding to incentivize municipal governments to land-use and zoning decisions that help reduce vehicle use and cut emissions. Cities themselves can also play a role by piloting innovative demand management strategies such as pricing to further incent use of transportation choices other than solo driving. Additional policies include electrifying city fleets and buses, promoting commuter incentives, congestion pricing, building more affordable housing near transit, and expanding bicycle and pedestrian networks.

**Equity Considerations:** When discussing public transit, urban settings often come to mind first, but it is important that policymakers do not leave rural communities behind. Rural households spend 7 percent more of their budgets on transportation compared to their urban counterparts. Rural workers also travel 38 percent more than urban workers, and low-income rural workers travel 59 percent more. Colorado is already the national leader in rural transit, and continuing to invest in these systems can help close the divide between rural and urban travelers. Additionally, if transportation options are convenient and reliable, rural and low-income people could avoid some vehicle costs.

## RECOMMENDATION 6: ADOPT A LOW CARBON FUEL STANDARD

**Relevant Agencies:** AQCC, CDOT, CEO

**Recommendation Details:** A low carbon fuel standard (LCFS) drives low-carbon innovation beyond what might occur with a price signal alone. LCFS is a technology-neutral, performance-based greenhouse gas emissions standard for fuels which works by limiting, and over time reducing, the amount of greenhouse gases that can be emitted per unit of transportation energy sold. The standard does not limit the amount of energy, just its carbon intensity, to encourage the use of cleaner fuel sources. Gradually decreasing the intensity standard forces a shift toward cleaner fuels such as electricity and sustainable biofuels that have been independently certified to the Roundtable on Sustainable Biomaterials (RSB) or equivalent standard. The standard also discourages large, long-lived investments in high-carbon dirty fuels such as tar sands, liquid coal, and oil shale. Moreover, a LCFS prevents emissions leakage by evaluating the entire lifecycle of fuels.

Accurate accounting is an important requirement of any LCFS. The standard must account for emissions that occur during fuel production nationally and internationally. These include, for example, the effects of tar sands development in Canada, where upstream fuel production emissions can be three times that of conventional gasoline. The LCFS must also account for indirect land use change emissions, which occur when U.S. land previously dedicated to food is switched to energy crops and the displaced food is instead grown internationally by cultivating land that previously stored vast amounts of carbon.

**Equity Considerations:** While its explicit focus is on carbon pollution, an LCFS would also drive deep reductions in criteria co-pollutants that impair air quality in the state. As with all of the policy recommendations, care should be taken that standards have specific targets and incentives for low-income communities, communities of color, and other pollution burdened residents. For LCFS in particular, leaning too heavily on such a policy without careful consideration of impacts in the 2030 timeframe could be expensive, affect air quality differently across the state, and encourage the use of biomass feedstocks of lower environmental standards.

## BUILDINGS RECOMMENDATIONS

**2025 Milestones for achieving 26 percent reduction in GHGs according to the Core Scenario:**

- Percentage reduction needed by 2025 relative to 2005 levels: 1 percent
- Absolute $CO_2$ emission budget for 2025: 11.9 MMT $CO_2$
- Percentage of new electric space heater sales for residential buildings: 29 percent
- Percentage of electric water heater sales for residential buildings: 27 percent
- Percentage of new homes that are all-electric: 55 percent
- Percentage of existing homes retrofitted with more efficient shells per year: 1 to 3 percent
- Percentage of new commercial electric space heater sales: 12 percent
- Percentage of new commercial electric water heater sales: 4 percent
- Percentage of new commercial electric stove sales: 58 percent

**2030 Milestones for achieving 50 percent reduction in GHGs according to the Core Scenario:**

- Percentage reduction needed by 2030 relative to 2005 levels: 13 percent
- Absolute $CO_2$ emission budget for 2030: 10.2 MMT $CO_2$
- Percentage of new electric space heater sales for residential buildings: 49 percent
- Percentage of electric water heater sales for residential buildings: 47 percent
- Percentage of new homes that are all-electric: All or almost all
- Percentage of homes retrofitted with more efficient shells each year: 2 to 4 percent
- Percentage of new commercial electric space heater sales: 36 percent
- Percentage of new commercial electric water heater sales: 30 percent
- Percentage of new commercial electric stove sales: 91 percent

## RECOMMENDATION 1: ADOPT BUILDING ENERGY CODES THAT MOVE TOWARDS ALL-ELECTRIC NEW CONSTRUCTION STATEWIDE

**Relevant Agencies:** AQCC with cost allocation support from the PUC

**Recommendation Details:** The easiest and cheapest way to abate GHG emissions from buildings is to build clean from the start because it avoids the costs of gas infrastructure. Buildings that are designed to run on clean electricity from day one also avoid the need for more expensive retrofits in later years. Based on our modeling, the standard should set a target of 55 percent of new homes being all electric by 2025, requiring all new homes to be all electric by 2030 or soon thereafter.

One way in which the state can begin this transformation is to adopt the 2021 International Energy Conservation Code (IECC). The code covers building components like insulation, lighting, and water heating efficiency, and will represent the biggest energy efficiency gains in at least a decade for constructing or renovating homes. The 2021 IECC also has requirements that ensure buildings will not face unnecessary costs to transition to running on 100 percent clean electricity. New commercial buildings will also be required to be more efficient. In later years Colorado will have to adopt statewide requirements for all-electric new construction. The 2021 IECC will lay the foundation for this statewide new construction code.

**Equity Considerations:** In many cases, it already is less expensive and faster to build new homes with all-electric appliances. All-electric construction is cheaper because it avoids the costs of gas infrastructure, including connecting gas lines, installing gas meters, and piping gas into the building to run the appliances. Avoiding all of these components can save thousands in land development and construction costs, but intervention from the Colorado PUC will be needed to ensure that these cost reductions flow down to low-income Coloradoans. Also, the AQCC should work with housing developers to create all-electric affordable housing options that incorporate energy storage and resiliency considerations in the event of power outages.

### RECOMMENDATION 2: ELIMINATE RESTRICTIONS ON FUEL-SWITCHING IN UTILITY EFFICIENCY PROGRAMS

**Relevant Agencies:** PUC

**Recommendation Details:** In Colorado, fuel switching (i.e., using an efficiency incentive to reduce end use energy consumption by switching from one fuel to another, such as by replacing an inefficient gas water heater with an electric heat pump water heater that is three or more times as efficient) has arguably been discouraged by outdated regulations. We should be gearing efficiency programs towards GHG reduction, but these rules restrict beneficial and strategic electrification that reduces both total energy use and greenhouse gas emissions. In order to resolve any uncertainty, the PUC must revisit and redesign fuel switching rules to clearly allow and encourage state electrification of end uses today served by combusting fossil fuels.

Specifically, PUC Rule 4756(b) states:

“Fuel switching. Fuel switching from natural gas to other fossil fuel derived energy sources shall not be included in the gas utility’s DSM program. Programs to save natural gas through switching to renewable energy sources such as solar heating and ground source heat pumps are allowed.”

Some have interpreted these rules as disallowing fuel switching from natural gas to electricity because electricity is still in part a “fossil fuel derived energy source.” It would be prudent for the PUC to revisit this rule and explicitly allow for electrification as a form of gas DSM.

**Equity Considerations:** The state should be helping Coloradans moving away from fossil fuels, not creating barriers. Additionally, the more difficult it is to switch from fossil fuel appliances, the slower the adoption will be for low-income customers and the higher the likelihood that low-income customers are stuck paying off the costs of the gas distribution infrastructure.

## RECOMMENDATION 3: MAXIMIZE BUILDING ELECTRIFICATION PROGRAMS

**Relevant Agencies:** PUC, AQCC, Utilities

**Recommendation Details:** The PUC must work with the AQCC to open a docket ensuring building electrification and decarbonization programs are maximized and policies, procedures, and incentives that accelerate the reduction of GHG emissions from buildings are developed. Programs and policies should advance the state's market for low-emission space and water heating technologies by educating consumers, training contractors and vendors, and developing upstream and midstream market programs.

Utilities play a crucial role in developing and carrying out electrification programs as well. They must provide programs and incentives for homes and businesses to shift their space and water heating to super-efficient electric heat pumps and cooking from burning fossil fuels to clean electricity. Where appropriate, programs should incentivize the high efficiency "cold climate" heat pump models that are able to efficiently address heating needs during much more of the Colorado winter than standard air source heat pump products.

As part of the docket, the AQCC and PUC can align customer-facing programs with state energy and environmental policy goals to accelerate the reduction of GHG emissions, improve experiences with utility programs, and create a framework that will inform and improve future programs' alignment with the state's climate targets. In addition to decarbonization strategies, the PUC and AQCC should work together to include an integrated process for long-term planning for gas demand projection, infrastructure maintenance, and the transition to a more limited fossil fuel delivery system.

**Equity Considerations:** It is critical that incentives and financing mechanisms are carved out for low- and moderate-income residents in electrification programs. As gas demand drops, those who are least able to electrify on their own risk being left to cover the escalating costs of a gas system in transition. Protecting Colorado's low-income families will require an approach that is inclusive, equitable, and specifically targets communities that have historically been unable to access energy programs. New policy development, program design, and implementation must all ensure that disadvantaged communities provide input and can access the benefits of decarbonization and that no households are left behind to pay for stranded fossil fuel infrastructure.

The state and workers in this sector will also benefit from a process that takes particular care in the inclusion of workforce development considerations and resources that provide technical assistance along the way. A statewide assessment of existing gas infrastructure, options for infrastructure contraction and other cost reductions, identification of customers that have limited options for electrification, and discussion and planning for a just transition for the gas delivery system workforce will all help put policy makers, utilities, and customers on the best path to transform the system.

### RECOMMENDATION 4: ADOPT AN EXISTING BUILDING PERFORMANCE STANDARD

**Relevant Agencies:** AQCC

**Recommendation Details:** A Building Performance Standard (BPS) is a long-term policy that requires certain buildings to meet minimum energy or carbon efficiency requirements by a given date. The central component of an existing building performance standard for Colorado should be an absolute emissions budget. Our modeling shows that emissions should not exceed 11.7 MMT $CO_2$ in 2025, and 10.5 MMT $CO_2$ in 2030. Based on these goals, AQCC staff should develop mid- and long-term performance requirements appropriate for both residential and commercial buildings and require the adoption of LEED platinum standards or other comparable standards for all existing and new construction of government buildings. Additionally, the AQCC could use Avert or EPA's eGRID data to develop suitable conversions which would need to be done on an ongoing basis with the changing grid.

As part of any existing building performance standard, the state should also adopt tools that can help support transitioning away from fossil fuels in existing buildings, such as energy auditing and disclosure requirements that make it easier to understand, verify, and improve a building's carbon footprint, and new incentives to promote electric equipment. The supporting policies should be made available to building owners well in advance of performance deadlines.

**Equity Considerations:** A building performance standard is an opportunity to decarbonize existing buildings in a way that lifts up communities and avoids unintended consequences on the availability and affordability of local housing. The AQCC should actively engage community stakeholders in planning and implementing building electrification programs so they do not unintentionally harm vulnerable populations. At a minimum, decarbonization policies should be paired with affordable housing preservation and anti-displacement provisions. Those provisions should be shaped by community input, and they should ensure that investments to electrify affordable buildings (deed-restricted or naturally occurring affordable housing) will not result in evictions or residents' inability to cover their living expenses.

Targeted pilots and research should be conducted as part of the rulemaking to better evaluate decarbonization opportunities in multifamily buildings, particularly affordable multifamily housing. There are many examples of all-electric low- and high-rise multi-family buildings that can serve as models for new construction and retrofit projects, but building the capacity to install and operate these solutions will require concerted programmatic effort. Again, it will be important to coordinate with communities and ensure that decarbonization policies are paired with affordable housing preservation policies, including anti-displacement provisions.

In the absence of support, high upfront capital costs will prevent low-income customers from being early adopters of decarbonization. Without the explicit prioritization of low-income and vulnerable communities, these customers run the risk of being stranded on a gas system with increasing costs. For that reason alone, equity must be a leading value in the efforts to decarbonize Colorado's buildings.

## OIL & GAS METHANE RECOMMENDATIONS

- **Policies for achieving the 2025 statewide goal of a 26 percent reduction in GHGs**

  Percentage reduction in 2005 emissions needed by 2025 in Core Case: n/a[14]

  Absolute CO2 emission budget for 2025 in Core Case: 15.8 MMT $CO_2e$

- **Policies for achieving the 2030 statewide goal of a 50 percent reduction in GHGs**

  Percentage reduction in 2005 emissions needed by 2030 in Core Case: 54 percent

  Absolute $CO_2$ emission budget for 2030 in Core Case: 9.2 MMT $CO_2e$

As with all other sectors, there are three components to successfully limiting emissions from the oil and gas sector: (1) setting an emission budget for the sector consistent with achieving the 2025 and 2030 goals in HB-1261; (2) setting performance standards to try to meet the emission budget (e.g., targets for emission rates, requirements to use the most effective emission reduction technology, etc.); and (3) establishing other mechanisms for reducing emissions if the performance standards are insufficient to keep total emissions at or below the emissions budget for the entire sector.

### RECOMMENDATION 1: ADOPT A MASS-BASED METHANE EMISSION LIMIT FOR THE ENTIRE OIL & GAS SECTOR IN COLORADO

**Relevant Agencies:** AQCC

**Recommendation Details:** SB 19-181 authorizes the OGCC to set various standards for oil and gas production, such as monitoring and reporting of methane leaks, targets for methane leakage rates, technology requirements, etc. These standards are critical, as discussed below in Recommendation 2.

14 Given the substantial increase in oil and gas development between 2005 and the present, and the resulting increase in GHG emissions, our modeling shows there is still an increase in oil and gas emissions between 2005 and 2025.

However, these kinds of standards cannot, by themselves, guarantee that total methane emissions from the oil and gas sector stay below the level needed for the state to meet the 2025 and 2030 targets in HB-1261. Limits on the methane leakage rate, or even mass-based limits on leakage from individual wells, leave the total amount of methane emissions subject to chance, because total emissions are equal to the emission rates times the amount of production. Ultimately, if production levels are high enough, even a very low methane leakage rate can lead to total emissions that exceed the overall emissions budget for the oil and gas sector.

Accordingly, to ensure that oil and gas emissions stay within an emission budget that allows the state to meet the goals in HB-1261 state policymakers must adopt a legally binding limit on total methane emissions from oil and gas production.

### RECOMMENDATION 2: ADOPT STRONG RULES TO IMPLEMENT SB 19-181

**Relevant Agencies:** AQCC, OGCC

**Recommendation Details:** SB 19-181 directs the OGCC to minimize methane emissions from the oil and gas sector and HB 19-1261 grants the AQCC authority to issue any rules necessary to achieve the GHG reductions in 1261. The OGCC, the AQCC, or both agencies should adopt technical standards for methane emissions from the oil and gas sector, including production, processing, transportation, distribution, and storage of oil and gas. Standards for methane leak detection and repair and inspecting, monitoring, and reporting methane emissions are critical to reducing methane emissions from the oil and gas sector.

### RECOMMENDATION 3: INCLUDE IN ALL NEW OIL & GAS PERMITS PROVISIONS FOR REOPENING OR REVOKING THE PERMIT IF OIL & GAS METHANE EMISSIONS EXCEED THE 2025 AND/OR 2030 EMISSION LIMITS

**Relevant Agencies:** AQCC, OGCC

**Recommendation Detail**s: If the standards that the OGCC issues under SB 19-181, combined with other initiatives, result in methane emissions that exceed 15.8 MMT $CO_2e$ in 2025, oil and gas production should be limited to the level at which the methane leakage rates multiplied by production equals 15.5 MMT for the year 2026. The production level should then be set for each subsequent year to put the oil and gas sector on a linear emissions trajectory to emit no more than 9.2 MMT $CO_2e$ in 2030.

To do this, the OGCC should issue a rule as soon as possible clarifying that all new oil and gas production permits contain provisions that allow the OGCC to reopen and/or revoke the permit if reported or modeled methane emissions from the oil and gas sector exceed an AQCC-specified emissions budget for 2025 and 2030. In 2025 and 2030, the AQCC would then calculate methane emissions from the entire oil and gas sector. If the sector's emissions exceed the sector's emission budget, the OGCC would reopen and redefine oil and gas permits to reduce production to a level consistent with the sector's emission budget. The OGCC would do this through setting production limits in permits and/or by revoking permits.

In addition, when deciding whether to issue a new permit, the OGCC should analyze whether the expected methane emissions from the new permit are consistent with the overall methane emission budget for the oil and gas sector for 2025 through 2030. The OGCC should not issue new permits if the analysis shows that the permit would be expected to cause the industry's overall methane emissions to exceed the industry's methane emissions budget for any year.

**Equity Considerations:** Significant funding for inspections and enforcement should be set aside and setbacks should be established that protect schools and homes, particularly in low-income communities and communitiea of color.

### RECOMMENDATION 4: CUT OVERALL OIL AND GAS PRODUCTION BY 25 PERCENT BY 2030 RELATIVE TO 2019 PRODUCTION LEVELS

**Relevant Agencies:** AQCC, OGCC

**Recommendation Details:** As discussed earlier, the total methane emissions could potentially still be high even with ambitious leakage rates, if production grows. Therefore, without some ability to control the overall amount of oil and gas production, it will be impossible for the state to ensure that oil and gas methane emissions are at a level consistent with the goals in HB-1261. This issue is one of the reasons we recommend that the AQCC and/or OGCC create a mechanism for reducing oil and gas production—particularly to address a situation in which total methane emissions from oil and gas production exceed the sector's methane emission budget.

Colorado's policies for energy supply should match its policies on energy demand. Both the Roadmap and our analysis show that demand for oil and gas must decline significantly between 2020 and 2030 and decline even more between 2030 and 2050 to meet the HB-1261 targets. In the electric sector, power plants must burn less gas; in the transportation sector, vehicles must burn less gasoline and diesel; in the buildings sector, Coloradans must use less gas for heating and cooking; and industry must burn less gas and petroleum-based fuels as well.

In our modeling, in the Core scenario, demand for oil and gas declines 30 percent by 2030 relative to 2019 (and declines by 40 percent in the Slow Electricity case). Thus, the 25 percent decline in oil and gas production is in line with the decrease in demand that our modeling shows is necessary to meet the state's climate targets.

It is fundamentally incompatible to say, on one hand, that decarbonization requires the state to use less oil and gas by 2030, but on the other hand say that the state should be permitted to produce more oil and gas by 2030. Given that Colorado must reduce demand for oil and gas to meet its climate targets, an increase in oil and gas production in Colorado necessarily means that state policymakers are assuming that other state(s) and/or countries will increase their use of oil and gas. This is a self-defeating climate policy because Colorado can succeed in preventing additional climate change only if other states and countries adopt policies similar to Colorado's. Thus, any comprehensive and effective climate policy cannot be based on Colorado increasing oil and gas production between 2020 and 2030 at the same time that Colorado must reduce oil and gas use by 2030.

For these reasons, the AQCC and OGCC should adopt rules to reduce overall oil and gas output 25 percent by 2030 relative to 2019 production levels. These rules should entail granting only an amount of new permits that is consistent with this overall production limit, and/or restricting the length of the permit and/or the amount of production allowed under the permit.

**Equity Considerations:** With reductions in methane and oil and gas production will come workforce implications that the state must prepare for. These industries have been providing jobs, economic benefits, and funding at the state and local level. State policymakers must develop detailed plans, informed by engagement with communities from the start and supported by the state budget, to ensure a just and equitable transition. If the state assumes that the industry will grow, and it turns out that it economically declines, the economic impacts will be worse than if the state actively plans for a transition and supports communities with economic investment, revenue replacement for local governments, and job training, healthcare, and other support for workers.

## INDUSTRIAL ENERGY AND PROCESSES RECOMMENDATIONS

- **Policies for achieving the 2025 statewide goal of a 26 percent reduction in GHGs**

  Percentage reduction in 2005 emissions needed by 2025 in Core Case: n/a[15]

  Absolute $CO_2$ emission budget for 2025 in Core Case: 22 MMT $CO_2e$

- **Policies for achieving the 2030 statewide goal of a 50 percent reduction in GHGs**

  Percentage reduction in 2005 emissions needed by 2030 in Core Case: n/a

  Absolute $CO_2$ emission budget for 2030 in Core Case: 17 MMT $CO_2e$

### RECOMMENDATION 1: ADOPT A RULE TO REQUIRE ZERO-EMISSION TECHNOLOGIES FOR EQUIPMENT USED IN OIL AND GAS PRODUCTION

**Relevant Agencies:** AQCC

**Recommendation Details:** Upstream GHG emissions from the oil and gas sector include not just the methane emissions discussed previously but also $CO_2$ emissions from burning gas in equipment used to produce, process, and transport oil and gas. The AQCC should adopt a rule requiring the use of zero-emissions technologies for certain gas-fired equipment used in oil and gas operations, including engines, controllers, compressors, and pumps. This rule should set a zero-emission standard for all lean burn engines and all rich burn engines with greater than 100 horsepower. The AQCC could allow for exemptions from this requirement in limited circumstances where electrification may be infeasible, particularly locations in which it would be prohibitively expensive to access the electric grid. Several studies, including analyses from the California Air Resources Board and Southwest Energy Efficiency Project, have concluded that electric engines cost less for both capital and fuel costs than gas-power engines, for certain sizes and classes of engines (particularly smaller engines). Thus, in many instances, electrifying the engines used in oil and gas operations can actually save operators money compared to the use of gas-fired engines.

15 Given the substantial increase in oil and gas development between 2005 and the present and the resulting increase in industrial energy use, industrial $CO_2$ emissions do not decline below 2005 levels by 2025 or 2030 even with the substantial reductions from today's emissions levels.

### RECOMMENDATION 2: ENACT A "BUY CLEAN" PROVISION TO INCENTIVIZE PUBLICLY PURCHASED INDUSTRIAL PRODUCTS TO BE INCREASINGLY LOW EMISSIONS

**Relevant Agencies:** AQCC, legislature

**Recommendation Details:** Colorado has a diverse manufacturing sector that produces metals, cement and concrete products, glass, chemicals, plastics and rubber, and other products. The state must reduce emissions from these manufacturing sectors through electrification, efficiency, and use of low-carbon fuels to meet its climate goals. Through a mix of transparency and disclosure requirements, standards, and incentives, a Buy Clean rule can help policymakers leverage state and local government procurement to encourage manufacturing facilities to develop lower emissions practices. Such a policy should require companies to track and report the embodied carbon emissions of their products (the emissions released in producing and transporting the product) via an Environmental Product Declaration (EPD)—or comparable mechanisms subject to high standards of consistency and verification—when bidding for publicly funded projects (e.g., expansion or renovation of public transit); establish a requirement for procured products to meet minimum $CO_2$ emissions performance standards that decline over time; and provide financial incentives to help instate facilities retool and offer products with lower $CO_2$ emissions intensity to meet those standards. Colorado should also incentivize more ambitious reductions in emissions intensity above the minimum threshold by applying discount rates to qualifying bids from instate producers that use the lowest carbon ingredients and processes. The rule should apply to energy-intensive products that are commonly procured, including but not limited to iron, steel, and concrete.