Pathways to Energy Affordability in Colorado

A report prepared by Physicians, Scientists, and Engineers for Healthy Energy and the Institute for Energy and Environmental Research for the Colorado Energy Office

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PSE is a multidisciplinary, nonprofit research institute dedicated to supplying evidence-based scientific and technical information on the public health, environmental, and climate dimensions of energy production and use. PSE puts its mission into practice by integrating scientific understanding across multiple disciplines, including engineering, environmental science, and public health. PSE conducts original research, translates existing research for nontechnical audiences, and disseminates scientific information and analyses to inform policy at the local, state, and federal levels.

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Table of Contents

SECTION 1

Overview of Energy Affordability and Energy Cost Burden

1.1 Introduction

1.1.1 Background

Access to energy is a fundamental pillar of modern society and an imperative for daily existence. It underlies every aspect of human life and plays a critical role in maintaining public health, individual well-being, and economic growth. Energy affordability is thus equally critical. Energy cost is a persistent burden for low-income communities across the country and is increasingly viewed as a major equity concern by both policymakers and energy equity advocates.[1] Results from the most recent U.S. Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS) indicate that in 2015, nearly one in three U.S. households struggled with their energy bills, one in five households reported reducing or skipping essentials like food and medicine to pay their energy bills, and one in seven reported receiving a disconnection notice for energy service.[2] In Colorado in 2015, approximately one in 10 households spent more than 10 percent of their income on utility bills and were classified as energy impoverished by the Colorado Energy Office (CEO).[3]

Energy affordability is commonly quantified in terms of ***energy cost burden***—the percentage of household income spent on residential energy needs. These can include electricity, gas, and fuels such as propane or biomass. Other metrics for energy burden are occasionally used and are reviewed in the following pages. As a metric, energy cost burden helps us visualize energy affordability. Energy cost burden is also a key driver of energy insecurity, defined as the inability of a household to meet their basic energy needs.[4] Low-income households tend to spend a larger fraction of their income on energy bills compared to other income groups because household incomes vary more widely than household energy consumption. This is true, even though

1 Drehbol, A. and Ross, L. (2016). Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities. *American Council for an Energy-Efficient Economy (ACEEE)*. https://aceee.org/research-report/u1602

2 Berry, C., Hronis, C., and Woodward, M. (2018). One in Three U.S. Households Faces a Challenge in Meeting Energy Needs. Today in Energy, U.S. Energy Information Administration. www.eia.gov/todayinenergy/detail.php?id=37072

3 Colorado Energy Office. (2015). Analysis of the Fulfillment of the Low-Income Carve-Out for Community Solar Subscriber Organizations. https://www.colorado.gov/pacific/sites/default/files/atoms/files/CEO%20Low-Income%20Community%20Solar%20Report.

4 Hernández, D. (2013). Energy Insecurity: A Framework for Understanding Energy, the Built Environment, and Health Among Vulnerable Populations in the Context of Climate Change. *American Journal of Public Health*, *103*(4), e32–e34. https://doi.org/10.2105/AJPH.2012.301179

low-income households tend to consume less energy per household on average.[5] Besides impacting low-income households, high energy burdens also tend to have disproportionate impacts along racial lines—studies have identified higher energy burdens within communities of color even when controlling for household income.[6,7,8]

Racial and ethnic backgrounds play significant roles in both income disparity and energy burden. While 12 percent of Coloradan families live in poverty, the poverty rate for White households is 8.7 percent. The poverty rates for Black, Indigenous, and Latino households in Colorado are 19.5 percent, 20.6 percent, and 21.4 percent, respectively. Likewise, the median energy burden for White households in Colorado is 3.3 percent, compared to 4.1 percent for Latino households and 5.4 percent for Black households.[9]

Black, Indigenous, and People of Color (BIPOC) communities often experience the highest energy cost burdens when compared with more affluent or White communities.[10] Systemic and structural inequities have contributed to this disparity between racial and ethnic groups, from federal government-sponsored segregation in housing (pushing Black households and other people of color out of suburban neighborhoods and into urban housing) to redlining (refusing to insure mortgages in and around Black neighborhoods).[11] These policies, as well as discriminatory lending practices, employment discrimination, and a legacy of segregated and underfunded schools, among other systemic barriers, have had massive impacts on economic and social inequality between racial groups that persist to this day.[12,13,14]

Because of such systemic exclusions, BIPOC communities also tend to live in less efficient and less healthy homes, and may experience

5 Krieger, E., Lukanov, B. et al. (2020). Equity-Focused Climate Strategies for Colorado: Socioeconomic and Environmental Health Dimensions of Decarbonization. *Physicians, Scientists, and Engineers for Healthy Energy.* https://www.psehealthyenergy.org/our-work/programs/clean-energy/western-states-deep-decarbonization/colorado/

6 Kontokosta, C., Reina, V., and Bonczak, B. (2019). Energy Cost Burdens for Low-Income and Minority Households. *Journal of the American Planning Association,* 86 (1): 89–105. doi.org/10.1080/01944363.2019.1647446

7 Lyubich, E. (2020). The Race Gap in Residential Energy Expenditures. *Energy Institute at HAAS*, WP-306. https://haas.berkeley.edu/wp-content/uploads/WP306.pdf

8 Krieger, E., Lukanov, B. et al. (2020). Equity-Focused Climate Strategies for New Mexico: Socioeconomic and environmental Health Dimensions of Decarbonization. *Physicians, Scientists and Engineers for Healthy Energy (PSE)*. https://www.psehealthyenergy.org/our-work/programs/clean-energy/western-states-deep-decarbonization/new-mexico/

9 Dobos, H. and Artale, E. (2017). Insights from the CEO Low-Income Community Solar Demonstration Project. *Colorado Energy Office.* https://lpdd.org/wp-content/uploads/2020/12/Insights-from-the-CEO-Low-Income-Community-Solar-Demonstration-Project.pdf

10 Drehobl, A., Ross, L., and Ayala, R. (2020). How High are Household Energy Burdens? *American Council for an Energy-Efficient Economy (ACEEE).* https://www.aceee.org/sites/default/files/pdfs/u2006.pdf

11 Gross, T. (2017). A 'Forgotten History' Of How The U.S. Government Segregated America. *NPR.* https://www.npr.org/2017/05/03/526655831/a-forgotten-history-of-how-the-u-s-government-segregated-america

12 Danyelle Solomon, C. M. (2019, August 7). *Systematic Inequality and Economic Opportunity.* Center for American Progress. https://www.americanprogress.org/issues/race/reports/2019/08/07/472910/systematic-inequality-economic-opportunity/

13 Lombardo, C. (2019). Why White School Districts Have So Much More Money. *NPR.* https://www.npr.org/2019/02/26/696794821/why-white-school-districts-have-so-much-more-money

14 Jargowsky, P. (2015). Architecture of Segregation: Civil Unrest, the Concentration of Poverty, and Public Policy. *The Century Foundation.* https://tcf.org/content/report/architecture-of-segregation/?agreed=1

higher costs when investing in energy efficiency upgrades.[15,16,17] BIPOC and low-income households are more often renters, more often struggle to pay fluctuating bills, face the risk of utility shutoffs, and otherwise struggle with energy insecurity, which can exacerbate underlying health conditions and reduce resilience to climate extremes.[18] In addition, studies have found that low-income and BIPOC communities are disproportionately exposed to air pollution[19] and are more likely to live near fossil fuel infrastructure facilities[20,21] that are associated with adverse health effects.[22,23,24]

Assessing cumulative socioeconomic and environmental burdens can help identify populations for whom interventions to alleviate energy cost burdens may prove particularly beneficial on multiple fronts. California uses the CalEnviroScreen environmental justice screening tool to identify *disadvantaged communities* and direct funding to increase clean energy access and reduce pollution burdens for these populations.[25] The U.S. Environmental Protection Agency (EPA) uses EJSCREEN to identify similar highly polluted and socioeconomically vulnerable populations nationwide.[26] The State of Colorado defines *disproportionately impacted communities* as the census block groups where the proportion of low-income, minority, or housing cost-burdened households is greater than 40 percent, or any other community that has a history of environmental racism perpetuated through redlining and other discriminatory practices, as well as communities where multiple socioeconomic stressors, environmental burdens, environmental degradation, and lack of public participation may act cumulatively to affect health and the environment and contribute to persistent disparities.[27] Colorado has recently developed a

15 Lewis, J., Hernandez, D., and Geronimus, A. (2019). Energy Efficiency as Energy Justice: Address Racial Inequalities throughInvestments in People and Places. *Energy Efficiency, 13,* 419–32. doi.org/10.1007/s12053-019-09820-z.

16 Reames, T. G. (2016). Targeting Energy Justice: Exploring Spatial, Racial/Ethnic and Socioeconomic Disparities in Urban Residential Heating Energy Efficiency. *Energy Policy*, *97*, 549-558.

17 Reames, T. G., Reiner, M. A., and Stacey, M. B. (2018). An Incandescent Truth: Disparities in Energy-Efficient Lighting Availability and Prices in an Urban US County. *Applied Energy*, *218*, 95-103.

18 The Race and Energy Nexus. (2021). *Pecan Street*. https://www.pecanstreet.org/raceenergynexus/

19 Tessum, C. W., et al. (2019). Inequity in Consumption of Goods and Services Adds to Racial–Ethnic Disparities in Air Pollution Exposure. *Proceedings of the National Academy of Sciences 116.13,* 6001-6006. https://www.pnas.org/content/116/13/6001

20 Thind, M. P., Tessum, C. W., Azevedo, I. L., and Marshall, J. D. (2019). Fine Particulate Air Pollution from Electricity Generation in the US: Health Impacts by Race, Income, and Geography. *Environmental Science & Technology, 53*(23), 14010-14019.

21 Krieger, E. M., Casey J.A., and Shonkoff, S.B.C. (2016). A Framework for Siting and Dispatch of Emerging Energy Resources to Realize Environmental and Health Benefits: Case Study on Peaker Power Plant Displacement. *Energy Policy 96*, 302-313. https://www.sciencedirect.com/science/article/abs/pii/S0301421516302798

22 Liu, X., Lessner, L., and Carpenter, D.O. (2012). Association Between Residential Proximity to Fuel-Fired Power Plants and Hospitalization Rate for Respiratory Diseases. *Environmental Health Perspectives 120.6,* 807-810. https://ehp.niehs.nih.gov/doi/10.1289/ehp.1104146

23 Ha, Sandie, et al.(2015). Associations Between Residential Proximity to Power Plants and Adverse Birth Outcomes. *American Journal of Epidemiology 182.3*, 215-224. https://academic.oup.com/aje/article/182/3/215/167933

24 Casey, Joan A., et al. (2018). Retirements of Coal and Oil Power Plants in California: Association with Reduced Preterm Birth Among Populations Nearby. *American Journal of Epidemiology 187.8,* 1586-1594. https://academic.oup.com/aje/article/187/8/1586/4996680

25 California Office of Environmental Health Hazard Assessment. CalEnviroScreen. https://oehha.ca.gov/calenviroscreen

26 U.S. Environmental Protection Agency. EJSCREEN. https://www.epa.gov/ejscreen

27 Colorado Senate Bill 21-272 (2021) and House Bill 21-1266 (2021).

Climate Equity Data Viewer to identify disproportionately impacted populations in the state and prioritize engagement efforts in those communities.[28]

1.1.2 Programs and Policies to Alleviate Energy Burden

Energy efficiency measures and clean energy interventions can help alleviate energy cost burdens. Efficient appliances and building weatherization can lower electric bills or the need for heating and cooling, while rooftop solar and community solar gardens can provide long-term economic savings and more stable electric bills. Unfortunately, low-income and BIPOC communities often face numerous social, economic, and informational barriers that impact their ability to access energy efficiency and clean energy resources, including limited access to financing, lack of information, linguistic isolation, split incentives between landlords and tenants (many low-income and BIPOC households are renters[29]), and others. Technologies like solar panels and heat pumps remain capital-intensive, even if they save money over the lifetime of the equipment. Energy efficiency programs that are not demographically targeted rarely reach low-income, BIPOC, and renter households[30,31] and solar adoption rates are disproportionately low in low-income, BIPOC, and disadvantaged communities.[32,33] Many energy efficiency, solar, and electric vehicle incentives are financed by raising fixed utility recovery charges on all customers, which underscores the need for targeted programs to ensure that costs are not shifted to non-adopters.

A number of programs and policies within the US do directly target low-income households with the goal of alleviating energy cost burdens. The two largest federal programs are the Low-Income Home Energy Assistance Program (LIHEAP) and the Weatherization Assistance Program (WAP). LIHEAP is a bill assistance program operated by the U.S. Department of Health and Human Services (HHS). It began in the 1970s in response to increasing energy prices and currently provides essential heating and

28 Climate Equity Data Viewer BETA Version. https://storymaps.arcgis.com/stories/be558ce8cb1f49f98a18d35d36d8156b. Colorado EnviroScreen will be launched in summer 2022. See: https://cdphe.colorado.gov/enviroscreen.

29 Non-Hispanic White Americans have a household ownership rate of 73 percent, as compared to 43 percent among Black Americans and 47.5 percent among Hispanic or Latino Americans. See: USAFacts. (2020). *Homeownership rates show that Black Americans are currently the least likely group to own home.* https://usafacts.org/articles/homeownership-rates-by-race/

30 Frank, M., and S. Nowak. (2016). Who's Participating and Who's Not? The Unintended Consequences of Untargeted Programs. *In Proceedings of the 2016 ACEEE Summer Study on Energy Efficiency in Buildings 2: 1–13. Washington, DC: ACEEE.* aceee.org/files/proceedings/2016/data/papers/2_542.pdf.

31 Samarripas, S. and York, D. (2019). Closing the Gap in Energy Efficiency Programs for Affordable Multifamily Housing. *ACEEE.* aceee.org/research-report/u1903.

32 Sunter, D., Castellanos, S., and Kammen, D. (2019). Disparities in Rooftop Photovoltaics Deployment in the United States by Race and Ethnicity. *Nature Sustainability 2.1*, 71-76. https://www.nature.com/articles/s41893-018-0204-z

33 Lukanov, B. R., Krieger, E. M. (2019). Distributed Solar and Environmental Justice: Exploring the Demographic and Socio-Economic Trends of Residential PV Adoption in California. *Energy Policy 134*, 110935. https://doi.org/10.1016/j.enpol.2019.110935

cooling assistance to 5.3 million households with an annual budget of $3.75 billion.[34] LIHEAP allocates funding to states which is then distributed to qualified households based on income eligibility and established federal or state criteria (typically 150 percent of the Federal Poverty Level or 60 percent of State Median Income).

WAP is the federally-funded Weatherization Assistance Program that aims to provide a more long-term solution to energy cost burden by improving energy efficiency in low-income households and thereby reducing residential energy expenditures. Created in 1976 and operated by the U.S. Department of Energy, WAP provides grants to US states, territories, and tribes, which then allocate the grants to local weatherization agencies. Households with incomes up to 200 percent of the Federal Poverty Level or 60 percent of the State Median Income can qualify for WAP funding. Collaboration between WAP and LIHEAP has proven valuable as LIHEAP recipients with high energy cost burdens can be referred directly to WAP for services. In addition, up to 15 percent (or 25 percent with a waiver) of LIHEAP funding can be spent on weatherization at the discretion of the authorizing state agency.

Two additional federal programs have been used to reduce energy cost burdens in low-income communities. The Energy Efficiency and Conservation Loan Program (EECLP) is run by the Rural Utility Service for the U.S. Department of Agriculture (USDA) and provides funding for energy efficiency and conservation programs in rural electric cooperatives that serve towns with no more than 20,000 inhabitants.[35] The Low-Income Housing Tax Credit (LIHTC) Program, managed by the U.S. Department of Housing and Urban Development (HUD), is the primary federal resource for creating affordable rental housing in the US. It has supported more than 3.2 million housing units to date.[36]

In Colorado, LIHEAP is implemented through the state's Low-Income Energy Assistance Program (LEAP) run by the Colorado Department of Human Services (CDHS). LEAP offers financial assistance for low-income Colorado residents to offset heating costs, as well as a heating repair and replacement program for those with broken heating systems called the Crisis Intervention Program (CIP). The eligibility limit for LEAP is 60 percent of Colorado's State Median Income.

Regulated utility companies in Colorado are required to offer a percentage of income payment plan (PIPP) that caps energy bills at an affordable percentage of household income. Colorado caps affordable electricity costs at six percent of income for households with electric heating.[37] For households with gas heating, electricity and gas costs are capped at three percent each.[38] As such, most

34 U.S. Department of Health and Human Services. (2021). LIHEAP Fact Sheet 2021. https://www.acf.hhs.gov/sites/default/files/documents/ocs/LIHEAP%20FactSheet-July%202021.pdf

35 US Department of Agriculture. Energy Efficiency and Conservation Loan Program. https://www.rd.usda.gov/programs-services/electric-programs/energy-efficiency-and-conservation-loan-program

36 U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Low-Income Housing Tax Credit (LIHTC). https://www.huduser.gov/portal/datasets/lihtc.html

37 Rules Regarding Electric Utilities 4 CCR 723-3.

38 Rules Regarding Gas Utilities 4 CCR 723-4.

PIPP-qualified households have their energy cost burden capped at six percent of income with the exception of households with both electric heating and gas services for other uses (such as cooking and hot water heating). Eligible households are currently limited to those with income at or below 185 percent of the Federal Poverty Level. This enables a greater number of households to qualify for PIPP compared to PIPPs in other states, which are often capped at 150 percent of Federal Poverty Level.[39] The PIPP eligibility ceiling, however, is still set lower than the 60 percent State Median Income limit for LEAP, which translates to above 200 percent of the Federal Poverty Level (except for households of seven or more).

Colorado's WAP program is administered by the CEO. It provides low-income residents with energy efficiency, beneficial electrification, and rooftop solar installations to increase energy cost savings. In addition, the non-profit organization Energy Outreach Colorado (EOC) provides free energy efficiency upgrades through their Colorado's Affordable Residential Energy (CARE) program as well as weatherization services through their Multifamily Weatherization Assistance Program and Affordable Housing Rebate Program. EOC also works to improve energy affordability for low-income Colorado residents by offering bill payment assistance, heating system repair and replacement through CIP, community solar garden subscriptions, and energy education.[40] Colorado state and federal energy assistance programs and their eligibility requirements are summarized in **Table 1.1**.

Table 1.1 List of Energy Assistance Programs.

Program Name	Program Type	State/ Federal	Eligibility Limits	Participation Rate[41]
Low-Income Home Energy Assistance Program (LIHEAP)	Utility bill assistance	Federal (HHS)	Income: 150% of Federal Poverty Level or 60%t of State Median Income	22% (Nationally)[42]
Weatherization Assistance Program (WAP)	Improve home energy efficiency to reduce energy expenses long-term	Federal (DOE)	Income: 200% of Federal Poverty Limit, or if qualified for LIHEAP or Title IV or XVI of the Social Security Act	19.4%[43]
Energy Efficiency and Conservation Loan Program (EECLP)	Provides loans to rural electric utilities to fund energy efficiency programs	Federal (USDA)	Rural towns with less than 20,000 inhabitants	N/A

39 Howat, J., Lusson, K. and Wein, O. (December 7, 2020). Utility Bill Affordability in Colorado. *National Consumer Law Center (NCLC).* Filed as Attachment A to Decision No. R20-0842-I in Proceeding No. 20M-0267EG of the Colorado PUC.

40 Energy Outreach Colorado. https://www.energyoutreach.org/

41 Given as a percent of eligible households.

42 Congressional Research Service. (2015). Need-Tested Benefits: Estimated Eligibility and Benefit Receipt by Families and Individuals. https://crsreports.congress.gov/product/pdf/R/R44327

43 Community Action Partnership. (2018). Estimated Number of Households Income-Eligible for the Department of Energy Weatherization Assistance Program as of 2015. https://communityactionpartnership.com/wp-content/uploads/2018/07/Estimated-Number-of-Households-Income-Eligible-for-WAP.pdf

Program Name	Program Type	State/ Federal	Eligibility Limits	Participation Rate[41]
Low-Income Housing Tax Credit (LIHTC)	Tax credits to state and territorial governments who award these credits to private developers to build subsidized, affordable housing	Federal (HUD)	Rental properties must meet one of three criteria: 1. At least 20% of units are occupied by tenants with income less than 50 percent of Area Median Income, 2. At least 40% of units occupied by tenants with income 60 percent or less of Area Median Income, 3. No units occupied by tenants with income greater than 80% of Area Median Income.	19.9%[44]
Low-Income Energy Assistance Program (LEAP)	Financial assistance to households with high heating costs	State (Colorado DHS)	60% of Colorado's Area Median Income	15%[45]
Crisis Intervention Program (CIP)	Repair and replacement of broken heating systems	State (Colorado DHS)	Primary home heating source is faulty or inoperable, household qualifies and is approved for LEAP	N/A
Colorado WAP	Provision of energy efficiency, rooftop solar, and other benefits to low-income households	State (CEO)	Income: 60% of State Median Income, or if qualified for LIHEAP, Temporary Aid to Needy Families (TANF), Supplemental Security Income (SSI), Aid to the Needy Disabled (AND), Supplemental Nutrition Assistance Program (SNAP), or Title IV or Title XVI of the Social Security Act.	12%[46]
Colorado's Affordable Residential Energy (CARE)	Energy efficiency upgrades for low-income households	State (Nonprofit–EOC)	Household is in a participating county and serviced by a participating utility,[47] meets income requirements (80% of Area Median Income)	N/A
Percentage of Income Payment Plan (PIPP)	Assistance plan through utilities to cap low-income household energy bills at 6% of income	State (Colorado Investor Owned Utilities)	Household income at or below 185 percent Federal Poverty Level, household qualifies for LEAP	8%[48]

44 Divided number of units built by LIHTC (from HUD's Office of Policy Development and Research) by the total number of affordable housing units in the US (from the National Low Income Housing Coalition).

45 Offenstein, J., Johnson, C., Bohannan, T., and Thomas, A. (2020). Evaluation of Percentage of Income Payment Plans. *ADM Associates.* https://www.admenergy.com/experience/colorado-energy-office-process-evaluation/

46 Colorado Energy Office. (2017, December). *Insights from the CEO Low-Income Community Solar Demonstration Project.* https://lpdd.org/wp-content/uploads/2020/12/Insights-from-the-CEO-Low-Income-Community-Solar-Demonstration-Project.pdf

47 Energy Outreach Colorado. (2021). *Colorado's Affordable Residential Energy Program (CARE).* https://www.energyoutreach.org/programs-for-individuals/care-program/

48 Offenstein, J., Johnson, C., Bohannan, T., and Thomas, A. (2020). Evaluation of Percentage of Income Payment Plans. *ADM Associates.* https://www.admenergy.com/experience/colorado-energy-office-process-evaluation/

Despite the existence of various bill assistance, weatherization, and energy efficiency programs, low-income and BIPOC communities remain a hard-to-reach group with many barriers to participation.[49] The federal LIHEAP program falls short of meeting overall need—it serves between 20 and 25 percent of eligible households.[50] The participation rate for PIPP in Colorado is estimated to be eight percent, indicating that the vast majority of qualified customers are not enrolled.[51] In general, the weatherization and energy efficiency needs of low-income and BIPOC communities far exceed available resources. Researchers have identified distributional disparities in low-income investments: utility companies often do not proportionally invest in energy efficiency programs designed to reach these populations.[52] A 2018 study found that only six percent of all US energy efficiency spending in 2015 was dedicated to low-income programs.[53] Unlike Colorado, many states impose cost-effectiveness requirements on utility energy efficiency programs, which place an additional burden on low-income programs because of their generally higher recruitment and installation costs, and because non-energy health, equity, and resilience benefits are not included in program planning and cost evaluations.[54] Overall, the US is continuing to experience growing wealth inequality and growing clean energy adoption disparities between BIPOC and White communities.[55,56] The confluence of energy burden and clean energy adoption disparities, wealth inequality, ethnicity, race, and socioeconomic class leads to issues of distributive, procedural, and intergenerational injustice.[57]

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49 Drehbol, A. and Ross, L. (2016). Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency can Improve Low Income and Underserved Communities. *American Council for an Energy-Efficient Economy (ACEEE).* https://aceee.org/research-report/u1602

50 Jackson, A. (2011). Fact Sheet: The Low Income Home Energy Assistance Program: A Critical Resource for Low-Income Households. *Washington, DC: AARP (American Association of Retired Persons) Public Policy Institute.* assets.aarp.org/rgcenter/consume/fs138_liheap.pdf.

51 Offenstein, J., Johnson, C., Bohannan, T., and Thomas, A. (2020). Evaluation of Percentage of Income Payment Plans. *ADM Associates.* https://www.admenergy.com/experience/colorado-energy-office-process-evaluation/

52 Reames, T., Stacey, B., and Zimmerman, M. (2019). A Multi-State Analysis of Equity in Utility-Sponsored Energy Efficiency Investments for Residential Electric Customers. *Ann Arbor: University of Michigan*. poverty.umich.edu/files/2019/05/Energy_efficiency.pdf.

53 Environmental Defense Fund (EDF). (2018). Low-Income Energy Efficiency: A Pathway to Clean, Affordable Energy for All. *EDF.* www.edf.org/sites/default/files/documents/liee_national_summary.pdf.

54 Drehobl, A. Ross, L. and Ayala, R. (2020). How High are Household Energy Burdens? *American Council for an Energy-Efficient Economy (ACEEE).* https://www.aceee.org/sites/default/files/pdfs/u2006.pdf

55 Reames, T. G. (2016). Targeting Energy Justice: Exploring Spatial, Racial/Ethnic and Socioeconomic Disparities in Urban Residential Heating Energy Efficiency. *Energy Policy,* 97, 549-558. https://doi.org/10.1016/j.enpol.2016.07.048

56 Sunter, D.A., Castellanos, S., and Kammen, D.M. (2019). Disparities in Rooftop Photovoltaics Deployment in the United States by Race and Ethnicity. *Nature Sustainability 2,* 71–76. https://www.nature.com/articles/s41893-018-0204-z

57 Carley, S. and Konisky, D. M. (2020). The Justice and Equity Implications of the Clean Energy Transition. *Nature Energy,* 5(8), 569-577. https://www.nature.com/articles/s41560-020-0641-6

1.2 Energy Affordability and Social Justice

Energy access and energy affordability have profound implications on human life, happiness, and welfare. Unaffordable energy can limit energy access for vulnerable populations and can lead to unique social harms and economic inequalities. Concerns related to these issues constitute the foundation of a rapidly growing field of scholarship on energy justice. Too often, energy policy discussions and technical analyses are framed in an ethical and normative vacuum, without incorporating broader social justice concerns.[58] Concepts from ethics and social justice, however, can provide an important framework to reexamine and remake a global energy system in transition.

Energy justice discussions often revolve around the concepts of energy insecurity and fuel poverty. Energy insecurity refers to the uncertainty that a household might face in being able to meet its basic energy needs.[59,60] Fuel poverty refers to the inability of a household to afford essential energy services for adequate heating and cooling resulting in health ramifications, material deprivation, or debt.[61] The two terms are often used interchangeably. High energy cost burdens produce both energy insecurity and fuel poverty. Unlike energy cost burden, however, energy insecurity and fuel poverty are more than just a straightforward relationship between household income and energy costs—they require understanding of energy policy, housing infrastructure, socioeconomic relations,

58 Sovacool, B. K., Heffron, R. J., McCauley, D., and Goldthau, A. (2016). Energy Decisions Reframed as Justice and Ethical Concerns. *Nature Energy, 1*(5), 1-6. https://doi.org/10.1038/nenergy.2016.24

59 Hernández, D. (2013). Energy Insecurity: A Framework for Understanding Energy, the Built Environment, and Health Among Vulnerable Populations in the Context of Climate Change. *American Journal of Public Health, 103*(4), e32–e34. https://doi.org/10.2105/AJPH.2012.301179

60 Hernández, D. (2016). Understanding 'Energy Insecurity' and Why it Matters to Health. *Soc. Sci. Med. 167,* 1–10. https://doi.org/10.1016/j.socscimed.2016.08.029

61 Reames, T. G. (2016). Targeting Energy Justice: Exploring Spatial, Racial/Ethnic and Socioeconomic Disparities in Urban Residential Heating Energy Efficiency. *Energy Policy, 97,* 549-558. https://doi.org/10.1016/j.enpol.2016.07.048

and historic inequities.[62,63] Researchers have advocated for a "relational approach" that incorporates various factors that are part of the lived experience of the poor, including material conditions of the home, lack of understanding of energy conservation and efficiency, lack of coordination between housing, health, and energy policies, etc.[64,65] Conceptualizing energy insecurity as an energy justice concern speaks to the nature of energy as a physical necessity and a basic human need.[66,67] Consequently, energy insecurity and fuel poverty can be viewed as violations of the basic principle of *distributive justice*, which is concerned with how social benefits and burdens are distributed in society.

Distributive justice theorists argue that all members of society have the right to equal treatment and that "outcomes," which can be either public benefits or public burdens, should be allocated fairly.[68] People should, therefore, be entitled to a set of basic modern energy services that enable them to enjoy a basic minimum of wellbeing. Viewing access to affordable energy as a basic human right therefore requires the equitable implementation of energy policies and energy resources to ensure access to clean and affordable energy for all people and to remediate historic harms caused by the current energy system.[69]

Although energy insecurity and fuel poverty are fundamentally the concerns of distributive justice, they are also the result of *procedural injustices* related to lack of access to information, lack of participation in decision-making, or lack of access to legal processes.[70] Procedural justice is concerned with the fairness and transparency of the processes that allocate resources and resolve disputes. Inclusive engagement of marginalized communities in the processes that develop and implement energy programs and policies is therefore key to procedural equity.[71] In addition, people who perceive a process as fair are more likely to accept decisions resulting from that process and are more likely to trust the institutions implementing it and making the final decisions.[72]

In addition to the distributive and procedural aspects of energy justice, another

62 Harrison, C. and Popke, J. (2011). Because You Got to Have Heat: The Networked Assemblage of Energy Poverty in Eastern North Carolina. *Ann. Assoc.Am.Geogr.101* (4), 949–961. https://doi.org/10.1080/00045608.2011.569659

63 The Race and Energy Nexus. (2021). *Pecan Street.* https://www.pecanstreet.org/raceenergynexus/

64 Hernández, D. and Bird, S. (2010). Energy Burden and the Need for Integrated Low-Income Housing and Energy Policy. *Poverty & Public Policy, 2*(4), 5-25. https://doi.org/10.2202/1944-2858.1095

65 Buzar, S. (2007). Energy poverty in Eastern Europe: Hidden Geographies of Deprivation. *Ashgate Publishing, Ltd.*

66 Shue, H. (2011). The Ethics of Global Climate Change. *ed. Arnold, D. G. Cambridge Univ. Press.*

67 Caney, S. (2005). Cosmopolitan Justice, Responsibility, and Global Climate Change. *Leiden Journal of International Law 18,* 747–775. https://doi.org/10.1017/S0922156505002992

68 Rawls, J. (1971). A Theory of Justice. *Belknap Press.*

69 Lanckton, T. and DeVar, S. (2021). Justice in 100 Metrics. *Initiative for Energy Justice.* https://iejusa.org/justice-in-100-report/

70 Reames, T. G. (2016). Targeting Energy Justice: Exploring Spatial, Racial/Ethnic and Socioeconomic Disparities in Urban Residential Heating Energy Efficiency. *Energy Policy, 97,* 549-558. https://doi.org/10.1016/j.enpol.2016.07.048

71 Curti, J., Andersen, F., and Wright, K. (2018). A Guidebook on Equitable Clean Energy Program Design for Local Governments and Partners. *The Cadmus Group.* https://cadmusgroup.com/papers-reports/a-guidebook-on-equitable-clean-energy-program-design-for-localgovernments- and-partners/

72 Lind, E.and Tyler, T. (1988). The Social Psychology of Procedural Justice. *Plenum Press.*

dimension can be added when considering *intergenerational justice* related to society's obligation to future generations. In the field of clean energy, intergenerational considerations frequently revolve around greenhouse gas emissions and their climate impacts. Clean energy programs contribute positively to intergenerational equity by reducing greenhouse gas emissions and mitigating global climate impacts related to human activity. How such programs impact the social, economic, and public health dimensions of intergenerational equity at a local level has generally received much less attention.[73]

With these considerations in mind, researchers have worked to develop a conceptual framework for energy justice. This framework delineates a global energy system that distributes the benefits and costs of energy services and resources fairly, corrects for historic and systemic inequities, and contributes to a fully representative and impartial energy decision-making process.[74] It demands that we accurately determine how energy-related costs and benefits are distributed in society and requires participatory governance that seeks to represent BIPOC and marginalized communities in all-stages of the energy decision-making process as a mechanism for fostering comprehensive stakeholder inclusion and transparency.

This broad framework for energy justice is fundamentally incompatible with pervasive energy insecurity and fuel poverty. While energy justice is a more expansive concept that encompasses aspects of distributional, procedural, and intergenerational justice, energy affordability is a critical precondition for energy justice and the latter can hardly be achieved without the former. Moreover, energy affordability is critical to mitigating the impacts of energy insecurity and energy poverty that we discuss next.

73 Brown, M. A., Soni, A., Lapsa, M. V., Southworth, K., and Cox, M. (2020). High Energy Burden and Low-Income Energy Affordability: Conclusions from a Literature Review. *Progress in Energy, 2*(4). https://iopscience.iop.org/article/10.1088/2516-1083/abb954/meta

74 Sovacool, B. K., Heffron, R. J., McCauley, D., and Goldthau, A. (2016). Energy Decisions Reframed as Justice and Ethical Concerns. N*ature Energy, 1*(5), 1-6. https://doi.org/10.1038/nenergy.2016.24

1.3 Impacts of Energy Insecurity and High Energy Burden

The effects of energy insecurity and fuel poverty have broad social, health, and economic impacts on households suffering from high energy burdens. Households are dependent on electricity for essential services like cooking, heating, lighting, and medical devices. According to the RECS survey, 2015 saw 17 million households receive an electricity disconnection notice, with 3 million of those households disconnected. When faced with energy insecurity and the threat of utility disconnection, households may engage in risky behavior to meet their energy needs, like taking up high-interest payday loans, using dangerous alternatives (e.g. ovens for heating), or forgoing other essential needs such as food and medicine.[75,76] This can have drastic impacts on physical health from lack of adequate heating and cooling (particularly in regions with cold winters and hot summers) and indoor air pollution from relying on alternative fuels (gas, wood),[77,78] as well as mental health due to the physical and financial stressors of uncertainty and high energy burdens. Energy insecure or burdened households are more likely to remain in or slip into poverty.[79] Energy insecurity also likely compounds other material hardships faced by these households (food, financial, medical insecurity), perpetuating the cycle of poverty.[80] Black, Latino, and Indigenous households are more likely to face energy insecurity after controlling for income, as well as those without a college degree or with young children. These challenges were exacerbated by the COVID-19 pandemic in 2020-2021.

Energy insecurity exposes additional vulnerabilities energy-burdened households face from severe climate impacts, such as extreme temperatures and wildfires. In February 2021, Winter Storm Uri blanketed much of the US, from the Pacific Northwest to the South. Texas was heavily impacted by the storm, as sudden temperature drops, snow, and ice shut down the state's electricity. Roughly one in three Texans lost power for up to five days, resulting in dozens of deaths amid single digit temperatures.[81] Electricity scarcity during the outage caused electric rates to soar and subsequent power outages disproportionately affected low-income households who were more likely to have their electricity disconnected. Additionally, research indicates a racial disparity in lost electricity during the storm—neighborhoods with higher concentrations

75 Bhattacharya, J., DeLeire, T., Haider, S., and Currie, J. (2002). Heat or Eat? Cold Weather Shocks and Nutrition in Poor American Families. *National Bureau of Economic Research.* http://www.nber.org/papers/w9004

76 Hernández, D., Phillips, D. and Siegel, E. (2016). Exploring the Housing and Household Energy Pathways to Stress: A Mixed Methods Study. *International Journal of Environment Research and Public Health, 13 (9)*, 916-28. https://doi.org/10.3390/ijerph13090916

77 Seals, B. and Krasner, A. (2020). Health Effects from Gas Stove Pollution. *Rocky Mountain Institute. https://rmi.org/insight/gas-stoves-pollution-health/*

78 Semmens, Erin O., et al. (2015). Indoor Particulate Matter in Rural, Wood Stove Heating Homes. *Environmental Research 138,* 93-100. https://doi.org/10.1016/j.envres.2015.02.005

79 Bohr, J. and McCreery, A.C. (2020). Do Energy Burdens Contribute to Economic Poverty in the United States? A Panel Analysis. *Social Forces,* Volume 99, Issue 1, Pages 155–177, https://doi.org/10.1093/sf/soz131

80 Memmott, T., Carley, S., and Graff, M. et al. (2021). Sociodemographic Disparities in Energy Insecurity Among Low-Income Households Before and During the COVID-19 Dandemic. *Nature Energy, 6,* 186–193. https://doi.org/10.1038/s41560-020-00763-9

81 Norton, K. (2021). Why Texas Was Not Prepared for Winter Storm Uri. PBS. https://www.pbs.org/wgbh/nova/article/texas-winter-storm-uri/

of populations of color were up to four times more likely to lose electricity than majority-White neighborhoods.[82] Winter Storm Uri also impacted Colorado, causing record-low temperatures throughout the state, sudden price spikes, and volatility in the gas market due to high demand. While Colorado's utilities avoided the catastrophic failures seen in Texas, the severe cold disproportionately affected older homes with poorer insulation and heating appliances.

Heatwaves have a similarly outsized effect on low-income and vulnerable populations across the country. Research shows that in cities, the lowest-income census tracts face higher average surface temperatures compared to wealthier tracts. Tracts with a higher proportion of residents of color also experience hotter temperatures than majority-White neighborhoods. Urban heat islands are created in large part by the physical infrastructure of these neighborhoods: low-income neighborhoods tend to be more built up, have less vegetation, and have higher population densities, which all contribute to higher surface temperatures in low-income communities across the US.[83] Furthermore, historically redlined communities are more likely to be impacted by the heat island effect today.[84] Low-income and otherwise energy cost burdened households are more likely to have poor insulation and inefficient cooling appliances, worsening the impact of high temperatures and heat waves.

Wildfires, increasingly common and destructive across the Western US (including Colorado), have high consequences for energy and economic security among energy cost burdened populations. In California, utilities have instituted rolling blackouts to combat periods of high electricity demand due to heat in order to avoid overwhelming the grid and sparking wildfires.[85] However, the power outages and blackouts highlight economic disparity. Middle- or higher-income households can afford alternatives in the event of a blackout, like portable generators or solar and battery storage. These options may be out of reach for many low-income households, who will then suffer the most without power during a heat wave.[86] Low-income, rural, and Indigenous communities also face the highest threat from fires, yet utility investments to protect the grid from extreme weather and fires tends to drive rates upwards.[87] What's more, low- and moderate-income households are least able to cope with the financial burdens of evacuations or home loss, events that occur more frequently as climate change impact intensifies.

82 Robinson, A. (2021). When the Lone Star State Froze Over: Winter Storm Uri and the Lived Experiences of Texas Low-Income Communities. *Texas Energy Poverty Institute.* https://txenergypoverty.org/2021/07/when-the-lone-star-froze-over-winter-storm-uri-report/

83 Benz, S. A. and Burney, J. A. (2021). Widespread Race and Class Disparities in Surface Urban Heat Extremes Across the United States. *Earth's Future,* 9, e2021EF002016. https://doi.org/10.1029/2021EF002016

84 Plumer, B., Popovich, N., and Palmer, B. (2020). How Decades of Racist Housing Policy Left Neighborhoods Sweltering. *The New York Times*. https://www.nytimes.com/interactive/2020/08/24/climate/racism-redlining-cities-global-warming.html

85 Plumer, B. and Penn, I. (2021, July 29). Climate Crisis Catches Power Companies Unprepared. *The New York Times.* https://www.nytimes.com/2021/07/29/climate/electric-utilities-climate-change.html

86 Bussewitz, C. (2019). California Power Outages Highlight Economic Disparity. *Associated Press. https://apnews.com/article/california-us-news-ap-top-news-income-disparity-ca-state-wire-abf6aa6a271447c1a2a3c1303f2b7884*

87 Masri, S., Scaduto, E., Jin, Y., and Wu, J. (2021) Disproportionate Impacts of Wildfires among Elderly and Low-Income Communities in California from 2000–2020. *International Journal of Environmental Research and Public Health.* 18(8), 3921. https://doi.org/10.3390/ijerph18083921

1.4 Drivers of High Energy Burden

A number of factors can contribute to high energy burden, ranging from the physical characteristics of homes and appliances (size, age, efficiency), to economic, policy, behavioral, and geographical drivers. These drivers are summarized in **Table 1.2**.

Table 1.2 Drivers of High Energy Burden.[88,89]

Physical	Housing characteristics (age, type, size) Housing materials (poor insulation, leaky roofs, inefficient HVAC) Old, inefficient appliances (stoves, dishwashers, refrigerators)
Socioeconomic	Sudden and/or persistent financial hardship (loss of employment, low wages, high debt) Difficulty affording energy-saving technologies and qualifying for financing options to upgrade home and appliances Race and ethnicity, number of individuals in household, age of individuals in household, disabilities
Policy	Availability of federal, state, and local aid programs to assist with weatherization, bill payments, etc. Existing policies insufficient or inaccessible for households that require bill payment assistance Utility rate design practices (e.g., high fixed customer charges) limit ability to afford high bills and limit ability to reduce bills through energy efficiency and renewable energy
Behavioral	Limited knowledge or access to information on bill payment and efficiency programs Lifestyle and cultural factors, using unconventional appliances for heating and cooling Split incentives between landlords and tenants (especially in multifamily homes), lack of control over energy bills
Geographical	Rural vs. urban household location Regions that experience temperature or weather extremes (heatwaves, wildfires, storms) Different regions of the US face different energy demands for heating and cooling and different fuel costs

88 American Council for an Energy Efficient Economy. (2019). Understanding Energy Affordability. *American Council for an Energy-Efficient Economy (ACEEE).* https://www.aceee.org/sites/default/files/energy-affordability.pdf

89 Brown, M. A., Soni, A., Lapsa, M. V., Southworth, K., and Cox, M. (2020). High Energy Burden and Low-income Energy Affordability: Conclusions from a Literature Review. *Progress in Energy, 2*(4). https://iopscience.iop.org/article/10.1088/2516-1083/abb954/meta

1.5 Definitions and Metrics of Energy Affordability

Energy affordability is most commonly quantified in terms of energy cost burden—the percentage of household income spent on residential energy needs. The American Council for an Energy Efficient Economy (ACEEE) defines *high* energy cost burden as household energy cost burden exceeding six percent of gross household income.[90,91] Fisher, Sheehan, and Colton use the same value as the limit for affordable home energy bills as a percent of household income. The number originates from a 1981 amendment to the 1969 Housing and Urban Development Act, stating that housing costs, including utilities, should not exceed 30 percent of gross income.[92] Fisher, Sheehan, and Colton further state that household energy-related expenses should not exceed 20 percent of the 30 percent housing costs limit. Applied together, the two thresholds result in the six percent affordability limit of gross income spent on energy. Fisher, Sheehan and Colton also define two percent of income as the affordability limit for heating and cooling alone.[93]

The CEO uses four classifications for energy burden:

1. **Not burdened:**
   <4 percent gross household income spent on energy needs.
2. **Energy stressed:**
   4-7 percent gross household income spent on energy needs.
3. **Energy burdened:**
   7-10 percent gross household income spent on energy needs.
4. **Energy impoverished**:
   >10 percent gross household income spent on energy needs.

In 2015, the CEO estimated that 11 percent of Colorado households were energy impoverished. Most residential energy use in Colorado households comes from gas used for space and water heating. Energy expenditures, however, are more evenly split between electricity and gas due to the higher cost of electricity per unit of energy.[94] It is important to acknowledge that transportation fuels are also expensive and tend to weigh heavily on already-burdened households. Transportation costs are beyond the scope of this literature review. However, it is worth noting that transportation electrification (e.g., electric vehicles) will likely contribute to increased household electricity costs over time. However, for those

90 Drehobl, A. and Ross, L. (2016). Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency can Improve Low-income and Underserved Communities. *American Council for an Energy-Efficient Economy (ACEEE).* https://aceee.org/research-report/u1602

91 Drehobl, A., Ross, L., and Ayala, R. (2020). How High are Household Energy Burdens? *American Council for an Energy-Efficient Economy (ACEEE).* https://www.aceee.org/sites/default/files/pdfs/u2006.pdf

92 Edson, C.L. (2011). The Legal Guide to Affordable Housing Development (2nd ed.). *American Bar Association.*

93 Fisher, Sheehan, and Colton. (2021). Home Energy Affordability Gap. *Public Finance & General Economics.* http://www.homeenergyaffordabilitygap.com/03a_affordabilityData.html

94 Cook, J. and Shah, M. (2018). Reducing Energy Burden with Solar: Colorado's Strategy and Roadmap for States. *National Renewable Energy Laboratory*. https://www.nrel.gov/docs/fy18osti/70965.pdf

who can afford electric vehicles and have access to charging, costs for personal vehicle energy requirements may decline.

Throughout the literature on energy burden and affordability, several other metrics have been used to quantify energy affordability and energy use such as socioeconomic vulnerability, hours at minimum wage, and social inequality. Additional metrics examine energy use as a function of home size, home efficiency, and household size. A list of metrics can be seen in **Table 1.3** below.

Table 1.3 Energy Affordability and Energy Use Metrics.

Energy Use and Affordability Metrics	Definition	Source
Energy Burden (absolute)	Annual energy bills as a percentage of household income	CEO,[95] ACEEE,[96] APPRISE[97]
Energy Burden (variance-based)	One standard deviation above mean energy burden	APPRISE[97]
Energy Burden (percentile-based)	Population share approach based on a percentile distribution	APPRISE[97]
Energy Insecurity	Vulnerability to utility disconnections	Berry, et. al (EIA)[98]
Affordability Gap	Home energy bills/affordable home energy bills (total state Home Energy Affordability Gap aggregated by weighting several low-income segments within each county)	Fisher, Sheehan, and Colton[99]
Affordability Ratio (AR)	($ essential services bill)/ ($ household income - non-discretionary expenses)	California PUC[100]

95 Colorado Energy Office. (2017, December). Insights from the CEO Low-Income Community Solar Demonstration Project. https://lpdd.org/wp-content/uploads/2020/12/Insights-from-the-CEO-Low-Income-Community-Solar-Demonstration-Project.pdf

96 American Council for an Energy Efficient Economy (ACEEE). (2019). Understanding Energy Affordability. https://www.aceee.org/sites/default/files/energy-affordability.pdf

97 Applied Public Policy Research Institute for Study and Evaluation. (2005). LIHEAP Energy Burden Evaluation Study. https://www.acf.hhs.gov/sites/default/files/documents/ocs/comm_liheap_energyburdenstudy_apprise.pdf

98 Berry, C., Hronis, C., and Woodward, M. (2018). Who's Energy Insecure? You Might Be Surprised. *U.S. Energy Information Association.* https://www.aceee.org/files/proceedings/2018/index.html#/paper/event-data/p393

99 Fisher, Sheehan, and Colton. (2021). Home Energy Affordability Gap. *Public Finance & General Economics.* http://www.homeenergyaffordabilitygap.com/03a_affordabilityData.html

100 California Public Utilities Commission. (2019). 2019 Annual Affordability Report. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/affordability

Energy Use and Affordability Metrics	Definition	Source
Hours at Minimum Wage (HM)	Hours of employment at city minimum wage necessary for a household to pay for essential utilities	California PUC
Socioeconomic Vulnerability Index (SEVI)	Poverty, unemployment, education, linguistic isolation, percent income spent on housing on a census tract level	California PUC
Energy Use Intensity (EUI)	EUI as a proxy for home energy efficiency (units of btu/m2), with larger EUI indicating lower home energy efficiency	Bednar, et. al[101]
EUI/household, EUI/capita, energy use/household, energy use/capita	EUI and energy use per household and per individuals	Tong, et. al[102]
Social inequality metrics: Gini coefficients and disparity ratios	Gini coefficient: general measure of dispersion that does not account for social stratification by income or race (range 0–1, equal distribution–unequal distribution). Disparity ratio: EUI reported in lowest income quintile vs EUI in highest income quintile	Tong, et. al
Mean Individual Burden	Average of the percent of income spent on energy by each household	Makhijani, et. al (IEER)[103]
Mean Group Burden	Overall energy expenditures as a percent of total income in the group	Makhijani, et. al (IEER)

101 Bednar, D., Reames, T., and Keoleian, G. (2017). The Intersection of Energy and Justice: Modeling the Spatial, Racial/Ethnic and Socioeconomic Patterns of Urban Residential Heating Consumption and Efficiency in Detroit, Michigan. *Energy and Buildings. 143.* doi.org/10.1016/j.enbuild.2017.03.028

102 Tong, K., et al. (2021) Measuring Social Equity in Urban Energy Use and Interventions Using Fine-Scale Data. *Proceedings of the National Academy of Sciences,* vol. 118, no. 24, doi:10.1073/pnas.2023554118

103 Makhijani, A., Mills, C., and Makhijani, A. (2015). Energy Justice in Maryland's Residential and Renewable Energy Sectors. *Institute for Energy and Environmental Research.*

The above metrics require a variety of dimensions to calculate. The most common dimensions needed to calculate energy burden and affordability are fuel use, fuel price, and household income, although house size, number of household members, and vulnerability to utility shutoffs are also relevant factors to consider. **Table 1.4** below shows which metrics require which inputs to calculate.

Table 1.4 Dimensions Used to Calculate Energy Affordability Metrics.

	Data Dimensions					
Energy Use and Affordability Metrics	**Fuel Use**	**Fuel Price**	**Income**	**Utility Shut-offs**	**House Size**	**Household Size**
Energy Burden (absolute)	X	X	X			
Energy Burden (variance-based)	X	X	X			
Energy Burden (percentile-based)	X	X	X			
Energy iInsecurity				X		
Affordability Gap	X	X	X			
Affordability Ratio (AR)	X	X	X			
Hours at Min Wage (HM)			X			
Socioeconomic Vulnerability Index (SEVI)			X			X
Energy Use Intensity (EUI)	X		X		X	
EUI/household, EUI/capita, energy use/household, energy use/capita	X		X		X	X
Social Inequality Metrics: Gini coefficients and disparity ratios	X		X		X	X
Mean Individual Burden	X	X	X			
Mean Group Burden	X	X	X			

1.6 Methods and Best Practices

Energy affordability can be assessed in a wide variety of ways. As mentioned, the most common metric for affordability is energy cost burden measured as the percentage of household income spent on energy bills. Some authors, however, make additional distinctions within this category. The 2005 LIHEAP Energy Burden Evaluation Study by the Applied Public Policy Research Institute for Study and Evaluation (APPRISE) makes distinctions between absolute energy burden, variance-based energy burden, and percentile-based energy burden. APPRISE defines a high absolute energy burden as one that exceeds a fixed percentage of income—most studies use the six percent threshold, though some may go as high as 25 percent—above which energy bills are considered unaffordable. This is APPRISE's preferred approach compared to the variance-based and percentile-based methods, as it makes tracking household energy cost burden easier and more consistent over time.

The variance-based approach defines high energy burden as lying one standard deviation above the mean energy burden. However, this approach assumes energy expenditures are normally distributed, when in reality the distribution is often skewed by high values for a small number of households. This results in a larger standard deviation as compared to a normal distribution, reducing the number of households considered energy-burdened. The percentile-based method classifies households depending on a percentile distribution (e.g., the 10 percent of houses with the highest burden). APPRISE considers this approach too rigid as it uses a relative method that does not account for factors that would change the true number of energy-burdened households, such as a sudden increase (or decrease) in electricity rates.[104]

A report by the Institute for Energy and Environmental Research (IEER) delineates two additional distinctions for energy cost burden, using terminology from LIHEAP: mean individual burden and mean group burden. IEER estimated average home energy use across Maryland and for households that receive Maryland Energy Assistance Program (MEAP) assistance for the fuel used. The percent of income spent on household energy bills is calculated for each individual household in a group; these percentages are then averaged over all households in the same group. This is called the "mean individual burden." In addition, the energy expenditures and incomes of all households in the group can be added up separately. The ratio of the totals represents the "mean group burden." Much of the underlying data were from low-income households that received weatherization assistance, as well as a 2011 report for the Maryland Public Service Commission, which provides billing and service data to calculate group energy burden but not household-by-household level energy burden. Energy burden was calculated for all households and for households receiving MEAP assistance.[105]

104 Applied Public Policy Research Institute for Study and Evaluation. (2005). *LIHEAP Energy Burden Evaluation Study.* https://www.acf.hhs.gov/sites/default/files/documents/ocs/comm_liheap_energyburdenstudy_apprise.pdf

105 Makhijani, A., Mills, C., and Makhijani, A. (2015). Energy Justice in Maryland's Residential and Renewable Energy Sectors. *Institute for Energy and Environmental Research.* https://ieer.org/wp/wp-content/uploads/2015/10/RenMD-EnergyJustice-Report-Oct2015.pdf

Both the ACEEE and the California Public Utilities Commission (CPUC) use income spent on energy bills to determine energy affordability. ACEEE has used the six percent figure as a benchmark: households spending more than six percent of their income on energy bills are considered energy-burdened. ACEEE calculated urban energy burdens using American Housing Survey (AHS) data (including household-level income and energy cost data), and focused on the 48 largest metro areas in the US, while their national analysis used RECS data.[106] CPUC makes an additional distinction, using what they call the "Affordability Ratio (AR)" metric. The AR quantifies the percentage of a representative household's income that would be used to pay for an essential utility service *after* non-discretionary expenses such as housing and other essential utility service charges are deducted from the household's income. The higher an AR, the less affordable the utility service. The AR may be calculated for a single essential utility service, a combination of services, or all essential utility services combined. To calculate the AR, CPUC used utility data obtained from California's Investor-Owned Utilities on monthly baseline rates in effect, monthly baseline quantities, and additional customer data.[107]

While many studies have focused on calculating energy affordability as a function of household income and energy bills, this metric alone fails to capture additional factors that influence energy burden and affordability. For example, it does not account for variables like home size, home and appliance efficiency, etc. Another commonly used metric that accounts for these dimensions is Energy Use Intensity (EUI). EUI examines the energy use per unit area of a household, taking inputs like total energy consumption and home square footage and outputting the EUI in British Thermal Units (BTUs) or Megajoules (MJ) per square meter (or square foot). The EUI accounts for home size and can therefore

106 American Council for an Energy Efficient Economy (AEEE). (2019). Understanding Energy Affordability. https://www.aceee.org/sites/default/files/energy-affordability.pdf

107 California Public Utilities Commission. (2019). 2019 Annual Affordability Report. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/affordability

serve as a proxy for energy efficiency and behavioral practices. A home with a higher EUI means more energy is being used per unit area than one with a lower EUI. This is often an indicator for poor home efficiency, as older or faulty appliances and HVAC can use more energy than necessary during operation, incurring additional costs to the household. Reames, et. al demonstrated that in Detroit, Michigan, low-income households and households of color have roughly equivalent energy use behaviors as wealthier and White households, but their EUI is higher due to less efficient appliances and homes. This analysis was performed by combining representative RECS sample data at the state level, representing household-level energy use patterns, with spatial data from ACS 2006-2010 at the census block level. EIA's RECS provides household-level data for a representative sample of occupied residences at the state level. 274 Michigan homes were surveyed to represent the state, and household socioeconomic and demographic information was obtained from the ACS spatial data. The authors used ordinary least squares regression to determine how various housing and demographic characteristics influence total heating fuel consumption and EUI.[108]

Tong, et. al examined EUI not just in terms of EUI/household but also EUI/capita, accounting for the number of individuals per household as well. The authors combined sociodemographic data with energy use, occupancy, program participation, and investment data covering all homes across all neighborhoods in two cities: St. Paul, Minnesota and Tallahassee, Florida. They used fine-scale sociodemographic data at the census block level (suitable to identify effects of race and income) to define metrics for cities to quantify social inequality in energy use by both income and race, and apply these metrics to analyze social equity in efficiency rebates, loans, etc. This approach unites inequality in both energy use and efficiency investments at the intraurban scale. The fine-scale data provides an assessment on how energy use inequality metrics are impacted by the spatial scale of data aggregation. Data was obtained from electric utilities under non-disclosure agreements to preserve data privacy, and was provided at premise level for Tallahassee's 90,000 households with one year of monthly energy use and five years of investment data, and at the census block level for St. Paul's 110,000 households.[109]

There are additional metrics that do not calculate energy affordability and energy use as directly as energy burden and EUI, but provide useful socioeconomic information that influences an individual or household's energy affordability. The CPUC, in addition to the Affordability Ratio, uses additional metrics such as the Hours at Minimum Wage (HM) and the Socioeconomic Vulnerability Index (SEVI) to determine energy burdens. The HM metric estimates the hours of

108 Bednar, D., Reames, T., and Keoleian, G. (2017). The Intersection of Energy and Justice: Modeling the Spatial, Racial/Ethnic and Socioeconomic Patterns of Urban Residential Heating Consumption and Efficiency in Detroit, Michigan. *Energy and Buildings.* 143. doi:10.1016/j.enbuild.2017.03.028.

109 Tong, K., et al. Measuring Social Equity in Urban Energy Use and Interventions Using Fine-Scale Data. *Proceedings of the National Academy of Sciences,* vol. 118, no. 24, 2021, doi:10.1073/pnas.2023554118

employment at the local minimum wage necessary for a household to pay for essential utility service charges. HM also considers the impact of essential utility service charges on lower-income customers regardless of the socioeconomic conditions of the rest of the community (CPUC, 2019). SEVI represents the relative socioeconomic standing of census tracts in terms of poverty, unemployment, educational attainment, linguistic isolation, and percentage of income spent on housing, and therefore considers how a rate change may affect one community's ability to pay more than another's (CPUC, 2019). CPUC obtained income and housing data at the census block level from the U.S. Census Bureau's Public Use Microdata Sample (PUMS), aggregated to utility or (Public Use Microdata Area) PUMA territories.

Finally, the Gini coefficient and disparity ratios used by Tong et al. attempt to account for additional social factors that may contribute to energy affordability concerns. The Gini coefficient examines population distributions without incorporating stratification by income or race, and is used to represent inequalities in EUI spatially across different regions of a city (in this case, St. Paul and Tallahassee). A coefficient of 0 indicates a perfectly equal distribution, while a coefficient of 1 indicates maximum inequality. Too much data aggregation (for instance, aggregating census block data into census tracts or higher) can decrease the Gini coefficient and make the distribution of EUI appear more equal than finer scale data would suggest.

A similar effect occurs with the disparity ratio, or the metric used to compare both energy use by the lowest and highest income quintiles, and the EUI disparity between the most racially diverse census block and the least diverse census block. As with the Gini coefficient, the disparity ratios are affected by spatial data aggregation: higher levels of aggregation affect both the income and race disparity ratios (although the race disparity ratio is impacted more).[110]

110 Tong, K., et al. Measuring Social Equity in Urban Energy Use and Interventions Using Fine-Scale Data. *Proceedings of the National Academy of Sciences,* vol. 118, no. 24, 2021, doi:10.1073/pnas.2023554118.

1.7 Our Approach

Of the above metrics, in the following sections we utilize estimates of absolute energy cost burden for census tracts and for household distributions within each census tract to gauge energy affordability across Colorado. We use average Energy Use Intensity by census tract as a proxy for home energy efficiency across income groups. Absolute energy burden is our preferred metric to calculate energy affordability as it is the most commonly cited method throughout the literature, is relatively simple to use, and provides consistent, reliable, and easy-to-track information on household energy burden over time. The EUI metric will be used in addition as it accounts not just for home energy use (which PSE's previous work examined), but also addresses the effect of home size and home efficiency on energy costs.

Within **Section 2**, the relationships between energy burden, EUI, economic factors, and demographic variables (race, rural/urban, housing tenure, education attainment, etc.) will be analyzed to assess how energy affordability affects different socioeconomic and demographic groups. This analysis will be conducted on a census tract level for improved spatial accuracy and reduced variability in the data (as discussed earlier with Gini coefficients and disparity ratios).

Within **Section 3**, we build upon the census tract estimates using a novel method to estimate energy usage for individual households within each census tract. These more detailed estimates will allow for isolating households with lower incomes in order to investigate how policies will impact their energy spending. All energy use estimates will be further broken down by fuel type used (electricity, gas, wood, etc.) and end use (space heating, space cooling, water heating, and appliances) and merged with fuel prices by utility area in order to capture the effects of varying prices across Colorado. The analysis will be compared to existing datasets on utility bills (as available) and further refined.

SECTION 2

Colorado Energy Cost Burden Analysis

2.1 Introduction

A detailed analysis of existing energy cost burdens is critical for identifying communities and populations who may struggle to pay their energy bills, as well as for developing policies and programs tailored towards specific communities and regions. Such analysis will ultimately create a baseline from which the effectiveness of future initiatives can be measured. In this section, we estimate energy cost burdens and analyze trends across the state of Colorado; we discuss the policies and programs that may help alleviate these burdens in **Section 3.**

We use a regression model based on geographic, demographic, housing-related, and climate variables to estimate census-tract level electricity and fuel use in residential buildings (see **Appendix** for methods). Our analysis includes the most commonly used residential fuels in Colorado: gas, electricity, propane, and wood. A small fraction of households use less common fuels, such as fuel oil (distillate), which are excluded from this analysis.

We calculate both ***energy cost burden***—the fraction of median household income spent on meeting household energy needs—and ***energy use intensity***—average energy consumed per square foot in a house or apartment.

We analyze energy cost burdens and energy use intensity in relationship to geography, climate, income, housing type, fuel type, demographics, and other key indicators.

BOX 2.1

Energy Cost Burden

Energy cost burden is defined as the percentage of household income spent meeting home energy needs. Typically, energy cost burdens over six percent are considered high.

Energy Use Intensity

Energy use intensity is the average energy consumed per square foot in a household or apartment. High energy use intensity typically indicates inefficient homes or appliances.

These factors provide insight into what kinds of policies and programs may help alleviate energy cost burdens and where they might be most useful. For example, rural homeowners with high energy use intensity in areas with high heating demand may greatly benefit from whole-house energy efficiency and weatherization programs and incentives for heat pumps. In this section, we analyze the existing landscape for energy use and energy cost burdens across Colorado, informing the policy recommendations we develop in the third part of this study. We report our findings on a census tract basis, highlighting areas in particular where the average household has an energy cost burden above the six percent threshold typically used to identify highly-burdened households. However, we note that individual households within census tracts may have significantly higher energy cost burdens than the estimated mean value. Such households should not be overlooked when developing interventions to improve energy affordability. In **Section 3**, we will provide a deeper analysis of the percentage of households *within* each census tract facing high energy cost burdens and will use this analysis as the basis for policy recommendations.

2.2 Energy Cost Burden Landscape in Colorado

2.2.1 Energy Cost Burdens by Census Tract

Our statewide regression analysis indicates that the landscape of energy cost burdens in Colorado varies widely with geography, urban/rural designation, and climate zone. **Figure 2.1** illustrates the uneven spatial distribution of residential energy cost burdens across the state. Many of the highest energy cost-burdened census tracts are located in rural areas, with a particularly high concentration of these tracts in the southwestern part of the state. The Denver area, shown on the right panel, tends to have average energy cost burdens below the six percent threshold—although individual households within each census tract may face significantly higher energy cost burdens.

On average, energy cost burdens are lower in Colorado than they are nationally, with the median Colorado household spending slightly above two percent of their income on energy in a year compared to three percent for the average American household.[111] Cost burdens remain substantial in portions of the state, however, as evidenced by the pronounced unevenness between urban[112] and rural census tracts shown in the map below. We find that in urban areas in Colorado, the median energy cost burden is two percent. In rural areas, on the other hand, the median is closer to six percent.

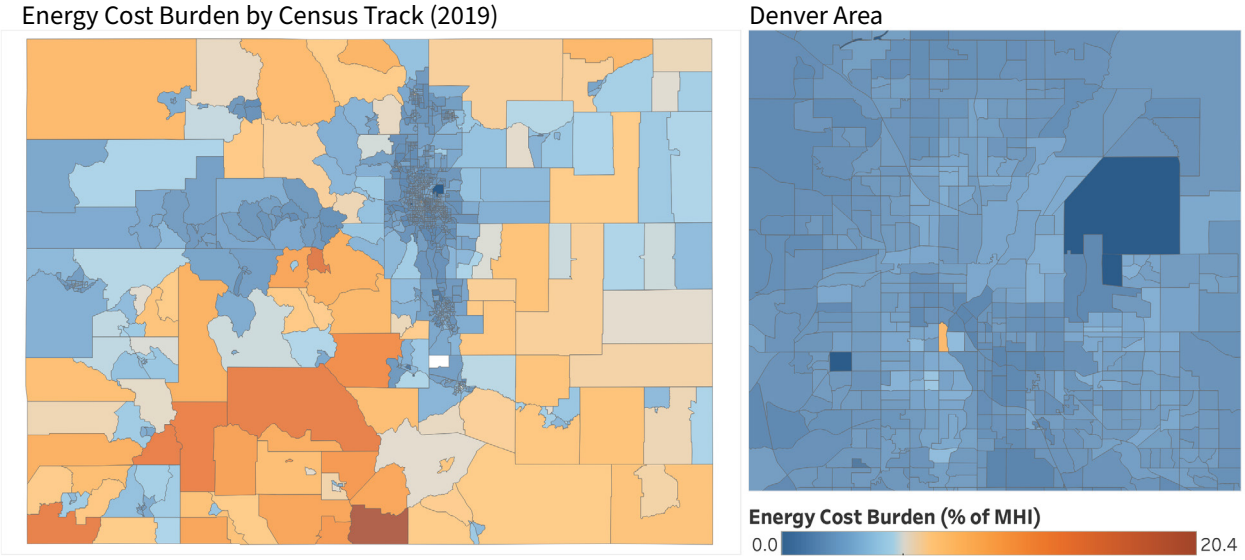

Figure 2.1. Colorado Energy Cost Burden Landscape. Average energy cost burdens by census tract shown on a blue-to-orange color divergent map, with orange color indicating high energy cost burdens. The blue-to-orange color transition point is set at six percent.

111 Office of Energy Efficiency and Renewable Energy. (n.d.). *Low-Income Community Energy Solutions.* U.S. Department of Energy. Retrieved October 27, 2021, from: https://www.energy.gov/eere/slsc/low-income-community-energy-solutions

112 We use "urban" to refer to U.S. Census-designated metropolitan areas.

As described in greater detail below, the discrepancy between urban and rural cost burdens can likely be attributed to several factors. Rural households consume more energy and pay higher prices for their electricity on average (**Figure 2.2**). They also tend to have lower median household incomes, as discussed in **Section 2.1.2** below. Further demographic, socioeconomic, and structural factors that can contribute to high energy cost burdens will also be examined in **Section 2.1.3** below.

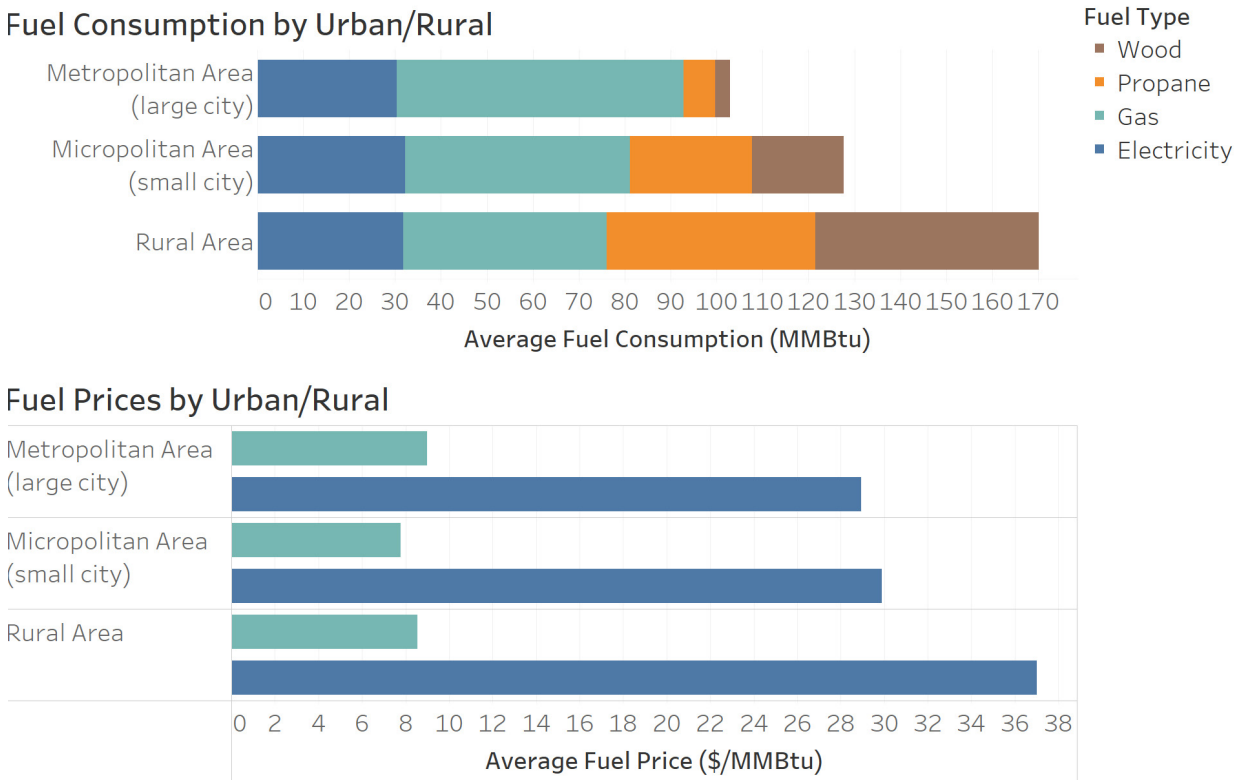

Figure 2.2. Fuel Consumption and Prices by Urban/Rural Designation. Rural households tend to consume more energy on average and pay more for their electricity than urban households.[113] Urban areas include both metropolitan areas (large city) and micropolitan areas (small city).[114]

Figure 2.3 shows the distribution of energy cost burdens by census tract ranked from lowest to highest, with the x-axis showing the cumulative percentage of households in census tracts with average energy cost burdens below the specific energy burden value. There is an inflection point close to the six percent mark, above which average energy cost burdens increase sharply for a small number of census tracts. Close to

113 Colorado Energy Office. (2021, September). *Colorado Electric Utility Data* [Personal communication].

114 *U.S. Census Bureau.* About. [Definitions of Metropolitan and Micropolitan.] https://www.census.gov/programs-surveys/metro-micro/about.html

five percent of Colorado's households live in census tracts where average energy cost burdens are above the six percent mark. The remaining 95 percent of households live in areas where energy cost burdens are lower, and in many of them substantially so. As the color legend indicates, high energy cost burdens are largely clustered in rural areas, although a number of urban tracts are also represented in this category. As noted previously, these values reflect *average* energy cost burden estimates by census tract. Some individual households within tracts may have significantly higher energy cost burdens, and some will have lower.

Many rural census tracts are located in harsher climate zones than Colorado's urban census tracts, contributing to increased heating needs. The Colorado Energy Office does not use designated climate zones in the State of Colorado. We therefore compiled data from weather stations across the state[115] and assigned each tract to the heating-degree-day (HDD) and cooling-degree-day (CDD) values for its nearest weather station. HDDs and CDDs are measures that indicate by how many degrees, and for how many days over a year, temperatures are below (for HDDs) or above (for CDDs) a standard reference temperature of 65°Fahrenheit.[116] We separated the ranges of HDDs and CDDs in Colorado into five heating and cooling zones (warmest to coldest for HDD, coolest to hottest for CDD) as proxies for regional climate zones. These heating and cooling climate zones are shown in **Tables 2.1** and **2.2.**

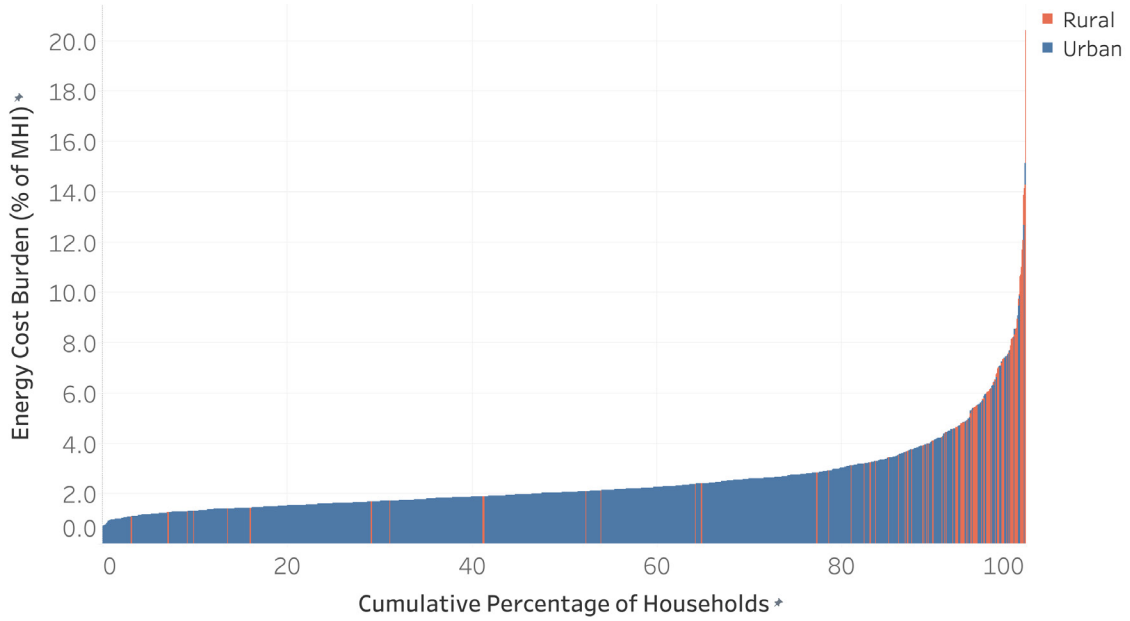

Figure 2.3. Distribution of Energy Cost Burden by Census Tract and Percent of Households. The distribution peaks steeply above the inflection point, close to an energy cost burden of six percent. Rural census tracts represent a much larger fraction of high energy burdened households.

115 Annual counts of degree days averaged from 2018-2020 obtained from Global Historical Climatology Network - Daily (GHCN-Daily), Version 3. Accessed on: October 2021. Available at: https://www.ncei.noaa.gov/products/land-based-station/global-historical-climatology-network-daily

116 U.S. Energy Information Administration. (2021). *Degree Days*. Available at: https://www.eia.gov/energyexplained/units-and-calculators/degree-days.php

Table 2.1. Heating Climate Zones and Heating Degree Days.

Heating Climates Zones (Code Names)	Heating Degree Days (HDD)
HZ 1	4,500 – 6,000 HDD
HZ 2	6,000 – 7,500 HDD
HZ 3	7,500 – 9,000 HDD
HZ 4	9,000 – 10,500 HDD
HZ 5	> 10,500 HDD

Table 2.2. Cooling Climate Zones and Cooling Degree Days.

Cooling Climate Zones (Code Names)	Cooling Degree Days (CDD)
CZ 1	0 – 300 CDD
CZ 2	300 – 600 CDD
CZ 3	600 – 900 CDD
CZ 4	900 – 1,200 CDD
CZ 5	> 1,200 CDD

The spatial distribution of heating and cooling climate zones is shown in **Figure 2.4.** The two climate zones with the largest number of heating degree days (HZ 4 and HZ 5) are located in the mountainous parts of the state. In contrast, the climate zones with the highest number of cooling degree days (CZ 4 and CZ 5) are located in the western and eastern parts of the state, including parts of the Denver Metropolitan Area.

The distribution of energy cost burdens by climate zone are shown in the box plots in **Figure 2.5**. Box plots are a standardized way of displaying the distribution of data based on summary statistics. They are useful when comparing distributions between several groups or datasets. The median of each distribution is shown within the grey-shaded box area, which defines the interquartile range between the 25th and the 75th percentile in the dataset. The whiskers (black lines) that stretch outside of the box represent the maximum and the minimum of the distribution at 1.5 times the minimum and maximum of the 25-75th percentile range shaded box. Outliers beyond the whiskers are also shown. Box plots can tell us visually how tightly the data are grouped, how skewed the distribution is, how symmetrical the dataset is, and where the outliers are.

Energy cost burdens are significantly higher in the census tracts that belong to the three harshest climate zones—HZ4, HZ5, and CZ5. These three climate zones have the highest median values for energy cost burden (4.8, 3.3, and 3.8 percent respectively) as well as the largest spread in the data. They also

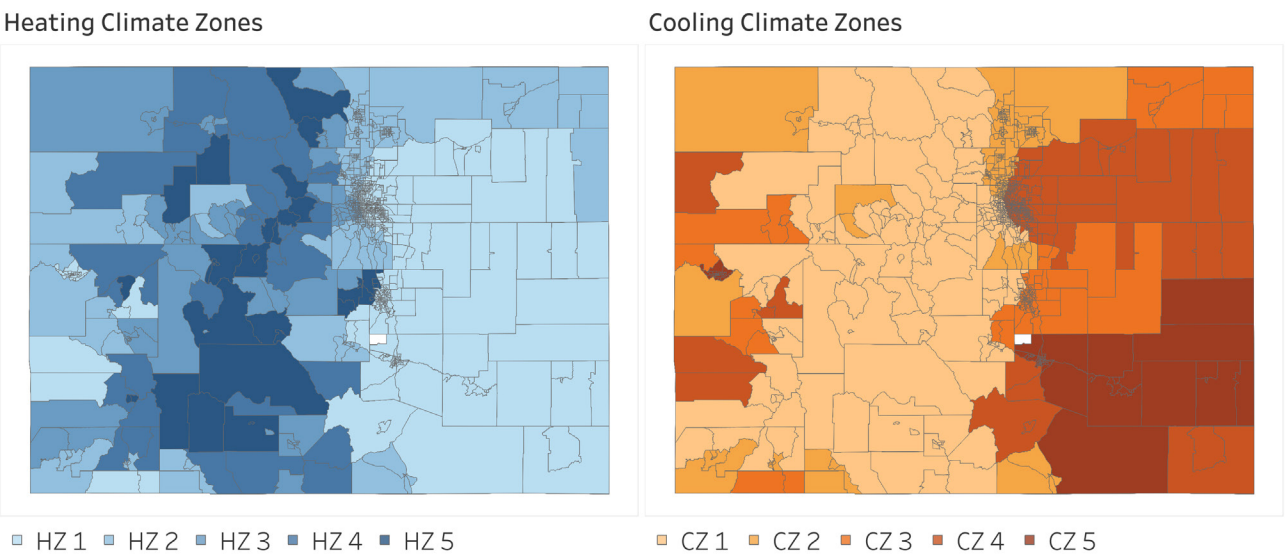

Figure 2.4. Heating Climate Zones and Cooling Climate Zones in Colorado.

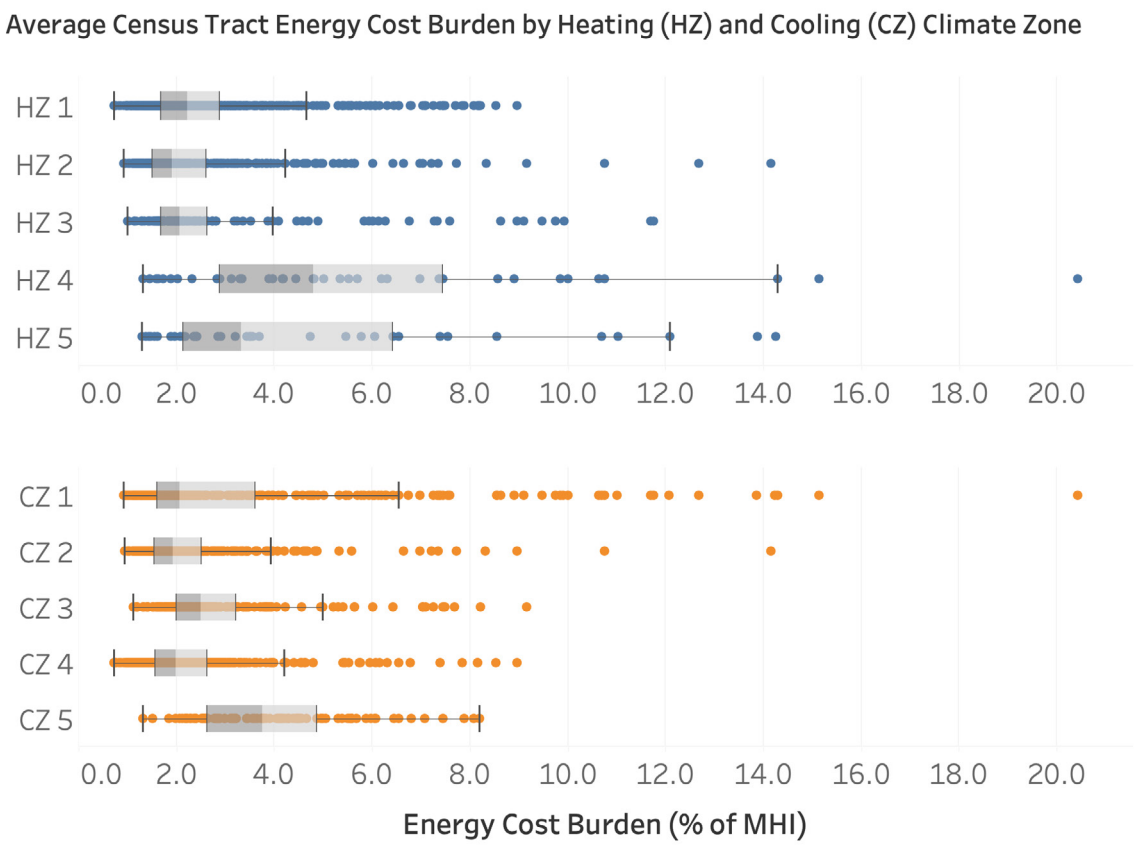

Figure 2.5. Box Plots of Energy Cost Burdens by Climate Zone. The median of each distribution is shown within the grey-shaded box area, which defines the range between the 25th and the 75th percentile of the dataset. The whiskers (black lines) that stretch outside of the box represent 1.5 times the minimum and maximum of the shaded box. Outliers are shown beyond the whiskers.

contain the smallest number of census tracts and the smallest number of outliers overall. CZ1 appears to have a large number of outlier census tracts with high energy cost burdens. The reason for this is that CZ1, the climate zone with the lowest number of cooling degree days, largely coincides with HZ4 and HZ5, the climate zones with the highest numbers of heating degree days.

We also compared the relationship between HDDs and CDDs for all census tracts to determine whether any tracts may have both high heating and high cooling energy requirements (**Figure 2.6**). We see a consistent inverse relationship between HDDs and CDDs, where census tracts with high heating requirements have lower cooling requirements and vice versa.

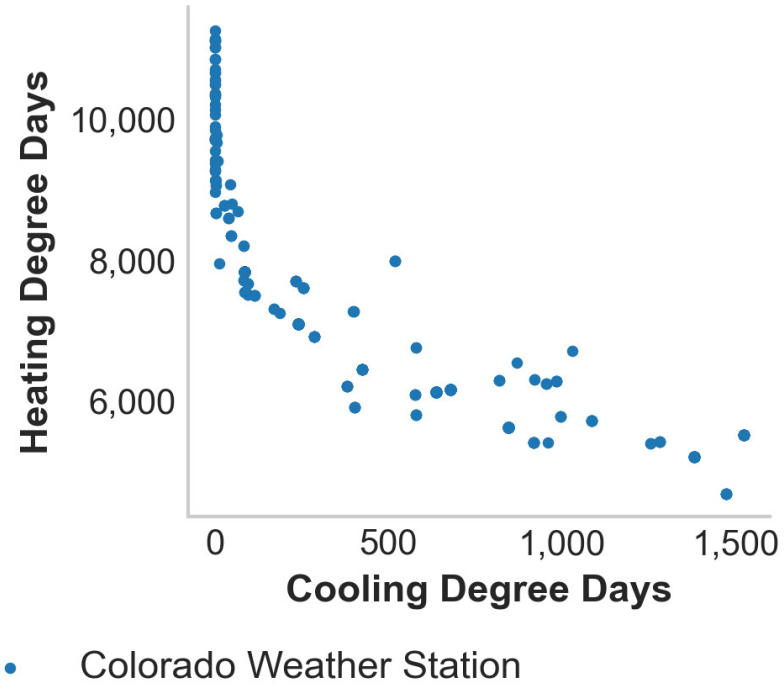

Figure 2.6. Heating Degree Days and Cooling Degree Days by Census Tract. Census tracts with high heating requirements tend to have lower cooling requirements and vice versa.

2.2.2 Energy Cost Burden and Income

By definition, energy cost burden is inversely related to household income. The relationship is nonlinear, however, and low-income census tracts tend to experience dramatically higher energy cost burdens relative to their higher income counterparts. This is illustrated in **Figure 2.7**, where we plot average household energy cost burdens by census tract as a function of the census tract median household income. On average, households in the lowest income census tracts spend a significantly higher fraction of their income on energy bills. We discuss the drivers behind this relationship, as well as additional factors affecting energy cost burdens, in the sections below.

The median census tract energy cost burden in Colorado is 2.1 percent, although for rural areas the median is substantially

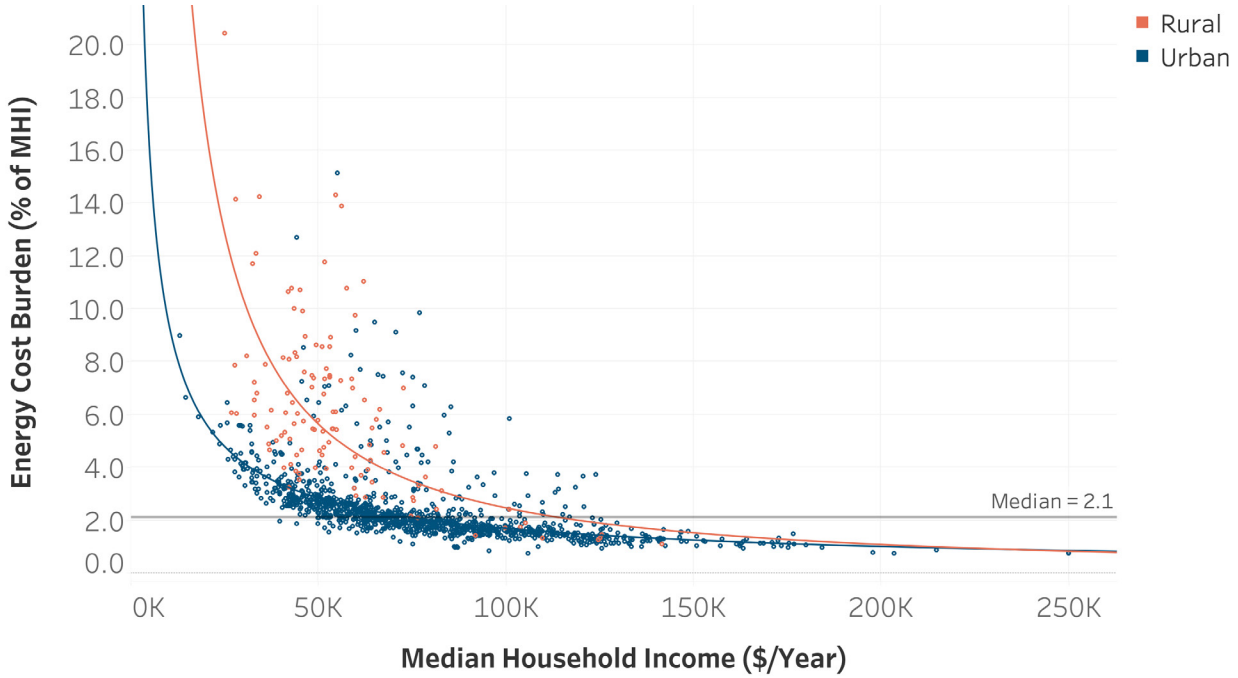

Figure 2.7. Census Tract Average Energy Cost Burden as a Percentage of Median Household Income. Lower-income census tracts tend to spend a much greater portion of their income on energy bills. Rural areas generally have higher energy cost burdens than urban areas.

higher at 5.6 percent. The highest estimated average energy cost burden for an individual census tract is 20.4 percent. For reference, the national average for non-low-income households is around 3.0 percent,[117] while the national average for low-income households is nearly three times higher at 8.6 percent.[118]

In addition to income, energy cost burden is by definition dependent on the quantity of energy consumed. Energy cost burdens can also vary substantially depending on the type of fuel used as the primary heating fuel, since different fuels differ in their price per unit energy, as well as their efficiency. **Figure 2.8** (left side) offers a more detailed breakdown of household energy cost burdens by income group, fuel type, and urban/rural designation. The panels on the right-hand side also display average household fuel consumption by fuel type (including electricity), income group, and urban/rural area to account for the possibility that high-income groups might be facing lower energy cost burdens because, theoretically, they might be consuming less energy per household. In fact, the opposite trend is true. While energy cost burdens are lower in high-income urban census tracts, energy use increases with income in urban tracts.

Gas use accounts for a large fraction of overall energy use in urban areas. However, it comprises a significantly smaller fraction of

117 U.S. Department of Energy. *Low-Income Community Energy Solutions.* https://www.energy.gov/eere/slsc/low-income-community-energy-solutions

118 U.S. Census Bureau. *U.S. Department of Energy Uses ACS Data to Power the Low-income Energy Affordability Data (LEAD) Tool.* https://www.census.gov/programs-surveys/acs/about/acs-data-stories/lead-tool.html

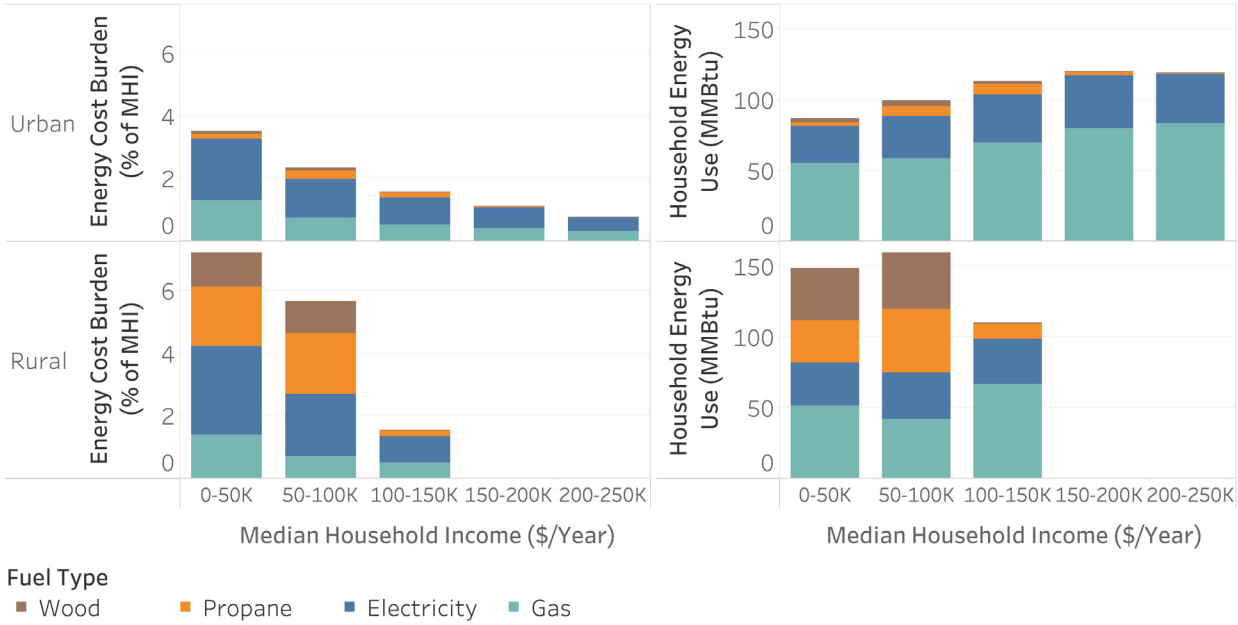

Figure 2.8. Average Energy Cost Burden and Average Annual Household Fuel Use. Energy cost burden and fuel consumption broken down by income, fuel type, and rural/urban area. Colored shading of bars indicate the the fraction of energy cost burden and the fraction energy use associated with each fuel type within the income bracket indicated on the x-axis.

energy cost burden in these areas due to the lower price of gas per million British thermal units (MMBtu) compared to other fuels.[119] In rural areas, propane tends to comprise a much larger fraction of overall energy consumption,and the higher cost of propane per MMBtu contributes to higher energy cost burdens.

The fact that energy consumption is higher in high-income urban census tracts is likely dependent on average house size. To control for this factor, we explore energy use intensity—the average household energy use per square foot—in **Section 2.2** below. In addition, energy cost burdens may be dependent on other demographic and socioeconomic factors besides income. We examine the influence of some of these demographic variables in **Section 2.1.3** below.

2.2.3 Energy Cost Burdens and Demographics

As discussed in **Section 1**, there are well-known correlations between income and demographic variables such as race, education, homeownership, and other socioeconomic and environmental justice indicators.[120] Such variables vary regionally in Colorado. Statewide, non-Hispanic White Coloradans comprise the largest racial group at 68 percent of the population. Hispanics/Latinos are the next largest group at 22 percent, followed by African American/Black (5 percent), Asian American (4 percent), and

119 Prices are based on 2019 values. Gas price volatility and potential rate increases, such as the spike in gas prices observed in 2021, could lead to increased costs for fossil gas customers in the near future.

120 Lukanov, B. R. and Krieger, E. M. (2019). Distributed Solar and Environmental Justice: Exploring the Demographic and Socioeconomic Trends of Residential PV Adoption in California. *Energy Policy* 134, https://doi.org/10.1016/j.enpol.2019.110935

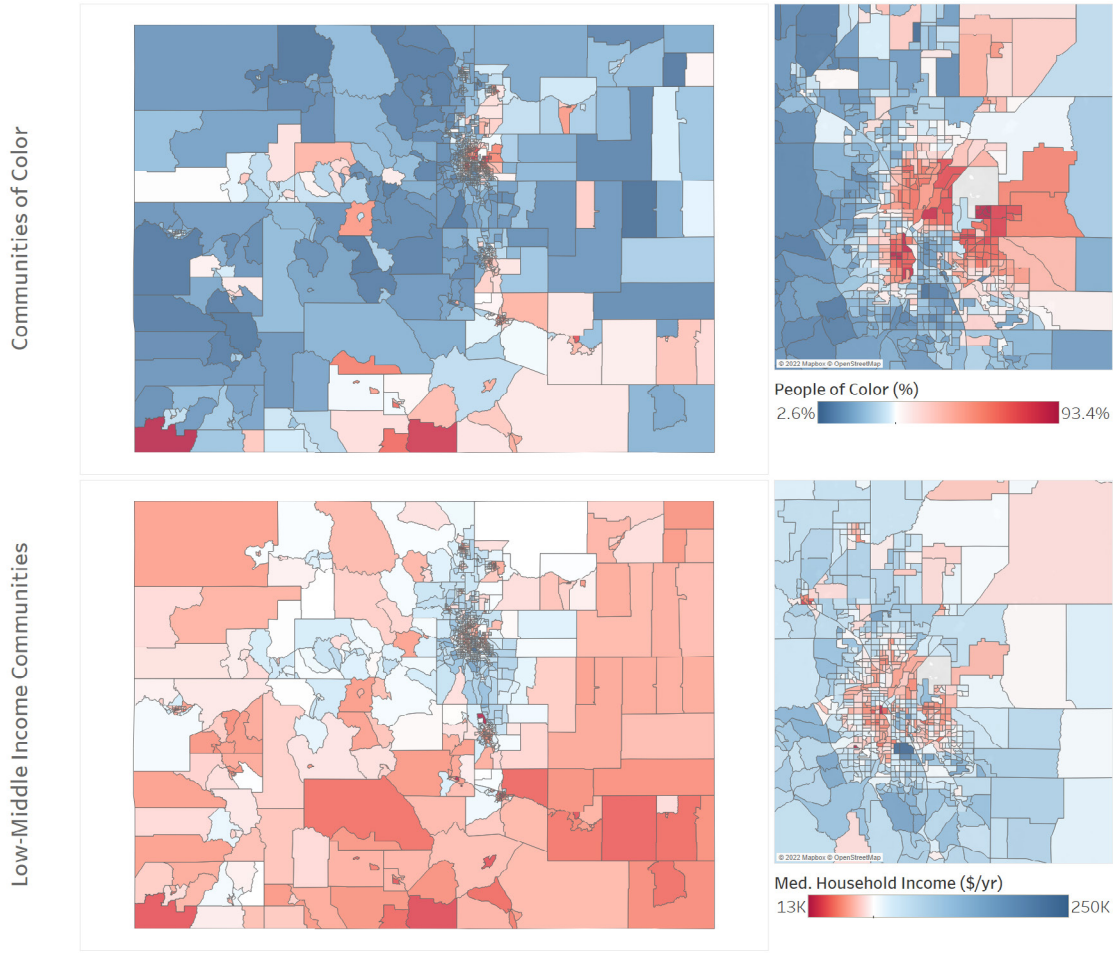

Figure 2.9. Colorado Sociodemographic Landscape. Communities of color are most concentrated in southern Colorado and parts of the Denver Metropolitan Area. Much of rural Colorado and portions of the Denver area are below the state's median income. In the above maps, the color break between red and blue indicates the statewide average. On the top map, communities of color are therefore shown in red, while on the bottom map, low-income communities are shown in red.

Native American (2 percent) Coloradans.[121] Parts of the state deviate from these overall trends. Communities of color comprise a larger portion of the population in many pockets of the state, notably in southern Colorado and in parts of the Denver Metropolitan Area, while many rural areas are disproportionately White. Similarly, the state's economic landscape varies within and between regions. The median household income statewide is $72,000,[122] though much of rural Colorado as well as clustered neighborhoods within urban areas have lower median incomes. These broad socioeconomic and demographic patterns are depicted in **Figure 2.9.**

121 U.S. Census Bureau. (2019, July). *U.S. Census Bureau QuickFacts: Colorado.* https://www.census.gov/quickfacts/CO

122 U.S. Census Bureau. (2019, July). *U.S. Census Bureau QuickFacts: Colorado.* https://www.census.gov/quickfacts/CO

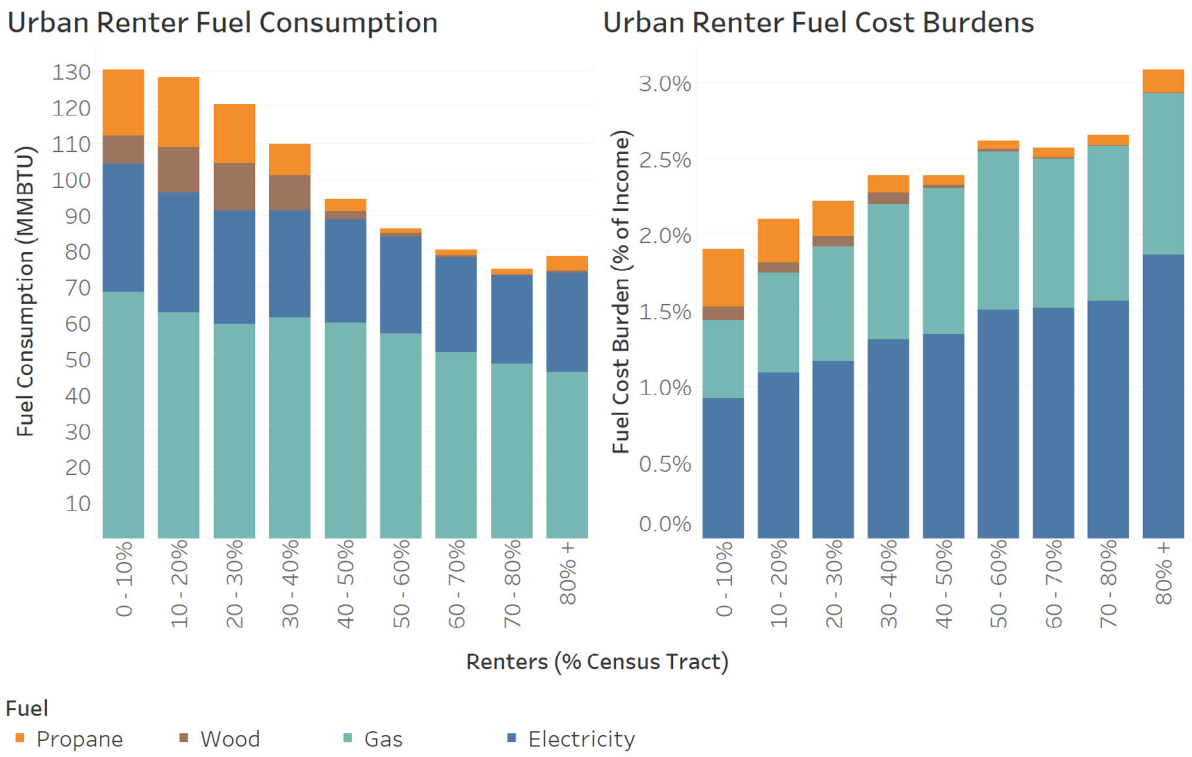

Figure 2.10. Urban Renter Energy Consumption (left) and Cost Burdens (right). Average household energy cost burdens increase as the proportion of renters increases within urban areas.

Due to these substantial differences in energy cost burdens between urban and rural areas as well as differing population compositions, many demographic, socioeconomic, and housing-related trends in energy cost burden are initially unclear on a statewide basis. By analyzing urban and rural areas separately, however, certain trends emerge. For example, **Figure 2.10** shows energy cost burdens in urban census tracts with high proportions of renter-occupied housing. When all census tracts are included, renter or homeowner status does not have a clear relationship with energy cost burden because there are more renters in urban areas than rural areas. However, restricting the analysis to metropolitan areas shows a clear trend: urban neighborhoods with more renters tend to have higher energy cost burdens (right), despite using less energy per household on average (left).

Like neighborhoods with a high proportion of renters, neighborhoods with a high proportion of people of color tend to face higher energy cost burdens. This is particularly true of neighborhoods with greater Black and Latino representation. Additional demographics analyses—such as the relationship between energy cost burdens and race or ethnicity—are difficult to analyze on a statewide basis because of the very low populations counts of certain non-White populations in rural areas. We therefore restrict this analysis to urban areas, including urban cores and their outlying suburbs. In both cases we identified a positive correlation with energy cost

burdens: as the Latino or Black population share increases, so do energy cost burdens. The opposite is true of census tracts with higher proportions of White populations. In these neighborhoods, as the proportion of White residents increases, average cost burden decreases **(Figure 2.11).** There were insufficient numbers of Asian American and Native American residents to examine trends for these groups, although we note that energy cost burdens are high in the Ute Mountain and Southern Ute reservations in the southwestern corner and the southern edge of the state, respectively **(Figure 2.1).**

One contributing factor to this trend is that communities of color also tend to be low-income communities (see **Figure 2.9** above). However, income level is not the only factor in this relationship—there are likely other non-income contributors as well—and lower income levels among populations of color stem in part from historic discriminatory policies in the first place, as we discuss below. To explore how such variables may influence energy cost burdens without the confounding effect of household income, we plot energy cost burdens by census tract for urban (left) and rural (right) areas, as a function of median household income (**Figure 2.12**). This time, however, tracts are colored by the difference from the fitted line. We define this difference as the excess energy cost burden. The excess energy cost burden represents the extra energy cost burden when compared to other tracts with the same income and rural/urban classification. This measure of excess energy cost burden will allow us to explore the effects of demographic variables such as race and educational level while controlling for household income.

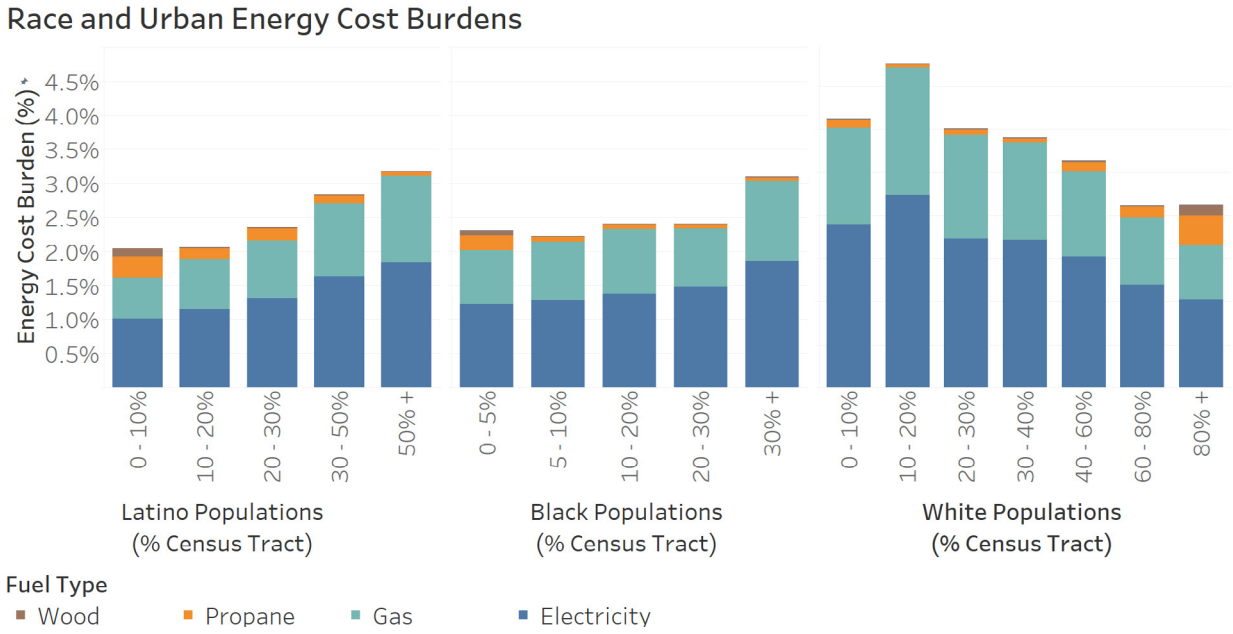

Figure 2.11. Neighborhood Racial Breakdown and Energy Cost Burdens. Communities of color, especially Latino neighborhoods, tend to have higher energy cost burdens than White neighborhoods.

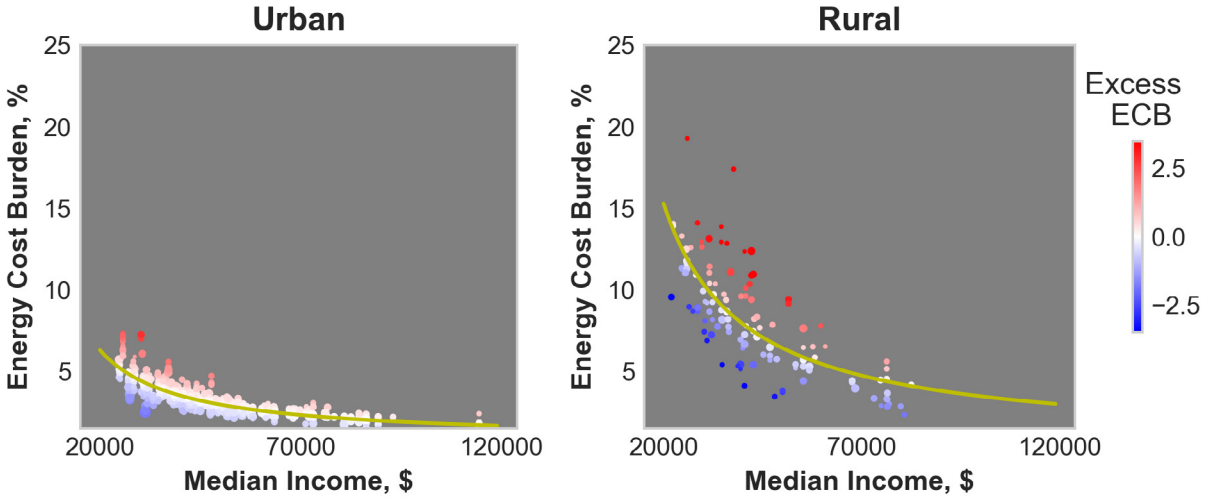

Figure 2.12. Average and Excess Energy Cost Burden by Census Tract as a Percentage of Household Income. Census tracts are colored by the difference between their energy cost burden (ECB) and the fitted line. This difference represents the excess energy cost burden when compared to other census tracts with the same median household income.

To investigate the sociological effects of race and education on energy cost burdens independently of effects due to differences in income, in **Figure 2.13** we plot excess energy cost burdens against the fraction of households that identify as non-Hispanic White (left) and the fraction of individuals aged 25+ with at least a four-year college degree (right). We find that communities of color and communities with lower

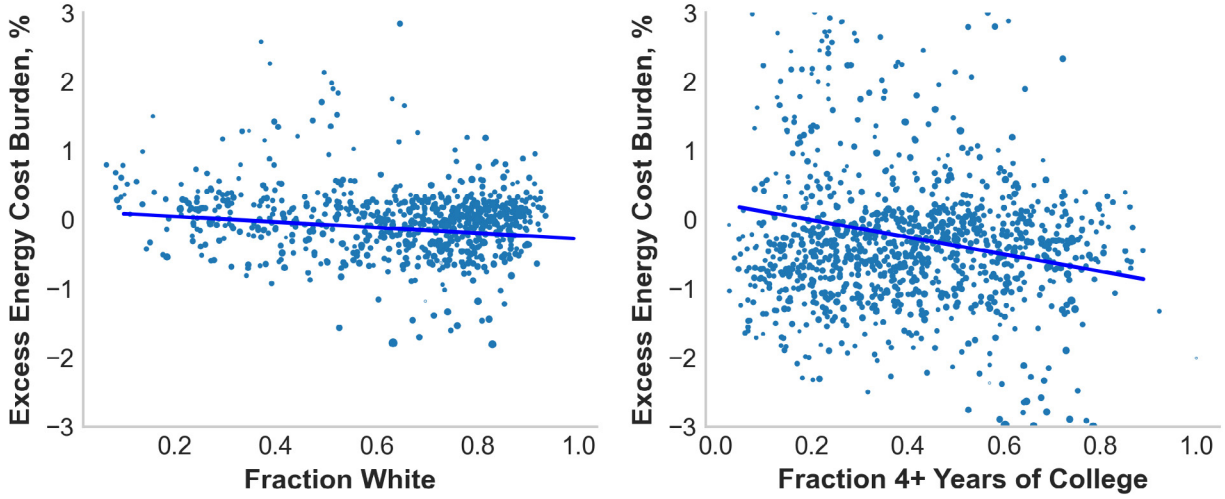

Figure 2.13. Excess Energy Cost Burden by Race and Education in Urban Areas. When controlling for income, census tracts with more people of color and lower average education levels have higher energy cost burdens than Whiter, more educated census tracts. These trends suggest that income levels alone are insufficient to explain energy cost burdens. Areas of markers are proportional to the number of households in each census tract and blue lines are results of weighted linear fits.

educational attainment experience greater energy cost burdens when controlling for income. For example, an urban tract with three quarters of households identifying as persons of color experiences 0.19 percent higher energy cost burden than a tract that has the same median income but with only one quarter of households identifying as persons of color. Likewise, an urban tract with three quarters of its adult population with less than a four-year degree experiences 0.35 percent higher energy cost burden than a tract with only one quarter with less than a four-year degree. In rural areas, there are insufficient numbers of households that identify as non-White to perform the same analysis shown for race, but a similar trend exists for educational attainment. While income inequality between White households and Black and Latino households remains the greatest cause of differences between energy cost burdens, this analysis implies that additional factors beyond income likely contribute to elevated energy cost burdens in these communities.

Census tract-level analyses make it difficult to isolate different factors that may contribute to elevated energy cost burdens in different demographic groups. Further study with household-level data may help shed light on some of these factors. At the neighborhood level, though, one possible explanation for elevated cost burdens for certain demographic groups is historic disinvestment and policy-level discrimination. For example, during the New Deal, the federal Home Owners' Loan Corporation (HOLC) intentionally issued maps discriminating against neighborhoods of color by deeming them high-risk for banks issuing mortgages

(labeling them "red" or "redlining" them). These maps made it difficult to obtain a home loan in neighborhoods of color and contributed to lingering generational wealth gaps.[123] Accordingly, there are lingering inequities between neighborhoods based on how they were classified by HOLC. **Figure 2.14** demonstrates how this manifests in the context of energy cost burdens. White

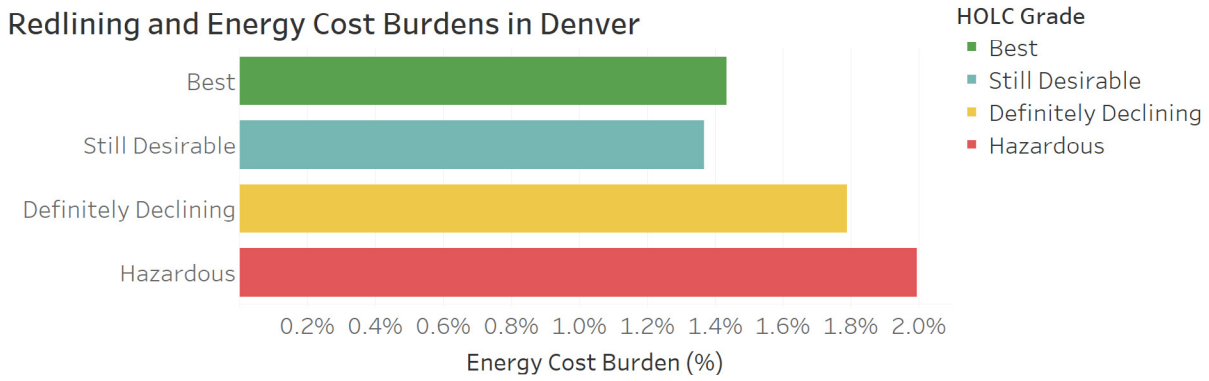

Figure 2.14. Energy Cost Burdens and Redlining in Urban Denver. Neighborhoods with more favorable HOLC classifications have lower energy cost burdens on average than neighborhoods of color that were classified as less desirable.

123 University of Richmond. (n.d.). *Mapping Inequality*. Retrieved October 29, 2021, from https://dsl.richmond.edu/panorama/redlining/

neighborhoods that were classified as "Best" or "Still Desirable" have lower energy cost burdens on average than neighborhoods of color that were classified as "Definitely Declining" and "Hazardous".

The Colorado Department of Public Health and Environment has developed a Climate Equity Data Viewer to provide a framework for decision-makers throughout the state to identify climate and environmentally vulnerable communities and consider how their decisions might impact these communities.[124] The Climate Equity Data Viewer assigns each census block group throughout the state a climate vulnerability score based on various environmental, climate-related, and demographic factors (**Figure 2.15**). As energy is inextricably linked with climate and environment, the Climate Equity Data Viewer provides a potentially useful means of framing demographic analyses on energy cost burdens.

The Climate Equity Data Viewer presents data at the census block group level, which is a geographic unit smaller than a census tract. Because our other analyses are at the census tract level, we calculated a climate equity score for each census tract by using the population-weighted average of tracts' constituent block groups. We found that these tract-level scores have a fairly strong, positive association with energy cost burdens in urban areas (**Figure 2.16**).

This implies that the Climate Equity Viewer may be a useful tool for decision-makers choosing which urban communities to prioritize for rooftop or community solar, efficiency upgrades, or other bill-relieving

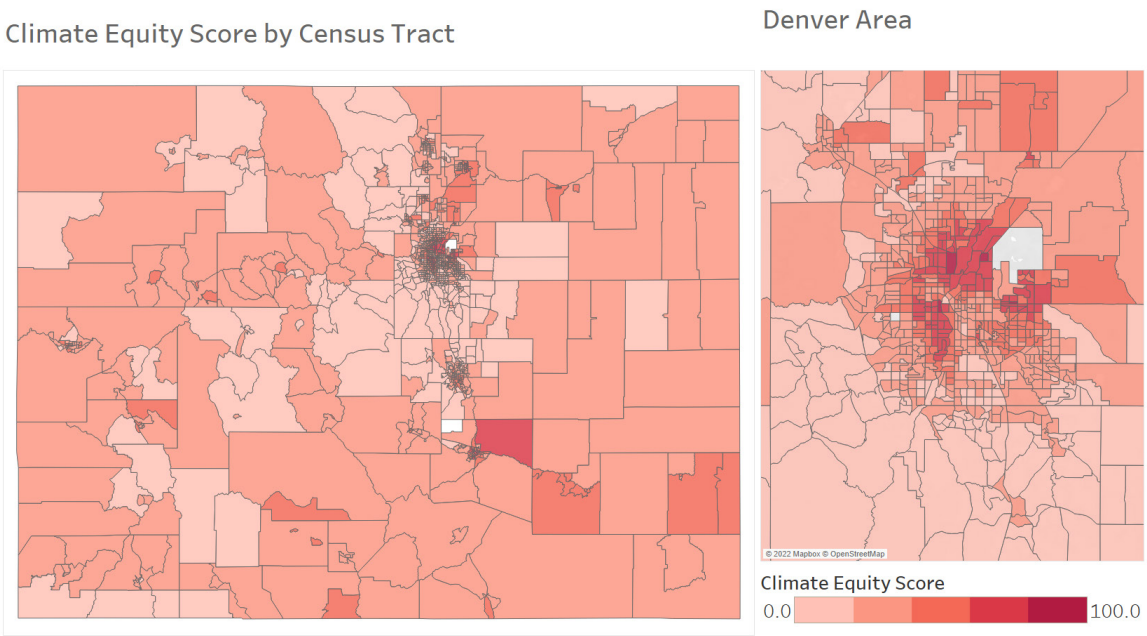

Figure 2.15. Census Tract Climate Equity Scores. Aggregated up to the census tract level, some of the communities with the highest (= worst) climate equity scores are in the Denver area.

124 Colorado Department of Public Health and Environment. (2021). *Climate Equity Data Viewer*. https://www.arcgis.com/apps/webappviewer/index.html?id=25d884fc249e4208a9c37a34a0d75235

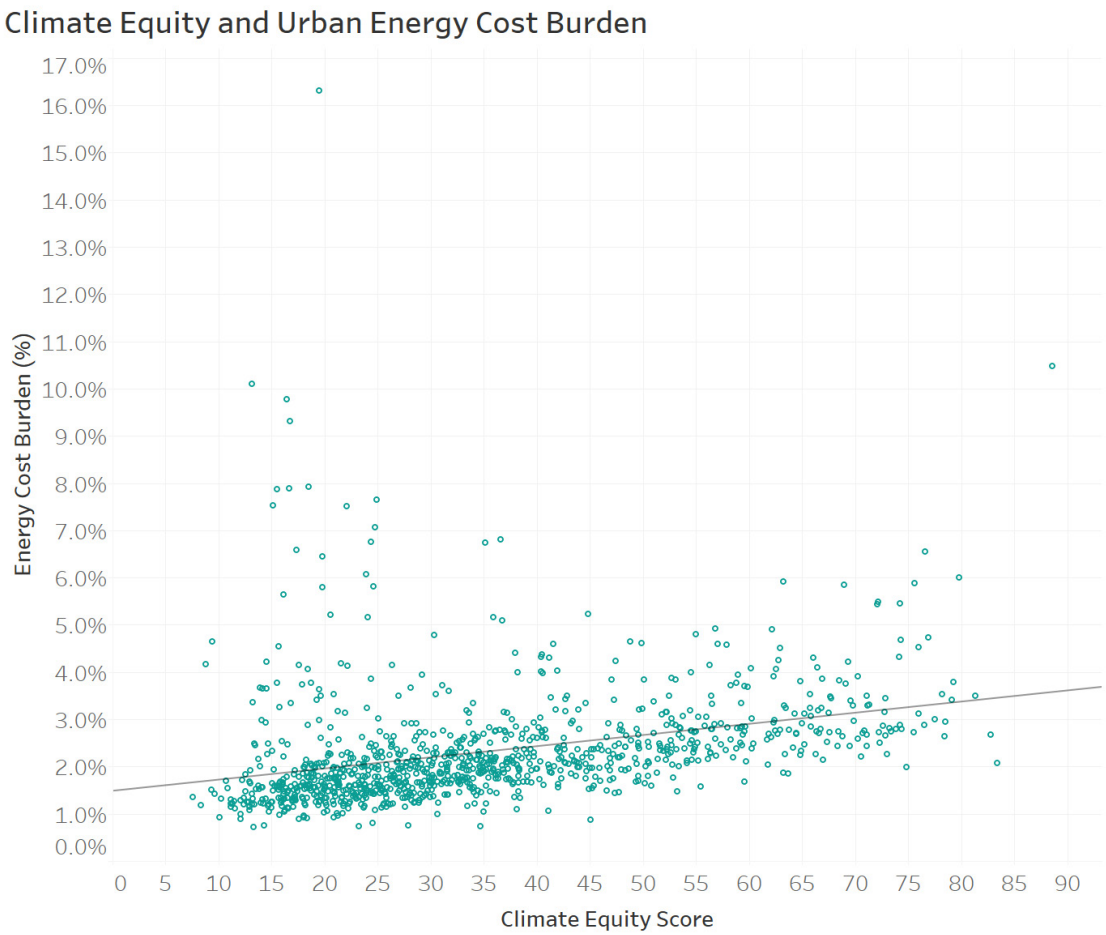

Figure 2.16. Climate Equity Score and Urban Energy Cost Burdens. Metropolitan census tracts that score higher on the Colorado Climate Equity Viewer tend to have higher average energy cost burdens.

clean energy interventions. However, there are some notable communities with low Climate Equity scores and very high energy cost burdens (in rural areas in particular), suggesting that the Climate Equity Data Viewer should not be used exclusively for funding prioritization.

2.2.4 Energy Cost Burden and Utility Service Territories

In addition to the demographic and socioeconomic factors discussed above, energy cost burdens vary based on utility and utility type. Whether the utility is a rural cooperative, investor-owned utility, or municipal utility is related to the prices paid in a neighborhood and accordingly, average energy cost burdens. Utilities also have different programs and policies for improving energy affordability for low-income households. Colorado is served by an array of electricity and gas providers (**Figure 2.17**). According to Department of Homeland

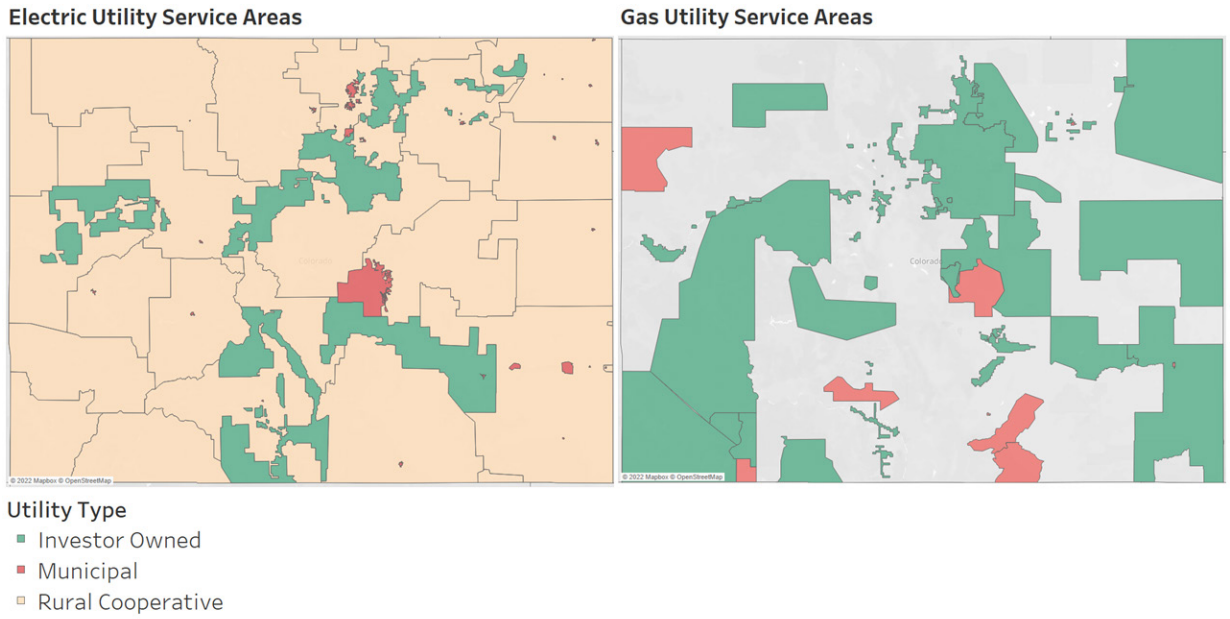

Figure 2.17. Electricity and Gas Service Areas. Colorado is served by many disparate investor-owned, cooperative, and municipal utilities. Rural cooperatives are the most common type of electric utility in terms of overall geographic area served, while investor-owned gas utilities are the most common type of gas utility both in terms of overall area and overall number of customers served.

Security data,[125] much of Colorado's land area is not within the territory of any gas provider, particularly in rural areas. Where gas is available, investor-owned utilities cover the largest land area and serve the most consumers. According to CEO data,[126] investor-owned electric utilities serve most Coloradans, though rural electric cooperatives cover most of the state's geographic area. Rural cooperatives principally serve rural, less densely populated areas. This leads to significantly higher distribution costs and likely contributes to higher electricity prices on average. The two investor-owned utilities have the next largest coverage, followed by municipal utilities, which provide electricity to a small portion of the state.

As noted above and in **Figure 2.2**, rural households tend to pay higher electricity rates. For both electricity and gas, there is substantial variation in utility prices (**Figure 2.18**).[127]

Low-income and other cost-burdened households within the most expensive utility territories for either fuel may be good targets for bill relief and clean energy programs.

Partially due to paying the highest electricity

125 Department of Homeland Security. (2017, August). *Homeland Infrastructure Foundation-Level Data (HIFLD): Natural Gas Service Territories*. https://hifld-geoplatform.opendata.arcgis.com/

126 Colorado Energy Office. (2021, September). *Colorado Electric Utility Data* [Personal communication].

127 Colorado Energy Office. (2021, September). *Colorado Electric Utility Data* [Personal communication].

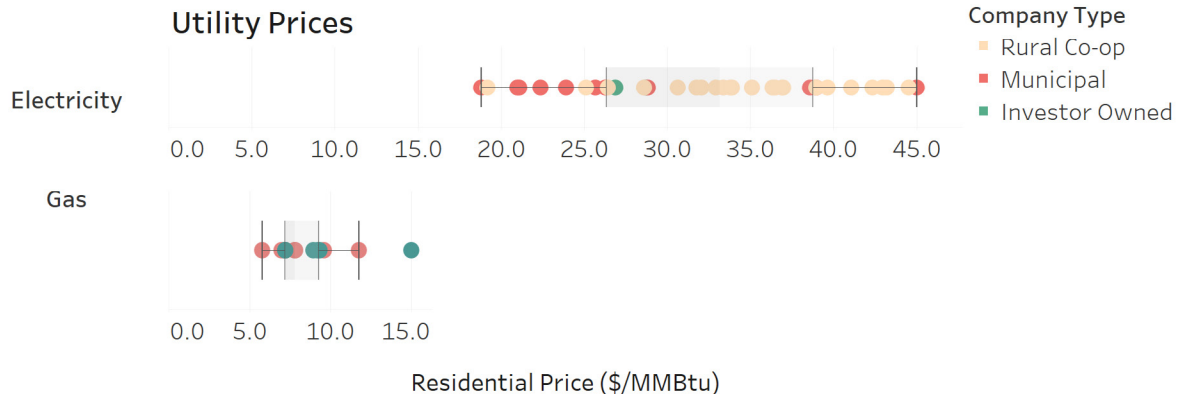

Figure 2.18. Electricity and Gas Prices by Utility Type. Rural cooperatives tend to have the highest electricity rates. There is no strong pattern as to the utility business model and gas rates.

prices, rural cooperative consumers tend to have the highest electricity cost burdens (**Figure 2.19**). Municipal and investor-owned electric utility customers generally have lower electricity cost burdens; at the same time, municipal gas utility customers tend to have higher gas cost burdens than consumers served by investor-owned gas utilities. The distribution of gas cost burdens among investor-owned utility customers is quite large, with many outlier census tracts experiencing significantly higher burdens than most other census tracts within investor-owned utility territories. These

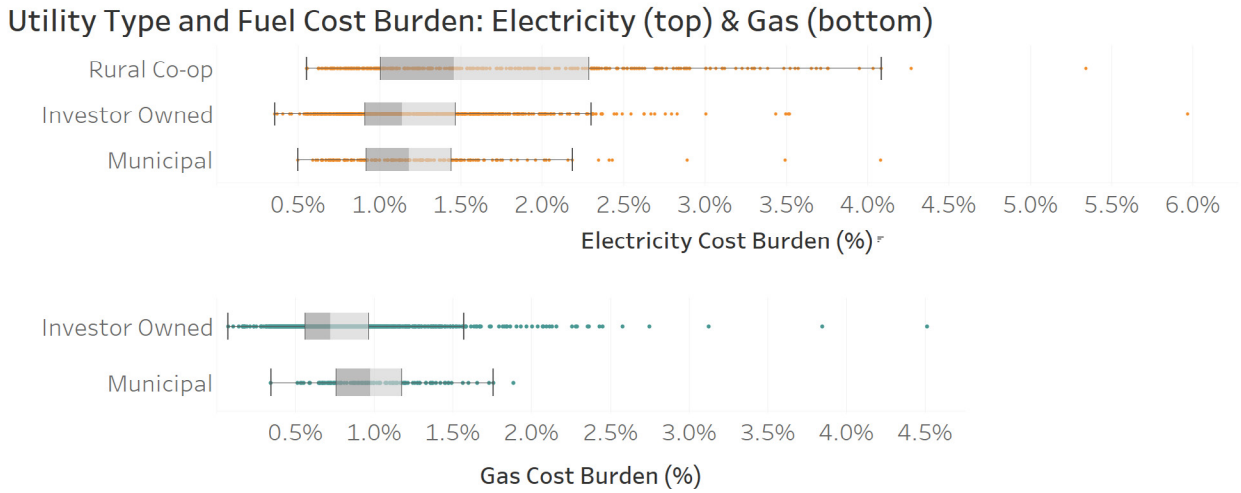

Figure 2.19. Fuel Cost Burdens by Utility Type. Electricity cost burdens are highest on average for households served by rural cooperatives. Gas cost burdens tend to be slightly higher for municipal utility customers, although the census tracts with the highest gas cost burdens are in investor-owned utility territory.

census tracts may prove high-yield targets for bill-relief policies and fuel-switching programs.

2.2.5 Energy Cost Burden and Housing Type

Housing type is also strongly indicative of the level of household energy cost burden. The highest energy cost burdens are typically found in rural mobile homes (**Figure 2.20**). This trend is largely due to reliance on propane for heating and a higher tendency for lower income households to live in mobile homes. In urban areas, mobile homes still experience the greatest energy cost burdens, but less so than in rural areas, in part due to greater access to gas and lower energy prices. Additionally, while multi-family homes tend to be more efficient than single family homes, in urban areas they have slightly greater energy cost burdens than single family homes due to higher concentrations of lower median income households. This analysis suggests that directing energy affordability programs at specific housing types can also help prioritize households that are most burdened by their energy bills.

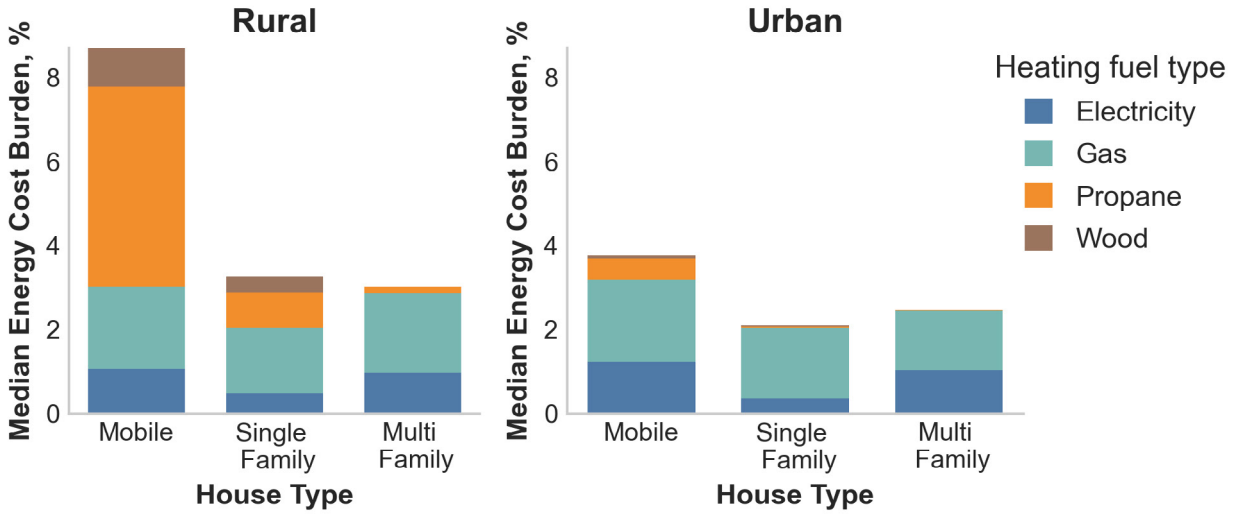

Figure 2.20. Energy Cost Burden by Housing Type in Rural and Urban Areas. Mobile homes have significantly higher energy cost burdens in both rural and urban areas.

2.3 Energy Use Intensity in Colorado

Thus far, we have analyzed energy affordability through the lens of energy cost burden, or the percentage of household income spent on energy needs. Although a crucial metric for evaluating energy affordability, energy cost burden fails to account for additional variables that may influence energy affordability, such as size and household energy efficiency. For instance, a house with old heating appliances or poor insulation may require more energy to heat or cool per square foot than a house with newer, more efficient appliances or improved insulation. A metric that can serve as a proxy for these variables is Energy Use Intensity (EUI). EUI is measured in terms of energy usage per home unit area (MMBtu/square foot) and can be used as a proxy for home energy efficiency. A smaller home with poorer insulation, for example, may require more energy per square foot to heat than a larger home with better insulation. Therefore, the smaller home will have a higher EUI. EUI can therefore be combined with energy cost burdens to assess both where affordability is a challenge and where efficiency may particularly improve affordability. We assessed household EUI across Colorado by calculating the total energy (in MMBtu) used for space heating and cooling for each census tract divided by total household area per census tract (total households times average home square footage per census tract). This EUI calculation only accounts for energy used for space heating from gas, electricity, wood, and propane fuels, or cooling from electricity. We do not include energy use from appliances or water heating as those do not inherently depend on the square footage of a home.

2.3.1 Energy Use Intensity Landscape Across the State

Figure 2.21 below shows average home EUI values by census tract across Colorado. The statewide average household EUI is 0.02 MMBtu/square foot, but many census tracts have average EUI values that exceed this value. Rural areas tend to have higher average household EUI than urban areas. Census tracts with the highest average household EUIs are found in Park, Hinsdale, and San Juan counties while tracts with the lowest EUIs are found in the Denver metropolitan area, as well as Mesa and Larimer counties.

It is worth noting that substantial differences in EUI values still exist within urban areas. The map on the right (**Figure 2.21**) provides a closer look at the Denver metropolitan area, highlighting the many census tracts scattered throughout the region with relatively higher EUIs compared to their neighbors. However, the magnitude of these high-EUI urban census tracts is lower than the EUI of much of rural Colorado. As noted earlier for energy cost burdens, individual households within low-EUI census tracts may still have very high individual EUIs.

Regional climate can be a strong factor for EUI. For instance, homes in areas with cold climates require increased use of space heating and homes with inefficient heating appliances or insulation may require more energy per square foot to heat. To assess climate effects on EUI, we used the Heating Climate Zones described in **Section 2.1** above. **Figure 2.22** maps the five Heating Climate Zones and compares them with census tract-level average home EUI for

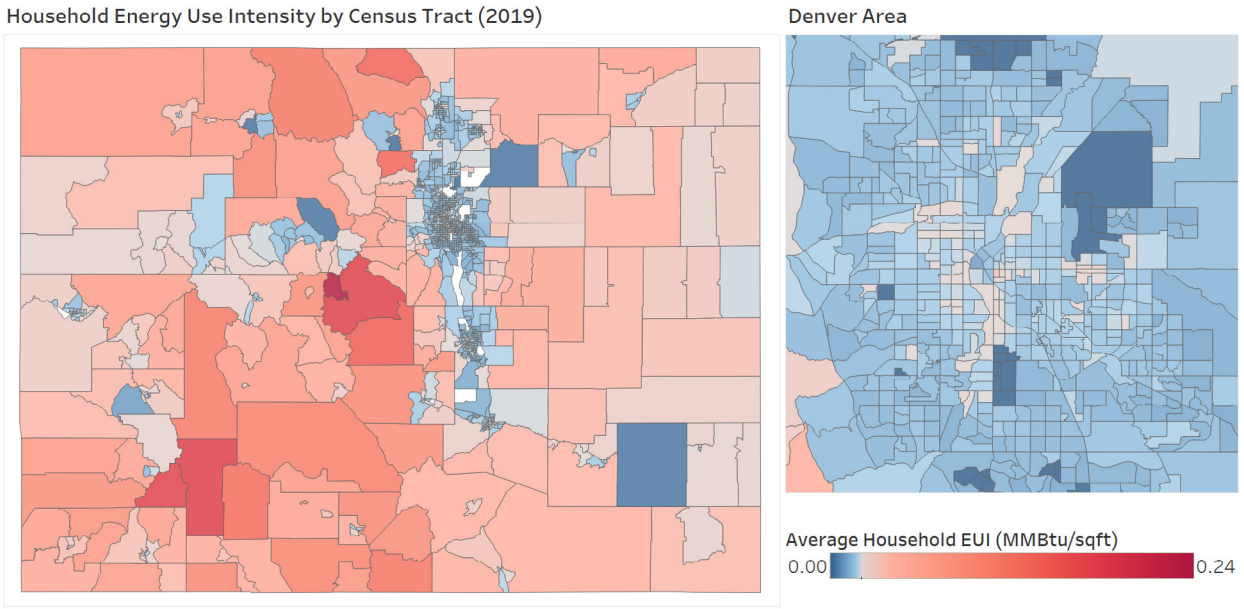

Figure 2.21. Average Household Energy Use Intensity Across Colorado (left) and Denver Metro Area (right). Rural areas tend to have higher average household EUIs (deeper red) than urban areas. However, several urban areas still have higher than average (0.02 MMBtu/sqft, indicated by the blue/red split) EUI values.

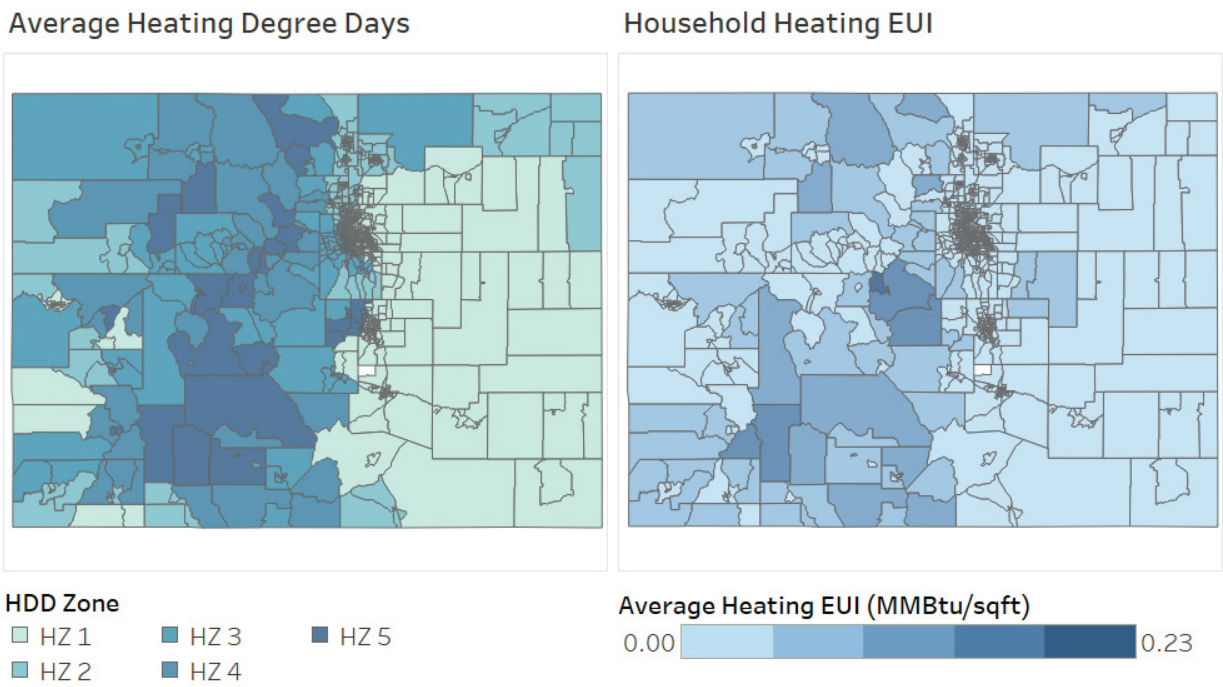

Figure 2.22. Heating Degree Days and Heating Energy Use Intensity Across Colorado. Heating Climate Zones (left) are compared with average home heating EUI (right). On the left, darker colors indicate higher HDDs, indicating colder days. On the right, darker colors indicate higher home heating EUI.

heating fuels (gas, wood, propane, and electricity) only. Many census tracts in colder areas of Colorado (HZ4 and HZ5) also have high heating EUIs. This trend is shown more clearly in **Figure 2.23** below.

Figure 2.24 shows the relationship between household heating EUI and the number of HDDs across the state. Higher HDD values indicate colder weather on average. There is a positive correlation between household heating EUI and the number of HDDs, however, the trend is more prominent in rural census tracts. In urban census tracts, for every additional HDD we see a slight (1.96 Btu/sqft) increase in heating EUI, whereas in rural tracts, each additional HDD correlates to a 12.4 Btu/sqft increase in heating EUI. For an average 2,000 square foot home, this would correspond to a 3,900 Btu increase (urban) or a 24,800 Btu increase (rural) in energy consumption for each additional HDD. This possibly indicates many rural census tracts have homes with less efficient heating systems or insulation, requiring more energy to heat the home per square foot in colder weather.

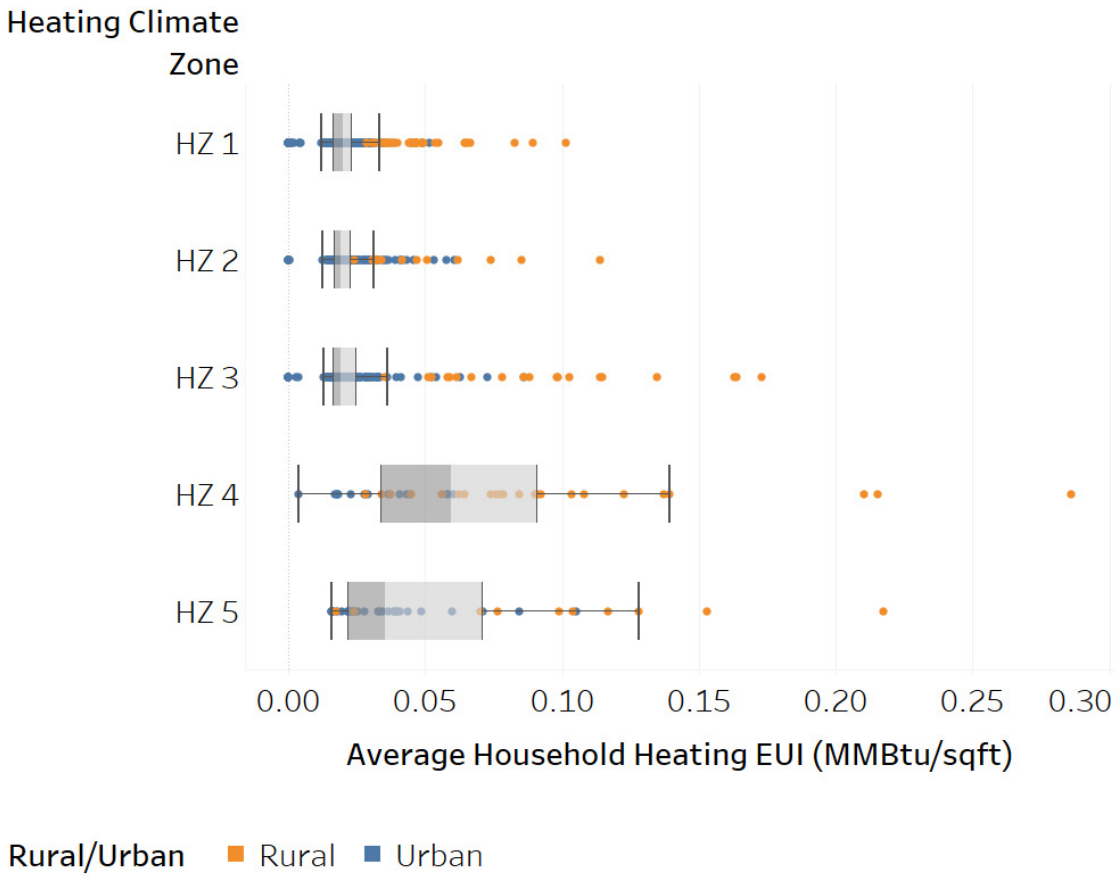

Figure 2.23. Average Household Heating Energy Use Intensity Compared to the Number of Heating Degree Days in 2019. While there is a positive correlation between the number of HDDs and household heating EUI, the trend is much more pronounced in rural areas compared to their urban counterparts.

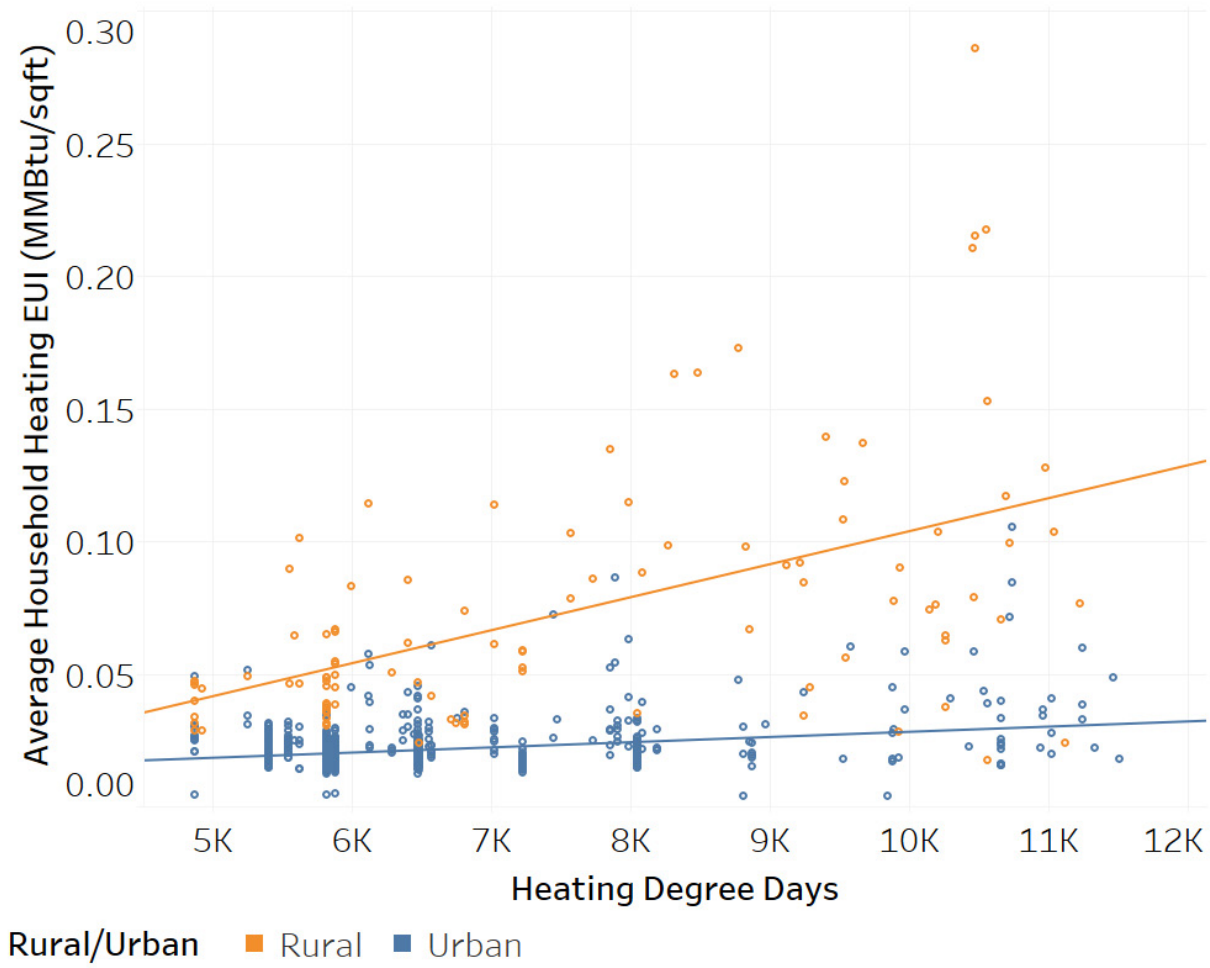

Figure 2.24. Boxplot of Household Heating Energy Use Intensity in Each Heating Degree Day Zone. The two coldest zones (bottom) have the largest spread and range in household EUI values, indicating higher variability in EUI values for these zones. Rural census tracts make up the majority of high EUI values across all HDD zones.

2.3.2 Energy Use Intensity and Income

In addition to geographical and climatic EUI trends, we assessed the relationship between household EUI and median household income by census tract (**Figure 2.25**).

As with energy cost burdens, there is a negative correlation between household EUI and the median household income on a census tract level. Lower-income census tracts tend to have higher household EUI values, and this trend is much more pronounced in rural tracts compared to urban tracts. For urban census tracts, each dollar increase in median household income correlates to a 0.101 Btu/sqft decrease in household EUI, whereas in rural census tracts

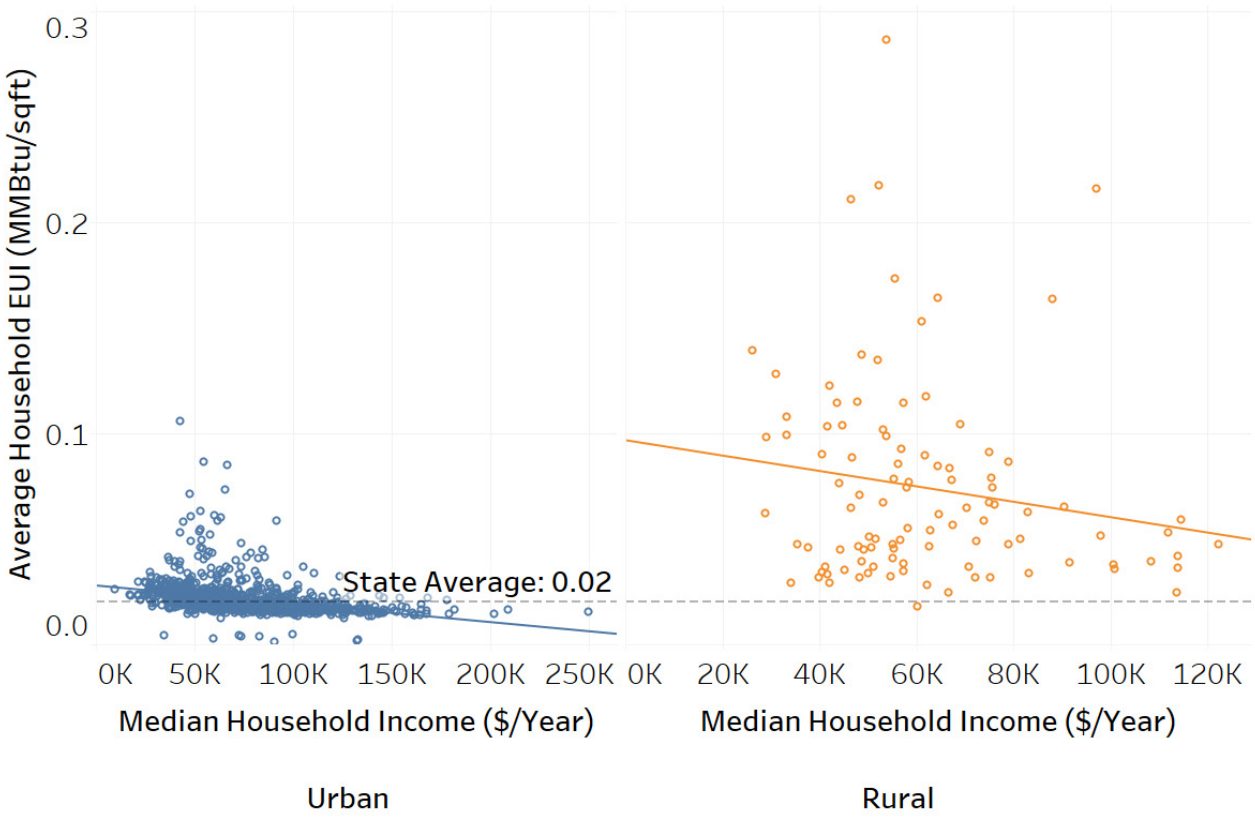

Figure 2.25. Average Household Energy Use Intensity as a Function of Median Household Income. Rural census tracts (right) on average have much higher household EUI values, and a larger spread of EUI values than urban census tracts. Lower-income households in both rural and urban tracts tend to have higher EUI values.

each dollar increase in income correlates to a 3.64 Btu/sqft decrease in household EUI.

Fuel type is another important factor to account for in EUI analysis, as there are differences in the proportion of fuels used across different income brackets, as well as urban and rural areas. **Figure 2.26** highlights these trends.

For both rural and urban areas, lower income brackets had higher household EUIs. Again, this trend is more pronounced in rural areas than in urban areas. Some of this difference is due to fuel use: rural areas are far more reliant on wood and propane as heating fuels. In contrast, urban EUIs stem predominantly from gas as this is the primary fuel used for space heating. Electricity is a relatively small contributor to EUI across income brackets for both rural and urban census tracts.

2.3.3 Energy Use Intensity and Demographics

Additional demographic analysis can also shed light on EUI trends and impacts across Colorado. We assessed EUI among White,

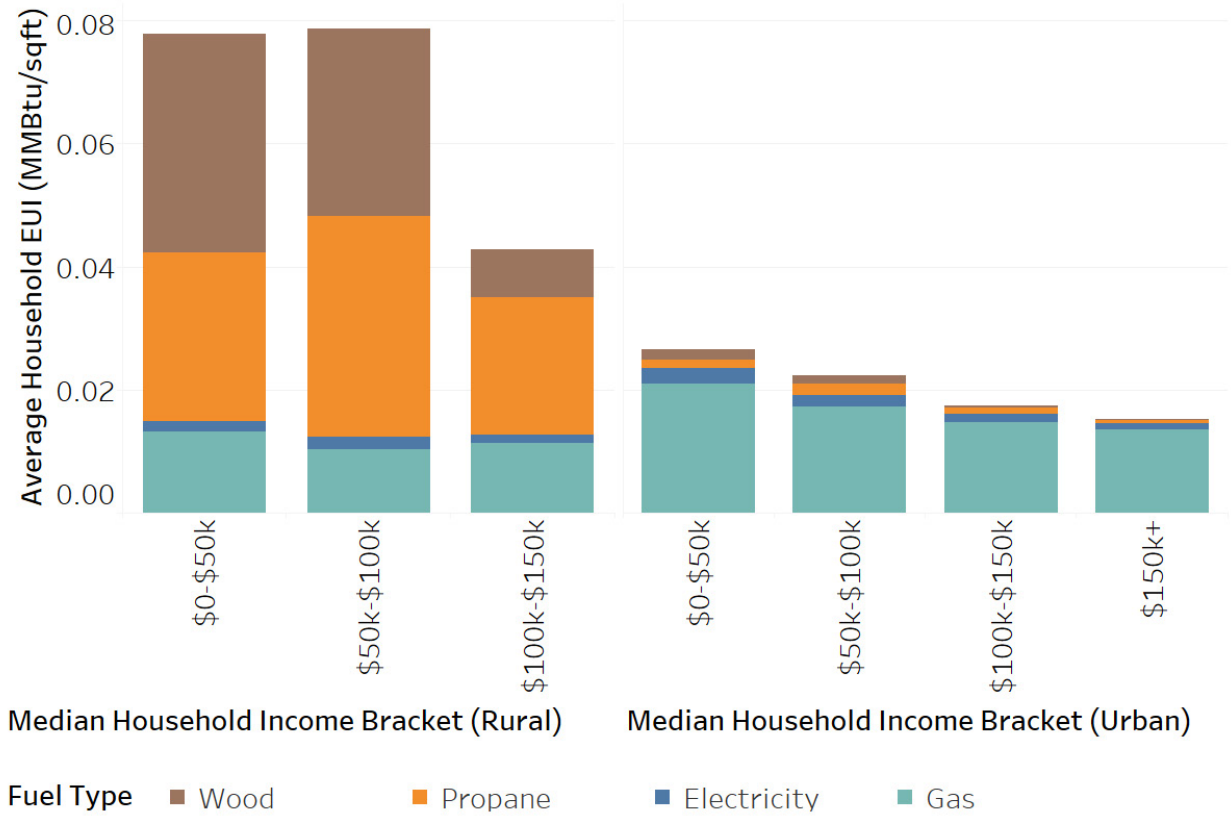

Figure 2.26. Energy Use Intensity, Household Income, and Fuel Use Trends. Household EUI by income bracket for rural (left) and urban (right) census tracts, split by the fuel type used for space heating and cooling. Colored shading of bars indicates the proportion that each fuel type contributes to average EUI within each income bracket indicated on the x-axis.

Hispanic/Latino, and Black populations throughout Colorado both regionally (rural/urban) and by fuel type to determine how EUI is affected by racial background. Our analysis found census tracts with the highest average household EUI tended to be majority-White (>85 percent) and rural (**Figure 2.27**), although some majority-Latino (>80 percent) rural tracts also have high EUI values. Census tracts with higher proportions of Black residents generally had lower EUIs than the state average (0.0258 MMBtu/square foot). This is likely due to the fact that areas with higher proportions of Black residents tend to be overwhelmingly urban.

Similarly, different racial groups had slightly different patterns in the types of fuel used. White and Latino-majority census tracts had a slightly increased reliance on wood and propane as fuel sources compared to tracts with higher proportions of Black residents, however, gas is the primary driver of EUI for all three racial groups in urban census tracts (**Figure 2.28**). Urban census tracts with higher fractions of Latino and Black residents have slightly higher average EUI values than majority-White urban census tracts, particularly due to gas and electricity use. **Figure 2.28** below, only examines urban census tracts, as rural census tracts generally

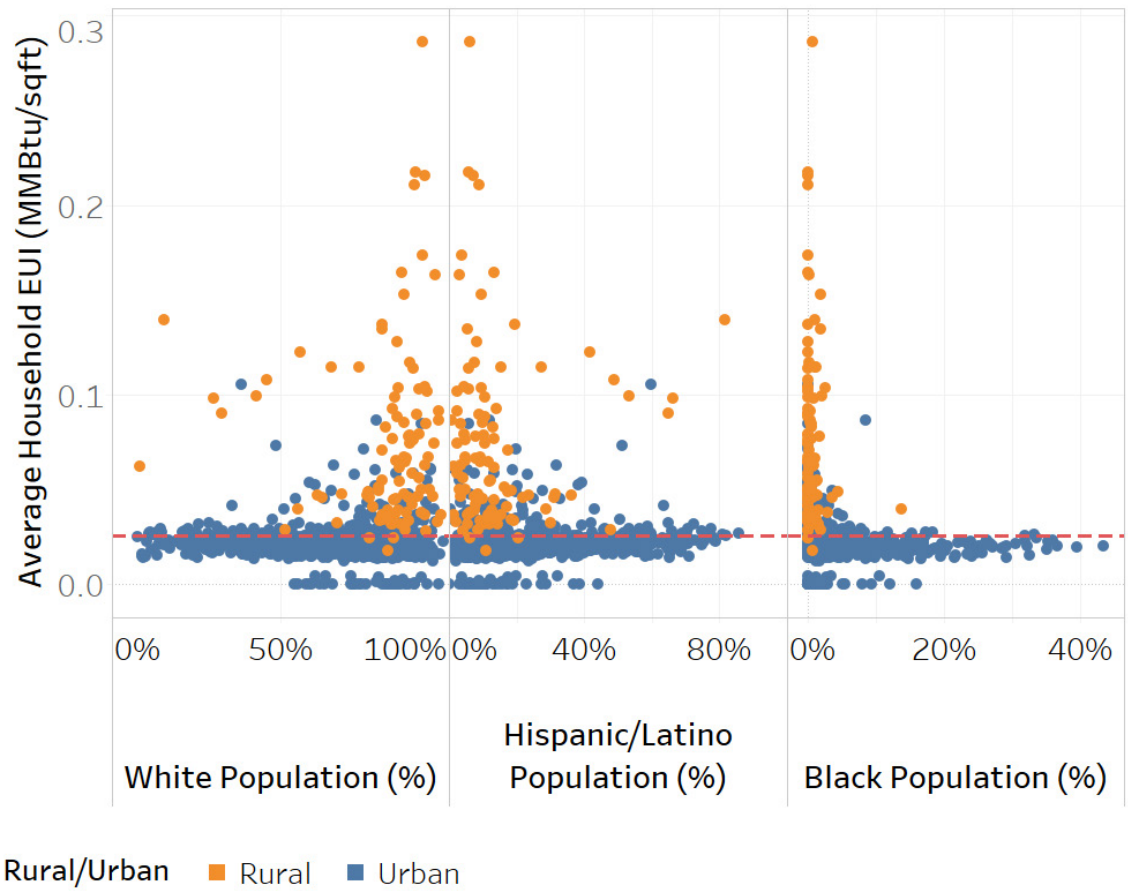

Figure 2.27. EUI and Demographics. Average household EUI by proportion of White, Hispanic/Latino, and Black residents by census tract, colored by rural and urban classification. The majority of rural census tracts are predominantly White, while Latino and Black residents are more represented in urban tracts.

have low proportions of people of color, with the exception of a couple Latino-majority rural tracts (**Figure 2.27**). It is important to note that rural census tracts (which are usually majority-White) will have high EUI values from propane and wood, as these fuels are used more heavily for heating in rural Colorado (**Figures 2.23**, **2.26**).

The heating energy use intensity analysis above clearly demonstrates the relationship between climate, urbanity, and heating energy. However, such analysis can conceal the impacts of socioeconomic effects such as income. To investigate the tract-level effects of median household income on efficiency, we also used a linear model to control for the effects of climate and urban/rural classification and found that households with greater incomes have lower EUI values. Specifically, for each decrease in median income by $10k, we find an increase in the EUI value of 0.9 Btu/sqft.

> ***For each decrease in median income by $10k, we find an increase in energy use intensity of 0.9 Btu/sqft.***

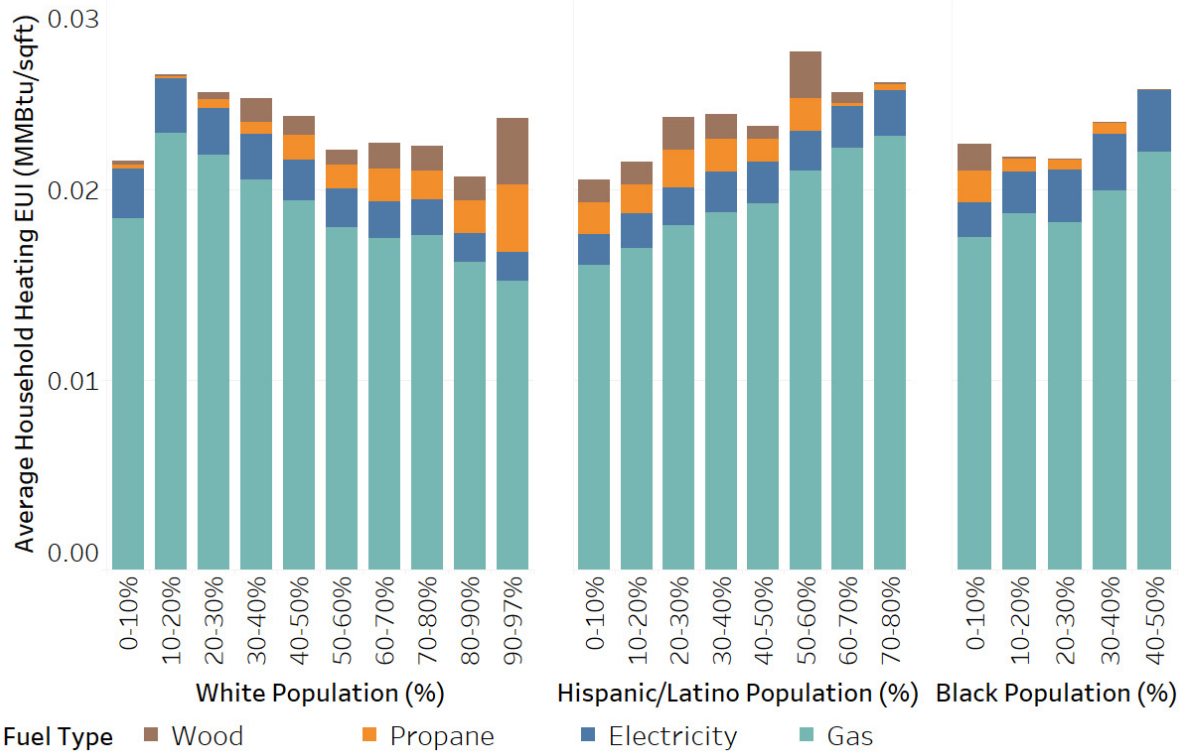

Figure 2.28. Heating Energy Use Intensity and Fuel Use for White, Latino, and Black Coloradans in Urban Census Tracts. Gas is the primary driver of EUI across all three racial groups, although census tracts with higher proportions of populations of color have higher gas and electricity EUI.

This difference approximately translates to an extra $30 in annual energy spending on heat for a home size of 2,000 square feet. We find a smaller influence due to the racial composition of a tract. A household in a tract with three quarters persons of color will have an EUI value 0.02 Btu/sqft higher than a household in a tract with close to zero persons of color.

2.3.4 Energy Use Intensity and Utility Service Territories

Finally, we assessed the relationship between gas utilities and gas heating EUI for investor-owned utilities and municipal gas utilities.

We focused on gas for this analysis because it is the primary utility-provided fuel driving high household EUI. Electricity, in contrast, contributed relatively little to household EUI. Households in investor-owned utilities had slightly higher average gas EUI on a census tract level, as well as a wider spread in EUI values, than municipal utilities (**Figure 2.29**).

Across both utility categories, lower-income households disproportionately had higher household gas heating EUI. The average gas EUI and average HDD in each utility territory are shown in **Figure 2.30**.

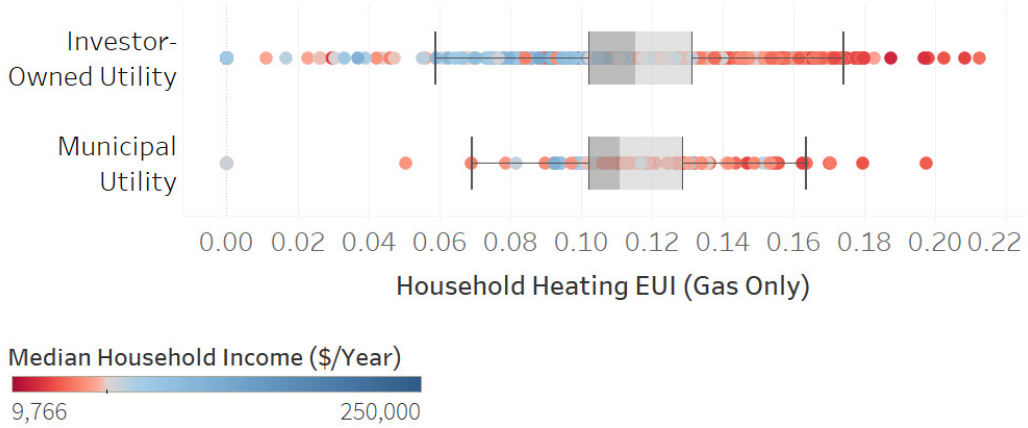

Figure 2.29. Gas Energy Use Intensity by Utility Type. Boxplot of gas utility service types by average EUI, colored by median household income (color center: $65,037/year). Investor-owned utilities had the largest spread of EUI values and had higher average household EUIs than municipal gas utilities.

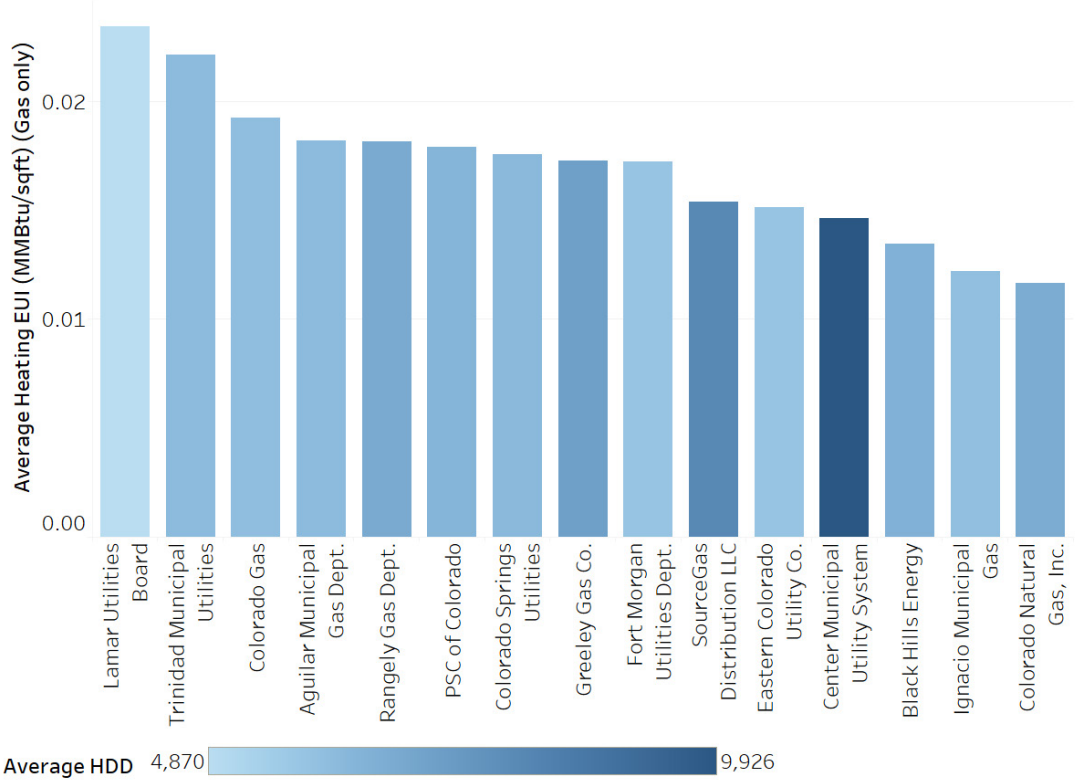

Figure 2.30. List of Gas Utilities by Gas Energy Use Intensity. Ranking of gas utility companies by the highest average EUI (gas only), colored by the average number of HDDs. Lamar, Trinidad, and Colorado Gas were the top three utility territories ranked by average gas EUI.[128]

128 SourceGas Distribution LLC is now owned by Black Hills Energy.

2.4 Energy Burden Themes

The analyses conducted thus far reveal a number of emergent themes about energy use and costs, both regionally and between different populations. Below, we summarize the rural/urban divide in energy trends as well as the relationship between demographics, housing type, heating fuel, and climate and energy consumption and cost burdens.

Urban and rural areas: Rural areas across Colorado typically have higher energy cost burdens and higher energy use intensity than urban areas. Homes in urban areas use less energy and are subject to lower average energy prices than rural areas, which are largely served by rural co-ops. Furthermore, rural homes are more likely to use propane and wood. The former tends to be more expensive and the latter is associated with higher indoor air pollution.

Population characteristics: Certain demographic and socioeconomic characteristics are also associated with energy cost burden and use. Lower-income households have the greatest energy burdens. Due to household income disparities these burdens fall disproportionately on populations of color. Even so, when controlling for the effects of income, we find that communities of color in urban areas, renters, and tracts with lower educational attainment are still subject to higher energy cost burdens than Whiter and more educated communities with the same income. In rural areas, populations tend to be more low-income, White, and in some regions Indigenous, and these areas also face high energy cost burdens.

Climate: Energy use per square foot is higher in colder climates due to increased space heating needs. When controlling for the climate and differences between urban and rural households, we find that households with higher incomes are more efficient despite using more energy. This disparity in efficiency may be due to limited funds in low-income households for efficiency upgrades as well as what is known as the "split incentive" problem, in which renters pay the energy bill but landlords are responsible for investments in efficiency.

Tenure and housing type: In urban areas, communities with a larger proportion of renters face higher energy cost burdens than those with more homeowners even though they use less energy on average. Apartments tend to be more energy efficient but also less owner occupied, which correlates strongly with income and therefore with energy cost burden.

SECTION 3

Policy Recommendations

3.1 Overview and Objective of Policy Recommendations

We introduce a set of policy recommendations with the broad goal of ensuring reliable access to affordable energy for all Colorado households. Specifically, the purpose of our recommendations is to reduce energy cost burdens for all low- and moderate-income households to six percent of their income or less, and to achieve this target through a suite of policies and programs over the course of approximately twenty years. This timeframe broadly aligns with the rate of building electrification and decarbonization required to achieve the statewide climate goal of reducing greenhouse gas emissions by 90 percent from 2005 levels by 2050, but following a pathway that prioritizes low- and moderate-income households in this transition. In parallel with reducing energy cost burdens, we identify approaches that reduce indoor and outdoor air pollution, mitigate climate impacts, and increase energy resilience.

The central pillars of our approach to reducing energy cost burden are ***energy investments*** and ***energy assistance***, which are supported by an array of enabling strategies including financing. We begin by developing a pathway to reduce energy cost burdens systemically through investments in energy efficiency, community solar gardens, beneficial electrification, and other technologies. These energy investments are meant to reduce the amount of energy used, such as through efficiency measures, as well as lower the cost of energy itself by providing discounted electricity from community solar gardens. Given that these investments will take time to yield results, and will

BOX 3.1

Energy Investments

Energy investments include community solar gardens, home weatherization and energy efficiency measures, beneficial electrification such as replacing fuel heating systems with heat pumps, smart technology to enable demand response, and other technological investments to systemically reduce energy demand and provide lower-cost energy.

Energy Assistance

Energy assistance includes programs, such as percentage of income payment plans, that reduce bills for income-qualified households to improve energy affordability. Existing assistance programs in Colorado are detailed in **Table 3.2**.

must align with climate-related building decarbonization efforts, we also identify energy assistance needs to reduce bills for low- and moderate-income households. Our goal is to increase enrollment in programs such as percentage of income payment plans (PIPP) in the near term, while reducing or phasing out the need for such assistance over time through home and energy infrastructure investments. Based on present modeling, the energy cost burdens of most low- and moderate-income households can be reduced to below six percent via systemic investments. Assistance will likely still be needed for the lowest-income households (such as those earning less than 50 percent of the Federal Poverty Level) and for emergency situations, such as a serious illness or loss of a job. In other words, energy assistance will likely still be needed at roughly current levels, but differently distributed among Colorado households.

We begin our policy recommendations with an overview of relevant existing policies and programs in Colorado (**Section 3.2**). These efforts include bill assistance programs, such as PIPP, the Colorado Low-income Energy Assistance Program (LEAP), and the Weatherization Assistance Program (WAP). These programs are also meant to reduce energy cost burdens, but will need greater funding and participation rates to reach all cost-burdened households in the state. We next describe a policy and program toolbox that can be used to address energy cost burdens (**Section 3.3**). In **Section 3.4**, we draw on our energy cost burden analysis (**Section 2**) and additional data to identify deployment strategies and priorities, such as investment needs in rural versus urban areas, or for mobile homes compared to single-family or multifamily buildings. In **Section 3.5** we identify a central set of programs and policies and model their impacts and costs over a twenty-year period. Finally, in **Section 3.6**, we address additional enabling considerations such as barriers to program participation. We summarize our recommendations in **Section 3.7**.

Our overarching approach is guided by a number of observations. First, all homes in Colorado will need to reach increasing levels of energy efficiency and the state will see increasing levels of electrification measures over the next 20-30 years to achieve climate goals, including installations in low- and moderate-income households. Prioritizing investments in these households can help increase energy affordability earlier. Second, reducing energy cost burdens for all households through energy assistance alone would require sustained levels of funding that may be difficult to maintain indefinitely, but prioritizing home, energy, and appliance investments can help reduce these assistance needs. Finally, many low- and moderate-income households face barriers to receiving assistance, including lack of information, lack of access to broadband, proximity to assistance offices, concern that such assistance may be accompanied by social stigma, mixed immigration status, linguistic isolation, and so forth. These reasons all support our long-term emphasis on energy investments, with increased energy assistance providing a bridge until sufficient investments can take place.

The current energy cost burden landscape is not static. Low- and moderate-income households may experience future bill increases from factors such as (i) increasing rates, including those required to make the

grid more resilient to climate disruption; (ii) inability to adapt to time-of-use or tiered rates; (iii) increasing electric demand for cooling as summers warm; and (iv) increasing rates due to gas price variability and due to gas distribution costs being borne by a declining number of customers, who are more likely to be from the lower end of the income spectrum. This changing landscape will affect our recommendations as well.

Our policy analysis leads us to recommend six core strategies to achieve energy cost burden reductions statewide. These recommendations include (i) the expansion of the PIPP program in the near term, (ii) expansion of grants for weatherization assistance for the very lowest income households (mainly less than 50 percent of the Federal Poverty Level); (iii) the use of the Colorado Clean Energy Fund to provide low- to no-interest financing for energy efficiency and electrification measures for low- and moderate-income households; (iv) the expansion of community solar gardens to provide discounted energy to low- and moderate-income households; (v) the expansion of demand response to provide additional energy cost benefits to residential households; and (vi) the reduction of routine PIPP assistance over time as the other measures effectively reduce energy cost burdens. We describe these programs and their deployment in the following sections, as well as the regions, populations, and housing characteristics that are most likely to benefit from specific types of interventions. Such targeted strategies may be particularly valuable for rural communities, cooperative utility customers, propane-users, mobile home occupants, renters, and medically-vulnerable populations, among others.

3.2 Policy and Program Landscape

3.2.1 Overview of Existing Policies and Participation Rates

Colorado has a range of existing programs to provide energy assistance and clean energy access for low-income and underserved communities. These include heating energy assistance provided by federal Low Income Home Energy Assistance Program (LIHEAP) funds (called LEAP in Colorado), some of which are also used for weatherization; the federal WAP, which additionally provides some funding for rooftop solar and whose funding levels are expected to increase under House Bill 21-1105;[129] PIPP, whose target is to reduce low- and moderate-income household energy cost burdens to six percent or less; and a community solar garden program. Additional energy efficiency and appliance upgrade programs include the Colorado Affordable Residential Energy (CARE) program and the Crisis Intervention Program (CIP). Thus, one of the principal goals of the present report—mapping a route to reduce energy cost burdens to affordable levels—is already part of state policy so far as most of the needed policy tools are concerned. However, participation rates are currently low and resources insufficient for achieving this goal for all low- and moderate-income households.

Table 3.1. Household Eligibility Requirements for LEAP, WAP, and PIPP Based on Household Size.[130] Under current Public Utilities Commission rules for PIPP programs, households must qualify for LEAP to be enrolled in PIPP.

Household Size	Maximum Gross Annual Income (LEAP and WAP) (60% of State Median Income)*	Maximum Gross Annual Income (PIPP) (185% Federal Poverty Level)*
1	$28,452	$23,606
2	$37,212	$31,894
3	$45,972	$40,182
4	$54,732	$48,470
5	$63,480	$56,758
6	$72,252	$65,046
7	$73,884	$73,334
8	$75,528	$81,622

*Based on 2020 numbers for Federal Poverty Level and state median income.

129 Legislative Council Staff. (2021). Final Fiscal Note: House Bill 21-1105. http://leg.colorado.gov/sites/default/files/documents/2021A/bills/fn/2021a_hb1105_f1.pdf

130 ADM Associates. (2020, October). Evaluation of the Percentage of Income Payment Plans, Table 4-2.

In addition to increasing funding for assistance and programs, additional funding will be required to reduce barriers to program access and increase participation rates. An overview of Colorado's key programs—LEAP, PIPP, WAP, and community solar gardens—as well as current funding and participation rates are described below. **Table 3.1** displays the household income requirements for WAP and the two bill-assistance programs, based on state median income for WAP and LEAP and the Federal Poverty Level for PIPP.

Low-income Energy Assistance Program (LEAP)

Colorado's LEAP program is a federally-funded program that aims to reduce heating costs for low-income Colorado households. The program is funded through the federal Low Income Home Energy Assistance Program, or LIHEAP, and provides direct financial payments to offset heating costs. LEAP additionally provides heating repair and appliance replacement for households with broken heating systems.[131] For fiscal year 2020, the program received a total of 108,692 applications. Of these, 76,629 were approved, 32,058 were denied, and five were pending. The average annual household benefit across all counties was $671.12.[132] These values are up from fiscal year 2019, when 94,666 applications were received, 68,192 were approved, 26,474 were denied, and the average benefit was $462.93. The spike in applications in 2020 may be COVID-related. Overall, in 2019 LEAP served roughly 18 percent of Colorado's over 377,000 eligible households.[133] The overall funding for the program was $82,822,810 for FY 2019-2020, up from $54,007,094 for FY 2018-2019.

Percentage of Income Payment Plan (PIPP)

The Colorado PIPP program requires investor-owned utilities to provide assistance to households with an income at or below 185 percent of the Federal Poverty Level, or who otherwise qualify for LEAP. PIPP provides low-income households with an affordable payment plan and a process to provide arrearage credits, and is funded through a surcharge on residential and nonresidential utility customers.[134] Residential surcharge rates are capped at $1.00/month, but can be lower if program costs can be covered through a lower fee.[135] The total budget for PIPP across all utilities was estimated to be at around $12 million for FY 2018-2019.[136]

Key Takeaways for LEAP and PIPP from the Colorado Energy Office PIPP Report

Despite the economic benefits PIPP provides for individual households, statewide enrollment rates are low. According to the report conducted for the Colorado Energy Office by ADM Associates evaluating PIPP,

131 ADM Associates. (2020, October). Evaluation of the Percentage of Income Payment Plans.

132 Colorado Low-income Energy Assistance Program (LEAP). (n.d.). https://cdhs.colorado.gov/leap

133 Administration for Children and Families. (2019). LIHEAP Performance Measures. https://liheappm.acf.hhs.gov/sites/default/files/private/congress/profiles/2019/FY%202019%20CO%20Profile.pdf

134 Department of Regulatory Agencies. (2020, December 23). *PUC issues emergency rules to expand utility programs for low-income customers during winter heating season.* https://dora.colorado.gov/press-release/puc-issues-emergency-rules-to-expand-utility-programs-for-low-income-customers-during

135 ADM. (2020, October). Evaluation of the Percentage of Income Payment Plans, Section 4.1.3.1.

136 ADM. (2020, October). Evaluation of the Percentage of Income Payment Plans, Table 4-15.

the majority of qualified customers are not enrolled in PIPP: across Colorado, 11 percent of households are PIPP-eligible, but only eight percent of these eligible households are enrolled in the program.[137]

> ***11 percent of households are PIPP-eligible, but only eight percent of these eligible households are enrolled in the program.***

This low participation rate may be due to several reasons, including a lack of awareness about the program and some barriers to participation. Many PIPP recipients are unaware of receiving the benefit, or do not understand the financial benefit the program brings. Customer understanding regarding LEAP was higher, likely because LEAP benefits appear as line items on customer bills. The LEAP office (along with nonprofit partners) focuses on large-scale communications and outreach efforts for the program, including media releases, TV ads, non-profit-provided applications, web materials, and a toll-free phone number. These outreach channels are provided in English and Spanish. However, the online LEAP materials do not make mention of PIPP. For most utilities, enrollment in PIPP is automatic for qualified customers enrolled in LEAP. Black Hills Colorado Electric is an exception, as they require an application for PIPP to receive the benefit—likely because the utility has insufficient funding to support the enrollment of all eligible customers. Utilities also use different program names for their PIPP assistance, which could hinder participation rates. Generally, LEAP enrollment drives PIPP enrollment. PIPP-qualified customers are generally also qualified for LEAP, as PIPP has a lower income requirement (with the exception of 8-person households). LEAP requires a member of the household to be a permanent resident or that the household members are all US citizens. As enrollment in LEAP was required for PIPP prior to the 2021-2022 heating season, non-permanent residents or non-citizens were not able to participate. Finally, utility PIPP assistance uses levelized billing, which surveys indicate can be a deterrent for many participants and potentially a primary factor in customers opting out of PIPP, according to survey respondents.

LEAP participation rates are also low, although at 18 percent participation (see **Table 3.2** below), the Colorado participation rate is similar to the average rate for the whole country. There are a host of barriers to participation, including documentation requirements, access to physical offices where eligible households can get in-person assistance for filling out applications, and lack of broadband access. Improving PIPP and LEAP participation while measures such as weatherization and electrification are put in place is a critical part of the path to an equitable energy transition.

Weatherization Assistance Program (WAP)

The Colorado WAP program aims to provide home weatherization for low-income households in order to improve overall home energy efficiency. The program has historically been funded through federal

137 ADM (2020, October) Evaluation of the Percentage of Income Payment Plans Section 1.1.1.

sources (LIHEAP, Department of Energy), as well as through severance taxes and utility-contributed rebates. Beginning in July 2022, WAP is expected to receive an additional $11 million in funds annually from a system benefit charge established in House Bill 21-1105, which will replace several tax funds.[138] Around 60-70 percent of homes enrolled in WAP also receive benefits from LEAP.[139] Utilities are also required to provide the Colorado Energy Office with the names and service addresses for participant households that exceed 10,000 kWh electricity consumption or 600 therms of gas consumption annually.[140, 141] Around 2,100 homes receive weatherization assistance annually. Weatherization costs roughly $7,000 per home on average, and the program director estimates there are roughly 500,000 homes in Colorado that require weatherization.[142] This means that current funding levels cannot support statewide weatherization needs. Households that qualify for LEAP or other assistance programs (TANF, SSI, SNAP), or have a household income of 60 percent of the state median income, also qualify for WAP.[143] The distribution of programs used by households to qualify for WAP are shown in **Figure 3.1.** WAP is administered and managed by region (**Figure 3.2**).

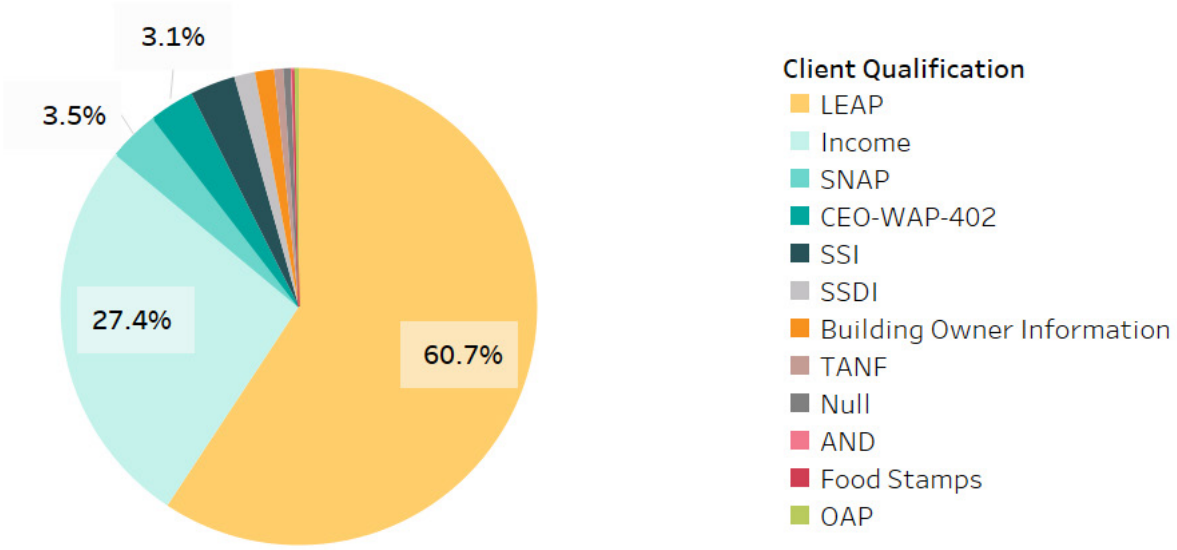

Figure 3.1. Programs That Qualified Recipients for WAP (2016-2021). The majority of participants qualified for WAP through LEAP or by meeting income level requirements.

138 Low-Income Utility Payment Assistance Contributions, HB 21-1105. (2021). http://leg.colorado.gov/sites/default/files/documents/2021A/bills/2021a_1105_enr.pdf

139 ADM. (2020, October). Evaluation of the Percentage of Income Payment Plans, Section 4.1.2.2.

140 723-3 Electric Utilities Rules

141 723-4 Gas Utilities Rules

142 ADM (2020, October). Evaluation of the Percentage of Income Payment Plans, Section 4.1.2.2.

143 Weatherization FAQs. (n.d.). https://energyoffice.colorado.gov/weatherization-assistance/weatherization-faqs.

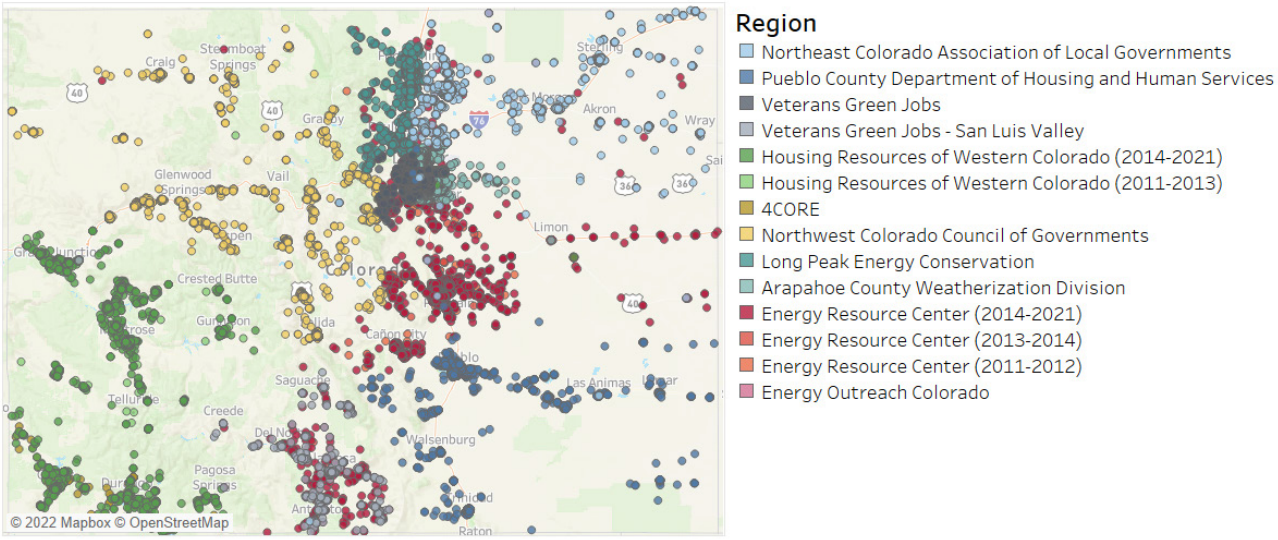

Figure 3.2. Weatherization Service Providers Across Colorado (2011-2021).

Other Energy Assistance Programs in Colorado

In addition to LEAP, PIPP, and WAP, Colorado has several programs that provide assistance to low-income households with high energy burdens. Among these is the Property Tax/Rent/Heat Credit Rebate (PTC Rebate), which provides tax rebates for home heating payments for residents 65 years of age or older, surviving spouses at least 58 years of age, and residents with disabilities regardless of age.[144] The PTC income limit varies annually—in 2020, the income limit was $15,591 for single person households and $21,057 for married couples.[145] The rebate amount is based on the applicant's income and expenses, but the maximum tax rebate in 2019 was $735, while the maximum heat expense rebate was $202.[146]

Energy Outreach Colorado is a 501(c)3 nonprofit organization that raises funds for energy assistance programs for low-income households through individual, organizational, and governmental resources. Energy Outreach Colorado provides funds to existing programs like LEAP and WAP, and assistance through their own programs like Colorado's Affordable Residential Energy

144 Colorado Department of Revenue. (2021, January 23). *About the PTC Rebate.* https://tax.colorado.gov/PTC-rebate

145 Colorado Department of Revenue. (2020). Colorado Property Tax/Rent/Heat Rebate Filing Guide. https://tax.colorado.gov/sites/tax/files/DR0104PTC_2020.pdf

146 Doherty, E. (2019, August 10). Residents in Subsidized Housing Now Eligible for Help with Rent. My Prime Time News. https://www.myprimetimenews.com/residents-in-subsidized-housing-now-eligible-for-help-with-rent/

(CARE) and the Crisis Intervention Program (CIP).[147] Energy Outreach Colorado's 2020 summary report indicated the organization provided over $29 million in funds for affordable home energy programs, of which $12.5 million went to energy assistance, $12.8 million went to free energy efficiency upgrades, and $3.7 million to CIP. Overall, the organization served nearly 33,000 households in 2020.

The total funding available through PIPP, WAP, LEAP, CIP, CARE, and EOC Bill Payment Assistance for fiscal year 2018-2019 is shown in **Figure 3.3. Table 3.2** summarizes the administrator, program type, eligibility requirements, participation rates, and funding levels for each of these programs.

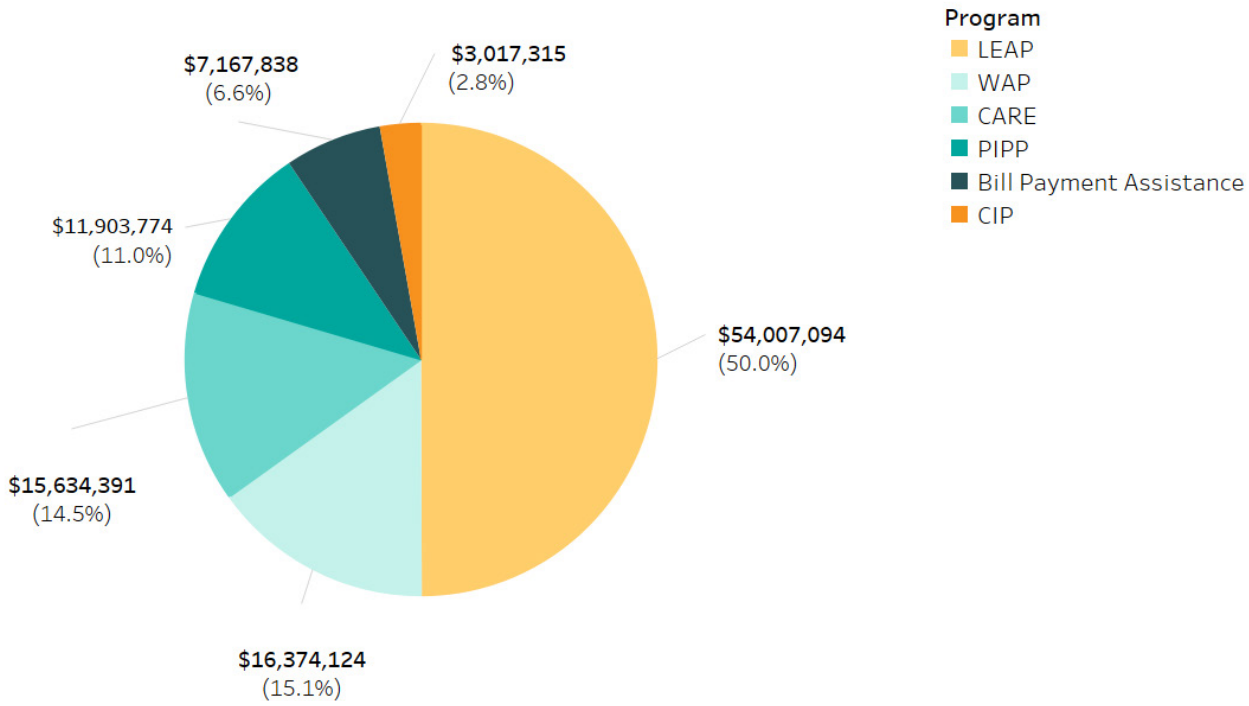

Figure 3.3. Total Funding Across PIPP, WAP, LEAP, CIP, CARE, and EOC Bill Payment Assistance. Data shown for fiscal year 2018-2019.

147 Energy Outreach Colorado. (2020). *Annual Report 2020.* https://www.energyoutreach.org/annual-report-2020/

Table 3.2. Summary of Energy Assistance Programs in Colorado.

Program Name	Administrator	Program Type	Eligibility Limits	Participation Rate	Annual Funding	Number of Eligible Households
Low-income Energy Assistance Program (LEAP)	Colorado Energy Office (CEO)	Financial assistance to households with high heating costs	Income below 60% of Colorado's State median income	14% (FY 2019-20) 18% (FY 2018-19)	$81,822,810 (FY 2019-20) $54,007,094 (FY 2018-19)	542,815[148] (FY 2019-20) 377,432 (FY 2018-19)[149]
Crisis Intervention Program (CIP)	Energy Outreach Colorado (EOC)	Repair and replacement of broken heating systems	Primary home heating source is faulty or inoperable, household qualifies and is approved for LEAP	N/A	$3,736,813 (FY 2019-20)[150] $3,017,315 (FY 2018-19)[151]	
Colorado WAP	Regional offices (see **Figure 3.2**), EOC for multifamily residences statewide	Provision of energy efficiency, rooftop solar, and other beneficial to low-income households	Qualify for LEAP, or other assistance programs like: Aid to the Needy and Disabled (AND), Supplemental Security Income (SSI), Supplemental Nutrition Assistance Program (SNAP), Temporary Assistance for Needy Families (TANF)	12%* [152]	$14,587,442 (FY 2019-2020)[153] $16,374,124 (FY 2018-2019)[154]	~500,000–700,000 (according to WAP Program Director)[155]
Colorado's Affordable Residential Energy (CARE) Program	EOC	Energy efficiency upgrades for low-income households	Household is in a participating county and serviced by a participating utility, meets income requirements (80% of Area Median Income)	N/A	$12,971,567 (FY 2019-2020)[156] $15,634,391 (FY 2018-2019)[157]	
Bill Payment Assistance	EOC	Provides payment assistance to households behind on their energy bills	Households pay bills directly to a utility, bill is late or household is low on fuel, and household income is at or below 80% Area Median Income		$12,568,438 (FY 2019-2020)[158] $7,167,838 (FY 2018-2019)[159]	
Percentage of Income Payment Plan (PIPP)	Investor-Owned Utilities	Assistance plan through utilities to cap low-income household energy bills at 6% of income	Household income at or below 185% Federal Poverty Level, household qualifies for LEAP	8%[160]	$11,903,774[161,162] (FY 2018-2019)**	303,653[163]

*This number reflects the total households in Colorado that have received WAP assistance since 1994.
**The PIPP rate has increased to $1.00 per residential customer per month,[164] which will increase overall funding.

Distributed Solar and Community Solar Gardens

Colorado requires all investor-owned utilities, co-ops, and those municipal utilities with more than 5,000 customers to provide net metering for distributed solar systems.[165] Customers owning those systems retain any renewable energy credits from solar electricity generated. Distributed solar in Colorado contributed 1.3 percent of total in-state electricity generation in 2020 (equivalent to about 1.25 percent of in-state electricity demand).[166] Access to rooftop solar is not distributed evenly across income brackets, however: the wealthiest 20 percent of households adopted solar at 17 times the rate of the lowest-income 20 percent of households in 2019.[167] Only 10 percent of rooftop solar is adopted by households with incomes below 200 percent of the Federal Poverty Level (**Figure 3.4**). Numerous barriers may contribute to this disparity in access to solar for low-income households, such as lack of access to capital and a lower rate of home ownership. To improve access to solar, Colorado passed a community solar garden bill in 2010[168] and an updated

148 Administration for Children and Families. (2020). *Welcome to LIHEAP Performance Management*. https://liheappm.acf.hhs.gov/sites/default/files/private/congress/profiles/2020/FY%202019%20CO%20Profile.pdf

149 Ibid

150 Energy Outreach Colorado. (2020). *Annual Report 2020*. https://www.energyoutreach.org/annual-report-2020/

151 Energy Outreach Colorado. (2019) *Annual Report 2019.* https://www.energyoutreach.org/wp-content/uploads/2020/06/Annual-Report-Addendum.pdf

152 Dobos, H. and Artale, E. (2017). Insights from the CEO Low Income Community Solar Demonstration. *Colorado Energy Office.* https://lpdd.org/wp-content/uploads/2020/12/Insights-from-the-CEO-Low-Income-Community-Solar-Demonstration-Project.pdf

153 Colorado Energy Office. (2020). FY2020 Annual Report. https://liheappm.acf.hhs.gov/sites/default/files/private/congress/profiles/2020/FY2020ColoradoProfile-508Compliant.pdf

154 ADM. (2020, October). Evaluation of the Percentage of Income Payment Plans, Table 4-5.

155 Ibid.

156 Energy Outreach Colorado. (2020). *Annual Report 2020.* https://www.energyoutreach.org/annual-report-2020/

157 Energy Outreach Colorado. (2019). *Annual Report 2019.* https://www.energyoutreach.org/wp-content/uploads/2020/06/Annual-Report-Addendum.pdf

158 Ibid.

159 Ibid.

160 ADM. (2020, October). Evaluation of the Percentage of Income Payment Plans, Section 1.1.1.

161 ADM. (2020, October). Evaluation of the Percentage of Income Payment Plans, Table 4-15.

162 This value for PIPP reflects the total program cost across all utilities for FY 2018-2019.

163 ADM. (2020, October). Evaluation of the Percentage of Income Payment Plans, Table 4-25.

164 Department of Regulatory Agencies. (2020, December 23). *PUC issues emergency rules to expand utility programs for low-income customers during winter heating season.* https://dora.colorado.gov/press-release/puc-issues-emergency-rules-to-expand-utility-programs-for-low-income-customers-during

165 The rule covers about 98 percent of Colorado electricity customers. See: DSIRE. (2018, November 30). *Net Metering.* https://programs.dsireusa.org/system/program/detail/271

166 Electricity Markets and Policy Group. (2019). Solar Demographics Tool. [Interactive Tool]. https://emp.lbl.gov/solar-demographics-tool

167 Electricity Markets and Policy Group. (2019). Solar Demographics Tool. [Interactive Tool]. https://emp.lbl.gov/solar-demographics-tool

168 Public Utilities, HB 10-1342. (2010). https://leg.colorado.gov/sites/default/files/images/olls/2010a_sl_344.pdf

version in 2019.[169] The Colorado Energy Office also began a low-income community solar garden pilot in 2015, which provided solar to 380 low-income households and yielded an average annual bill savings of $382 per subscriber.[170] More broadly, investor-owned utilities are required to carve out at least ten percent of community solar project capacity for eligible low-income subscribers.[171] This requirement does not apply to co-ops whose wholesale electricity supplier is Tri-State. These co-op contracts generally last 50 years and require retail co-ops to purchase at least 95 percent of their energy from Tri-State. Behind-the-meter generation is not counted as part of this requirement. In theory, retail co-ops could choose to devote the remaining five percent to community solar gardens. In addition, distribution co-ops can now add the lesser of two megawatts or two percent of sales to community solar gardens in their territory.[173]

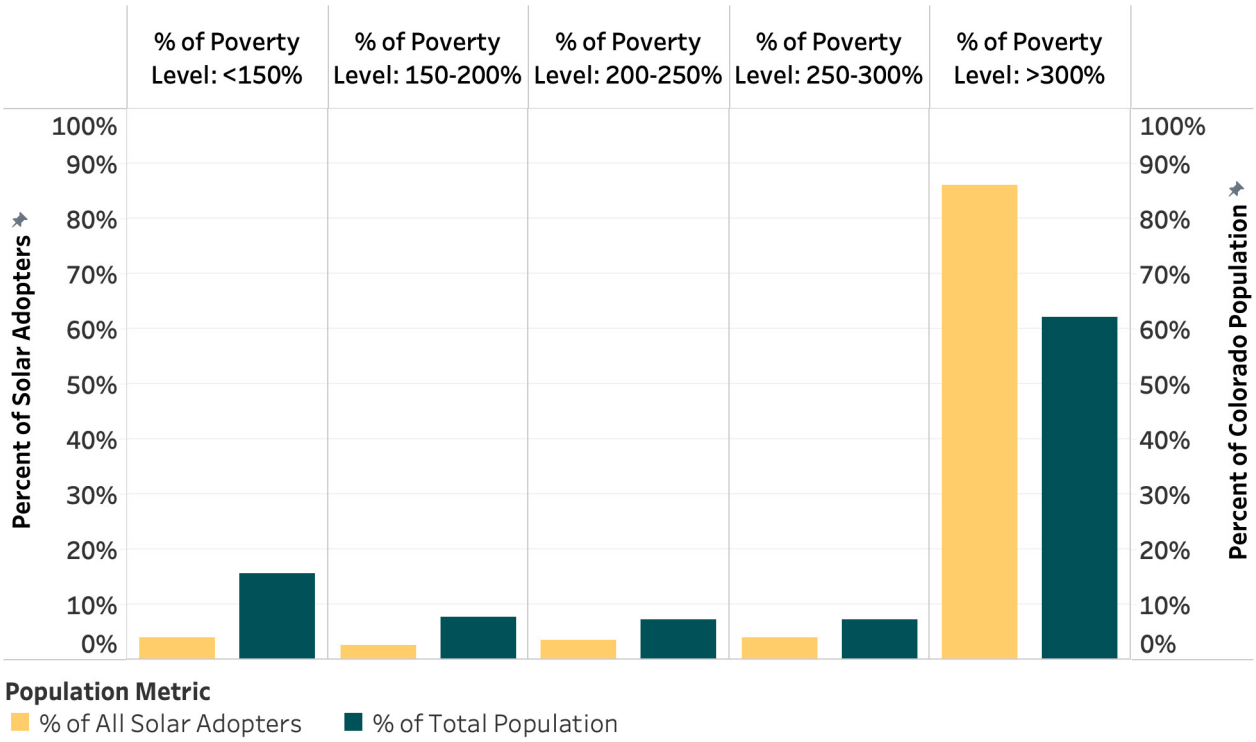

Figure 3.4. Rooftop Solar Adoption by Income Level. 85 percent of distributed solar in Colorado is adopted by households with incomes above 300 percent of the Federal Poverty Level.[173]

169 Community Solar Gardens Modernization Act, HB 19-1003. (2019). https://leg.colorado.gov/bills/hb19-1003

170 Dobos et al. (2017). Insights from the CEO Low-Income Community Solar Demonstration Project. *Colorado Energy Office.* https://lpdd.org/wp-content/uploads/2020/12/Insights-from-the-CEO-Low-Income-Community-Solar-Demonstration-Project.pdf

171 4 CCR 723-3-3887(e)

172 Fitzgibbon, M. and Rusin, P. (personal communication, December 3, 2021).

173 Electricity Markets and Policy Group. (2019). Solar Demographics Tool. [Interactive Tool]. https://emp.lbl.gov/solar-demographics-tool; U.S. Census Bureau. *American Community Survey.* https://www.census.gov/programs-surveys/acs

3.3 Policy and Program Toolbox

A variety of policies and programs can help facilitate a reduction in energy cost burdens, and a combination of these may be most effective. Community outreach efforts to characterize barriers to participation, evaluate program effectiveness, and identify community priorities can influence the design of an effective subset of these initiatives. We outline a few of these policy and program options in the following categories:

1. **Rates and assistance:** Energy rates, including assistance programs that provide discounted rates or spending caps for low-income customers, directly influence energy affordability.
2. **Clean energy investments:** Investments in clean energy and efficiency can help systematically reduce energy burdens and the need for energy assistance. These investments include:
    a. **Energy efficiency:** Building weatherization and efficient appliances.
    b. **Solar:** Rooftop and community solar gardens.
    c. **Demand response:** Compensation for customers to reduce peak electricity use.
    d. **Heating and appliance electrification:** Efficient electrification of fossil fuel heating and appliances.[174]
3. **Standards:** Building and appliance standards can help ensure efficiency is realized for new homes and appliance purchases.
4. **Financing:** Investments are enabled by financing mechanisms, such as on-bill financing, and state-supported entities, such as green banks.

3.3.1 Rates and Assistance

Utility rate structures inherently affect bills and therefore directly affect energy affordability. The fundamental structure of any rate (such as the magnitude of fixed charges, the rates charged to different customer classes, tiered structures with higher rates for higher usage, or time-of-use rates) will all influence energy cost burdens. Ensuring that rates mitigate—or at least do not exacerbate—energy cost burdens can take a couple of forms. The first of these is to incorporate an assessment of bill impacts on low-income households during rate cases, energy resource planning, and other regulatory proceedings. The second is to provide rates or energy assistance targeted at low- and moderate-income households, such as the PIPP program, to improve affordability.

Regulatory considerations. A number of components of various regulatory proceedings can impact rates and affordability. In the case of electric resource plans, for example, any rate-based investment from the utility will get passed on to customers. Therefore investments in

174 It is also possible to electrify homes that have wood as the primary heating fuel, but it is more economically complex because some or much of the wood supply may be supplied by personal effort without having to purchase it. Wood heating conversion is discussed in **Section 3.4.3**.

fossil fuel power plants and infrastructure that might end up as stranded assets in a carbon-constrained future pose a rate risk—and bill risk—likely have the greatest impact on those already struggling to pay their bills. The choice to invest more heavily in residential efficiency and demand response efforts, rather than energy infrastructure, to meet capacity needs can also directly impact residential bills. One approach to addressing these impacts is to model and compare the projected bill impacts for low- and moderate-income households in various proposed scenarios in any of these regulatory proceedings. In particular, modeling should focus on whether specific decisions would move households in either direction across an energy cost burden threshold of six percent.

Rate structures. A second consideration are the rate structures used for various customer classes. Tiered rates and time-of-use rates can be valuable tools to encourage energy savings and shift energy use to periods of low electricity demand. However, rates can pose an affordability risk to certain populations if not designed intentionally or effectively. For example, renters generally do not have control over large household appliances—nor appliance efficiencies; this can result in higher energy usage that could push them into a higher electricity rate tier. Similarly, time-of-use rates or demand charges are more beneficial for customers who have access to and can time smart appliances to run at less expensive hours of the day. These kinds of barriers can result in inadvertently penalizing low-income or renter households who have less flexible energy use or barriers

to participation. Fixed charges and riders, if very high, can also lead to high bills even for low-consumption customers, but these very riders can also be used to fund low-income energy assistance programs. Such risks can be mitigated through various measures, such as the option for low- and moderate-income households to opt-out of time-of-use rates, guarantees that bills will be capped at the same level of the previous year if rate structures are redesigned, and energy assistance programs (discussed next). Public Service is currently rolling out smart meters and plans to extend time-of-use rates to all customers, including an option to opt-out of the time-of-use rates.[175]

Rate structure can also impact whether electrification of space and water heating increases energy burdens. Currently, Colorado's investor-owned utilities have a lower general residential rate for the first 500 kWh per month than all consumption above that. A heuristic calculation examining a flat rate structure yielding the same revenue indicates that the energy burden for a typical gas household would increase slightly, while the reverse would be true for all-electric homes. Colorado might therefore consider introducing a flat rate option for all-electric households (including multi-family

175 Jaffe, M. (2021, July 1). If You're an Xcel Energy Customer, You're Getting a "Smart Meter" that will Charge More for Electricity Used During Peak Periods. *The Colorado Sun.* https://coloradosun.com/2021/07/01/xcel-energy-smart-meters-time-of-use-billing/

buildings). Co-ops have flat rates already. A flat rate would also augment the beneficial impact of efficient electrification of fossil fuel heated homes. However, the impact might be complex because many or most households currently heated with gas may see their electricity costs increase prior to electrification. Thus, some adjustment of gas rate structure might be needed to compensate in the interim (i.e., before electrification).

Energy assistance programs. Discounted energy rates and energy assistance programs can also help improve energy affordability. Discounted energy rates can provide a *percentage* savings on bills. For example, the California Alternate Rates for Energy (CARE) program provides a bill discount of 30-35 percent on electricity and 20 percent on gas for qualifying low-income households.[176] Colorado has instead pursued a *cap* on bills for low-income households in the form of its PIPP program, which caps utility bills at a percentage of household income but is not directly proportional to energy use unlike the CARE program. In concept, the PIPP program is the most comprehensive approach to reduce energy cost burdens via bill payment assistance. That is because its direct goal and impact is to provide sufficient assistance to reduce household energy bills to an affordable level. PIPP also has the advantage that assistance levels are adjusted (decreased) as investments in weatherization, community solar, electrification, and demand response reduce the gap between the actual energy burden and an affordable energy burden of six percent.

Ease of enrollment, especially with self-certification of income (with an audit of a small sample), is a hallmark of the California program. This is reflected in very high participation rates. In the 2021 pandemic year, the rate increased to over 100 percent of those who would normally have been eligible, reflecting its flexibility and adaptability to an extraordinary eventuality. 4.8 million of 17.1 million investor-owned utility customers were eligible and 5.3 million participated; the enrollment increase during the pandemic was about 466,000 customers.[177] Of course, increased participation also means an increased commitment of resources from non-participating ratepayers. The California CARE model, however, does not reduce energy assistance needs over time without additional investments to reduce energy burden.

Since enrollment in PIPP is currently very low, Colorado may want to consider incorporating the self-attestation aspect of California into the program as a way for boosting participation rates. This does not require adopting the California CARE model itself as an alternative to PIPP, though that option could be considered in time if PIPP participation remains low in the coming years, since providing assistance via discounted rates may be more straightforward for utilities.

176 California Public Utilities Commision. (2021). *Electrical Energy: CARE/FERA Programs.* https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/care-fera-program

177 Pacific Gas and Electric Company, Southern California Edison, SDGE, SoCal Gas. (2021). Joint IOU Report of the CARE and ESA, Programs, Low Income Oversight Board Meeting. https://liob.cpuc.ca.gov/wp-content/uploads/sites/14/2021/09/Item-9-IOUs-Consolidated-Template-revised.pdf

Increasing impact. The effectiveness of energy assistance and discounted energy rate programs is mediated by participation rates, coverage, and funding levels. Utility PIPP programs in Colorado have had rather low enrollment for a variety of reasons. There has been a cap of $0.31 per month per customer; utilities are permitted to recover actual expenses plus administrative expenses up to 10 percent. Only one utility has actually reached that cap and has a waiting list. The cap has been increased to $1 per month, allowing room for considerably more enrollment.[178] The PIPP program is also limited by the fact that it applies only to investor-owned utilities that are regulated by the state's Public Utilities Commission.

Only 18 percent of eligible households are enrolled in heating assistance. There is near-total overlap between LEAP and PIPP eligibility; yet, with exceptions, the enrollment in PIPP is often only a small fraction of enrollment in LEAP.[179] However, PIPP assistance levels and the number of participants can now be increased (including for Black Hills Energy, which can provide funds for households on its waiting list) since the funds available will approximately triple from 2022 onwards.

Additional measures to reduce barriers to program enrollment will be key to increase participation. Allowing for income self-attestation for participation, rather than proof of income, is discussed in **Section 3.6.1**.

3.2.2 Clean Energy Programs and Investments

A wide range of investments in clean energy and efficiency technologies can provide or enable energy affordability benefits. Typically, low-income households lag behind in access to clean energy technologies, such as solar,[180] energy efficiency, and smart appliances.[181] Populations of color typically lag behind in access to technologies such as solar as well.[182] Below we outline a few of these technologies, their affordability benefits, and programmatic approaches to increasing access for underserved households and communities. Some include existing programs, and some new.

Rooftop solar. Rooftop solar can provide long-term economic benefits and bill consistency, particularly if enabled through net metering. However, as noted previously, low-income rooftop solar adoption in Colorado lags significantly behind that of wealthier households.[183] This lack of

178 Department of Regulatory Agencies and the Colorado Public Utilities Commission. (2020). PUC issues emergency rules to expand utility programs for low-income customers during winter heating season. https://dora.colorado.gov/press-release/puc-issues-emergency-rules-to-expand-utility-programs-for-low-income-customers-during

179 ADM. (2020, October). Evaluation of the Percentage of Income Payment Plans, Section 4.1.2.1.

180 Sunter, D.A., Castellanos, S., and Kammen, D.M. (2019). Disparities in Rooftop Photovoltaics Deployment in the United States by Race and Ethnicity. *Nature Sustainability* 2.1, 71-76. https://doi.org/10.1038/s41893-018-0204-z

181 Xu, X., and Chen, C. (2019). Energy Efficiency and Energy Justice for US Low-income Households: An Analysis of Multifaceted Challenges and Potential. *Energy Policy* 128 (2019): 763-774. https://doi.org/10.1016/j.enpol.2019.01.020

182 Sunter, D.A., Castellanos, S., and Kammen, D.M. (2019). Disparities in Rooftop Photovoltaics Deployment in the United States by Race and Ethnicity. *Nature Sustainability* 2.1, 71-76. https://doi.org/10.1038/s41893-018-0204-z

183 Electricity Markets and Policy Group. (2019). Solar Demographics Tool. [Interactive Tool]. https://emp.lbl.gov/solar-demographics-tool

access may be due to numerous barriers, such as lack of access to capital, low home ownership, aging rooftops, and linguistic isolation. A number of efforts can help reduce these barriers, such as low-interest or zero-interest financing, community outreach, ongoing support for net metering for low- and moderate-income households even if such policies are changed for wealthier households, and community solar gardens (below). Rooftop solar is not an option available to most low- and moderate-income households because many are renters. Community solar gardens are an option that would, in principle, be open to all, including those homeowners whose roofs are unsuitable (e.g., too shady), who may intend to move before the end of the payback period for rooftop solar, etc.

Community solar gardens. Community solar programs with virtual net metering can enable subscribers who otherwise face barriers to rooftop solar adoption to benefit from solar. Community solar subscriptions can be arranged such that subscribers can bring the subscriptions with them if they move, and can be designed with various levels of discounted rates for low- and moderate-income households. The Colorado Energy Office's Low Income Community Solar Demonstration Project has illustrated how community solar subscriptions can greatly reduce utility costs for low-income households.

Building weatherization. Building weatherization efforts help improve house-wide efficiency and reduce overall energy demand.[184] Home energy audits can help identify effective measures to reduce energy demand by measuring energy use and air flow throughout the home. Building weatherization strategies include such measures as installing insulation in walls, floors, ceilings, ducts, and pipes; repairing or replacing water and space heating and cooling systems and improving ventilation; installing smart control systems for heating, cooling, and thermostats; replacing inefficient appliances and lights; sealing windows and doors or installing technologies such as double-pane windows; and other similar measures. Because weatherization

184 Office of Energy Efficiency and Renewable Energy. (N.d). Whole-house Weatherization. U.S Department of Energy. https://www.energy.gov/eere/wap/whole-house-weatherization

requires up-front investments to reduce long-term energy use and provide bill savings, it can be hard to finance for those without access to capital in the absence of programs such as WAP.

Beneficial Electrification. Electrification of heating and other gas- or propane-powered appliances, including cooking, can hold numerous benefits. First, there is a public health benefit associated with reducing in-home combustion of fossil fuels, which can produce health-damaging air pollutants which impact cardiovascular and respiratory functions (detailed in **Section 3.4.3**).[185] Second, propane in particular is expensive, and replacement with high efficiency electrically-powered air source heat pumps can generally provide significant savings (see **Section 3.5.2** below). Replacing aging gas furnaces at the time of replacement with cold-climate heat pumps increases capital costs, but creates potential to reduce the overall cost of providing heating over time. This is particularly true if the heat pump is replacing a standard air conditioning unit as well. However, within the low-income context, it is important to consider the interaction between beneficial electrification and rate design. High charges from tiered electricity use rates as well as time-of-use rates that overlap with typical winter heating times may discourage electrification. Some proposals to ensure electrification is beneficial and accessible for low- and moderate-income households are elaborated in the Beneficial Electrification in Colorado report prepared for the Colorado Energy Office.[186] Vehicle electrification can also help reduce overall pollution burdens, which tend to accrue in disadvantaged communities, and can provide lower operating and maintenance costs for cars and open up significant new opportunities for demand response. Vehicle electrification is explored further in a forthcoming report for the Colorado Energy Office.

Energy storage. Residential energy storage, particularly when coupled with rooftop solar, can provide multiple benefits. First, storage can enable more agile participation in demand response programs and time-of-use rate structures. Second, when combined with appropriate inverters, distributed solar and storage can provide a wider range of electricity services to the grid, including frequency and voltage support, which may be in greater demand in rural areas. Third, energy storage can provide resilience in the case of outages. Such resilience may be particularly valuable for those who live in areas with frequent outages, in rural areas, and in places facing climate disruption. Benefits will be even greater for specifically vulnerable populations, such as those reliant on electricity to support medical equipment or elderly populations reliant on electricity to provide cooling and prevent heat stroke. Some of these regions are detailed in **Section 3.4.5**. below.

Microgrids. Solar and storage-powered microgrids can increase resilience beyond the household level. Deployment of microgrids at schools, community centers, and critical facilities such as wastewater

185 Seals, A.B., and Krasner A. (2020). Health Effects from Gas Stove Pollution, Rocky Mountain Institute. https://rmi.org/insight/gas-stoves-pollution-health

186 Hasselman, R. and Duckwall, J. (2020). Beneficial Electrification in Colorado. *GDS Associates*. https://drive.google.com/file/d/1d_O7u2SUgt4ASvJ0LLry16h5dffNF19l/view

treatment plants and clinics can provide places for people to access electricity during emergencies. In this way, microgrids help ensure the provision of critical services to vulnerable populations, including charging cell phones, refrigerating medicines, and providing access to cooling on hot days. Microgrids can also be strategically deployed in places such as affordable housing developments to provide backup across the community. A resilient energy supply is needed to adapt to climate change impacts everywhere, but it is all the more important in communities that are disproportionately impacted by climate extremes, such as rural areas or urban areas with a lower density of suitable community support emergency facilities. Since future energy resilience must be compatible with climate and emission reduction goals, integrating it with solar and storage planning will be important, including to avoid investments in gas-centered microgrids that would result in stranded costs.

3.3.3 Building Codes and Appliance Standards

Building codes and appliance standards can help ensure energy efficiency is realized up front rather than achieved through costlier retrofits at a later point in time. There is some evidence that appliance standards themselves actually drive down appliance costs by spurring innovation,[187] in addition to the long-term cost and energy savings that these technologies yield. Building standards can yield long-term energy and cost savings that might not be realized if only up-front construction costs are minimized, and can take the form of specific efficiency requirements or even net-zero-energy building standards.

Building codes. Building codes in Colorado are set by counties and other local jurisdictions. Most counties have them; some have been recently updated. Of the 337 jurisdictions that could adopt building codes, 279, or 83 percent, have done so.[188] Most urban and suburban jurisdictions do have building codes; the largest ones—including the City and County of Denver and Fort Collins—have up-to-date codes (2018 IECC).

187 Van Buskirk, R. D., et al. (2014). A Retrospective Investigation of Energy Efficiency Standards: Policies May Have Accelerated Long Term Declines in Appliance Costs. *Environmental Research Letters* 9.1, 114010.

188 Colorado Building and Energy Codes by Jurisdiction. Retrieved December 8, 2021, from: https://docs.google.com/spreadsheets/d/10D-4QyLwVe6j07hedwG5Y0EeB-aDMecRFo0B9HzvUv4/edit#gid=0,

Thus, the vast majority of Coloradans live in areas that have building codes; these are places where a requirement that new homes be net-zero-energy could be specified within the existing norms about and expectations regarding the role of building codes. Such standards for new homes would be especially beneficial since most population growth is projected for the areas that have building codes. Building codes similar to those for new homes could also be adopted for major retrofits.

Some of the least populated rural jurisdictions with very high energy burdens, like Costilla and Custer counties, have no building codes for building energy performance. Between them, these two counties have fewer than 200 households with incomes below 50 percent of the Federal Poverty Level.[189] Not coincidentally, these are also areas with high electricity rates and no gas service. This combination of factors may present an opportunity, however: homes in these areas are likely to give much bigger returns for efficiency investments as well as highly efficient electrification (see below for further discussion of areas with high rates). A focus on Colorado Clean Energy Fund lending, grants for weatherization, and easily navigable application requirements for low-income households could result in norms replacing standards and accomplishing the same purpose.

Appliance standards. Appliance standards can help not only encourage energy efficiency but also enable flexible demand management. Governor Jared Polis signed a set of new standards into law in 2019, such as for air compressors and portable air conditioners.[190] The Colorado Department of Public Health and Environment (CDPHE) manages energy efficiency standards for numerous appliances and local jurisdictions are permitted to set more stringent standards.[191] More comprehensive appliance standards can further improve efficiency and can also be used to facilitate demand

189 U.S. Census Bureau. American Community Survey. https://www.census.gov/programs-surveys/acs

190 HB 19-1231, 2019. https://leg.colorado.gov/sites/default/files/documents/2019A/bills/2019a_1231_rer.pdf

191 Colorado Department of Public Health and Environment. (2022). Efficiency Standards for Appliances. https://cdphe.colorado.gov/sustainability-programs/colorado-green-business-program/efficiency-standards-for-appliances

response. For example, standards could be set that would require appliances to be smart-grid compatible, enabling them to participate in demand response programs once smart meters are rolled out and residential demand response is in place. Such standards could facilitate the expansion of programs such as the Fort Collins Water Heater Program, which uses smart water heaters to provide demand response and reduce peak load.[192]

3.3.4 Financing

The scale of the gap between an affordable energy cost burden (six percent of income) for all Colorado households and current energy burden is about $280 million per year. This estimate was derived by calculating the total amount of money spent on energy beyond six percent of household incomes for all households up to 200 percent of the Federal Poverty Level. Of this, $100 million is available in assistance via a variety of funds, mainly via LEAP, and the ratepayer-financed PIPP (including the increase of the PIPP charge from a cap of $0.31 to $1 per month per customer). The approach taken in this report is that the gap will be filled by a combination of increasing energy assistance and decreasing energy burdens by investments, with the former increasing at first and then declining to current levels or below as investments in weatherization, community solar gardens, etc. reduce energy burdens systemically. For the investor-owned utility service territories and municipal utilities, the funds for these investments can come from Colorado's Clean Energy Fund, which supports service to underserved communities among its principal goals. We primarily assume that financing will come in the form of loans (through on-bill financing) and grants, with the latter going to the lowest-income households.

The Colorado Clean Energy Fund

The Colorado Clean Energy Fund (CCEF), Colorado's green bank, currently has start-up capitalization of $30 million.[193] The scale of funds needed to address energy affordability is substantially greater, in part because the CCEF's portfolio extends beyond loans to reduce the energy cost burdens of low-income households. CCEF funds could be used to enable clean energy investments, such as weatherization and heating electrification, by providing low-interest loans and on-bill repayment (described below). CCEF could recover its capital by bundling and securitizing the loans and selling them—a process that would be made easier by national cooperation among green banks. Low-interest weatherization and heating electrification (e.g., heat pump) loans would likely be bundled with loans at somewhat higher rates for commercial projects to make the overall bundle attractive enough for investors.

The State of Colorado also makes investments and could be another avenue for the sale of bundled loans. The need to recover capital in order to re-lend it for weatherization requires a sufficiently high interest rate to make it marketable under the circumstances described above. Obviously,

192 Peaker Partners. (2021, December). *The Peak Partners Water Heater Program*. City of Fort Collins Utilities. www.peakpartnersfortcollins.com/smart_water_heater_program

193 SB 21-230. (2021). https://leg.colorado.gov/sites/default/files/documents/2021A/bills/2021a_230_rer.pdf

this must be balanced with the need to keep the interest rate low enough so that the overall energy burden is reduced for the customer when the added cost of the loan and the lower energy use are taken into account. That interest rate, at this stage, appears to be about three percent. As experience is gained and if defaults are low, it may be possible to reduce this rate. The portion of any financing provided by grants could also be increased if federal climate legislation greatly increases the capital available to states for energy transition investments.

Financing weatherization

The Weatherization Assistance Program (WAP) currently consists entirely of grants to participants with funding from the federal government and other sources. Our modeling (described further below) indicates that an expansion of this program to cover all low-income households with energy cost burdens greater than six percent would involve an estimated cumulative investment of about $2.8 billion, which amounts to $140 million per year if the program is carried out over 20 years. Current weatherization expenditures are about $16 million per year (**Figure 3.3**), but the program funding is expected to significantly expand through both a system benefit charge established in 2021 legislation and the federal infrastructure act. However, the goal of reducing energy burdens to six percent (or less) does not require weatherization *grants* for all parts of the low-income spectrum. This remains an option, but would need a significant expansion of grant and assistance funds from the state or federal government. Another option, which is analyzed in more detail in this analysis, is for the higher income groups to receive a part or all of the weatherization investment as a low-interest *loan*, with the loan and grant portions being tied to energy cost burden level. Specifically, as described later, the estimates here are generated by assuming that grants are mainly oriented to the lowest-income groups (less than 100 percent of the Federal Poverty Level), while low-interest loans constitute the vast majority of the investment in other cases.

An efficient and economical way to make weatherization investments would be on-bill financing with capital from the CCEF (which would be available at much lower rates than the rate of return accorded to the investor-owned utilities). Co-ops have access to several other sources of low-interest funds, including the United States Department of Agriculture (USDA).

On-bill financing is preferable to a stand-alone loan, even if the latter is low-interest, for a number of reasons:

- A stand-alone loan would likely require a lien against the property, making access difficult for some and putting the property of others at risk. The interest of the borrower in keeping the lights on is, in itself, a kind of security for the loan.
- A single utility bill payment is preferable and involves fewer complications than a separate loan payment.
- If the audits and subsequent weatherization are done competently, the energy bills of the household should go down, making the payment of the utility

bill in full and on time more likely—a plus for the utility and the customer. As a result, on-bill financing for weatherization is likely to reduce incidence of disconnect notices and actual disconnections compared to payment of two bills—a utility bill and a loan payment—for households whose finances are generally quite stressed.

- In the case of the investor-owned utilities, the Public Utilities Commission would have oversight into the functioning of the program.
- Weatherization and the consequent bill reductions could be coordinated with PIPP, which is also a utility-run program, making it simpler to achieve the goal of reducing burdens to six percent or less; the metrics would all be close at hand.

The above reasoning applies in a fairly general way, though the specific implementation challenges may be different depending on the size and type of utility. On-bill financing can be coupled with other options, including bundling and securitization of loans, as discussed below. In some cases, it may not be the most suitable approach, such as for small co-ops that may not have the capacity to handle another function. Direct loans (and their bundling and securitization) would remain options, including for households in areas served by co-ops. Finally, options other than CCEF for low-cost financing may also be available in many cases, such as USDA funds for co-ops or issuance of tax-free bonds by municipal utilities.

Co-ops present specific issues since their oversight is provided by their members and not the Colorado Public Utilities Commission. Most distribution co-ops are supplied by Tri-State, which is a generation and transmission co-op that sells electricity wholesale to most of the distribution co-ops in the state, including the smallest ones. PSE Healthy Energy and IEER explored some of the issues with Tri-State representatives in a conversation on December 3, 2021. They indicated that Tri-State "is moving toward providing energy-as-a-service….For example, Tri-State is evaluating weatherization as one element of "energy-as-a-service."" They indicated an openness to helping the state meet specific annual goals with regard to weatherization.[194] Of course, the distribution co-ops may want to build their own capacity and implement programs. Closer coordination between the State and co-ops could also help electrification, which is especially important for reducing energy cost burdens in the rural areas where propane is the main heating fuel.

194 Fitzgibbon, M. and Rusin, P. (personal communicaiton, December 3, 2021, op. cit.)

Supporting solar equity

Community solar gardens are the most straightforward way to integrate the state's goal of reducing greenhouse gas emissions in the residential sector with the goal of promoting equity. Community solar electricity is typically lower in cost per customer than residential rooftop solar, though it does involve more use of the distribution system than rooftop solar. It is also accessible to renters and to those homeowners whose roofs are unsuitable, who may not otherwise want or be able to afford rooftop solar, or who may intend to move in a period shorter than typical payback times.

For the purposes of assessing policy, this analysis assumes that community solar gardens can produce and sell electricity at a rate that is on the order of 20 percent lower than utility rates, though this will of course vary depending on the utility area. But overall no grant, rebate, or incentives other than those available at present would need to be directed to attract low-income subscribers. The main hurdles to low-income subscription are related to credit scores and history (including a lack of such history), low income levels, and the difficulty of qualifying for a long-term contract under these circumstances. A loan loss reserve that guarantees contracts for community solar gardens by low-income households against default is the single most important financial mechanism that is needed to make access practical. The size of this loss reserve will, of course, depend on the rate of default. Experience in Florida with community solar for low-income households indicates low default rates (see **Section 3.5.3**). Setting up and maintaining the loan loss reserve at adequate levels could be a principal function of the CCEF in this context (rather than loans at low rates, though that may also be considered). A loan loss reserve would be a necessary condition but may not be sufficient by itself to achieve the high level of enrollment. Outreach, educational materials, and, in areas with low electricity rates, low-interest loans may also be needed as complements. Self-attestation of income

would also be helpful in this context and, as applicable, for rooftop solar.

Unlike a loan default, a community solar contract default does not mean the loss of the entire balance of the sum due on the contract. The electricity is still being generated and can be sold to someone else. In other words, the contract can be assigned to another party and the revenue stream would resume. Thus, the losses would be limited to what should normally be a short period between contract default and contract reassignment. If there is a pipeline of customers and reassignment is rapid, the loss reserve would not be large. For instance, at a one percent default rate annually on 200,000 total contracts at $100 per month, the loss per month that the contracts are not reassigned would be $200,000. But if the reassignment could be done in a few days or a week, the annual amount required for the loss reserve would be small.

The entire process would be further strengthened by what is known as "consolidated billing." In some deregulated states, such as Maryland, third-party suppliers purchase electricity on the wholesale market and sign up retail customers to whom they resell it. Consolidated billing is the process by which both the amount due to the third party supplier and the utility is put on a single bill and sent to the customer, even though the sum is disbursed to two distinct corporate entities. Maryland's regulators have gone one step further whereby regulated distribution utilities "purchase" the amount due to the third party supplier and pay the supplier (at a slight discount). Thus the collection of the entire amount becomes exactly like a normal utility bill. This process is called "Purchase of Receivables."

One potential downside of purchase of receivables is that the seller of the electricity no longer bears the risk of the failure of the customer to pay. This risk has created incentives to overprice electricity, to sign up low-income customers for variable rates, and various other problems. These would not apply to community solar gardens in investor-owned utility service territories since all aspects of these utilities are regulated.

Consolidated billing would make the process of community solar garden contracting and bill payment simpler. Purchase of receivables would make it more attractive for developers to build community solar gardens and may also reduce the cost of community solar. However, utilities would be taking on the task of collecting the bill even as net metering reduces their revenues, so adequate allowance for the costs of collection would have to be made. These can be minimized if there is a loan loss reserve that guarantees payment in the event of contract default. Since this is a complicated issue that needs evaluation with utility, community, and solar industry input, we are not recommending it outright. Rather, we recommend that it be given a close look by the Public Utilities Commission for its potential to more rapidly expand community solar gardens at lower cost. If this can be combined with on-bill financing of weatherization (in those instances where that involves loans rather than grants) and electrification of heating, a simplified customer-centric system for the energy transition could be created that could fully integrate equity and energy-related greenhouse gas emission reduction issues into a single package.

3.4 Deployment Priorities and Strategies

Our baseline analysis of energy cost burdens across the State of Colorado yielded a number of priority regions, populations, and technologies to reach the state's most cost-burdened populations. In this section, we look at priority populations based on socioeconomic and demographic indicators, regions (specifically comparing urban and rural areas and climate zones), fuel types, health benefits, housing and ownership types, potential resilience benefits, coal securitization impacts, and utility types. In many cases, these factors are closely intertwined—cooperative utilities typically operate in rural areas with high energy cost burdens, lower-income populations, and a higher share of propane users. We detail these trends and strategies to reach energy cost-burdened populations below.

3.4.1 Socioeconomic and Demographic Indicators

Our **Section 2** baseline socioeconomic analysis of energy cost burdens revealed that lower-income census tracts experience significantly higher energy cost burdens on average, despite the fact that households in low-income communities tend to use less energy per household (**Figure 2.8**). Low-income census tracts are distributed unevenly across the state. **Figure 2.9** showed that many rural communities have median household incomes well below the state's median. These communities also tend to have the highest energy cost burdens, particularly in the southern parts of the state (**Figure 2.1**), and should therefore be prioritized. In addition to low-income rural areas, there are clustered neighborhoods within urban areas, notably in parts of the Denver Metropolitan Area, where median household incomes are substantially lower than the state median. The average energy cost burdens in those urban neighborhoods are generally below six percent (**Figure 2.1**). However, it is important to remember that within urban low-income areas, approximately three-fifths of individual households face energy cost burdens greater than six percent and one-fifth face energy cost burdens greater than fifteen percent and as such, should be prioritized.

Section 2 also revealed a strong negative correlation between household energy use

intensity and median household income by census tract, suggesting that investments in weatherization and energy efficiency should be the priority policy tool in the lowest-income communities. This is particularly true of rural areas, where energy use intensities are substantially higher compared to urban census tracts (**Figure 2.25**). We found that each dollar increase in median household income in rural census tracts correlates to a 3.64 Btu/sq.ft decrease in household energy use intensity, whereas in urban census tracts, each dollar increase in income correlates to a 0.1 Btu/sq.ft decrease in household energy use intensity, suggesting that the impact per dollar invested in efficiency, fuel switching, and weatherization in low-income rural areas would be much greater than in urban areas.

> ***Energy use intensity is much higher in rural areas than urban areas, suggesting that investments in efficiency, fuel switching, and weatherization may be particularly impactful in rural communities. Households with high energy cost burdens in urban areas may benefit more from energy assistance and access to discounted community solar in the near term, although to reach the state's climate goals, all households will need financing to support adoption of efficiency and electrification in the long term.***

As we saw in **Section 2**, much of the difference between rural and urban energy use intensity is attributable to fuel type and heating degree days, but also to insulation, housing type/age, and other variables (**Figures 2.2, 2.5** and **2.8**).

Our demographic analysis indicated that communities of color, which comprise a large fraction of the population in several pockets of the state, including southern Colorado and parts of the Denver Metropolitan Area, also tend to be characterized by high poverty levels (**Figure 2.9**). We found that in urban areas, energy cost burdens, while generally lower than six percent, tend to increase as the share of Black and Latino population increases (**Figure 2.11**). The opposite is true for urban census tracts with a larger share of White population and higher average education levels. This is true even when controlling for income, suggesting that additional factors beyond income may contribute to elevated energy cost burdens in communities of color, including historic disinvestments and discriminatory policies that we discussed in earlier chapters. This implies that while urban areas generally experience lower energy cost burdens compared to rural areas, communities of color within urban areas may experience significantly higher levels of energy cost burden on the local level, warranting the prioritization of these communities in weatherization and bill-assistance programs to alleviate entrenched energy burdens and redress historic inequities.

The Climate Equity Data Viewer, developed by CDPHE, provides an important tool for policymakers to identify climate- and environmentally-vulnerable populations throughout the state and evaluate the impacts of policy decisions on these communities. We calculated the overall climate equity scores for each census tract based on the various environmental, climate, and demographic factors included in the Climate Equity Viewer. While tract-level climate equity scores had a fairly

strong positive correlation with energy cost burdens in urban areas (**Figure 2.16**), this was not the case for rural census tracts where communities with high energy cost burdens tend to be less environmentally-burdened compared to urban tracts and therefore tend to have lower climate equity scores. This finding implies that the Climate Equity Viewer is not a good proxy for energy cost burden outside of urban areas and may not be the best tool to use exclusively for funding prioritization related to energy affordability; instead, a focus on households using propane, with high energy use intensity, in cold climates, and/or paying high rates may help alleviate energy cost burdens in rural areas.

Based on the above considerations, we highlight the following broad deployment strategies related to the program and policy tools outlined in the previous section:

Building efficiency and weatherization. Low-income rural communities stand to benefit the most from expanded building efficiency and weatherization programs and should be prioritized in light of their higher average energy use intensities, higher average energy cost burdens, and the associated higher potential impact per dollar spent in those communities. In addition, expanded weatherization and building efficiency efforts in targeted urban areas with historically disadvantaged and non-White communities will help lower energy cost burdens in those communities and redress historic inequities.

PIPP. Many dense urban areas in Colorado are characterized by low average energy use intensities. Many of these areas are served by investor-owned utilities and gas distribution systems, suggesting that a focus on expanding PIPP participation in those communities would be the most effective approach in the near term. In the long term, urban homes in Colorado will need to adopt greater energy efficiency and electrification to achieve state climate goals, including all low- and moderate-income households, as well as homes where electrification of gas heating is currently not the most cost-effective option.

Beneficial electrification. Fuel-switching programs will need to prioritize low-income rural areas where alternative and more expensive heating fuels such as propane are prevalent. Replacing propane heating with electric heat pumps will need to be accompanied with building weatherization measures, particularly in colder climate zones, in order to minimize the impacts of fuel switching on the electric grid and maximize the energy savings potential of electric heat pumps. This replacement can also improve indoor air quality (see **Section 3.4.3**). In urban areas, it would be prudent to strategically plan for a gradual phase-out of the gas distribution system from one region to the next. This strategy would reduce long-term maintenance costs and minimize upgrades that would otherwise have to be shouldered by fewer and fewer gas customers that are left to pay for a gas distribution system in transition.

3.4.2 Rural Areas

Our energy cost burden analysis (**Figure 2.18**) shows that rural co-ops have some of the highest rates and also some of the lowest rates; some municipal utilities also span a similar range. Evidently, areas with high electricity rates can benefit greatly from weatherization and other investments that increase the efficiency of electricity use, like more efficient refrigerators, lighting, and Energy Star appliances. Households in areas with no gas infrastructure would also derive significant benefits from conversion of propane space and water heating to efficient heat pumps.

Since most areas with high electricity rates are rural, significant strengthening of the grid for resilience as well as accommodation of increased electricity transmission and distribution infrastructure will be needed. The causes of high rates are likely to be varied, although an important contributing factor is likely the cost of electricity distribution in sparsely populated areas. This can be inferred from the fact that the same wholesale generation and transmission co-op, Tri-State Generation and Transmission (Tri-State), supplies most rural distribution co-ops in Colorado but rates tend to be high in areas with low populations. Custer and Costilla counties have less than 10,000 people in a combined area of about 2,000 square miles. They do not have a gas supply and have among the highest energy burdens in the state. In this context, it is important not to expand gas infrastructure where it does not yet exist and put the stress on creating the electricity infrastructure needed. Two heating system conversions—from propane to gas and then from gas to electricity—would mean high costs and high stranded cost risks in addition to higher than necessary carbon dioxide emissions.

Low population density areas are also likely to benefit disproportionately from investment in community solar gardens at a significant scale because such installations could produce lower cost electricity while also reducing distribution system losses. Rooftop solar installations may also be especially beneficial for the same reasons.

The financial and policy questions associated with construction of a significant number of local solar installations in rural co-op areas are challenging. Most rural distribution co-ops in Colorado are obliged by contract

to purchase at least 95 percent of their electricity requirements from their wholesale supplier. These power supply contracts can be as long as 50 years. The fees for exiting a contract can be high; they are, at present, a matter of some contention in Colorado. Untangling these issues is beyond the scope of the present approach. We note them here for two reasons:

1. Rural areas, especially those with no gas infrastructure, have among the highest energy burdens. This means increasing the fraction of electricity supplied from discounted local solar generation, including community solar gardens and utility-scale generation, is important;
2. Converting propane heating to electricity and reducing low- and moderate-income electricity rates are crucial to reducing energy burdens consistent with Colorado's climate goals.

As noted above, Tri-State now allows community solar gardens beyond the five percent contractual limit allowed for generation by distribution co-ops so long as the added community solar amount is the lesser of two percent of sales or two megawatts. While this allowance will provide some room in the near term for the construction of community solar gardens, the cap is too small to make a significant dent in the requirements for enrolling the vast majority of low- and moderate-income customers in community solar garden accounts.

Tri-State's current resource plan, the Tri-State Responsible Energy Plan,[195] seeks to shut down its large coal-fired power plant in Colorado (the Craig Station) by 2030 and build one gigawatt of wind and solar in its territory by 2024. This renewable energy target would mean that half of the electricity sold to the distribution co-ops will be renewable in approximately three years. However, Tri-State has no provision for community solar scale installations within the territories of the distribution co-ops that it supplies. Expansion of community solar in rural areas served by co-ops with Tri-State contracts is a critical medium- and long-term issue that has no ready answers. One option could be for Tri-State to expand its solar generation beyond its 2024 renewable energy goals with the express aim of supplying locally-generated solar to distribution co-ops from which they could enroll community solar garden subscribers. Another option would be the exemption of low- and moderate-income community solar subscriptions from the five percent local generation cap. This latter option has precedent in that Tri-State already exempts behind-the-meter solar in this manner.

195 Tri-State. (2020). Responsible Energy Plan, https://tristate.coop/sites/tristategt/files/PDF/Responsible-Energy-Plan/Tri-State-Responsible-Energy-Plan-Jan2020.pdf

3.4.3 Health Benefits

In addition to contributing to burdensome utility bills, residential fuel consumption in Colorado creates both indoor and outdoor air pollution. Electrification of gas and propane heating, as well as whole building efficiency measures, can therefore bring the additional benefit of improving air quality. While emissions from residential fuels contribute in part to statewide ambient air pollution, in-home fuel combustion is of particular concern for indoor air quality. Like ambient air pollution, indoor air pollution is associated with adverse respiratory and cardiovascular health outcomes. Furthermore, the average American spends roughly 90 percent of their time indoors,[196] which increases the potential for adverse exposures.[197]

Gas combustion can contribute to significant in-home emissions of carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter ($PM_{2.5}$) and formaldehyde.[198] Propane has similar emission factors to gas and therefore has a similar effect on indoor air pollution.[199] Leakage from unburned gas from appliances, besides releasing methane, may also result in increased exposure to known human carcinogens including benzene and other volatile organic compounds (VOCs). There is a lack of research on the magnitude of exposure to health-damaging air pollutants due to incomplete combustion and gas leakage. In addition to indoor air pollution, NO_x emissions from gas contribute to outdoor air pollution both directly and as a precursor for the secondary formation of $PM_{2.5}$ and ozone in the atmosphere.

196 Klepeis, N.E., et al. (2001). The Human Activity Pattern Survey (NHAPS): A Resource for Assessing Exposure to Environmental Pollutants. *Journal of Exposure Science and Environmental Epidemiology* 11.3, 231-252

197 U.S. Environmental Protection Agency. Indoor Air Quality. https://www.epa.gov/report-environment/indoor-air-quality

198 Seals, B. and Krasner, A. (2020). Health Effects from Gas Stove Pollution. Rocky Mountain Institute. https://rmi.org/insight/gas-stoves-pollution-health/

199 California Air Resources Board. Residential Emissions Factors. https://ww2.arb.ca.gov/carb-miscellaneous-processmethodologies-residential-fuel-combustion. Environmental Protection Agency. Residential Emission Factors. https://www3.epa.gov/ttn/chief/ap42/ch01/index.html

While gas accounts for the majority of residential fuel use, its use is clustered in urban and suburban areas with gas distribution infrastructure (**Section 2**). Homes in rural areas rely largely on propane and wood for home heating, the latter emitting ten times as much $PM_{2.5}$ as gas annually, despite generating less than a tenth as much energy statewide.[200] About 45,000 of Colorado's 2.1 millions households, largely in rural areas, use wood as their primary heat source.

Weatherization measures can reduce household energy use, thereby lowering emissions from the air pollutants outlined above and reducing the associated health impacts. In addition, switching from fossil fuels to electricity has the potential to entirely eliminate combustion-related air pollution from residential buildings. The health benefits of electrifying gas would be conferred mostly to urban and suburban areas in Colorado. From a health standpoint, the electrification of gas heating may be particularly valuable for the Denver region because it is out of attainment for federal ozone standards[201] and is affected by emissions from nearby oil and gas industrial activities. Conversely, targeting buildings that burn propane and wood in rural areas can help reduce high energy cost burdens associated with propane use and improve indoor air quality in the case of both propane and wood, leading to better health outcomes in the rural areas where these fuels are most commonly used. While electrification of wood heating is not always cost-effective, considerations should be given to strategies for replacing conventional wood stoves with pellet stoves.[202] The latter can significantly lower particulate and VOC emissions without increasing energy cost burdens.

Consideration should be given to proper air ventilation systems when energy efficiency and weatherization measures are implemented in buildings with high indoor air emissions. Such systems should be required to improve indoor air quality because certain weatherization measures may limit outdoor and indoor air exchanges and increase indoor air quality risks.

Finally, there are also indirect health benefits of reducing energy burdens; the reduced stress on household budgets results in fewer conflicts between food, medicine, rent, and utility bills. Loss of housing is arguably the most severe impact; and homelessness is generally accompanied by increased health problems and emergency room visits.[203]

3.4.4 Housing and Ownership Types

As previously described in **Section 2,** housing-related trends are somewhat unclear when analyzed on a statewide basis due to substantial differences in energy cost burdens, demographics, and housing characteristics between rural and urban areas. When analyzing urban and rural areas

200 Krieger, E., et al. (2020). Equity-Focused Climate Strategies for Colorado. *PSE Healthy Energy*. https://www.psehealthyenergy.org/wp-content/uploads/2020/12/Equity-Focused-Climate-Strategies-for-Colorado-Report.pdf

201 U.S. Environmental Protection Agency. (2021). Colorado Nonattainment/Maintenance Status for Each County by Year for All Criteria Pollutants. https://www3.epa.gov/airquality/greenbook/anayo_co.html

202 U.S. Environmental Protection Agency. (2021). *Pellet Stoves.* https://www.epa.gov/burnwise/pellet-stoves

203 Makhijani, A., C. Mills and A. Makhijani. (2015, October). Energy Justice in Maryland's Residential and Renewable Energy Sectors. A report of the Renewable Maryland Project. *Institute for Energy and Environmental Research*. (pp. 89-90).

separately, however, certain trends emerged. **Figure 2.10** showed that urban census tracts with a higher fraction of renters tend to have higher energy cost burdens, despite consuming less energy per household on average. This trend can be explained by the fact that renter communities also tend to be in census tracts with a higher fraction of low-income households and households of color, both of which are correlated with higher energy cost burdens. Renters are at a clear disadvantage in regard to weatherization and demand response programs since they do not own their houses and generally do not own their large house appliances. Therefore, the priority interventions in rental communities should revolve around energy bill assistance programs such as PIPP and community solar gardens to lower electricity rates. It may be particularly valuable to target households facing high cumulative bills, resulting in both high rent burdens and high energy cost burdens (**Figure 3.5**.)

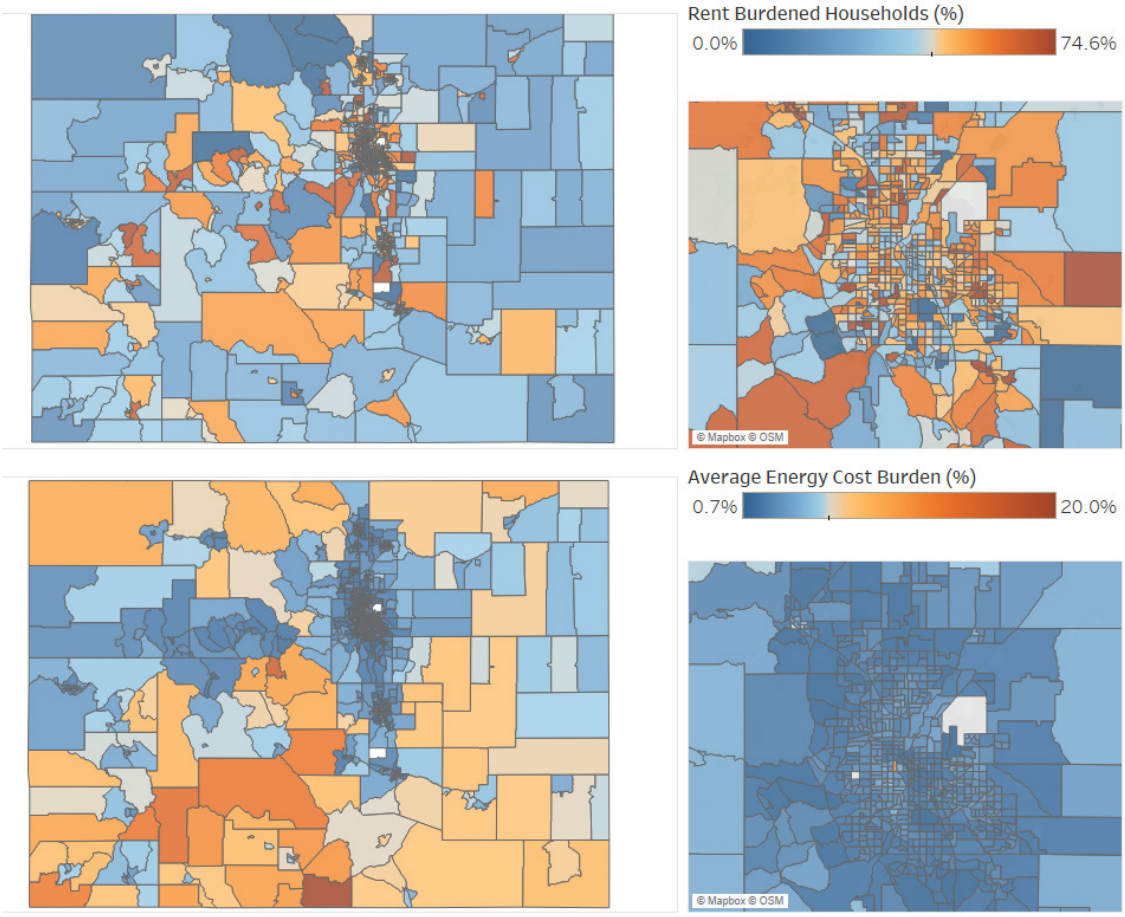

Figure 3.5. Rent Burdens and Energy Cost Burdens. Households with both high energy cost and rent burdens[204] may especially benefit from cost-saving interventions. Households with moderate energy burdens but high rent burdens may also benefit. A rent-burdened household here is a household paying greater than 30 percent of its income in rent, non-inclusive of utilities.

204 U.S. Census. (2019). American Community Survey. Gross Rent as a Percentage of Household Income in the Past 12 Months.

Housing type is another variable that tends to be correlated with energy cost burden. This is particularly true of rural areas. **Section 2 (Figure 2.20)** shows that in rural areas, average energy cost burdens for households in mobile housing units are nearly three times as large as single-family or multi-family homes. This is largely due to two factors. First, mobile homes are about six times more likely to be heated with propane, which is a more expensive fuel. Second, households living in mobile homes have median household incomes that are half the state median household income. Therefore, policies aimed at weatherizing and electrifying mobile homes can have substantial impact on energy cost burdens in those communities.

3.4.5 Climate Zones, Climate Change, and Resilience Benefits

Specific energy interventions and benefits will vary by climate zone across the state of Colorado. In **Section 2** we identified energy cost burdens based on the number of heating and cooling degree days in various locations (**Figure 2.5**), and found the highest energy cost burdens were found in the regions with greater than 9,000 heating degree days and more than 1,200 cooling degree days. The highest heating degree days occur in the state's more mountainous regions, whereas the greatest cooling needs are seen in the plains in the east and west. Both of these regions would benefit from a mix of weatherization efforts and heating electrification, with some variations. The colder regions (see **Figure 2.4**) may require cold-climate heat pumps, and propane users will likely see the fastest payback times. Warmer regions where air conditioning is already in place may benefit more directly from heating electrification efforts, namely heat pumps, which also provide cooling benefits and can replace less efficient air conditioners.

Changing climate patterns highlight the additional value of certain clean energy interventions. Distributed solar generation paired with energy storage, as well as microgrids, can improve resilience, particularly in the face of growing climate impacts. Coloradans with frequent outages, vulnerable populations, and those particularly susceptible to climate change impacts could therefore especially benefit from programs which encourage the adoption of distributed solar with battery storage. The levelized costs of this storage can be reduced if storage is also enabled to provide demand response and deferral of grid distribution upgrades. **Table 3** provides some non-exhaustive examples of such populations as well as the solar capacity that would need to be installed to meet their current and projected electricity consumption. Example populations include low- and middle-income households making less than two times the Federal Poverty Level, rural households living outside of metropolitan areas, households with electricity-dependent Medicare recipients, and households in any county projected to have 50 or more days over 95°F per year by mid-century. Other target populations may include those facing frequent wildfire- or storm-related outages, vulnerable populations (such as the elderly) who face heat stroke risks if the electricity goes out, and those reliant on electricity to power wells or sumps.

Table 3.3. Approximate Solar Capacity Required to Meet Demand for Vulnerable Groups.

Climate-vulnerable and cost-burdened Coloradans may particularly benefit from distributed energy resources. Many potential target populations comprise a relatively small portion of the state, making them high-yield targets for policies incentivizing technologies like community solar gardens and solar+storage.

Population of Interest	Number of Households	Solar Capacity (GW) Needed to Meet 100% of Electricity Demand	
		Baseline	2030[205] (GW)
Reference: All Coloradans	2,150,000	12.0	12.7
Electricity-Dependent Medicare Beneficiaries[206]	100,000	0.6	0.6
Rural Households[207,208]	274,000	1.6	1.7
Households in Projected High Heat Counties[209,210]	146,000	0.7	0.7
Low- and Middle-Income Households[211,212]	550,000	3.0	3.2

Figure 3.6 shows areas with high projected heat days under climate change and high energy cost burdens. These increasingly high heat days will pose affordability challenges to those who need air conditioning but face affordability barriers, and may particularly benefit from efficient air source heat pumps and weatherization.

205 Energy + Environmental Economics (E3) and Colorado Energy Office. (2021). Colorado Greenhouse Gas Pollution Reduction Roadmap. https://drive.google.com/file/d/1jzLvFcrDryhhs9ZkT_UXkQM_0LiiYZfq/view

206 U.S. Department of Health and Human Services. *HHS emPOWER Map.* https://empowerprogram.hhs.gov/about-empowermap.html

207 IPUMS NHGIS. *2015-2019 American Community Survey.* U.S. Census Bureau. https://nhgis.org

208 Includes those households located outside of a census-designated metropolitan area.

209 Rasmussen, D.J., et al. (2016). Probability-weighted Ensembles of U.S. County-level Climate Projections for Climate Risk Analysis: Monte Carlo Patterns/Residual (MCPR) Data Set RCP26." Rutgers University Repository. https://rucore.libraries.rutgers.edu/rutgers-lib/51391/

210 Includes counties projected to experience 50 or more days over 95 degrees Fahrenheit by mid-century under a median probability warming scenario.

211 IPUMS NHGIS. *2015-2019 American Community Survey.* U.S. Census Bureau. https://nhgis.org

212 Includes households making less than two times the Federal poverty level, consistent with the eligibility criteria for CEO's low-income weatherization program.

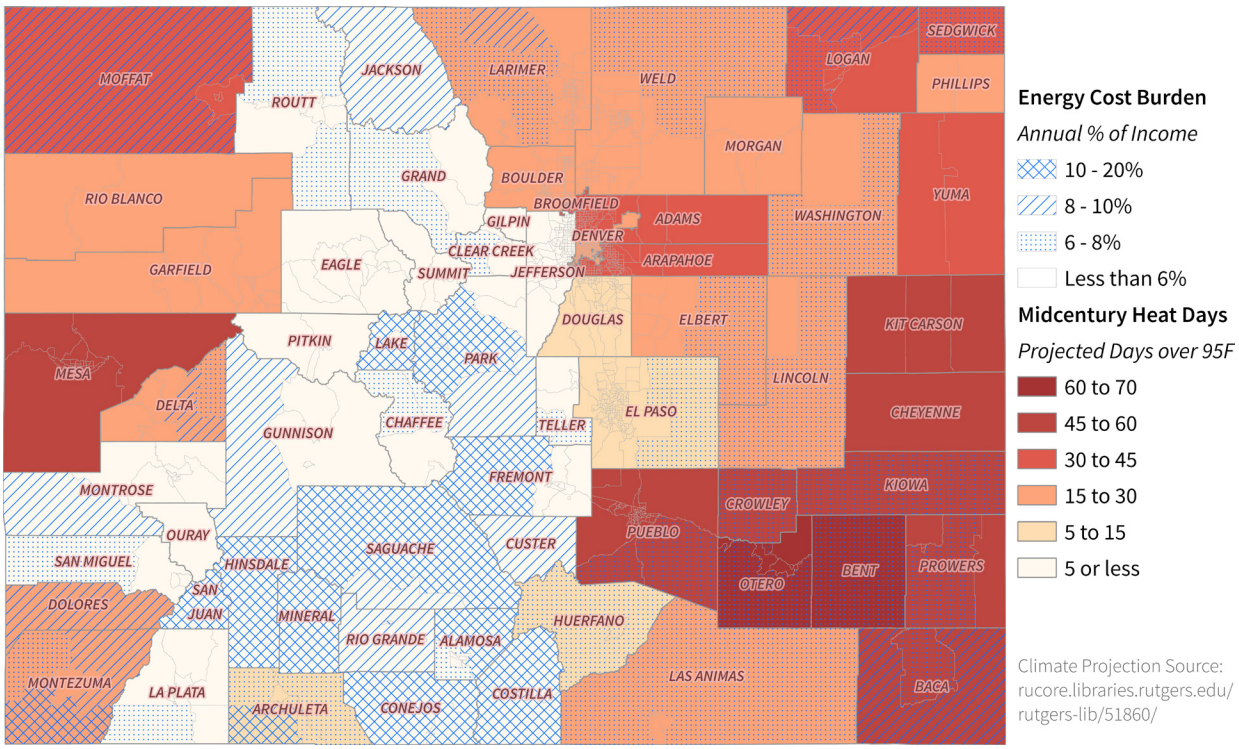

Figure 3.6. Energy Cost Burden and Projected Heat Days. Regions projected to experience severe climate impacts like heat waves may be high-priority for resilience-enhancing clean energy investments like solar+storage. This is especially true for regions with severe impacts and already cost-burdened populations such as, for example, Pueblo, Mesa, and Adams Counties.

3.4.6 Coal Plant Retirements

After a number of notable recent coal plant retirements, Colorado currently has six coal-fired facilities larger than five megawatts (MW). The planned retirement dates of these remaining plants has been accelerated by recent policy developments, potentially leaving only two units online by 2030, one of which (Pawnee) may be converted to gas.[213] Retirement of the remaining plant, Comanche 3, was recently proposed for 2035, although it was originally scheduled to operate until 2070.[214] While most of the remaining plants are targeted for retirement between 2027 and 2029, accelerated retirement for these facilities would help advance climate changemitigation efforts and reduce the emissions of health-damaging air pollutants.

The current portfolio of coal plants serve Public Service (Comanche 3, Pawnee, Hayden, Craig), the City of Colorado Springs (Ray D Nixon, which also recently retired Martin Drake), Tri-State (Craig) and the Platte

213 Brasch, S. (2021). Xcel Energy Says Natural Gas is Critical as it Transitions to More Renewable Power. *Colorado Public Radio.* https://www.cpr.org/2021/02/24/xcel-energy-clean-energy-plan-natural-gas-transition-renewable-power/

214 Associated Press. (2021). Xcel Files Plan to Close Coal-Power Plant in Pueblo. *U.S News and World Report.* https://www.usnews.com/news/best-states/colorado/articles/2021-11-24/xcel-files-plan-to-close-coal-fired-power-plant-in-pueblo

River Authority (Rawhide Energy Station). Accelerated retirement of these units may require alternative financing approaches, such as securitization, to pay off remaining debt. Securitization enables utilities to refinance and repackage existing loans at lower interest rates, reducing the costs to ratepayers and enabling earlier retirement. This approach may be effective for Public Service's plants, as well as Tri-State and Platte River; however Colorado Springs already has access to lower-interest loans to support its coal plant, and securitization will likely provide less financial benefit.[215]

Many of Colorado's coal plants are in rural areas, although the pollutant emission impacts from these plants can stretch for hundreds of miles. The most urban of Colorado's plants in recent years—Martin Drake—shut down in 2021. From a demographic standpoint, four of the state's six coal plants rank above the fiftieth state percentile or above for low-income populations living within a three-mile radius of the plant; the population near Comanche facility in particular is notable for ranking at the 77th percentile statewide for population of color and 81st percentile for low-income population.[216] Although Comanche is located at the periphery of the City of Pueblo, it is a highly visible facility and its emissions-related health impacts aggregated over Colorado and beyond are responsible for an estimated 18 mortalities per year.[217] When compared to the state's other power plants, this mortality impact is second only to Craig, which has an annual estimated mortality impact of 21. Comanche units 1 and 2 are planned to shut down in 2022 and 2025, but the newer Comanche 3 is projected to continue to run and will have ongoing health and climate impacts. These health impacts, as noted, stretch over large regions, but are highest per capita near and downwind from the plant.

Comanche stands out from an equity standpoint for being located in a disproportionately low-income and population of color community, and as one of the top two plants from a health

215 Best, A. (2018). How Refinancing Could Help Retire Colorado Coal Plants Sooner. *Energy News Network*. https://energynews.us/2018/10/02/how-refinancing-could-help-retire-colorado-coal-plants-sooner/

216 EPA Clean Air Markets. (2021). Power Plants and Neighboring Communities. https://www.epa.gov/airmarkets/power-plants-and-neighboring-communities

217 Clean Air Task Force. (2019). Toll From Coal. [Interactive Map]. https://www.tollfromcoal.org/#/map/

impacts standpoint. Comanche 3 is also the newest coal unit in Colorado, and was originally expected to run for 60 years. This unit in particular may therefore benefit from securitization efforts to enable it to retire early. In turn, Craig and Hayden have two of the highest health impacts *per unit of energy* generated. Investments in demand-reducing efficiency measures, community solar, and energy storage that displace generation from these plants—such as by providing capacity value in similar locations or reducing electricity demand at times the plant tends to operate—will have the greatest health benefits for every megawatt hour of clean energy generated.

3.4.7 Utility Type

Strategies to reduce energy cost burdens will necessarily require tailoring policies and programs to utility type. Investor-owned utilities, municipal utilities, and rural cooperatives all have different governance structures as well as regulatory and legal requirements. Below, we detail some of these differences, who might get excluded from certain policy efforts, and approaches to overcoming them.

Percentage of Income Payment Plans outside of investor-owned utility territory

Utility PIPP programs in Colorado are implemented in the areas where its investor-owned utilities supply energy. Cooperatives and municipal utilities have their own assistance programs or rely on third parties, such as non-profits or charitable organizations (in addition to LEAP) to provide bill-payment assistance. At the same time, the highest energy cost burdens tend to be in rural areas where propane heating is common, poverty rates are higher than the state average, and, in many cases, electricity rates are higher (see **Section 2**, **Figures 2.18** and **2.19**; the former shows that both the lowest and highest electricity rates are in areas supplied by rural co-ops). Achieving an equitable transition therefore indicates special attention must be provided to these areas that are served by utilities not regulated by the Colorado Public Utilities Commission.

Community solar gardens for rural co-ops

Most retail distribution co-ops are served by Tri-State, the Generation & Transmission co-op that sells them electricity wholesale. This energy is provided under long-term contracts which generally require the distribution co-ops to purchase at least 95 percent of their electricity from Tri-State. Some co-ops purchase all their electricity from Tri-State while others generate up to five percent of their electricity locally. Behind-the-meter rooftop solar is exempt from the five percent requirement, so long as the electricity generation remains equal to or less than the annual consumption. Supporting distribution co-ops through loan loss reserves and targeting community solar subscriptions on the lowest income households reserves to focus community solar subscriptions on the lowest income households (less than 50 percent of the Federal Poverty Level) would be one way to maximize the impact of generation on low-income households while remaining under the five percent limit. Even so, it is unlikely that all households under 50 percent of the Federal Poverty Level could be accommodated within this limit. Since behind-the-meter installations are exempt from the limit, rooftop solar for low-income homeowners (as for instance those who live in manufactured homes) could provide

a complement to community solar. As noted above, Tri-State could also choose to exempt community solar gardens with a high proportion of low- and moderate-income subscribers. Such an exemption could go a long way towards joining equity and climate considerations in rural areas. Colorado's community solar garden pilot program showed that bill reductions of a few hundred dollars are possible.[218] At about 50 percent of the Federal Poverty Level, a 20 percent reduction in the electricity bill would reduce the overall energy cost burden by a few percent for fossil fuel-heated households.

A grant program for the lowest income households to own a share of a community solar installation may also be effective. At $1.50/watt-dc, a grant of $3,750 would purchase 2.5 kW-dc, and reduce the energy cost burden of a household with $7,500 annual income by 5 to 10 percent (depending on the electricity rate in the area).

Municipal utilities are not under the same constraints as many rural co-ops. For instance, Colorado Springs Utilities has four MW of community solar gardens. The utility works with SunShare Community Solar which specializes in community solar installations. The example shown on the company's website would reduce a $1,200 annual electricity bill by $56, or almost five percent. Providing this type of company with lower-cost financing as well as a guarantee against contract default by the CCEF could enable low-income community solar subscriptions at greater discounts.

Rates

Each of the utilities has a unique rate structure. These rate decisions matter for a number of energy cost burden-related reasons:

- **Average rates:** Average residential retail rates vary widely, with rural co-ops offering some of the highest and lowest rates. Very high overall rates contribute to high energy cost burdens, and these regions would benefit from efficiency measures in particular. Very high electricity rates but low gas rates may be a disincentive to electrification.
- **Time-of-use rates and demand response:** Time-of-use rates and demand response are enabled by smart meter infrastructure as well as access to smart technologies. Utility adoption of smart meter infrastructure varies, with early adoption by some co-operatives, upcoming adoption in Public Service territory, and lagging adoption for

218 H. Dobos et al. (2017). Insights from the Colorado Energy Office Low-Income Community Solar Demonstration Project. *Colorado Energy Office.* https://drive.google.com/file/d/1m0__YjV5m0Ai9J4C0slpJKiAtT6V9ZyF/view

other territories. These rates help meet system needs, but better distribution of enabling technologies may be needed to ensure that low- and moderate-income households benefit from them.

- **Tiered rates:** Tiered rates may also offer a disincentive to electrify if the additional electric load of electrified heating and cooking pushes households into a higher electricity rate tier.

The investor-owned utilities are regulated by the Public Utilities Commission, meaning the Commission can consider the impact of these rates on energy cost burdens. More specifically, Senate Bill 07-022 allows for rate designs to have "reasonable preference" for low-income ratepayers.[219] However, rural co-ops and municipal utilities are governed separately, and any rate considerations may have to take place in a piecemeal way.

3.4.8 New Homes

Colorado's population is expected to increase by approximately 27 percent over the next 20 years as shown in **Figure 3.7**. This significant growth will be most prominent in urban areas (1.25 million individuals by 2040) with significant growth also expected in urban clusters (150,000 individuals by 2040) and rural areas (180,000 individuals by 2040). This demographic growth will necessarily require the construction of new housing. Policy regarding the construction of new housing can thus have a great impact on reducing energy costs.

With these demographic trends, a significant share of low- and moderate-income households may be living in housing built between 2022 and 2042, a target timeline for completion of an emission-free, affordable low- and moderate-income energy transition. This projected new housing demand provides an opportunity to construct efficient, all-electric buildings, saving costs on future retrofits and providing lower overall utility bills than existing structures. Given plummeting rooftop solar costs in recent years, it is also now more economical in many situations to have a net-zero-energy home built with solar rather than to build to "solar-ready" specifications and install the solar at a later time.[220] A key reason is that specifying solar for new residential buildings eliminates the large "customer acquisition" cost of rooftop solar when it is retrofitted on existing homes. This high customer acquisition cost, which is on the order of 40 cents per Watt-dc (and sometimes more),

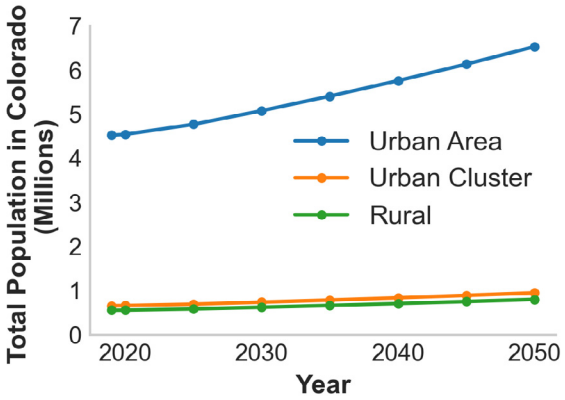

Figure 3.7. Projected Populations Change in Urban Areas (densest population), Urban Clusters (less densely populated urban places), and Rural Areas.

219 PUC Low Income Regulatory Consideration. Colorado SB 07 022. (2007). https://leg.colorado.gov/sites/default/files/images/olls/2007a_sl_78.pdf

220 A. Makhijani. (2020). Gold on the Roof: The Economics of a Net-Zero Energy Rooftop Solar Mandate for New Residential Housing in Montgomery County, Maryland. *Institute for Energy and Environmental Research*. https://ieer.org/resource/distributed-energy/gold-on-the-roof/

is due to the fact that a solar developer typically spends time with many prospective customers before being asked to provide detailed estimates (including possible site visits) for perhaps three customers to get one contract. Given that residential rooftop solar capacities are typically in the single-digit kilowatts, these substantial customer acquisition costs are spread out over a small capacity, raising the cost per Watt significantly.[221]

For the same reasons, installation of geothermal heat pumps in new homes is more economical. In the colder regions of Colorado (say, 6,000 degree-days of heating per year or more), using geothermal heat pumps as the standard for new construction would help obviate or reduce the cost of managing winter electricity demand peaks once a majority of homes are electrified. There is thus a general public economic interest in providing suitable rebates that correspond to the likely significant avoided costs, especially in the colder regions.

Net-zero electricity residences are being built in Colorado. The Southwest Energy Efficiency Project has compiled a list of recent examples, such as a development with 18 townhomes with geothermal heat pumps and rooftop solar. New homes with rooftop solar and geothermal heat pumps have short simple payback times. For instance, a development in Arvada with these features has a payback time of just five years (after federal and utility incentives).[222]

221 A more detailed description of this issue can be found in Arjun Makhijani, Gold on the Roof. (2020). https://ieer.org/resource/distributed-energy/gold-on-the-roof/

222 Southwest Energy Efficiency Project. (2021). All-Electric New Homes & Buildings in Colorado. https://swenergy.org/publications/building

3.5 Deployment Scenarios

We investigate the costs, bill impacts, and financing needs for deployment scenarios for four main technology investments:

1. **Energy efficiency:** These measures include investments in building envelopes and increasing the efficiency of electric appliances such as lighting and water heaters.
2. **Community solar:** We assess the build-out of sufficient community solar to ultimately ensure subscriptions are equal to 100 percent of low- and moderate-income electricity requirements, including to meet the increase in electricity requirements from electrification.
3. **Demand response:** Residential demand response is enabled through the adoption of smart appliances and build-out of broadband infrastructure.
4. **Beneficial electrification:** The electrification of heating, including conversion of gas- and propane-heated homes, increases efficiency. Some electrification measures will increase total electricity demand, but the expansion of cold-climate heat pumps to replace some electric heating will mitigate some of this growth.

We calculate the required investments, financing, and energy assistance strategies for various low-income brackets and the deployment rates required to reduce energy cost burdens below six percent for all households within twenty years.

3.5.1 Methods

Here, we implement policy scenarios using a mixture of programs aimed at reducing energy cost burdens and investigate their funding implications. In order to target low- and moderate-income households, we developed a method (**Appendix**) that simulates individual household profiles and their energy spending across Colorado for the year 2019. Unlike our **Section 2** census tract estimates, which allowed us to explore statewide trends, this approach enables us to investigate the specific number of energy cost-burdened households in various income brackets—and therefore the cost and impact of different interventions. We estimated energy cost burdens within the following income brackets.

- <50% Federal Poverty Level;
- 50-99% Federal Poverty Level;
- 100-149% Federal Poverty Level;
- 150-184% Federal Poverty Level; and
- 185-200% Federal Poverty Level.

Summary statistics of the household energy cost burdens are shown in **Figure 3.8**. The left plot presents the numbers of households in each of these income brackets. The orange

portion of the bars show the total number of households with energy cost burdens (ECB) greater than six percent and the blue show the number of households that have energy cost burdens less than six percent. The right plot presents the total financial support needed in the form of bill payment assistance to bring household energy cost burdens to the level of six percent for the year 2019.

The total bill assistance needed to reduce energy cost burdens for all households earning less than twice the Federal Poverty Level comes to approximately $280 million per year. The majority of this theoretical total assistance (from all sources)—69 percent—is for households with incomes under the Federal Poverty Level. Over 89 percent of the maximum assistance is accounted for by households with incomes below 150 percent of the Federal Poverty Level. There are two reasons for this result. First, energy burdens are much higher at lower income levels due to the very fact of lower household incomes. Second, the vast majority of the households in these categories have energy burdens considerably greater than six percent. Higher incomes and lower energy cost burdens will further reduce the total energy assistance requirements in the income brackets from 150-200 percent of the Federal Poverty Limit after energy investments have occurred. Only a fraction of the households in this category have energy cost burdens over six percent: in the case of the 150-185 percent bracket, the fraction is 34 percent; it is much lower for the highest bracket. Further, most households with energy burdens more than six percent do not exceed that affordability threshold by large amounts. However, households with energy cost burdens above six percent do exist in the highest income category analyzed: 185-200 percent of the Federal Poverty Level. It is worth noting that these households do not currently qualify for PIPP.

Using the simulated portfolio of low and median income households, we then calculate the impact of investments in the four core technologies: energy efficiency,

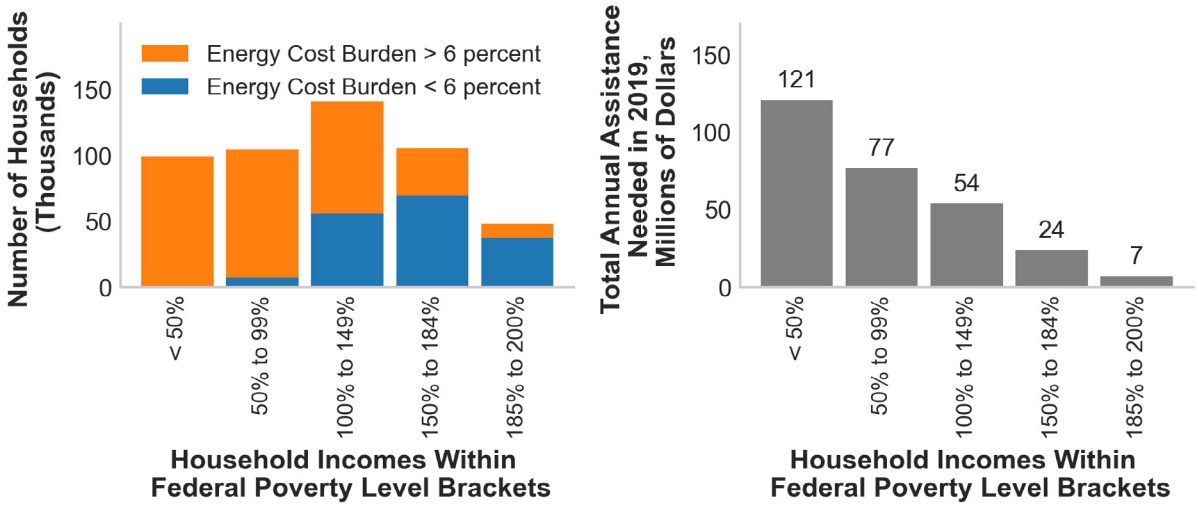

Figure 3.8. Energy Cost Burdens by Income Bracket. (Left) Number of total households in income brackets with energy cost burdens less than (blue) and greater than (orange) six percent. (Right) Total annual financial bill assistance needed to bring energy cost burdens down to six percent for the year 2019 for households within income brackets.

beneficial electrification of heating, community solar, and demand response. Each of these steps requires its own financing strategy.

Energy Efficiency. To approximate the impact of efficiency investments on household energy bills, we estimated the cost and benefits of energy efficiency improvements using data reported by an Oak Ridge National Laboratory (ORNL) assessment of the WAP program for cold and very cold climates.[223] We chose to use ORNL data because data from Colorado's WAP are rather sparse. We do, however, use the available Colorado data as validation of the estimates derived from ORNL to ensure reasonableness and relevance to Colorado.

Based on the reported ORNL data, we estimate that every $1,000 in efficiency investments reduces bills by $101 per year ($2019, adjusted from the ORNL 2008 value using the Federal Reserve Gross Domestic Product Deflator[224] =1.19). For comparison, limited data from Colorado WAP program suggests a savings of $196 per $1,000 of investment if only the direct efficiency investments are taken into account and $117 per $1,000 invested (**Figure 3.9**) if including the gross cost. This calculation includes health-related investments that must be done for the efficiency-related measures to be implemented. These data suggest that the value of $101 per $1,000 invested is on the conservative side. A lower number than the Colorado WAP data is also appropriate since the amount of investment we assume will be considerably larger per home than past WAP investments and energy bills savings per dollar invested might decline with increasing investment.

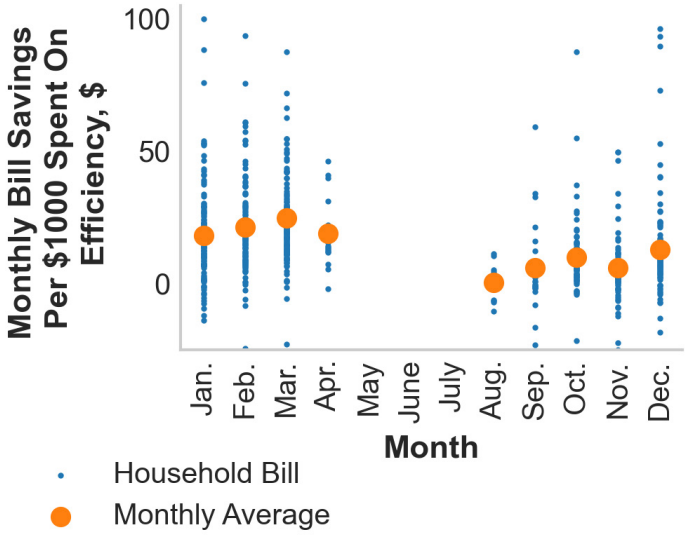

Figure 3.9. Estimated Monthly Savings Per $1000 Gross Total Cost of Efficiency Investment from WAP Data in Colorado. Average savings in monthly bills from WAP jobs in Colorado for each thousand dollars invested in efficiency. Blue dots are for individual household bills and orange dots are for average savings across a month. These savings sum to $117 per year excluding months for which no data are available.

223 Blasnik, M. et al. (2014). National Weatherization Assistance Program Impact Evaluation: Energy Impacts for Small Multifamily Buildings. *USDOE Office of Energy Efficiency and Renewable Energy (EERE).* https://www.osti.gov/biblio/1223639

224 Federal Reserve. (2021). Gross Domestic Product Deflator. [Interactive Tool]. https://fred.stlouisfed.org/series/GDPDEF

We should note that the above discussion relates to direct monetary savings per unit of investment, and this investment includes health-related items that do not directly reduce bills. As such, the calculations of savings here do not take into account the non-energy benefits of those health-related investments in terms of better health, lower medical bills, and related increased ability to pay utility bills and rent. Given the importance of weatherization savings, we also did a sensitivity analysis using a range of $70-$130 in annual bill savings per $1,000 invested.

The maximum investment was assumed to be three times the ORNL report average (adjusted to 2019 dollars); this amounts to a maximum of about $10,000. We assumed that this amount would be in the form of grants for households at less than 50 percent of the Federal Poverty Level; above that income, the grant portion would decline rapidly and the remaining amount would be a low-interest loan. This maximum efficiency level is calculated first for all households; those whose bills remain above six percent of their household income are assumed to receive this full maximum investment, while investments are reduced for other households to the level needed to bring energy cost burdens to six percent.

To finance these energy efficiency investments, we use a combination of grants and loans, which we assume will be supported by the CCEF. The loan investment is assumed to be in the form of low-interest on-bill financing (three percent interest rate and a 15-year loan term). Households with the highest energy cost burdens receive primarily grant assistance, while those with the lowest energy cost burdens (over six percent) receive a larger share of financing through loans. We assign a mix of grants and loans by assuming that, for every percentage point a household's energy cost burden exceeds six percent, the grant component of the weatherization increases by 10 percent, up to a maximum of 100 percent. By this approach, weatherization for a household with an energy cost burden of seven percent would be provided by 10 percent grants and 90 percent loans; any investments in a household with an initial energy cost burden of 16 percent or higher would receive entirely grants.

Community Solar Gardens. We assume the build-out of sufficient community solar gardens to cover all electricity demand for households whose incomes are under 200 percent of the Federal Poverty Level. Subscriptions to this community solar power are discounted at 20 percent compared to existing electricity rates. For non-electrically heated homes, the *overall* energy cost reduction from this community solar subscription would be roughly 10 percent. This value would vary by heating type—it would be a little more for propane-heated homes and a little less for gas-heated homes. Electrically-heated homes would see the full 20 percent cost reduction. We assume that low- and moderate-income participation will be facilitated by CCEF-provided insurance of the contract. This would be done by creating a loss reserve against contract default; in effect, CCEF would provide the credit assurance for low-income subscribers to remove the credit and income-qualification hurdles to participation.

Demand Response. Residential demand response is expanded through a gradual market transition to smart appliances, smart thermostats, and broadband infrastructure that would enable all households to

participate. At this stage, no significant assistance component is included, although it is recognized that landlords may need incentives to purchase smart appliances to enable renters to participate. Broadband access will also be required but should be addressed by the Colorado Broadband Office. We assume demand response revenue for participant households is equivalent to a bill reduction of $100 per year for non-electrically heated homes and $200 per year for electrically heated homes. This revenue stream would not be realized in the near-term, but rather would gradually increase with the fraction of variable electricity—solar and wind—on the grid and with the transformation of the electricity market from one oriented to selling electricity to an energy-services model.[225] The resultant energy cost burden estimates are therefore indicative of a low-emissions, predominantly renewable electricity grid.

Beneficial Electrification. We evaluate two electrification scenarios: one in which gas, propane, and wood heating is converted to electricity with the installation of a cold-climate heat pump; the other in which no such conversion takes place. We assume that the heat pump would be installed at the time of heating system replacement for an added marginal cost of $2,500 which is paid for through on-bill financing (three percent interest rate and a 15-year loan term).[226] For the electrification scenario, we calculate energy cost burdens post-weatherization and post-electrification.

3.5.2 Scenario Results

Below, we describe our scenario results *with* and *without* considering the electrification of propane and gas heating.

3.5.2.1 Scenario 1: No Conversion to Electric Heating

For each income group, we compare initial energy cost burdens to the post-weatherization and post-community solar subscription burdens. These energy investments greatly reduce households' energy cost burdens, but the lowest-income households will still require some measure of energy assistance to reduce their burden to below six percent. **Figure 3.10** shows the impact of the full suite of investments, except heating electrification, on assistance requirements, assuming that all qualified households receive assistance. After these investments are made, the total amount of assistance is about the same as at present. The major difference is that essentially *all* households would have energy cost burdens that are affordable, whereas currently only some households receive assistance and the

225 Gerke, B.F., et. al.. (2020). The California Demand Response Potential Study, Phase 3: Final Report on the Shift Resource through 2030. *Lawrence Berkeley National Laboratory.* Figure ES-3, pdf p. 21. According to this study, significant demand response capacity can be elicited by utilities at costs in the $100 to $200 per year range, although the study is specific to California. The demand response elicited in Colorado would be higher for heating and lower for air conditioning, given the differences in climate. A Colorado-specific evaluation would yield more detailed insights.

226 American Council for an Energy-Efficient Economy. (2021). All Electric New Homes & Buildings in Colorado. P.3. https://swenergy.org/publications/building estimates the marginal added cost for replacing a gas furnace and central air-conditioning as $1,000. However, many gas-heated homes do not have air conditioning. Change to Group 14 Engineering (2020). Electrification of Commercial and Residential Buildings. Table 1, P. 4. https://group14eng.com/service/energy-efficient-services/ estimates the added cost of replacing an efficient gas system with an efficient heat pump as $2,100. We have used $2,500 to represent a diversity of situations, including added costs in some cases for electrification in rural areas.

number of households with energy burdens greater than six percent is about 320,000. The calculations below do not factor in current energy assistance. The overall gap between actual energy cost burdens and six percent is about $280 million per year. Present energy assistance programs of all types cover about 20 percent of this gap. With the increase in PIPP funding, total assistance at present levels would be about $115 million per year, not including the electricity bill assistance provided to low-income customers by the state's electric co-ops. This also does not take into account any remaining COVID-19 pandemic-related funds provided by the federal government.

The sequential use of efficiency, community solar, and demand response using the financing strategies outlined above have different impacts upon households at different income levels as shown in **Figure 3.10**. For the lowest-income bracket (less than the Federal Poverty Level) efficiency investments have the greatest impact because all of the efficiency investments in this bracket are provided in the form of grants. In the higher income brackets, most of these investments are in the form of loans that are repaid as part of energy bills—in other words, via on-bill financing. The specific impact of weatherization on energy cost burdens therefore depends not only on the reduction of energy use produced but also on the way the threshold for grants versus loans is set. While a large majority of the energy cost burdens are reduced to less than six percent, there remain some households still in need of assistance, especially among the households with the lowest incomes.

The impact of discounted community solar that provides less expensive electricity

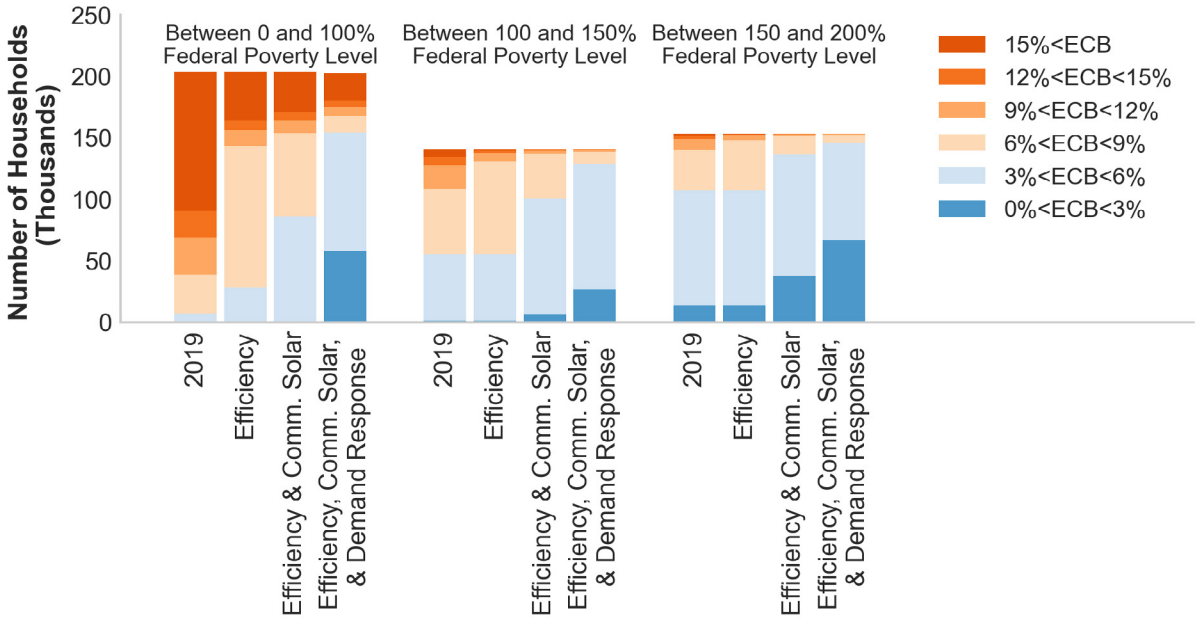

Figure 3.10. **Cumulative Impact to Energy Cost Burden (EBC) of Each Intervention.** Illustration of the sequential impact of the various investment components on reducing energy cost burdens within income brackets.

than that from the utility would be greater, in absolute dollar terms, in the areas with higher electricity rates, such as certain co-ops. The reverse would be true in areas with lower electricity rates, which is also true of some rural co-op areas.

3.5.2.2 Scenario 2: With Conversion to Electric Heating

Efficient electrification of heating can have a significant impact on energy cost burdens even in cases where gas, the lowest cost heating fuel per million Btu, is the heating fuel. A comparison of heating costs for new homes in Colorado by the American Council for an Energy Efficient Economy indicated that, at average electricity and gas prices, heating costs were comparable provided that cold climate heat pumps were installed—$593 per year for a gas furnace and $588 for the heat pump.[227] These investments also play a key role in decarbonizing buildings and reaching state climate targets. In the case of heating retrofits, we assume that:

- The conversion to electric heating would take place when the furnace needs replacement;
- The counter-example where a gas furnace replacement occurs would be with an efficient furnace and include central air conditioning;
- The heat pump would be a cold-climate heat pump.

Under these assumptions, the cost of a heat pump would be about $1,000 more than an efficient gas furnace plus central air-conditioning.[228] However, in many cases, gas-heated homes may not include air-conditioning, in which case the cost differential for the heat pump would be higher. The Colorado Building Electrification Study estimates the end-of-life retrofit cost differential between an efficient gas system and an efficient electric system as $2,100.[229] We have used $2,500 in the calculations to represent a diversity of retrofit situations. We note, however, that the cooling benefits of heat pump installations will be increasingly valuable in a warming climate, and can save on future air-conditioning investment needs. We additionally assume that the heat pump would be financed at a three percent interest rate and the cost would be added to the electricity bill.

The overall impact on energy cost burdens in the case of heating electrification is not significantly different than when heating is *not* electrified, even though the added cost of the heat pump is paid for in the electricity bill. The main driver of this result is that electrification of heating allows all of the electricity to be supplied by lower-cost community solar—assuming a subscription

227 American Council for an Energy Efficient Economy (2021). All Electric New Homes & Buildings in Colorado .https://swenergy.org/publications/building

228 Ibid.

229 Group 14 Engineering (2020). Electrification of Commercial and Residential Buildings. Table 1, P. 4.https://group14eng.com/service/energy-efficient-services/

level at 100 percent of use. In other words, electrification magnifies the cost savings achieved through community solar; however, these cost savings are approximately offset by the added cost of the heat pump. These results are approximate, and specific savings must be evaluated on a case by case basis. Such evaluations may also support different levels of efficiency investments; for example, a higher level of weatherization might be cost-effective if those costs are offset by a smaller heat pump size. This need for case-by-case evaluation of electrification of space heating indicates that capacity for such conversions at the scale needed would need to be built up. This is especially true in rural areas that are off the main interstates where the distances to the job site alone may make it cost-prohibitive to do retrofits under some current circumstances.

While the electrification of heating does not significantly change overall impacts to energy cost burdens in Colorado, it is useful to identify which households will expect the greatest reduction in energy bills through conversion to electric heat pumps (**Figure 3.11**). The blue box plots consider energy bills alone (i.e., without the cost of conversion or the net benefits of weatherization) while the pink box plots add the impact of heating electrification and weatherization and also include on-bill payments. For this analysis, we assume efficiency for electric heating will be lower in colder climates to capture decreases in efficiency of air-source cold weather heat

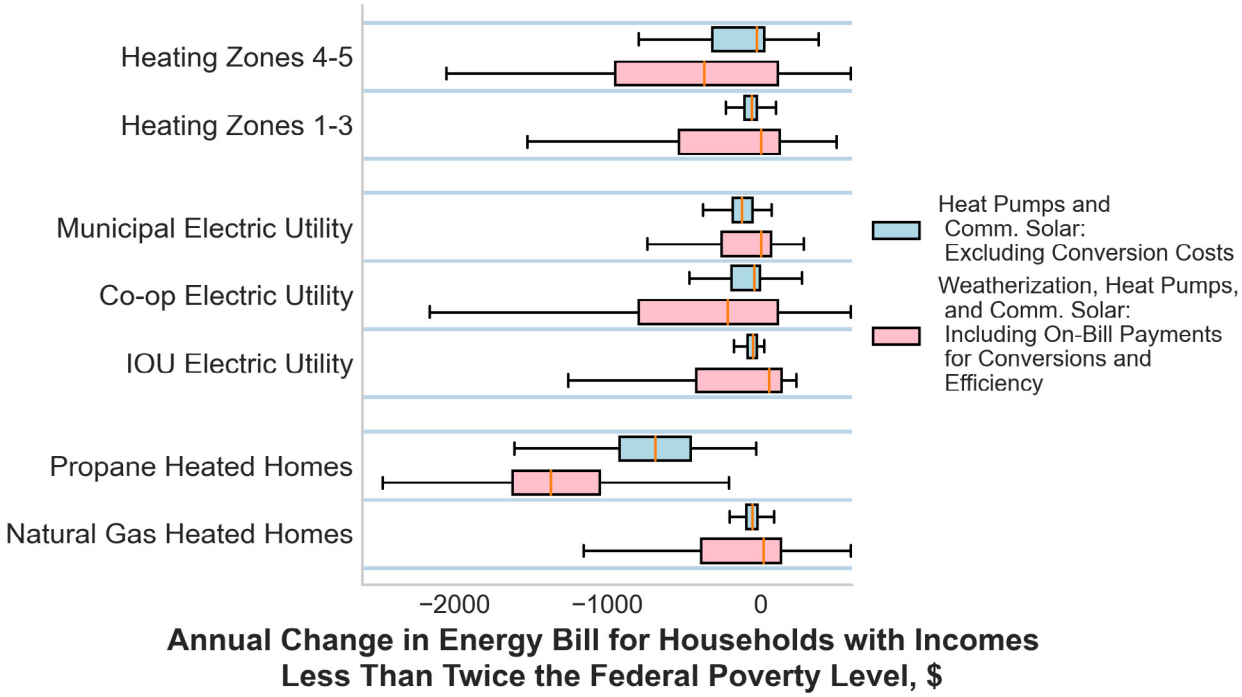

Figure 3.11. Bill Savings from Heat Pump Adoption Under Two Scenarios. Changes in heating bill after switching to cold weather heat pumps for homes within different heating zones, utility territory type, and for different heating fuel types across Colorado. Heating zones 4-5 are colder than heating zones 1-3. (IOU=Investor-owned utility). Blue box plots assume heat pump adoption with no conversion costs but do include reduction in electricity rates from community solar. Pink box plots assume weatherization, heat pump conversions, and community solar and also include on-bill payments for efficiency described in Scenario 1 and on-bill payments for heat pump conversion described in Scenario 2.

pumps at very low temperatures.[230] We then estimate changes in their annual heating bills assuming a 20 percent reduction in electricity rates using community solar. This analysis includes variations in local prices for energy and the amount of energy needed for heating for each home. The pink box plots also include the impacts of household income to determine whether households are eligible for grants versus loans for weatherization. We then group homes into categories and visualize the distribution of these changes for homes within each category using box plots in which the orange line represents the median change, the rectangle includes the interquartile range (the middle half of all expected changes) and the whiskers extending out from the box capture the extremes in the cost change.

For energy bills alone (blue boxes), essentially all investor-owned and municipal electric utility customers—about three-fourths of the total—and many co-op customers would save money with heating electrification. So would essentially all homes heated with propane. The small fraction—about 7 percent—who would experience an increase would be customers of co-ops that have rates much higher than the state average and who live in the coldest areas. (See **Section 2** for discussion of rates.) The greatest predictor of savings, however, is whether a home uses propane or gas for its heating fuel. All homes that use propane can expect savings after switching to electric heat pumps. Conversion of gas heated homes is roughly neutral in cost.

The picture becomes more complex when weatherization costs and benefits and the added cost of electrifying heating is taken into account. For the lowest-income households in rural areas using propane heating the bill savings increase significantly, especially if they are in areas where co-op electricity rates are low. This is because they are assumed to receive weatherization as a grant. On the other hand, at the higher end of the income range and in higher electric rate areas, there could also be an increase in bills. Overall, a significant majority of co-op supplied homes and essentially all propane heated homes would see lower utility bills, many by $100 per month or more. The picture with gas conversions is more mixed—about half would see somewhat lower costs and half somewhat higher costs.

The cost picture will be better than the one portrayed in **Figure 3.11** when demand response is factored in. We have estimated demand response revenues to be roughly around $200 per household; however, that assumes that there will be smart appliances and broadband, even in rental housing. In those cases, the demand response revenue may accrue partly to the landlord (as an incentive to install the needed infrastructure) and partly to the renter. Demand response potential will also increase as electric vehicle use and vehicle-to-grid technology comes into use. Therefore the potential exists for reducing or eliminating bill increases in those cases where they would occur and for greater savings than shown in **Figure 3.11** for most households.

One major benefit of heat pumps is the accompanying cooling technology during hot days. However, for homes that did not previously have air-conditioning, energy bills

230 Specifically, we assume Coefficient of Performance (COP) values decrease linearly from 3.0 to 2.0 from the areas with the fewest heating degree days (4,500) to the areas with the greatest heating degree days (12,500).

during the summer months may increase after conversion, especially for homes that used propane for heating such as rural manufactured homes, which will offset some of the savings discussed above. This effect, not included in this analysis, is likely to be more of a concern in the coldest areas where the cooling degree days are typically very low (see **Figure 2.4**) and fewer people currently have air conditioning—although more will likely need it as the climate warms. In sum, the issues related to electrification are more complex and specific to regions, local energy prices, and housing types than other investments related to reducing energy burden.

Finally, it is critical to note that from the point of view of climate and emission reduction goals, heating electrification, as is generally recognized, enables the most energy-intensive of all residential energy uses to be met by renewable energy. In this context, the fact that electrification overall does not change energy burdens significantly even when the process for low- and moderate-income households is not subsidized with grants is very important. In effect, it achieves the elimination of emissions from the most emissions-intensive part of residential energy use at close to zero public cost overall—though with the various regional and housing-type caveats noted just above and the availability of discounted community solar.

3.5.3 Policy and Financing Implications

To achieve the energy cost burden reductions as outlined above will require a significant amount of funding to support energy investments and energy assistance, although these investments will decline over time as investments offset the need for energy assistance. To expand current energy assistance levels to all qualifying households—i.e. to increase PIPP participation rates to 100 percent of eligible households—would require two to three times more assistance funds than currently available, increasing from $100 million to approximately $280 million. This estimate does not include the significant added resources that would be needed to boost *enrollment* in PIPP to very high levels.

Such high levels of assistance will be hard to sustain. Instead, energy efficiency investments are likely to be the largest and most effective single public investment to reduce energy bills systemically. These investments include weatherization as well as rebates and grants for efficient furnaces, appliances, and light bulbs. Currently, WAP is funded by a mix of federal, state, and other resources. However, the funds available, even with recent increases, will be far short of the pace needed to reduce emissions and achieve widespread energy affordability within the time frame of Colorado's climate goals. A significant ramping up of these investments is essential if the state's climate and energy goals are to be achieved in a manner consistent with equity, and may be achieved through a mix of grants and on-bill financing as described above. The number of low-income households weatherized annually would need to be increased from the 1994-2017 average of about 5,600 per year to 25,000 per year to accomplish the conversion of the estimated 500,000 households estimated to be eligible for WAP over the 20-year period modeled in this analysis.

The overall approximate estimates presented above indicate a need for roughly $2.8 billion

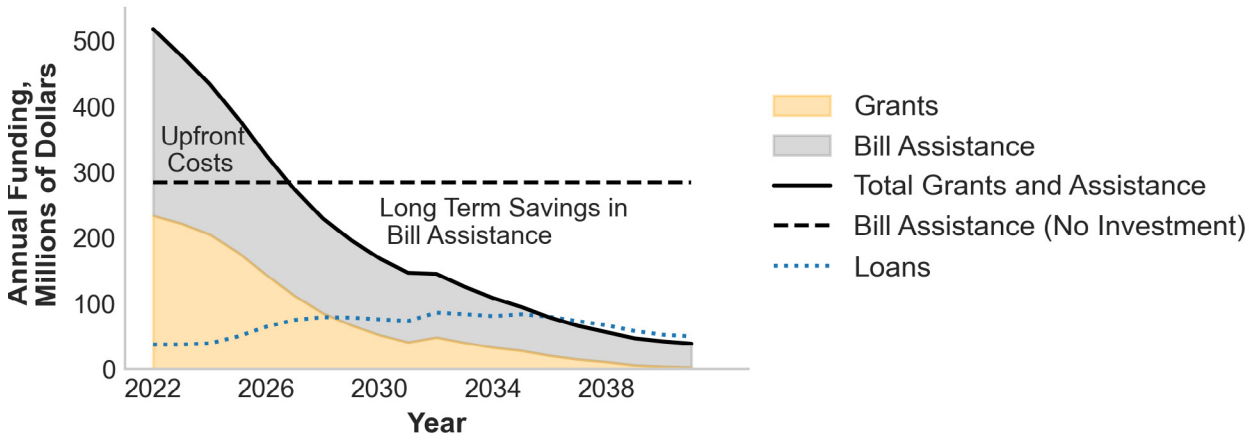

Figure 3.12. Simulated Financing Needs to Reach Target Energy Cost Burdens.

in energy efficiency investments in low- and moderate-income households that have an energy burden of more than six percent. This amounts to roughly $140 million per year for the next twenty years. This investment takes the form of both grants and low-interest loans, and approximately 55 percent would be distributed as grants focused on the lowest-income households.

In **Figure 3.12**, we show the modeled annual funding required to support loans, grants, and energy investments to reduce energy cost burdens. The neediest households are targeted first and an equal number of households are targeted each year for investments until all energy-burdened households are addressed. Initially, funding in the form of energy bill assistance needed to reduce energy cost burdens for all households to six percent (shaded gray area) is high, representing initial levels of needed energy bill assistance (inclusive of energy-burdened households not currently enrolled in bill assistance programs). The dotted black line assumes no investment is made into new efficiency and energy cost burdens remain at their current level. The shaded gray area above the dotted black line, then, represents the higher upfront costs resulting from the high initial levels of energy bill assistance needed plus the initial grants needed for weatherization. As total investments grow and reduce energy burden, the total of grants and bill assistance declines to a level below the assistance needed had there been no investments. The white area below the dotted black line represents the savings, which grow over the rest of the 20-year time span of Scenario 2 in which heating is electrified. The steady growth of discounted electricity from community solar over time is taken into account.

The grants needed for weatherization (orange curve) are initially high since the lowest-income households are the first recipients and they receive all support in the form of grants. The new loans needed for efficiency and heat pumps (blue dotted curve), however, increase over time because households upgraded later have higher incomes and receive more support in the form of loans. By the end of the modeled scenario, energy cost burdens decline to affordable levels for essentially all low- and moderate-income households; the bill-payment assistance requirement is low compared to the no-investment approach. The cumulative bill payment assistance

over this time period is approximately $2.5 billion dollars (shaded gray area). The cumulative grants spent on weatherization and efficiency for the lowest income most energy-burdened households is $1.6 billion dollars. If no efficiency or electrification were built and bill payment assistance were the only means of reducing energy cost burdens, the cumulative funds required would instead be $5.6 billion dollars (area under dotted gray line); this means that investments in efficiency, community solar gardens, and electrification result in a cumulative reduction in bill assistance of $3.1 billion compared to a bill assistance-only approach. When including the costs of grants for weatherization and efficiency, we find a net savings of $1.5 billion dollars over a 20-year period compared to a bill assistance-only approach.

> ***Reducing energy cost burdens for all households through energy assistance alone would require roughly $5.6 billion over the next 20 years. Investing in efficiency, community solar gardens, and electrification would save approximately $1.5 billion as compared to an assistance-only approach.***

There is some uncertainty in the savings corresponding to weatherization investments. A sensitivity analysis done by varying energy cost reduction per $1,000 of weatherization investment indicates that the range of net savings relative to an assistance-only scenario is $1.3 billion to $1.8 billion. In addition, carbon dioxide emissions from low-income households' fossil fuel use would continue if an assistance only approach is taken. Thus, systemic investments in efficiency, community solar, and electrification provide a pathway to reduce emissions that is compatible with equity. This pathway is also more economical and secure for the climate and for low- and moderate income families than reducing energy burdens with bill assistance alone.

Assuming 300,000 conversions from fossil fuel to electric heating at $2,500 apiece, about $750 million (rounded) would be needed to finance electrification of homes now heated with fossil fuels. This analysis assumes the entire amount would be as loans. On the order of 2,200 MW-dc of solar would be needed to supply all of the electricity requirements of 300,000 households, assuming improved energy efficiency due to weatherization improvements and electrification using cold climate heat pumps and heat pump water heaters.[231] The simulation shown in **Figure 3.12** is a heuristic simulation because it assumes that participation in energy assistance would increase to 100 percent in the very first year. In practice, that would take a few years, so that the assistance expenditures would rise from about $100 million in 2022 to a maximum less than $280 million (since a portion of homes would have been weatherized by then and a portion would also be enrolled in community solar gardens).

Our estimates of the costs and benefits of efficient electrification of gas- and propane-heated homes are based on replacement at the end of the life of existing equipment. Our assumption in the cost analysis is that

231 NREL. (2021). PVWatts. https://pvwatts.nrel.gov/

a gas or propane furnace plus a central air conditioner is being replaced by an efficient heat pump. This is a reasonable assumption for most of the highly populated areas of the state, where many homes have air-conditioners or evaporative coolers. However, the central part of Colorado is a low-cooling requirement zone where the total cooling degree days are generally less than 300 per year (see **Table 2.2**). Low- and moderate-income homes are unlikely to have air conditioning in this zone; hence an additional incentive may be needed to compensate for the added air-conditioning function in these areas. As noted previously, this air conditioning may be increasingly needed in a warming climate. Most of this zone does not have gas service, so the majority of heat pump installations would be replacing propane heating, providing a much greater energy cost burden reduction than estimated in **Figure 3.12** and offsetting some of the additional cooling cost. In that context, an additional incentive may not be needed.

Still, the areas that have the highest heating needs also have very low cooling requirements. These are also the areas where electric winter heating would contribute most to winter peaking load. Powering heating with renewable energy that does not require heat pumps would therefore provide benefits to the grid that would not be provided by the usual type of electrification—that is heat pumps or resistance heating.

Seasonal geothermal storage of heat could provide an option that would avoid installation of air conditioning where it is not needed and make use of surplus electricity that would normally be available in the autumn at high penetrations of wind and solar electricity supply. As an example, the 52-home Drake Landing Solar Community in Alberta, Canada has been one of the pioneers of seasonal heat storage.[232] Solar water heaters are used to store heat in insulated cells in the ground before the winter; glycol is the fluid used to gather and transfer the heat. The heat is withdrawn in the winter by pumping it out with glycol as the medium. It routinely supplies more than 90 percent of the winter heating requirements of the community. The system was first put into operation in 2007.

An electricity system powered mainly by wind and solar plants will tend to have significant surpluses in the spring and fall; there may be considerable curtailments in these seasons unless long-term storage (other than batteries) is available. Thermal storage provides one approach that could be beneficial in terms of economical use of capacity and more resilient and economical supply of heat in the winter. Pilot projects, both as retrofits to existing housing and in new housing, in the coldest areas would allow Colorado-specific evaluations of this innovative approach to renewable heating. It could be done with solar water heaters or simply with resistance heaters that draw on surplus electricity in the fall.

It should be noted that our financial estimates are static, based on our calculation that 320,000 households living at or below 200 percent of the Federal Poverty Level have energy burdens greater than six percent. Over time, as new housing is built and poverty levels go down, the fraction of low- and moderate-income households in the housing stock as of 2019 may decline. In light of this, our approach of a static number

232 A description of the system and a number of publications are available at the community's website at: http://www.dlsc.ca/

of households that need investment would still provide an approximate estimate of the investments needed to reduce energy burdens to affordable levels for essentially all low- and moderate-income households.

Energy burdens will increasingly depend on the quality of new housing stock across the entire range of housing types, from manufactured housing to multifamily apartments, in addition to variances due to income and energy costs. The following dynamic is proposed for the goal of keeping assistance amounts (including bill assistance and weatherization grants) to about the same level as available assistance funds today:

- Net zero energy, all-electric new home standards, for all new housing, which would have the impact of reducing assistance requirements. Given that most population growth is projected to be in urban areas, the fraction of households needing assistance to lower energy cost burdens below six percent would decline with the construction of new housing. However, the absolute rate of reduction in energy assistance and weatherization grants will depend on three other factors: changes in the number of households living at or below 100 and 200 percent of the Federal Poverty Level, the rate at which old housing is demolished and replaced by new housing, and how much new housing construction is targeted towards low-income households.
- Annual grants of about $75 million for weatherization of homes of households, almost all at or below 100 percent of the Federal Poverty Level.
- The CCEF (or equivalent financing from other sources by rural co-ops) low-interest loans for weatherization.
- A loss reserve by the CCEF to underwrite low-income household subscriptions to community solar to 100 percent of electricity requirements.
- Modest incentives for landlords to acquire demand-response-ready appliances.
- Universal broadband access, which is desirable for many reasons and whose cost, therefore, is not included in this energy transition assessment.

Colorado has set up the CCEF with a capitalization of $30 million. Additional funds for investment in energy transition are in the Infrastructure and Investment Jobs Act passed in November. Specifically, it contains $3.5 billion for investments in weatherization assistance (or roughly $60 million for Colorado on a per person basis).[233] Additional funds may be forthcoming from the federal government as part of investments in the energy transition. With sufficient capitalization, the CCEF would be the ideal vehicle to provide low-interest loans and to leverage its public status to help underwrite loans and contracts so as to make private investment more secure. The CCEF could by itself, or in partnership with other green banks around the country, bundle and securitize energy-related loans and sell them to recover its capital. This would materially reduce the capitalization required to transition low- and moderate-income households to an emission-free, efficient, and affordable energy future.

233 Chi, S. (2021). Climate and Environmental Justice in the Infrastructure Bill. *Just Climate Solutions.* https://www.justsolutionscollective.org/blog-posts/climate-and-environmental-justice-and-the-infrastructure-bill

In very round numbers the cumulative investment needed in the form of weatherization grants to the lowest income households would be on the order of $2.3 billion and the loans for weatherization and heating electrification combined would be another $1.9 billion ($675 million and $1.25 billion respectively). All investments considered here are exclusively for households with incomes less than twice the federal poverty level and would be over a 20-year period. The investments in the form of grants would be for households with pre-assistance energy burdens greater than sixteen percent while households who are eligible for weatherization but have energy burdens below sixteen percent would be in the form of loans and grants (except for any down payments customers might make). Grants can be made via utilities, in the same manner as rebates for appliances, water heaters, etc. The overall cumulative loans made by the CCEF would be $1.9 billion—or about $95 million per year. In addition, the CCEF would need operating funds to cover its costs. At present $5 million of the $30 million capital infusion is for operating costs because the bank is in a start-up phase. The fraction for funds needed for operating costs should be lower than that relative to the added capital requirements. It should be noted that these estimates represent only the low-income segment of the market that the CCEF would operate in. The larger portfolio of the CCEF (beyond low-income households) would enable it to bundle low-interest loans with more commercial ones, making the package attractive for investors.

Evidently, the scale of the investments would need an increase in the CCEF's capitalization; its operating funds would also need to be sufficient to enable it to reach customers in all parts of the state. Colorado, like other states, has received infusions of federal funds, including some directed at equity (under the rubric of "Justice40"). More funds may also be forthcoming.

We have not assumed large public investment will be needed for supporting community solar gardens. These can be financed with private capital, as is generally the case today. Subscriptions by low- and moderate-income households for community solar—as well as any rooftop solar—do need public support, however. The most important obstacles these households face are related to income, credit scores, and other financial criteria that may indicate a higher risk of default on the long-term contracts that are typically required. These are deterrents both for low- and moderate-income households and for solar developers. In this context, a loan loss reserve provided by the CCEF to low- and moderate-income households would enable developers to make contracts with them on the same terms as non-low-income households. Such a program could provide the needed public investment. Experience indicates that the default rate is expected to be low. The Solar Energy Loan Fund, created for providing solar access to underserved communities in Florida, has experienced a default rate of less than two percent. This loan loss reserve would be quite small, since the solar energy

corresponding to the defaulted contracts would, in most cases, be transferred to a new subscriber.

As is discussed elsewhere in this report, low- and moderate-income households have not benefited proportionately from public investments and rebates provided to residential solar installations. As such, there have been some cross-subsidies to the extent that those incentives are provided by utilities and recovered from all ratepayers. Many studies have shown that there are overall net economic, social, and environmental benefits of net metering rooftop and community solar (virtual net metering, in the latter case). However, it is also generally recognized that net metering is likely to give way to other rate types as the penetration of net-metered installations grows. Given that lower income households have, for a variety of reasons, been marginalized so far as access to solar is concerned, we recommend here that net metering be available indefinitely for all low- and moderate-income households, even if it is not maintained for wealthier households or in the commercial sector.

The maintenance of net metering for low- and moderate-income households should not have a major impact on the transformations of the business model of utilities as part of the transition to variable energy sources, storage, demand response, and a much larger role for distributed solar energy. Renewable energy supply to low- and moderate-income households will be a mix of utility-scale resources, virtual net-metered sources, such as community solar, and rooftop net-metered resources. In turn, residential distributed resources will be a fraction of overall distributed resources. It is difficult at present to estimate precisely the total amount of low- and moderate-income residential net-metered generation after a full transition, but an order-of-magnitude estimate can be inferred. Low- and moderate-income household electricity consumption is roughly four percent of the total—a fraction that is likely to remain about the same. Given a balance between wind and solar resources, net-metered low- and moderate-income solar would be less than 10 percent of solar generation.[234] This indicates that the transformation of the business model and the accompanying rate structures should not be impacted in a significant way by maintaining net metering for low- and moderate-income households as a matter of fairness, since they have benefited less relative to other income groups.

Demand response will require smart meters, smart appliances, and universal broadband. This assessment does not attribute any additional public investment costs in the form of grants and subsidies for appliance purchases for low- and moderate-income households relative to wealthier households, since we assume most appliances are likely to be replaced within the period under consideration for an energy transition.

234 Residential electricity consumption was about a third of the Colorado total use in 2019. Low- and moderate-income households with high energy cost burdens (more than six percent) are about 15 percent of total households and they consume somewhat less electricity than average, giving a rough estimate of electricity use by that group of about four percent of the Colorado total. If solar and wind are generated in about equal amounts and the fractions of overall consumption remain the same, the fraction of solar energy consumed by low-income households would be about eight percent. It would be speculative to estimate the fraction of distributed solar that would be net-metered for low- and moderate-income households because the fraction distributed solar in the overall system depends on many factors, including the future business model, that are at present not known with any precision.

3.6 Enabling Considerations

3.6.1 Reducing Barriers to Engagement

A number of barriers to engagement limit the participation of energy cost-burdened households in energy affordability and weatherization-focused programs. A few are discussed below.

Addressing landlord-tenant split incentives for demand response. Demand response can provide a significant reduction in energy burdens for households with smart appliances and broadband located in utility areas that provide such peak load reduction and load shifting incentives. The general business model of utilities must move in that direction, especially with increasing penetration of variable renewables, enabling homeowners to participate as their existing appliances are replaced by new demand-response capable ones. Of course, this is already generally the case with heating and cooling controlled by smart thermostats and many water heaters.

Renters are at a clear disadvantage in regard to demand response since they do not own the appliances. Landlords do not have an incentive to pay the marginal added cost of a smart appliance when the renter gets the benefit of the demand response payment. A rebate covering the marginal cost of the smart appliance relative to a standard one would be one approach to level the playing field for renters in regard to demand response. Sharing demand response utility bill credits would also be possible, especially in multi-family housing, since some of the credit earned by a particular renter could be assigned to the meter registering common electricity use. This may be less feasible and involve privacy issues when it concerns rental of single-family properties.

Increasing PIPP enrollment by decreasing documentation requirements. PIPP enrollment is currently connected to enrollment in LEAP—and as discussed above, is in most cases lower than that in LEAP. The Colorado Public Utilities Commission is evaluating decoupling PIPP enrollment from LEAP following the enactment of House Bill 21-1105,[235] Senate Bill 21-272[236], and Senate Bill 21-199[237]. Documentation requirements pose significant hurdles to enrollment in both LEAP and PIPP. These hurdles become much higher in mixed status families where some members may be documented and others not. Disconnecting PIPP enrollment from the documentation and residency status requirements of LEAP could significantly increase enrollment. Self-attestation of income as the one requirement of enrollment would simplify the process and reduce overhead costs. California's CARE program has income self-certification; the customer is informed at the time of self-certification that a small fraction of applicants are audited. Civic Works, a non-profit in Baltimore, Maryland, has been implementing weatherization and efficiency measures as well as rooftop solar in Baltimore low- and moderate-income households since 2009

235 Low-Income Utility Payment Assistance Contributions, HB 21-1105, 2021. http://leg.colorado.gov/sites/default/files/documents/2021A/bills/fn/2021a_hb1105_f1.pdf

236 Colorado Senate Bill 21-272 (2021)

237 Remove Barriers to Certain Opportunities, SB 21-199, 2021. https://leg.colorado.gov/bills/sb21-199

both on its own and in cooperation with Baltimore City and Maryland government agencies. Civic Works uses self-declaration of income as sufficient proof for a household to qualify for its programs. It audits a small fraction of these declarations. Civic Works has found minor errors but no instance of fraud or false declarations. The program has reduced costs, increased participation and increased trust with the community.[238]

Complementary actions for increasing enrollment. Low enrollment in energy assistance programs is both typical and complex. Self-attestation of income can help but other options could complement it to increase participation even more substantially. Making the income requirements for LEAP, WAP, and PIPP the same by adjusting them to the more generous level would be one small step. Other options include automatic enrollment in PIPP for households receiving other forms of assistance, person-to-person outreach in the appropriate language as well as publication of PIPP materials in multiple languages. Integrating assistance, community solar garden subscriptions, and weatherization loans into a single consolidated utility billing system (in which the components would be clearly shown) may simplify the process of putting the various pieces of energy affordability together and also help remove or at least reduce the social stigma that some people feel in getting energy assistance.

3.6.2 Distribution Grid Infrastructure

A significant upgrade of the distribution infrastructure is likely to be required, especially in rural areas, to accomodate a greater intensity of electricity use per household (due to electrification of space and water heating and increased use of electric vehicles).[239] Some of the highest (as well as the lowest) electricity rates are in rural areas served by retail co-ops. Dispersed, low density of housing is a likely contributing factor to high rates, along with low use per customer.[240] Electrification can be expected to be a positive factor in helping to lower rates. However, investments in storage, demand response, and efficiency, and in many cases upgrading distribution system capacity, will likely be needed. Costs associated with distribution upgrades may be mitigated to some extent by distributed storage and demand response.

Holy Cross Energy, a co-op that aims to achieve a 100 percent decarbonized electricity system by 2030, offers a glimpse into this future because it offers a number of programs from solar to weatherization to demand response. An important and innovative example is the way in which Holy Cross is integrating on-site solar and on-site storage with demand response capabilities that increase distribution system capacity, flexibility, and resilience. This approach enables the charging of an on-site battery with on-site solar or grid electricity. Holy Cross integrates these customer-friendly features with benefits to the utility by retaining control of the battery system to

238 Schwartz, E. (personal communication, December 17, 2021).

239 Increased use of electric vehicles has not been factored into the calculations in this report.

240 There is a negative correlation 0f -0.35 between the sales per customer by rural co-ops and the average retail rate (for all customer classes). Based on analysis of U.S. Energy Information Administration retail sales data in Form 861 for 2019. https://www.eia.gov/electricity/data/eia861/

enable withdrawal from or delay of charging at most 10 times a month.[241] Innovative ways of strengthening the distribution system and minimizing transfer costs will be important as distributed generation, including community solar gardens and storage, increase.

In this context it is important to note that gas infrastructure should not be extended to areas that do not now have it. This is essential to reducing the risk of stranded costs and to getting the full economic benefit from upgrading electricity distribution infrastructure.

3.6.3 Workforce

A full discussion of workforce development needs to support the clean energy transition is beyond the scope of this report. However, we do note that building up capacity for audits, weatherization, HVAC upgrades, and other measures—*particularly in rural areas*—will be a critical foundational component for successful WAP and electrification expansion. The capacity of the larger retail co-ops, as well as wholesale suppliers to retail co-ops (both investor owned utilities and Colorado's generation and transmission co-op), can be tapped to expand this capacity. Current capacity also includes the non-profit Energy Outreach Colorado, which provides weatherization services to low-income households (in addition to supplemental energy assistance). Colorado's co-ops refer low-income customers to Energy Outreach Colorado for weatherization. As another example, CORE co-op (formerly Intermountain Rural Electric Association), "provides free energy efficiency consultations to members interested in lowering their usage."[242] Thus between leading distribution co-ops, generation and transmission co-ops (Tri-State), municipal utilities and investor-owned utilities, much of the foundation for increasing capacity exists.

3.6.4 Broadband

One of the central components of our proposed energy cost burden strategy is residential demand response. Demand response helps improve grid flexibility, integrate renewable energy resources, and reduce peak demand and therefore grid capacity investment needs. However, it is typically enabled by smart appliances, such as thermostats or water heaters that can respond to utility signals and shift electric loads to times of lower demand. These smart appliances require internet access to operate, meaning that households that do not have access to the internet—or who have unreliable internet or disconnections—will not be able to participate in demand

241 Holy Cross Energy. (n.d). *Programs Overview.* https://www.holycross.com/programs-overview/

242 U.S. Census. (2019). American Community Survey. Types of Computers and Internet subscriptions.

response. Coloradans have greater access to the internet than the national average, but 8.8 percent of households (nearly 200,000) still do not have access at all.[243] Another 9.6 percent of Coloradans only have access through their cellular data plan, meaning 18.4 percent of households are precluded from participating in demand response based on their access to the internet.

Lack of access is particularly high for low-income households. 29 percent of households with an income below $20,000 per year do not have an internet subscription, as compared to three percent of households with incomes over $75,000 per year. We do not include investments in broadband as part of our calculations, as we know that broadband expansion is an ongoing effort of the Colorado Broadband Office. However, there may be value to coordinating between investments in efficient, smart appliances for low- and moderate-income homes and broadband hook-ups. These homes may also benefit from affordable broadband subscription programs. Participation in demand response is also enabled by access to smart appliances, which may require additional incentives, including for landlords to provide such appliances in addition to internet access to their tenants.

3.6.5 Community Engagement

Programs to address energy cost burdens and affordability will require up-front and ongoing meaningful community engagement to design programs to reach currently underserved populations. The current programs targeted at improving energy affordability (e.g. PIPP) have very low participation rates. Ongoing and sustained community engagement, including in multiple languages, can help identify barriers and iterate and test through solutions that increase this participation rate, such as expanding the number of locations to sign up or self-attestation of income levels to enroll. This engagement to increase participation will grow increasingly important with the expansion of supportive programs, such as community solar gardens and low-income demand response programs. Colorado's HB21-1105, "Low-income Utility Payment Assistance Contributions," has laid some of the foundations for increasing enrollment by automatic enrollment of households receiving supplemental nutrition benefits that are not enrolled in energy assistance and by expanding funds available for bill payment assistance.[244]

243 U.S. Census. American Community Survey. (2019). Types of Computers and Internet subscriptions.

244 Low-income Utility Payment Assistance Contributions, HB21-1105, 2021. https://leg.colorado.gov/bills/hb21-1105

3.6.6 Addressing Winter Peaks

Large-scale conversion of non-electric heating to electric heating will create significant winter electricity demand peaks. Heat pumps typically include resistance elements for the coldest weather; these elements are more likely to operate when the weather is both very cold and windy, resulting in severe peaks. Such peaks are to be expected in the coldest areas of Colorado—heating zones 4 and 5—in the central north-south zone in the mountains west of Denver (**Figure 2.4**), where moreover, the air conditioning requirements are low.

Geothermal heat pumps that are sized to accommodate this contingency combined with demand response may be more appropriate for electrification of heating in such areas. However, these heat pumps, including the geothermal well component, typically cost several thousand dollars more than cold-climate heat pumps. Pilot projects and detailed investigations of the issue are needed to address the technical and economic issues and explore alternatives.

For instance, one alternative could be thermal storage in insulated cells in the ground using surplus power in the fall season. Seasonal thermal storage has been used in the Drake Landing Solar Community in Alberta, Canada, for well over a decade where, in recent years, it has consistently supplied over 90 percent of winter space heating requirements. The heat is stored in community borehole fields built for the purpose. It is supplied by solar thermal panels; however, the borehole thermal storage concept is independent of the source of heat.[245] A heat pump operated using surplus renewable energy could accomplish the same purpose. The only electricity required in the winter is for the pumps and a small amount of supplemental heat when needed. We note in this context that the National Renewable Energy Laboratory anticipates that the per-unit energy costs of long-term thermal storage are expected to be much lower than battery storage.[246]

Seasonal thermal storage and geothermal heat pump technologies both involve drilling wells; its development could therefore provide opportunities for well-paid renewable energy jobs with a familiar technology in the oil and gas production areas of Colorado, such as the Denver Basin and the Uinta Basin.

245 Mesquita, L., et. al. (2017). Drake Landing Solar Community: 10 Years of Operation. *ISES Solar World Congress.* http://www.dlsc.ca/reports.htm

246 Augustine, C. and Blair, N. (2021). Storage Futures Study: Storage Technology Modeling Input Data Report. *National Renewable Energy Laboratory,* NREL/TP-5700-78694, Figure ES-8, p. xvi. https://www.nrel.gov/docs/fy21osti/78694.pdf

This winter peak demand becomes increasingly important in the case where utilities promulgate time-of-use rates. While these rates are currently opt-in for many Colorado utilities, if they become opt-out or required (as is planned for Public Service[247]), mid-winter electric heating and mid-summer cooling may result in very high seasonal bills if these demands push household electricity demands into a higher price tier. Weatherization investments as well as enrollment in bill protection measures, such as PIPP, become increasingly valuable in this case.

3.6.7 Recommended Pilot Projects

A number of pilot projects may provide particular insight into enabling effective energy cost burden strategies. The Colorado Energy Office has already pursued community solar demonstration projects, and has used these to evaluate program deployment and effectiveness. Additional pilot projects may include:

- Enabling whole-house demand response capacity, including heating and cooling (if applicable), water heaters, and major appliances (dishwashers, clothes washers, clothes dryers) for one set of low-income homes in each climate zone with time-of-use rates.
- Low-income cold-weather geothermal heat pumps compared to cold-weather heat pumps in the coldest areas.
- Seasonal thermal storage for heating new multi-family commercial construction, new housing developments, and new residential structures in low-population density rural areas, as well as for heating retrofits in the coldest areas with low-air conditioning needs.
- Public-purpose renewable microgrid projects with solar plus storage and/or seasonal thermal storage for emergency shelter locations.
- Pilot to prune a portion of the gas system, e.g. for an entire block or neighborhood, and electrify all end-users.
- Expansion of electrification to propane users in lieu of gas distribution line expansion.
- A pilot project on integration of solar, storage, and grid resilience along the lines of the Holy Cross integration described above but in the context of electrification of heating in a rural area with propane heating and expanding community solar garden capacity.

3.6.8 Coordination Opportunities Between Programs

A number of coordination efforts will likely reduce overhead costs and improve program effectiveness. A few of these include:

- Coordinate with the Colorado Broadband Office to ensure low-income households have internet access to enable smart appliance adoption.
- Consider conducting whole-home electrification retrofits, rather than incentivizing appliance and home

247 Xcel Energy. (2021). *Rates: Information about your bill and pricing. [Residential Time of Use Rates].* https://www.xcelenergy.com/company/rates_and_regulations/rates/colorado_residential_time_of_use_rate

efficiency and electrification measures in a piecemeal manner.

- Provide consolidated billing and on-bill financing so that households only have to pay a single bill per month.
- Create automatic enrollment in PIPP for households enrolled in other assistance programs.
- Ensure households prioritize weatherization and efficiency before adopting heat pumps, rooftop solar, or energy storage to ensure that these systems are not over-sized. It may be beneficial to electrify homes as well before designing any rooftop solar system.
- Consider developing thermal storage and community geothermal pilot projects in rural areas as collaborations between the Colorado Energy Office, the Colorado Department of Agriculture, and the state's oil and gas industry with the aim of exploring transfer of skills from fossil fuel drilling to renewable heating.
- Consider incentives for increasing capacity in rural areas for weatherization and space heating electrification, for instance by supporting co-op utilities that apply for loans for job training under the federal Rural Economic Development Loan and Grant program;[248] the program requires the loan recipient to provide 20 percent of the needed funds. The state could consider providing all or part of that 20 percent.

3.6.9 Recommended Future Research and Data Collection

Our analysis has yielded a number of recommendations for both data collection and future research. Data collection efforts, in particular, would be valuable to both refine the model estimates we have reported here as well as to evaluate the effectiveness of policies and programs to reduce energy cost burdens going forward. A few of these recommended areas of data collection include:

- Utility-reported household-level energy consumption and bills pre- and post-weatherization (with appropriate privacy measures) will be essential to evaluate the effectiveness of investments. These data should be transparent, up-to-date, and accessible for state agencies, program managers, energy service providers, and researchers consistent with Public Utilities Commission data access and privacy Rules.
- Smart meter data can enable household bills to be analyzed for individual appliance loads, because certain appliances—e.g., refrigerators—cycle following recognizable patterns. For customers who opt-in, these data could be used to identify inefficient appliances that could be targeted for upgrades. These data could likely be used to infer whether electricity or gas is being used for space and water heating as well.
- Ongoing evaluation of program participation rates and barriers will enable iterative community outreach

248 Rural Development. (2022). *Rural Economic Development Loan & Grant Program in Colorado.* US Department of Agriculture. https://www.rd.usda.gov/programs-services/business-programs/rural-economic-development-loan-grant-program/co

and program design updates to increase effectiveness.

- Assessment of workforce development needs and opportunities to support weatherization and electrification, particularly for low-income and rural households.
- Evaluate the non-energy benefits of substantial reductions in energy burdens, especially for the lowest income brackets; the metric could include reductions in evictions and eviction notices, reductions in mortgage defaults, reductions in energy cut-off notices, reductions in emergency room visits, improvements in nutrition, and increases in property values. Nationally, about five percent of households that got LIHEAP energy assistance at least once in a five year period lost their homes to eviction or mortgage default as a result of such financial stresses. About three-fourths move to homes of family members or friends; the rest become homeless or move to public shelters. These events have severe impacts on families; what is less recognized is that they have significant financial impacts on the rest of society. A Maryland evaluation estimated that the costs of added emergency room visits and public shelter at $28,000 per homelessness event.[249] The benefits of preventing such outcomes have also been studied. The Baltimore Green and Healthy Homes Initiative found a wide range of non-energy benefits from a holistic approach to retrofitting homes. In addition to benefits for individual households, there were also neighborhood benefits in the form of a reduction in abandoned housing.[250]

249 Makhijani, A., Mills, C., and Makhijani, A. (2015, October). Energy Justice in Maryland's Residential and Renewable Energy Sectors. A Report of the Renewable Maryland Project. Institute for Energy and Environmental Research, pp. 87-90.https://ieer.org/resource/books/energy-justice-maryland-book/

250 Ibid., p. 68

3.7 Conclusions and Key Recommendations

Our analysis suggests that a wide array of policies and programs can help alleviate energy cost burdens. The central steps we identify to achieve energy cost burden reductions are as follows:

1. Increase funding and enrollment efforts to expand the PIPP program to alleviate energy cost burdens for as many eligible households as possible. Decoupling LEAP and PIPP enrollment and introducing self-attestation of income in PIPP would likely greatly increase enrollment.
2. Provide weatherization and electrification grants to the lowest-income households at or below 50 percent of the Federal Poverty Level.
3. Use funds from the CCEF to finance weatherization and electrification for other low-to-moderate income households, with loans paid through on-bill financing.
4. Expand community solar gardens to provide electricity at discounted rates for low- and moderate-income households.
5. Support the adoption of smart appliances and expand demand response to provide additional energy cost benefits to residential households.
6. Adjust PIPP and other energy assistance programs over time as the other measures reduce overall energy cost burdens. Some assistance will likely continue to be needed for the lowest income households (well under 50 percent of Federal Poverty Level). High or near-universal enrollment in PIPP could allow other modifications to assistance, such as changing arrearage management to emergency situations.
7. Stop the expansion of gas infrastructure to areas that do not have it. Give priority to those areas for weatherization and upgrading of electricity distribution infrastructure where needed to accommodate electrification of heating. In this context, priority should also be given to conversion of propane heating to efficient electric systems.

A number of enabling measures can help ensure that these energy assistance and investment efforts are effective. A few of these include:

1. Capitalize the CCEF adequately.
2. Build out local infrastructure, including trained auditors and retrofit contractors to do weatherization on a much larger scale. In the rural areas, where this would be the most difficult, support efforts to expand capacity by co-ops (both distribution co-ops and generation and transmission co-ops).
3. Build out rural broadband infrastructure to enable demand response participation, among numerous other benefits.
4. Conduct ongoing community outreach to improve program enrollment and design.

Additional considerations and prioritization strategies include:

1. Prioritize areas with propane heating, especially those with high electricity rates, for weatherization, community solar gardens, and electrification; community solar gardens should accompany electrification in high rate areas, except when geothermal heat pumps are installed.
2. Prioritize community solar gardens in urban areas to reduce electricity bills with efficient electrification and weatherization done simultaneously.
3. Set net-zero electricity and all-electric construction standards for new homes, with rooftop solar fulfilling all requirements for detached single family homes and allowance for a combined rooftop and dedicated community solar garden for the rest. This will prevent gas from being used in new homes and unnecessary emissions during the period when the grid is a mix of renewable and non-renewable energy sources. Complementary policies could include building in resilience with storage and microgrids in new housing developments.
4. Evaluate a discounted electricity rate model with self-certification of income as an alternative, or supplement, to PIPP to increase participation rapidly in a manner that also would be simpler for utilities to implement.
5. Extend net-metering indefinitely to low- and moderate-income households.
6. In some cases, provide added incentives for conversion to electric heating for homes that have no air-conditioning at present.
7. Implement pilot projects that include seasonal thermal storage, including community seasonal thermal storage, especially in the coldest climate zones are needed to design for resilience and management of winter peaks as electrification of heating is increased.
8. Develop options for co-ops with high rates to reduce them with more local renewable installations without the penalties of exiting current contracts with suppliers.
9. Have the CCEF create a loan loss reserve for low- and moderate-income community solar garden subscribers.
10. Explore avenues for Tri-State and distribution co-ops to overcome legacy contracts that derive largely from coal generation to increase community solar and utility scale solar (and possible wind), especially in areas with high rates. One potential approach would be to carve out portions of utility scale solar and wind and dedicate them as virtually net metered community renewable supply in areas with high retail electric rates and relatively low populations. Increasing behind-the-meter solar is another possible option, since that generation is not included in the ceiling on non-Tri-State electricity procurement so long as it does not exceed the annual load of the home or business.

APPENDIX

1. Estimation of Tract Scale Median Energy Cost Burdens

To estimate the amount of energy used for a typical home within a census tract shown in **Section 2**, we use a linear regression model that simultaneously approximates energy consumption by fuel type (propane, gas, electricity, and wood) and end use (space heating, space cooling, water heating, and appliances) given properties of a house and its demographics. Specifically, we generate these estimates using previously developed models[251,252] with a combination of updated data from the 2015 Residential Energy Consumption Survey (RECS),[253] 2015-2019 American Community Survey (ACS) tract scale demographics,[254] climate data,[255] and utility price data.[256] For more details, see Krieger et al. (2020).[257]

2. Estimation of Household Properties and Energy Expenditures

In order to understand how policy will affect energy cost for low-income households, we extend upon the method used in **Section 2** to generate median tract energy cost burdens by simulating a portfolio of all the households within these tracts and their energy costs across Colorado. These numbers were used for analysis in **Section 3** as well as **Figure 2.20**. We used a combination of the same data listed above and then followed a three-step process.

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251 Min, J., Hausfather, Z., and Lin, Q. F. (2010). A High-Resolution Statistical Model of Residential Energy End Use Characteristics for the United States. *Journal of Industrial Ecology, 14*(5), 791-807.

252 Jones, C., and Kammen, D. M. (2014). Spatial Distribution of US Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density. *Environmental Science & Technology, 48*(2), 895-902.

253 U.S. Energy Information Administration. "Residential Energy Consumption Survey 2015." Available at: www.eia.gov/consumption/residential/data/2015/

254 U.S. Census Bureau. "TIGER/Line FTP Archive: 2019 ACS." Accessed: October 2021.

255 Menne, M.J., I. Durre, B. Korzeniewski, S. McNeal, K. Thomas, X. Yin, S. Anthony, R. Ray, R.S. Vose, B.E.Gleason, and T.G. Houston (2012). Global Historical Climatology Network–Daily (GHCN-Daily), Version 3. Accessed: October 2021.

256 U.S. Energy Information Administration. (2020). "Residential Sector Energy Price and Expenditure Estimates, 1970-2018, Colorado." https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_prices/res/pr_res_CO.html&sid=CO

257 Krieger, E. M., Lukanov, B., McPhail, A., Smith, A., and Dillon, A. (2020). Equity-Focused Climate Strategies for Colorado. PSE Healthy Energy. www.psehealthyenergy.org/wp-content/uploads/2020/12/Equity-Focused-Climate-Strategies-for-Colorado-Report.pdf

The first step is to use an integer programming method for each census tract to sample households from the RECS survey data constrained to match the following population count breakdowns from the ACS data:

- Number of household members;
- Type of fuel used for heating;
- Household income bracket;
- Type of home (mobile, single-unit attached, single-unit detached, apartment within a building with two to four units, apartment within a building with five or more units);
- Urban/rural designation.

Importantly, the resulting simulated portfolio of Colorado households preserves relationships between these household properties and allows for the investigation of energy cost burdens across income groups, heating fuel types, and home types. We additionally merge this portfolio with the number of heating and cooling degree days and other demographic averages from the ACS census data.

The second step is to build a predictive model of the amount of energy used for each household by energy type (gas, electricity, propane, and wood) and for different energy uses (space heating, space cooling, water heating, and appliances). We build this model using data from the RECS survey in a manner similar to that of the linear model used for tract scale estimates in Section 2 with one significant difference: instead of using linear regression to estimate the household energy consumption, we use random forest regression since we find that it is less sensitive to extrapolation errors and can more easily accommodate additional household data without concerns of over-fitting.

The final step is to apply the energy estimation regression to the portfolio of simulated households within Colorado in order to estimate energy use by energy type for each household. We then merge these estimates with local energy price data and calculate the approximate energy expenditures for each household. This portfolio of households and the energy expenditures were then used to calculate how income dependent policies would affect each simulated household and thus provide estimates of the cumulative funds needed to implement various policy alternatives and how they would impact energy bills for a given household in Colorado.

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