# Air Quality and Health Impacts of Public Service's Clean Heat Plan

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## About PSE Healthy Energy

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## About the Authors

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## 1. Introduction

Regulatory decision-making around residential and commercial energy use holds implications for the indoor and outdoor environment, climate, air quality, and public health. Gas appliances directly emit health-damaging air pollutants, such as nitrogen oxides ($NO_x$), fine particulate matter ($PM_{2.5}$), and benzene, that have the potential to impact air quality indoors, particularly if they are vented inside (e.g., stoves, space heaters). Pollutants emitted from gas appliances located inside or adjacent to primary living spaces (e.g., water heaters, heat pumps) are ultimately transported to the outdoor environment and widespread use of these appliances can impact local and regional air pollution and may lead to secondary pollutant formation (e.g., $PM_{2.5}$, ozone ($O_3$)).

There are also lifecycle emissions associated with the use of gas appliances. Research has shown that methane, a potent greenhouse gas, leaks throughout the natural gas supply chain and that air pollutants are nearly always emitted with methane.[1] Direct use of gas appliances and lifecycle emissions from appliance use are associated with both Criteria[2] or Hazardous[3] Air Pollutants that have been identified by the U.S. Environmental Protection Agency (EPA) as being harmful to human health. When inhaled, these air pollutants can cause a range of negative health impacts including increased risk of cancer and non-cancer chronic and acute health effects that may impact the respiratory, cardiovascular, and neurological systems. Some Criteria Air Pollutants, such as $PM_{2.5}$ and $O_3$, are linked to premature mortality for those with preexisting cardiovascular or respiratory conditions.[4]

Public Service, a natural gas and electric utility company in Colorado, submitted its Clean Heat Plan to the Colorado Public Utility Commission (CPUC) in August 2023 in response to Senate Bill (SB) 21-264. This bill requires that gas distribution utilities submit a plan for reducing greenhouse gas emissions by 4 percent by 2025 and 22 percent by 2030, relative to 2015 levels.[5] Public Service's Clean Heat Plan spans 2024-2030 and provides a proposal for

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[1] Michanowicz, D. R., Lebel, E. D., Domen, J. K., Hill, L. L., Jaeger, J. M., Schiff, J. E., ... & Shonkoff, S. B.C. (2021). Methane and Health Damaging Air Pollutants from the Oil and Gas Sector: Bridging 10 Years of Scientific Understanding. *PSE Healthy Energy*, provided as Attachment KB-2.
[2] United States Environmental Protection Agency (USEPA). (2023, November 30). Criteria Air Pollutants.
[3] USEPA. (2023, November 9). Hazardous Air Pollutants.
[4] Murray, C. J., Aravkin, A. Y., Zheng, P., Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M., ... & Borzouei, S. (2020). Global Burden of 87 Risk Factors in 204 Countries and Territories, 1990–2019: A Systematic Analysis for the Global Burden of Disease Study 2019. *The Lancet*, *396*(10258), 1223-1249.
[5] Colorado General Assembly. SB21-264 Adopt Programs Reduce Greenhouse Gas Emissions Utilities. Retrieved in January 2024.

how Public Service will meet residential and commercial energy needs across its service territory.

In 2021, the EPA estimated that 30 percent of greenhouse gas emissions in the U.S. came from the commercial and residential sectors when considering electricity end use.[6] Colorado residents are more likely to use natural gas as compared to the average U.S. household; 76 percent of Coloradoans use natural gas as their main space heating fuel compared to 51 percent nationally; 10 percent of homes are all-electric in Colorado compared to 25 percent nationally.[7]

Senate Bill 21-264 includes a number of elements that are relevant to air quality, health, and environmental justice. Specifically, § 40-3.2-108(6)(d)(I) requires that the Commission, in evaluating a clean heat plan, take into account: "the additional air quality, environmental, and health benefits of the plan in addition to the greenhouse gas emission reductions," and "whether investments in a clean heat plan prioritize serving customers participating in income-qualified programs and communities historically impacted by air pollution and other energy-related pollution."[8]

In this report, we examine the air quality, public health, and equity dimensions of Public Service's Clean Heat Plan. In **Section 2**, we provide a brief overview of the scientific literature on residential gas appliances and their implications on indoor air quality and health. In **Section 3**, we analyze the demographics of populations living within Public Service's gas service territory and identify the health and environmental exposure disparities within the territory. In **Section 4**, we compare the air quality and $PM_{2.5}$ health impacts of Public Service's Amended Preferred Portfolio and WRA's Pollution-Free Buildings Portfolio. For each of the above sections, we outline the relevant methodologies used. Finally, in **Section 5**, we provide our conclusions and recommendations.

## 2. Air Quality and Health Impacts of Residential Gas Appliances

The air quality impacts of gas appliances can stem from (1) gas appliance leaks that release small amounts of unburned gas that contain Hazardous Air Pollutants (e.g., benzene, toluene,

[6] USEPA. (2023, November 16). Sources of Greenhouse Gas Emissions.
[7] United States Energy Information Administration (EIA). (2023, August 10). 2020 Residential Energy Consumption Survey Dashboard.
[8] Col. Rev. Stat. § 40-3.2-108

and hexane)[9] or (2) from combustion or incomplete combustion of gas when the appliances are used (e.g., $PM_{2.5}$, $NO_x$, benzene and other $O_3$ precursors).[10] Air pollution from gas appliances can impact indoor air quality if they are vented indoors and ultimately impact outdoor air quality when the air pollutants from the appliances are actively or passively vented into the atmosphere.

The gas delivery system that powers these appliances also has the potential to leak throughout the gas supply chain from production to processing and distribution. While the majority of research is focused on methane emissions[11] resulting from these leaks, there is also strong evidence that these leaks contain Hazardous Air Pollutants, which impact outdoor air quality and have the potential to impact human health.[12,13,14] Depending on the local atmospheric conditions, volatile organic compounds (VOCs) from these leaks also have the potential to form secondary air pollutants such as $PM_{2.5}$ and $O_3$.[15]

Below, we summarize the available research on the air quality and health implications of residential gas appliances. Our summary below builds on a national-scale literature review we conducted in 2022 on the impacts of residential energy use on indoor air quality and health.[16] We further extend this work by incorporating literature that has been published since our initial review.

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[9] Lebel, E. D., Michanowicz, D. R., Bilsback, K. R., Hill, L. A. L., Goldman, J. S., Domen, J. K., ... & Shonkoff, S. B. (2022b). Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California. *Environmental Science & Technology*, *56*(22), 15828-15838, provided as Attachment KB-3.

[10] Kashtan, Y. S., Nicholson, M., Finnegan, C., Ouyang, Z., Lebel, E. D., Michanowicz, D. R., ... & Jackson, R. B. (2023). Gas and Propane Combustion from Stoves Emits Benzene and Increases Indoor Air Pollution. *Environmental Science & Technology, 57,* 9653-9663, provided as Attachment KB-4.

[11] Sargent, M. R., Floerchinger, C., McKain, K., Budney, J., Gottlieb, E. W., Hutyra, L. R., ... & Wofsy, S. C. (2021). Majority of US Urban Natural Gas Emissions Unaccounted for in Inventories. *Proceedings of the National Academy of Sciences*, *118*(44), e2105804118.

[12] Lebel et al., 2022b.

[13] Michanowicz, D. R., Dayalu, A., Nordgaard, C. L., Buonocore, J. J., Fairchild, M. W., Ackley, R., ... & Spengler, J. D. (2022). Home is Where the Pipeline Ends: Characterization of Volatile Organic Compounds Present in Natural Gas at the Point of the Residential End User. *Environmental Science & Technology*, *56*(14), 10258-10268

[14] Nordgaard, C. L., Jaeger, J. M., Goldman, J. S. W., Shonkoff, S. B. C., & Michanowicz, D. R. (2022, October 3). Hazardous Air Pollutants in Transmission Pipeline Natural Gas: An Analytic Assessment. *Environmental Research Letters*, *17.* 104032.

[15] Seinfeld, J. H., & Pandis, S. N. (2016). *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*. John Wiley & Sons.

[16] Makhijani A., Kinkhabwala Y., Jaeger J., Bilsback, K., Hill L.L., Peltier, L., Lukanov, B., Krieger E. (2023, February) Energy Affordability in Maryland: Integrating Public Health, Equity, and Climate. *PSE Healthy Energy*, provided as Attachment KB-5.

## *2.1 Air Pollutants Associated with Gas Appliances*

The Clean Air Act was passed in 1970 to protect the public from air pollution. At the time, reducing smog was a priority for regulators, resulting in the designation of six Criteria Air Pollutants, pollutants that are regulated by the EPA by establishing the National Ambient Air Quality Standards.[17] These Criteria Air Pollutants include carbon monoxide (CO), $PM_{2.5}$, coarse particulate matter ($PM_{10}$), $NO_x$, sulfur dioxide ($SO_2$), $O_3$, and lead (Pb).[18] The Clean Air Act also required the EPA to regulate Hazardous Air Pollutants on a pollutant-by-pollutant basis, based on health risk.[19] Today, the list of Hazardous Air Pollutants includes 188 different pollutants with known adverse health effects, including risk of cancer, non-cancer chronic health impacts, and acute health impacts.[20]

Natural gas combustion, which is needed to power residential gas appliances, results in emissions of Criteria and Hazardous Air Pollutants.[21] Key pollutants associated with gas appliances include Criteria Air Pollutants such as $NO_x$, $PM_{2.5}$, $SO_2$, CO, and Hazardous Air Pollutants such as formaldehyde, benzene, and hexane.[22] Below, we list several health-damaging air pollutants that are (1) present in natural gas and therefore may impact human health when natural gas is leaked from appliances or distribution systems and/or (2) are a byproduct of natural gas combustion (incomplete or complete) and may impact human health when natural gas is burned. **Table 1** provides the source (natural gas leaks or natural gas combustion), classification (Criteria or Hazardous Air Pollutant), and a summary of the health effects of each pollutant.

**$NO_x$**, a group of highly reactive gases that are emitted as a byproduct of natural gas combustion. $NO_x$ include nitrogen dioxide ($NO_2$) and nitric oxide (NO), the latter of which oxidizes quickly to $NO_2$.[23] $NO_2$ is a respiratory irritant that, with short-term exposure, can aggravate pre-existing respiratory diseases like asthma and increased respiratory symptoms,

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[17] USEPA. (2013, March 22). *The Clean Air Act in a Nutshell: How It Works*.
[18] USEPA. (2023, March 15). *NAAQS Table.*
[19] USEPA. (2013, March 22). *The Clean Air Act in a Nutshell: How It Works*.
[20] USEPA. (2023, December 7). *Initial List of Hazardous Air Pollutants with Modifications.*
[21] USEPA. (1998). Chapter 1: External Combustion Sources, Section 1.4 Natural Gas Combustion. *AP-42: Compilation of Air Emissions Factors from Stationary Sources* (5th ed., Volume I).
[22] USEPA. (1998). Chapter 1: External Combustion Sources, Section 1.4 Natural Gas Combustion. *AP-42: Compilation of Air Emissions Factors from Stationary Sources* (5th ed., Volume I).
[23] Singer, B. C., Pass, R. Z., Delp, W. W., Lorenzetti, D. M., Maddalena, R. L. (2017). Pollutant Concentrations and Emission Rates from Natural Gas Cooking Burners without and with Range Hood Exhaust in Nine California Homes. *Building and Environment, 122*, 215-229.

emergency department visits, and hospital admissions.[24] Long-term exposure to $NO_2$ may contribute to the development of asthma.[25] Studies have found that prenatal exposure to $NO_x$ can increase the risk of low birth weight[26] and reduced fetal growth,[27] and increase the risk of preterm births.[28]

**$PM_{2.5}$**, or particulate matter with a diameter of 2.5 microns or less, can be composed of small droplets of liquid, dry solid fragments, or solid cores with liquid coatings.[29] Inhalation of $PM_{2.5}$ can impact heart and lung function. Short-term exposure is associated with premature mortality, increased respiratory symptoms (coughing, shortness of breath), aggravated asthma, and increased hospital admissions and emergency room visits.[30] Long-term exposure is associated with premature death in people with pre-existing heart and lung diseases and reduced lung function growth in children.[31]

**$SO_2$** is known to cause short-term adverse health impacts to the respiratory system and can make breathing difficult and is the primary component of sulfur oxides ($SO_x$).[32] Under certain atmospheric conditions, $SO_x$ can also react with other compounds in the atmosphere to form $PM_{2.5}$ (discussed above). [33]

**CO** is a colorless, odorless, and tasteless gas that results from incomplete oxidation of carbon during natural gas combustion.[34] At low concentrations, CO exposure is associated with fatigue and chest pain; at high concentrations, exposure can lead to impaired vision and

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[24] USEPA. (2023, July 25). *Basic Information about NO2.*
[25] USEPA. (2023, July 25). *Basic Information about NO2.*
[26] Mendoza-Ramirez, J., Barraza-Villarreal, A., Hernandez-Cadena, L., Hinojosa de la Garza, O… & Romieu, I. (2018). Prenatal Exposure to Nitrogen Oxides and its Association with Birth Weight in a Cohort of Mexican Newborns from Morelos, Mexico. *Annals of global health, 84*(2), 274–280.
[27] Iñiguez, C., Esplugues, A., Sunyer, J., Basterrechea, M., Fernández-Somoano, A., Costa, O… & INMA Project (2016). Prenatal Exposure to NO2 and Ultrasound Measures of Fetal Growth in the Spanish INMA Cohort. *Environmental health perspectives*, *124*(2), 235–242.
[28] Mendola, P., Wallace, M., Hwang, B. S., Liu, D., Robledo, C., Männistö, T., Sundaram, R., Sherman, S., Ying, Q., & Grantz, K. L. (2016). Preterm Birth and Air Pollution: Critical Windows of Exposure for Women with Asthma. *Journal of Allergy and Clinical Immunology*, 138(2), 432-440.
[29] California Air Resources Boards (CARB). *Inhalable Particulate Matter and Health (PM2.5 and PM10).*
[30] CARB. *Inhalable Particulate Matter and Health (PM2.5 and PM10).* Retrieved January 2024.
[31] CARB. *Inhalable Particulate Matter and Health (PM2.5 and PM10).* Retrieved January 2024.
[32] USEPA. (2023, February 16). *Sulfur Dioxide Basics.*
[33] USEPA. (2023, February 16). *Sulfur Dioxide Basics.*
[34] USEPA. (2023, December 11). *What is carbon monoxide?*

coordination, nausea, dizziness, and can limit oxygen uptake, which can be fatal.[35] Prenatal exposure to CO may harm a child's mental development and can lead to miscarriages.[36]

**Formaldehyde** is a known human carcinogen.[37] Acute exposure can result in eye, skin, and respiratory irritation.[38] Long-term exposure is associated with adverse non-cancer effects on the respiratory system.[39]

**Benzene** is also a known human carcinogen.[40] Acute exposure can result in adverse non-cancer effects on the reproductive, development, immune, and hematologic (blood) systems.[41] Long-term exposure is associated with adverse non-cancer effects on the nervous and hematologic systems.[42] Benzene is known to be present in unburned gas, which has impacts on indoor and outdoor air quality as gas can leak unburned in buildings and from gas infrastructure outdoors.[43] Benzene is also emitted as a byproduct of combustion during typical operation of a gas appliances.[44]

**Hexane** is a Hazardous Air Pollutant known to be present in unburned natural gas[45] and may be formed as a byproduct of natural gas combustion. Inhalation of hexane can cause mild central nervous system symptoms (dizziness, nausea, headache, etc.) after a short-term exposure and polyneuropathy after long-term exposure, causing numbness in extremities, muscular weakness, blurred vision, and headache.[46]

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[35] USEPA. (2023, December 11). *What is carbon monoxide?*
[36] Agency for Toxic Substances and Disease Registry (ATSDR). (2012). *Toxicological Profile for Carbon Monoxide*.
[37] Office of Environmental Health Hazard Assessment (OEHHA). *Formaldehyde*. Retrieved January 2024.
[38] National Institute for Occupational Safety and Health (NIOSH). (2019, June 21). *Formaldehyde.*
[39] OEHHA. *Formaldehyde*. Retrieved January 2024.
[40] USEPA. (2016, September). *Benzene.*
[41] OEHHA. *Benzene.* Retrieved January 2024.
[42] OEHHA. *Benzene.* Retrieved January 2024.
[43] Lebel, et al., 2022b
[44] Kashtan, et al., 2023
[45] Lebel, et al., 2022b
[46] USEPA. (2016, September). *Hexane.*

**Table 1:** Selected list of air pollutants with documented emissions from residential natural gas combustion appliances and their associated adverse health effects.[47]

| Pollutant(s) | Description | Adverse Health Effects |
|---|---|---|
| **Nitrogen oxides ($NO_x$)** | **Phase:** Gas<br><br>**Type:** Criteria Air Pollutant<br><br>**Source:** Byproduct of natural gas combustion | • Aggravated asthma, resulting in increased respiratory symptoms, emergency department visits, & hospital admissions[48]<br>• $NO_2$ may contribute to the development of asthma (chronic)<br>• $NO_x$ increases risk of low birth weight, with potential lifelong adverse health implications[49]<br>• $NO_x$ exposure 3 months before & first 7 weeks of pregnancy increases risk of preterm births, more so for women with asthma[50] |
| **Fine particulate matter ($PM_{2.5}$)** | **Type:** Criteria Air Pollutant<br><br>**Source:** Byproduct of natural gas combustion | • Premature death in people with pre-existing heart and lung disease[51]<br>• Nonfatal heart attacks<br>• Irregular heartbeat<br>• Low birth weight[52]<br>• Increased respiratory symptoms (coughing, shortness of breath)[53]<br>• Aggravated asthma<br>• Decreased lung function |
| **Sulfur dioxide ($SO_2$)** | **Type:** Criteria Air Pollutant<br><br>**Source:** Byproduct of natural gas combustion | • Aggravated asthma[54]<br>• Increased respiratory symptoms (nasal mucus, choking, cough, and reflex bronchi constriction)[55]<br>• Irritation to the eyes, nose and throat |
| **Carbon monoxide (CO)** | **Type:** Criteria Air Pollutant<br><br>**Source:** Byproduct of natural gas combustion | • Fatigue and chest pain (low concentrations)[56]<br>• During pregnancy may impact child mental development and cause miscarriages[57]<br>• Impaired vision & coordination, nausea, dizziness[58]<br>• Fatal at high concentrations |
| **Formaldehyde** | **Type:** Hazardous Air Pollutant | • Carcinogenic effects[59]<br>• Eye, nose, and respiratory irritation (acute)[60] |

[47] Adapted from: Makhijani, et al., 2023
[48] USEPA. (2023, July 25). *Basic Information about NO2.*
[49] Mendoza-Ramirez, et al., 2018
[50] Mendola, et al., 2016
[51] USEPA. (2023, August 23). *Health and Environmental Effects of Particulate Matter (PM).*
[52] Fong, K. C., Kosheleva, A., Kloog, I., Koutrakis, P., Laden, F., Coull, B. A., & Schwartz, J. D. (2019). Fine Particulate Air Pollution and Birthweight: Differences in Associations Along the Birthweight Distribution. *Epidemiology (Cambridge, Mass.)*, 30(5), 617–623.
[53] USEPA. (2023, August 23). *Health and Environmental Effects of Particulate Matter (PM).*
[54] USEPA. (2023, February 16). *Sulfur Dioxide Basics.*
[55] NIOSH. (2019, June 21). *Sulfur Dioxide*. Centers for Disease Control and Prevention.
[56] USEPA. (2023, December 11). *What is carbon monoxide?*
[57] ATSDR. (2012). *Toxicological Profile for Carbon Monoxide*.
[58] USEPA. (2023, December 11). *What is carbon monoxide?*
[59] OEHHA. *Formaldehyde*. Retrieved January 2024.
[60] USEPA. (2016, September). *Formaldehyde*.

| | | |
|---|---|---|
| **($CH_2O$)** | **Source:** Byproduct of natural gas combustion | • Adverse non-cancer effects to respiratory system (chronic)[61] |
| **Benzene ($C_6H_6$)** | **Type:** Hazardous Air Pollutant<br><br>**Source:** Present in natural gas and a byproduct of combustion. | • Carcinogenic effects[62]<br>• Adverse non-cancer effects on reproduction/development, immune, & hematologic systems (acute)<br>• Adverse non-cancer effects on development, nervous, & hematologic systems (chronic) |
| **Hexane ($C_6H_{14}$)** | **Type:** Hazardous Air Pollutant<br><br>**Source:** Present in natural gas and a byproduct of combustion. | • Mild central nervous system depression (dizziness, giddiness, slight nausea, headache (acute)[63]<br>• Dermatitis and irritation of the eyes and throat (acute)<br>• Sensory polyneuropathy (numbness in extremities, muscular weakness, blurred vision, headache, and fatigue (chronic) |

## *2.2 Indoor Air Quality and Health Impacts of Heating Appliances*

Most studies, to our knowledge, that measured the indoor air quality impacts of gas heating appliances examined unvented gas fireplaces, which release natural gas combustion byproducts directly into living areas. These studies found elevated indoor levels of a range of health-damaging air pollutants. One study of two homes in Boulder, Colorado, found elevated indoor levels of CO, $NO_2$, and total polycyclic aromatic hydrocarbons (PAHs) when an unvented fireplace was used.[64] In an Illinois-based study that monitored air pollutants in 30 homes with unvented fireplaces, researchers found that $NO_2$ levels exceeded the one-hour World Health Organization (WHO) threshold (110 parts per billion [ppb]) in 80 percent of the homes studied and that CO levels exceeded the eight-hour EPA NAAQS guideline (9 parts per million [ppm]) in 20 percent of the homes studied.[65] A California study found that the presence of pilot burners (in stoves or space heaters) led to worse indoor air quality than appliances without pilot burners and that exterior-venting appliances had less indoor air pollution compared to appliances that vented inside the home.[66] Finally, a study of Navajo homes in the southwestern United States found elevated levels of CO in some homes that

[61] OEHHA. *Formaldehyde*. Retrieved January 2024.
[62] OEHHA. *Benzene.* Retrieved January 2024.
[63] USEPA. (2016, September). *Hexane.*
[64] Dutton, S. J., Hannigan, M. P., & Miller, S. L. (2001). Indoor Pollutant Levels from the Use of Unvented Natural Gas Fireplaces in Boulder, Colorado. *Journal of the Air & Waste Management Association,* 51:12, 1654-1661.
[65] Francisco, P. W., Gordon, J. R., & Rose, B. (2010). Measured Concentrations of Combustion Gases from the Use of Unvented Gas Fireplaces. *Indoor Air. 20*(5). 370-379.
[66] Mullen, N. A., Li, J., Russell, M. L., Spears, M., Less, B. D., & Singer, B. C. (2016). Results of the California Healthy Homes Indoor Air Quality Study of 2011-2013: Impact of Natural Gas Appliances on Air Pollutant Concentrations. *Indoor Air, 26*(2), 231–245, provided as Attachment KB-6.

used natural gas or propane as a primary heating fuel but did not find exceedances of WHO's one-hour or eight-hour guidelines.[67]

### *2.3 Indoor Air Quality and Health Impacts of Cooking Appliances*

Residential natural gas cooking appliances tend to use less gas and, therefore, emit fewer total greenhouse gases per year, compared to heating appliances.[68] However, natural gas stoves, ranges, and burners typically pose a greater indoor health risk because—like unvented gas heaters (**Section 2.2.1**)—they are vented directly into people's homes and are not required to have a vent that exhausts the combustion byproducts outside. The user is also more likely to be near the appliance during operation and therefore more likely to breathe in the combustion byproducts. In contrast, properly vented natural gas furnaces and water heaters vent more of the combustion byproducts outside the home, if properly installed and maintained.

Measurements from several studies show that cooking with natural gas increases $NO_x$, $PM_{2.5}$, formaldehyde, and benzene in indoor air concentrations above health-based reference air concentrations, in some cases even with the operation of the exhaust hood.[69,70,71,72] One modeling study found that natural gas cooking burner emissions in California homes without ventilation may lead to $NO_2$, CO, and formaldehyde concentrations during cooking that exceed the acute national and state health-based standards.[73] Another study focused on natural gas cooking burner usage in households in Northern California, where researchers at Lawrence Berkeley National Laboratory observed that indoor $NO_2$ concentrations in nearly half of homes exceeded the one-hour NAAQS (100 ppb $NO_2$) during operation of the burners with venting range hoods; although, range hood use substantially reduced indoor cooking pollutant concentrations.[74] A recent study measuring air pollutant concentrations in homes

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[67] Casey, J. G., Ortega, J., Coffey, E., & Hannigan, M. (2018). Low-Cost Measurement Techniques to Characterize the Influence of Home Heating Fuel on Carbon Monoxide in Navajo Homes. *Science of the Total Environment, 625*. 608-615.

[68] United States Energy Information Administration (EIA). (2023, August 10). 2020 Residential Energy Consumption Survey Dashboard.

[69] Mullen et al., 2015

[70] Singer et al., 2017

[71] Kashtan et al., 2023

[72] Lebel, E. D., Finnegan, C. J., Ouyang, Z., & Jackson, R. B. (2022a). Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science & Technology, 56*(4). 2529-2539.

[73] Logue, J. M., Klepeis, N. E., Lobscheid, A. B., & Singer, B. C. (2014). Pollutant Exposures from Natural Gas Cooking Burners: A Simulation-Based Assessment for Southern California. *Environmental Health Perspectives, 122*(1), 43-50.

[74] Singer et al., 2017

with gas stoves found that indoor concentrations of $NO_x$ were correlated with the amount of natural gas burned during stove usage. Additionally, the authors found that the one-hour NAAQS for $NO_2$ (100 ppb) can be exceeded within a few minutes of stove usage, particularly in small kitchens with poor ventilation.[75] Another recent study found that gas stoves also emit benzene while in use and in some cases indoor concentrations of benzene could be comparable to secondhand smoke. Electric resistance stoves with coil burners, meanwhile, emitted approximately 10 times less benzene than gas and no benzene emissions were detected from electric induction stoves.[76]

Several studies[77] have linked gas stove use to elevated levels of risk for instances of asthma and pneumonia as well as risk of respiratory symptoms (e.g., cough, wheezing).[78] For example, a recent meta-analysis that analyzed the health risk of gas stoves linked 12.7 percent of childhood asthma cases in the United States to gas stove use.[79] Additionally, an extensive health study that evaluated >3,000 data points on respiratory symptoms of children under five years old from the National Health and Nutrition Examination Survey (1988–1994) found that children who lived in homes where gas stoves were used for heat (i.e., an auxiliary use) without ventilation had an increased risk of pneumonia and cough compared to children who lived in homes where gas was only used for cooking.[80]

Evidence using measurements[81] and models[82] suggests that using cooking appliance ventilation hoods can lower pollutants like CO and $NO_x$. However, ventilation hoods are often not routinely used during cooking.[83] Ventilation hoods are particularly important in newer building stock, if gas appliances as used, as new residences are becoming more air-tight and energy efficient than older buildings.

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[75] Lebel et al., 2022a
[76] Kashtan et al., 2023
[77] Paulin, L. M., Samet, J. M., & Rice, M. B. (2023). Gas Stoves and Respiratory Health: Decades of Data, but Not Enough Progress. *Annals of the American Thoracic Society*, *20*(12), 1697-1699.
[78] Lin, W., Brunekreef, B., & Gehring, U. (2013). Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children. *International journal of epidemiology*, *42*(6), 1724-1737.
[79] Gruenwald, T., Seals, B A., Knibbs, L. D., & Hosgood III, H. D. (2023). Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States. *International Journal of Environmental Research and Public Health, 20*(1), 75.
[80] Coker, E. S., Smit, E., Harding, A. K., Molitor, J., & Kile, M. L. (2015). A Cross Sectional Analysis of Behaviors Related to Operating Gas Stoves and Pneumonia in U.S. Children Under the Age of 5. *BMC Public Health, 15*(1), 1-10.
[81] Mullen et al., 2015
[82] Louge et al., 2014
[83] Zhao, H., Chan, W. R., Delp, W. W., Tang, H., Walker, I. S., & Singer, B. C. (2020). Factors Impacting Range Hood Use in California Houses and Low-Income Apartments. *International Journal of Environmental Research and Public Health, 17*(23), 8870.

### *2.4 Indoor Air Quality and Health Impacts of Energy Efficiency Measures*

Energy efficiency retrofit programs often rely on energy efficiency measures including weatherization, which is defined as limiting unintended air and heat exchange between the indoor and outdoor environments, to reduce wasteful energy usage.[84] Weatherization is achieved by implementing measures such as sealing ducts, caulking cracks, replacing leaky windows, and increasing insulation.

While energy efficiency reduces greenhouse gas emissions because less energy is needed for heating, if efficiency measures are not coupled with appliance electrification and/or maintained or increased ventilation rates, a more air-tight homes may degrade indoor air quality, due to the lower rates of natural infiltration of outdoor air. This could also be a health and safety issue for potential gas leaks inside a home—with fewer air changes per hour (ACH), gas leaks can more easily build up and become an explosive hazard quicker, and contaminants present in unburned gas will build up in the house sooner. For example, a recent study measured concentrations of pollutants present in unburned natural gas throughout California and found benzene in nearly every sample that was collected. By using an indoor air quality model, the study found that leaks of unburned natural gas from gas stoves when they are leaking (i.e., turned off) can lead to health-based guideline exceedances and indoor air concentrations of benzene that were similar to tobacco smoke.[85] Because people do not use their exhaust hoods while their stoves are not in operation, these pollutants may only be exhausted through natural ventilation; as homes become more energy efficient and natural ventilation rates decrease, the contribution of leaks of unburned gas become more relevant to overall indoor air concentrations.

The installation of mechanical ventilation systems can help offset the increased levels of indoor air pollution linked to airtight buildings and energy efficiency retrofits, so long as the residence is not located in areas with high levels of outdoor air pollution.[86] For example, when weatherization is accompanied by an ASHRAE residential ventilation standard, indoor air quality and health improve in homes, in particular when using the most recent ASHRAE

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[84] NASEM (National Academies of Sciences, Engineering, and Medicine. (2011). Climate Change, the Indoor Environment, and Health.
[85] Lebel et al., 2022b
[86] Wang, C., Wang, J., & Norbäck, D. (2022). A Systematic Review of Associations between Energy Use, Fuel Poverty, Energy Efficiency Improvements and Health. *International Journal of Environmental Research and Public Health, 19*(12), 7393.

standards.[87] Further, one study found that homes that included mechanical ventilation during weatherization retrofits incurred significantly lower formaldehyde concentrations, whereas homes that conducted weatherization without mechanical ventilation found increases in benzene and other toxics.[88] Beyond reducing air pollution from gas appliances, mechanical ventilation may also improve environmental quality more generally (e.g., relief from dampness and mold).[89]

While degraded indoor air pollution levels may be addressed by higher mechanical ventilation rates, the best way to reduce all risk of indoor air pollution associated with gas appliances is to couple energy efficiency and weatherization measures with appliance electrification, which eliminates the air pollution associated with gas appliance leaks and combustion altogether. While this does not eliminate the air pollution generated from substances being cooked, studies have found that electric and induction stoves reduce indoor air pollution relative to gas appliances.[90,91] Overall, the greatest indoor air pollution benefits can be achieved by eliminating appliances that vent directly into the living area (e.g., stoves, unvented heating appliances).

## 3. Demographics and Equity

Air pollution does not impact all people the same way. Certain populations are biologically more susceptible to air pollution, such as children (who breathe more air per body weight and whose brains and bodies are still developing), the elderly, and those with underlying health conditions (e.g., asthma).[92] Many studies have also shown the low-income communities and people of color experience more environmental burdens, e.g., higher air pollution levels, because these communities tend to be situated near more air pollution sources (e.g., traffic, industry).[93] Additionally, it has been shown that extrinsic social

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[87] Francisco, P. W., Jacobs, D. E., Targos, L., Dixon, S. L., Breysse, J., Rose, W., & Cali, S. (2017). Ventilation, Indoor Air Quality, and Health in Homes Undergoing Weatherization. *Indoor Air, 27*(2), 463–477.
[88] Du, L., Leivo, V., Prasauskas, T., Täubel, M., Martuzevicius, D., & Haverinen-Shaughnessy, U. (2019). Effects of Energy Retrofits on Indoor Air Quality in Multifamily Buildings. *Indoor Air, 29*(4), 686–697.
[89] Fisk, W. J., Singer, B. C., & Chan, W. R. (2020). Association of Residential Energy Efficiency Retrofits with Indoor Environmental Quality, Comfort, and Health: A Review of Empirical Data. *Building and Environment*, *180*, 107067.
[90] Kashtan et al., 2023
[91] Less, B., Mullen, N., Singer, B., & Walker, I. (2015). Indoor Air Quality in 24 California Residences Designed as High-Performance Homes. *Science and Technology for the Built Environment*, *21*(1), 14-24.
[92] USEPA. (2023, June). Research on Health Effects from Air Pollution.
[93] Tessum, C. W., Apte, J. S., Goodkind, A. L., Muller, N. Z., Mullins, K. A., Paolella, D. A., ... & Hill, J. D. (2019). Inequity in Consumption of Goods and Services Adds to Racial–Ethnic Disparities in Air Pollution Exposure.

vulnerability factors, such as race and income, may amplify risks from existing environmental hazards and contribute to health disparities.[94]

The Colorado EnviroScreen tool is an interactive mapping tool that identifies environmental inequities and health burdens across different demographics at the county, census tract, and census block group level to identify communities impacted by environmental injustice.[95] The tool uses population and environmental factors to calculate an EnviroScreen Score: a high EnviroScreen Score in a community means that that community is more likely to be affected by environmental health injustice. The EnviroScreen Score is comprised of a Health and Social Factors Score, which summarizes the area's prevalence of sensitive populations and demographics with social and economic vulnerabilities, and the Pollution & Climate Burden Score, which summarizes the area's exposure to environmental risks, proximity to hazardous sites, and vulnerability to extreme climate (see **Figure *1***). These scores are developed based on an area's relative ranking (percentile) of individual data indicators. The indicators are summarized by score component below:

1. **Sensitive Populations:** asthma hospitalization rate, cancer prevalence, diabetes prevalence, heart disease prevalence, life expectancy, low birth weight rate, mental health indicators, percent of the population over the age of 65, and percent of the population under the age of 5
2. **Demographics:** percent of people living with disabilities, housing cost burden, educational attainment, limited English proficiency, income, and race/ethnicity
3. **Environmental Exposure:** diesel particulate matter (DPM), traffic proximity, $O_3$, $PM_{2.5}$, air toxics, other pollutants, lead exposure risk, drinking water violations, and noise
4. **Environmental Effects:** proximity to mining, oil and gas, impaired surface waters, wastewater discharge facilities, Superfund sites, facilities that use hazardous chemicals, and hazardous waste facilities
5. **Climate Vulnerability:** risk of drought, flood, extreme heat, and wildfire

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*Proceedings of the National Academy of Sciences*, *116*(13), 6001-6006; Tessum, C. W., Paolella, D. A., Chambliss, S. E., Apte, J. S., Hill, J. D., Marshall, J. D. (2021). $PM_{2.5}$ Polluters Disproportionately and Systemically Affect People of Color in the United States. *Science Advances, 7*(18).

[94] Morello-Frosch, R., Zuk, M., Jerrett, M., Shamasunder, B., & Kyle, A. D. (2011). Understanding the Cumulative Impacts of Inequalities in Environmental Health: Implications for Policy. *Health Affairs (Project Hope)*, *30*(5), 879–887.

[95] Colorado Department of Public Health & Environment (CDPHE). (2023, May). *Colorado EnviroScreen v 1.0 Basic User Guide*, provided as Attachment KB-7.

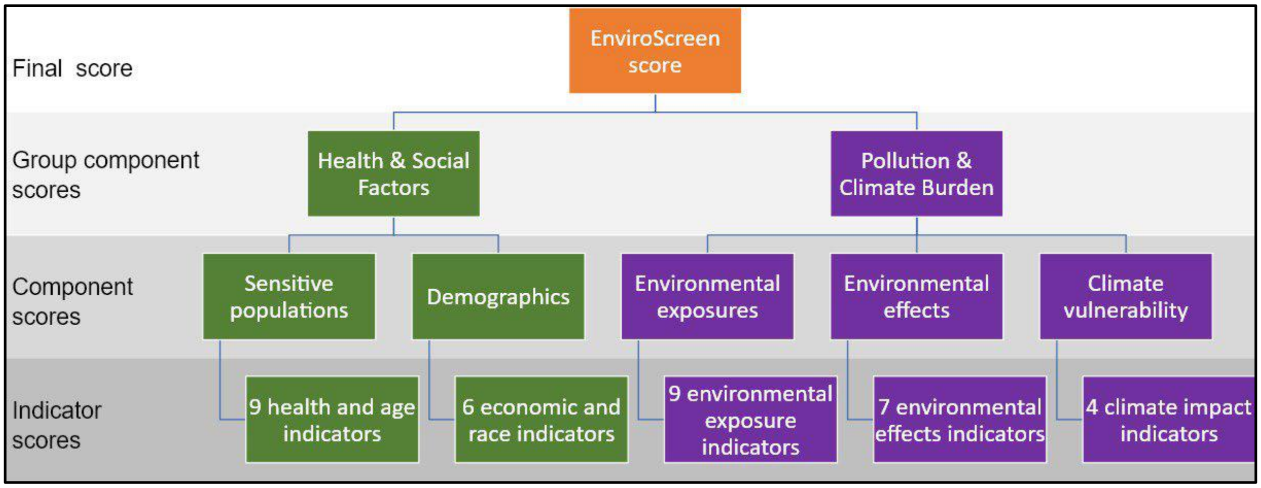


**Figure 1: Colorado EnviroScreen group score, component score, and indicator score breakdown.** This figure is reproduced from the Colorado EnviroScreen v 1.0 Basic User Guide.[96]

For this demographic and equity analysis, we focused on studying the cumulative environmental and health burdens, because these metrics are generally linked with natural gas residential appliance use; however, we note that not all data indicators included within these Colorado EnviroScreen scores are directly relevant to the specific health and equity concerns that arise from natural gas residential appliance use. As discussed in **Section 2.1**, natural gas combustion results in emissions of harmful contaminants like $NO_x$, which also serves as a precursor for $O_3$ formation, as well as $PM_{2.5}$ and Hazardous Air Pollutants like formaldehyde and benzene. These contaminants may aggravate asthma, contribute to cancer risk, increase risk of hospitalizations for people with heart disease, increase risk of low birth weight among newborns, and increase risk of premature mortality, particularly among those with preexisting cardiovascular or respiratory conditions (**Section 4**). As a result, this analysis focused on the EnviroScreen environmental exposure indicators for $O_3$, $PM_{2.5}$, air toxics and the EnviroScreen health indicators for asthma hospitalization rate, cancer prevalence, heart disease prevalence, low birth weight, and life expectancy. This analysis also focused on the EnviroScreen demographic indicators for people of color and low income.

To identify communities with elevated environmental justice concerns within the Public Service's service area, we analyzed the census block group percentiles for each indicator

[96] Colorado Department of Public Health & Environment (CDPHE). (2023, May). *Colorado EnviroScreen v 1.0 Basic User Guide*.

within the Public Service's natural gas service territory, as defined by the U.S. Department of Homeland Security.[97]

We found that nearly half of the population served by Public Service reside in a "Disproportionately Impacted Community" as defined by Colorado House Bill 23-1233.[98] This definition includes census blocks with an EnviroScreen Score percentile above 80 or where either 40 percent of the population are low-income, 50 percent of the households are housing cost-burdened, 40 percent of the population are people of color, or 20 percent of households are linguistically isolated. This definition also includes mobile home communities, Ute Mountain Ute and Southern Ute Reservations, and areas that qualify as disadvantaged in the federal Climate and Economic Justice Screening Tool.[99] Nearly a quarter of the population served by Public Service has an environmental exposure score at or above the 80th percentile. Exposure to environmental risks is driven by disproportionate $PM_{2.5}$ exposure; nearly 30 percent of residents in Public Service's service territory are at or above the 80th percentile for this indicator.

The environmental justice concerns within Public Service's service territory are concentrated in the Denver County, Adams County, and Arapahoe County area (**Figure *2***), where almost all census block tracts are considered Disproportionately Impacted Communities **(Figure *3*)**. Nearly half of the population in this area is at or above the 80th percentile for environmental exposure **(Figure *4*)**: around 65 percent are at or above the 80th percentile for exposure to $PM_{2.5}$, and around 50 percent are at or above the 80th percentile for exposure to air toxics, such as formaldehyde and benzene.

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[97] U.S. Department of Homeland Security. (2022). *Natural Gas Service Territory* [Shapefile]. Homeland Infrastructure Foundation-Level Data (HIFLD) Open Data.
[98] CO HB 23-1233. (2023, May 23).
[99] White House Council on Environmental Quality. (2022). *Climate and Economic Justice Screening Tool* (Version 1.0).

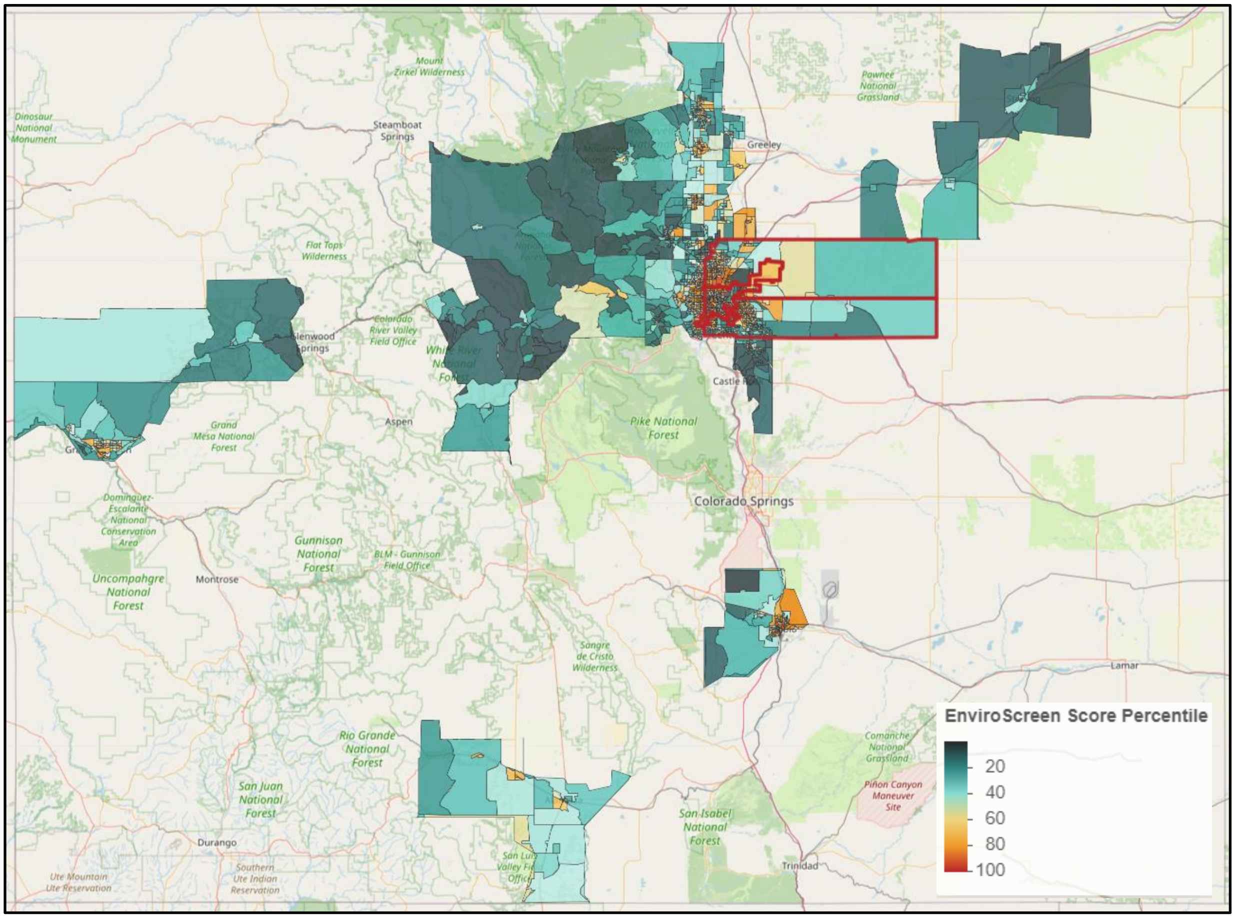
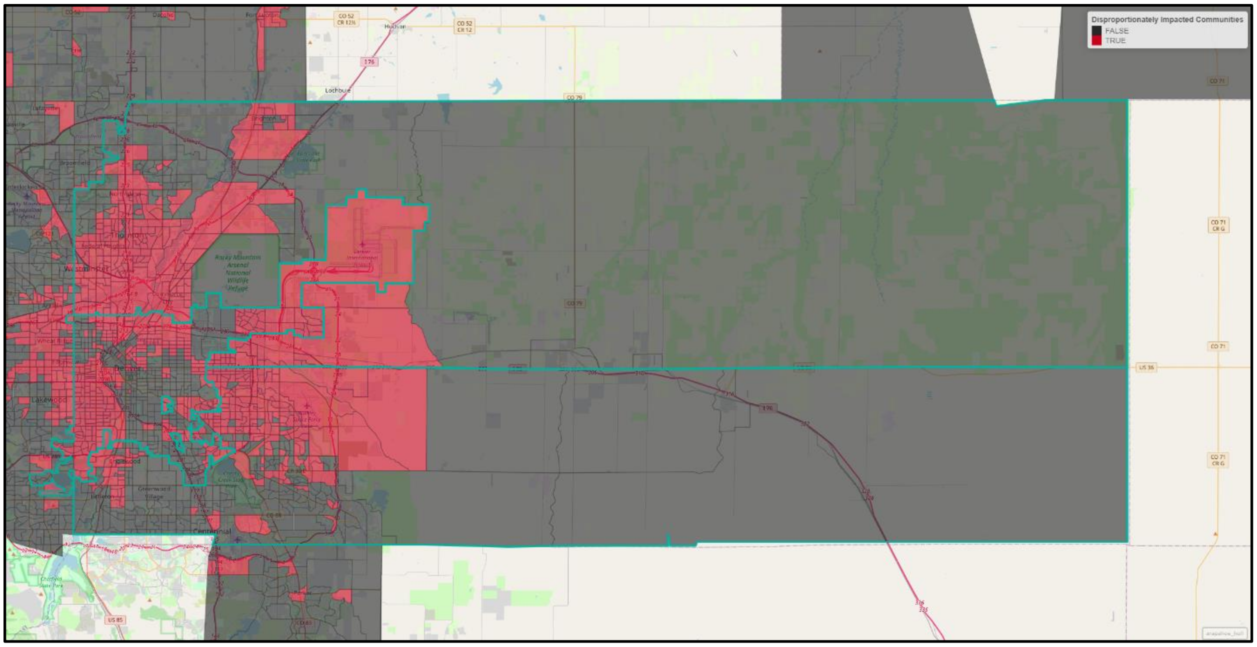
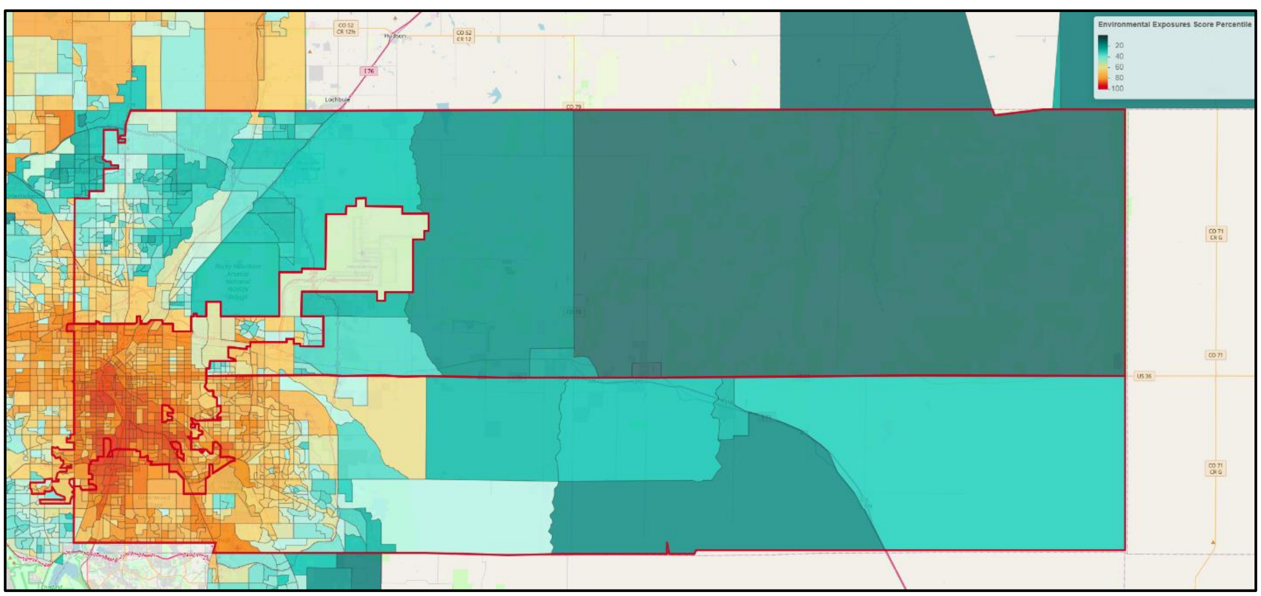



**Figure 2: Overall Colorado EnviroScreen percentile at the census block group level for Public Service's natural gas service territory.** Reds indicate a higher percentile (higher score), and blues indicate a lower percentile (lower score). Denver, Adams, and Arapahoe County are outlined in red as this area experiences greater concentration of environmental justice concerns.




**[Figure 3](#): Disproportionately Impacted Communities, as defined by Colorado House Bill 23-1233, in the Denver County, Adams County, and Arapahoe County area (outlined in blue) at the census block group level.** Disproportionately impacted communities within the Public Services' gas service territory are in red and other communities within the gas service territory are in gray.




**[Figure 4](#): Environmental Exposures score percentile, as reported in Colorado EnviroScreen, in the Denver County, Adams County, and Arapahoe County area (outlined in red) at the census block group level.** Reds indicate a higher percentile (higher exposures) and blues indicate a lower percentile (lower exposures).

The population living within the Public Service's gas service territory also experiences disproportionate health concerns when compared to the state of Colorado as a whole, meaning that greater than 20 percent of the population living in the service territory lives in a census block group at or above the $80^{th}$ percentile across multiple health indicators. The gap is the highest for asthma hospitalizations: 43 percent of the population residing in Public Service's gas service territory lives in a census block group at or above the 80th percentile (**Figure 5**). However, this is also seen for other indicators such as heart disease (27 percent), life expectancy (34 percent), low birth weight (35 percent), and cancer (33 percent). These disproportionate environmental and health concerns are further compounded by the increased representation of socially and economically vulnerable demographic groups, in particular, people of color (50 percent) and low-income people (36 percent).

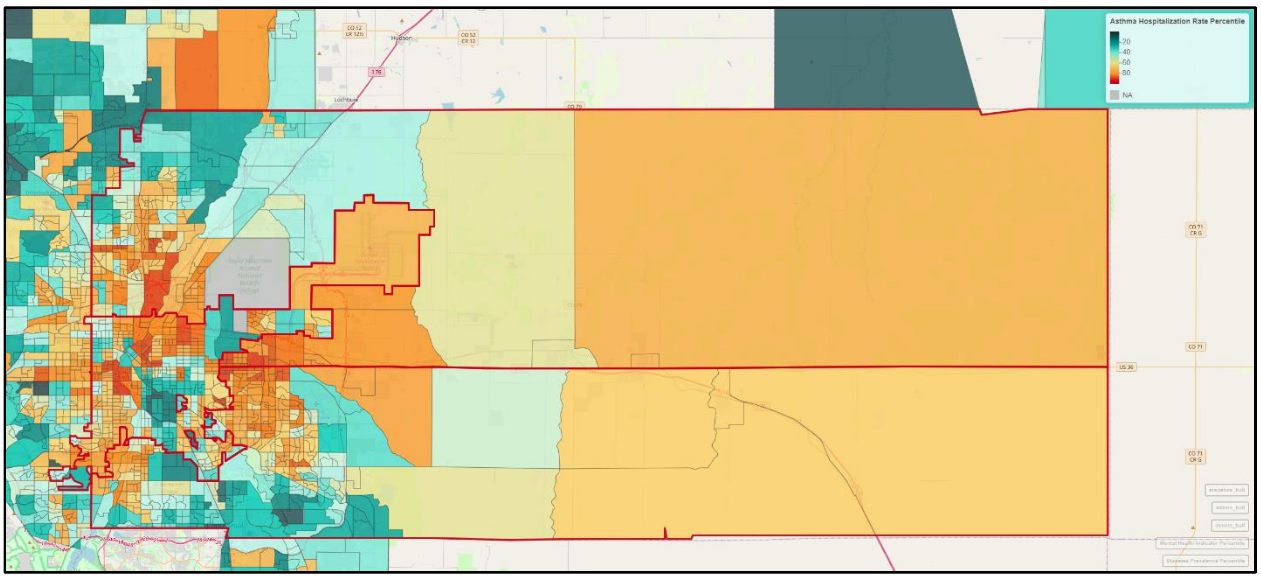



**Figure 5: Asthma hospitalization rate percentile, as reported in Colorado EnviroScreen, in the Denver County, Adams County, and Arapahoe County area (outlined in red) at the census block group level.**

Overall, our analysis can be used as a starting point to identify disproportionately impacted communities within Public Service's service territory. We have identified census block groups with elevated environmental and health indicators, such as those identified above within the Denver County, Adams County and Arapahoe County area. To offset the elevated environmental and health burdens within these regions, census block groups with elevated indicators could be targeted for air pollution reduction strategies, including residential energy efficiency retrofits (coupled with appropriate ventilation strategies) and electrification incentives, because these measures have the potential to reduce the air pollution associated with natural gas combustion within residential homes and across communities (if there is more widespread adoption).

If targeted programs and incentives result in emissions reductions indoors and outdoors within these communities, these actions could help ameliorate the higher cumulative air pollution burdens in these communities, potentially offsetting some health impacts known to be correlated with increased air pollution, such as asthma and other respiratory issues, heart and lung disease, and prenatal health concerns such as low birth weight.

Finally, we want to highlight that environmental justice tools, like the Colorado EnviroScreen tool, are useful for identifying areas where resources can be prioritized to reduce pollution and other sources of environmental injustice;[100] however, community input should also be solicited and considered when developing specific programs designed to offset cumulative air pollution burdens in disproportionately impacted communities.

## 4. $PM_{2.5}$-Related Health Impacts of Public Service's Clean Heat Plan

### *4.1 Health Impact Modeling Methods*

We used two reduced-form models, the EPA's Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)[101] and a peer-reviewed tool called the Intervention Model for Air Pollution (InMAP),[102] to evaluate the outdoor annual $PM_{2.5}$-related health impacts of Public Service's Amended Preferred Portfolio[103] and WRA's Pollution-Free Buildings Portfolio.[104] These models are widely used to estimate the public health impacts of air pollution control policies.[105] Both COBRA and InMAP can be used to calculate how changes in emissions of primary $PM_{2.5}$ and $PM_{2.5}$ precursors (i.e., $NO_x$, $SO_2$, ammonia, and VOCs) impact outdoor annual $PM_{2.5}$ concentrations and use concentration-response functions from the epidemiological scientific literature to calculate the $PM_{2.5}$-related public health impacts associated with changes in ambient $PM_{2.5}$. Both models report the number of annual health incidences (e.g. asthma exacerbations, hospital admissions) and monetary impacts

[100] Colorado Department of Public Health & Environment (CDPHE). (2023, May). *Colorado EnviroScreen v 1.0 Basic User Guide*
[101] USEPA. CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA). Retrieved January 2024.
[102] Tessum, C. W., Hill, J. D., & Marshall, J. D. (2017). InMAP: A Model for Air Pollution Interventions. *PloS One*, 12(4), e0176131.
[103] *See* Hrg. Ex. 102, Attachment DRA-1.
[104] *See* Hrg. Ex. 1400, Attachment MF-6, WRA, SWEEP and NRDC, *A Path to Pollution-Free Buildings* (July 2023).
[105] USEPA. (2021, September 4). Publications that Cite EPA's CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool; Paolella, D. A., Tessum, C. W., Adams, P. J., Apte, J. A., Chambliss, S., Hill, J., Muller, N. Z., & Marshall, J. D. (2018). Effect of Model Spatial Resolution on Estimates of Fine Particulate Matter Exposure and Exposure Disparities in the United States. *Environmental Science & Technology Letters, 5*(7), 436-441; Thakrar, S. K., Balasubramanian, S., Adams, P. J., Azevedo, I. M. L., Muller, N. Z., Pandis, S. N., Polasky, S… & Hill, J. D. (2020). Reducing Mortality from Air Pollution in the United States by Targeting Specific Emission Sources. *Environmental Science & Technology Letters, 7*(9), 639-645; Tessum et al., 2019.

associated with those incidences. Recent studies have demonstrated that reduced-complexity models, including COBRA and InMAP, provide significant computational advantages with only a minor loss in fidelity, compared to numerical chemical-transport models that explicitly simulate atmospheric transport, chemistry, and deposition.[106]

We chose to use two different models because each model has different strengths. COBRA provides information about a greater number of health endpoints, while InMAP provides more granular spatial information. InMAP only provides information about $PM_{2.5}$-related mortality, while COBRA provides more health endpoints, including mortality, asthma exacerbations, number of days that activity was reduced (but not severely restricted) (i.e., minor restricted activity days), and number of workdays lost due to illness (i.e., work loss days). Model outputs are given at up to 1 km resolution in InMAP, while COBRA only provides health incidences at the county level. Additionally, InMAP has built-in racial and ethnic demographic information, which enabled us to evaluate how different scenarios may impact different demographic groups. The $PM_{2.5}$-related mortality estimates from InMAP and COBRA do not agree perfectly because the two models use different methods to simulate the fate of air pollution in the atmosphere as well as different $PM_{2.5}$ concentration-response functions, and different underlying demographic information; therefore, therefore, we use both models together to provide a more comprehensive understanding of the public health implications of each of several of the scenarios being evaluated as part of this proceeding.

Overall, the health impacts quantified in this section underestimate the total lifecycle health impacts of gas appliance usage. COBRA and InMAP are limited to quantifying the outdoor $PM_{2.5}$-related health impacts of $PM_{2.5}$ and $PM_{2.5}$ precursors, which does not include the impacts of $O_3$ or the direct impacts of VOCs, many of which are classified as Hazardous Air Pollutants by the EPA.[107] This analysis focuses on $PM_{2.5}$ because (1) $PM_{2.5}$ is the primary driver of outdoor air-pollution-related health impacts and (2) scientifically-validated computationally inexpensive models only exist for estimating $PM_{2.5}$-related health impacts, other air pollutants require more complex models. Gas appliances are a source of both VOCs and $NO_x$, which may react in the atmosphere to form $O_3$, the second most important contributor to ambient air pollution health impacts after $PM_{2.5}$.[108] While further work is needed to evaluate the contribution of residential and commercial gas use to $O_3$ nonattainment on the Front Range,

[106] Gilmore, E. A., Heo, J., Muller, N. Z., Tessum, C. W., Hill, J. D., Marshall, J. D., & Adams, P. J. (2019). An Inter-Comparison of the Social Costs of Air Quality from Reduced-Complexity Models. *Environmental Research Letters*, *14*(7), 074016.
[107] USEPA. (2023, November 9). Hazardous Air Pollutants.
[108] Murray et al., 2020.

we note that the Denver metro/north Front Range is currently classified as being in "severe" nonattainment for $O_3$ by the EPA.[109] This analysis also does not capture the indoor air quality impacts of gas appliances. Instead, we cover the indoor air quality impacts of residential gas appliances as part of a literature review in **Section 2**. While these models do not capture all the lifecycle health impacts associated with gas appliance usage, they provide an important estimate for one of the dominant ways that gas appliances impact human health.

### *4.2 Scenario Air Pollutant Emissions*

The projected emissions changes of Public Service 's Amended Preferred Portfolio[110] and the Pollution-Free Buildings Portfolio[111] were calculated using the change in gas usage reported in dekatherms per year for beneficial electrification and energy efficiency between 2024 and 2030 and AP-42 emissions factors from the EPA for residential gas combustion (**Figure 6**).[112] While some of the gas reductions may come from the commercial sector, we used residential emissions factors, since the residential sector accounts for most of the gas savings.

House Bill 23-1161 sets a low-$NO_x$ standard for new gas appliances being sold in January of 2026.[113] To capture this change in our emissions estimates, we developed a low-$NO_x$ emissions factor by scaling the AP-42 $NO_x$ emissions factor by a weighted percent reduction that took into account the expected $NO_x$ reductions from water heaters (75 percent) and furnaces (65 percent)[114] and the proportion of gas consumed in the Mountain North by space heating and water heating.[115] We developed this low-$NO_x$ emissions factor using metrics from the residential sector, since most of the gas usage is driven by the residential sector and this aligns with our approach for choosing emissions factors. When calculating the cumulative NOx emissions from the gas savings between 2024 and 2030, we applied the EPA's AP-42 emissions factor for any gas savings in 2024 and 2025. To account for the impacts of Colorado House Bill 23-1161, which requires gas furnaces and water heaters to meet an ultra-low $NO_x$ standard starting in 2026, we used a low-$NO_x$ emissions factor for any new gas savings

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[109] Colorado Department of Public Health & Environment (CDPHE). Nonattainment of Federal Ozone Pollution Standards. Retrieved January 2024.
[110] Hrg. Ex. 102, Attachment DRA-1 at 61, table 70.
[111] *See* Hrg. Ex. 1400, Attachment MF-6.
[112] USEPA. (2021, March). COBRA User Fact Sheet: Analyzing Avoided Natural Gas Emissions Using COBRA.
[113] CO HB 23-1161. (2023, June 1).
[114] SWE Energy. (2023, April). Environmental Standards for Certain Products: HB23-1161.
[115] EIA. (2023, June). Table CE4.5: Annual Household Site End-Use Consumption by Fuel in the West – Totals. In *2020 Residential Energy Consumption Survey (RECS).*

starting in 2026. This low-$NO_x$ factor reduces the EPA AP-42 $NO_x$ emissions factor by 64.8 percent. The same approach was used to calculate the $NO_x$ emissions across both portfolios.

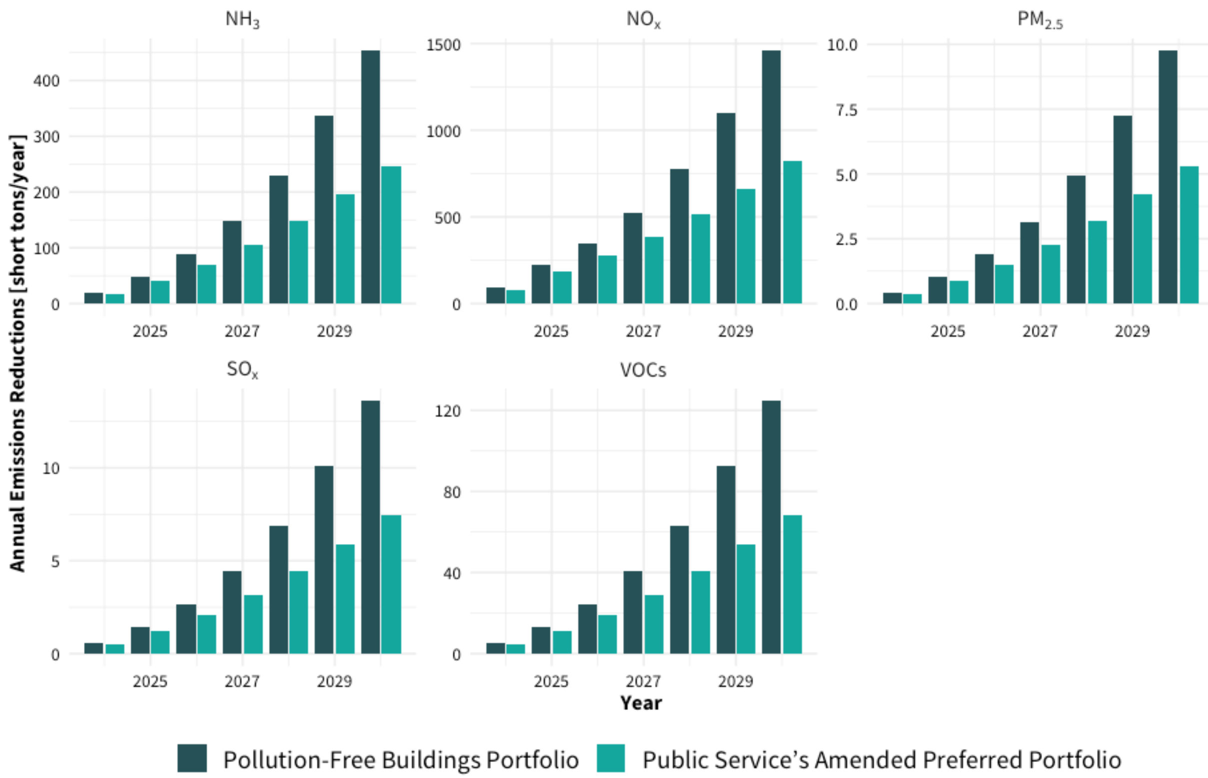


**Figure 6: Annual Emissions Reductions from Public Service's Amended Preferred Portfolio and the Pollution-Free Buildings Portfolio compared to the gas throughput baseline (described below).**

For InMAP, only the gas reductions were needed to run the model, while for COBRA we needed to generate emissions both for a base case that included no change in emissions and a control case that captured the emissions reductions from each of the plans. We used the adjusted reference case gas throughput baseline from the *A Path to Pollution-Free Buildings* report[116] to develop baseline emissions estimates for both portfolios. As Ms. Fickling explains in her testimony, this baseline adjusts the gas throughput baseline from the E3 model used by Public Service to account for the Commission's decision in Proceeding No. 22A-0309EG (DSM-BE Strategic Issues).[117] To account for the impacts of the low-$NO_x$ appliance standard we used the Company's assumption that furnaces and water heaters are replaced at end of life, and assumed that the maximum useful life for both appliances was 18 years. This implies an appliance turnover rate of 5.6 percent per year, meaning that the total gas usage from new

[116] Hrg. Ex. 1400, Attachment MF-6.
[117] Hrg. Ex. 1401, Fickling Answer Testimony at 85.

low-$NO_x$ appliances in the reference case baseline accounted for 5.6 percent of gas usage in 2026 and 27.8 percent of gas usage in 2030.

To generate spatially distributed emissions inputs, we generated population-weighted emissions by county for COBRA and by census tract for InMAP using counties or tracts that fell within Public Service's gas service territory.[118] The same spatial weighting approach was used for all modeled years, meaning that all geographies were assumed to have the same rate of change in emissions from year to year.

### *4.3 Cumulative $PM_{2.5}$-Related Health Benefits*

We estimated the cumulative $PM_{2.5}$-related health impacts of Public Service's Amended Preferred and the Pollution-Free Buildings Portfolio using COBRA between 2024 and 2030 (**Table 2**). Overall, we find that reductions in residential and commercial gas usage lead to $10s-$100s of millions of dollars in health benefits across six years. These benefits are on the same order of magnitude as taking a gas plant offline for several years.[119] Most of the health benefits from both plans are driven by the averted $PM_{2.5}$-related related mortalities which have the largest valuation.

Between 2024 and 2030, the Pollution-Free Buildings Portfolio will *save* an additional $23 million-$52 million in $PM_{2.5}$-related health damages from pollution and approximately 2-5 $PM_{2.5}$-related mortalities compared to Public Service's Amended Preferred Portfolio. The additional health benefits of the Pollution-Free Buildings Portfolio are due to the larger gas savings from both electrification and energy efficiency measures that are a part of this plan. The total gas savings from electrification and energy efficiency measures in the Pollution-Free Buildings Portfolio are 15 percent–83 percent higher between 2024 and 2030 compared to Public Service's Amended Preferred Portfolio. These gas savings in the Pollution-Free Buildings Portfolio, across six years, translated to 56 percent greater total health benefits, relative to Public Service's Amended Preferred Portfolio.

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[118] U.S. Department of Homeland Security. (2022). *Natural Gas Service Territory* [Shapefile]. Homeland Infrastructure Foundation-Level Data (HIFLD) Open Data.
[119] Bilsback, K. R. (2023). Public Health Testimony on DTE's Integrated Resource Plan.

**Table 2: Total $PM_{2.5}$-related health benefits of savings between 2024 and 2030.** Metrics were developed using COBRA. Ranges are given for health endpoints that are calculated using multiple epidemiological models, which represent low and high estimates. Health impacts were calculated 2023 model inputs, so the difference between modeled years is due to changes in estimated emissions only. Values are given in 2017 dollars and calculated using a 3 percent discount rate.

| | Public Service's Amended Preferred Portfolio | | Pollution Free Buildings Portfolio | |
|---|---|---|---|---|
| | Incidence Reductions (cases) | Monetary Benefits ($2017) | Incidence Reductions (cases) | Monetary Benefits ($2017) |
| Mortality | 3.8-8.5 | $41,147,757-$93,292,264 | 5.8-13.2 | $63,753,004-$144,543,532 |
| Infant Mortality | 0.02 | $296,150 | 0.03 | $458,948 |
| Nonfatal Heart Attacks | 0.4-3.8 | $65,792-$611,325 | 0.6-5.9 | $101,941-$947,202 |
| All Respiratory Hospital Admissions | 0.9 | $32,896 | 1.4 | $50,963 |
| All Cardiovascular Hospital Admissions | 0.8 | $42,581 | 1.3 | $65,965 |
| Acute Bronchitis | 6.2 | $3,838 | 9.7 | $5,948 |
| Upper Respiratory Symptoms | 112 | $4,789 | 174 | $7,421 |
| Lower Respiratory Symptoms | 79 | $2,133 | 122 | $3,305 |
| Emergency Room Visits, Asthma | 2.2 | $1,232 | 3.4 | $1,910 |
| Minor Restricted Activity Days | 3,328 | $291,709 | 5,157 | $452,108 |
| Work Loss Days | 568 | $113,651 | 880 | $176,146 |
| Asthma Exacerbation | 117 | $8,701 | 182 | $13,484 |
| **Total Benefits** | | **$42,011,229-$94,701,268** | | **$65,091,143-$146,726,932** |

### *4.4 Spatial Distribution of $PM_{2.5}$-Related Health Benefits*

**Figure 7** shows the spatial distribution of the *total* and *per capita* $PM_{2.5}$-related health benefits for the Pollution-Free Buildings Portfolio. Total health and per capita health benefits tend to be highest near more densely populated areas, e.g., the Front Range, because there is more widespread appliance use leading and therefore a greater proportion of total emissions originating from more densely populated regions. The health benefits of Public Service's Amended Preferred Portfolio are lower, compared to the Pollution-Free Buildings Portfolio, but follow a similar spatial pattern, since we used the same approach to distribute the emissions from both portfolios.

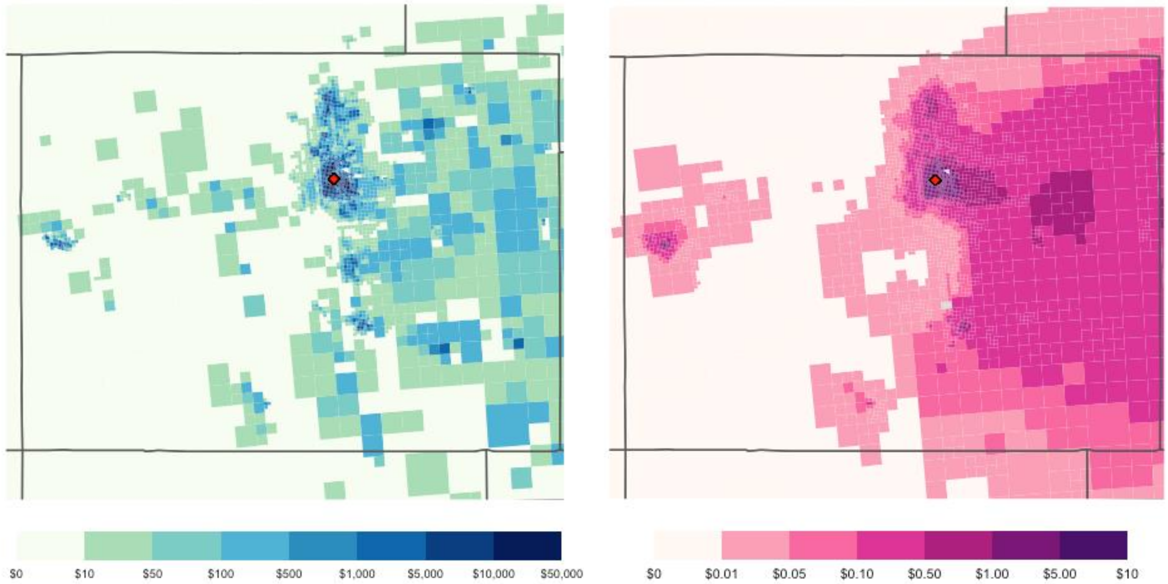


**Figure 7: Spatial distribution of annual $PM_{2.5}$-related health benefits.** Maps were generated using the InMAP model and 2024 emissions data from the Pollution-Free Buildings Portfolio. The left figure provides *total* health benefits, and the right figure provides *per capita* health benefits. The location of Denver is shown as a red dot for reference. Both maps only include mortality as a health outcome and do not include a discount rate for economic valuation.

Overall, both plans will lead to greater per capita $PM_{2.5}$-related health benefits to Latino and White communities than the overall population (**Table 3**) while Black, Native, and Asian communities may see a smaller proportion of per capita benefits than the overall population, likely because there are more White and Latino people living on the Front Range, compared to other groups, which is where the emissions reductions are the highest.

**Table 3: Annual per capita health benefits by race and ethnicity.** Data are from InMAP and were generated using emissions estimates from 2024. Calculations only include mortality as a health outcome and does not include a discount rate for economic valuation.

| | **Public Service's Amended Preferred Portfolio** | **Pollution Free Buildings Portfolio** |
|---|---|---|
| | **Health Benefits ($ per 100 people)** | **Health Benefits ($ per 100 people)** |
| **Black** | 1.1 | 1.2 |
| **Latino** | 2.3 | 2.6 |
| **Native** | 1.3 | 1.5 |
| **Asian** | 1.2 | 1.4 |
| **White** | 1.8 | 2.0 |
| **Overall** | **1.7** | **2.0** |

The per capita health benefits of the Pollution-Free Buildings Portfolio are higher overall than Public Service's Amended Preferred Portfolio, because the averted mass of emissions is higher; however, the ratio of benefits by each race and ethnicity group to the overall population are similar across both portfolios, because the emissions distribution was distributed based on population density for both portfolios. Thus, with any gas usage reductions across Public Service's service territory we expect to see greater outdoor $PM_{2.5}$-related air quality benefits for Latino and White communities, compared to the overall population. However, as noted earlier in this section, we did not quantify the indoor health impacts associated with electrification and weatherization, which may be different for different demographic groups, due to differences in their build environments.

## 5. Conclusions and Recommendations

Decision making on both the part of utility companies and regulators around residential and commercial energy use holds implications for the indoor and outdoor environment, climate, air quality, and public health. In addition to requiring specific greenhouse gas reduction targets, Senate Bill 21-264 includes several elements that are relevant to our analysis. Statute § 40-3.2-108(6)(d)(I), in particular, requires that the Commission, in evaluating a clean heat plan, take into account: "the additional air quality, environmental, and health benefits of the plan in addition to the greenhouse gas emission reductions," and "whether investments in a clean heat plan prioritize serving customers participating in income-qualified programs and communities historically impacted by air pollution and other energy-related pollution."[120]

In support of decision making around this statute, within this report, we present metrics and analysis on Public Service's Clean Heat Plan. Our analysis relies on publicly-available data sources and tools and scientifically-grounded methods. We recommend that future analysis on the part of Public Service include a more detailed health and equity analysis that incorporates, or goes beyond, the metrics and methods presented here.

As demonstrated in **Section 2**, the scientific literature shows that natural gas appliances and gas delivery systems emit a range of pollutants that are harmful to human health. These studies show that these pollutants can be emitted both indoors and outdoors either through gas leaks or as a byproduct of combustion. Adverse health impacts associated with exposure to air pollutants associated with natural gas leaks and combustion include cancer, asthma,

[120] Col. Rev. Stat. § 40-3.2-108

heart attacks, and premature death. The contaminants are especially harmful for those with preexisting lung and heart diseases and are associated with increased prenatal risks. By eliminating the leak- and combustion-related appliance emissions, such as through appliance electrification, energy providers can reduce the risk of harmful health impacts to residents. Finally, our literature review highlights that while residential energy retrofits are an important tool for mitigating greenhouse gas emissions, energy efficiency measures and programs must be carefully paired with appliance electrification and/or mechanical ventilation to achieve both climate and health benefits.

In **Section 3**, we show that many communities within Public Service's natural gas service territory are identified as Disproportionately Impacted Communities according to Colorado's EnviroScreen tool. These communities are likely facing high cumulative impacts because they are experiencing disproportionately high environmental and health burdens and have higher social and economic vulnerabilities. We recommend that Disproportionately Impacted Communities be prioritized for coupled appliance electrification and energy efficiency incentives. If these programs are implemented successfully, they have the potential to offset the high cumulative burdens in these communities by improving local indoor and outdoor air quality. Further, if these households in these communities qualify for bill assistance, efficiency measures would have public health benefits, reduce energy cost burdens, and, for those families already on bill assistance save money for the utility by reducing the number of customers requiring assistance.[121] Finally, we note that identifying priority communities for incentives should use scientific data as well as input from local communities.

In **Section 4**, we show that the Pollution-Free Buildings Portfolio will lead to greater emissions reductions for all contaminants analyzed, when compared to Public Service's Amended Preferred Portfolio. These emissions reductions stem from greater gas savings in the Pollution-Free Buildings Portfolio. Further we estimate that between 2024 and 2030, the Pollution-Free Buildings Portfolio will *save* an additional \$23 million-\$52 million in $PM_{2.5}$-related health damages from pollution and approximately 2-5 $PM_{2.5}$-related mortalities compared to Public Service's Amended Preferred Portfolio. Finally, we find that, due to the distribution of emissions savings, Latino and White communities are expected to have the greatest proportion of health benefits.

[121] Lukanov, B., Makhijani, A., Shetty, K., Kinkhabwala, Y., Smith, A., Krieger, E. (2022, January). Pathways to Energy Affordability in Colorado. *PSE Healthy Energy*, provided as Attachment KB-8.