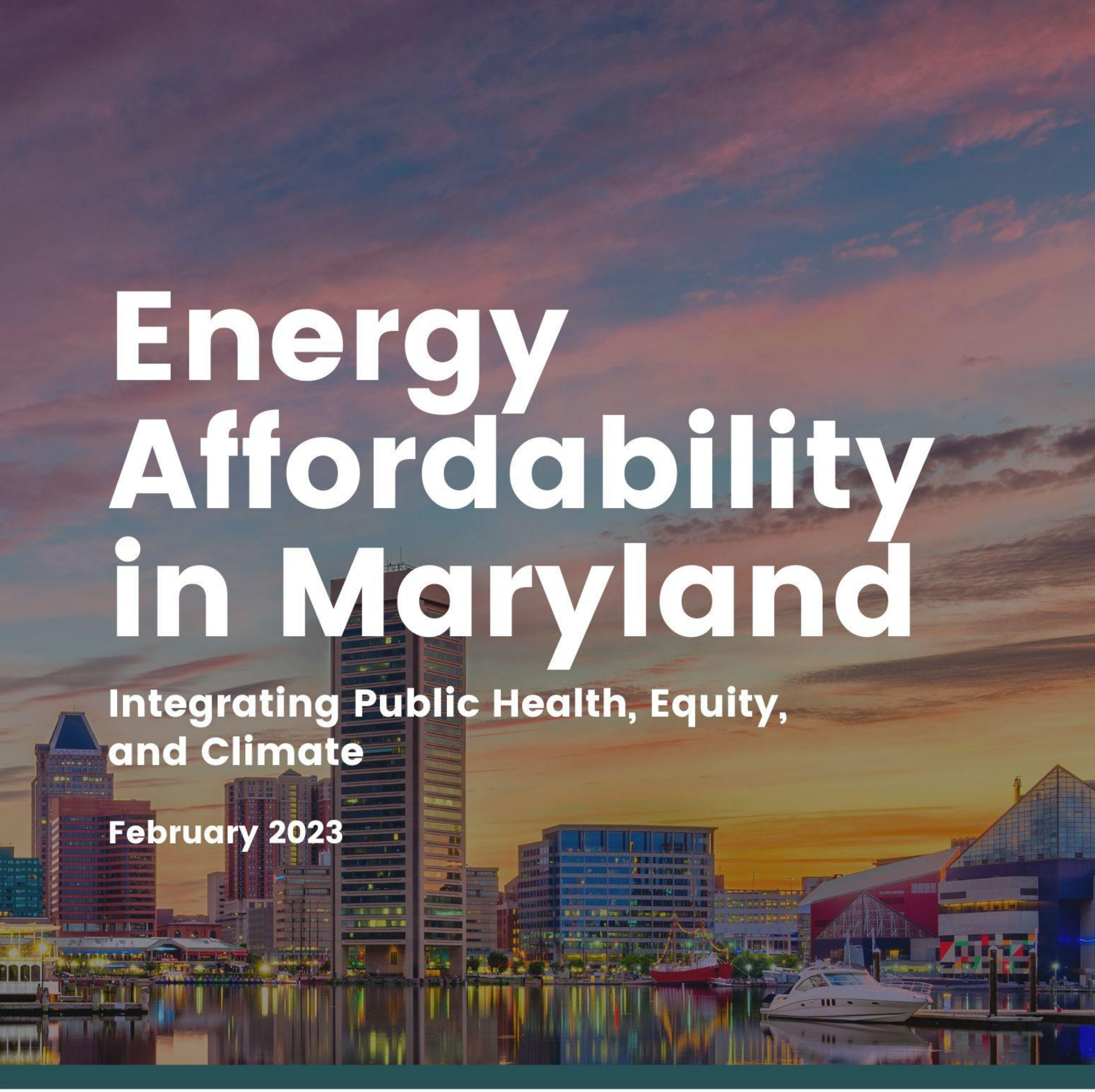

Energy Affordability in Maryland

Integrating Public Health, Equity, and Climate

February 2023

PSE

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About PSE Healthy Energy

PSE Healthy Energy is a 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. We are the only interdisciplinary collaboration focused specifically on health and sustainability at the intersection of energy science and policy. **Visit us at psehealthyenergy.org and follow us on Twitter @PhySciEng**.

About IEER

IEER is a nonprofit research institute that provides activists, policy-makers, journalists, and the public with understandable and accurate scientific and technical information on energy and environmental issues. IEER's aim is to bring scientific excellence to public policy issues in order to promote the democratization of science and a safer, healthier environment.

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Executive Summary

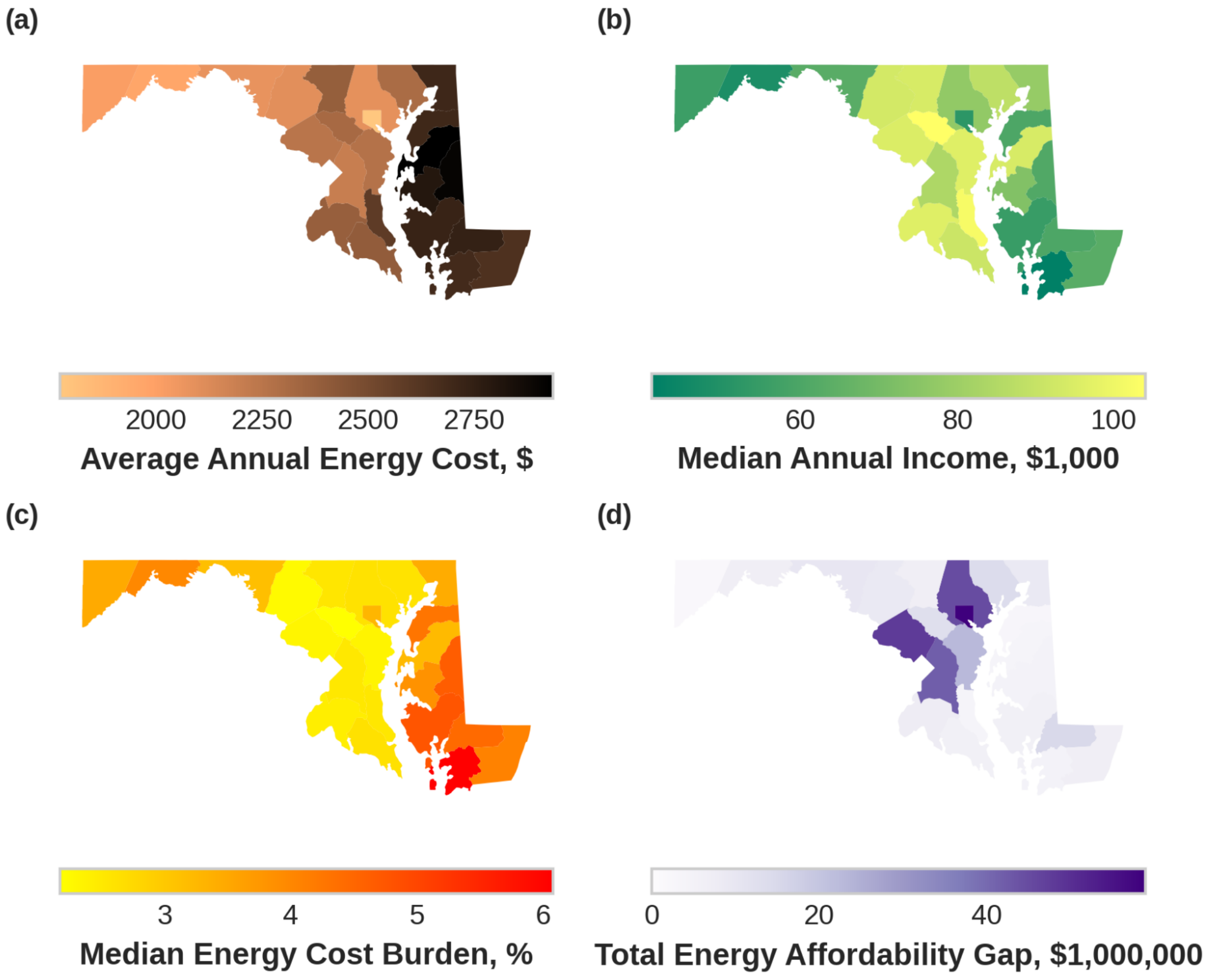
Almost 400,000 Maryland households pay more than six percent of their income on home energy bills. These high energy cost burdens often force individuals and families to make impossible choices between paying utility bills and other essentials such as rent or medicine. Over the next twenty-five years, energy costs will likely increase as utilities invest billions to replace natural gas infrastructure under the 2013 Strategic Infrastructure Development and Enhancement (STRIDE) law. Yet whether these investments will serve their useful life remains unclear, as state climate policy requires a dramatic shift away from fossil fuels, creating a serious risk of stranded costs.

In this report, The Institute for Energy and Environmental Research (IEER) and PSE Healthy Energy (PSE) outline strategies to alleviate energy cost burdens, while improving public health and achieving carbon emissions reduction goals. We find that providing near-term utility bill assistance alongside significant, long-term investments in residential building weatherization and electrification—with prioritization for low- and moderate-income households—holds the potential to simultaneously mitigate climate and health-damaging air pollutant emissions, while alleviating energy cost burdens for those who need it most. These efforts will save money in achieving affordability for all, compared to assistance alone.

The Intertwined Challenges of Energy Affordability, Climate Change, and Public Health

Energy policy in Maryland has historically treated energy affordability, public health, and climate change as separate challenges. In reality, they are deeply intertwined. Households across Maryland currently use electricity, natural gas, propane, and fuel oil to heat their homes and run their appliances, and regional patterns in fuel use affect how much people pay, which pollutants they are exposed to, and what their climate impact is. The energy system's impacts are also influenced by historic structural inequities that disproportionately harm low-income households, communities of color, and urban renters, among other populations. Equitable strategies to transition to a cleaner energy system must address the compounding burdens faced by these households.

Figure ES-1: a) Household energy costs, b) median household incomes, c) energy cost burdens (percent of household income), and d) total energy affordability gap for low- and moderate-income households by county across Maryland.

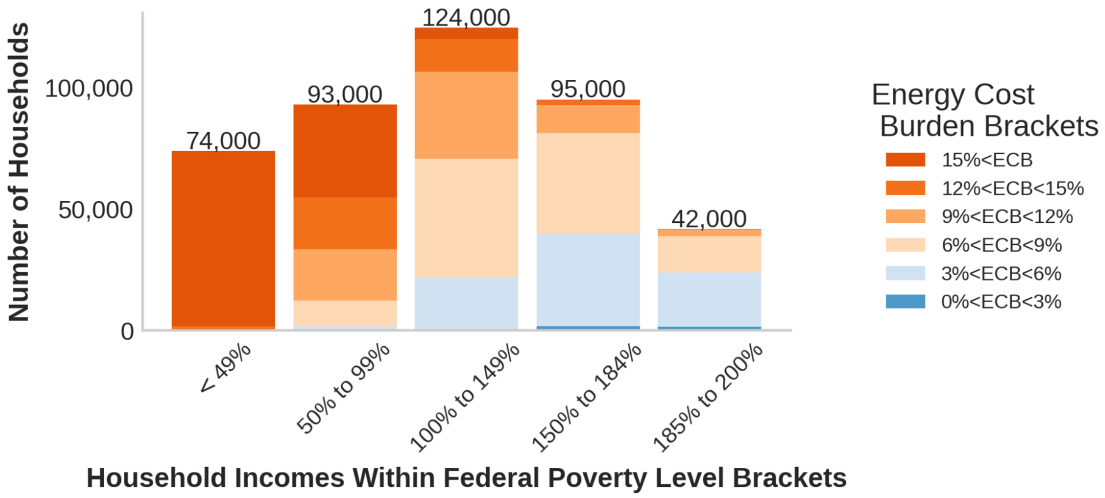


Affordability

Energy required for space and water heating, cooking, and operating lighting and other appliances is unaffordable for many Maryland households. High energy cost burdens can contribute to cascading financial challenges or a lack of energy to meet critical needs. We estimate that approximately 400,000 Maryland households (18 percent) pay energy bills that are considered high—exceeding six percent of their income. Between 80,000 and 90,000 low- and moderate-income households have received energy bill payment assistance in recent years. Very high energy cost burdens, sometimes exceeding 30 percent of income, are disproportionately found in low-income areas of Baltimore City with a higher density of Black households, among propane users, and in rural areas, notably on much of the Eastern Shore and certain parts of Southern and Western Maryland. Many of these households face energy poverty and energy insecurity, which can contribute to adverse health outcomes, debt, and even homelessness. The energy affordability gap, defined as the difference between the total energy bills paid by low- and moderate-income households and the amount they can reasonably afford (six percent of income or less), is in the range of $350 million to $450 million per year in Maryland. About $40 million of this gap is due to excess third-party electricity and natural gas supply charges. **Figure ES-1** maps energy cost burdens across Maryland and their relationship to energy costs and income. Energy cost burdens by income bracket for households earning up to double the federal poverty level (FPL), shown in **Figure ES-2**, can exceed 15 percent for the lowest-income households.

The transition to cleaner household fuels holds the potential to either alleviate or exacerbate these challenges. As households transition away from natural gas to electricity, natural gas rates will rise as fewer and fewer households pay to support the aging gas infrastructure. These rates are likely to impact low-income households, renters, and others who are unable to electrify. Without policy action (legislative and/or regulatory), energy cost burdens for low- and moderate-income households reliant on the natural gas system will rise, potentially skyrocketing after the mid-2030s. This result stems from current policies and laws that allow continued investments in the natural gas distribution system while at the same time requiring deep reductions in greenhouse gas emissions and encouraging electrification of heating.

Figure ES-2: Number of households within federal poverty level brackets broken down by energy cost burden (ECB).



Public Health

People in the United States spend more than 80 percent of their time indoors. Given this fact, policies shaping indoor environments—such as new building construction or retrofit standards—can have significant impacts on quality of life and public health.

Residential fuel combustion for space and water heating and cooking appliances emits air pollutants such as particulate matter ($PM_{2.5}$), nitrogen oxides (NO_x), carbon monoxide (CO), benzene, and formaldehyde, which are associated with a variety of adverse cardiovascular and respiratory health effects, among others. Elevated indoor air concentrations of nitrogen dioxide (NO_2) and CO have been observed in Maryland households with gas stoves. Recent studies have shown that gas-based appliances can leak, even when they are not in use—contributing to hazardous air pollutant concentrations indoors.

Low-income communities and communities of color tend to be disproportionately impacted by, and are more susceptible to, environmental risk factors and adverse health outcomes. Because Maryland has a higher proportion of people of color than the national average, and Baltimore City has a higher poverty rate than the state or national average, its residents may be particularly vulnerable to degraded indoor air quality. Additionally, those with underlying respiratory or cardiovascular conditions may also be particularly vulnerable to indoor air pollution. Notably, the majority of Baltimore City neighborhoods have the highest prevalence of asthma compared to averages for the state **(Figure ES-3)**.

Climate Change

The combustion of fossil fuels in residential buildings in Maryland produced 4.3 million metric tons of carbon dioxide (CO_2) in 2021. Methane, a powerful greenhouse gas, also leaks throughout the entire natural gas system, inclusive of production, processing, transmission, and distribution, resulting in another three million metric tons of CO_2-equivalent emissions (based on a 20-year global warming potential for methane, as required by Maryland law). The Climate Solutions Now Act of 2022 requires 60 percent emission reductions of greenhouse gases by 2031 relative to 2006, and carbon neutrality by 2045.[1] Commercial and residential buildings in Maryland accounted for 55 percent of total natural gas use in 2021. These buildings will have to implement efficiency measures and electrify heating, cooking, and other end-uses in order to meet the state's climate targets. At the same time, the 2013 Strategic Infrastructure Development and Enhancement (STRIDE) Act incentivizes significant

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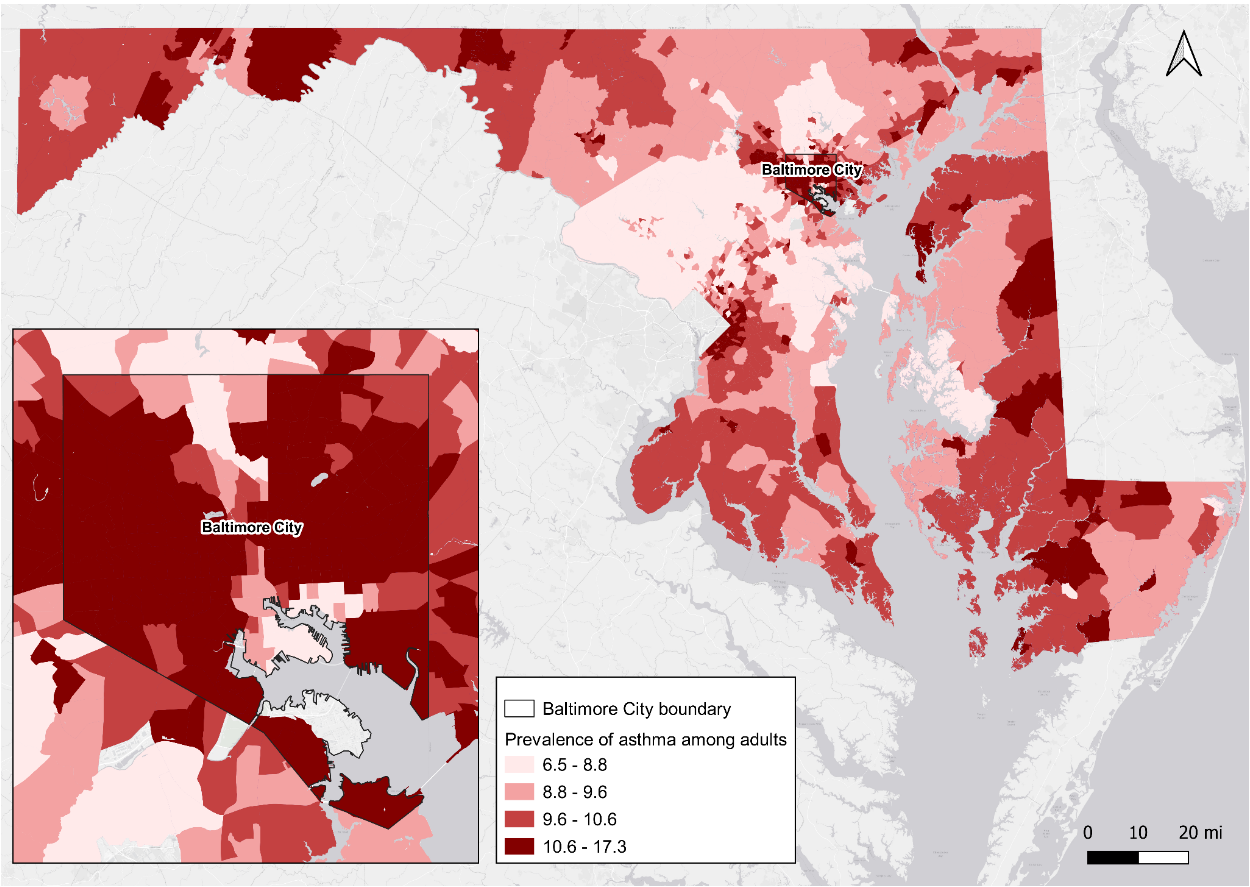
[1] Maryland General Assembly, Climate Solutions Now Act of 2022, Senate Bill 528, Effective Date June 1, 2022, at https://mgaleg.maryland.gov/2022RS/bills/sb/sb0528E.pdf

investments by gas utilities in pipeline replacement. If approved by the Public Service Commission, ratepayers will be paying for these investments decades after 2045.

Figure ES-3: Model-based estimate for crude prevalence (%) of current asthma among adults aged ≥18 years (census tract level), 2020, Baltimore City and Maryland. *Source: CDC (2022)*.[2]



Addressing Legacy Conditions

Mitigating the affordability, public health, and climate ramifications of Maryland's residential energy system will require decarbonizing individual buildings while simultaneously addressing system-wide challenges and inequities such as historic disinvestment, incompatible energy policies, and insufficient funding and policy support for energy-burdened households. Maryland's climate strategy must address these legacy conditions to ensure that public health and energy affordability goals are also achieved. **Figure ES-4** identifies three of the core problems of Maryland's current residential energy system—affordability, public health, and climate change—alongside primary drivers and proposed policy solutions.

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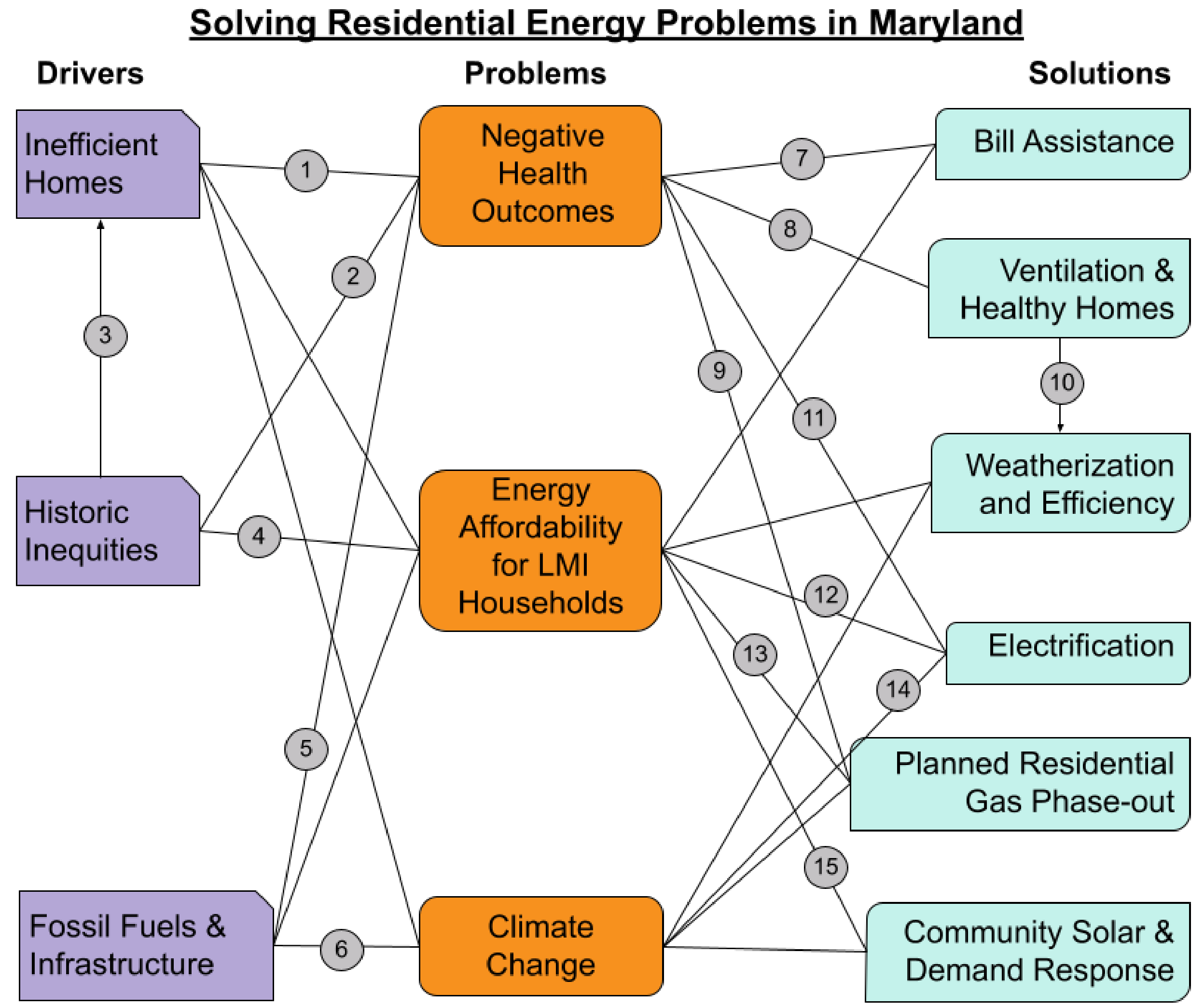
[2] U.S. Center for Disease Control and Prevention (2022). PLACES: Census Tract Data. https://chronicdata.cdc.gov/500-Cities-Places/PLACES-Census-Tract-Data-GIS-Friendly-Format-2022-/yjkw-uj5s

Figure ES-4: Core problems facing Maryland's residential energy system, historic drivers of these problems, and potential policy solutions outlined in this report.



1) Inefficient homes can contribute to poor indoor environmental conditions
2) Inequities drive disproportionate adverse health outcomes
3) Homes for LMI households are less efficient on average
4) Disadvantaged households lack ability to improve homes and reduce energy bills
5) Indoor air pollution & gas transmission safety issues
6) CO_2 & methane emissions contribute to climate change
7) Reduced energy poverty helps households pay for other essentials
8) Reduced exposure to indoor air pollutants, allergens, and mold
9) Reduced exposure to gas transmission leaks
10) Home improvements often needed before weatherization
11) Electric appliances do not emit air pollutants associated with combustion
12) Total energy bills for efficient electric homes are typically the lowest in Maryland
13) Households remaining on gas lines will face higher future bills to maintain infrastructure
14) Efficient fully electric homes are responsible for fewer greenhouse gases
15) Prioritized solar and demand response for LMI households can reduce energy bills

Existing Housing Stock and Fuel Infrastructure

While low incomes are the primary driver of high energy cost burdens, as shown in **Figure ES-2**, a variety of key factors related to building stock and housing arrangements are also associated with energy unaffordability:

- **Fuel type:** Households using costly fuel oil and propane for heating, which is more common in rural areas such as the Eastern Shore, tend to have higher energy cost burdens than those heating with gas or electricity.
- **Renter status:** Low- and moderate-income households are more likely to be renters, particularly in urban areas, including Baltimore. Renters are more likely to face barriers to efficiency upgrades and other clean energy measures because these decisions are often made by landlords, while the benefits accrue to tenants, leading to a split incentive problem.
- **Home quality:** Low- and moderate-income households tend to live in homes that are less efficient per square foot, and more likely to have problems such as mold, lead, and leaky roofs. These problems must be remediated before such households can be weatherized or measures such as rooftop solar can be adopted; but resources for these upgrades are limited.
- **Demographics:** Energy costs tend to be disproportionately higher for communities of color, even when controlling for household income.[3,4,5] Systemic and structural inequities have contributed to this disparity between racial and ethnic groups, from federal government-sponsored segregation in housing, to redlining (e.g., refusing to insure mortgages in and around Black neighborhoods).[6] Because of such systemic exclusions, Black, Indigenous, and People of Color (BIPOC) communities also tend to live in less efficient and less healthy homes, and may experience higher costs when investing in energy efficiency upgrades.[7,8,9]

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[3] Kontokosta, C., V. Reina, and B. Bonczak. (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

[4] Lyubich, E. (2020). "The Race Gap in Residential Energy Expenditures". *Energy Institute at HAAS*. WP-306

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

[6] Gross, T. (2017, May 3). A 'Forgotten History' Of How The U.S. Government Segregated America. https://www.npr.org/2017/05/03/526655831/a-forgotten-history-of-how-the-u-s-government-segregated-america

[7] J. Lewis, D. Hernandez, and A. Geronimus. (2019). "Energy Efficiency as Energy Justice: Addressing Racial Inequalities through Investments in People and Places." *Energy Efficiency, 13,* 419–32. doi.org/10.1007/s12053-019-09820-z.

[8] 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.

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

Competing Policies and Rate Structures

Certain Maryland energy policies—notably, retail choice and STRIDE—increase energy cost burdens for low-income households; the latter is poised to further exacerbate these burdens in the coming decades.

- **Retail choice:** Third-party suppliers of electricity and natural gas frequently charge rates that are higher than regulated utility "Standard Offer Service." For low- and moderate-income households participating in retail choice, the excess cost in 2021 for electricity was at least $30 million; for natural gas, the excess cost was about $7 million. In all, the two add about 10 percent to the affordability gap. Due to successful advocacy efforts, a prohibition on supply at rates above Standard Offer Service to bill payment assistance recipients will be implemented in 2023. This will eliminate the excess cost for them; however, since most eligible households do not get assistance, most of the excess cost will remain until the prohibition is extended to all eligible households, whether they get assistance or not.
- **STRIDE:** Maryland's 2013 STRIDE law—enacted to authorize and create a funding mechanism for billions of dollars in natural gas pipeline replacements—allows continued investments in existing natural gas infrastructure without a formal rate case being conducted first, with all capital costs and return on investments to be recovered from ratepayers over the next 70 years or so. This law assumes the continued use of gas pipelines. At least for residential buildings, the subject of this report, this is in contradiction with the 2022 Climate Solutions Now Act, which requires net-zero greenhouse gas emissions by 2045 and implies near-total phase out of natural gas use in residential buildings by that date. In spite of its safety ambitions, serious accident frequency data do not indicate that the 2013 STRIDE law has had an impact on reducing pipeline accidents.

If STRIDE-related investments continue to be approved and building electrification continues, consumer natural gas rates will increase significantly, likely accelerating the migration from gas to cheaper electric space and water heating options by those who can afford it. This is likely to create spiraling rate increases for households left on the natural gas system equaling roughly $40 per million British Thermal Unit (MMBTU[10]) by 2040 and roughly $100 per MMBTU by 2045, even if commodity natural gas rates do not rise. If natural gas is replaced by synthetic gas and green hydrogen, with most heating being done electrically, gas rates could increase even more, to about $140 per MMBTU. In other words, gas prices would rise by more than

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[10] A thermal unit of measurement for natural gas.

three times from about $12 per MMBTU in 2021 by 2040 and could increase by more than ten times by 2045. Low- and moderate-income households that cannot electrify completely (for instance, because they are renters) will face steeply rising energy cost burdens, putting upward pressure on the amounts needed for bill assistance.

Inadequate Bill Assistance and Support for Weatherization

Energy bill assistance can play a critical role in reducing energy cost burdens immediately, but only 26 percent of eligible households in Maryland actually received such assistance in 2021. Many of the households who receive assistance still have energy cost burdens over six percent; the vast majority of eligible households who do not get assistance are also left with unaffordable burdens.

Numerous factors may contribute to low enrollment, but most notable are the onerous application process for assistance and burdensome documentation requirements. These include proof of up to 27 data points on sources of income, social security numbers, as well as name, citizenship status, and birthdate of each member of the household; in case someone has no income, an additional declaration is required for that. The application is explicitly punitive in its tone. Moreover, there are insufficient funds to provide bill assistance to all those who need it: we estimate that current energy bill assistance needs are in the range of $350 million to $450 million per year. We have used $400 million as the affordability gap in this report; about $40 million (or more) of this gap is due to the higher rates that low- and moderate-income households pay to third party suppliers compared to Standard Offer Service rates. Once this problem is fixed (as it has been for assistance recipients) the true gap, based on regulated utility rates, is still about $360 million. About $120 million per year is available from current sources for bill payment and arrearage clearance assistance; this leaves a gap of $240 million to fully fund a bill assistance program that guarantees affordable energy bills across the state, such as a Percentage of Income Payment Plan (PIPP).

Policy Solutions

We propose a mix of policy solutions to reduce energy cost burdens while achieving climate and public health goals across Maryland’s residential sector. In the near term, removing barriers to enrollment in bill assistance—and adequately funding assistance programs—can help improve energy affordability for low- and moderate-income households. In the long term, this bill assistance can be reduced or even phased out for most eligible households as investments in weatherization (inclusive of public health measures such as a secure building envelope and proper ventilation), electrification of appliances, provision of discounted community solar, residential demand response, and ultimately the retirement of the gas distribution infrastructure for buildings can help achieve climate goals while systematically reducing energy cost burdens.

Fully Funded Bill Assistance Programs with Low Barriers to Participation

Energy bill assistance can be provided in numerous forms, such as grants to reduce bills, discounted rates, or a PIPP. The latter is the most direct method for ensuring that a household's energy bills are capped at an affordable threshold. For PIPP and any other assistance measures to be effective, enrollment barriers must be removed. Applications should be simplified greatly, with upfront documentation requirements eliminated for state and ratepayer funded programs, and restructured to enable mixed immigration status households to apply without fear. Income and other facts in the application should be by self-attestation, which can be verified later with random audits.

To ensure affordability for all Maryland households, the amount of funding for assistance programs would have to be increased by about $280 million per year under current circumstances. The amount would be reduced to about $240 million if the ban on third party supply at rates above utility "Standard Offer Service" is extended to all households eligible for assistance. Full integration of affordability into the energy transition would require substantial additional funds; however, the vast majority of these could come from the Inflation Reduction Act until 2032.

Over time, the total amounts needed for assistance would decline to well below $120 million, the level of currently available funds, as bills are lowered through weatherization, electrification, and discounted community solar measures. Progressive funding sources, such as a wealth tax, would limit cost shift impacts to the vast majority of non-low-income households. After full integration of all eligible households into the energy transition, the majority of them would no longer require assistance because their bills would be lowered sufficiently to be affordable. Bill payment assistance totalling about $40 million less the amount available today for assistance would still be needed for about 60 percent of the households with income less than the federal poverty level depending on their type of home.

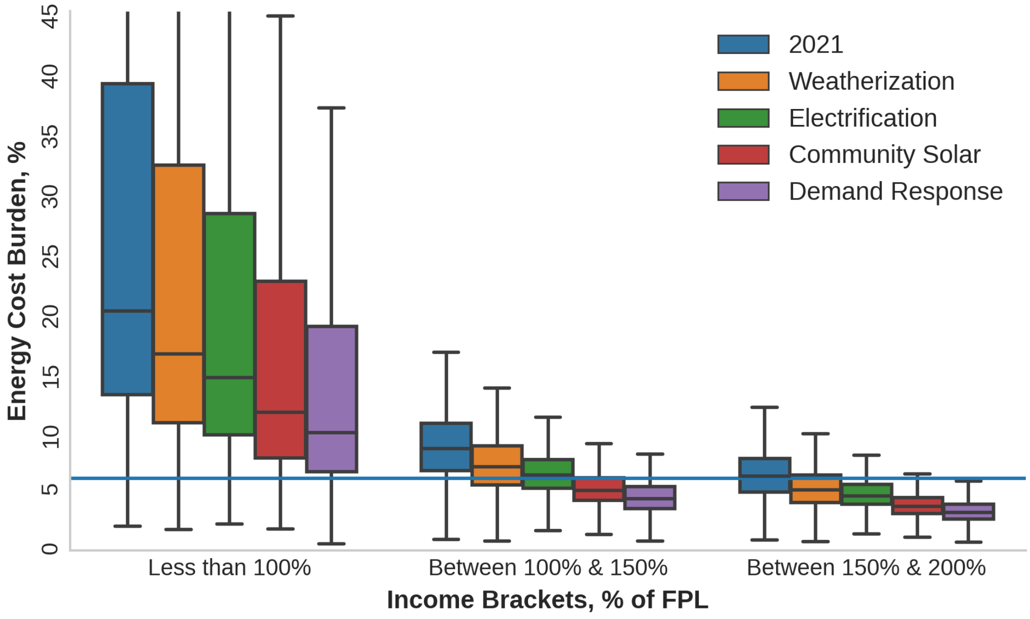
Weatherization, Ventilation, and Electrification

The greatest energy affordability, energy efficiency, and public health benefits will be derived when targeted weatherization, ventilation, and electrification retrofit programs are implemented carefully with a focus on low-and moderate-income households and populations most vulnerable to poor indoor air quality (e.g., children, older adults, people of color, those with preexisting respiratory and cardiovascular conditions). Retrofit measures and benefits include:

- **Weatherization:** The current rate of weatherization of low- and moderate-income homes will need to be accelerated by five to ten times and combined with electrification in order to meet state climate targets. Accelerating low-income weatherization programs will allow the state to take full advantage of funds available under the federal Inflation Reduction Act.
- **Electrification:** Electrification of household appliances, particularly those located within the living space, e.g., stoves, ovens, space heaters, can eliminate combustion-related emissions that contribute to poor indoor air quality and increased health risks. Moreover, homes that are fully electrified using efficient technologies generally have lower bills than equivalent fossil fuel users. Policies and programs will be needed to support electrification for households that cannot afford the up-front costs, ideally replacing all fossil fuel use in a single retrofit. Priority should be given to low- and moderate income households, including renters, because (i) they are most at risk of being stranded on the gas system and facing its rising costs and (ii) the Inflation Reduction Act provides major incentives and rebates for electrification which would make it even more economical to electrify these households.
- **Solar Energy:** Virtual net metering is a valuable strategy for providing discounted electricity to low- and moderate-income households. Virtually net-metered discounted community solar electricity can play a key role in reducing energy assistance requirements. We estimate that providing discounted community solar (at 20 percent discount) can reduce energy cost burdens significantly, the more so as homes are electrified. Enabling low- and moderate-income households to participate in demand response can help bring costs down even further.
- **Ventilation:** Access to and utilization of mechanical ventilation (e.g., range hoods, HVAC systems) can aid indoor air quality by reducing indoor air pollutant concentrations attributable to combustion-based appliances. Ventilation can also provide indoor air quality benefits when electric stoves and ovens or induction ranges are used by reducing indoor air pollutant emissions related to types of foods being cooked. Educational campaigns should promote activities that increase ventilation during cooking (e.g., using range hood, opening windows) as a precaution whenever cooking occurs. High-quality ventilation systems should be prioritized when conducting energy retrofits or upgrades to ensure that household ventilation is maintained or improved when energy retrofits are implemented.

- **Coupled interventions with cross-cutting benefits:** Energy cost burdens would be greatly reduced by a combination of weatherization, efficient electrification, and discounted community solar electricity supply. As a result of these investments and interventions, the funds needed for energy assistance for universal affordability will gradually decline over time. Additionally, coupled air sealing, mechanical ventilation and filtration, electrification, and educational efforts can improve both energy efficiency and indoor air quality, resulting in simultaneous benefits for climate and public health. A holistic, green and healthy homes approach should be adopted while retrofitting existing homes; grants for that purpose should be made available to owner-occupied households with incomes at or below the federal poverty level. While it is difficult to quantify the benefits of added housing security and improved health, the available evidence indicates that the non-energy benefits of making bills affordable, increased housing security, and improved air quality may well be of the same order of magnitude as the costs of added assistance and full integration into the energy transition of low- and moderate-income households.[11] **Figure ES-5** demonstrates how a combination of weatherization, electrification, community solar, and demand response alongside proposed financing strategies can lower energy cost burdens for each income bracket.

Figure ES-5: The sequential affordability benefits of weatherization, electrification, community solar, and demand response by income group.



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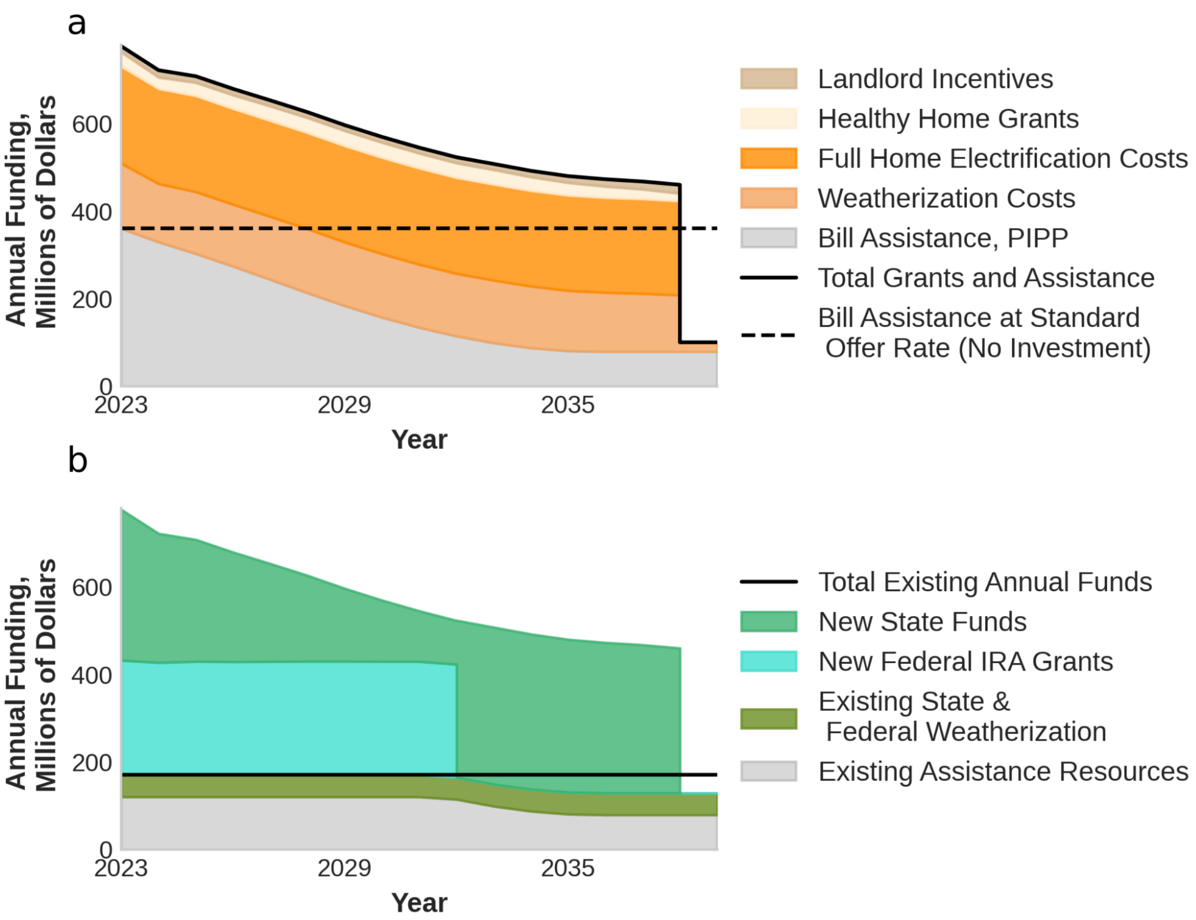
[11] See **Section 5.3** for references and discussion.

Figure ES-6(a) shows the funds needed for each element of to achieve affordability for all over time; note that the need for assistance falls steadily as low-income households are fully integrated into the energy transition—with the steps shown in **Figure ES-5** above to be completed in 15 years in these calculations. **Figure ES-6(b)** shows the sources of funds, including new state funds and new federal funds available, mainly from the Inflation Reduction Act. About $4 billion dollars in new funds would be needed (present value, three percent discount rate). About $1 billion (2023 present value) of this cost would be offset by savings after that would continue after that at the same rate. Full integration of low- and moderate-income households into the energy transition would, over the rest of the century (the usual time for climate calculations), save a net of $8 billion (2023 present value) relative to sustaining affordability with assistance alone.

Figure ES-6(a): Uses of funds for universal affordability and energy transition integration; **Figure ES-6(b):** potential sources of funds for achieving that goal.



Gas System Planning and Retirement

As more customers electrify, costs of the gas system will be distributed among fewer households, increasing costs for the remaining customers. One solution to mitigate rising costs is to prune—that is, retire—entire sections of the gas distribution system at a time to reduce fixed costs, and electrify all affected households. Maryland should discontinue its current program of natural gas pipeline replacement under the 2013 STRIDE law and phase out the natural gas infrastructure supplying buildings, especially in the residential sector, in consonance with the Climate Solutions Now Act. Any investments needed to ensure the safety of the natural gas distribution system should be done via formal rate cases, where consideration can be given to retiring the pipelines in question and electrifying those neighborhoods. Only investments strictly needed for safety should be allowed until electrification can be carried out so that entire sections of the natural gas infrastructure can be shut down in an orderly way. Networked geothermal wells with heat pumps are emerging as an alternative to natural gas investments in areas with sufficient load density.

The vast majority of serious injuries and fatalities from natural gas explosions in recent years have occurred in apartment buildings. This needs to be investigated, including whether there have been disproportionate impacts on BIPOC and immigrant communities.

Enabling Considerations

Certain enabling considerations are critical components to ensure that energy transition programs and policies are effective and equitable. These include:

- **Holistic approach:** Energy affordability, climate change, and public health have historically been addressed in siloes, but greater benefits may be achieved by working collaboratively across agencies, programs, and sectors to identify multi-benefit strategies to decarbonize residential buildings.
- **Prioritization:** Geographically concentrated areas where the highest cost burdens and/or public health burdens are concentrated, as well as those most at risk for escalating costs during a transition, should be prioritized for interventions.
- **Community engagement:** Affected communities should be engaged up front and throughout the design, implementation, and evaluation of programs, including considerations of compensation for time to support participation.
- **Broadband:** Participation in demand response, the ability to respond to time-of-use-rates, and adoption of other distributed resources require access to

broadband and smart appliances. Ensuring universal broadband access is an important complement to an equitable energy policy.

- **Financing and grants:** Low-interest financing and grants can enable low-income households to adopt clean energy technologies with high upfront costs. Existing weatherization grant programs are funded to the tune of about $50 million per year. The Inflation Reduction Act provides some funds for weatherization grants, incentives to landlords, and far more for heat pump electrification of space heating. Additional state-level funds, however, may be needed, such as those provided through a green bank.
- **Contract backstops and other incentives for community solar:** Low- and moderate income households are not benefiting from Maryland's community solar program to the extent they could with proper incentives for solar developers and investors. The risk profile of low- to moderate- income households with varying credit histories, combined with higher marketing and customer management costs, means that it is currently more expensive for community solar developers to serve low- and moderate-income households than non-low- and moderate-income households. Contract default backstops, provided by green banks or non-government organizations are one way to address this issue. Grants, added tax incentives and/or low-cost financing for projects serving low-income subscribers, such as those currently provided in small numbers by the Maryland Energy Administration and included in the Inflation Reduction Act, would also provide solar developers with the financial assurance needed to elect to sell to low- and moderate income subscribers.
- **Utility Consolidated Billing with Purchase of Receivables for community solar:** Even though available to all other third-party electricity suppliers, current regulations do not offer community solar developers and subscribers the benefit of Utility Consolidated Billing with Purchase of Receivables, by which the utility sends a single consolidated bill to the subscriber and purchases any debt owed by the solar subscriber to the developer. Without Utility Consolidated Billing many low-income community solar subscribers risk the loss of electricity bill payment assistance if subscribed to community solar power because bill payment assistance is currently only provided through the utility, not through the community solar provider. Utility Consolidated Billing would also allow community solar customers to pay their bills in cash or by check as part of their utility bills; low-income customers without credit or debit cards cannot currently participate in community solar.

- **Data collection and sharing:** Regular collection and transparent sharing of data regarding participation in weatherization, electrification, and bill assistance programs, and the concomitant energy and cost savings, will enable the ongoing modification of these programs to improve effectiveness. It would also be valuable to measure indoor air pollution for a subset of households to better determine the public health benefits of selected interventions.
- **Workforce:** Over a million homes will need to be converted from fossil fuel heating technologies to highly efficient air-to-air and geothermal heat pumps. A variety of workforce development programs are needed. In addition to in-person training and apprenticeships, examples from other states include on-demand video training materials (Vermont), directories of training materials (New York) and intensive training webinars (California).[12]
- **Pilot programs:** Maryland should implement several pilot programs similar to other states to test the feasibility and economics of new technologies and programs. These include, for example, an exploration of the networked geothermal well approach for simultaneously reducing stranded costs, promoting full electrification of space heating, and reducing CO_2 emissions. New York and other states have passed laws promoting geothermal well networks; there are also examples of pilot programs.

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[12] Stephen Mushegan and Claire McKenna, “Opportunities for Job Training While Sheltering in Place,” Rocky Mountain Institute, April 29, 2020 at https://rmi.org/building-electrification-opportunities-for-job-training-while-sheltering-in-place/

1.0 Overview of Energy Affordability

1.1 Introduction

Energy-cost-burdened households are defined as paying six percent or more of income on energy bills—a threshold met by roughly 18 percent of all Maryland households. We estimate that the total number of households with energy cost burdens more than six percent is close to 400,000. Low-income households often pay significantly more. We estimate that in 2021, about 440,000 Maryland households earned below 200 percent of the federal poverty level[13] and around 80 percent of these households were energy cost-burdened.[14] In addition there are some households with income above 200 percent of the federal poverty levels who are energy cost-burdened.

These high energy cost burdens often force households to make wrenching financial choices about paying for necessities, such as rent, medicine, and the fuel needed to heat homes. When electric bills go unpaid, utility companies may cut off electricity or natural gas and families may face eviction. These events have ripple effects throughout the economy. A 2015 analysis of energy affordability in Maryland estimated that each incidence of homelessness lasted seven months on average and cost an added $28,000 per displaced family, in addition to the losses and distress suffered by the family.[15]

The decarbonization of Maryland's energy system under the Climate Solutions Now Act[16] creates the potential to alleviate energy cost burdens, or to exacerbate them. Likewise, there

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[13] APPRISE. *2018 National Energy Assistance Survey: Final Report.* Prepared for National Energy Assistance Directors' Association. Washington, DC: NEADA, December 2018. http://www.appriseinc.org/wp-content/uploads/2019/02/NEADA-2018-LIHEAP-Survey.pdf p. ii

[14] The energy affordability threshold is derived first of all from the U.S. Department of Housing and Urban Development definition of affordable housing costs as being 30 percent of income, including utility bills. Legal Guide to Affordable Housing Development (2nd ed.). *American Bar Association.* Twenty percent of the housing cost — that is, six percent of overall income — is considered an affordable energy cost burden, according to Fisher, SHeehan and Colton, with a sublimit of two percent for heating and cooling costs alone: Fisher, Sheehan, and Colton. (2021). Home Energy Affordability Gap. *Public Finance & General Economics.* http://www. homeenergyaffordabilitygap.com/03a_affordabilityData.html The six percent threshold is also defined as the affordability limit by the American Council for an Energy Efficient Economy: see 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; and Drehobl, A., Ross, L., and Ayala, R. (2020). How High are Household Energy Burdens? *American Council for an Energy-Efficient Economy (ACEEE).*

[15] Arjun Makhijani, Christina Mills, and Annie Makhijani, *Energy Justice in Maryland's Residential and Renewable Energy Sectors*. Takoma Park Maryland: Institute for Energy and Environmental Research. (2015). https://ieer.org/wp/wp-content/uploads/2015/10/RenMD-EnergyJustice-Report-Oct2015.pdf pp. 89-91.

[16] Maryland General Assembly, Climate Solutions Now Act of 2022, Senate Bill 528, Effective Date June 1, 2022, at https://mgaleg.maryland.gov/2022RS/bills/sb/sb0528E.pdf

is an opportunity to simultaneously improve public health by phasing out the use of fossil fuels in homes—thereby eliminating associated emissions of health-damaging air pollutants—and adopting a holistic approach to retrofits that support the addition of proper envelope sealing and ventilation to achieve these health goals, particularly for low-income households. In this chapter, we examine Maryland's past efforts to reduce energy cost burdens and provide a summary of existing programs, funding levels, and effectiveness to provide a comprehensive view of obstacles and opportunities to achieving universal energy affordability. In **Chapter 2**, we analyze energy cost burdens statewide and examine the gap between existing energy costs and affordable costs. **Chapter 3** addresses the indoor air quality and public health implications of residential energy use. **Chapter 4** explores the contradictions between existing policies that allow continued investments in natural gas infrastructure under a 2013 law and the 2022 Climate Solutions Now Act. In the final **Chapter 5**, we analyze the policy changes that will be needed to make the energy transition an instrument of equity, health, and affordability.

1.2 Maryland's Energy Affordability Landscape

Maryland had a population in 2021 of about 6.1 million people, of whom nine percent lived below the federal poverty level; there were about 2.3 million households in 2021. Maryland's median household income was about $91,000[17] the highest in the United States. Yet, about 400,000 households were energy cost-burdened; we estimate that the total gap between the actual energy cost burden for all these households and six percent of income was approximately $400 million (see **Chapter 2**). At the lowest income level, less than 50 percent of the federal poverty level, energy cost burdens in Maryland approach and sometimes exceed 40 percent of income. When income is in the range of 50 to 99 percent of the federal poverty level, energy cost burdens are typically 15 to 20 percent of income. Without explicit policies and actions to alleviate them, high energy cost burdens are likely to be exacerbated by the transition to a decarbonized energy system.

High energy cost burdens are part of the mix of severe financial stresses that result in people not buying enough medicine to take as prescribed or postponing payment of utility bills. Cascading problems can follow. For instance, utility shut-offs can aggravate health problems or result in eviction. The National Energy Assistance Directors' Association periodically surveys families who have received federal assistance (via the states) to help pay their heating bills. The findings of a recent survey (2018)[18] were stark:

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[17] U.S. Census. QuickFacts Maryland. 2017-2021; at https://www.census.gov/quickfacts/fact/table/MD/PST045221

[18] APPRISE. *2018 National Energy Assistance Survey: Final Report.* Prepared for National Energy Assistance Directors' Association. Washington, DC: NEADA, December 2018. http://www.appriseinc.org/wp-content/uploads/2019/02/NEADA-2018-LIHEAP-Survey.pdf p. ii.

- More than one out of seven households surveyed had had their electricity or natural gas supply cut off because of their inability to pay their utility bills—and nearly half of these households resorted to using candles or lanterns for lighting;
- Nearly one in three families were using the stove or oven for heating—a problem known to exacerbate indoor air pollution;
- Over one in three households went without food for at least a day and nearly a third of the families were unable to afford medicine at all or unable to purchase the full doses of medicines they needed at least once in the past five years.

Loss of homes due to conflicts between paying utility bills or paying the rent or mortgage is among the most devastating outcomes. The survey found that 23 percent—nearly one in four—of the households who received assistance at least once in the past five years had lost their homes within that time due to a variety of financial stresses, including utility bills and rent/mortgage payment conflicts. This is an average of nearly five percent every year. About three-fourths of affected households found shelter with friends and family; one-fourth became homeless.[19]

1.1.1 Existing State and Federal Policies

In Maryland, like other states, the serious impacts of high energy cost burdens have led to a variety of policies and approaches to reduce them. Several streams of funding provide assistance to low-income households:

1. **Low-Income Home Energy Assistance Program (LIHEAP):** Funded by the federal government, this program goes by the name Maryland Energy Assistance Program (MEAP).[20] These funds are also used to assist households who use non-regulated fuels, specifically fuel oil and propane.
2. **Universal Service Protection Program (USPP):** This Public Service Commission regulatory program is designed to help MEAP participants avert utility shut-offs. USPP requires participation in a budget billing program, which evens out monthly utility bill payments based on the prior year's average. Customers are kept apprised of actual usage and the amount is adjusted during the year, if needed.

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[19] Ibid.

[20] Office of Home Energy Programs. Electric Universal Service Program Annual Report to the Maryland Public Service Commission: Fiscal Year 2021. Baltimore, Maryland: Maryland Department of Human Services, December 2021, at https://webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?FilePath=//Coldfusion/Casenum/8900-8999/8903/579.pdf ; hereafter OHEP 2021.

3. **Electric Universal Service Program (EUSP):**[21] This ratepayer- and RGGI[22]-funded program is used to reduce electricity bill burdens by providing a credit on the customer's electric bill. Some of the funds are also used to help customers clear accumulated arrears and for weatherization of homes, at most once in five years. There is no specified affordability target that the program seeks to achieve.[23] It is provided in addition to LIHEAP assistance. Since 2016, LIHEAP requires states to report on how well they are targeting households with the highest energy cost burdens; there has been steady progress in energy cost burden reductions for the targeted group since that time. Bill assistance eligibility criteria for the EUSP program have been the same as for the state's LIHEAP program (MEAP), though they have now been expanded from the 175 percent of federal poverty level for MEAP to 200 percent in the case of families with at least one household member over 67 years old.[24] The Electric Universal Service Program has two sources of funds:
    a. A charge on electricity sold, paid by ratepayers;
    b. Half of the funds in the state's Strategic Energy Investment Fund (SEIF). Almost all of the funds for SEIF come from the sale of CO_2 allowances as part of the multi-state RGGI cap-and-trade program.[25]
4. **Private charities:** The Fuel Fund of Maryland[26] and others supplement these federal and state programs. Sources of funds include utilities and charitable contributions.

Figure 1-1 shows the various sources of assistance in 2019, totalling about $122 million.

In-kind resources also contribute to the assistance programs. Specifically, there are a large number of volunteers who work with low-income households, the elderly, people with critical medical needs, and others who need guidance to navigate the process of applying for and receiving assistance.[27]

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[21] OHEP 2021.

[22] Regional Greenhouse Gas Initiative

[23] The annual program report states the purpose as follows: "The Electric Universal Service Program ("EUSP"), enacted in the Electric Customer Choice Act of 1999 ("the Act"), was designed by the Maryland General Assembly to assist low income electric customers to retire utility bill arrearages, to make current bill payments, and to access home weatherization following the restructuring of Maryland's electric companies and electricity supply market." OHEP 2021, p. 1.

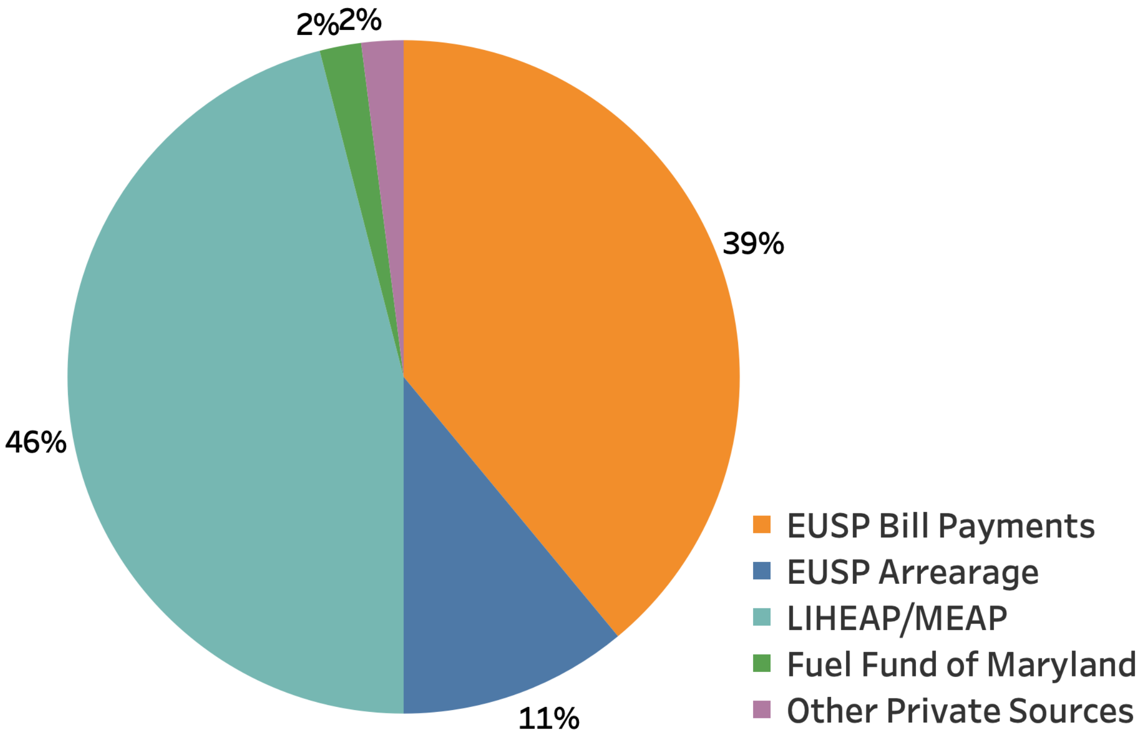
[24] Maryland House of Delegates, House Bill 606, 2021, at https://legiscan.com/MD/text/HB606/2021

[25] Strategic Energy Investment Fund. Activities for FY 2021, Volume 1. Baltimore, Maryland: Maryland Energy Administration, 2021, at https://energy.maryland.gov/SiteAssets/Pages/Strategic-Energy-Investment-Fund-%28SEIF%29-/FY21%20SEIF%20Report%20Vol%201%20Final.pdf; hereafter SEIF 2021.

[26] Fuel Fund of Maryland is the largest such charity. Small amounts also come from other charities. Among the private sources, only Fuel Fund resources have been included in this analysis.

[27] The Cancer Support Foundation is a leading Maryland non-profit in this arena.

Figure 1-1: **Sources of bill payment and arrearage assistance in Maryland in 2019.** The total for 2019 was $122 million.



In addition to direct assistance, weatherization and energy efficiency measures are used as a complement to assistance to lower energy bills and energy cost burdens. Maryland implements weatherization for low- and moderate-income households under three major programs, with total funding per year in the period 2017 to 2019 being about $30 million, including administrative expenses:[28]

- The federal Department of Energy's Weatherization Assistance Program (WAP);
- The EmPOWER program, which is the state's efficiency program funded by ratepayers and regulated by the Public Service Commission. It incentivizes efficiency, including weatherization for all households—both owner-occupied and rented. The program provides cost-free weatherization and efficiency measures for low- and moderate-income households. Detached single-family as well as multi-family structures are covered.

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[28] Report Greenhouse Gas Emission Reductions for CY 2019 Energy Efficiency for Affordable Housing, State of Maryland 2020, pdf. Pp. 1-2 2 and pdf p. 6, at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Publications/2020%20DHCD%20Agency%20Report.pdf

- The MEAP emergency program, which repairs or replaces heating, ventilation, and air conditioning (HVAC) equipment in cases where equipment has failed.

The above three programs are run by the Maryland Department of Housing and Community Development (DHCD). In addition, the Maryland Energy Administration provides funding for retrofitting low- and moderate-income households to a number of local governments and their agencies as well as to a variety of nonprofits. The budget for FY2023 is $16.5 million.[29] There are also charitable efforts that fund retrofits. In total the existing funding for retrofits for low- and moderate-income housing amounts to approximately $50 million per year. Weatherization is done at no cost to income-eligible homeowners who are living in their homes. For EmPOWER programs, landlords are required to furnish 50 percent of the cost of weatherization when high cost appliances, including heat pumps and air-conditioning, are involved, either from their own funds or other resources.[30]

Federal and state programs, as well as private funders and local governments, provide funding streams for these efforts. The federal government provides funds for efficiency improvements through the WAP; there are also other sources as well, such as the state's efficiency program. The state's community solar program has a low-income component whereby the state provides subsidies to enable developers to offer deeply discounted subscriptions to low-income households. The two in combination can significantly reduce energy bills. About $50 million a year is currently devoted to weatherization and efficiency programs, as noted above.

Finally, state, local, and private funds are also used to facilitate access to rooftop and community solar energy.[31] Maryland has a pilot program for community solar that includes incentives for participation by low- and moderate-income households. A principal aim for the pilot program is to provide renewable electricity to low- and moderate-income households at rates that are substantially lower than normal residential rates offered by utilities, enabling them to reduce their energy cost burdens. As will be discussed in **Chapter 5**, an outstanding policy issue is to ensure that the energy cost burden reductions from community solar participation are fully complementary to the state's energy assistance programs.

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[29] FY23 Low to Moderate Income Energy Efficiency Grant Program, Maryland Energy Administration, viewed on December 14, 2022, at https://energy.maryland.gov/govt/pages/cleanenergylmi.aspx

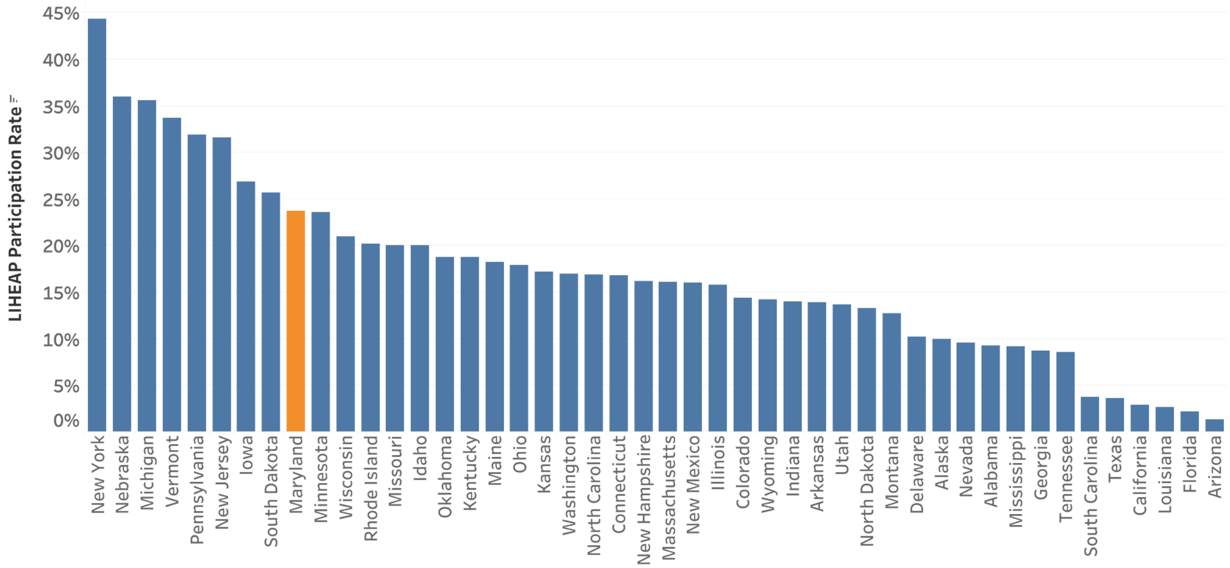
[30] Housing and Energy Programs, Energy Efficiency Program Operations Manual v.3, Department of Housing and Community Development, 2021, p. 12 and pp. 48-50, at https://dhcd.maryland.gov/Residents/Documents/wap/EnergyEfficiencyProgramOperationsManualv.3-2021.pdf

[31] Civic Works is an example of a non-government organization that does weatherization and solar installations for low- and moderate-income households. Baltimore Shines is a collaboration between Civic Works and the Baltimore City government.

1.1.2 Effectiveness of Existing Policies

Both energy bill assistance and weatherization programs are assessed in this report by two principal metrics: the fraction of eligible households that participate in the program and the extent to which the programs make energy bills affordable—that is, bring them to six percent of income or lower. A related metric is whether eligibility policies include all households that have energy cost burdens of more than six percent of income. The principal state criterion to qualify for all energy bill assistance programs is household income at or below 175 percent of the federal poverty level. The number of eligible households in 2021 was about 364,000, down somewhat from its peak of about 393,000 in 2016.[32] Eligibility was expanded by a 2021 law to include households with incomes up to 200 percent of the federal poverty level if the household had someone 67 years or older.[33] This leaves out the thousands of households in the 175 percent to 200 percent of federal poverty level range—or higher—who do not have an older adult in the household but do have energy cost burdens of more than six percent. Were the eligibility increased to 200 percent of the federal poverty level across the board, the total number of eligible households would be about 440,000.

Figure 1-2: **LIHEAP participation rates by state, 2021.** Percentage of eligible households that received assistance from the federal LIHEAP program (administered by the states) in Fiscal Year 2021—all types of assistance. *Source: LIHEAP Data Warehouse.*[34]



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[32] Custom report compiled from the LIHEAP Data Warehouse at https://liheappm.acf.hhs.gov/datawarehouse

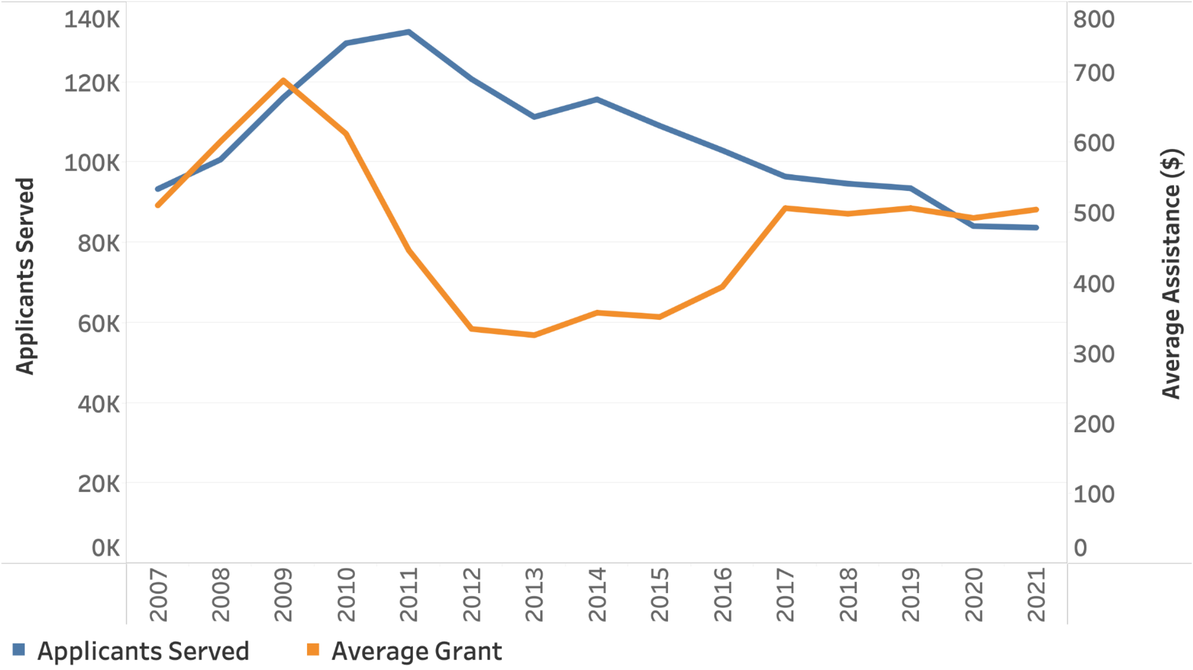
[33] Office of Home Energy Programs. Electric Universal Service Program: Proposed Operations Plan for Fiscal Year 2022. Baltimore, Maryland: Maryland Department of Human Services, December 2021, hereafter OHEP 2022 Plan.

[34] Custom report compiled from the LIHEAP Data Warehouse at https://liheappm.acf.hhs.gov/datawarehouse

In 2021, there were about 364,000 Maryland households eligible for MEAP (the name for LIHEAP in Maryland) under the 175 percent criterion.[35] However, only about 24 percent of those received MEAP assistance. While about three-quarters of qualified Maryland households do not receive MEAP grant assistance, the state's assistance rate for heating is still higher than the majority of states (**Figure 1-2**)

The number of households receiving assistance has declined significantly in the last decade. The vast majority of those who receive MEAP heating assistance also receive electricity bill payment assistance. **Figure 1-3** shows that the number of EUSP recipients has declined sharply from a peak of above 130,000 in 2011 to about 85,000 in 2021. The chart also shows the average amount of electricity bill payment assistance per household served in current (i.e., non-inflation adjusted) dollars. The assistance per household has fluctuated a good deal; although it has risen from its 2012-2015 low, it is still well below the high of the 2007-2010 period. Energy assistance appears to have risen in the 2007-2010 period at least partly in response to the precipitous rise in electricity rates during that time; rates rose by 16 percent from 2007 to 2008 and another 8 percent in the subsequent year.[36]

Figure 1-3: Maryland Electric Universal Service Program: Customers served and average assistance per customer per year, (current $, not adj. for inflation). *Source: OHEP 2021, Table 1.*



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[35] LIHEAP Data Warehouse at https://liheappm.acf.hhs.gov/datawarehouse

[36] Calculated from the Maryland State Electricity Profile, Energy Information Administration, Table 8. The full set of tables can be downloaded at https://www.eia.gov/electricity/state/maryland/state_tables.php

Figure 1-4 shows that the number of applicants for assistance has stayed roughly steady over the last decade; however, the rate of denials crept up in 2016 and stayed high, and then rose sharply during the COVID-19 pandemic, with about 40 percent of the applicants being denied.

Figure 1-4: Energy assistance applications, acceptances and denial rates. *Source: Office of Home Energy Program Reports to the Maryland Public Service Commission, Docket No. 8903, Various Years, at: https://webpsc.psc.state.md.us/DMS/case/8903*

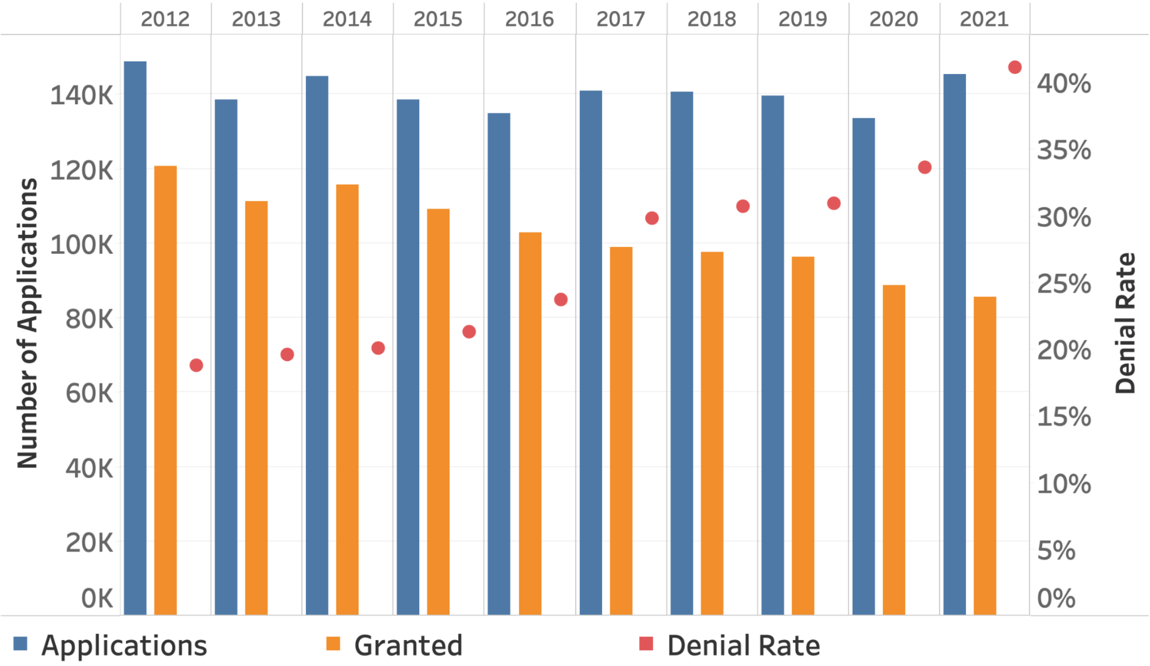
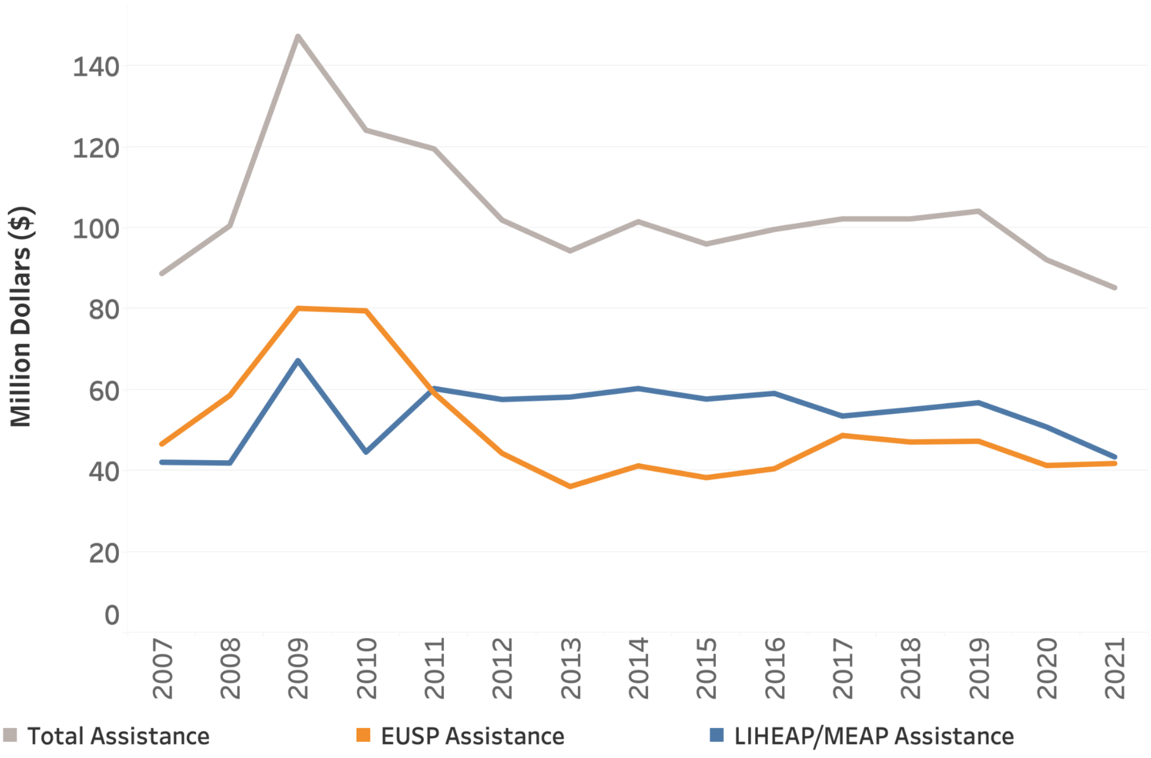


Figure 1-5 shows the combined MEAP and EUSP assistance amounts disbursed in the period since 2007. Some of the assistance is for clearing arrearages, which is included in the EUSP total. Approximately 15,000 households received assistance in 2021 to clear their electric bill arrearages so that they can start afresh. A household can receive arrearage clearance assistance at most once in five years. The totals in each category are in millions of current dollars. Total assistance has declined from the peak of 2008 when there was a severe economic recession. The dollar amounts disbursed have been approximately constant since about 2013; hence the assistance in inflation-adjusted dollars has actually declined, as was pointed out by the Office of People's Counsel in its 2021 filing with the Public Service Commission:

> The decline in BPA [Bill Payment Assistance] cannot be truly appreciated using nominal dollar amounts that do not reflect the effect of inflation.…When these inflation-adjusted values are plotted…a clear decline in the purchasing power of the EUSP BPA benefit is revealed. In fact, the average BPA benefit OHEP paid

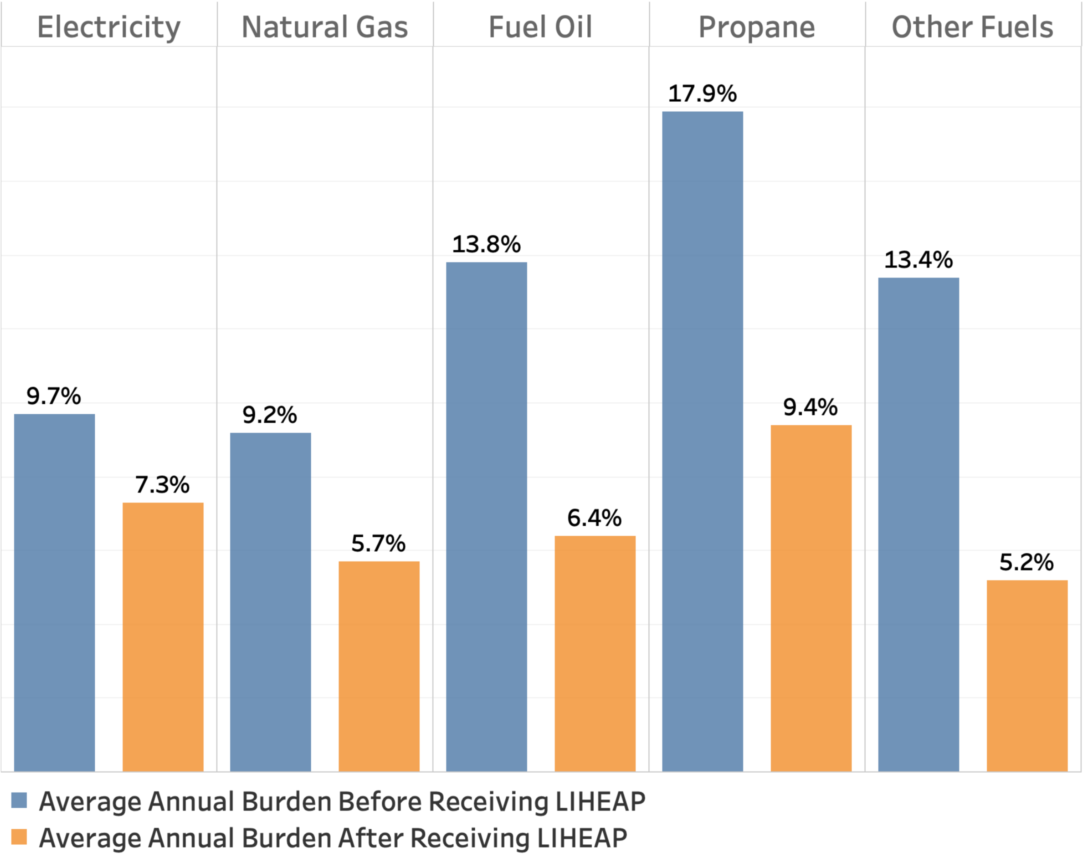
to participants in FY 2021 ($504) was over $368 less than the inflation-adjusted value of the BPA paid to customers in FY 2009 ($872.19).

Figure 1-5: EUSP, MEAP, and total assistance amounts to all households receiving energy bill payment assistance, including arrearages cleared. *Source: OHEP 2021, Tables 1 and 2.*



Overall, only about 26 percent of eligible households received some form of bill payment assistance in 2019, including amounts credited to utility bills and arrearage clearance. Most eligible households never apply. Those who receive assistance usually receive support through both MEAP and EUSP, lowering their energy cost burdens. In some cases, such as households using gas for heating, energy cost burdens are actually lowered, on average, to below six percent of income. However, many households despite the assistance still remain over the generally accepted affordability norm of six percent of household income, in particular those using propane, as can be seen in **Figure 1-6**.

Figure 1-6: Pre- and post-LIHEAP energy cost burdens, by heating fuel type, 2020. *Source: OHEP 2022 Plan, Table 9.*



As noted, the main problem is that the vast majority of eligible households do not receive assistance for a variety of reasons. The number of households getting assistance has actually declined over time, from about 134,000 who got LIHEAP assistance in 2010 to just 88,600 households in 2020.[37]

The severity of the energy cost burden problem for the lowest income bracket—those earning less than 50 percent of the federal poverty level—is shown, by county, in **Figure 1-7**. There were more than 75,000 Maryland households in this category in 2021.

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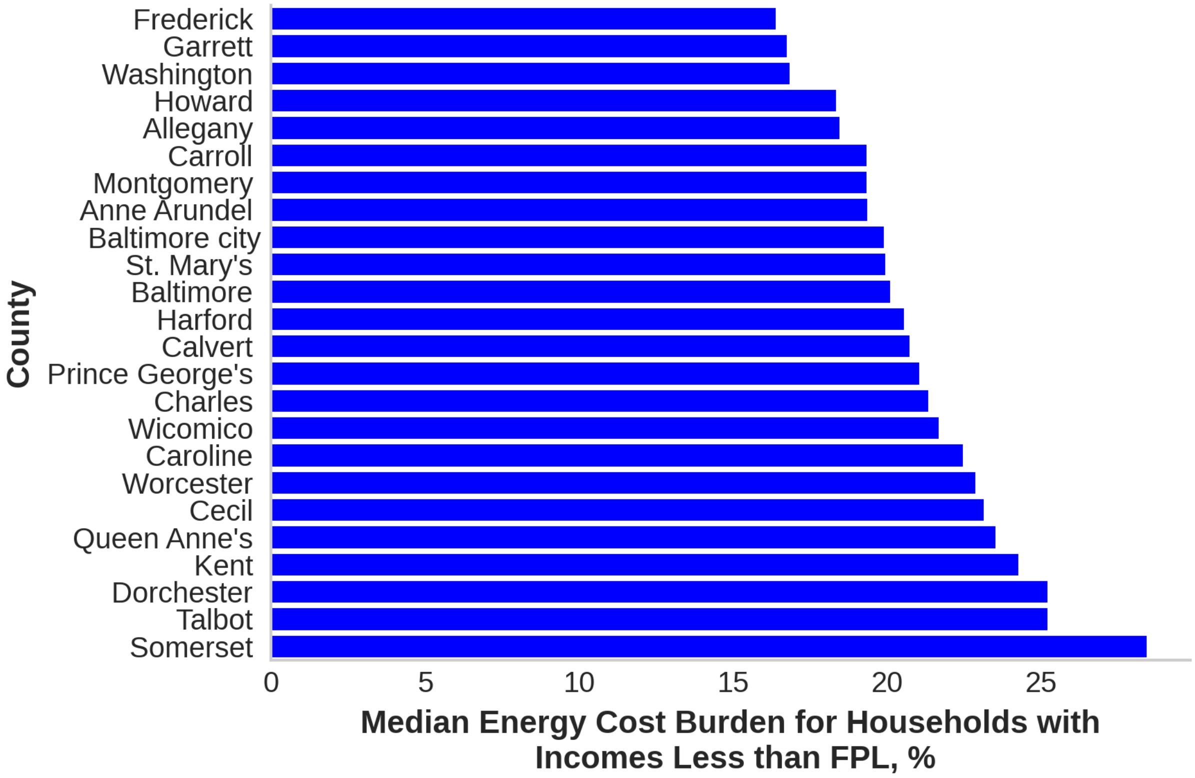
[37] OHEP 2021, Table 2. A recent paper published by the Just Solutions Collective has explored the many barriers facing low-income households in applying for and getting assistance as a major reason for the generally low rate of eligible households benefiting from energy assistance programs. Zully Juarez, Energy Burden and the Clean Energy Transition: Challenges and just solutions from energy assistance practitioners and advocates from around the country, Just Solutions Collective, 2022, at https://assets-global.website-files.com/5fd7d64c5a8c62dc083d7a25/6246ab05aca2107884fb1632_Energy%20Burden%20and%20the%20Clean%20Transition%20-r4.pdf

Figure 1-7: Estimated median energy cost burdens for Maryland households with incomes less than the federal poverty level, 2021.



Beyond programs for bill payment and arrearage assistance, Maryland's weatherization program is a principal strategy designed to reduce energy bills for low-income households. **Figure 1-8** shows the number of weatherizations of low- and moderate-income households carried out using funds from state and federal sources.

Since 2021, households with incomes less than 200 percent of the federal poverty level or less that 80 percent of the area median income are eligible for free weatherization through DHCD programs; thus, as of 2022, the eligibility for weatherization is more expansive than the eligibility for bill payment assistance. Almost half-a-million households are eligible for free efficiency improvements in Maryland. The application for bill payment assistance has a check-off box for customers to indicate whether they want such investments.[38]

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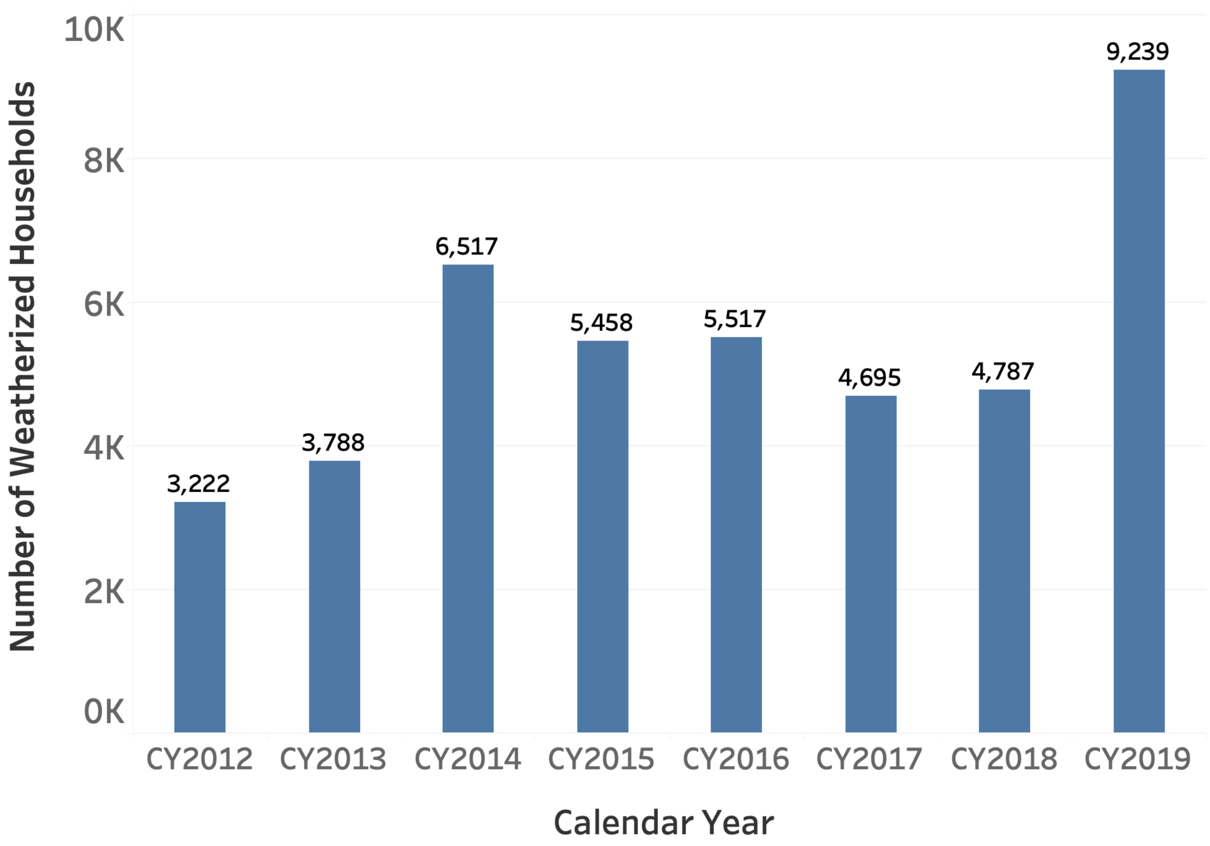
[38] Office of Home Energy Programs, State of Maryland, assistance application at https://dhs.maryland.gov/documents/DHR%20Forms/FIA%20Forms/English/OHEP/OHEP_-Application_2023_EN_Fillable.pdf In the rest of this report, we use the term "weatherization" to include both improvement of building envelope performance and appliance efficiency improvements.

Figure 1-8: Low- and moderate Income households receiving weatherization services in Maryland. *Source: Report Greenhouse Gas Emission Reductions for CY 2019 Energy Efficiency for Affordable Housing, State of Maryland 2020, p. 2.*



Historically, the actual number of weatherization participants, shown in **Figure 1-8,** has been an order of magnitude or more lower than the number of households getting bill payment assistance (**Figure 1-4** above). A 2020 report by the Department of Housing and Community Development on the weatherization program noted that the vast majority of cases where applicants for assistance indicate they want to participate in the weatherization program do not result in actual projects:

> DHCD receives a large number of client referrals through OHEP's energy assistance program, Network Partners, and other referring organizations. A high percentage (80-85%) of these leads do not convert to on-site projects for various reasons—clients may become unresponsive or do not fully understand the value in energy efficiency programs, and many renters cannot gain landlord consent for participation.[39]

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[39] 2021-2023 EmPOWER Maryland Program: Limited Income Program, Department of Housing and Community Development, August 31, 2020, p. 12.

Historically, only about one percent of eligible households have actually been able to participate in weatherization programs each year. In theory, this low rate means that it would take a century to weatherize all eligible homes; in practice it means that many or most eligible homes will never be weatherized. Recognizing this problem, the Department of Housing and Community Development has increased its target for annual weatherizations several fold for the current 2021-2023 program period.[40]

The Maryland Department of Housing and Community Development also finances “Net Zero or Net Zero Ready” construction for both single-family and multi-family affordable housing.[41]

1.3 Summary

Low- and moderate-income Marylanders routinely experience high energy cost burdens with adverse impacts on health, housing stability, and family finances. State assistance programs have effectively reduced energy cost burdens below six percent of income for many households, but energy remains unaffordable for many, despite assistance. However the largest problem by far is that they only reach slightly more than a fifth of eligible households. What’s more, the proportion of households receiving assistance has been declining, exposing the vast majority of energy cost-burdened households to financial hardship.

Besides ratepayers, unaffordable energy bills also create costs for taxpayers, insurance companies, and non-profit service agencies. For example, when low-income families become homeless due to financial stresses, state and local governments cover the cost of shelter. Homeless families tend to need more emergency room visits, the costs of which are covered by some combination of insurance companies, hospitals, and taxpayers.

The federal government provides funds for WAP; there are also other sources as well, like the state’s efficiency program; these reach only about one percent of the eligible households every year. The state’s community solar pilot program has a low-income component whereby the state provides subsidies to enable developers to offer deeply discounted subscriptions to low-income households. The two in combination can significantly reduce energy bills. Both are discussed in **Chapter 5** on policy.

In this report, we focus on residential buildings only since the issue of affordable energy applies to that set of structures; we note here that some of the policies and strategies in relation to climate change mitigation would also apply to commercial buildings.

In **Chapter 2** we explore the landscape of energy cost burdens and estimate the gap between present bills and affordable bills, defined as six percent of income.

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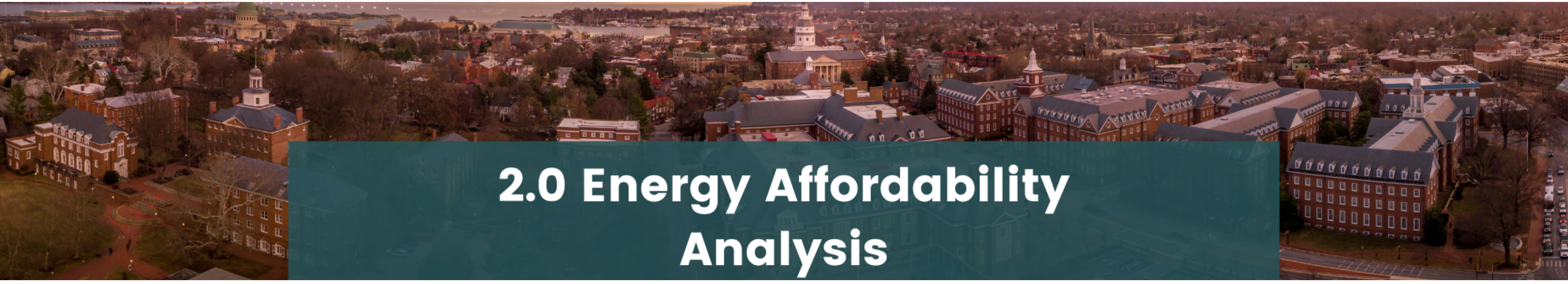
[40] Ibid. p. 9

[41] Ibid., p. 86



2.0 Energy Affordability Analysis

2.1 Introduction

In this chapter we examine various aspects of high energy cost burdens, including their causes, in geographic, technical, and demographic detail. This analysis is essential to understand the scope of the problem and the policies and strategies that can be used to address it (**Chapter 5**). For instance, energy cost burdens for rural homeowners are often correlated with propane costs, while city dwellers are more likely to be impacted by fluctuations in the price of natural gas. A detailed analysis of Maryland's existing energy cost burdens is therefore critical to identify the characteristics of communities and populations who may struggle to pay their energy bills and the most effective strategies to alleviate these burdens. Here we analyze energy cost burdens in geographic detail and by income bracket to help determine priority areas, housing types, and income groups that most need relief. The analysis also shows where clean energy investments might result in the greatest systemic reductions in energy bills to reduce the need for bill assistance to achieve affordability.

We first estimate the distribution of existing energy cost burdens across the state of Maryland. We then analyze trends in energy affordability across the Eastern Shore, Central Maryland, and Western Maryland and identify specific demographic groups, geographic regions, and populations that struggle to pay their energy bills. The goal of this analysis is to a) provide an energy affordability baseline against which the effectiveness of future initiatives can be measured and b) provide the data needed to tailor policies and programs to at-risk demographic groups and geographic regions. We discuss policies and programs that may help alleviate these burdens in the **Policy Section** (**Chapter 5**).

2.2 Measuring Affordability

By definition, variations in energy cost burdens depend on differences in energy costs and incomes. Because incomes are more variable than energy costs, they are the primary determinant of high energy cost burdens. Low-income households typically spend a larger fraction of their income on energy bills compared to other income groups, even though low-income households tend to consume less energy per household on average.[42] However, energy costs are still an important factor in determining energy cost burdens and vary

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[42] Krieger, E., Lukanov, B., Krieger E. et al. (2020). Equity-Focused Climate Strategies for Colorado: Socioeconomic and Environmental Health Dimensions of Decarbonization. *PSE Healthy Energy.*

substantially across different geographic regions,[43] climate zones, utility service areas, home types, and fuel types.

KEY FINDINGS

- Maryland has an affordability gap of $400 million; current annual assistance funds of $120 million only cover 30 percent.
- Higher electricity bills from third-party retail choice suppliers are responsible for roughly $30 million of the affordability gap; another $7 million is due to higher gas rates.
- Approximately 400,000 Maryland households are energy cost burdened—spending more than 6 percent of their income on energy.
- 90 percent of energy-cost-burdened households have incomes less than twice the Federal Poverty Level. Half of all energy-cost-burdened households are renters.
- Urban energy cost burdens are typically concentrated in certain neighborhoods, including historically red-lined areas.
- In Baltimore City, Black households spend on average 4 percent of their income on energy compared to 2.3 percent for the rest of Baltimore City's population.
- Rural homes reliant on expensive fuels—propane and fuel oil—in areas such as the Eastern Shore are the most cost-burdened, with very high energy bills.
- Targeted interventions for low- and moderate-income households can reduce annual affordability gaps from $400 million to $80 million while also helping to meet carbon targets.

Since detailed data on energy bills and household demographics are not publicly available, we use models based on geographic, demographic, housing-related, and climate variables to estimate household-level electricity and fuel use in a simulated portfolio of all residential buildings in Maryland (see **Appendix** for methods). Our analysis includes the most commonly used residential energy fuels in Maryland: natural gas, electricity, fuel oil, and propane. Using these estimates of household spending, we are able to aggregate households across Maryland, such as homes using natural gas for heating, and investigate trends in affordability across various types of households.

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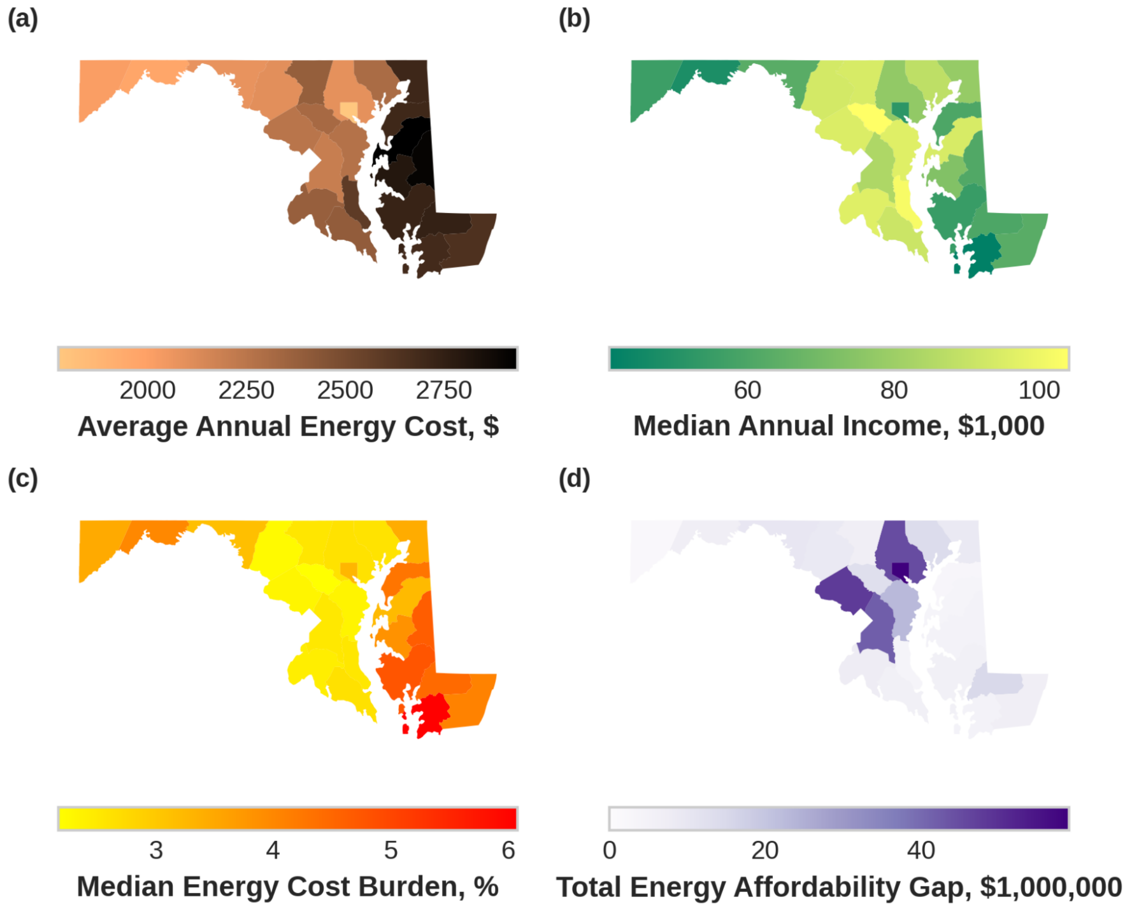
[43] B. Lukanov, Makhijani, A., Shetty, K., Kinkhabwala, Y., Smith, A. and Krieger, E. Pathways to Energy Affordability in Colorado. (2022). *PSE Healthy Energy.*

Indicators of energy affordability are derived from these estimates of household income and annual energy costs as shown in **Figure 2-1a,b**.[44] One indicator used here is *energy cost burden*—the percentage of household income spent on residential energy needs. The median energy cost burdens within counties in Maryland are shown in **Figure 2-1c**.

Figure 2-1: Energy bill and income statistics for counties in Maryland aggregated from household scale estimates generated for this report.



As a metric, energy cost burden helps us compare energy affordability between different populations and is also a key indicator of energy insecurity, the inability of a household to meet their basic energy needs.[45] Typically, energy cost burdens in excess of six percent are

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[44] All data regarding energy affordability rely on energy use and cost estimates generated for this report as described in the **Appendix**.

[45] 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

considered high and present an undue strain on household finances.[46] This threshold leads to a secondary metric of affordability, the *energy affordability gap*: the total amount of money paid for energy bills in excess of six percent of a household's income.[47]

The total affordability gap by county is mapped in **Figure 2-1d**. Counties with greater populations and greater energy cost burdens have larger affordability gaps. This metric helps to quantify the magnitude of the affordability problem and the associated opportunities to provide savings to ease household budgets. Combined, these two metrics serve to both target households in need and identify the financial extent by which homes are burdened.

Energy costs tend to be disproportionately higher for communities of color, even when controlling for household income.[48,49,50] Systemic and structural inequities have contributed to this disparity between racial and ethnic groups, from federal government-sponsored segregation in housing, to redlining (refusing to insure mortgages in and around Black neighborhoods).[51] Such 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.[52,53,54] Because of such systemic exclusions, Black, Indigenous, and People of Color (BIPOC) communities also tend to live in less efficient and less healthy homes, and may experience higher costs when investing in energy efficiency upgrades.[55,56,57] BIPOC

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[46] The federal Department of Housing and Urban Development defines affordable housing costs as 30 percent of income, including utility bills. Twenty percent of this amount—or six percent of income—is generally considered the affordability limit for energy bills. See Arjun Makhijani, Addressing Energy Burden: Estimate of Funds for Low- and Moderate-income Households during the Transition to a Clean, Regenerative, and Just Energy System, Just Solutions Collective, 2021, p. 18. At https://ieer.org/wp/wp-content/uploads/2022/02/Addressing-Energy-Burden_Just-Solutions-Collective.pdf

[47] Ibid.

[48] Kontokosta, C., V. Reina, and B. Bonczak. (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

[49] Lyubich, E. (2020). "The Race Gap in Residential Energy Expenditures". *Energy Institute at HAAS*. WP-306

[50] Krieger, E., Lukanov, B. et al. (2020). Equity-Focused Climate Strategies for New Mexico: Socioeconomic and Environmental Health Dimensions of Decarbonization. *PSE Healthy Energy*.

[51] Gross, T. (2017, May 3). A 'Forgotten History' Of How The U.S. Government Segregated America. https://www.npr.org/2017/05/03/526655831/a-forgotten-history-of-how-the-u-s-government-segregated-america

[52] Danyelle Solomon, C. M. (2019, August 7). Systematic Inequality and Economic Opportunity. https://www.americanprogress.org/issues/race/reports/2019/08/07/472910/systematic-inequality-economic-opportunity/

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

[54] Jargowsky, P. (2015). Architecture of Segregation: Civil Unrest, the Concentration of Poverty, and Public Policy. *New York: The Century Foundation*.

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

[56] 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.

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

and low-income households are more often renters, more often struggle to pay fluctuating bills, face the risk of utility shut-offs, and otherwise struggle with energy insecurity, which can exacerbate underlying health conditions and reduce resilience to climate extremes.[58]

2.3 Energy Affordability in Baltimore City

Baltimore City presents challenges and opportunities that differ from less urban and rural areas in the rest of Maryland. First, low- and moderate-income households in Baltimore City are more often renters, accounting for roughly 70 percent of households compared to 50 percent in the rest of Maryland. The type of housing in Baltimore City is also different. In Baltimore, low- and moderate-income households mostly live in single attached homes such as row houses (47 percent) or multi-family structures (42 percent) with the remainder living in single detached homes (11 percent). For low- and moderate-income households in the rest of Maryland, single attached homes are more rare (17 percent) while multi-family homes are still somewhat common (35 percent) and single detached homes much more common (45 percent) with the remaining households living in manufactured or mobile homes (3 percent). The increased percentage of renters living in multi-family or single attached structures in Baltimore City then influence the type of policies needed in order to bring down energy bills for these households.

Although energy bills for low- and moderate-income households in Baltimore City are typically lower than the rest of Maryland, energy cost burdens remain high due to lower incomes. The lower energy bills in Baltimore are due in part to smaller home sizes that require less energy to heat or cool, and the use of piped natural gas, which enables the avoidance of more costly fuel oil or propane. For these reasons, the average low- and moderate-income household's annual total energy usage and cost across all fuels in Baltimore is 69 MMBTU and $1,700 as opposed to 75 MMBTU and $2,070 in the rest of Maryland. However, incomes in Baltimore City are lower than surrounding counties. For example, Baltimore City's median annual income is $54,000, significantly less than $91,000 for Maryland as a whole.[59] Additionally, while Baltimore City only contains roughly 11 percent of Maryland's households, it is home to 19 percent of Maryland's low- and moderate-income households.

Fine-grained, census-tract-level maps in **Figure 2-2** demonstrate that affordability challenges are not uniformly distributed across Baltimore City but are concentrated in certain

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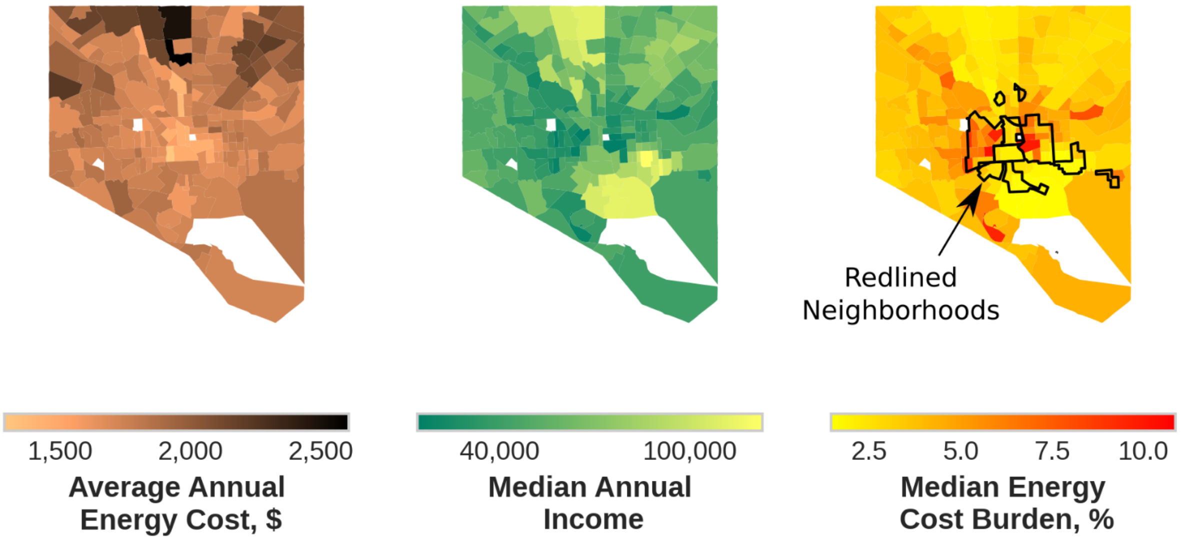
[58] The Race and Energy Nexus. (2021). *Pecan Street*. https://www.pecanstreet.org/raceenergynexus/

[59] Baltimore City and Maryland Quick Census Facts 2017-2021; at https://www.census.gov/quickfacts/baltimorecitymaryland and https://www.census.gov/quickfacts/fact/table/MD/PST045221

neighborhoods. The neighborhoods with the highest energy cost burdens historically have also been the most disadvantaged, due in part to policies such as redlining, which disproportionately affected BIPOC households. The median incomes for BIPOC households in Baltimore City, which represent roughly 70 percent of households in the city, is only $44,000, as compared to $78,000 for households categorized as non-Hispanic White. These inequities result in a disproportionate amount of Maryland's energy affordability challenge lying in Baltimore City and, more specifically, its historically disadvantaged populations.

Figure 2-2: Energy bill, income statistics, and energy cost burden indicators for census tracts in Baltimore City. "Redlined neighborhoods" outlined in black received the lowest score by the Home Owners' Loan Corporation.[60]



2.4 Energy Cost Burdens by Income

Income inequality is the primary driver of differences in energy cost burdens. While 80 percent of households earning less than twice the federal poverty level are energy cost-burdened, only 3 percent of households greater than twice the federal poverty level are energy cost-burdened. For this reason, we focus primarily on the 20 percent of Maryland's households with incomes less than twice the federal poverty level who we categorize as low- and moderate-income. In **Figure 2-3**, we plot the energy cost burden distribution of households within federal poverty level-derived income brackets. We see here that practically

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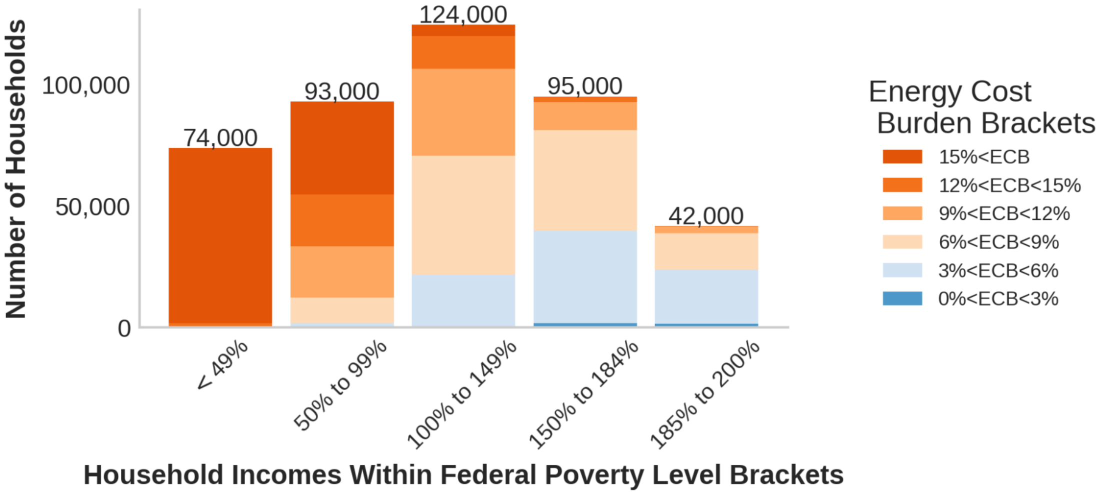
[60] Mapping Inequality: Redlining in New Deal America. https://dsl.richmond.edu/panorama/redlining/#loc=11/39.293/-76.79&city=baltimore-md&area=B1

all households earning less than the 100 percent of the federal poverty level in Maryland have energy cost burdens that exceed the six percent threshold. As expected, higher income households are less burdened.

Figure 2-3: Number of households within federal poverty level brackets broken down by energy cost burden (ECB). Not shown in the figure are ~50,000 households with income above 200 percent of federal poverty level and cost burdens greater than six percent.



Energy cost burdens capture the relative burden for a household, but do not directly represent the cumulative magnitude of the financial challenge statewide, which is better captured by the energy affordability gap metric shown in **Figure 2-3**. The total estimated annual energy affordability gap for 2021 in Maryland is roughly $400 million.[61] The gap is highest for the lowest income bracket despite the fact that the number of households in this bracket is comparatively low. This is due to the fact that, on average, a greater proportion of the lowest income households' energy bills must be paid down in order to reach the six percent threshold. This sum, then, represents the total annual funds needed in the form of bill assistance to ensure that no household spends more than six percent of their income on their energy needs. There are also roughly 50,000 households with incomes above 200 percent of the federal poverty level who have energy cost burdens greater than six percent. In these cases, they are generally only slightly above six percent. Our estimate of the affordability gap of $400 million includes these households (not shown in **Figure 2-3**).

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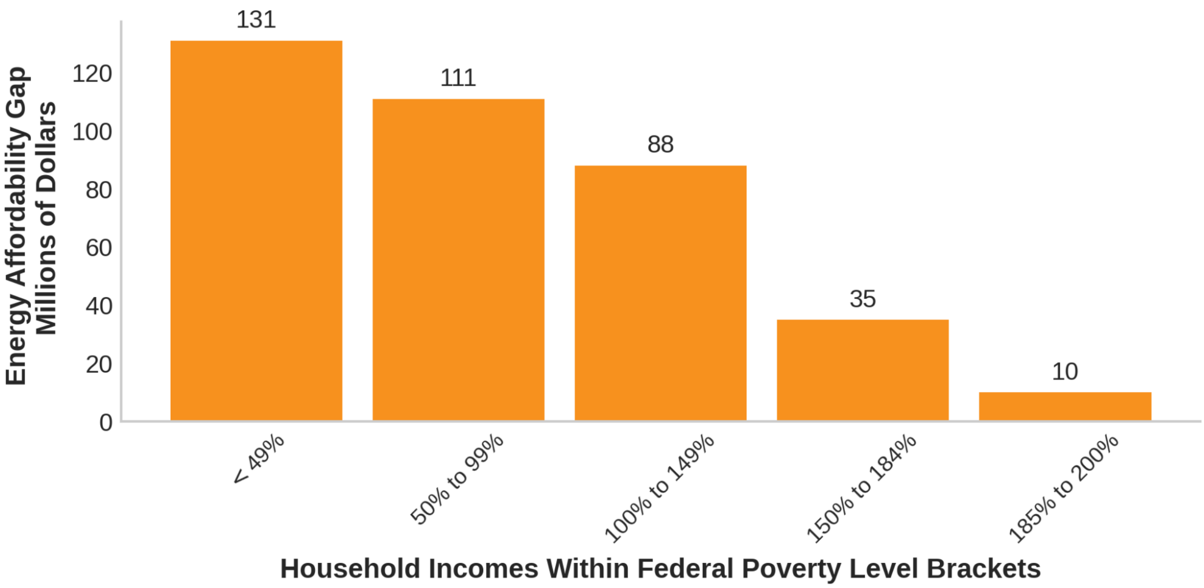
[61] Fisher, Sheehan, and Colton have previously estimated $708 million for this gap. Differences in estimates of energy affordability gaps are discussed in the **Appendix**. We have adjusted our estimate of $350 million upward to $400 million to account for the somewhat lower energy use estimates that our method produces compared to official data. See the **Appendix**.

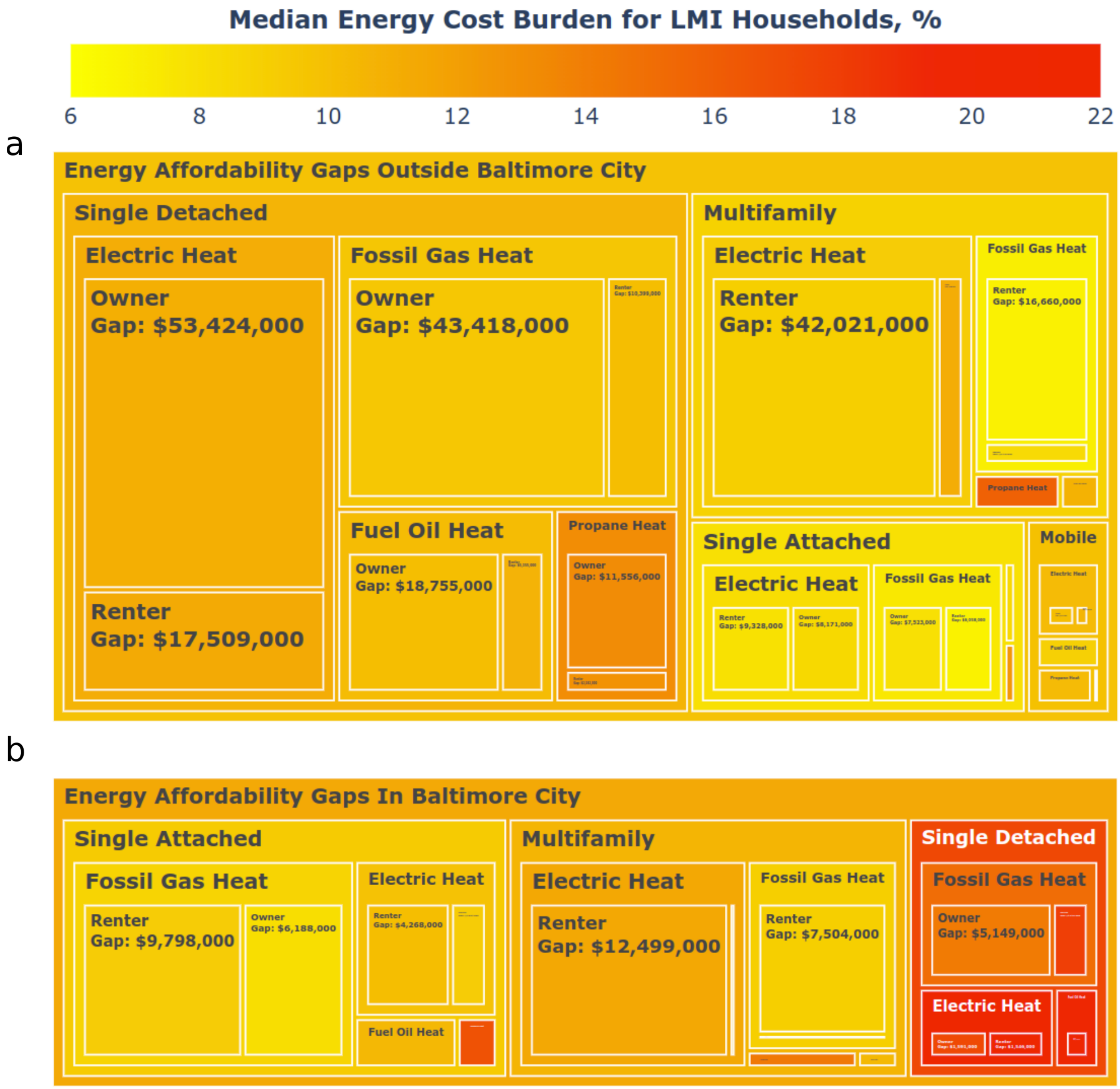
Figure 2-3: Total energy affordability gap within income groups defined by the federal poverty level.



2.5 Energy Cost Burden Analysis

We see significant variations in energy affordability that are driven by a variety of factors, which function together to increase or decrease a household's burden in complicated ways. Here, we identify populations that may benefit most from targeted interventions by grouping together households according to their location, type of heating fuel, type of home, and whether they rent or own their home. In **Figure 2-4**, we summarize the affordability indicators for low- and moderate-income households broken down by these categories. Areas of rectangles in this figure are proportional to affordability gaps while their shading indicates the median cost burdens thus representing the interplay between these two indicators. For example, single detached homes outside of Baltimore City heated by propane have higher cost burdens than homes heated by gas indicated by the redder color in the figure, but propane-heated homes have a smaller *overall* gap—indicated by the size of the rectangle—than gas-heated homes, since those homes are less common. Importantly, since this figure only considers low- and moderate-income households, it does not represent the differences seen within the entire population. For example, in Baltimore City, the energy cost burden for just low- and moderate-income households in single detached homes is the highest among the different home types due to larger average bills as shown in **Figure 2-4b**, but the average burden for all households in Baltimore City in single detached homes is actually the smallest since the median income for such households is much higher. In the following sections, we investigate the causes for the trends shown here.

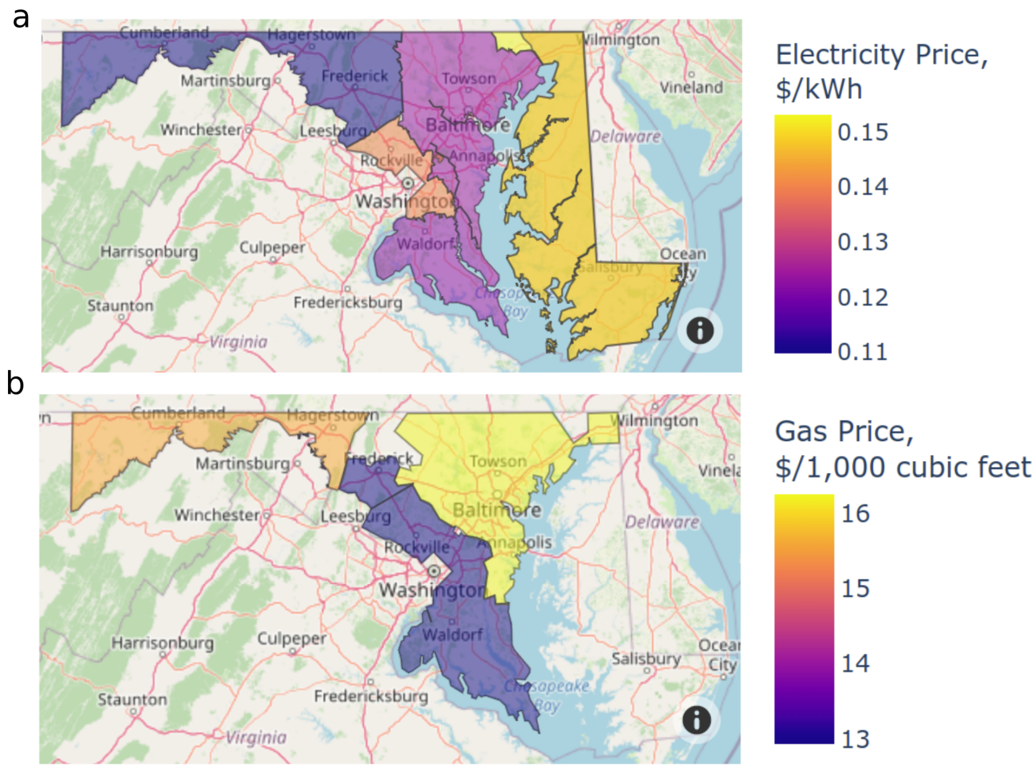
Figure 2-4: Treemap of the breakdown of the total energy affordability gap for low- and moderate-income households **(a)** outside Baltimore City and **(b)** in Baltimore city categorized by home type, fuel used for space heating, and renter versus owner-occupied status. Color shading indicates the median energy cost burden and the size of the rectangles are proportional to the total energy affordability gap for each subset of households.



2.5.1 Energy Cost Burdens by Fuel Type

The type of fuel used for water and space heating strongly influences overall energy bills due to significant differences in rates charged for each fuel. In this chapter, we only consider the financial impacts of residential consumer rates for each of these fuels and reserve discussion of the health, safety, reliability, and climate impacts of these different fuels in the following chapters. For natural gas and electricity, we use rates specific to the largest utility service areas shown in the maps in **Figure 2-5**. **Table 2-1** summarizes the average rates for each of these different fuels for the year 2021.

Figure 2-5: Average annual prices from 2021 for (**a**) the six largest bundled electricity utilities and (**b**) the three largest natural gas , excluding impacts from retail choice marketers.[62]



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[62] Prices were estimated by dividing total residential revenue by total residential sales for each utility as reported to the EIA for 2021 in forms EIA-861 and EIA-176 for electricity and natural gas respectively.

Table 2-1: Average 2021 rates for different fuels used across Maryland.

Fuel Type	Average rate across Maryland in 2020, Dollars per MMBTU[63]
Electricity	$39.20 excluding retail choice ($0.134/kWh)
Fossil Gas	$14.50 excluding retail choice ($1.45/therm)
Propane	$27.79
Fuel Oil	$18.43
Wood	$7.04

As of 2021, natural gas was the most affordable fuel per unit energy (other than wood), propane was the most expensive fossil fuel, and electricity the most expensive per unit energy. However, comparison of fuels based on cost per unit energy does not provide the full picture. Although electricity has a higher cost per unit of energy delivered, using electrically-powered efficient heat pump technology can drastically reduce the total energy needed to heat a home and, for most homes, can provide the lowest energy bills. **Figure 2-6** plots the expected savings in annual energy bills for homes when outfitted with efficient heat pumps.[64] These findings are in line with other related studies.[65] We assume conversion to an efficient heat pump results in average annual heating energy savings of 72 percent, which corresponds to a heat pump seasonal coefficient of performance (SCOP) value of 3.0 replacing older thermal heating sources with efficiencies of 80 percent.[66] Most new residential construction already relies on efficient electric heat pump technology due to their many benefits. For example, using rates for the year 2021 shown in **Figure 2-5**, nearly all homes experience energy bill savings when the cost of conversion is excluded. If we group households by their current space heating fuel, we find average annual savings of $150, $352, $780, and $476 for natural gas, fuel oil, propane, and electric resistive heating respectively. We assume here that, at present, existing heat pumps are primarily in detached homes while homes in multi-family structures use electric resistance heating. The amount a natural gas-using household saves is highly dependent on the local rates and climate. Geographically,

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[63] Average electric and natural gas rates for utilities were estimated by dividing revenue by sales as reported by the EIA in forms EIA-861 (https://www.eia.gov/electricity/data/eia861/) and EIA-176 (https://www.eia.gov/naturalgas/ngqs/#?report=RPC&year1=2018&year2=2021&company=Name) respectively and then averaged by total number of customers. Rates for other fuels were obtained from the EIA State Energy Data System. https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_btu_res.html&sid=US

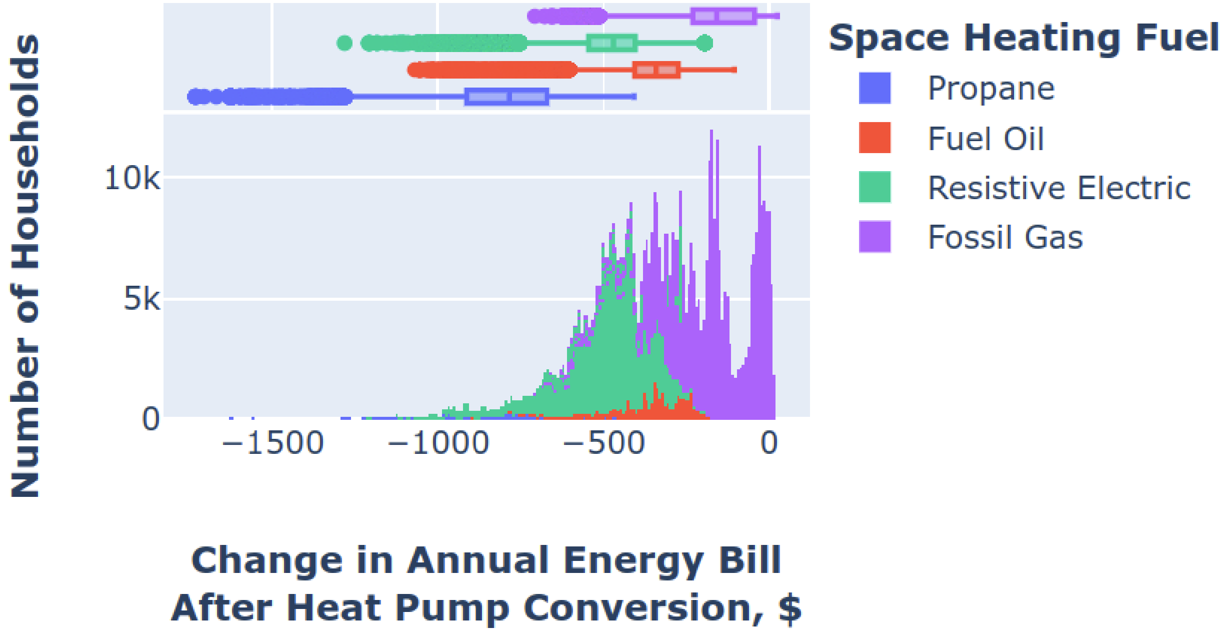
[64] These costs exclude conversion costs and only considers usage. Incorporation of conversion costs is discussed in **Chapter 5**.

[65] Deetjen, T. A., Walsh, L., & Vaishnav, P. (2021). U.S. residential heat pumps: the private economic potential and its emissions, health, and grid impacts. *Environmental Research Letters*, *16*(8), 084024.

[66] https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/MWG/Decarbonizing%20Buildings%20in%20Maryland.pdf. Table 3. We assume that, in general, home heating will be electrified when the furnace or boiler would otherwise be replaced.

the savings are greatest where electricity is cheap and natural gas is expensive (see **Figure 2-5)** such as Western Maryland. Savings are lowest in Montgomery and Prince George's Counties where the opposite was true in 2021. However, the price of natural gas fluctuates substantially, which leads to significant uncertainty regarding expected savings over time. A recent report for Maryland[67] cited that conversion to heat pumps are economic (NPV>0) for only 20 percent of natural gas heated homes in the year 2019; however, using rates from 2021 and funding available from the Inflation Reduction Act for low- and moderate-income households discussed in **Chapter 5**, we see that value shift to greater than 90 percent. With improvements in heat pump technology, expected increases in residential natural gas prices discussed in **Chapter 4**, and a warming shift in climate, the annual savings provided by electric heat pumps are only expected to increase.

Figure 2-6: Changes in annual energy bill after conversion to electric heat pumps broken down by fuel type at 2021 rates.



Importantly, the above comparison of heat pumps with other heating technologies excludes many of the additional benefits of electrification. For example: space cooling from high-end heat pumps is more efficient on average than conventional air conditioners thus providing savings in the summer; indoor humidity is better controlled with heat pumps providing cleaner and healthier indoor air in humid environments; retirement of indoor fossil fuel use

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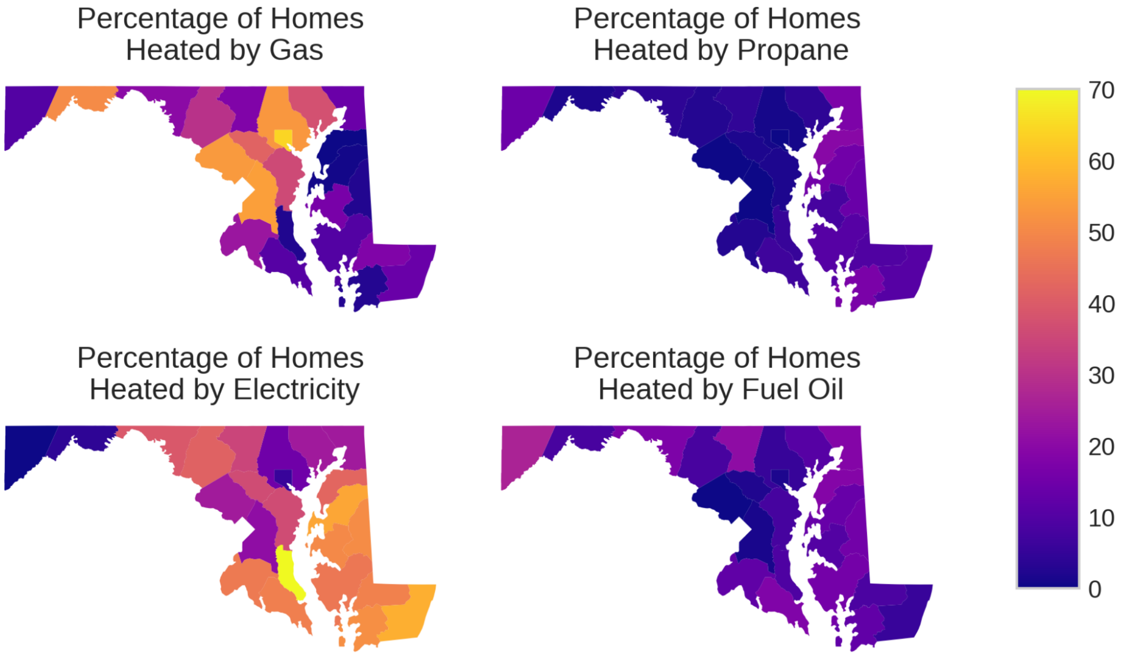
[67] Ibid. Reported on page 13, cited from Mayernik, J. Cost Effectiveness of Electrification with Air-Source Heat Pumps. Presentation to the Maryland Commission on Climate Change's Buildings Subgroup. August 2020.

improves indoor air quality as discussed in **Chapter 3**; heat pumps provide space cooling that many homes currently lack—but which they will increasingly need as the climate warms; and heating with heat pumps instead of fossil fuels reduces the overall climate impacts of heating.[68]

Geographic differences in affordability are largely driven by fuel choice shown in **Figure 2-7**. Since space heating is the largest end use for residential energy consumption, we use the fuel chosen for space heating to characterize homes even though appliances and water heaters may use different fuels. Where piped natural gas is available, typically in more urban areas, it is the most common heating fuel. In geographies with milder winters along the eastern coast of Maryland, there is limited natural gas service and relatively more usage of the more costly fuels—fuel oil and propane. The different penetrations of fuels contribute to the surprising effect that, although the *total* energy used for heating is lower in the milder winters along the Eastern Shore, household bills are not as low as would be expected because the fuels used are more expensive (see **Figure 2-1a)**.

Figure 2-7: Percentage of homes by county using the four most common fuels for home heating.



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[68] IEA, Relative CO_2 emissions from the operation of air-source heat pumps compared with the most efficient condensing gas boilers by region in the Net Zero Scenario, 2010-2030, IEA, Paris https://www.iea.org/data-and-statistics/charts/relative-co2-emissions-from-the-operation-of-air-source-heat-pumps-compared-with-the-most-efficient-condensing-gas-boilers-by-region-in-the-net-zero-scenario-2010-2030, IEA. Licence: CC BY 4.0

In addition to the fuels described above, less common fuels used in Maryland include wood and coal, with the coal heated homes almost exclusively found in Garrett County. Prices for these fuels are difficult to estimate accurately. For example, some wood-burning homes collect their own wood from their own land. While such homes are more exposed to indoor air pollutants than electrically-heated homes, it is difficult to estimate their energy bills.

2.5.2 Home Type and Renter Status

Home type is another strong indicator of energy affordability challenges. The U.S. Census categorizes homes into the following: detached single-family houses, attached single-family houses (e.g. row homes), apartments in buildings with 2-4 units, apartments in buildings with five or more units, and mobile homes. Here, we group all apartments into multi-family units with the remainder being single-family homes. Factors such as geographical location, fuel types, income of habitants, and size drive energy affordability differences between these homes. We discuss the significant trends between home types shown in **Figure 2-4** above and present detailed breakdowns based on fuel use for space heating, energy bills, and ownership status in **Table 2-2**.

Table 2-2: Statistics of energy cost and affordability gap for all Maryland households broken down by home type.

Home Type	Average Annual Energy Cost, $	Median Annual Income, $	Median Energy Cost Burden, %	Total Gap, Million $	Percent of Gap Renter Occupied
Single Detached Home	$2,617	$99,000	2.6%	$196 M	21%
Single Attached Home	$1,886	$80,000	2.3%	$58 M	55%
Multifamily w/ 2-4 Units	$1,667	$42,000	3.8%	$18 M	93%
Multifamily w/ 5+ Units	$1,654	$58,000	2.8%	$74 M	90%
Mobile Home	$2,162	$44,000	4.8%	$9 M	30%

Across Maryland, 55 percent of the total affordability gap is concentrated in single detached homes despite the fact that only 39 percent of low- and moderate-income households live in single detached homes. This is driven in part by low-income households with high energy bills in rural areas. These single detached homes also disproportionately use more expensive fuels for heating. The average energy bill for just the low- and moderate-income households in single detached homes is $2,350 compared with $1,910 for all low- and moderate-income households. These homes are also typically owner-occupied, and these owner-occupied homes account for 79 percent of the single detached home affordability gap.

In multifamily housing, however, 90 percent of the energy affordability gap for low- and moderate-income households is in renter-occupied homes. These homes are primarily found in urban areas of Maryland. Specifically, 57 percent of the gap from multi-family homes is found in Baltimore City (23 percent), Prince George's County (15 percent), and Montgomery County (19 percent) with the latter two counties representing closer-in suburbs of Washington, D.C. In these homes, 95 percent of the gap is found in homes heated by electricity or natural gas.

Single attached homes (or rowhouses) share trends that lie somewhere between apartments and single detached homes. They are more often owner-occupied than apartments but less so than detached homes.

Mobile homes are a less common but unique subset of homes in Maryland. While approximately 1.2 percent of all Marylanders live in mobile homes, that number rises to 2.5 percent for low- and moderate-income households, representing also 2.5 percent of the total affordability gap. They also have a median cost burden of 4.8 percent, the highest of the home types considered here. Although heating needs are typically lower for these homes given their smaller floor area, they tend to pay outsize bills due to poorer insulation and their increased reliance on propane or fuel oil for space heating. These two fuels account for 23 percent and 22 percent of the mobile home affordability gap respectively; these homes are most likely to benefit from fuel switching to efficient electric heat pumps.

2.5.3 Race and Ethnicity

Disadvantaged racial groups on average experience greater degrees of energy poverty. The primary cause is due to severe income inequality between racial groups. The median household incomes for Maryland households identifying as White, Hispanic, and Black, are roughly $90,000, $75,000, and $70,000 respectively, with corresponding median energy cost burdens of 2.5, 2.9, and 2.9 percent. However, this disparity dramatically increases in certain geographical areas. In Baltimore City, while the median energy cost burden is only 2.2 percent for White households, it is 3.0 percent for Hispanic households, and increases to 4.0 percent for Black households, reflecting a racial income gap, among other factors.

The disparities described above between racial groups are primarily driven by income inequality, but do not fully capture additional disparities that may exist due to differences in cost. Studies[69] have shown using fine scale raw data that historically disadvantaged racial groups still experience even greater energy cost burdens often due to inhabiting less efficient homes (which in turn may be related to historical inequities). Due to insufficient data specific to Maryland to predict differences in efficiency between households of different racial groups, we do not fully account for the disparities in energy efficiency and thus expect that energy cost burdens for historically disadvantaged groups are likely even higher than the values presented here.

2.5.4 Utility Type

Maryland customers are served by three kinds of electric utilities: investor-owned (89 percent of households), cooperative (10 percent), and municipal (1 percent). While electricity and gas rates are similar across the three utility types, total energy costs in areas served by coops tend to be higher largely because of the higher prevalence of fuel oil and propane as heating fuels. Coops also have a larger fraction of detached homes which have greater heat losses per unit area than multi-family structures. Electricity costs depend on whether the home is electrically heated and, if so, on the type, and quality, of structure.

Beyond the regulated bundled utility services shown above, Maryland households also have the option to choose an alternative energy supplier for electricity or natural gas. Third party suppliers acquire electricity and natural gas on the deregulated wholesale markets and deliver them to retail customers via the regulated electricity and natural gas distributed infrastructure. Customers pay for the electricity and natural gas commodity costs as charged by third party suppliers, and for distribution and other costs, such as taxes and monthly connection charges, they pay the regulated rates. Retail choice served roughly 404,000 residential customers in 2021, or 17.6 percent of all Maryland households, from 42 different retail supplier companies. Regulated retail electricity supply rates, with the energy commodity (electricity or natural gas) bundled with the distribution costs, varied in 2021 from $0.08 to $0.14 per kWh. While customer geographical data is not available for each third-party

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[69] Tong, Kangkang, et al. "Measuring social equity in urban energy use and interventions using fine-scale data." *Proceedings of the National Academy of Sciences* 118.24 (2021): e2023554118.

retail energy supplier, we calculate that retail choice electricity residential accounts paid more, on average, than electricity customers who choose Standard Offer Service.

For example, in 2021, the statewide weighted average delivery and supply electricity rate for the bundled regulated customers was approximately $0.128 per kWh. All Maryland utility residential customers paid a weighted average delivery rate of $0.056 per kWh, regardless of which entity supplied their electricity. Maryland's weighted average third party electricity supply rate in 2021 was $0.10 per kWh compared to regulated utility rate of $0.072 per kWh. While regulated customers paid all-in $0.128 per kWh, 404,000 retail choice energy customers rates averaged 22 percent more: all-in $0.156 per kWh, resulting in an average of $291 more per account. For this reason, retail choice households spend more on energy on average than households on Standard Offer Service supply. Assistance provided to low- and moderate-income households who are on third party supply is less effective in reducing energy cost burdens because, in effect, some of the assistance just flows to third party suppliers to pay the excess costs, rather than reducing the energy cost burden. For example, a household with an income of $20,000 and an energy cost burden of 10 percent would see their burden reduced to 7.5 percent with assistance of $500; a typical third party supply rate would increase the cost by about $300, and the burden to 11.5 percent. The same assistance would leave the households with a post-assistance cost burden of 9 percent.

Detailed data on demographics regarding who is more impacted by retail power marketing companies is not available. In order to incorporate these rates into the dataset presented here, we randomly assigned homes to retail choice companies according to the number of delivery-only customers reported by utilities within their respective service areas. Alongside the local delivery rate, we added a weighted average wholesale electricity rate of $0.10 per kWh for these retail choice customers. Incorporating retail choice for the fraction of households that are low- and moderate-income on a proportional basis resulted in an increase of the total affordability gap by $30 million as compared to a scenario in which all households would have used their standard offer service for electricity. Moreover, given that customers of retail power marketing are often low-income customers, we performed a sensitivity analysis in which only households earning less than four times the federal poverty level (roughly half of all households) were customers of retail power marketing. This increased the total affordability gap for electricity by $30 million.

Retail choice is also available for natural gas customers. Data for rates for these utilities are even less transparent than for retail choice for electricity consumers. We do know that 200,000 customers belong to retail choice for their natural gas. A conservative estimate from a survey of energy bills is that retail choice adds an additional $2.50 per MMBTU to rates, approximately a 17 percent increase. This adds about $7 million to natural gas bills of low- and moderate-income households.

Overall, the impact of third party supply on low- and moderate-income energy bills for third-party electricity and gas rates above standard offer service is about $40 million.

2.6 Additional Considerations for Energy Affordability

2.6.1 Changes in Natural Gas Prices

Energy bills depend on energy rates and rate structures. Thus far, our analysis has assumed rates approximated from the year 2021[70] shown in **Table 2-1**. However, rates can change, especially for natural gas. It is therefore important to investigate how historic and projected rates impact affordability.

The highly variable price of natural gas can lead to drastic changes in energy affordability. While actual natural gas prices for BG&E increased 15 percent between 2018 and another 7 percent from 2020 to 2021, real electricity prices have changed by less than 5 percent in all since 2012. Increases in the price of natural gas are responsible for increased median energy cost burdens for fossil gas reliant low- and moderate-income households by 0.7 percent (from 7.8 to 8.5 percent) just over the three-year period from 2018 to 2021 alone. Moreover, while data for the year 2022 are not yet available, we note that BG&E commodity prices for natural gas are thus far 60 percent higher than in 2021 using data from the months of January-October, suggesting even larger impacts from turbulent fossil gas prices may already be underway. We note that this analysis only accounted for the change in gas prices and not the resulting, but proportionally smaller, increase in electricity prices associated with the increase in gas prices. Prices for electricity are more stable than natural gas due to electricity's dependence on a wide variety of technologies and the smaller fraction that fuel cost typically plays in total electricity cost. Finally, in **Chapter 4** we show that gas prices could skyrocket in the 2030s if the present direction of continued investments in gas infrastructure is allowed to persist.

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[70] As reported in EIA forms EIA-861 and EIA-176 and EIA State Profiles and Energy Estimates. https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_btu_res.html&sid=US

2.6.2 Homes with Very High Energy Use

Our findings thus far are based on models that estimate typical energy usages for homes and thus tend to omit outlier homes that use far more or far less energy than found in our estimates. One source for such data is the Office of Home Energy Programs (OHEP) which released annual electricity usage for surveyed low- and moderate-income homes in the year 2014. While the average low- and moderate-income household electricity consumption for estimates in this report is comparable to the average usage from the report, 11,300 kWh/year and 11,900 kWh/year respectively, there are significant outlier homes within the OHEP dataset that consumed much more than average. For example, while we estimate that only 2 percent of households use more than 25,000 kWh/year, the OHEP dataset triples that value to 6 percent. If these homes with exceptionally high usage were incorporated into our estimates, we would expect a significant increase of the energy affordability gap. Low-income households with very high usage such as these have the most potential for savings and would greatly benefit from interventions that improve efficiency.

2.7 Summary

Energy bills for the majority of low- and moderate-income households in Maryland cause an undue financial burden. This burden is more acute in households using more expensive fuels such as propane and fuel oil. The buildings where low- and moderate-income households live are also typically less efficient. There are large concentrations of households strained by energy bills due to concentrated poverty in urban areas including Baltimore City and some areas surrounding DC, where multifamily renter-occupied housing is more common.

In homes that have natural gas appliances, high energy cost burdens are accompanied by health-damaging indoor air pollution caused by burning gas, a topic explored further in **Chapter 3** below.

3.0 Energy Use, Indoor Air Quality, and Health

3.1 Introduction

People in the United States spend more than 80 percent of their time indoors.[71] Given this simple fact, policies shaping indoor environments—such as new building construction or retrofit standards—can have significant impacts on quality of life and public health.

In Maryland, 8.3 percent of energy-related greenhouse gas emissions come from burning fossil fuels in residential buildings for space and water heating and appliances.[72] In addition to releasing greenhouse gases, fuel combustion and use in homes produces health-damaging air pollutants, which can contribute to poor indoor air quality. State climate policy currently promotes reduction of these emissions through energy efficiency and by transitioning to cleaner sources of fuel and energy. By taking a holistic approach, Maryland can ensure these policies also improve public health by reducing indoor air pollutant emissions and ensuring that upgrades to improve building efficiency incorporate measures, such as proper ventilation, that can improve indoor air quality.

In this chapter, we summarize current scientific understanding on the impacts of energy use and retrofits on air quality and public health. An overview of our methods is included in the **Appendix**. In **Section 3.2**, we summarize the influence of indoor air quality on human health and describe populations particularly vulnerable to indoor air pollution. In **Section 3.3**, we assess the potential impacts of household fuel type on indoor air quality and health, focusing specifically on combustion sources. In **Section 3.4**, we summarize the impacts on indoor air quality of healthy homes programs; low-carbon retrofits; and household interventions intended to improve energy efficiency, ventilation, and/or to decarbonize (e.g., weatherization, electrification). Where available, we highlight the relevance of study findings for the residents of Maryland and Baltimore City.

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[71] Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., Behar, J. V., Hern, S. C., & Engelmann, W. H. (2001). The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Analysis and Environmental Epidemiology*, *11*(3), 231–252. https://doi.org/10.1038/sj.jea.7500165

[72] Derived from Maryland Department of Environment 2022. Maryland 2020 Greenhouse Gas Inventory, November 24, 2022, at https://mde.maryland.gov/programs/air/ClimateChange/Documents/VIMAL/MD_2020_GHG_Inventory_2022-09-24.xlsx Does not include indoor leaks of natural gas as methane.

KEY FINDINGS

- Weatherization, electrification, and ventilation can be combined to improve both energy efficiency and indoor air quality, resulting in simultaneous benefits for climate and public health.
- Energy cost burdens can be greatly reduced by a combination of weatherization, efficient electrification, and discounted community solar electricity supply.
- Energy efficiency and decarbonization-related interventions that improve indoor air quality should be prioritized, particularly within vulnerable populations.

3.2 Indoor Air Quality and Health

Indoor air quality in residential settings is impacted by biological (e.g., mold, allergens), chemical (e.g., gaseous combustion emissions from gas appliances), and physical (e.g., ventilation, insulation) factors.[73] Indoor air pollution represents a mix of hundreds to thousands of gas and particle phase compounds, the levels and types of which are influenced by the air exchange rate of the home, which in turn is modified by home size, the household's HVAC system, localized ventilation systems (e.g., presence of a hood fan over the stove), and the permeability of the home (e.g., presence of cracks or gaps).

In multifamily housing (i.e. apartments, attached townhouses, and condos), indoor air pollutants can influence indoor air quality in neighboring units.[74] Outdoor pollution may also influence indoor air quality if it enters the home through the HVAC system or unintentional cracks or openings.[75] Indoor particulate matter (PM) levels in the home, for example, are influenced by outdoor sources as well as indoor activities, including cooking, fireplace use, smoking, fuel combustion for heating, and burning candles and incense.[76]

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[73] Weitzman, M., Baten, A., Rosenthal, D. G., Hoshino, R., Tohn, E., & Jacobs, D. E. (2013). Housing and Child Health. *Current Problems in Pediatric and Adolescent Health Care*, 43(8), 187–224. https://doi.org/10.1016/j.cppeds.2013.06.001

[74] U.S. EPA. (2017). Indoor Air Quality in Multifamily Housing [Overviews and Factsheets]. https://www.epa.gov/indoor-air-quality-iaq/indoor-air-quality-multifamily-housing

[75] Zhang, L., Ou, C., Magana-Arachchi, D., Vithanage, M., Vanka, K. S., Palanisami, T., Masakorala, K., Wijesekara, H., Yan, Y., Bolan, N., & Kirkham, M. B. (2021). Indoor Particulate Matter in Urban Households: Sources, Pathways, Characteristics, Health Effects, and Exposure Mitigation. *International Journal of Environmental Research and Public Health*, 18(21), 11055. https://doi.org/10.3390/ijerph182111055

[76] Ibid.

Poor indoor air can substantially impact human health, especially for populations that are most vulnerable (e.g., low income households, people of color, pregnant people, children, older adults, and those with chronic respiratory conditions such as asthma).[77,78] Poor indoor air is a major driver of respiratory, cardiovascular, and neurological health and can adversely impact pregnancy outcomes. Energy-related emissions can influence indoor air quality through a variety of factors including but not limited to: the type, quality, and number of appliances in use; household fuel activities (e.g., cooking, heating); and fuel type used (e.g., natural gas, biomass, electricity). Other factors that can help mitigate the impact of poor indoor air include activities such as opening a window or using a fan for ventilation; household characteristics (e.g., size, layout, and presence of HVAC); and reducing how much time people spend in their home.[79, 80]

Certain populations are at higher risk from air pollution. For instance, low-income populations and people of color, and especially children, are disproportionately exposed to environmental housing hazards and have higher rates of asthma.[81,82] Renters also frequently lack the financial means or freedom to implement interventions to improve air quality in the home. Populations with underlying health conditions (e.g., lung disease) have increased susceptibility to adverse health outcomes when exposed to residential hazards.[83, 84, 85, 86]

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[77] Krieger, J. W., Takaro, T. K., & Rabkin, J. C. (2011). Breathing Easier in Seattle: Addressing Asthma Disparities Through Healthier Housing. In R. A. Williams (Ed.), Healthcare Disparities at the Crossroads with Healthcare Reform (pp. 359–383). Springer US. https://doi.org/10.1007/978-1-4419-7136-4_19

[78] Phillips, T. J., & Levin, H. (2015). Indoor environmental quality research needs for low-energy homes. *Science and Technology for the Built Environment*, 21(1), 80–90. https://doi.org/10.1080/10789669.2014.975056

[79] 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. https://doi.org/10.1016/j.buildenv.2020.107067

[80] Zhang, L., Ou, C., Magana-Arachchi, D., Vithanage, M., Vanka, K. S., Palanisami, T., Masakorala, K., Wijesekara, H., Yan, Y., Bolan, N., & Kirkham, M. B. (2021). Indoor Particulate Matter in Urban Households: Sources, Pathways, Characteristics, Health Effects, and Exposure Mitigation. *International Journal of Environmental Research and Public Health*, 18(21), 11055. https://doi.org/10.3390/ijerph182111055

[81] Krieger, J. W., Takaro, T. K., & Rabkin, J. C. (2011). Breathing Easier in Seattle: Addressing Asthma Disparities Through Healthier Housing. In R. A. Williams (Ed.), Healthcare Disparities at the Crossroads with Healthcare Reform (pp. 359–383). Springer US. https://doi.org/10.1007/978-1-4419-7136-4_19

[82] Pacheco, C. M., Ciaccio, C. E., Nazir, N., Daley, C. M., DiDonna, A., Choi, W. S., Barnes, C. S., & Rosenwasser, L. J. (2014). Homes of low-income minority families with asthmatic children have increased condition issues. *Allergy and Asthma Proceedings*, 35(6), 467–474. https://doi.org/10.2500/aap.2014.35.3792

[83] Adamkiewicz, G., Zota, A. R., Fabian, M. P., Chahine, T., Julien, R., Spengler, J. D., & Levy, J. I. (2011). Moving Environmental Justice Indoors: Understanding Structural Influences on Residential Exposure Patterns in Low-Income Communities. *American Journal of Public Health*, 101(S1), S238–S245. https://doi.org/10.2105/AJPH.2011.300119

[84] Jacobs, D. E. (2011). Environmental Health Disparities in Housing. *American Journal of Public Health*, 101(S1), S115–S122. https://doi.org/10.2105/AJPH.2010.300058

[85] Mankikar, D., Campbell, C., & Greenberg, R. (2016). Evaluation of a Home-Based Environmental and Educational Intervention to Improve Health in Vulnerable Households: Southeastern Pennsylvania Lead and Healthy Homes Program. *International Journal of Environmental Research and Public Health*, 13(9), 900. https://doi.org/10.3390/ijerph13090900

[86] Tripathii, E., & Laquatra, J. (2018). Managing Indoor Air Quality in the Child Breathing Zone: Risk Analysis and Mitigation. *Journal of Architectural Engineering*, 24(1), 04018002. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000300

Additionally, older adults are disproportionately impacted by indoor environmental quality in part due to increased susceptibility to illness (decreased immune function). Near-elderly populations, defined as older adults, "who are not of retirement age but may lack financial security and resilience," for example, face more financial hardships than other households; financial hardships are strongly correlated with poorer health and worsening home conditions.[87] Populations vulnerable to air pollution in Baltimore City, Maryland are discussed in the box below.

POPULATIONS VULNERABLE TO AIR POLLUTION IN BALTIMORE CITY, MD

In Baltimore City, homes in low-income communities are often in deteriorating condition, with environmental hazards present, such as high levels of dust, pests, mold, and poor indoor air quality, among others. Poor indoor air quality can contribute to the development of asthma and can exacerbate symptoms among those with asthma.[88] Approximately 62 percent of Baltimore City's population is Black;[89] Black populations experience a higher rate of poverty, with 23.7 percent of the population living below the federal poverty line compared to 13.5 percent in the U.S. Similarly, Baltimore City has nearly double the rate of households in poverty (20 percent) compared to the state (10 percent) and the U.S. (12 percent). The poverty rate among Black residents of Baltimore City is 24.1 percent compared to 10.1 percent for White residents.[90]

Baltimore City residents also experience a higher rate of child and adult asthma prevalence, asthma-related emergency department visits, hospitalizations, and deaths compared to other Marylanders and the United States as a whole.[91] For example, 18.6 percent of children living in Baltimore City have asthma compared to the U.S. average of five percent (+/- three percent).[92] Black residents in Baltimore City

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[87] Tonn, B., Hawkins, B., Rose, E., & Marincic, M. (2021). Income, housing and health: Poverty in the United States through the prism of residential energy efficiency programs. *Energy Research & Social Science*, 73, 101945. https://doi.org/10.1016/j.erss.2021.101945

[88] Noonan, C. W., & Ward, T. J. (2012). Asthma randomized trial of indoor wood smoke (ARTIS): Rationale and methods. *Contemporary Clinical Trial*s, 33(5), 1080–1087. https://doi.org/10.1016/j.cct.2012.06.006

[89] U.S. Census Bureau. (2021). U.S. Census Bureau QuickFacts: United States, Maryland, and Baltimore City. https://www.census.gov/quickfacts/fact/table/US/PST045221

[90] Baltimore, Maryland (MD) Poverty Rate Data. Accessed 2023.

[91] GHHI. (2015, April 22). The Green & Healthy Homes Initiative. https://www.asthmacommunitynetwork.org/node/15680

[92] Ibid.

face higher rates of asthma-related emergency room visits (6.5 times more often than White residents), higher asthma hospitalization rates for children (two times the rate of Maryland as a whole), and higher rates of asthma-related mortality (three times higher than White residents).[93] Baltimore County and other Eastern Shore counties also have higher average annual energy costs and lower median annual household incomes, resulting in higher median annual energy cost burdens as compared to other Maryland counties (**see Chapter 2**, **Figure 2-2**).

Improvements to indoor air quality in Baltimore would have substantial benefits for residents particularly vulnerable to air pollution exposure, such as children, older adults, those without health insurance, and people of color, who often have limited access to health services and are subjected to worse environmental pollution when compared to White communities.[94] When comparing Baltimore City's proportion of people of color, people under five years old, and people over age 64 to the state and national average, we find that while the percentage of people under five (all three geographies estimated at six percent) and over 64 (geographies ranged from 14-16 percent) are on par with averages for Maryland and the United States, the percentage of people of color is much greater, estimated to be 73 percent for the City compared to 50 percent for the state and 40 percent for the United States (**Figure 3-1 below**).[95]

Additionally, the proportion of households without health insurance is lower in Baltimore and the state of Maryland compared to the U.S., with the city and state estimated to be six to seven percent compared to 10 percent nationwide. **Figure 3-2** below shows a map of the percent of asthma prevalence among adults aged 18 years or older.[96] As you can see in **Figure 3-2**, the majority of Baltimore City neighborhoods have the highest prevalence of asthma compared to averages for the state.[97]

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[93] Ibid.

[94] Ibid.

[95] U.S. Census Bureau. (2021). U.S. Census Bureau QuickFacts: United States, Maryland, and Baltimore City. https://www.census.gov/quickfacts/fact/table/US/PST045221

[96] Asthma prevalence represents the model-based estimate for crude prevalence.

[97] U.S. Center for Disease Control and Prevention (2022). PLACES: Census Tract Data. https://chronicdata.cdc.gov/500-Cities-Places/PLACES-Census-Tract-Data-GIS-Friendly-Format-2022-/yjkw-uj5s

Figure 3-1: Comparison of socioeconomic indicators in Baltimore City to Maryland and U.S. averages. *Source: 2016-2021 ACS 5-year estimates, U.S. Census (2021)*.

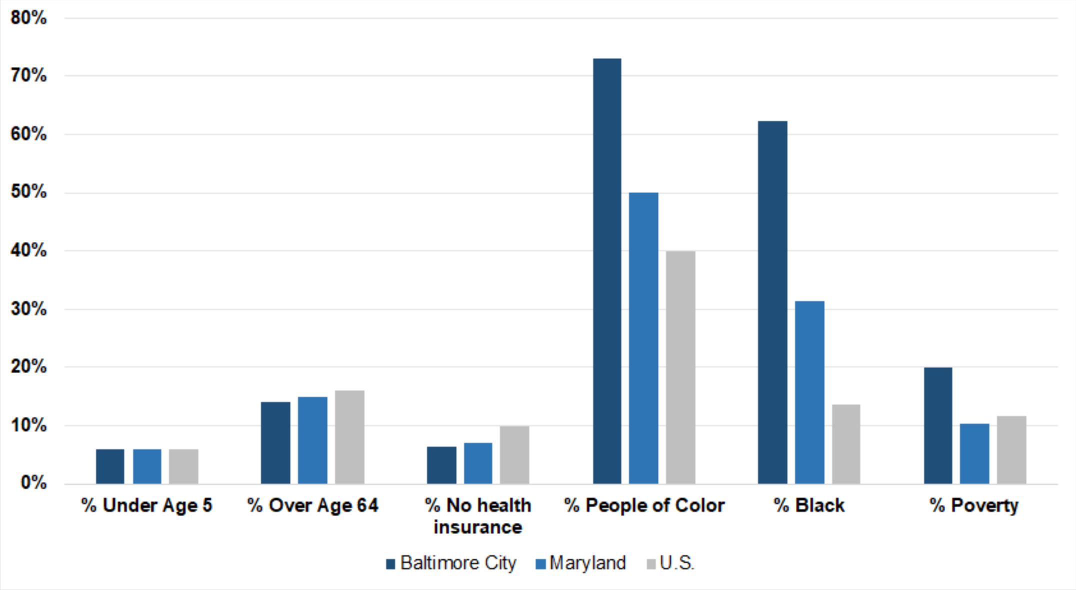
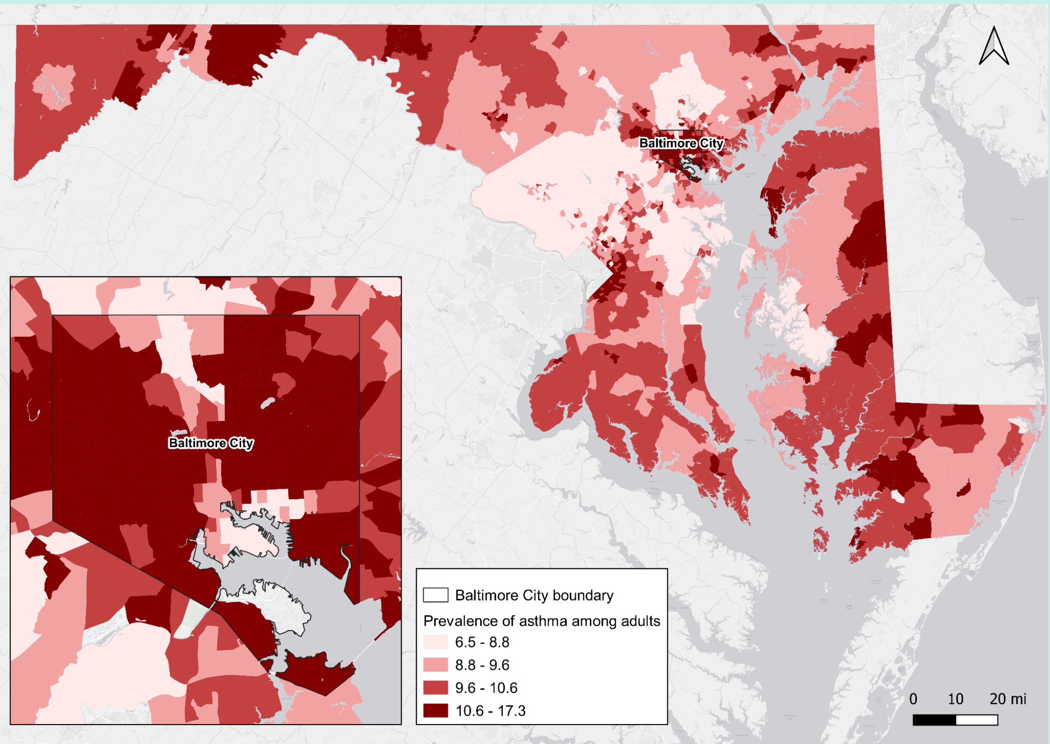


Figure 3-2: Model-based estimate for crude prevalence (%) of current asthma among adults ≥18 years (census tract), 2020, Baltimore City & Maryland. *Source: CDC (2022).*[98]



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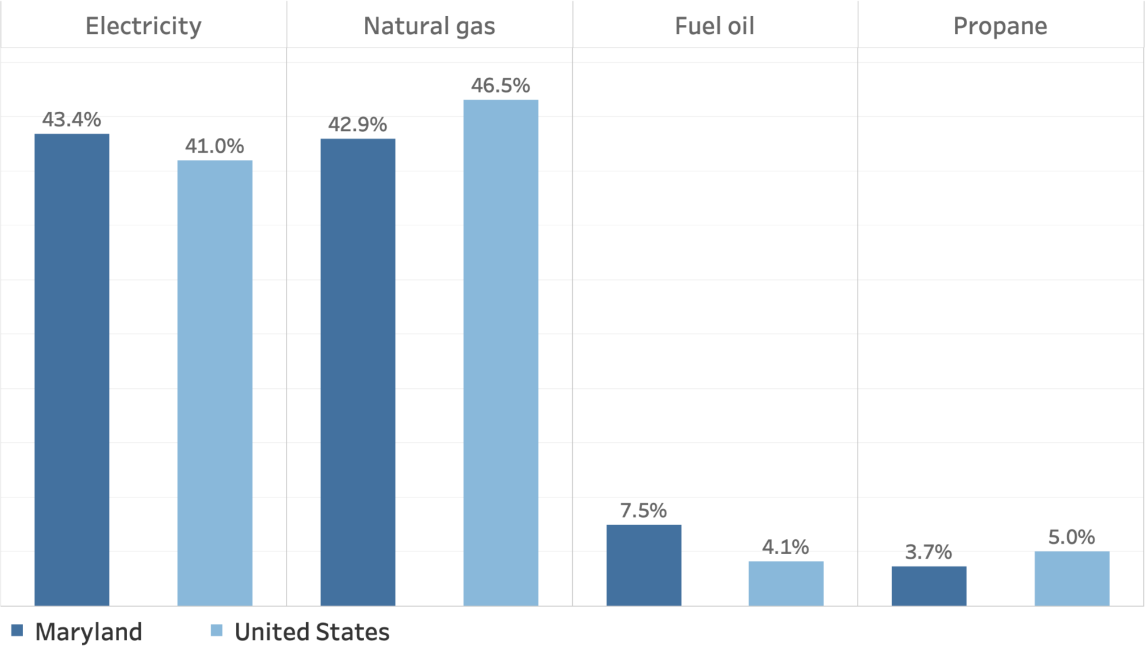
[98] U.S. Center for Disease Control and Prevention (2022). PLACES: Census Tract Data. https://chronicdata.cdc.gov/500-Cities-Places/PLACES-Census-Tract-Data-GIS-Friendly-Format-2022-/yjkw-uj5s

3.3 Impacts of Residential Fuel Use on Indoor Air Quality and Health

In this section, we summarize the research on indoor air quality and the health implications of residential energy use. Across Maryland, 43 percent of homes use electricity as their main source of home fuel heating, while the remaining households rely on one or several combustion-based heating fuels that may impact indoor air quality and health (natural gas: 42.9 percent, propane: 3.7 percent, fuel oil: 7.5 percent) **(Figure 3-3)**.[99]

Figure 3-3: Proportion of main residential heating fuels used in the home, 2021, Maryland statewide average compared to the United States.[100]



Below, we provide an overview of pollutants associated with combustion appliances (**Section 3.3.1**). We then summarize the impacts of combustion-based cooking (**Section 3.3.2**) and household heating appliances (**Section 3.3.3**), but we note that Marylanders may use additional combustion-based appliances that may influence air quality in their homes (e.g., natural gas dryers).

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[99] Maryland data from the 2021 American Community Survey, Table S2504 at https://data.census.gov/table?q=+Maryland+housing&tid=ACSST1Y2021.S2504.

[100] Maryland data from the 2021 American Community Survey, Table S2504 at https://data.census.gov/table?q=+Maryland+housing&tid=ACSST1Y2021.S2504; US data from the Energy Information Adminstration at https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Space%20Heating%20Fuels.pdf

3.3.1 Key Air Pollutants Associated with Combustion Appliances

While there are various sources of indoor air pollution, in this report, we focus on combustion-based appliances used for cooking and heating. In **Table 3-1** below we summarize key health-relevant pollutants emitted from the combustion and incomplete combustion of natural gas, oil, and biomass and their corresponding health-based standards. Additional health-relevant air pollutants beyond those shown in **Table 3-1** are discussed below with their respective fuel and appliance types.

Table 3-1: Key indoor air pollutants emitted from residential combustion appliances and their associated health-based international, federal, or state standards and relevance for human health. The list of pollutants shown is not inclusive of all relevant pollutants (*Sources: CalEPA OEHHA, 2020; U.S. EPA, 2014, 2016, 2017, 2021; World Health Organization, 2010*).

	Pollutant(s)	Description	Health-Based Standards	Adverse Health Effects
U.S. EPA Criteria Air Pollutants	**Fine inhalable particulate matter ($PM_{2.5}$)**[a]	Liquid- or solid-phase particles suspended in air. Includes soot (i.e., black carbon), organic carbon, and metals	U.S. EPA NAAQS: 12.0 $\mu g/m^3$ (1 year)[b] U.S. EPA NAAQS: 35 $\mu g/m^3$ (24 hours)[c]	● Premature death in people with pre-existing heart & lung disease ● Nonfatal heart attacks ● Irregular heartbeat ● Low birthweight ● Increased respiratory symptoms (coughing, shortness of breath) ● Aggravated asthma ● Decreased lung function
	Carbon monoxide (CO)	An odorless, colorless gas	WHO: 10 ppm (8 hours) U.S. EPA NAAQS: 9 ppm (8 hours)[d] U.S. EPA NAAQS: 35 ppm (1 hour)[d]	● Fatigue & chest pain, impacts to child mental development (low concentrations) ● Impaired vision & coordination, nausea, dizziness, can limit oxygen uptake & be fatal, during pregnancy can cause miscarriages (at high concentrations)
	Nitrogen oxides (NO_x)	A group of highly reactive gases including nitrogen monoxide (NO) and nitrogen dioxide	**NO_2** U.S. EPA NAAQS: 100 ppb (1 hour)[e] U.S. EPA NAAQS: 53 ppb (1 year)	● Aggravated asthma, resulting in increased respiratory symptoms, emergency department visits, & hospital admissions ● NO_2 may contribute to the

		(NO_2). Combustion of residential fuels emit NO_x primarily in the form of NO but also in the form of NO_2	WHO: 110 ppb (1 hour)[f]	development of asthma (chronic) ● NO_x increases risk of low birth weight, with potential lifelong adverse health implications ● NO_x exposure 3 months before pregnancy & first 7 weeks of pregnancy increases risk of preterm births, more so for women with asthma
U.S. EPA Hazardous Air Pollutants	**Formaldehyde**	Colorless, strong-smelling gas	U.S. EPA Inhalation Unit Risk (cancer): 1.3 x 10^{-5} per μg/m^3 CalEPA OEHHA REL: 55 μg/m^3 (1 hour) CalEPA OEHHA REL: 9 μg/m^3 (8 hour and chronic)	● Carcinogenic effects ● Eye & respiratory irritation (acute) ● Adverse non-cancer effects to respiratory system (chronic)
	Benzene	Colorless liquid with a sweet smell that evaporates when exposed to air. Present in distribution-level natural gas as well as being a byproduct of combustion.	U.S. EPA Inhalation Unit Risk (cancer): 2.2 x 10-6 per μg/m^3 CalEPA OEHHA REL: 27 μg/m^3 (1 hour) CalEPA OEHHA REL: 3 μg/m^3 (8 hour and chronic)	● Carcinogenic effects ● Adverse non-cancer effects on development, immune, & hematologic systems (acute) ● Adverse non-cancer effects to the hematologic system (chronic)

[a] Particulate matter less than or equal to 2.5 microns in diameter.
[b] Annual mean, averaged over 3 years.
[c] 98th percentile, averaged over 3 years.
[d] Not to be exceeded more than once per year.
[e] 98th percentile of 1-hour daily maximum concentrations, averaged over 3 years.
[f] Annual mean.

(CalEPA OEHHA REL: California Environmental Protection Agency Office of Environmental Health Hazard Assessment Reference Exposure Level; NAAQS: National Ambient Air Quality Standards; ppb: parts per billion; ppm: parts per million; U.S. EPA: United States Environmental Protection Agency; WHO: World Health Organization; μg/m^3: microgram per cubic meter).

Health-based guidance values and standards are commonly established to help mitigate the health impacts associated with harmful environmental hazards by determining a “safe” level of exposure. Health-based guidance values and standards from the U.S. Environmental Protection Agency (U.S. EPA), World Health Organization (WHO), and California Environmental

Protection Agency Office of Environmental Health Hazard Assessment (CalEPA OEHHA) are shown for key air pollutants in **Table 3-1**. In most cases, numerical thresholds are set using the best available data, and regulations rely upon established thresholds above which air quality standards would be violated. While some thresholds are designed for outdoor air concentrations (e.g., U.S. EPA National Ambient Air Quality Standards, NAAQS), we consider them for indoor air as no standards for indoor air exist. Indoor air pollution exposure levels are dependent on the pollutant concentrations in the home and the length of exposure—either short, one-time, or infrequent exposures (acute) or repeated, continuous exposures over a lifetime (chronic).

Key pollutants associated with household combustion appliances include criteria air pollutants and hazardous air pollutants (HAPs). A summary discussion of each pollutant and its associated health impacts is provided below.

Criteria air pollutants. The Clean Air Act requires NAAQS to be set for criteria air pollutants, which encompass six air pollutants known to impact human health and the environment, including ground-level ozone, lead, sulfur dioxide (SO_2), particulate matter (PM), carbon monoxide (CO), and nitrogen oxides (NO_x).[101] Of these pollutants, fine inhalable particulate matter ($PM_{2.5}$), CO, and NO_x are typically emitted by residential combustion appliances (**Table 3-1**).

Exposure to $PM_{2.5}$ is associated with premature death in people with pre-existing heart and lung disease, as well as nonfatal heart attacks, irregular heartbeat, low birth weight, increased respiratory symptoms (coughing, shortness of breath), aggravated asthma, and decreased lung function. At higher levels, exposure to CO during pregnancy can cause miscarriages; at lower levels, exposure to CO during pregnancy can harm the child's mental development.[102] Exposure to CO at low concentrations is associated with fatigue and chest pain, but at high concentrations, exposure can lead to impaired vision and coordination, nausea, dizziness, and can limit oxygen uptake, which can be fatal. Limited oxygen uptake occurs during exposure because CO creates carboxyhemoglobin (COHgb)—a stable complex of carbon monoxide that forms in red blood cells, which inhibits key functions, including delivery of oxygen to cells.[103] The relationship between CO exposure and the prevalence of COHgb in the blood can be determined using the exposure duration and concentration of CO during the exposure event. In some cases, CO exposure to levels as low as 10 ppm can lead to detectable

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[101] U.S. EPA. (2014). Criteria Air Pollutants [Other Policies and Guidance]. https://www.epa.gov/criteria-air-pollutants
[102] ATSDR. (2012). Toxicological Profile for Carbon Monoxide (p. 347). https://www.atsdr.cdc.gov/ToxProfiles/tp201.pdf
[103] Ibid.

COHb levels of ~2 percent.[104] For context, an elevated COHgb level of 2 percent for non-smokers "strongly supports a diagnosis of CO poisoning."[105]

NO_x represents a group of highly reactive gases, including nitrogen monoxide (NO) and nitrogen dioxide (NO_2). Residential combustion emits NO_x primarily in the form of NO but also in the form of NO_2. In the atmosphere, NO is quickly oxidized to NO_2. Similar to CO, NO_2 is also a respiratory irritant that can aggravate pre-existing respiratory diseases like asthma, which may result in increased respiratory symptoms, emergency department visits, and hospital admissions. Long-term exposure to NO_2 may contribute to the development of asthma. NO_x exposure increases the risk of low birth weight, with potential lifelong adverse health implications.[106] Exposure to NO_x in the three months before pregnancy and in the first seven weeks of pregnancy may increase the risk of preterm births, the impacts of which are greater for women with asthma.[107]

Hazardous air pollutants. HAPs are pollutants with known or suspected carcinogenic effects or are associated with other serious health impacts, such as reproductive and birth defects.[108] In total, the U.S. EPA has identified 188 pollutants that qualify as HAPs. Key HAPs associated with combustion appliances include, but are not limited to, formaldehyde and benzene (**Table 3-1**). Formaldehyde is a known human carcinogen. Acute exposure can result in eye and respiratory irritation. Long-term exposure is associated with adverse non-cancer effects on the respiratory system.[109] Benzene is also a known human carcinogen. Acute exposure can result in adverse non-cancer effects on the development, immune, and hematologic (blood) systems. Long-term exposure is associated with adverse non-cancer effects on the hematologic system.[110]

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[104] Rose, J. J., Wang, L., Xu, Q., McTiernan, C. F., Shiva, S., Tejero, J., & Gladwin, M. T. (2017). Carbon Monoxide Poisoning: Pathogenesis, Management, and Future Directions of Therapy. *American Journal of Respiratory and Critical Care Medicine*, 195(5), 596–606. https://doi.org/10.1164/rccm.201606-1275CI

[105] CDC. (2020). Clinical Guidance for Carbon Monoxide Poisoning | Natural Disasters and Severe Weather. https://www.cdc.gov/disasters/co_guidance.html

[106] Mendoza-Ramirez, J., Barraza-Villarreal, A., Hernandez-Cadena, L., de la Garza, O. H., Sangrador, J. L. T., Torres-Sanchez, L. E., Cortez-Lugo, M., Escamilla-Nuñez, C., Sanin-Aguirre, L. H., & 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. https://doi.org/10.29024/aogh.914

[107] 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.e5. https://doi.org/10.1016/j.jaci.2015.12.1309

[108] U.S. EPA. (2015). Hazardous Air Pollutants [Collections and Lists]. https://www.epa.gov/haps

[109] ATSDR. (1999). Toxicological Profile for Formaldehyde. https://www.atsdr.cdc.gov/toxprofiles/tp111.pdf

[110] ATSDR. (2007). Toxicological Profile for Benzene. https://www.atsdr.cdc.gov/toxprofiles/tp3.pdf

3.3.2 Cooking Appliances

Combustion appliances used for cooking primarily include ranges, cooktops, and ovens. In Maryland, 40 percent of households have at least one natural gas cooking appliance, similar to national averages, and 69 percent of households have at least one (non-combustion) electric cooking appliance.[111] Indoor air quality impacts of cooking appliances can stem from gas appliance leaks,[112, 113] from combustion or incomplete combustion of gas during cooking,[114, 115] and from food that is being cooked.[116] Gas stoves, cooktops, and ovens can leak when not in use, resulting in indoor emissions of methane, the primary component of natural gas and a potent greenhouse gas, along with hazardous air pollutants such as benzene, hexane, and toluene, among others.[117, 118, 119] Of note, gas composition can vary by region[120, 121] and seasonally.[122] Combustion of natural gas during cooking results in direct emissions of

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[111] U.S. EIA (Energy Information Administration). (2022). Highlights for appliances in U.S. homes by state, 2020. https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Appliances.pdf

[112] Lebel, E. D., Finnegan, C. J., Ouyang, Z., & Jackson, R. B. (2022). Methane and NO_x Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science & Technology*, 56(4), 2529–2539. https://doi.org/10.1021/acs.est.1c04707

[113] Michanowicz, D. R., Dayalu, A., Nordgaard, C. L., Buonocore, J. J., Fairchild, M. W., Ackley, R., Schiff, J. E., Liu, A., Phillips, N. G., Schulman, A., Magavi, Z., & 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*, acs.est.1c08298. https://doi.org/10.1021/acs.est.1c08298

[114] Lebel, E. D., Finnegan, C. J., Ouyang, Z., & Jackson, R. B. (2022). Methane and NO_x Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science & Technology*, 56(4), 2529–2539. https://doi.org/10.1021/acs.est.1c04707

[115] 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. https://doi.org/10.1111/ina.12190

[116] Zhai, S. R., & Albritton, D. (2020). Airborne particles from cooking oils: Emission test and analysis on chemical and health implications. *Sustainable Cities and Society*, 52, 101845. https://doi.org/10.1016/j.scs.2019.101845

[117] Lebel, E. D., Finnegan, C. J., Ouyang, Z., & Jackson, R. B. (2022). Methane and NO_x Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science & Technology*, 56(4), 2529–2539. https://doi.org/10.1021/acs.est.1c04707

[118] Lebel, E. D., Michanowicz, D. R., Bilsback, K. R., Hill, L. L., Goldman, J. S. W., Domen, J. K., Jaeger, J. M., Ruiz, A., & Shonkoff, S. B. C. (2022). Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California. *Environmental Science & Technology*. https://doi.org/10.1021/acs.est.2c02581

[119] Michanowicz, D. R., Dayalu, A., Nordgaard, C. L., Buonocore, J. J., Fairchild, M. W., Ackley, R., Schiff, J. E., Liu, A., Phillips, N. G., Schulman, A., Magavi, Z., & 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*, acs.est.1c08298. https://doi.org/10.1021/acs.est.1c08298

[120] Lebel, E. D., Michanowicz, D. R., Bilsback, K. R., Hill, L. L., Goldman, J. S. W., Domen, J. K., Jaeger, J. M., Ruiz, A., & Shonkoff, S. B. C. (2022). Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California. *Environmental Science & Technology*. https://doi.org/10.1021/acs.est.2c02581

[121] Michanowicz, D. R., Dayalu, A., Nordgaard, C. L., Buonocore, J. J., Fairchild, M. W., Ackley, R., Schiff, J. E., Liu, A., Phillips, N. G., Schulman, A., Magavi, Z., & 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*, acs.est.1c08298. https://doi.org/10.1021/acs.est.1c08298

[122] Ibid.

criteria air pollutants, including NO_X.[123] The blending of natural gas with hydrogen may hold implications for enhanced NO_X emissions. There are mixed results for changes in NO_X emissions associated with residential end-use combustion reported in the peer-reviewed literature, with mean and worst case NO_X emission scenarios indicating increases in NO_X emissions with hydrogen blending.[124]

Ventilation by whole-house mechanical ventilation, the use of range hoods (particularly those that vent externally rather than recirculate air), and the opening of windows can reduce indoor air pollution during cooking (see **Section 3.4.2**). Studies evaluating the influences of gas versus electric stoves on indoor air quality show that combustion-related air pollutant concentrations were significantly reduced in homes with electric appliances (see **Section 3.4.3**).[125, 126] Given our focus in this section on combustion-based cooking appliances, below we discuss studies that report elevated indoor air pollutant concentrations associated with natural gas cooking appliances, including studies that report exceedances of health-based standards.

3.3.2.1 Indoor Air Pollutant Concentrations Associated With Natural Gas Cooking Appliances

The majority of studies that compare indoor air concentrations to health-based guidance values and standards are focused on gas stoves, ranges, and burners as significant indoor sources of air pollution. Studies described below were focused in California. A study measuring indoor air quality in low-income apartments with natural gas cooking appliances found that measured indoor $PM_{2.5}$ and NO_2 concentrations exceeded the U.S. EPA NAAQS and California Ambient Air Quality Standards (CAAQS) for ambient air quality and World Health Organization's limits for personal exposure. Concentrations of formaldehyde, for which there are numerous indoor sources, including but not limited to gas stoves, were generally above CalEPA chronic reference exposure levels.[127] In a study focused on natural gas cooking burner

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[123] Lebel, E. D., Finnegan, C. J., Ouyang, Z., & Jackson, R. B. (2022). Methane and NO_x Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science & Technology*, 56(4), 2529–2539. https://doi.org/10.1021/acs.est.1c04707

[124] Wright, M. L., & Lewis, A. C. (2022). Emissions of NO_x from blending of hydrogen and natural gas in space heating boilers. *Elementa: Science of the Anthropocene*, 10(1), 00114. https://doi.org/10.1525/elementa.2021.00114

[125] Mullen, N. A., Li, J., Russell, M. L., Spears, M., Less, B. D., & Singer, B. C. (2016b). 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. https://doi.org/10.1111/ina.12190

[126] Paulin, L. M., Diette, G. B., Scott, M., McCormack, M. C., Matsui, E. C., Curtin-Brosnan, J., Williams, D. L., Kidd-Taylor, A., Shea, M., Breysse, P. N., & Hansel, N. N. (2014). Home interventions are effective at decreasing indoor nitrogen dioxide concentrations. *Indoor Air*, 24(4), 416–424. https://doi.org/10.1111/ina.12085

[127] Zhao, H., Chan, W. R., Cohn, S., Delp, W. W., Walker, I. S., & Singer, B. C. (2021). Indoor air quality in new and renovated low-income apartments with mechanical ventilation and natural gas cooking in California. *Indoor Air*, 31(3), 717–729. https://doi.org/10.1111/ina.12764

usage in households in Northern California, researchers at Lawrence Berkeley National Laboratory observed that indoor NO_2 concentrations in nearly half of homes exceeded the 1-hour NAAQS (100 parts per billion [ppb] NO_2) during operation of the burners with venting range hoods; although, range hood use substantially reduced indoor cooking pollutant concentrations.[128] Modeled estimates of natural gas cooking burner emissions in California homes without ventilation also suggested that occupants may be exposed to NO_2, CO, and formaldehyde concentrations during cooking that exceeds the acute national and state health-based standards.[129] Further, the use of ventilation hoods are not ubiquitous in houses or apartments that have hoods.[130] A recent study measuring air pollutant concentrations in homes 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 1-hr NAAQS for NO_2 (100 ppb) can be exceeded within a few minutes of stove usage, particularly in small kitchens with poor ventilation.[131] Another recent study measured HAP concentrations in natural gas from gas stoves across California, using measured leakage rates when stoves were not in use to estimate indoor concentrations of benzene. The authors found that leakage from stoves and ovens not in use can result in benzene concentrations that exceed the California EPA 8-hour and chronic reference exposure level and in some cases are comparable to tobacco smoke.[132]

3.3.2.2 Maryland Department of Housing and Community Development Compliance Appliance Safety Inspections

The Maryland Department of Housing and Community Development (DHCD) performed combustion appliance safety inspections for vented appliances in households by measuring indoor CO concentrations near combustion appliances. Combustion appliances are a significant source of CO indoors. CO is an odorless, colorless, toxic gas. Exposure to CO can be fatal at high concentrations over short durations and is associated with various adverse health

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[128] 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. https://doi.org/10.1016/j.buildenv.2017.06.021

[129] 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. https://doi.org/10.1289/ehp.1306673

[130] 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. https://doi.org/10.3390/ijerph17238870

[131] Lebel, E. D., Finnegan, C. J., Ouyang, Z., & Jackson, R. B. (2022). Methane and NO_x Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science & Technology*, 56(4), 2529–2539. https://doi.org/10.1021/acs.est.1c04707

[132] Lebel, E. D., Michanowicz, D. R., Bilsback, K. R., Hill, L. L., Goldman, J. S. W., Domen, J. K., Jaeger, J. M., Ruiz, A., & Shonkoff, S. B. C. (2022). Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California. *Environmental Science & Technology*. https://doi.org/10.1021/acs.est.2c02581

effects at lower levels.[133] CO is also a criteria air pollutant, for which the U.S. EPA establishes NAAQS for outdoor air to protect public health and welfare (**Table 3-1**).[134] Indoor ambient CO concentrations were measured in *"combustion appliance zones"*, namely in close proximity to residential combustion appliances, including cooking appliances such as cook stoves and gas ovens.[135] Throughout the inspections, 4,626 combustion appliances were evaluated across 2,257 Maryland residences in 2021. Residences included single family homes, multifamily apartment units, mobile homes, and renter- and owner-occupied spaces.[136,137]

Table 3-2 summarizes measured indoor CO concentrations by combustion appliance type. Briefly, 98 (2.1 percent) of the combustion *appliances* evaluated had indoor CO concentrations detected at or above (≥) nine parts per million (ppm) within the respective combustion appliance zone after approximately five to 10 minutes with the main burner in operation.[138] Nine ppm is the NAAQS for CO concentrations averaged over an eight-hour period and is not to be exceeded more than once per year (U.S. EPA, 2022; **Table 3-1**). However, concentrations below reflect single point in time measurements and are not necessarily reflective of indoor air concentrations over longer durations.

As part of the compliance safety inspections, if concentrations greater than or equal to nine ppm are detected, it is recommended that 1) the occupant be notified that CO has been detected, 2) the area be ventilated, and 3) the occupant contacts a qualified professional to evaluate potential appliance sources of CO (BPI, 2016). Seventy-eight (3.5 percent) of *households* evaluated had at least one combustion appliance with indoor CO detected ≥ nine ppm; twenty households (0.89 percent) had more than one combustion appliance with indoor CO detected greater than or equal to nine ppm within the combustion appliance zones. Notably, over five percent of cook stoves and gas ovens evaluated had indoor CO detected ≥ nine ppm (**Table 3-2**).

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[133] U.S. EPA. (2021). Carbon Monoxide's Impact on Indoor Air Quality [Overviews and Factsheets]. https://www.epa.gov/indoor-air-quality-iaq/carbon-monoxides-impact-indoor-air-quality

[134] U.S. EPA. (2022). NAAQS Table [Other Policies and Guidance]. https://www.epa.gov/criteria-air-pollutants/naaqs-table

[135] Building Performance Institute, Inc. (BPI). (2016). Combustion Appliance Safety Inspection for Vented Appliances. https://www.bpi.org/sites/default/files/COMBUSTION%20APPLIANCE%20SAFETY%20INSPECTION%20FOR%20VENTED%20APPLIANCES.pdf

[136] Maryland Department of Housing and Community Development (DHCD). (2022).

[137] While the Maryland Department of Housing and Community Development sample is large, consisting of more than two thousand housing units, it is not necessarily a statistically representative sample of the population in Maryland since the sample consists entirely of low-income households receiving weatherization assistance. There are about 1.2 million gas customers in Maryland (see **Chapter 4, Table 4-2**). There are therefore millions of non-electric combustion appliances in the state, including space and water heating as well as gas stoves and ovens.

[138] While main burners in cooking appliances (gas stoves and ovens) were in operation at the time of measurement, cooking activities (e.g., sauteing or baking of foods or boiling of water) did not occur during sampling.

Sixty combustion appliances (1.3 percent) evaluated had indoor ambient CO measured ≥ 35 ppm. 35 ppm is the NAAQS for CO averaged over a one-hour period and is not to be exceeded more than once per year (U.S. EPA, 2022). If concentrations above 35 ppm are detected, in addition to the recommendations mentioned above, it is also recommended that potential sources of CO are turned off (BPI, 2016). Forty-three households (1.9 percent) had at least one combustion appliance with indoor ambient CO concentration detected ≥35 ppm within the combustion appliance zone. Sixteen households (0.71 percent) had more than one combustion appliance with indoor ambient CO concentrations detected ≥ 35 ppm within the combustion appliance zone. Of combustion appliance types, cook stoves were most likely to have measured indoor CO concentrations ≥ 35 ppm within the combustion appliances zone (3.7 percent) (**Table 3-2**).

Table 3-2: Indoor CO concentrations observed in the ambient air in the room with the combustion appliance at five minutes of main burner operation, by appliance type. Counts reflect the number of appliances by appliance type with indoor CO concentration exceeding the specified threshold. Percent (%) reflects the proportion of appliances by appliance type evaluated with indoor CO concentrations that exceeded specified thresholds. *(Raw data source: DHCD, 2022)*

Appliance Type	**≥ 9 ppm *(%)***	**≥ 35 ppm *(%)***	**≥ 70 ppm *(%)***	**Maximum Observed Value (ppm)**
Cook stove[1]	39 *(5.4%)*	27 *(3.7%)*	19 (2.6%)	91.9
Furnace	26 *(1.8%)*	23 *(1.6%)*	14 (1.0%)	90.1
Gas oven	23 *(5.6%)*	1 *(0.2%)*	1 (0.2%)	80.6
Hot water tank	9 *(0.7%)*	8 *(0.6%)*	6 (5.4%)	87.9
Gas fireplace	1 *(4.5%)*	0 *(0.0%)*	0 *(0.0%)*	18
Total	98 *(2.1%)*	59 *(1.3%)*	40 *(0.9%)*	-

[1] Consolidated counts of "Cook Stove", "Cook Stove2", "Cooktop Frnt Rt", "Cooktop Rear Lft", and "Cooktop Rear Rt" from original dataset.

[2] Fuel type for specific appliances was not able to be determined based on available data. Natural gas is assumed to be the primary fuel type for cooking appliances, whereas heating appliances may rely on natural gas, propane, oil, etc.

For indoor CO concentrations over 70 ppm, occupant evacuation is recommended and emergency services should be notified. There were 40 instances of ambient air in rooms with appliances with concentrations higher than 70 ppm; 20 of these were in kitchens (19 associated with a gas stove and one with an oven).

Cook stoves were also associated with the highest observed indoor CO concentration within a combustion appliance zone (91.9 ppm), with a maximum concentration of more than 2.5 times the 1-hour NAAQS for ambient CO (**Table 3-2**). More than five percent of gas stoves and ovens exhibited concentrations of more than 9 ppm and more than three percent of kitchens with gas stoves had over 35 ppm levels of CO.

3.3.2.3 Health Risks and Impacts Associated with Gas Cooking Appliances

While many studies examine indoor air pollutant concentrations and emissions, few studies explicitly evaluate specific health risks and impacts associated with gas cooking appliances. One study focused in Baltimore evaluated the effect of indoor NO_2 concentrations on asthma morbidity among inner-city preschool children, and found that higher household indoor NO_2 concentrations were associated with increased asthma symptoms. Furthermore, the presence of a gas stove and the use of a space heater or oven/stove for heat were associated with higher NO_2 concentrations.[139] A recent study estimated the population level effects of gas stove use on current childhood asthma in the U.S.[140] The authors found that 12.7 percent of current childhood asthma cases in the U.S. can be attributed to gas stove use.

Additional studies suggest the use of ventilation in homes with gas stoves as a protective factor. A study focused across the United States found that in homes with gas stoves, children of parents who reported using ventilation when using the stove had lower odds of asthma, wheeze, and bronchitis and higher lung function compared to homes that did not use ventilation or did not have access to ventilation options.[141]

3.3.3 Heating Appliances

Residential heating appliances that rely on combustion (e.g., gas fireplaces, gas furnaces, or wood stoves) may contribute to indoor air pollution, especially if they are vented indoors.

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[139] Hansel, N. N., Breysse, P. N., McCormack, M. C., Matsui, E. C., Curtin-Brosnan, J., Williams, D. L., Moore, J. L., Cuhran, J. L., & Diette, G. B. (2008). A longitudinal study of indoor nitrogen dioxide levels and respiratory symptoms in inner-city children with asthma. *Environmental Health Perspectives*, 116(10), 1428–1432. https://doi.org/10.1289/ehp.11349

[140] Gruenwald, T., Seals, B. A., Knibbs, L. D., & Hosgood, 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), Article 1. https://doi.org/10.3390/ijerph20010075

[141] Kile, M. L., Coker, E. S., Smit, E., Sudakin, D., Molitor, J., & Harding, A. K. (2014). A cross-sectional study of the association between ventilation of gas stoves and chronic respiratory illness in U.S. children enrolled in NHANESIII. *Environmental Health*, 13(1), 71. https://doi.org/10.1186/1476-069X-13-71

Residential space heating in Maryland is dominated by natural gas and electricity (each about 43 percent), 7.5 percent fuel oil or kerosene and 3.7 percent propane, with the rest being other fuels or no fuel (**Figure 3-3 above**). For geographic distribution of fuel use for heating in Maryland, see **Chapter 2, Figure 2-7**. Below, we summarize the literature on the indoor air quality and health impacts of heating by fuel and appliance type.

3.3.3.1 Indoor Air Pollutant Concentrations Associated with Heating Appliances

3.3.3.1.1 Gas Heating Appliances

Measurements from the literature indicate that gas heating leads to elevated levels of air pollutants indoors.[142, 143, 144, 145] For example, a study measuring CO, NO_2, and polycyclic aromatic hydrocarbons (PAHs) in two homes (Boulder, CO) found that the use of an unvented gas fireplace increased levels of all three pollutants.[146] In another study, researchers measured CO concentrations in 17 homes that were heated with gas (i.e., natural gas or propane) and found elevated peak concentrations of CO.[147] Further, a study measured elevated levels of NO_x (and NO_2) in homes that had pilot burners in their gas furnaces compared to homes that did not have pilot burners, but noted that the differences became less apparent when adjusted for home size.[148]

Heating with unvented gas fireplaces, which do not have a chimney and therefore release combustion products directly into the living space, may be of particular concern. In a study that measured concentrations of combustion byproducts in 30 homes where unvented gas

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[142] 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. https://doi.org/10.1080/10473289.2001.10464395

[143] Francisco, P. W., Gordon, J. R., & Rose, B. (2010). Measured concentrations of combustion gases from the use of unvented gas fireplaces: Field measurements of unvented gas fireplaces. *Indoor Air*, 20(5), 370–379. https://doi.org/10.1111/j.1600-0668.2010.00659.x

[144] 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. https://doi.org/10.1111/ina.12190

[145] 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, 608–618. https://doi.org/10.1016/j.scitotenv.2017.12.312

[146] 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. https://doi.org/10.1080/10473289.2001.10464395

[147] 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, 608–618. https://doi.org/10.1016/j.scitotenv.2017.12.312

[148] 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. https://doi.org/10.1111/ina.12190

fireplaces were used, researchers found that in 43 percent of the homes studied, NO_2 levels exceeded the 1-hour WHO threshold (110 ppb) and in 20 percent of the homes studied, CO levels exceeded the 8-hour U.S. EPA NAAQS guideline (9 ppm).[149] In contrast, a study funded by the Propane Education & Research Council, an organization that is funded and operated by the propane industry,[150] used an indoor air quality model to conclude that unvented gas fireplaces would not exceed health-based standards for CO and NO_2, noting that previous studies did not consider unvented fireplaces that met current certification requirements. We note that these modeled results should elicit some skepticism as they are counter to measured exceedances.[151] Moreover, there are unvented gas fireplaces of various vintages in use; therefore even older publications (2010) should give regulators and health authorities pause in regard to the continued use and sale of these appliances.

3.3.3.1.2 Wood Heating Appliances

The evidence reviewed here strongly indicates that wood-based heating can lead to exceedances of health-based air quality standards. For example, researchers measured indoor $PM_{2.5}$ concentrations over 6 days in homes that used wood stoves in the rural United States and found that 70 percent of homes had $PM_{2.5}$ concentrations that exceeded the U.S. EPA's annual NAAQS for $PM_{2.5}$ (12 $\mu g\ m^{-3}$; **Table 3-1**).[152] Additionally, two studies both measured 48-hour $PM_{2.5}$ concentrations in homes using wood stoves and observed that the study-average $PM_{2.5}$ concentrations were similar to the U.S. EPA's 24-hour NAAQS for $PM_{2.5}$ (35 $\mu g\ m^{-3}$; **Table 3-1**).[153,154] Further, researchers found exceedances of the 8-hour (10 ppm) WHO guidelines for indoor air quality in some wood-burning homes.[155]

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[149] Francisco, P. W., Gordon, J. R., & Rose, B. (2010). Measured concentrations of combustion gases from the use of unvented gas fireplaces: Field measurements of unvented gas fireplaces. *Indoor Air*, 20(5), 370–379. https://doi.org/10.1111/j.1600-0668.2010.00659.x

[150] Whitmyre, G. K., & Pandian, M. D. (2018). Probabilistic assessment of the potential indoor air impacts of vent-free gas heating appliances in energy-efficient homes in the United States. *Journal of the Air & Waste Management Association*, 68(6), 616–625. https://doi.org/10.1080/10962247.2018.1426652

[151] Francisco, P. W., Gordon, J. R., & Rose, B. (2010). Measured concentrations of combustion gases from the use of unvented gas fireplaces: Field measurements of unvented gas fireplaces. *Indoor Air*, 20(5), 370–379. https://doi.org/10.1111/j.1600-0668.2010.00659.x

[152] Walker, I., Less, B., Lorenzetti, D., & Sohn, M. D. (2021). Development of Advanced Smart Ventilation Controls for Residential Applications. *Energies*, 14(17), 5257. https://doi.org/10.3390/en14175257

[153] McNamara, M., Thornburg, J., Semmens, E., Ward, T., & Noonan, C. (2013). Coarse particulate matter and airborne endotoxin within wood stove homes. *Indoor Air*, 23(6), 498–505. https://doi.org/10.1111/ina.12043

[154] Semmens, E. O., Noonan, C. W., Allen, R. W., Weiler, E. C., & Ward, T. J. (2015). Indoor particulate matter in rural, wood stove heated homes. *Environmental Research*, 138, 93–100. https://doi.org/10.1016/j.envres.2015.02.005

[155] 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, 608–618. https://doi.org/10.1016/j.scitotenv.2017.12.312

Under some conditions wood pellet stoves may have lower emissions than wood stoves that burn logs;[156, 157] however, wood pellet storage systems may also lead to degraded indoor air quality. Wood pellet boilers may require several tons of wood pellets per year and are often stored in rooms or large bag-type containers. Off-gassing from these large pellet quantities in enclosed storage locations may lead to CO concentrations that exceed health-based guidelines and have reportedly led to fatal accidents.[158] Scientists recommend that storage areas be equipped with a CO monitor and alarm system and that rebate programs for the installation of wood-pellet boilers include clauses that require outdoor bulk pellet storage.[159]

Interventions aimed at reducing indoor air pollutant concentrations and subsequent exposures from wood-fueled appliances led to mixed results, highlighting that meaningful improvements may require a multi-source intervention approach. For example, researchers conducted a community-scale intervention in Libby, Montana replacing old wood-burning stove models with new EPA-certified wood stoves and they found that the stove interventions reduced indoor $PM_{2.5}$ by 54 percent on average, but that a subset of homes did not experience

$PM_{2.5}$ reductions.[160] While another study conducted in Alaska, Montana, and the Navajo Nation (Arizona and New Mexico) did not find meaningful differences in $PM_{2.5}$ (or health effects) through low-cost education and air filtration interventions.[161]

3.3.3.2 DHCD Data on Heating Appliances

In the Maryland Department of Housing and Community Development combustion appliance inspections (described above), indoor CO measurements were collected in the rooms with household and water heating appliances, including furnaces, hot water heaters, and gas fireplaces. 1.6 percent of furnaces and 0.6 percent of hot water tanks had measured indoor CO concentrations $\geq$ 35 ppm in rooms with combustion appliances (**Table 3-2**). Among heating

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[156] Bäfver, L. S., Leckner, B., Tullin, C., & Berntsen, M. (2011). Particle emissions from pellets stoves and modern and old-type wood stoves. *Biomass and Bioenergy*, 35(8), 3648–3655. https://doi.org/10.1016/j.biombioe.2011.05.027

[157] Lamberg, H., Sippula, O., Tissari, J., Virén, A., Kaivosoja, T., Aarinen, A., Salminen, V., & Jokiniemi, J. (2017). Operation and Emissions of a Hybrid Stove Fueled by Pellets and Log Wood. *Energy & Fuels*, 31(2), 1961–1968. https://doi.org/10.1021/acs.energyfuels.6b02717

[158] Soto-Garcia, L., Huang, X., Thimmaiah, D., Rossner, A., & Hopke, P. K. (2015). Exposures to Carbon Monoxide from Off-Gassing of Bulk Stored Wood Pellets. *Energy & Fuels*, *29*(1), 218–226. https://doi.org/10.1021/ef5021186

[159] Rossner, A., Jordan, C. E., Wake, C., & Soto-Garcia, L. (2017). Monitoring of carbon monoxide in residences with bulk wood pellet storage in the Northeast United States. *Journal of the Air & Waste Management Association*, 67(10), 1066–1079. https://doi.org/10.1080/10962247.2017.1321054

[160] Noonan, C. W., & Ward, T. J. (2012). Asthma randomized trial of indoor wood smoke (ARTIS): Rationale and methods. *Contemporary Clinical Trials*, 33(5), 1080–1087. https://doi.org/10.1016/j.cct.2012.06.006

[161] Walker, E. S., Semmens, E. O., Belcourt, A., Boyer, B. B., Erdei, E., Graham, J., Hopkins, S. E., Lewis, J. L., Smith, P. G., Ware, D., Weiler, E., Ward, T. J., & Noonan, C. W. (2022). Efficacy of Air Filtration and Education Interventions on Indoor Fine Particulate Matter and Child Lower Respiratory Tract Infections among Rural U.S. Homes Heated with Wood Stoves: Results from the KidsAIR Randomized Trial. *Environmental Health Perspectives*, 130(4), 047002. https://doi.org/10.1289/EHP9932

appliances, furnaces and hot water tanks had high observed indoor ambient CO concentration measured within the combustion appliance zone (90.1 ppm and 87.9 ppm, respectively) (**Table 3-2**). These maximum concentrations are more than 2.5 times the 1-hour NAAQS for ambient CO and represent levels at which evacuation is recommended.

3.3.3.3 Health Risks and Impacts Associated with Heating Appliances

3.3.3.3.1 Gas Heating Appliances

One study found that using gas stoves for heat without ventilation increased the risk of pneumonia and cough, compared to children who lived in homes where gas was only used for cooking.[162] This study was extensive, using >3,000 parent-reported data points for multiple respiratory symptoms of children under 5 years old from the National Health and Nutrition Examination Survey (1988–1994).

3.3.3.3.2 Wood Heating Appliances

Several studies have found health outcomes associated with the use of wood for heating. In a study of Alaska Native children's respiratory symptoms, researchers reported that the use of wood fuel as a primary heat source was associated with a higher risk of coughs between colds.[163] Furthermore, a New York-based study found that burning synthetic logs in a fireplace increased breast cancer risk by 42 percent, although there was not a significant increase in risk from burning wood alone.[164]

Studies that investigated the efficacy of interventions in reducing respiratory symptoms and diseases among children in homes that use a wood stove had disparate results. One study found that a multi-faceted intervention approach, which included stove and ventilation remediation and household education, led to decreases in parent-reported respiratory symptoms, respiratory visits, and school absences.[165] In contrast, another study did not

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[162] 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), 77. https://doi.org/10.1186/s12889-015-1425-y

[163] Singleton, R., Salkoski, A. J., Bulkow, L., Fish, C., Dobson, J., Albertson, L., Skarada, J., Kovesi, T., McDonald, C., Hennessy, T. W., & Ritter, T. (2017). Housing characteristics and indoor air quality in households of Alaska Native children with chronic lung conditions. *Indoor Air*, 27(2), 478–486. https://doi.org/10.1111/ina.12315

[164] White, A. J., Teitelbaum, S. L., Stellman, S. D., Beyea, J., Steck, S. E., Mordukhovich, I., McCarty, K. M., Ahn, J., Rossner, P., Santella, R. M., & Gammon, M. D. (2014). Indoor air pollution exposure from use of indoor stoves and fireplaces in association with breast cancer: A case-control study. *Environmental Health*, *13*(1), 108. https://doi.org/10.1186/1476-069X-13-108

[165] Singleton, R., Salkoski, A. J., Bulkow, L., Fish, C., Dobson, J., Albertson, L., Skarada, J., Ritter, T., Kovesi, T., & Hennessy, T. W. (2018). Impact of home remediation and household education on indoor air quality, respiratory visits and symptoms in Alaska Native children. *International Journal of Circumpolar Health*, 77(1), 1422669. https://doi.org/10.1080/22423982.2017.1422669

observe meaningful differences in lower respiratory tract infections after implementing low-cost education and air filtration interventions.[166]

3.4 Impacts of Residential Retrofits on Indoor Air Quality and Health

Below we discuss the impacts of residential retrofits and upgrades—including energy efficiency and weatherization retrofits (**Section 3.4.1**), ventilation and filtration retrofits (**Section 3.4.2**), electrification of fossil-fuel-powered combustion appliances (**Section 3.4.3**) and healthy homes programs (**Section 3.4.4**)—on indoor air quality and human health. Efforts aimed to support residential retrofits in Maryland are discussed in **Chapter 5**.

3.4.1 Energy Efficiency and Weatherization

Residential energy-efficiency retrofits are often offered through governmental and utility programs, and require site-specific audits to identify measures appropriate for a specific home. Measures frequently include replacements of air conditioning and filtration systems, weatherization measures such as insulation and air sealing measures, and installation of energy-efficient home appliances.[167] While concerns have been raised regarding the impact of air sealing measures on the health and safety of residents,[168] many retrofit programs have required existing or retrofitted mechanical ventilation systems to meet current standards.[169] The specific interactions of housing design, materials used, occupant behaviors, outdoor air, and the changing climate all ultimately influence the health risks of energy efficiency interventions and zero net energy homes.[170]

Broadly, energy efficiency retrofits can affect indoor environmental quality parameters including temperature, humidity, and air pollutant concentrations.[171] In tightly sealed homes without the availability or utilization of mechanical or passive ventilation measures (e.g., opening windows), indoor air pollutant concentrations may dramatically increase during

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[166] Walker, E. S., Semmens, E. O., Belcourt, A., Boyer, B. B., Erdei, E., Graham, J., Hopkins, S. E., Lewis, J. L., Smith, P. G., Ware, D., Weiler, E., Ward, T. J., & Noonan, C. W. (2022). Efficacy of Air Filtration and Education Interventions on Indoor Fine Particulate Matter and Child Lower Respiratory Tract Infections among Rural U.S. Homes Heated with Wood Stoves: Results from the KidsAIR Randomized Trial. *Environmental Health Perspectives*, 130(4), 047002. https://doi.org/10.1289/EHP9932

[167] Francisco, P. W. (2016). Indoor Air Quality in Residential Energy Retrofits. *ASHRAE Journal*, 58(6), 80+. Gale Academic OneFile. https://link.gale.com/apps/doc/A525003701/AONE?u=anon~6e7096a&sid=googleScholar&xid=543c6a40

[168] NASEM (National Academies of Sciences, Engineering, and Medicine. (2011). Climate Change, the Indoor Environment, and Health. https://doi.org/10.17226/13115

[169] Francisco, P. W. (2016). Indoor Air Quality in Residential Energy Retrofits. *ASHRAE Journal*, 58(6), 80+. Gale Academic OneFile. https://link.gale.com/apps/doc/A525003701/AONE?u=anon~6e7096a&sid=googleScholar&xid=543c6a40

[170] Hemsath, T. L., Walburn, A., Jameton, A., & Gulsvig, M. (2012). A review of possible health concerns associated with zero net energy homes. *Journal of Housing and the Built Environment*, 27(3), 389–400. https://doi.org/10.1007/s10901-011-9260-7

[171] 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. https://doi.org/10.1016/j.buildenv.2020.107067

certain activities (e.g., cooking) when concentrations may have a slow rate of decay in the home.[172] A review of studies evaluating the influence of residential energy efficiency retrofits on indoor air quality and self-reported comfort and health symptoms found mixed results. Some studies reported decreases in average indoor concentrations of NO_2 and volatile organic compounds (VOCs) (except for formaldehyde) after retrofits, while others reported increases in the same compounds after retrofits. Studies reported that indoor radon and formaldehyde concentrations increased after retrofits that did not include whole-house mechanical ventilation.[173] Another study relying on modeling the impact of energy and ventilation retrofits on indoor air quality found that indoor air pollutant concentrations were reduced even with a wide variety of activities, while retrofits without ventilation resulted in increases in $PM_{2.5}$ and NO_2 for some households.[174] This indicates that sealing a building envelope can negatively influence air quality without properly controlled ventilation measures, so careful consideration and proper education are needed when energy efficiency retrofits are implemented. Sufficient ventilation is an important consideration when implementing energy efficiency retrofits. In this context it is important to point out that the weatherization programs of Maryland's Department of Housing and Community Development strictly follow the ventilation standards of the American Society of Heating, Refrigeration, and Air-conditioning Engineers.[175]

A recent review found self-reported perceived comfort and general health tend to improve after energy efficiency retrofits, while changes in asthma-related improvements were mixed pre- and post-retrofit.[176] Occupant reports of dampness and mold nearly always decreased after retrofits, and self-reported thermal comfort, non-asthma respiratory symptoms, general health, and mental health generally improved after retrofits. Additionally, given the variety of study designs and differences in reported results across studies, it was not possible to evaluate the influence of *specific* energy efficiency interventions on indoor air quality and health here.[177]

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[172] Militello-Hourigan, R. E., & Miller, S. L. (2018). The impacts of cooking and an assessment of indoor air quality in Colorado passive and tightly constructed homes. *Building and Environment*, 144, 573–582. https://doi.org/10.1016/j.buildenv.2018.08.044

[173] 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. https://doi.org/10.1016/j.buildenv.2020.107067

[174] Underhill, L. J., Fabian, M. P., Vermeer, K., Sandel, M., Adamkiewicz, G., Leibler, J. H., & Levy, J. I. (2018). Modeling the resiliency of energy-efficient retrofits in low-income multifamily housing. *Indoor Air*, 28(3), 459–468. https://doi.org/10.1111/ina.12446

[175] Nicola Tran, DHCD, personal communication with Arjun Makhijani, IEER, December 19, 2022

[176] 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. https://doi.org/10.1016/j.buildenv.2020.107067

[177] Ibid.

Two studies modeled changes in indoor air pollutant concentrations from retrofits and translated these findings into health impacts and associated health costs. One study modeled indoor $PM_{2.5}$ associated with residential energy-efficiency retrofits and $PM_{2.5}$-related health impacts and costs in a multifamily building in Boston, Massachusetts, comparing health savings and retrofit-related savings. Weatherization retrofits without ventilation or filtration resulted in health costs that far exceeded energy savings and population-level health savings, due to the increase in indoor $PM_{2.5}$. Meanwhile, weatherization paired with ventilation and filtration retrofits offered the largest savings overall (Underhill et al., 2020). A more recent study, also focused in Boston, Massachusetts, evaluated modeled indoor air quality and pediatric asthma exacerbation instances to evaluate the potential impacts of different energy retrofits in affordable housing.[178] The authors reported that modeled retrofit scenarios resulted in improved overall health outcomes and healthcare cost savings when energy-saving sealing retrofits were coupled with mechanical ventilation. These retrofits resulted in healthcare cost savings of $200 annually for families in scenarios with indoor exposures to tobacco smoke and gas-stove cooking. Meanwhile, without mechanical ventilation, air sealing retrofits alone in the same households would result in an *increase* of nearly $200 annually in healthcare utilization costs.[179]

Additionally, studies note that combinations of interventions such as weatherization, healthy home interventions (discussed in **Section 3.4.4**), and broader educational efforts can improve childhood asthma control.[180] In sum, energy efficiency retrofits serve as an important tool aimed to meet climate goals. Coupled air sealing, mechanical ventilation and filtration, and educational efforts can allow a controlled level of air change to balance addressing both energy efficiency and indoor air quality goals and can result in simultaneous benefits for climate and public health.

3.4.2 Household Ventilation and Filtration

The studies reviewed here indicated that, in practice, increasing household ventilation may not unequivocally lead to indoor air quality improvements. One study found that ventilation resulted in reductions in average indoor/outdoor air pollutant ratios across a range of

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[178] Tieskens, K. F., Milando, C. W., Underhill, L. J., Vermeer, K., Levy, J. I., & Fabian, M. P. (2021). The impact of energy retrofits on pediatric asthma exacerbation in a Boston multi-family housing complex: A systems science approach. ^, 20(1), 14. https://doi.org/10.1186/s12940-021-00699-x

[179] Ibid.

[180] Breysse, J., Dixon, S., Gregory, J., Philby, M., Jacobs, D. E., & Krieger, J. (2014). Effect of Weatherization Combined With Community Health Worker In-Home Education on Asthma Control. *American Journal of Public Health*, 104(1), e57–e64. https://doi.org/10.2105/AJPH.2013.301402

pollutants (PM, ozone, NO_2, CO_2, CO, formaldehyde).[181] Another study found that both exhaust ventilation and exhaust ventilation with enhanced filtration substantially reduced indoor $PM_{2.5}$.[182] In contrast, some researchers found that high ventilation rates in residences in urban areas may have negative effects on respiratory health due to the infiltration of outdoor air pollution indoors.[183] Two other studies found that infiltration and intermittent ventilation can increase indoor air pollution concentrations under some conditions and that increasing air mixing in most homes may not benefit average indoor air quality.[184, 185]

In a study of 70 homes, scientists found that houses in compliance with California's mechanical ventilation requirements can be simultaneously built to stringent efficiency standards and maintain indoor air quality compared to households built prior to these requirements.[186] Several studies further indicated that high-quality ventilation systems should be prioritized when conducting energy retrofits or upgrades. One study found that energy retrofits that are not coupled with ventilation retrofits may lead to elevated levels of $PM_{2.5}$ or NO_2, especially in homes with heavy cooking or smoking activities.[187] Another study found that modeled homes that saved energy by reducing the flow of outdoor air into the indoor environment led to increases in exposure concentrations.[188] Further, a study of high-performance green homes,[189] reported that very airtight homes are particularly liable to design, installation, and operation faults of mechanical ventilation systems.

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[181] Kang, I., McCreery, A., Azimi, P., Gramigna, A., Baca, G., Abromitis, K., Wang, M., Zeng, Y., Scheu, R., Crowder, T., Evens, A., & Stephens, B. (2022). Indoor air quality impacts of residential mechanical ventilation system retrofits in existing homes in Chicago, IL. *Science of The Total Environment*, 804, 150129. https://doi.org/10.1016/j.scitotenv.2021.150129

[182] 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. https://doi.org/10.1016/j.buildenv.2017.06.021

[183] Carlton, E. J., Barton, K., Shrestha, P. M., Humphrey, J., Newman, L. S., Adgate, J. L., Root, E., & Miller, S. (2019). Relationships between home ventilation rates and respiratory health in the Colorado Home Energy Efficiency and Respiratory Health (CHEER) study. *Environmental Research*, 169, 297–307. https://doi.org/10.1016/j.envres.2018.11.019

[184] Sherman, M. H., Logue, J. M., & Singer, B. C. (2011). Infiltration effects on residential pollutant concentrations for continuous and intermittent mechanical ventilation approaches. *HVAC&R Research*, 17(2), 159–173. https://doi.org/10.1080/10789669.2011.543258

[185] Sherman, M., & Walker, I. (2010). Impacts of Mixing on AcceptableIndoor Air Quality in Homes. *HVAC&R Research*, 16(3), 315–329. https://doi.org/10.1080/10789669.2010.10390907

[186] Singer, B. C., Chan, W. R., Kim, Y., Offermann, F. J., & Walker, I. S. (2020). Indoor air quality in California homes with code-required mechanical ventilation. *Indoor Air,* 30(5), 885–899. https://doi.org/10.1111/ina.12676

[187] Underhill, L. J., Fabian, M. P., Vermeer, K., Sandel, M., Adamkiewicz, G., Leibler, J. H., & Levy, J. I. (2018). Modeling the resiliency of energy-efficient retrofits in low-income multifamily housing. *Indoor Air*, 28(3), 459–468. https://doi.org/10.1111/ina.12446

[188] Walker, I., Less, B., Lorenzetti, D., & Sohn, M. D. (2021). Development of Advanced Smart Ventilation Controls for Residential Applications. *Energies*, 14(17), 5257. https://doi.org/10.3390/en14175257

[189] 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. https://doi.org/10.1080/10789669.2014.961850

Several studies find that mechanical ventilation and filtration may lead to health benefits.[190,191] In one study, increased home ventilation was associated with improved respiratory metrics, although associations were stronger in healthy populations compared to those with asthma.[192] Another study found that home ventilation treatment significantly reduced the risk of death, hospitalizations, and emergency room visits in medicare beneficiaries with chronic obstructive pulmonary disease and chronic respiratory failure.[193]

Two studies further indicated that non-mechanical ventilation interventions, such as opening windows and doors, may lead to both indoor air quality and health benefits. For example, one study found that venting the indoor environment by opening windows and doors substantially reduced VOC concentrations and another study found that pregnant women who did not report the use of frequent window ventilation (i.e., had their windows open for less than half the day) had an increased risk of adverse birth outcomes.[194, 195] However, these non-mechanical ventilation interventions are likely not a permanent solution for Marylanders and may only be practical during the shoulder seasons, i.e., spring and fall, when heating and air conditioning systems are used less frequently or not at all.

Although national data for how many homes have proper stove ventilation is lacking, researchers have found that gas stoves without properly vented exhaust hoods are common in inner-city households, including in Baltimore. Current literature also indicates that improved mechanical ventilation and filtration can allow a controlled level of air change that results in improved indoor air quality within the home. Such improvements are health relevant, reducing the risk of respiratory diseases, such as childhood asthma in Baltimore.[196]

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[190] Carrer, P., Wargocki, P., Fanetti, A., Bischof, W., De Oliveira Fernandes, E., Hartmann, T., Kephalopoulos, S., Palkonen, S., & Seppänen, O. (2015). What does the scientific literature tell us about the ventilation–health relationship in public and residential buildings? *Building and Environment*, 94, 273–286. https://doi.org/10.1016/j.buildenv.2015.08.011

[191] Zhao, D., Azimi, P., & Stephens, B. (2015). Evaluating the Long-Term Health and Economic Impacts of Central Residential Air Filtration for Reducing Premature Mortality Associated with Indoor Fine Particulate Matter (PM2.5) of Outdoor Origin. *International Journal of Environmental Research and Public Health*, 12(7), 8448–8479. https://doi.org/10.3390/ijerph120708448

[192] Humphrey, J. L., Barton, K. E., Man Shrestha, P., Carlton, E. J., Newman, L. S., Dowling Root, E., Adgate, J. L., & Miller, S. L. (2020). Air infiltration in low-income, urban homes and its relationship to lung function. *Journal of Exposure Science & Environmental Epidemiology*, 30(2), 262–270. https://doi.org/10.1038/s41370-019-0184-8

[193] Frazier, W. D., Murphy, R., & van Eijndhoven, E. (2021). Non-invasive ventilation at home improves survival and decreases healthcare utilization in medicare beneficiaries with Chronic Obstructive Pulmonary Disease with chronic respiratory failure. *Respiratory Medicine*, 177, 106291. https://doi.org/10.1016/j.rmed.2020.106291

[194] Kristensen, K., Lunderberg, D. M., Liu, Y., Misztal, P. K., Tian, Y., Arata, C., Nazaroff, W. W., & Goldstein, A. H. (2019). Sources and dynamics of semivolatile organic compounds in a single-family residence in northern California. *Indoor Air*, ina.12561. https://doi.org/10.1111/ina.12561

[195] Ghosh, J. K. C., Wilhelm, M., & Ritz, B. (2013). Effects of Residential Indoor Air Quality and Household Ventilation on Preterm Birth and Term Low Birth Weight in Los Angeles County, California. *American Journal of Public Health*, 103(4), 686–694. https://doi.org/10.2105/AJPH.2012.300987

[196] Breysse, P. N., Diette, G. B., Matsui, E. C., Butz, A. M., Hansel, N. N., & McCormack, M. C. (2010). Indoor Air Pollution and Asthma in Children. *Proceedings of the American Thoracic Society*, *7*(2), 102–106. https://doi.org/10.1513/pats.200908-083RM

3.4.3 Electrification of Fossil Fuel-Powered Cooking and Heating Appliances

Low-energy and energy-efficient homes, retrofits, and low-carbon requirements for housing are being increasingly established in the United States to help meet near-term climate goals. As a result, the question of how electrification measures impact indoor air quality and health has become increasingly important, especially for those populations most vulnerable to indoor air pollution (**Section 3.2**).

A range of electric alternatives to fossil fuel-powered appliances are available and increasingly used in the United States today. Furnaces and boilers powered by natural gas, propane, or heating oil can be replaced by ground- or air-source heat pumps; gas-powered water heaters can be replaced by an electric equivalent; and gas-powered ovens and stove tops can be replaced with electric range ovens and induction cooktops, respectively.[197, 198, 199]

Electrification of fossil fuel-powered heating and cooking appliances has become an increasingly popular climate mitigation strategy.[200] In the United States, buildings account for 40 percent of the country's energy use-related greenhouse gas emissions, with 46 percent of all households using natural gas as their main heating fuel.[201, 202] In Maryland this value is slightly lower, with 43 percent of all households using natural gas as their main heating fuel.[203] Similarly, 38 percent of U.S. households (40 percent in Maryland) use a natural gas appliance for cooking.[204] As natural gas furnaces are the most common space heating appliance in the U.S., the replacement of fuel-powered furnaces (and boilers) with heat pumps would substantially decrease the number of natural gas appliances used for residential heating.[205]

The proportion of households that rely on fossil fuels for heating and cooking also varies by demographic factors such as income, with low-income households relying on fossil fuel-based

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[197] Gerdes, J. (2020, July 5). So, What Exactly Is Building Electrification? https://www.greentechmedia.com/articles/read/so-what-exactly-is-building-electrification

[198] Hopkins, Takahashi, Glick, & Whited. (2018). Decarbonization of Heating Energy Use in California Buildings. Technology, Markets, Impacts, and Policy Solutions. https://www.californiageo.org/wp-content/uploads/Decarbonization-of-heating-in-CA-Bldgs-Synapse-2018.pdf

[199] Deetjen, T. A., Walsh, L., & Vaishnav, P. (2021). US residential heat pumps: The private economic potential and its emissions, health, and grid impacts. *Environmental Research Letters*, 16(8), 084024. https://doi.org/10.1088/1748-9326/ac10dc

[200] Ibid.

[201] U.S. EIA (Energy Information Administration). (2022, June). Highlights for appliances in U.S. homes by state, 2020. https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Appliances.pdf

[202] Gerdes, J. (2020, July 5). So, What Exactly Is Building Electrification? https://www.greentechmedia.com/articles/read/so-what-exactly-is-building-electrification

[203] Maryland data from the 2021 American Community Survey, Table S2504 at https://data.census.gov/table?q=+Maryland+housing&tid=ACSST1Y2021.S2504.

[204] U.S. Energy Information Administration. (2022). Highlights for appliances in U.S. homes by state, 2020. https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Appliances.pdf

[205] Ibid.

appliances at a higher rate than higher-income households.[206, 207] In Baltimore City, Maryland, for example, 63 percent of low-income households rely on natural gas as their main heating fuel compared to the national average of 46 percent in the U.S.,[208] with only 31 percent of low-income households relying on electric-powered heating sources.[209] Therefore, the full replacement of gas-powered heating appliances with electric alternatives could also have important health and equity benefits.

Health-damaging air pollutants emitted during household fossil fuel combustion activities (e.g., cooking, heating) substantially contribute to indoor air pollution, exposure to which is associated with various adverse health outcomes (e.g., childhood asthma, lung disease, respiratory infections, cancer, increased risk of adverse pregnancy outcomes) (**Section 3.2** and **Section 3.3**). While the replacement of these appliances with electric-powered alternatives would not eliminate the byproducts generated by the substances being cooked (e.g., fumes from cooking oils),[210] it would help to improve indoor air quality and subsequent health in the home by avoiding combustion-related emissions inherent to fossil fuel appliances altogether.[211] Additionally, findings suggest that electrification of fossil fuel-based kitchen appliances would have substantial impacts not only on indoor air quality in the kitchen but throughout the home.[212]

This notion is supported by evidence in the peer-reviewed literature, summarized below, which suggests that indoor air pollution is reduced when cooking and heating (e.g., furnaces, boilers) appliances are electrified. It should be noted that the impacts of gas appliances are discussed above (**Section 3.3**), while here we discuss the direct comparison between different types of appliances to assess the benefits of electrification. For example, a California study found ultrafine particulate matter ($PM_{1.0}$) concentrations in homes with induction cooktops (particle count = 5,430 #/cm^3) to be substantially lower than concentrations found in

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[206] Maryland Office of People's Counsel. (2018). Maryland Low-Income Market Characterization Report. Energy Efficiency for All. https://www-new.energyefficiencyforall.org/resources/maryland-low-income-market-characterization-report/

[207] U.S. EIA. (2020). Residential Energy Consumption Survey (RECS) State Data. https://www.eia.gov/consumption/residential/data/2020/index.php?view=state

[208] Ibid.

[209] Maryland Office of People's Counsel. (2018). Maryland Low-Income Market Characterization Report. Energy Efficiency for All. https://www-new.energyefficiencyforall.org/resources/maryland-low-income-market-characterization-report/

[210] Zhai, S. R., & Albritton, D. (2020). Airborne particles from cooking oils: Emission test and analysis on chemical and health implications. *Sustainable Cities and Society*, 52, 101845. https://doi.org/10.1016/j.scs.2019.101845

[211] CARB. (2022). Combustion Pollutants & Indoor Air Quality. https://ww2.arb.ca.gov/resources/documents/combustion-pollutants-indoor-air-quality

[212] Seals, B. A., & Krasner, A. (2020). Health Effects from Gas Stove Pollution. Rocky Mountain Institute, Physicians for Social Responsibility, Mothers Out Front, and Sierra Club.

households using natural gas (particle count=231,583 #/cm^3) burners.[213] Additionally, this same study found NO_2, NO, and NO_x concentrations in homes using gas powered appliances for cooking to be higher compared to homes using electric cooking appliances (gas vs. electric, respectively: NO_2 = 13.1 vs. 5.4 ppb; NO = 13.8 vs. 7.4 ppb; NO_x = 29.9 vs. 10.9 ppb).[214]

These findings have important health implications. For example, $PM_{1.0}$ exposure can impact health, largely due to the elevated health risks associated with exposure to particles of such a small size. When inhaled, $PM_{1.0}$ is able to travel to smaller airways and alveoli within the body that larger particles cannot, and diffuse and deposit onto respiratory surfaces, accumulating in the lung and remaining there permanently. Over time, frequent and repeated exposure can overburden the pulmonary system, resulting in more severe local and systemic responses to exposure.[215] Therefore, reductions in ultrafine particulates in the home would help reduce health risks.

SELECT STUDIES CONDUCTED IN BALTIMORE CITY, MD

The use of unvented gas stoves in homes is common in urban areas like Baltimore City.[216] As increased indoor NO_2 concentrations are directly associated with gas stove use, replacement with electric alternatives would help mitigate the health impacts associated with fossil fuel combustion emissions. Peer-reviewed studies on electrification of home appliances in Baltimore City, while limited, support this notion, highlighting indoor gas stove use as a major contributor to elevated indoor pollutant concentrations, in this case NO_2.

A study published in 2014 found that replacing unvented gas stoves in Baltimore City homes with electric alternatives was associated with a 51 percent decrease in NO_2 concentrations in the kitchen and a 42 percent reduction in NO_2 in the bedroom.[217] This trend was observed for the majority of homes in the study, despite the

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[213] 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. https://doi.org/10.1080/10789669.2014.961850

[214] Ibid.

[215] U.S. EPA. (2014). Particle Pollution Exposure [Collections and Lists]. https://www.epa.gov/pmcourse/particle-pollution-exposure

[216] Paulin, L. M., Diette, G. B., Scott, M., McCormack, M. C., Matsui, E. C., Curtin-Brosnan, J., Williams, D. L., Kidd-Taylor, A., Shea, M., Breysse, P. N., & Hansel, N. N. (2014). Home interventions are effective at decreasing indoor nitrogen dioxide concentrations. *Indoor Air*, 24(4), 416–424. https://doi.org/10.1111/ina.12085

[217] Ibid.

concurrent (and varied) use of other fossil-fuelled appliances (e.g., furnaces). This suggests that unvented gas stove use is a major contributor to indoor NO_2 concentrations.

Findings from Paulin et al. (2017) identify gas stove use as a major contributor to indoor NO_2 concentrations. The authors found that each hour of kitchen appliance use in Baltimore City homes with gas stoves and furnaces was associated with an increase in 24-hour averaged indoor NO_2 concentration. NO_2 increased by 18 ppb overall, by as much as 25 ppb NO_2 in the winter season, and by as much as 35 ppb when windows were closed.[218] Findings from Paulin et al. (2017) also demonstrate that substantial pollutant reductions could be achieved when gas stoves are replaced with electric stove alternatives.

An earlier study, Hansel et al. (2008), focused on children's exposure in low-income homes (with 91 percent African American children), found the range of NO_2 concentrations in from 2.9 ppb to 394 ppb, the latter value being almost four times the EPA one-hour limit for outdoor air. The authors found that an increase in 20 ppb of NO_2 was associated with statistically significant increases of respiratory symptoms in children including wheezing, coughing without a cold, and waking up at night because of respiratory symptoms.

These findings are health relevant. Acute exposure to elevated levels of NO_2 can aggravate the respiratory system, leading to increased asthma exacerbations, respiratory symptoms (wheezing, coughing, difficulty breathing), and respiratory-related hospitalizations and emergency department visits.[219] Similarly, chronic exposure to elevated levels of NO_2 can contribute to the development of asthma and may increase one's susceptibility to respiratory infections.[220] In fact, adverse health impacts associated with elevated NO_2 concentrations are observed in Paulin et al. (2017). The authors found children with asthma living in homes with

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[218] Paulin, L. M., Williams, D. 'Ann L., Peng, R., Diette, G. B., McCormack, M. C., Breysse, P., & Hansel, N. N. (2017). 24-h Nitrogen dioxide concentration is associated with cooking behaviors and an increase in rescue medication use in children with asthma. *Environmental Research*, 159, 118–123. https://doi.org/10.1016/j.envres.2017.07.052

[219] U.S. EPA. (2016). Basic Information about NO_2 [Overviews and Factsheets]. https://www.epa.gov/no2-pollution/basic-information-about-no2

[220] Ibid.

elevated NO_2 concentrations reported increased use of overnight emergency inhalers in the evening following exposure.[221] More specifically, each ten-fold increase in the previous day's NO_2 concentration was associated with an increased odds of night time emergency inhaler use in children with asthma.[222]

Improvements to indoor air quality are associated with improvements in respiratory disease outcomes, such as asthma symptoms in Baltimore City children. A review focused on studies conducted by the Johns Hopkins Center for Childhood Asthma in the Urban Environment and other relevant epidemiologic studies suggest that reductions in PM, NO_2, and mouse allergens in the home are effective asthma management strategies.[223] For example, for each 10 mg/m^3 increase in indoor $PM_{2.5–10}$ concentration, there was a 6 percent increase in the number of days a child experienced cough, wheeze, or chest tightness.[224] Additionally, reductions in indoor $PM_{2.5}$ concentrations were positively associated with both reductions in respiratory symptoms and rescue medication use. Results from the Baltimore Indoor Environment Study of Asthma in Kids (BIESAK) also show that Baltimore City homes have high indoor NO_2 concentrations.[225, 226] Higher NO_2 concentrations were associated with statistically significant increases in respiratory symptoms in preschool children with asthma. Additionally, higher NO_2 concentrations were found in homes with a gas stove (average of ~33 ppb) compared to households without a gas stove (average of ~17 ppb).[227] These results suggest that modifications in the home to reduce PM and NO_2 levels, such as electrification of cooking appliances, for example, would be an effective asthma management strategy.[228, 229]

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[221] Paulin, L. M., Williams, D.'Ann L., Peng, R., Diette, G. B., McCormack, M. C., Breysse, P., & Hansel, N. N. (2017). 24-h Nitrogen dioxide concentration is associated with cooking behaviors and an increase in rescue medication use in children with asthma. *Environmental Research*, 159, 118–123. https://doi.org/10.1016/j.envres.2017.07.052

[222] Ibid.

[223] Breysse, P. N., Diette, G. B., Matsui, E. C., Butz, A. M., Hansel, N. N., & McCormack, M. C. (2010). Indoor Air Pollution and Asthma in Children. *Proceedings of the American Thoracic Society*, *7*(2), 102–106. https://doi.org/10.1513/pats.200908-083RM

[224] Ibid.

[225] Hansel, N. N., Breysse, P. N., McCormack, M. C., Matsui, E. C., Curtin-Brosnan, J., Williams, D. L., Moore, J. L., Cuhran, J. L., & Diette, G. B. (2008). A longitudinal study of indoor nitrogen dioxide levels and respiratory symptoms in inner-city children with asthma. *Environmental Health Perspectives*, 116(10), 1428–1432. https://doi.org/10.1289/ehp.11349

[226] Breysse, P. N., Diette, G. B., Matsui, E. C., Butz, A. M., Hansel, N. N., & McCormack, M. C. (2010). Indoor Air Pollution and Asthma in Children. *Proceedings of the American Thoracic Society*, *7*(2), 102–106. https://doi.org/10.1513/pats.200908-083RM

[227] Ibid.

[228] Ibid.

[229] Hansel, N. N., Breysse, P. N., McCormack, M. C., Matsui, E. C., Curtin-Brosnan, J., Williams, D. L., Moore, J. L., Cuhran, J. L., & Diette, G. B. (2008). A longitudinal study of indoor nitrogen dioxide levels and respiratory symptoms in inner-city children with asthma. *Environmental Health Perspectives*, 116(10), 1428–1432. https://doi.org/10.1289/ehp.11349

3.4.4 Healthy Homes

Healthy home programs have been widely adopted across the United States by states and cities such as Maryland and Baltimore City, in an effort to improve the environmental quality inside the home.[230, 231] Generally, the intended goal of a healthy homes program is to prevent, identify, and address environmental health and safety concerns in an effort to provide every person with a safe, clean, and healthy home that promotes their well being.[232] Those most vulnerable to home health and safety hazards, including low-income households and adults and children with asthma, are often prioritized for healthy home programs.[233, 234] The particular focus for this chapter are programs that specifically integrate energy efficiency and energy use retrofits, including decarbonization, into the intervention's design.

A major health concern often targeted in healthy home programs is the prevalence of childhood asthma and risk of exposure to household asthma triggers, especially in low-income households that are disproportionately impacted. The Lowell Healthy Homes Program in Massachusetts, for example, implemented in-home interventions from 2009 to 2012 aimed at reducing and/or eliminating household allergens and asthma triggers in low-income households that have children with asthma.[235] Home visits and environmental assessments helped identify any household asthma triggers and were used to inform household-specific interventions. Remediation plans included interventions such as pest management, commercial cleaning, providing healthy cleaning equipment and supplies (e.g., green cleaning chemicals), education, and, on occasion, structural interventions. Results from this study demonstrated a statistically significant health improvement between baseline and follow-up visits. Participants had lower asthma-related symptoms (e.g., wheezing, asthma attacks) and lower health care utilization (e.g., emergency department visits, hospitalizations) post-intervention.[236]

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[230] GHHI. (2015, April 22). The Green & Healthy Homes Initiative. AsthmaCommunityNetwork.Org. https://www.asthmacommunitynetwork.org/node/15680

[231] MD Department of Environmental Health. (2022). Pages—Healthy Homes. Maryland Healthy Homes Programs. https://health.maryland.gov/phpa/OEHFP/EH/Pages/default.aspx

[232] Ibid.

[233] Ferguson, A. C., & Yates, C. (2016). Federal Enactment of Healthy Homes Legislation in the United States to Improve Public Health. *Frontiers in Public Health*, 4. https://doi.org/10.3389/fpubh.2016.00048

[234] Mankikar, D., Campbell, C., & Greenberg, R. (2016). Evaluation of a Home-Based Environmental and Educational Intervention to Improve Health in Vulnerable Households: Southeastern Pennsylvania Lead and Healthy Homes Program. *International Journal of Environmental Research and Public Health*, 13(9), 900. https://doi.org/10.3390/ijerph13090900

[235] Turcotte, D. A., Alker, H., Chaves, E., Gore, R., & Woskie, S. (2014). Healthy Homes: In-Home Environmental Asthma Intervention in a Diverse Urban Community. *American Journal of Public Health*, 104(4), 665–671. https://doi.org/10.2105/AJPH.2013.301695

[236] Ibid.

These same improvements in asthma-related health outcomes, symptoms, and healthcare utilizations from interventions aimed at reducing asthma triggers were observed in healthy home programs in Michigan, New York, and Southeastern Pennsylvania.[237,238] For example, a study conducted in New York evaluated the impact of state-funded healthy home interventions on asthma outcomes in adults and children.[239] The New York State (NYS) Healthy Neighborhoods Program (HNP) operates in communities with a higher burden of housing-related adverse health impacts and associated risk factors.[240,241] Interventions within this program that were aimed at reducing and/or eliminating asthma triggers were found to significantly improve environmental conditions in the home, as well as improve self-reported asthma symptoms, self-management of asthma symptoms, health care visits, and asthma morbidity outcomes.[242,243] This program also significantly reduced tobacco smoke, fire, lead, indoor air pollution, pests, and mold hazards.[244]

3.5 Summary

Electrification can eliminate combustion-related emissions associated with residential space and water heating and cooking appliances, including air pollutants such as $PM_{2.5}$, NO_x, CO, benzene, and formaldehyde which are associated with a variety of adverse cardiovascular and respiratory health effects.

Studies have shown that gas-based appliances can leak, even when they are not in use—contributing to hazardous air pollutant concentrations indoors. Indoor combustion of fossil fuels and wood in cooking and heating appliances contributes to poor indoor air quality,

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[237] Largo, T. W., Borgialli, M., Wisinski, C. L., Wahl, R. L., & Priem, W. F. (2011). Healthy Homes University: A Home-Based Environmental Intervention and Education Program for Families with Pediatric Asthma in Michigan. *Public Health Reports*, 126(1_suppl), 14–26. https://doi.org/10.1177/00333549111260S104

[238] Mankikar, D., Campbell, C., & Greenberg, R. (2016). Evaluation of a Home-Based Environmental and Educational Intervention to Improve Health in Vulnerable Households: Southeastern Pennsylvania Lead and Healthy Homes Program. *International Journal of Environmental Research and Public Health*, 13(9), 900. https://doi.org/10.3390/ijerph13090900

[239] Reddy, A. L., Gomez, M., & Dixon, S. L. (2017a). An Evaluation of a State-Funded Healthy Homes Intervention on Asthma Outcomes in Adults and Children. *Journal of Public Health Management and Practice*, 23(2), 219–228. https://doi.org/10.1097/PHH.0000000000000530

[240] Ibid.

[241] Reddy, A. L., Gomez, M., & Dixon, S. L. (2017b). The New York State Healthy Neighborhoods Program: Findings From an Evaluation of a Large-Scale, Multisite, State-Funded Healthy Homes Program. *Journal of Public Health Management and Practice*, 23(2), 210–218. https://doi.org/10.1097/PHH.0000000000000529

[242] Gomez, M., Reddy, A. L., Dixon, S. L., Wilson, J., & Jacobs, D. E. (2017). A Cost-Benefit Analysis of a State-Funded Healthy Homes Program for Residents With Asthma: Findings From the New York State Healthy Neighborhoods Program. *Journal of Public Health Management and Practice*, 23(2), 229–238. https://doi.org/10.1097/PHH.0000000000000528

[243] Reddy, A. L., Gomez, M., & Dixon, S. L. (2017a). An Evaluation of a State-Funded Healthy Homes Intervention on Asthma Outcomes in Adults and Children. *Journal of Public Health Management and Practice*, 23(2), 219–228. https://doi.org/10.1097/PHH.0000000000000530

[244] Reddy, A. L., Gomez, M., & Dixon, S. L. (2017b). The New York State Healthy Neighborhoods Program: Findings From an Evaluation of a Large-Scale, Multisite, State-Funded Healthy Homes Program. *Journal of Public Health Management and Practice*, 23(2), 210–218. https://doi.org/10.1097/PHH.0000000000000529

particularly when they are vented indoors (e.g., gas cooking stoves). Appliances reliant on electricity do not require indoor combustion and therefore do not emit combustion-related emissions. However, the use of electric or induction ranges and ovens may contribute to indoor air pollutant emissions related to types of foods being cooked. Ventilation can also improve indoor air quality benefits when electric stoves and ovens or induction ranges are used.

Low-income communities and communities of color tend to be disproportionately impacted by and are more susceptible to environmental risk factors and adverse health outcomes. Because Maryland has a higher fraction of people of color than the national average and Baltimore City has a higher poverty rate than the national average, its residents may be particularly vulnerable to degraded indoor air quality.

Energy efficiency retrofits serve as an important tool aimed to meet climate goals. Programs and interventions can be structured to achieve simultaneous climate and health benefits. Coupled air sealing, mechanical ventilation and filtration, and electrification efforts can improve both energy efficiency and indoor air quality resulting in simultaneous benefits for climate and public health. The research indicates that high-quality ventilation systems should be prioritized when conducting energy retrofits or upgrades to ensure that household ventilation is maintained or improved when energy retrofits are implemented. The greatest benefit will be derived when targeted programs are implemented carefully and focus on populations vulnerable to poor indoor air quality.

In **Chapter 4**, we examine a specific Maryland law that would entrench natural gas use, and leave low- and moderate income households with high bills and indoor air pollution that could be avoided with suitable electrification and ventilation strategies.

4.0 Impacts of Natural Gas Investment

4.1 Introduction

Continued reliance on natural gas presents a complex economic, environmental justice, and climate dilemma for the state of Maryland. The Climate Solutions Now Act establishes climate targets that are among the most ambitious in the world: 60 percent greenhouse gas emission reductions by 2031 relative to 2006, and a carbon-neutral economy by 2045.[245]

At the same time, the 2013 Strategic Infrastructure Development and Enhancement (STRIDE) law encourages utility investments in natural gas infrastructure into the 2040s. The law was created with the ostensible purpose of improving safety and reducing leaks. It authorized Maryland's Public Service Commission (PSC) to allow accelerated cost recovery for the replacement of existing natural gas distribution pipes with limited review, and bypassed the more rigorous rate-setting process, which normally also covers safety. (See **Section 4.3** below). Yet, the investments are allowed to be added to the rate base (after deducting the accelerated recovery), enabling utilities to earn a rate of return that they might not get in many cases if leaks were detected and repaired. These features incentivized natural gas companies to propose billions of dollars of pipe replacements without any quantitative estimate of leak reductions or safety improvements. By making natural gas infrastructure a more appealing investment, STRIDE:

- Locks in continued recovery of revenues from natural gas for decades even as the Climate Solutions Now Act requires the phasing out of fossil fuels;
- Implies continued use of gas infrastructure well after 2045 at great cost and in conflict with the Climate Solutions Now Act;
- Creates the risk of significant stranded costs as Maryland's residential and commercial sectors decarbonize.

A conflict is apparent between climate goals and continued large investments in natural gas infrastructure under STRIDE. In this chapter, we will explore climate imperatives, the potential for stranded costs given the ambitious goals of Maryland's 2022 Climate Solutions Act, and historical safety issues as they may be linked to the implementation of STRIDE. We will also refer to the more general health and safety imperatives associated with natural gas and the need to eliminate it from residential use, as discussed in **Chapter 3**.

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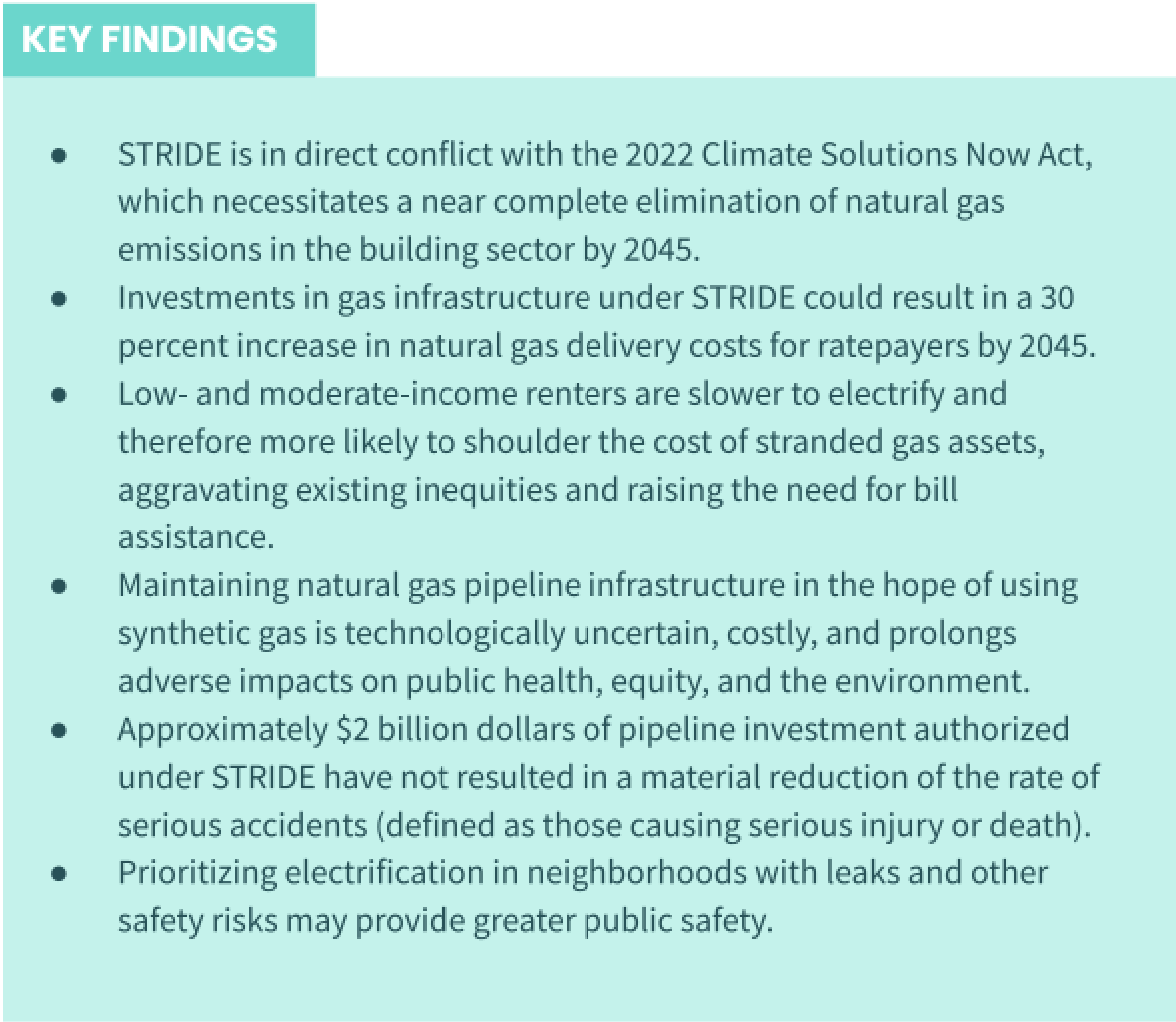
[245] Maryland General Assembly, Climate Solutions Now Act of 2022, Senate Bill 528, Effective Date June 1, 2022, at https://mgaleg.maryland.gov/2022RS/bills/sb/sb0528E.pdf



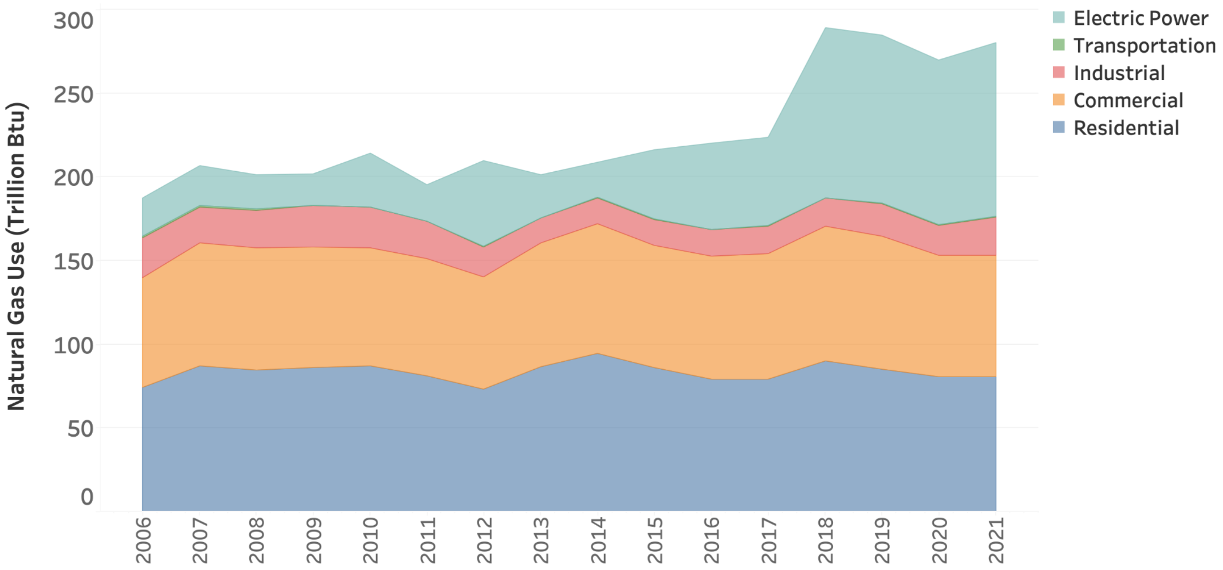
KEY FINDINGS

- STRIDE is in direct conflict with the 2022 Climate Solutions Now Act, which necessitates a near complete elimination of natural gas emissions in the building sector by 2045.
- Investments in gas infrastructure under STRIDE could result in a 30 percent increase in natural gas delivery costs for ratepayers by 2045.
- Low- and moderate-income renters are slower to electrify and therefore more likely to shoulder the cost of stranded gas assets, aggravating existing inequities and raising the need for bill assistance.
- Maintaining natural gas pipeline infrastructure in the hope of using synthetic gas is technologically uncertain, costly, and prolongs adverse impacts on public health, equity, and the environment.
- Approximately $2 billion dollars of pipeline investment authorized under STRIDE have not resulted in a material reduction of the rate of serious accidents (defined as those causing serious injury or death).
- Prioritizing electrification in neighborhoods with leaks and other safety risks may provide greater public safety.

4.2 Direct Natural Gas Use in Maryland and Associated Emissions

It is useful to gain some perspective on the role of converting buildings from natural gas to electric space and water heating in Maryland's climate targets. The residential and commercial sectors account for more than 80 percent of Maryland's direct natural gas use. **Figure 4-1** shows natural gas use in Maryland from 2006, the baseline year for Maryland greenhouse gas accounting, to 2021 by sector. The energy to deliver the natural gas and leaks and losses are not shown in **Figure 4-1**.

Figure 4-1: Natural gas consumption in Maryland, by sector, in trillion BTU per year. *Source for natural gas data: U.S. Energy Information Administration.*[246]



The main growth in natural gas use in Maryland has been for electricity generation. Despite the fact that electricity generation is currently the largest single use of natural gas, the combined direct use in the residential and commercial sectors—that is, in buildings—is the largest use of the fuel, representing about 55 percent of the total use and about 87 percent of all direct end-uses of natural gas (that is, excluding electricity generation). Thus, decarbonizing the buildings sector, and within that the residential sector (which represents more than half of the use in the buildings sector), is a critical part of meeting the emission reduction targets of the Climate Solutions Now Act.

Figure 4-2 shows the greenhouse gas emissions associated with natural gas end-uses in the residential and commercial sectors. Natural gas combustion produces CO_2, but methane also leaks through the entire lifecycle of natural gas, inclusive of production, processing, transmission and distribution. **Figure 4-2** shows the direct CO_2 emissions due to combustion as well as the CO_2-equivalent of methane leaks evaluated at the 20-year warming potential of 84 (relative to $CO_2 = 1$).[247] The assumed leak rate was 2.7 percent on an end-use basis.[248] This

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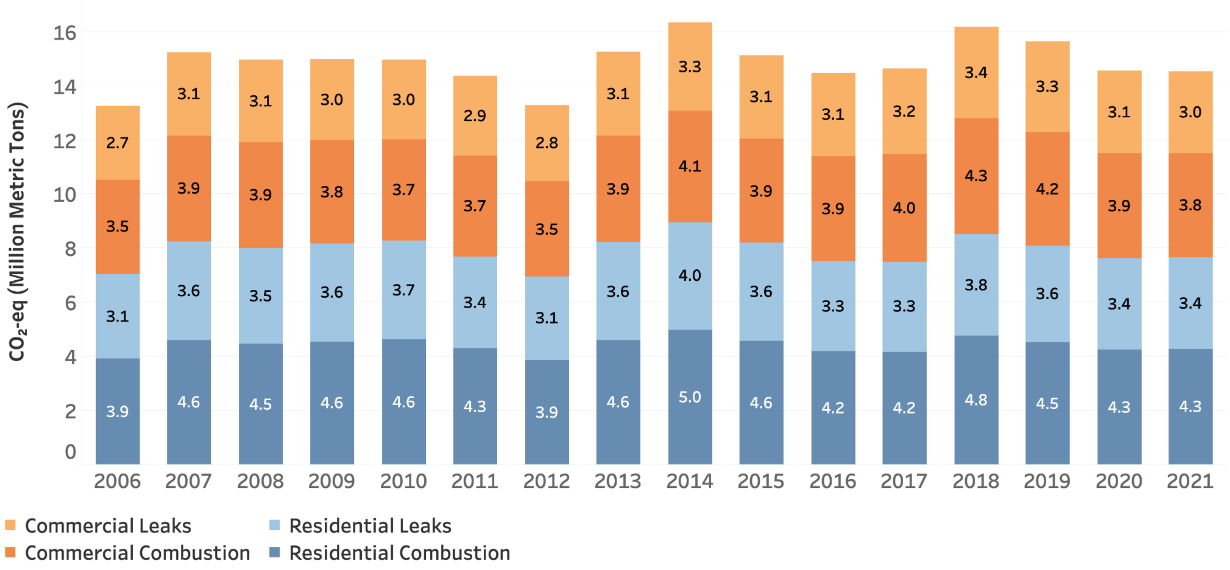
[246] Natural Gas Consumption by End Use – Area: Maryland, Energy Information Administration, August 31, 2022, at https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SMD_a.htm The data were converted from cubic feet of natural gas to Btu using an average conversion factor of 1,040 Btu/cubic foot for all years.

[247] Maryland Greenhouse Gas Inventory for 2020, Maryland Department of Environment, September 24, 2022, at https://mde.maryland.gov/programs/air/ClimateChange/Documents/VIMAL/MD_2020_GHG_Inventory_2022-09-24.xlsx

[248] Natural Gas Consumption by End Use – Area: Maryland, Energy Information Administration, August 31, 2022, at https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SMD_a.htm In addition, the Climate Solutions Now Act requires

includes leaks from the entire natural gas system up to the meter at the end-user, but does not include leaks inside homes and commercial establishments at the point of use, such as a gas cooking stove or oven or a gas water heater or gas furnace. As such, the emissions shown are likely an underestimate of the total.

Figure 4-2: Residential and commercial sector CO_2-equivalent emissions due to natural gas use in Maryland, with methane leaks evaluated at a 20-year global warming potential. The leak rate of 2.7 percent is calculated from Alvarez et al. 2018.[249]



The direct CO_2 emissions attributable to combustion in the residential sector in 2021 were 4.3 million metric tons; the warming impact of the methane in natural gas leaks evaluated at its 20-year warming potential increases the total CO_2-equivalent emissions by almost 70 percent to 7.7 million metric tons. The commercial sector totals were only slightly smaller. The total methane leak impact of natural gas use in buildings (assuming it is entirely coincident with the residential plus commercial sectors) in 2017 was 5.7 million metric tons, or more than 8 percent of the reported energy-related greenhouse gas inventory, 70.7 million metric tons, for that year, conventionally calculated. Maryland has traditionally calculated the CO_2-equivalent of methane with its 100-year warming potential and included only in-state methane leaks in that calculation. The Climate Solutions Now Act of 2022 requires the Maryland Department of

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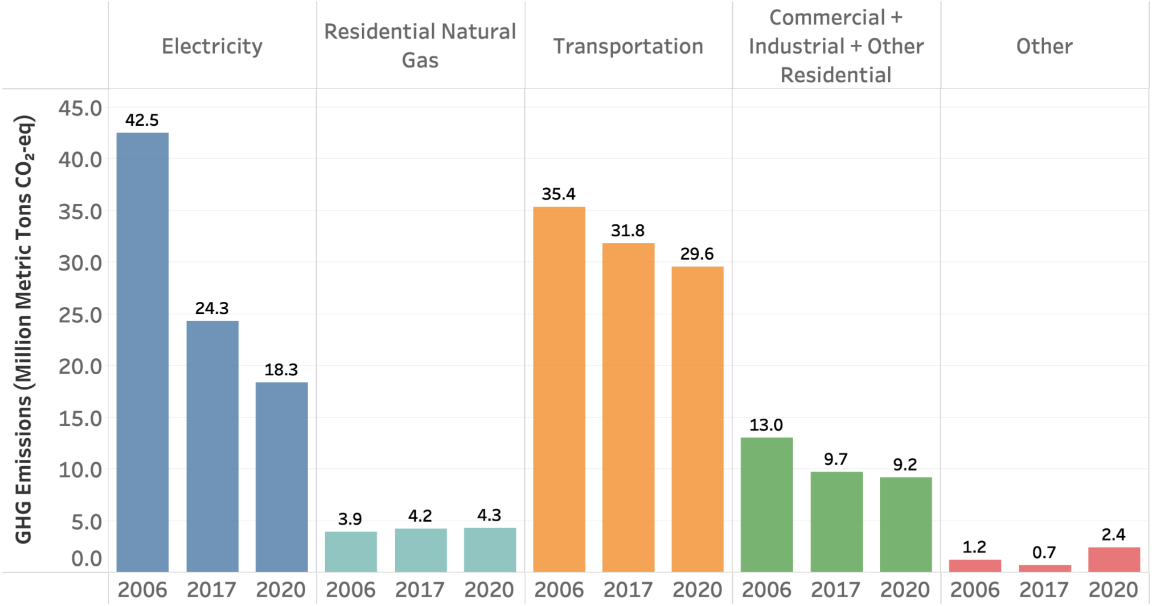
calculation of the warming impact of methane using the 20-year global warming potential. Maryland General Assembly, Climate Solutions Now Act of 2022, Senate Bill 528, Effective Date June 1, 2022, at https://mgaleg.maryland.gov/2022RS/bills/sb/sb0528E.pdf

[249] Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., ... & Hamburg, S. P. (2018). Assessment of methane emissions from the US oil and gas supply chain. *Science*, *361*(6398), 186-188 gives a leak rate of 2.3 percent based on natural gas production and an overall methane leakage of 13 teragrams in 2015 Based on these estimates and a usage of 25 trillion cubic feet in that year, we estimate a leak rate based on usage of 2.7 percent.

Environment to calculate the CO2 equivalent of methane pollution using its 20-year warming potential.[250]

Figure 4-3 shows the residential sector natural gas emissions in comparison to all of Maryland's energy sector greenhouse gas emissions, calculated in the traditional way by the Maryland Department of Environment. Only the CO_2 component of residential natural gas is shown since the methane leak component is very small, as estimated by the Department.

Figure 4-3: Maryland greenhouse gas emissions in 2006 (baseline year), 2017, and 2020, by sector. *Source: Maryland Department of Environment.*[251]



Natural gas use in the residential and commercial sectors has increased in absolute terms from about 139 trillion BTU in 2006 to 154 trillion BTU in 2017. Natural gas use in buildings has mainly fluctuated with the weather in recent years; it was 153 trillion BTU in 2021.

Continuing significant use of natural gas in the residential and commercial sectors is in conflict with the goals of Maryland's Climate Solutions Act. **Thus, by law, whatever the undepreciated amount of building-related pipeline replacement investments remain, they will likely have little value on January 1, 2046.** This is the classic situation of stranded

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[250] Maryland General Assembly, Climate Solutions Now Act of 2022, Senate Bill 528, Effective Date June 1, 2022, at https://mgaleg.maryland.gov/2022RS/bills/sb/sb0528E.pdf

[251] Maryland Department of Environment, Greenhouse Gas Inventory 2006 , 2017, at mde.maryland.gov/programs/air/ClimateChange/Documents/VIMAL/MD_2006_Base_Year_GHG_Emission_Inventory_20210610.xlsm , mde.maryland.gov/programs/air/ClimateChange/Documents/VIMAL/MD_2017_GHG_Emission_Inventory_20210610.xlsx and mde.maryland.gov/programs/air/ClimateChange/Documents/VIMAL/MD_2020_GHG_Inventory_2022-09-24.xlsx respectively. Note that these CO_2-eq values are based on a 100-year global warming potential (GWP) for methane. Maryland required the use of a 20-year GWP under the Climate Solutions Now Act of 2022; the 20-year GWP is used in the rest of this chapter.

costs. Indeed, most of the natural gas distribution system is likely to become a stranded cost well before that date, since rising rates will induce rapid conversion or heating from natural gas to electricity by all those who can afford it.

We first analyze the impact on rates of the 2013 law that allows advance recovery of pipeline investments and then address the broader question of the impact of rising rates and falling number of consumers using natural gas in Maryland.

4.3 Maryland's STRIDE Law

In September, 2010, a massive natural gas pipe explosion in San Bruno California triggered national concern over the safety of natural gas systems. As in many other states, Maryland's STRIDE law was passed in 2013 in response, in part at federal urging. STRIDE authorized significant investments supposedly to address leaking and potentially unsafe infrastructure in Maryland's natural gas system. In evaluating STRIDE, it is therefore important to understand whether the fundamental causes of the San Bruno accident relate in material ways to the Maryland situation. We will turn to the specifics of Maryland's gas infrastructure after examining the San Bruno accident briefly to illuminate the national events that followed.

4.3.1 The 2010 San Bruno Pipeline Explosion

The Pipeline Safety Trust Report described the September 9, 2010 explosion as follows:

> The rupture produced a crater about 72 feet long by 26 feet wide. The section of pipe that ruptured, which was about 28 feet long and weighed about 3,000 pounds, was found 100 feet south of the crater. The released natural gas ignited, resulting in a fire that destroyed 38 homes and damaged 70. Eight people were killed, many were injured, and many more were evacuated from the area.[252]

The National Transportation Safety Board oversees major transportation accidents, including natural gas pipelines (which transport natural gas). Its investigation into the San Bruno explosion concluded that the rupture was caused by a problem at the time of the installation of the pipe:

> The National Transportation Safety Board's investigation found that the rupture of Line 132 was caused by a fracture that originated in the partially welded longitudinal seam of one of six short pipe sections, which are known in the industry as "pups." The fabrication of five of the pups in 1956 *would not have*

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[252] Pipeline Safety Trust Report (2011). https://pstrust.org/map-of-major-incidents/sanbruno/?doing_wp_cron=1655840790.7332940101623535156250

> *met generally accepted industry quality control and welding standards then in effect*, indicating that those standards were either overlooked or ignored. The weld defect in the *failed pup would have been visible when it was installed*. The investigation also determined that a sewer line installation in 2008 near the rupture did not damage the defective pipe.[253]

The Board Chair explicitly criticized lax regulation and far too much trust in the company without adequate verification of its assertions as contributing factors:

> The NTSB investigation revealed that for years, PG&E exploited weaknesses in *a lax system of oversight*. We also identified *regulators that placed a blind trust in the companies that they were charged with overseeing—to the detriment of public safety.*
>
> In the pipeline industry, there must be effective oversight and strong enforcement….In too many instances, the regulators in this case didn't really know what was going on or require the operator to live up to their commitments.
>
> For example, our investigators identified poor record-keeping, flawed assumptions in PG&E's integrity management programs, a failure to increase safety on an aging pipe in a high-consequence area with remote control valves or in-line inspections, and inadequate drug and alcohol testing protocols.
>
> ….Ronald Regan [sic] famously said, "Trust but verify." For government to do its job—safeguard the public—it cannot trust alone. It must verify through effective oversight.[254]

A few things are critical to note about the causes of the accident in light of the national and state-level events that followed:

- The core problem that led to the explosion was the faulty installation of the pipe.
- While the pipe was 54 years old at the time of the explosion, specific deterioration of the section of the pipe due to aging of the section of the pipe was *not identified as a cause*. The Chair of the National Transportation Safety Board did imply that the utility should have replaced that section of pipe as part of its aging management for

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[253] National Transportation Safety Board, Pacific Gas and Electric Company Natural Gas Transmission Pipeline Rupture and Fire San Bruno, California September 9, 2010: Accident Report, NTSB/PAR-11/01 PB2011-916501, August 30, 2011, p. x, italics added, at https://www.ntsb.gov/investigations/accidentreports/reports/par1101.pdf.

[254] Ibid. p. 135, italics added.

replacing pipes in a seismically active ("high consequence") area (see the quote just above).

- The Board's chair explicitly exhorted vigilant regulation and verification if regulatory bodies like the California Public Utilities Commission were to fulfill their responsibilities for public safety.

Exacerbating the catastrophe, the gas utility, PG&E, was unable to stop the flow of gas to the accident site for 1 hour and 35 minutes. This excess gas flow fueled the inferno adding to the destruction and the inability for 900 crew to extinguish the fire. The explosion also destroyed a water main pipe, hampering fire-fighting operations.

In brief, the 2010 San Bruno explosion was a catastrophe that commanded national attention, all the more so after the findings of the National Transportation Safety Board clearly fingered the company's faulty installation of the pipe ("the failed pup would have been visible when it was installed") as the cause, and inadequate oversight and regulation as contributory factors.

Almost simultaneously with the issuance of the findings of the National Transportation Safety Board, Ray LaHood, then-Secretary of Transportation, issued a broad "Call to Action" to address safety issues associated with, among other things, aging pipelines and improperly installed infrastructure. He called upon "all parties to step up efforts to identify high-risk pipelines and ensure that they are repaired or replaced." State regulators and natural gas companies were, of course, included among those parties.[255] While he mentioned other pre-San Bruno accidents, Secretary LaHood's call was clearly linked to the San Bruno catastrophe, which was worse than accidents in the two prior years.

The San Bruno explosion, and the National Transportation Safety Board 2011 report on the accident, seemed to create an urgency about safety and replacement of aging pipeline infrastructure, even though the core cause was not aging, but blatantly faulty installation. Even worse, as noted above, the National Transportation Safety Board said that "weld defect …would have been visible when it was installed"; apparently no one, including the regulators, was doing the necessary job of verifying that the installation was safe. Even more remarkably, pipeline safety had actually improved since 1991, according to the press release that followed the San Bruno accident but preceded Secretary LaHood's Call to Action by a few months:

> Pipeline incidents resulting in serious injury or death are **down nearly 50 percent over the last 20 years.** In 1991, there were 67 such incidents compared to 36 in 2010, and an average of 42 per year over the last 10 years.

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[255] Ray LaHood, U.S. Department of Transportation Call to Action To Improve the Safety of the Nation's Energy Pipeline System. Washington, D.C.: U.S. Department of Transportation, revised November 1, 2011 at www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/Action%20Plan%20Executive%20Version%201%20NOV%2011.pdf

> However, a series of recent incidents have highlighted the need to address the nation's aging pipeline infrastructure.[256]

Nonetheless, Secretary LaHood's "Call to Action" urged pipeline owners and operators to make aggressive efforts to "conduct a comprehensive review of their oil and gas pipelines to identify areas of high risk and accelerate critical repair and replacement work." In reviewing Maryland's efforts in this regard, it is essential to keep in mind that the first step is to identify the areas of high risk. Moreover, while the focus on Secretary LaHood's statement was on pipelines, improving safety, as is documented below, requires a focus on the causes of serious accidents, which may or may not involve the replacement of pipelines.

Congress passed legislation in 2012 on the matter and states began to take action. National spending on pipeline replacements skyrocketed after the legislation passed, as can be seen in **Table 4-1**. The result in Maryland was the 2013 STRIDE legislation.

Table 4-1: U.S. gas utility distribution expenditures. *Source: American Gas Association, Table 12-1.*[257]

Period	Avg. Yearly Gas Utility Distribution Expenses, *Billion $*	Percent Change From Prior Period
1972-1981	$1.2	
1982-1991	$2.9	133%
1992-2001	$4.5	54%
2002-2012	$5.2	16%
2013-2020	$13.7	162%

Note: Values not adjusted for inflation.

4.3.2 Prelude to STRIDE

Neither natural gas safety nor pipeline replacement were new issues in 2013, when the STRIDE legislation was passed, or indeed, when the San Bruno accident put them on the national policy map. Safety has been tracked by the federal government; accidents involving serious injury or fatalities are investigated for causes and lessons learned by the National Transportation Safety Board (as occurred in the aftermath of the San Bruno accident). Safety

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[256] "U.S Transportation Secretary Ray LaHood Announces Pipeline Safety Action Plan *U.S. DOT Initiates National Effort to Prevent Hazardous Pipeline Incidents*," U.S. Department of Transportation Press Release, April 4, 2011 at https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/dot4111.pdf

[257] American Gas Association, Annual Construction Expenditures: Construction Expenditures by Type of Facility, 1972-2020, at https://www.aga.org/contentassets/5d9888f793ad4508bb35cb6b5f2c1865/table12-1.pdf

is a central responsibility of gas utilities, and overseeing it and ensuring safety is part of the function of the Maryland Public Service Commission.

What was new in Maryland was the notion that pipeline replacement investments should not be decided during normal rate cases but that these investments could be initially recovered through surcharges on ratepayers on an expedited basis.

A 2011 application by Washington Gas (WGL), one of the three principal gas utilities in Maryland, provided a prelude to utilities' view by requesting an increase to rates in part to replace pipes. The Commission, in its final order, described the application as follows:

> The Application, which was filed on April 15, 2011,... requested that the Commission approve rates and charges designed to increase the Company's Maryland annual operating revenues by $30 million, or 5.9%... The Company claimed that its test year return fell below the return necessary for the Company to attract capital on reasonable terms. In addition to seeking a rate increase, the Company also asked us to approve an *Accelerated Pipe Replacement Plan* ("APRP"), *a plan through which it would spend $115 million over five years to replace its piping infrastructure and recover the costs through a surcharge.*[258]

In its Order deciding the case, the PSC approved the request in part and denied it in part. It approved recovery of safety and reliability expenditures already made as well as a slight increase in rates although "substantially less than the Company sought." And in regard to replacement of pipe for safety and reliability and recovery of those costs through a surcharge, the PSC decided as follows:

> Although we agree fully with the Company that safe and reliable infrastructure is the highest priority and that *it should accelerate its program to replace pipe*, *we decline to authorize a surcharge* for the recovery of future pipe replacement expenses. Based on the record in this case, we find that the Company has historically demonstrated the ability to replace the infrastructure when necessary to ensure safety and reliability, and that it can do so using traditional ratemaking procedures without compromising Its ability to earn an appropriate return. The Company's witnesses confirm that WGL has the operational and financial ability to accelerate its existing pipe replacement program, and we

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[258] In the matter of the Application of the Washington Gas Light Company for Authority to Increase its Existing Rates and Charges and to Revise its Terms and Conditions for Gas Service, Maryland Public Service Commission Order 84475, Rate Case 9267, November 14, 2011, (italics added), at https://webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?FilePath=//Coldfusion/Casenum/9200-9299/9267/98.pdf

> authorize the Company to do so. But *the mere fact that the Company plans increased infrastructure investments does not justify a surcharge*, which would represent a fundamental shift from long-standing rate-making principles. *To the contrary, the record in this case demonstrates that the Company can invest significant amounts in infrastructure and can readily recover those costs in rates with an appropriate return.*[259]

Clearly, the PSC put “the highest priority” on safety and reliability of the gas infrastructure. It ordered recovery of those expenditures. It assessed the ability of the company to make the necessary investments based on its history and its standing in the markets; on that basis the PSC denied the request for a surcharge. That matter was at the heart of the 2013 STRIDE law.

4.3.3 Features of the STRIDE Law[260]

Maryland’s 2013 Strategic Infrastructure Development and Enhancement (STRIDE) authorized the PSC to oversee replacement of existing natural gas distribution pipeline infrastructure and recover the cost, including a rate of return on investment, from ratepayers. Recovery via a surcharge, capped at $2 per month per residential customer, was also permitted. The investment could be a “replacement” or “improvement” in the infrastructure; the one restriction was that the pipeline not connect to a new customer. The main feature of the bill, both for those who supported it and those who opposed it, was the ability of the utility to collect a surcharge from ratepayers even before the replacement pipeline is in service and without having to go through a normal rate case. In rate cases, recovery can occur only after the investment is in service. Only a part of the STRIDE investment is recovered via the surcharge, which is only the initial recovery that short-circuits the rate-case process. The rest is put into the rate base after the utility files a rate case.

Utilities proposed that the surcharge would allow them to bypass the rate case process and accelerate investments to replace aging pipelines. Evidence was provided that surcharges enabled accelerated investment. However, while general arguments about safety were made, there was no specific evidence provided, one way or another, that going through a normal rate case process had negatively affected safety in the past.[261]

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[259] Ibid.

[260] Maryland General Assembly. Senate Bill SB 8, 2013 at https://mgaleg.maryland.gov/mgawebsite/Legislation/Details/sb0008?ys=2013RS&search=True.

[261] Mary Dempsey and Alexander Núñez Position Statement of Baltimore Gas and Electric on House Bill 89 – Gas Companies – Rate Regulation – Infrastructure Replacement Surcharge, January 24, 2013

A key feature of the STRIDE bill is that if the PSC approves the plan for pipeline replacement prepared by the utility as "reasonable and prudent," the utility's proposed recovery of funds via surcharges of up to $2 per month per residential ratepayer would be automatically approved as well. Assuming a comparable amount per unit of gas sold would be collected from commercial customers, the annual surcharges could be as high as $60 million per year. So far utilities have kept the surcharge generally below the limit, but there has nonetheless been a proposal to lift the cap to $2.50 per month.[262] The surcharge is set to zero when the investment is put into the rate base.

The law had a number of other features that are important to the analysis in this report:

- The investments authorized were for existing infrastructure only; infrastructure for new customers was not included; the latter investments would continue to go through normal rate-case procedures.
- It incentivizes investments in pipe replacements over smaller repairs without due comparison of costs and safety impacts, even though the latter may be better on one or both counts. Utilities can recover the costs of repairs as operational expenses, but these are not included in the rate base and earn no profit, when the replaced pipe is short.
- Regulated gas companies were to prepare plans and submit them to the Commission, which was required to ensure that they were "reasonable and prudent" and that they were "designed to improve public safety or infrastructure reliability over the short term and long term."
- At the time of the passage of the law, the PSC was neither required to consider nor prohibited from considering the compatibility of its approvals with the state's climate goals and the implications that the legislation may have for stranded costs.
- The word "repair" does not appear in the legislation. The Commission was not prohibited from considering alternatives to the same safety and reliability purposes, should they be cheaper. The Commission was empowered to deny utilities' project proposals if they were not "reasonable and prudent." The criterion of "prudency" in regulatory review generally involves a cost test to protect consumers from excessive investments by utilities that could result in unneeded projects and added costs to consumers without commensurate benefit.

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[262] David Lapp, Office of People's Counsel, Testimony on House Bill 890, Natural Gas: Strategic Infrastructure Development and Enhancement Surcharge and Plans, before the Maryland House Committee on Economic Matters, February 18, 2021

- Utilities were allowed to proceed with investments even without PSC approval, if that approval was not given within six months. But, if the PSC found the investments to be not reasonable or prudent, the utilities would be required to refund the amount.

In testimony, the Commission stated that it already had the authority to allow companies to recover investments through surcharges, though it did not oppose the 2013 STRIDE bill so long as it retained the authority to deny recovery if it deemed the investment to be not reasonable and prudent.[263]

The STRIDE bill gave the utilities greater latitude to impose surcharges to recover expenses, in place of regular rate-making procedures. Remarkably, though this extraordinary step was taken in the name of safety and reliability by reducing leaks of natural gas, no investment-specific metrics were put in place to ensure safety was actually improving in the form of reduced rates of serious accidents. As the Office of People's Counsel noted in its testimony opposing the bill, if the objective is to improve public safety and reliability by reducing leak rates, a baseline for leak rates and metrics for reductions in leak rates that result from the Plan and surcharge are needed as an incentive to control costs and prioritize repairs.

The bill also does not require demonstration of improved safety by the metric of reduction in the frequency of severe accidents or in their severity, as measured by the average number of serious injuries or fatalities per accident. Finally, the potential conflict with climate goals or the improvements in safety and health by accelerating phase out of natural gas in the residential sector were also not considered. As discussed below, both conflicts are much more serious than was recognized at the time the STRIDE bill was passed.

4.3.4 STRIDE Investments and Cost Recovery

As elsewhere in the United States, utilities prepared projects rapidly after the Maryland PSC approved investments for pipeline replacement. Six tranches of investments were proposed, each with a five-year time horizon. Investments began in 2014 and are proposed to continue until 2043. It is useful to consider some basics about the utilities before describing the scale of the investments, cost recovery, and the stranded cost risks associated with STRIDE.

4.3.4.1 Maryland's Major Natural Gas Utilities

Table 4-2. shows the three major Maryland gas distribution utilities that are overseen by the Public Service Commission and the numbers of residential and commercial customers served by each.

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[263] Maryland Public Service Commission, "PSC POSITION: Informational Comments; Technical Amendments Recommended," Testimony on House Bill 89 before the Maryland House of DelegatesJanuary 24, 2013.

Table 4-2: Major Maryland investor-owned natural gas utilities and number of customers. *Source: PSC Gas Enrollment Report, December 2021.*[264]

Maryland Utility	# Residential accounts	# Commercial Accounts	Total Gas Customers
BGE	651,589	44,081	695,670
Washington Gas	473,731	31,534	505,265
Columbia Gas	0	3,660	3,660
Total	**1,125,320**	**79,275**	**1,204,595**

Note: Smaller gas suppliers and publicly owned utilities are not included. They have a relatively small number of customers; the latter are not under the purview of the Maryland PSC. About half of Maryland's residential electricity customers have natural gas connections; about 85 percent of them use it as the main heating fuel, while the rest use it only for other purposes, such as cooking. The rest heat with electricity, fuel oil, and propane; a small number (less than one percent) use wood as their principal heating fuel.

Among the three major gas utilities, Baltimore Gas and Electric (BGE) has the largest number of gas customers and the most electricity customers in the state. It is owned by Exelon, a public utility holding company that also owns Pepco, an electric utility, and Delmarva Power, another electric utility. Exelon, via its regulated gas utility, serves about 58 percent of the gas customers; via its electric utilities, it serves about 80 percent of the electricity customers in Maryland.

4.3.4.2 STRIDE Investments

Two tranches of STRIDE investments have been approved by the Maryland PSC since the law went into effect on June 1, 2013; each was for investments over a five-year period. As shown in **Table 4-3**, work under the first tranche from 2014–2018 is complete. The second tranche, from 2019–2023, is being implemented. The other four tranches, which will extend the STRIDE investments to the year 2043, have not yet been applied for or approved.

The Office of People's Counsel, which officially represents residential ratepayer interests in rate cases before the PSC (and which opposed the STRIDE legislation) has analyzed utility revenue requirements corresponding to these six five-year tranches of STRIDE investments. The schedule of revenues for each utility and the combined total (by year), as estimated by the Office of People's Counsel are shown in **Figure 4-4.**

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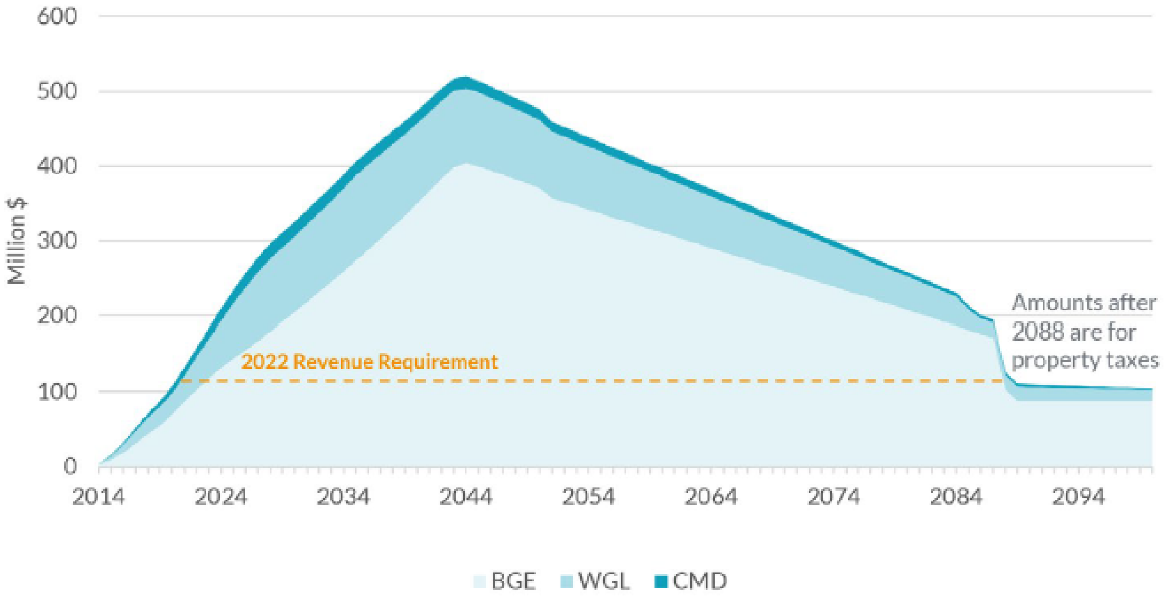
[264] Public Service Commission, Gas Choice Enrollment Report: All Utilities Where Gas Choice IS Available in Maryland – Quarter Ending December 2021, at https://www.psc.state.md.us/gas/wp-content/uploads/sites/4/12-2021-Gas-Choice-Enrollment-Report.pdf

Table 4-3: STRIDE Investments as approved (STRIDE I and II), and proposed (STRIDE III, IV, V, and VI). *Source: OPC 2022.*[265]

Stride Investment Plans, Largest Gas Utilities, Million $			
	BGE	**WGL**	**Columbia**
Actual STRIDE I, 2014-2018	$ 522.73	$ 218.50	$ 66.19
Actual/authorized, STRIDE II, 2019-2023	$ 827.28	$ 363.07	$ 87.22
STRIDE III, 2024-2028	$ 693.39	$ 439.44	$ 57.38
STRIDE IV, 2029-2033	$ 803.83	$ 194.82	$ -
STRIDE V, 2034-2038	$ 931.86	$ 74.0	$ -
STRIDE VI, 2039-2043	$ 1,034.0	$ -	$ -
Total, per utility	$ 4,813.58	$ 1,302.19	$ 210.79
Grand total, all three utilities			**$6,326.56**

Figure 4-4: Revenue requirements for the six STRIDE tranches as estimated by the Office of People's Counsel for Baltimore Gas and Electric, Washington Gas, and Columbia Gas. *Source: OPC 2022.*[266]



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[265] Office of People's Council. (October 2022.) Maryland Gas Utility Spending: Projections and Analysis. Office of People's Council, State of Maryland, Table 1.1, p. 2.

[266] Ibid. p. 3

It is clear that under the terms of the 2013 STRIDE law, the recovery of revenues, including profit, will continue for decades after the end of the investments; the recovered amounts will be roughly four times the investment amount. The recovery stretches out to the nearly the end of the 21st century. This is decades beyond Maryland's 2022 Climate Solutions Now Act's requirement of net zero greenhouse gas emissions by 2045. Some analysis is provided in the next section; suffice it to note here that four of the six tranches have not yet been approved. Investments under the two tranches of STRIDE that have been approved will continue into the 2030s for the two largest natural gas utilities (BGE and Washington Gas); as a result, ratepayers will be paying for those investments into the 2060s.

Table 4-4 shows the investments that are proposed for STRIDE tranches III to VI, by utility as well as the total for all three; it also shows the last date of investment in pipeline replacements, 2043, as currently proposed. Of the total STRIDE investments of about $6.4 billion for all six tranches, two-thirds have yet to be authorized.

Table 4-4: Remaining proposed STRIDE investments 2024 onwards, not yet approved. *Source: Based on OPC 2022,*[267] *Figure 1b, omitting the 2022-2023 investments shown in that table.*

(in millions of dollars)	**BGE**	**WGL**	**Columbia**
STRIDE III-VI	$3,463.6	$720.6	$57.4
Total STRIDE III-VI, all three utilities			**$4,240.6**

4.3.5 STRIDE and Maryland's Climate Law

Stranded costs can occur in any commercial situation, but they are a very specific problem when it comes to investments by regulated utilities that are overseen and approved by utility commissions such as Maryland's Public Service Commission. In states like Maryland, wholesale electricity and natural gas transactions are not subject to state regulation of rates; but electricity and natural gas distribution companies are regulated; they purchase electricity and natural gas on wholesale regional markets and distribute it though electricity and gas distribution networks that they own. They get cost recovery on the purchase of natural gas on unregulated wholesale markets.

HIstorically, regulatory oversight was established over the distribution companies because they are granted monopolies over specified service territories—it would be far too expensive to have competing distribution networks. As part of the arrangement, they can recover their

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[267] Ibid. Table 2.2, p. 11

operating and maintenance costs, the costs of procuring energy, depreciation of their equipment, and a constitutionally guaranteed opportunity to earn a reasonable rate of return on the undepreciated amount. Rates are set so as to enable distribution utilities the opportunity to recover their costs and earn a profit.

The risk of stranded costs with natural gas or electric utilities can arise in several different ways. Generally, stranded assets emerge when a utility is systematically unable to recoup investments, including the rate of return, as well as operating costs, through revenues charged to customers on approved rate schedules. For instance, a significant part of electricity investments in costly nuclear power plants in areas where wholesale supply was deregulated became stranded because market prices were below the cost of nuclear electricity production. Coal plants were also at risk. One 1993 study calculated coal and nuclear stranded costs of electric utilities in the PJM grid (of which Maryland is a part) as $11 billion, about equal to the book value of the utilities in question.[268]

4.4 Building Sector Decarbonization Implications

In the present instance, the general problem of stranded costs in the natural gas system comes from the need to eliminate fossil fuels from Maryland's entire energy system as completely as possible by 2045—the date that the Climate Solutions Act has set for "net zero" emissions. The intermediate target is also very stringent: a 60 percent reduction in greenhouse gas emissions by 2031, relative to the baseline year of 2006.[269]

The 2022 climate legislation adopted the recommendation in the 2020 Annual Report of the Maryland Commission on Climate Change that the state adopt a target of net zero greenhouse gas emissions by 2045.[270] Given the importance of building energy consumption, the Maryland Department of Environment, the umbrella agency for the Maryland Commission on Climate Change, commissioned a Building Energy Transition Plan[271] that became a formal part of the Annual Report 2021 report of the Commission.[272]

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[268] Lester Baker, Eric Hirst, Estimating Potential Stranded Commitments for U.S. Investor-Owned Electric Utilities, ORNL/CON-406. Oak Ridge National Laboratory, Oak Ridge, Tennessee, January 1995, p. 8, at https://www.osti.gov/servlets/purl/10122421

[269] Maryland General Assembly, Climate Solutions Now Act of 2022, Senate Bill 528, Effective Date June 1, 2022, Article 2-1201 and Article 2-2014.1, at https://mgaleg.maryland.gov/2022RS/bills/sb/sb0528E.pdf

[270] Maryland Commission on Climate Change, 2020 Annual Report, Maryland Department of the Environment, 2020, at https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Documents/MCCCAnnualReport2020.pdf

[271] Maryland Commission on Climate Change, Transition Plan: A Roadmap for Decarbonizing the Residential and Commercial Energy Sectors in Maryland, Maryland Department of the Environment, 2021, at https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Commission/Building%20Energy%20Transition%20Plan%20-%20MCCC%20approved.pdf

[272] Maryland Commission on Climate Change, 2021 Annual Report, Maryland Department of the Environment, 2021, at https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Documents/2021%20Annual%20Report%20FINAL%20%282%29.pdf

The Building Energy Transition Plan provides a sound starting point to consider the question of stranded costs associated with natural gas, widely used as a heating fuel in Maryland. The next two fossil fuels for buildings, in order, are fuel oil and propane. Neither is regulated. The situation for those two fuels is therefore much like that of petroleum in general, including pipelines, gas stations, distribution companies, etc.; it is beyond the scope of this chapter. Fuel oil and propane are considered in the energy cost burden and policy chapters, since efficient electrification of households heated with these fuels can provide some of the greatest economic, emission reduction, and energy cost burden benefits.

The most important assumption underlying the building transition plan is that a net zero energy sector by 2045 implies a 95 percent reduction of greenhouse gas emissions in the building sector. It initially considered three scenarios: "high electrification," "electrification with fuel backup," and "high decarbonized methane," to achieve this goal, based on a study by the company E3.[273]

The initial draft of the E3 study concluded that the lowest total cost decarbonization scenario for buildings would be to use a gas supplement for heat pumps for use in times of the coldest weather in both the residential and commercial sectors. The main reason was that with electric heat pumps alone, heating demand on the coldest days would cause very high electric peak loads, necessitating high investments and costs in the electricity system.[274]

A number of problems with this conclusion were pointed out on review of the study by the Buildings Sub-Group of the Mitigation Working Group (MWG) of the Maryland Commission on Climate Change. For instance, it would be difficult to ensure that supplemental gas heating would be used only during the coldest hours. High gas costs would then deeply impact overall energy costs. A critical point was that with deep reductions in gas use, "delivery rates could increase more than 20-times the current rate for consumers left on the gas system, leading to significant equity concerns."[275]

In light of this review, E3 constructed a fourth building decarbonization scenario, called the "MWG Policy" scenario. The final Building Energy Transition Plan describes its core as follows:[276]

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[273] Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

[274] Ibid., Slides 25 and 29.

[275] Maryland Commission on Climate Change, Building Energy Transition Plan: A Roadmap for Decarbonizing the Residential and Commercial Energy Sectors in Maryland, Maryland Department of the Environment, 2021, p. 9, at https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Commission/Building%20Energy%20Transition%20Plan%20-%20MCCC%20approved.pdf

[276] Ibid., p. 9.

- Ensure an equitable and just transition, especially for low-income households
- Construct new buildings to meet space and water heating demand without fossil fuels
- Replace almost all fossil fuel heaters with heat pumps in existing homes by 2045
- Implement a flexible Building Emissions Standard for commercial buildings."

New residential and commercial buildings would be mandated to be all-electric starting in 2024. That is, new buildings would have no natural gas connections. In the present report, we use 2025 for this mandate, to allow about the same amount of time for the recommendation to be implemented as in the November 2021 Building Energy Transition report.

The major change from the earlier E3 study recommendation of electric heating with a gas supplement in both the residential and commercial sectors is that the MWG Policy scenario would have an essentially all-electric residential sector by 2045, with priority in the transition to low- and moderate-income retrofits, but there would be much more latitude for use of natural gas in the commercial sector. Overall natural gas use in all buildings, residential and commercial, would decline by only 75 percent by 2045. Since the residential sector would be all-electric, commercial sector natural gas use would decline only by about half, to about 36 trillion BTU. (See **Figure 4-1** above for historical use of natural gas in Maryland). Natural gas costs would rise several-fold, given increased distribution system costs. In addition, it is assumed that commercial sector buildings would choose to pay alternative compliance payments of $100 per metric ton on more than 3 million tons of remaining CO_2-equivalent emissions.[277] We note that if half of the commercial sector natural gas continues, it would not meet the target of 95 percent reduction in building sector greenhouse gas emissions by 2045 initially set forth in the E3 study.[278]

We are in general agreement with the recommendations of the MWG Policy scenario for the residential sector and note that they imply the dismantling of much of the natural gas pipeline infrastructure in residential areas. We have not analyzed buildings in the commercial sector and note that the Building Energy Transition report calls the assumptions about the commercial sector, including the alternative compliance payment "rough." The assumption that commercial sector natural gas use would decline only by half while costs increased

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[277] Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, Slides 49 and 60 at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

[278] A 95 percent reduction in building sector emissions would leave well under 1 million metric tons of CO2-equivalent emissions in 2045. But the revised E3 study recommendation would leave 3.1 million metric tons of CO2-equivalent in 2045. See p. 46 of Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

several-fold surely deserves more scrutiny. Would many businesses still consume so much natural gas when the cumulative tab would be over a billion dollars a year plus the cost of carbon payments? What about major retrofits? Or alternative heating systems? For instance, there are major efforts to develop thermal storage technologies.[279] Likewise, development of distributed hydrogen production could make it economical at the point of use, avoiding hydrogen transportation problems. In this light "several times" the current natural gas rate (that is, $30, $40 or more per MMBTU) is an unsuitable basis for long-term planning. Given the Climate Solutions Now Act, much more scrutiny is needed than a "rough" assumption for planning the future of heating in the commercial sector.[280] We have not retained this "rough" assumption in the analysis below as it appears economically speculative. Rather we have used deeper reductions in natural gas, with most of the remaining gas being used in the industrial sector in the analysis in **Section 4.5**.

Based on the E3 analysis of the MWG Policy scenario, the Building Energy Transition Report estimates that residential electricity prices would increase by about two cents per kilowatt-hour (in constant dollars), or about 15 percent. However, the E3 analysis did not take demand response into account. The Building Energy Transition report recommends that demand response (also called "demand management") be included in electric system planning.[281] Given electrification of transportation, vehicle-to-grid technology is likely to play a large role in moderating peaks and increasing resilience. With the right incentives, demand response is likely to change the picture regarding peak electricity demand and electricity system investments considerably.

4.5 Natural Gas Distribution System Stranded Costs—Preliminary Considerations

The clear implications of the requirements of building sector decarbonization are that a complete or near complete elimination of natural gas emissions from the building sector by 2045 is necessary. It also means a steady decline of natural gas use between the effective date of the law, June 1, 2022 and 2045, especially since the intermediate goal for greenhouse gas emission reductions in the Climate Solutions Now Act for 2031 is a stringent 60 percent.

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[279] Department of Energy, Thermal Energy Storage - Buildings, at https://www.energy.gov/eere/buildings/thermal-energy-storage , viewed on January 23, 2023

[280] For instance, $40 per million Btu is equivalent to about $5 per kilogram of hydrogen. This is roughly double the projected cost of distributed hydrogen production with electricity at 3 cents /kWh. Department of Energy, Hydrogen Production Cost from PEM Electrolysis - 2019, Table 1, at https://www.hydrogen.energy.gov/pdfs/19009_h2_production_cost_pem_electrolysis_2019.pdf

[281] Maryland Commission on Climate Change, Building Energy Transition Plan: A Roadmap for Decarbonizing the Residential and Commercial Energy Sectors in Maryland, Maryland Department of the Environment, 2021, p. 11 and p. 23, at https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Commission/Building%20Energy%20Transition%20Plan%20-%20MCCC%20approved.pdf

Transportation sector emissions are likely to decline more slowly than those from either the buildings or electricity sector given that nearly the entire stock of vehicles uses fossil fuels and the turnover rate of vehicles is slow. Moreover, unlike buildings, no economical retrofit technologies for converting existing fossil fuel vehicles is readily available. As a result, the reduction of natural gas use in buildings must be as close to 100 percent as possible.

Thus, an implication of the 2022 Climate Solutions Now Act of 2022 is that the natural gas distribution system serving buildings will likely become a stranded asset. *When* it becomes a stranded asset is a more complex question, but steeply rising costs are likely to accelerate that date. Most STRIDE investments and gas mains for supplying new infrastructure residential and commercial buildings have sixty-year periods over which they are depreciated.[282] Revenue requirements are largely determined by recovery of investments, in addition to operating and maintenance requirements; profits are entirely related to investments that are in the rate base. The capital recovery and return on investment are fixed revenue requirements, while a large portion of the operating and maintenance cost is also fixed, and depends, among other factors, on the length of the pipelines in service.

Arguably, if natural gas supplied in the regulated arena—that is, mainly to buildings—is almost entirely phased out by 2045, the remaining book value of those assets could be considered stranded. However, much of the stranding will likely occur well before that time, since the cost of supplying a unit of gas will be, as a first approximation, inversely proportional to the amount of gas supplied unless entire sections of the distribution pipeline system are decommissioned and removed from the rate base as space heating and water heating are electrified.

For instance, the E3 report projected the cost of delivery of natural gas in 2045, when almost all heating is electrified, at $140 per MMBTU.[283] At a typical household use of 60 MMBTU per year of natural gas, the cost of delivery alone, at that rate, would be $8,400 per year. Three percent of income is considered an affordable gas bill. Thus, for the delivery charge alone to be affordable, that household would have to have an income of $280,000 per year. Add the

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[282] Mark D. Case, Rebuttal Testimony presented to the Maryland Public Service Commission on behalf of Baltimore Gas and Electric, Case Number 9331, November 6, 2013, p. 12, at https://webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?filepath=//Coldfusion/Casenum/9300-9399/9331/Item_16\9331-CaseRebuttalwATT(Final).pdf

[283] The "unstructured" case in the E3 report is cited here. The report claims that requirements for revenues from ratepayers could be reduced report bu admits that it has not examined the key question of who would fill that revenue gap. In any case, even the "structured" – reduced revenue case – has delivery costs estimated at $100 per million Btu, which is also clearly unaffordable. Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, pdf p. 32 at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

cost of the natural gas itself and using gas would be unaffordable for all but the very wealthiest Maryland households, who would likely have left the system long before that time.

The stranded cost question is therefore a dynamic one of considering an interaction between the Public Service Commission raising rates as consumption declines to match revenue requirements and customers investing in efficiency to reduce use and ultimately leaving the system altogether. Normally, conversion of a heating system would take place when an existing gas system needs to be replaced. Thus, the cost comparison between continuing on the gas system and electrifying with efficient heat pumps is a central issue in when the rest of the gas system becomes unviable. Put another way, the system becomes stranded at the point where *en masse* defections from gas to electricity occur due to high or very high gas prices. Continued STRIDE investments and investments in infrastructure to supply new buildings will only increase stranded costs.

The Buildings Subgroup of the Mitigation Working Group of the Maryland Commission on Climate Change compared highly efficient heat pumps with gas furnaces both in new housing and as retrofits for single family homes. The summary table from that report is reproduced in **Table 4-5**.

Table 4-5: Comparison of natural gas plus central air conditioning costs with heat pump costs, including new construction and retrofits. *Source: Buildings Subgroup Report 2020, Table 4.*[284]

	New Construction			Retrofit		
	Energy Cost	Fixed Cost	Total Cost	Energy Cost	Fixed Cost	Total Cost
ASHP Space Conditioner and ASHP Water Heater	$4,850	$6,850	$11,700	$11,175	$10,550	$21,725
Gas Space Heater, Gas Water Heater, and Electric AC	$5,475	$9,300	$14,775	$10,575	$11,625	$22,200
Difference	**($625)**	**($2,450)**	**($3,075)**	**$600**	**($1,075)**	**($475)**

By this assessment, from a residential heating point of view, the natural gas system already had marginal economics in 2020 both for new construction and for retrofits in single family

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[284] Buildings Subgroup, *Decarbonizing Buildings in Maryland*, Report to the Mitigation Working Group of the Maryland Commission on Climate Change, Maryland Department of Environment, September 2020.

homes, which constitute over 70 percent of the state's housing.[285] Since that time, natural gas prices have risen due to national and global factors quite apart from the in-state STRIDE and other investments that have been authorized by the PSC.

Figure 4-5: Henry Hub natural gas spot prices (wholesale), monthly averages. *Source: EIA 2022*.[286]

Figure 4-5 shows the Henry Hub natural gas monthly average spot price history since the STRIDE law was passed in 2013. Prices have been rising since December 2021 (that is, before the start of the Russian invasion of Ukraine on February 24, 2022) from less than $4 per MMBTU to more than $7 per MMBTU in 2022. The lowest price in recent years was $1.63 per MMBTU in May 2020 (impacted by the declining demand at the start of the COVID-19 pandemic). The costs of natural gas transportation through interstate pipelines to what is known as the "City Gate" where the regulated distribution service starts is in addition to the wholesale price of the gas itself. The price exclusive of distribution charges, taxes and other charges under the purview of the PSC is called the "commodity price," which is passed on to utilities' customers, subject to a later prudence review by the Commission. The commodity price cost of residential and general gas supply by Baltimore Gas and Electric, Maryland's

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[285] Maryland Housing Statistics at https://www.infoplease.com/us/census/maryland/housing-statistics viewed on August 15, 2022.

[286] Energy Information Administration, Henry Hub Natural Gas Spot Price, at https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm viewed on August 19, 2022.

largest gas utility, rose from a recent low of $3.53 per MMBTUu in September 2019 to $11.02 per MMBTU in August 2022,[287] implying a typical increase in residential gas bills of almost $40 per month. In contrast, electricity prices in Maryland have declined for many years down to $130.10 per megawatt-hour (MWh) in 2020.[288] The recent increase to $141/MWh in May 2022 is attributable to the increase in the wholesale price of natural gas, which is almost 40 percent of the state's electricity generation and a substantial part of its imported electricity.[289]

In brief, global, national, as well as in-state factors have set the stage for the distribution assets of Maryland's regulated natural gas companies to become stranded assets in the context of the state's ambitious Climate Solutions Now Act.

4.5.1 Basis of Stranded Cost Calculations

The E3 report prepared for the Maryland Department of the Environment, which hosts the Maryland Commission on Climate Change, estimated the 2021 natural gas system delivery cost (that is, apart from the commodity price, as discussed above) to be about $1.05 billion.[290] Revenue requirements will increase as a result of already authorized STRIDE investments and the four additional STRIDE tranches if they are authorized, as they may well be under current law. We consider the impact of recovery of $1.05 billion per year plus STRIDE investment (in round numbers) as natural gas use in the regulated sector declines steadily reaching a 95 percent reduction by 2045. This reduction in use is assumed to be due to electrification of natural gas uses or to use of hydrogen produced on site and/or transported by dedicated pipelines.

The framework used is to assume that the main declines will occur because homes and businesses using natural gas for space and water heating will depart the system at an accelerating pace and rates increase to keep revenues constant as natural gas use declines. We will assume, for simplicity, that the commodity price of natural gas—production plus transport to the "city gate"—will stay constant at $6 per MMBTU, the approximate level in early 2022 before the Russia-Ukraine war. We also do a sensitivity analysis to demonstrate

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[287] Baltimore Gas and Electric, Gas Commodity Prices: Schedule D – Residential and Schedule C – General Service, at www.bge.com/MyAccount/MyBillUsage/Documents/Gas/GasCommodity_SchedD%20and%20SchedC.pdf viewed 8/19/2022.

[288] Average residential electricity prices have declined since 2013 to 2020. They declined almost every year. Energy Information Administration State Electricity Profiles, Profile for Maryland at https://www.eia.gov/electricity/state/maryland/ viewed on 8/19/22.

[289] EIA State Electricity Profile for Maryland, ibid., EIA Monthly electricity report for May 2022, release date July 26, 2022 at https://www.eia.gov/electricity/monthly/current_month/july2022.pdf amd Henry Hub price data cited in the next footnote.

[290] Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, read from the chart on p. 112, at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

that the commodity price assumption is not central to the stranded cost calculation. We also examine how much earlier than 2045 the natural gas system might be considered to be stranded. **Table 4-6** shows the approximate level of reductions in various sectors that would be required to achieve the 2031 and 2045 goals of the Climate Solutions Now Act.

Table 4-6: Conceptual levels of reduction in sector greenhouse gas emission reductions needed to achieve Climate Solutions Now Act targets (rounded). *Source for 2006 greenhouse gas inventory Maryland Department of Environment 2006.*[291]

	2006	2031		2045		Comments
	Million mt CO_2e	Million mt CO_2e	% reduction	Million mt CO_2e	% reduction	
Electric power	42.5	12.8	70%	0	100%	
Res., Comm. Industrial, natural gas, propane	9.21	5.5	40%	0.9	90%	Note 1
Residential, Comm. Industrial, other fossil fuels	7.69	3.5	55%	0	100%	Note 1
Transportation, on road	29.6	11.8	60%	1.5	95%	Note 2
Transportation, other	5.9	4.7	20%	1.2	80%	Note 2
Fossil Fuel industry	1.3	0.5	60%	0.06	95%	
Emissions and % reduction	96.2	38.8	59.7%	3.7	95%	

Note 1: *Fuel oil and propane have been higher in cost than natural gas; the assumption here is that those direct end uses would be electrified first. However, that assumption may not hold as petroleum use declines and the cost of natural gas rises due to revenue recovery requirements from smaller volumes. Most or all of the remaining natural gas would likely be in the industrial sector.*

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[291] Maryland Department of Environment, Greenhouse Gas Inventory, 2006, at https://mde.maryland.gov/programs/air/ClimateChange/Documents/VIMAL/MD_2006_GHG_Inventory_updated%202022-09-24.xlsx

Note 2: *The 2031 60 percent goal for on-road transportation emission reductions requires roughly 70 percent of new vehicle sales be EVs by that date. The 20 percent is a derived number to achieve ~50 percent transportation reductions by 2031.*

The basic assumption in a calculation of stranded costs of natural gas infrastructure is that the volume of energy sold through that infrastructure will also decline. As discussed in above, the "highly decarbonized methane" scenario in the E3 study envisions such an option though most of the gas in its high decarbonized methane scenario would be synthetic methane.[292] This scenario had the highest costs (with methane costs in the $30 to $70 per MMBTU range); these costs were in addition to the delivery costs of methane, which would be on the order of $15 to $20 per MMBTU.[293] This would make for a total cost of $45 to $90 per MMBTU of delivered gas. This means that a typical residential consumption of about 70 MMBTU per year would result in an annual fuel cost of $3,000 to $5,000 (rounded). Mass migration away from "highly decarbonized gas" would occur long before that cost was reached, leaving fewer and fewer consumers to pay for the gas infrastructure. Renters with gas heating would likely be the most adversely affected, with low-income renters suffering the worst—unless massive amounts of energy bill payment assistance are provided. In that case, the bills of other ratepayers would go up even more; in the alternative, taxpayers would bear the burden. Neither is an attractive or even realistic option; see **Chapter 5**.

The E3 study acknowledges that the "highly decarbonized gas" scenario is also the most technologically uncertain of the three it considered (electrification and electrification with a fuel supplement being the other two). It would require large amounts of biomass inputs, some of which would have to come from outside Maryland; in the alternative, more synthetic gas would have to be made by CO_2 capture and hydrogen produced by renewable energy, a higher cost option.[294]

Finally, the E3 study also did not consider the health impacts of continued use of methane as a fuel, whether this related to outdoor or indoor air pollution. Further, adding hydrogen to the methane mix may also increase NO_x pollution due to the higher flame temperature; the much higher flame speed of hydrogen also requires specialized equipment when the hydrogen fraction in the fuel is high.[295]

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[292] The E3 study has an "optimistic case" and a "conservative" case for decarbonized gas supply. Even in the "optimistic case, about 85 percent of the supply is synthetic methane, the most costly element of supply. Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, p. 13 at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

[293] Ibid. pp. 114-115

[294] Ibid. pp. 13-14.

[295] General Electric, Hydrogen for Power Generation: Experience, Requirements, and Implications for Use in Gas Turbines, March 2022, pp. 13-14, at

In sum, the use of existing natural gas infrastructure for mixtures of methane and hydrogen to supply building is unrealistic to the point of being infeasible from the point of view of cost, environmental justice, health, or sheer practicality, since it is highly likely that most customers would abandon the option of energy delivery for heating and cooking uses via pipeline long before a substantial fraction of the required energy could be supplied in that fashion, contrary to the assumption in the E3 study that gas energy use via the pipeline infrastructure would decline only 19 percent relative to 2021.[296]

The practical implication for this study is that all-electric new buildings and all electric retrofits are most likely to become the norm and are compatible with the greenhouse gas targets of the Climate Solutions Now Act. For simplicity, we examine the impact on fuel rates and heating bills of those who may not have the option to convert to efficient electric heating; the most likely impacted households would be renters and, among them, low-income renters would likely be disproportionately represented. This highlights the need to give priority to electrification of heating of low- and moderate-income households.

Figure 4-6 shows the evolution of natural gas rates under the assumptions of reduction of natural gas use shown in Table 4-3 above (40 percent by 2031 and 90 percent by 2045).

A rapidly declining portion of the total rate would be represented by the natural gas itself (not separately shown in **Figure 4-6**). In 2035, that fraction would be 25 percent; in 2045, it would be only six percent. In other words, from the 2030s and into the 2040s, the delivery cost would dominate the rate; within the distribution portion the fraction attributable to STRIDE would increase from about 10 percent in the early to mid-2020s to over 30 percent in 2045.

The above is a rather optimistic construct of the use of the natural gas infrastructure since it assumes that natural gas would continue to be used and that it would be available at low cost. The much more likely case in the context of the Climate Solutions Now Act is that the gas would be synthetic "decarbonized gas" produced at high cost; this is the assumption, for instance, in more than one scenario in the E3 study. Heavy industries (like cement production) and non-road transportation, notably air transportation, are difficult sectors to decarbonize; in the latter case no clear path is even available at present, though electrification, hydrogen, and biofuels are being explored.

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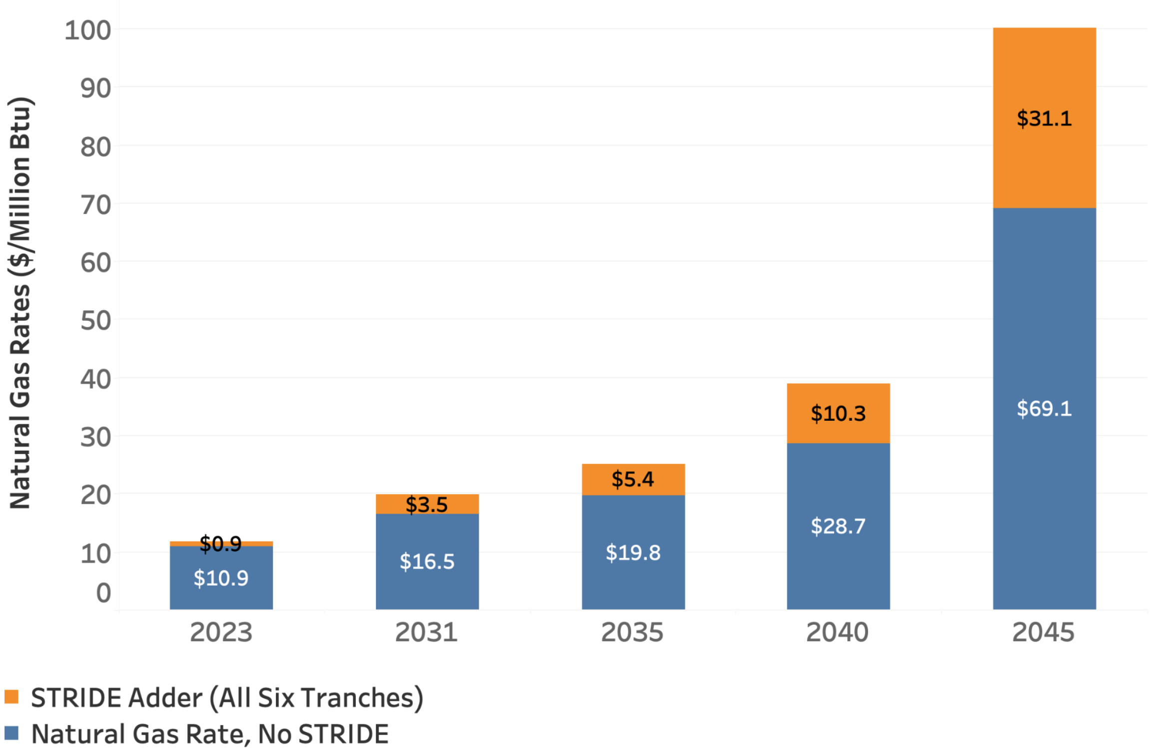
https://www.ge.com/content/dam/gepower-new/global/en_US/downloads/gas-new-site/future-of-energy/hydrogen-for-power-gen-gea34805.pdf

[296] Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, p. 12, at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

Figure 4-6: Potential evolution of natural gas rates for 40 percent reduction of natural gas end-use by 2031 and 90 percent by 2045.



Note: *The commodity price of natural gas is assumed to stay constant at $6/MMBTU. This is considerably lower than the price in 2022 (average price from January to August 2022 was $7.70; in August 2022 it was $10.10).*[297]

Given the cost and complexity of carbon capture and sequestration, these difficult sectors are likely to be the preferred ones to apply that approach for achieving net zero by 2045. As a result the likely options for buildings are (i) complete disconnection from gas, or (ii) use of verifiably decarbonized synthetic gas. In the former case, the entire natural gas distribution system will become a stranded cost by 2045 at the latest. In the latter case the high cost of commodity gas will add to the rates shown in **Figure 4-3** above. **Figure 4-7** shows the result of assuming a gradual increase in the cost of commodity gas from the $6/MMBTU assumed in **Figure 4-6** (about $5 lower than August 2022 cost) to $12/MMBTU in 2031, linearly increasing to $50/MMBTU by 2045. The latter cost is the middle of the range of “highly decarbonized gas” cost estimates in the E3 study.[298]

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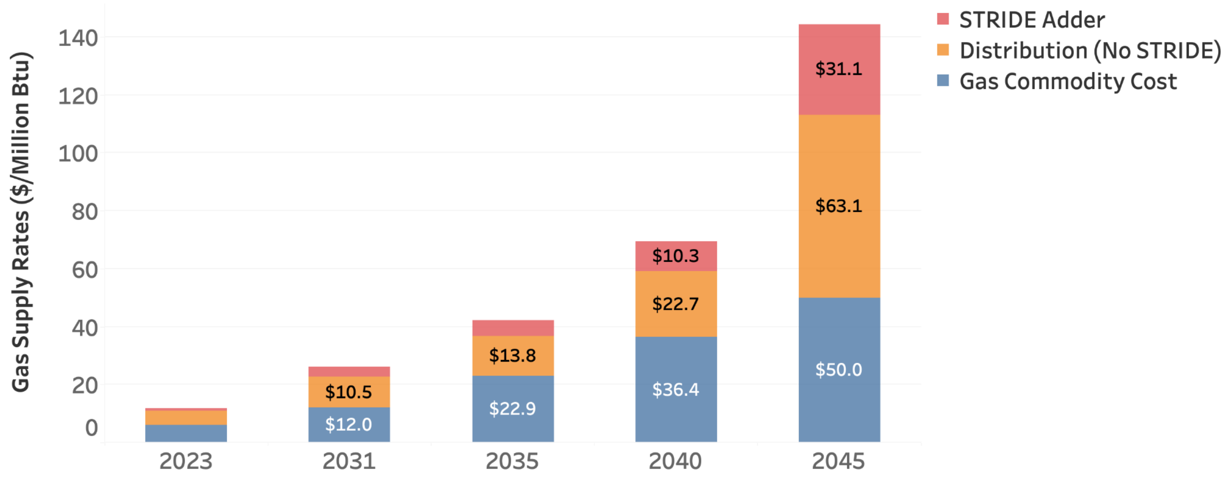
[297] Baltimore Gas and Electric, Gas Commodity Prices: Schedule D – Residential and Schedule C – General Service, at https://www.bge.com/MyAccount/MyBillUsage/Documents/Gas/GasCommodity_SchedD%20and%20SchedC.pdf

[298] Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, p. 114, at

Figure 4-7: Estimated rates for gas supply with synthetic decarbonized gas supplying 10 percent of the requirements in 2045.



Note: *The commodity price of natural gas is assumed to stay constant at $6/MMBTU. This is considerably lower than the price in 2022 (average price from January to August 2022 was $7.70; in August 2022 it was $10.10).*[299]

This synthetic gas scenario can also be used to examine the option of electric heating with a gas supplement of 10 percent of the total heating requirement. With total costs rising to $140/MMBTU by 2045, the cost of that 10 percent would be about $1,000 (rounded) assuming a heating end-use requirement of 70 MMBTU, a typical amount used currently; incidentally it is also a typical total annual gas bill. Thus, a small fraction of the heating energy requirement in 2045 would essentially double the cost of heating relative to the present. From the point of view of customers who have a choice, complete electrification would be much more economical, whether in new construction or at the time of replacing an existing gas system. This is because the heat pump costs are approximately on par with natural gas furnace heating plus central air conditioners at present (see **Table 4-5** above). Even with the most expensive—and most efficient—option, geothermal heat pumps, would be very attractive. This is because the added cost of the geothermal heat pump, attributable to the geothermal well, which is on the order of $10,000, would be generally lower than the cost of the supplemental gas.[300] In addition, geothermal heating and cooling would significantly reduce

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https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

[299] Baltimore Gas and Electric, Gas Commodity Prices: Schedule D – Residential and Schedule C – General Service, at https://www.bge.com/MyAccount/MyBillUsage/Documents/Gas/GasCommodity_SchedD%20and%20SchedC.pdf

[300] Geothermal heat pump costs average about $25,000 (before rebates and incentives): Home Remodeling: "How Much Does a Geothermal Heat Pump Cost to Install?" March 19, 2021 at https://homeguide.com/costs/geothermal-heat-pump-cost . The installed cost of highly efficient air-to-air heat pumps are in the $12,000 to $18,000 range: Home Remodeling Cost Guide, "Top 10 Heat Pumps for 2022:Costs, Unit Pros & Cons," February 21, 2022, at www.remodelingcosts.org/top-10-heat-pumps-costs/.

the cost of electricity and both the summer and winter peak loads on the system (relative to air-to-air heat pumps), providing benefits both to the household and the electric grid.

If the supplemental decarbonized gas approach is adopted as policy it would mean that only low- and moderate-income households who are unable to transition to full electrification would remain in the system, with harmful consequences for energy cost burdens and health. For instance, an increase in gas bills by $1,000 per year would increase the energy cost burden of a family of three at 50 percent of the federal poverty level by more than eight percent, making even *the increment in cost unaffordable all by itself* at that income level or below.

The Maryland Office of People's Council published a more detailed study in November 2022 examining the impact of declining natural gas use on rates. The results are broadly similar to those discussed above, but differ in detail because the scenarios evaluated were somewhat different.[301]

4.5.2 Avoiding Stranded Costs[302]

An essential element of avoiding stranded costs is to stop new investments in natural gas infrastructure and to stop open-ended STRIDE investments that are put into the rate base. This will minimize stranded costs but will not altogether avoid them since investments in recent years have recovery periods considerably beyond 2045. Alternative uses of the infrastructure or the infrastructure underground space could help mitigate much or most of the problem, provided those uses are compatible with the Climate Solutions Now Act, affordability, and equity.

The E3 study, discussed above, proposed two such approaches. One of them, replacing natural gas mainly with synthetic gas is technologically speculative and economically unaffordable. The other would be to maintain the pipeline infrastructure for synthetic gas and biogas as a supplemental fuel. Among other things, this would mean that the entire cost of the infrastructure would be imposed on a small fraction of the gas use, apart from all other considerations such as indoor air pollution. Yet, the study acknowledges that the costs of

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Assuming a 25-year loan at 5%, and a $10,000 added cost, the added annual cost would be about $700 (rounded). The cost with a shorter loan term of 15 years would be about $960 per year. Taking the 30 percent federal tax incentive into account, the annual added cost for a geothermal heat pump would be about $500 per year (25-year loan) or about $670 per year (15-year loan).

[301] Synapse Energy Economics, Climate Policy for Maryland's Gas Utilities: Financial Implications, report prepared for the Maryland Office of People's Counsel, November 2022. For BGE, the largest gas utility, the report estimated the rates in 2035 to be between $29 per MMBTUmillion and $39 per MMBTUmillion, while the range estimated above is $25 to $42 per MMBTU. Similarly the Office of People's Counsel estimated the rates in 2050 to be between $101 per MMBTUmillion and $146 per MMBTUmillion. The estimates in this report for 2045 are between $100 and $140 per MMBTUmillion; (all estimates round). The Office of People's Counsel rates estimated for the smaller gas utilities to be somewhat lower than for BGE.

[302] This section covers only natural gas distribution infrastructure as it relates to supply to buildings for space and water heating, cooking, and clothes drying. It does not cover industrial uses of natural gas, which requires separate study.

delivery of gas alone would rocket from well under $10 per MMBTU to between $90 and $140 per MMBTU by 2045, due to the much smaller amount of gas flowing through the pipes. It admits that its analysis “does not address the question of how utilities would reduce the revenue requirement or how it would bear the cost gap between reduced revenue requirement and unavoidable costs of the remaining gas system.”[303]

The best approach is to create an orderly transition enabling utilities to shut down the natural gas distribution infrastructure, neighborhood by neighborhood, by focusing energy transition efforts, especially electrification, along those lines. Priority could, and should, be given to those areas with older pipes considered vulnerable or areas identified as having safety issues. Stranded costs could be avoided in some or many cases by using the underground right of way to replace the natural gas pipes with geothermal pipes carrying heating and cooling energy from shallow geothermal closed-loop wells to individual buildings equipped with suitable heat pumps.

Gas utilities in some parts of the United States, among others, are considering replacing gas pipeline distribution infrastructure with networked geothermal heating and cooling pipe infrastructure, which is distributed by nature. For example, Eversource is a company that supplies electricity, natural gas, and water to parts of Massachusetts, Connecticut, and New Hampshire. It has embarked on a program of networked geothermal wells to supply heat, starting with a pilot project that “could lead to expansion of the technology in the future.”[304] An example of a project that has been completed is the one built at Colorado Mesa University. The project cost was $8.2 million; the annual energy bill savings are $1 million. Demonstration projects are being planned or built in several states, facilitated by suitable legislation.[305] While the pipelines themselves would be removed, they would be replaced by similar pipe infrastructure for carrying glycol, the commonly used fluid for geothermal wells. It is as yet unclear how widely this approach may be applicable and what incentives would be needed for broad adoption.

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[303] Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, p. 32, at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

[304] “Networked Geothermal Energy, Eversorurce, at https://www.eversource.com/content/ema-c/residential/about/sustainability/renewable-generation/geothermal viewed on November 21, 2022

[305] Energy We Can’t Afford Coalition, How Networked Geothermal Can Help Get Minnesota Off natural gas, Fresh Energy Webinar video, September 21, 2022, at 26 minutes, 21 seconds, slides by www.heet./org at https://www.youtube.com/watch?v=Qt2d0FILzZg In July 2022, New York passed a law that would “promote the development of thermal energy networks throughout the state and to provide jobs to transitioning utility workers who have lost or are at risk of losing their employment.” The term “thermal energy networks” includes geothermal well networks. “New York Approves Landmark Thermal Network Legislation,” Geothermal Rising, July 6, 2022, at https://geothermal.org/our-impact/blog/new-york-approves-landmark-thermal-network-legislation

Using distributed geothermal wells and heat pumps to electrify heating in neighborhoods depends on the density of space heating needs; it can consist of a mixture of residential and commercial structures. Below a certain density, individual wells and heat pumps are suitable; above a certain maximum, supplemental wells not on the same street may be required to meet all the requirements. Obviously, building envelope improvements could also help fill some or all of the gap in such cases. This approach would be particularly suitable in Baltimore City, which is a big part of Baltimore Gas and Electric territory where most of the STRIDE investments are taking place.[306]

4.6 Brief Overview of the Gas Pipeline Leak, Safety, and STRIDE

STRIDE investments, which involve pipeline replacements, have generally been justified in Maryland, as elsewhere, in the name of safety. However, according to the PSC interpretation in a 2013 case involving Baltimore Gas & Electric, the 2013 law allows investments that are far broader so long as a safety improvement is claimed, even without metrics for those investments. Specifically, BGE proposed not only to replace pipes that were leaking under the terms of STRIDE, but also to replace pipes that might be “leak-prone.”[307] Thus the metrics of actually reducing leaks, reducing greenhouse gas emissions, and improving safety in the short-term that may justify accelerated replacement and recovery with surcharges, was conflated with a judgment of the company that essentially lacks the clear metric of reducing leaks, not to speak of the metric of reducing serious accidents.

We have already cited (above in this chapter) a generally similar case in 2011, that is, before the STRIDE law was passed, in which Washington Gas Light had applied to the PSC to replace pipes and apply a surcharge as part of the recovery of the investment. The PSC affirmed, in agreement with the company, “that safe and reliable infrastructure is the highest priority” but did not approve the surcharge for “the recovery of future pipe replacement expenses”—the economic essence of the STRIDE law and of the PSC’s approval of the BGE 2013 application under that law. The basic argument in the 2011 rejection of the surcharge was that both normal and safety-related accelerated pipeline replacement could occur “using traditional

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[306] Burohappold Engineering, GEo Micro District Feasibility Study, heet, 2021, at https://heet.org/wp-content/uploads/2019/11/HEET-BH-GeoMicroDistrict-Final-Report-v2.pdf

[307] Testimony of BGE witness Biagiotti, as quoted in the Commission’s Order in Case 9331, p. 21. Maryland Public Service Commission, Order No. 86147 in the Matter of the Application of the Baltimore Gas and Electric Company for Approval of a Gas System Infrastructure Development and Enhancement Plan and Accompanying Cost Recovery Mechanism: Before the Public Service Commission, Base No. 9331, January 19, 2014, at https://webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?FilePath=//Coldfusion/Casenum/9300-9399/9331/37.pdf

ratemaking procedures without compromising its [the utility's] ability to earn an appropriate return."[308]

Climate and stranded costs were not a central consideration in 2011 or in 2013, the year the STRIDE law was passed, so far as natural gas use was concerned. The passage of the Climate Solutions Now Act in 2022 has dramatically changed that. Moreover, a 2021 law requires the PSC to take the climate change impacts of its actions into account using the latest science published by the Intergovernmental Panel on Climate Change.[309] The Climate Solutions Now Act greenhouse gas targets for 2031 and 2045 are broadly consonant with that science. The federal Inflation Reduction Act is also likely to have a major impact in spurring electrification of the economy, due to its many provisions spurring the energy transition. These include a ten-year extension of the investment tax credit for solar energy and storage, weatherization investments, and rebates for high efficiency electric homes.[310]

As demonstrated in the analysis in this chapter, continued investments in STRIDE, and by implication, new investments that increase the rate base of Maryland's gas utilities will accelerate the stranding of Maryland's gas pipeline infrastructure, significantly increase costs, and also exacerbate economic, environmental, and health inequities in the state's energy system. Thus, it is essential to find ways to minimize exposure of the state's ratepayers (and potentially taxpayers) to stranded costs while improving safety and meeting the goals of the Climate Solutions Now Act. These matters are discussed in **Chapter 5** on policy. It is nonetheless important to look at national and state safety data in light of the rush of investments in pipeline replacements and consequent increases in profits of regulated utilities that followed the report of the National Technical Safety Board on the 2010 San Bruno, California accident and subsequent actions by the federal Department of Transportation (discussed above).

4.6.1. National Serious Accident Data

Table 4-7 shows the number of serious natural gas accidents in the United States between 2005 and 2021 (inclusive), sorted by the causes of the accidents. Accidents are classified as "serious" whenever there is a serious injury or fatality involved.

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[308] In the matter of the Application of the Washington Gas Light Company for Authority to Increase its Existing Rates and Charges and to Revise its Terms and Conditions for Gas Service, Maryland Public Service Commission Order 84475, Rate Case 9267, November 14, 2011, at https://webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?FilePath=//Coldfusion/Casenum/9200-9299/9267/98.pdf

[309] Maryland Code, Public Utilities, § 2-113, Duty of Commission to supervise and regulate public service companies, Effective: October 1, 2021

[310] Sylvia Chi, IRA: Our Analysis of the Inflation Reduction Act, Just Solution Collective, 2022, at https://assets-global.website-files.com/5fd7d64c5a8c62dc083d7a25/63232854dd4d104128f01b8c_JSC%20-%20Analysis%20of%20the%20Inflation%20Reduction%20Act%20-r3.pdf

Table 4-7: National data on serious natural gas accidents. Source: Data from PHMSA 2022[311] sorted for this report.

Serious Accidents 2005-2021, National Data			
Equipment failure	10	2.3%	
Corrosion	16	3.7%	Possibly & and pipe material related
Natural force damage	24	5.6%	
Material failure of pipe or weld	41	9.5%	
All other causes	54	12.5%	
Incorrect operation	64	14.8%	
Excavation damage	108	25.0%	
Other outside force damage	115	26.6%	69% due to vehicular damage
Total	432	100.0%	

Corrosion, which can be attributed to age and type of pipe, was responsible for only 3.7 percent of all serious accidents, while incorrect operation, excavation damage, vehicular damage were responsible for a significant majority of accidents. Material failures accounted for 9.5 percent of the total. For example, in the 2010 San Bruno accident, discussed above, the problem with the weld that caused the accident dated to the time of installation and should have been noticed then; age was thus not the primary causative factor in that accident. Further, the frequency of serious accidents in the eight-year period 2014–2021 (inclusive) was only marginally better than in the prior eight year period 2006–2013 (inclusive), indicating that the investments in pipeline replacement that have been made in the wake of the accident have not materially improved safety.[312] **Table 4-8** shows Maryland data, by year and cause of accident in the 2005-2021 period.

All of the fatalities in the Maryland natural gas system and the vast majority of injuries in the 2005-2021 period occurred after the passage of the STRIDE law. The vast majority of both fatalities and injuries were due to a single 2016 accident at the Flower Branch Apartments in Silver Spring Maryland, which did not involve the gas distribution system. The NTSB concluded that the cause was “the failure of an indoor mercury service regulator with an

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[311] Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation at https://portal.phmsa.dot.gov/analytics/saw.dll?Go

[312] The comparison periods were chosen because, as in the case of Maryland, 2014 would be the first year in which widespread investments would have been made pursuant to federal and state legislation and regulatory actions by state regulatory bodies.

unconnected vent line…"[313] inside the building. The NTSB made a number of recommendations, some of which involved utility actions and costs.[314] However, no STRIDE type of program for accelerated recovery of costs outside of rate cases was put in place.

Table 4-8: Serious natural gas system accidents in Maryland, 2002-2021.

Year	Date	City	County	System Part	Cause	SubCause	# of Fatalities	# of Injuries
2007	7/14/07	Frederick	Frederick	Pressure Limiting and Regulating Facility	Other Outside Force Damage	Vehicle Not Engaged in Excavation	0	1
2008	4/29/08	Baltimore	Baltimore City	Service Line	Corrosion	External	0	1
2009	5/7/09	District Heights	Prince George's	Main	All Other Causes	Misc.	0	2
2013	8/2/13	Beltsville	Prince George's	Other	All Other Causes	Unknown	0	1
2014	2/19/14	Baltimore		Other	All Other Causes	Unknown	1	2
2016	8/11/16	Silver Spring	Montgomery	Other	All Other Causes	Unknown	7	33
2018	6/9/18	Baltimore	Baltimore City Is Not Within Baltimore County	Main	Material Failure of Pipe or Weld	Other Pipe/Weld/ Joint Failure	0	1
2021	5/14/21	Pikesville	Baltimore County	Main	Incorrect Operation	Other Incorrect Operation	1	1

Source: Data extracted from PHMSA 2022[315] sorted for this report.

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[313] National Transportation Safety Board Press Release, "Failed Gas Regulator, Unconnected Vent Line Led to Maryland Apartment Building Explosion," April 23, 2019 at https://www.ntsb.gov/news/press-releases/Pages/nr20190423.aspx

[314] National Transportation Safety Board, "Building Explosion and Fire, Silver Spring, Maryland: Public Meeting April 23, 2016", August 10, 2016, NTSB/PAR-19/01 at https://go.usa.gov/xmBNC

[315] Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation at https://portal.phmsa.dot.gov/analytics/saw.dll?Go

The 2014 fatality was due to falling debris caused by a gas explosion inside a building (in Baltimore City); the building was destroyed.[316] The ninth and latest fatality in the 2005-2021 period occurred in 2021; a worker was killed in an excavation accident; as is clear from **Table 4-8**, this is the most frequent kind of serious accident related to natural gas.

In addition to the above list of serious accidents in Maryland, two other explosions that caused serious injuries apparently caused by natural gas occurred in March 2022[317] and November 2022.[318] Both were in Montgomery County, Maryland's most populous, were inside buildings and caused significant damage. While official National Transportation Safety Board reports are not yet available, neither explosion appears to have involved pipelines.

So far as Maryland is concerned all the fatalities in serious natural gas explosions in the 2005-2021 period occurred after the passage of the STRIDE law. Only one serious injury in the entire period was due to an accident where the primary cause is listed as pipe corrosion. Moreover, as noted, STRIDE does not require a prioritization for detection of actual unsafe conditions and corroded pipes. The broad assumption is that by replacement of aging pipes or pipes prone to corrosion and leaks, safety would be improved—over a time period that is expected to take decades since utilities are planning pipeline investments well into the 2040s.

This is not to say that leaks should not be repaired or safety be given anything less than the highest priority. If safety is the highest priority and its improvement is to be accelerated, the historical record in Maryland and nationally shows that investments and expenditures would have been better prioritized in other areas, such as natural gas infrastructure in buildings, worker safety, and worker training. Given the scale of injuries and fatalities related to apartment building explosions, these should evidently be a high priority both for safety and electrification with disconnection of natural gas. We are not aware of any environmental and health justice investigations that have been done in relation to the serious accidents in Maryland rental properties in recent years and natural gas safety.

Among other things, minimizing the looming stranded cost problem requires that urgent repairs or replacements needed for safety be distinguished from non-urgent problems. Creative approaches such as electrifying neighborhoods with greater leakage or safety issues with higher priority and decommissioning the gas infrastructure in those neighborhoods should be considered. Networked geothermal heat pump systems could also provide utilities with the option of maintaining a significant rate base; however, this would require a

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[316] Katie Lange, "BGE settles lawsuit with family of boy killed in home explosion," WBAL TV, Baltimore, August 15, 2014 at https://www.wbaltv.com/article/bge-settles-lawsuit-with-family-of-boy-killed-in-home-explosion/7088705
[317] Tim Fitzsimmons, Ten hospitalized after apparent gas explosion in Maryland apartment, NBC News, March 3, 2022, at https://news.yahoo.com/10-hospitalized-apparent-gas-explosion-190244127.html
[318] Kristina Sgueglia and Eliott C. McLaughlin, Maryland condo explosion leaves 12 people, including 4 kids, injured, CNN, November 16, 2022, at https://www.cnn.com/2022/11/16/us/maryland-condo-gas-explosion/index.html

commitment to phase out decommission natural gas infrastructure supplying buildings instead of expanding it.

4.7 Conclusions

The Climate Solutions Now Act has major implications for accelerating the decarbonization of buildings. Specifically, the analysis in this chapter shows that the use of existing natural gas distribution infrastructure is not a realistic option from the points of view of cost, health, or environmental justice. We will examine the policy implications in **Chapter 5**. Suffice it to say here, from an equity point of view, that the recommendation of the Maryland Commission on Climate Change to retrofit all low-income Maryland households by 2030[319] should be adopted as a principal goal both for the energy transition and for economic and environmental justice. The above analysis clearly shows that use of the gas infrastructure should not be included in these retrofits. In fact, the safety objectives that were part of the motivation for the STRIDE law can be joined to the climate objectives of the Climate Solutions Now Act by systematically prioritizing and accelerating the electrification of neighborhoods where there are older pipes and or leaky pipeline infrastructure.

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[319] Maryland Commission on Climate Change, 2021 Annual Report, Maryland Department of the Environment, 2021, p. 8, at https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Documents/2021%20Annual%20Report%20FINAL%20%282%29.pdf

5.0 Policy

5.1 Introduction

Energy affordability policy in Maryland must ensure the achievement of two goals:

1. Reduction of energy cost burdens below six percent for all eligible low- and moderate-income households, defined here as households that have incomes of 200 percent or less of the federal poverty level.
2. Full integration of all eligible low- and moderate-income households into the energy transition, including weatherization, access to renewable energy (notably solar), access to demand response, and accelerated electrification of fossil fuel appliances.

The first goal, energy affordability for all, is a longstanding one, and, as a matter of economic justice, is independent of the decarbonization imperatives related to climate change. The two goals are now joined because decarbonization itself creates serious issues that impact affordability and equity. For example, as discussed in **Chapter 4**, the distribution of costs of natural gas would rise steeply as wealthier households electrify. Low-income renter properties are unlikely candidates for electrification given that, without policy interventions, landlords would pay the costs of electrification, while renters would reap the benefits—the classic split incentive problem. Almost all renters pay their heating bills; heat is included in the rent in only about 12 percent of cases.[320]

Steeply rising energy costs for low-income households would increase energy cost burdens, resulting in greater assistance requirements to maintain affordability or greater dislocation and negative impacts such as ill-health, disconnections, and rising evictions due to energy bill and rent payment conflicts. In fact, both outcomes are likely since, under typical conditions such as those currently prevailing, the majority of households eligible to receive bill payment assistance do not get it (see **Chapter 1**).

Reducing residential fuel use will not only help mitigate carbon emissions, it will also help to reduce in-home emissions of health-damaging air pollutants, providing public health benefits that may be particularly valuable for low-income households, children, the elderly, those with underlying health conditions, and other vulnerable populations.

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[320] Maryland Office of People's Counsel. (2018). Maryland Low-Income Market Characterization Report. Energy Efficiency for All. p.51. https://www-new.energyefficiencyforall.org/resources/maryland-low-income-market-characterization-report/

Of course, there is the direct impact on decarbonization of a failure to integrate low-income households. Net zero emissions will be difficult enough, given the challenges posed by sectors such as air travel and air freight where no economical technologies for complete decarbonization are currently available. This makes decarbonization of all areas where economical approaches and technologies are available an imperative for decarbonization.

About one-fifth of the households in Maryland have unaffordable energy cost burdens. We estimate that about 200,000 Maryland households have very high energy cost burdens, defined as more than 10 percent of income (**Chapter 2**). Of those, around 50,000 households have energy burdens higher than 30 percent of income, a disastrous level. For reference, according to the guidelines of the U.S. Department of Housing and Urban Development, 30 percent is the affordability limit for the *entire cost of housing, including utilities*.[321]

Further, the analysis in **Chapter 4** shows that, in the absence of strong preventive action, the utility bills of households that now heat with natural gas are likely to increase dramatically if those families are unable to electrify their space and water heating and disconnect from the natural gas system. Specifically, policies and laws that allow further natural gas investments, such as STRIDE, are now at cross purposes with the Climate Solutions Now Act, which requires net zero greenhouse gas emissions by 2045. Low- and moderate-income renters are much more likely to be stuck, being unable to electrify. The above considerations mean that it is essential to join the goal of making energy affordable for all households, especially those with high energy cost burdens, with the integration of those same households into the energy system decarbonization with high priority in ways that can benefit affordability, public health, and climate objectives. The Building Energy Transition report recommended holistic retrofits—including weatherization and heat pumps—of all low-income homes by 2030.[322]

In this chapter we first discuss tools for achieving affordability goals, in particular bill assistance, followed by the systemic ways in which bills can be reduced, such as weatherization and electrification, which simultaneously reduce the need for assistance by lowering bills while meeting climate objectives.

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[321] *Glossary of Terms to Affordable Housing*. Washington, D.C.: U.S. Department of Housing and Urban Development, terms archived in 2011. https://archives.hud.gov/local/nv/goodstories/2006-04-06glos.cfm

[322] Maryland Commission on Climate Change, Transition Plan: A Roadmap for Decarbonizing the Residential and Commercial Energy Sectors in Maryland, Maryland Department of the Environment, 2021,p. 20, at https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Commission/Building%20Energy%20Transition%20Plan%20-%20MCCC%20approved.pdf The term “low-income” was not defined in the report or during the discussions in the Building Sub-Group that oversaw its production. Mark Stewart, Program Manager, Climate Change Program, Maryland Department of the Environment, personal email communication with Arjun Makhijani, December 28, 2022, cited with permission.

5.2 Tools for Affordability

5.2.1 Energy Assistance: The Current Situation

The traditional tool for improving affordability in Maryland has been energy bill assistance, as discussed in **Chapter 1**. One form of assistance helps clear accumulated energy bill arrears to prevent low-income families from being disconnected from utility service. The other is direct bill payment assistance, which reduces energy bills, making the remainder more affordable or less unaffordable. As discussed in **Chapter 1**, direct bill payment assistance has two major components: the federal component is directed mainly at assistance to reduce heating bills; the state component is directed at reducing electricity bills. Both the federal and state components have modest weatherization assistance as well; this helps to reduce energy bills systemically by improving efficiency, including both building envelope efficiency and appliance efficiency. Weatherization is covered in subsequent sections in this chapter; this section focuses on bill assistance.

Current assistance helps reduce energy cost burdens significantly for those who get it. **Table 5-1** below is based on actual utility bill data of assistance recipients. It shows energy costs and the impact of assistance on energy costs burdens for households using different types of heating fuel.

Table 5-1 shows energy cost burden reduction impact for less than half the households assisted since it is limited to those households for which energy costs were available for a full twelve-month period. The average bills for this group appear to be somewhat lower than is typical (see **Chapters 1 and 2**). Nonetheless, it is clear that even with only heating bill assistance, energy cost burdens are substantially reduced, in many cases below the six percent affordability threshold.[323] Yet, many households remain above the six percent limit; average burdens for electricity-, fuel oil-, and propane-heated homes post-assistance remain above six percent. A further reduction in energy cost burdens is accomplished by electric bill assistance, not shown above. It should be noted that these are average results; there is a considerable spread in outcomes within each income group and type of heating fuel.

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[323] LIHEAP has required states to report on how well the energy cost burdens of the highest burdened eligible households are being reduced. The performance of the Office of Home Energy Programs has steadily increased since that time. Office of Home Energy Programs , Analysis of the Maryland Executive Budget, FY 2022, Maryland Department of Human Services, 2021, Exhibit 4, p. 10.

Table 5-1: Sample of households assisted in Maryland's Fiscal Year 2020, with energy cost burdens before and after MEAP assistance, grouped according to main heating fuel.

	All Households	Electricity	Natural Gas	Fuel Oil	Propane	Other
A. Unduplicated Number of MEAP Bill Payment-Assisted Households	88,639	40,986	35,125	7,522	3,296	1,710
B. All Households with 12 Consecutive Months of Bill Data (Main Fuel and Electric)						
1. Unduplicated Number of Households with 12 Consecutive Months of Bill Data (Main Fuel and Electric)	39,998	17,908	15,721	3,718	1,614	1,037
2. Average Annual Household Income	$16,108	$15,809	$16,163	$16,954	$16,988	$16,036
3. Average Annual Total MEAP Benefit per Household (including Heating, Cooling, Crisis, Supplemental Benefits)	$599	$381	$560	$1,241	$1,443	$1,326
4. Average Annual Main Heating Fuel Bill	$1,210	$1,541	$669	$1,617	$1,952	$1,064
5. Average Annual Electricity Bill	$461	$0	$820	$717	$1,092	$1,092
6. Average Annual Total Residential Energy Bill	$1,671	$1,541	$1,489	$2,334	$3,044	$2,156
7. Average Annual Burden Before Receiving MEAP	10.4%	9.7%	9.2%	13.8%	17.9%	13.4%
8. Average Annual Burden After Receiving MEAP	6.7%	7.3%	5.7%	6.4%	9.4%	5.2%
9. Average Percentage Point Change in Energy Cost Burden	3.7%	2.4%	3.5%	7.3%	8.5%	8.3%
10. Average Percentage Reduction in Energy Cost Burden	35.8%	24.7%	37.6%	53.2%	47.4%	61.5%

Source: Table 9, reproduced from: Office of Home Energy Programs, Electric Universal Service Program (EUSP) Proposed Operations Plan for Fiscal Year 2022, , Maryland Department of Human Services, submitted to the Maryland Public Service Commission Docket No. 8903, July 2021, Item # 569, at *https://webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?filepath=//Coldfusion/Casenum/8900-8999/8903/Item_569\EUSP_OPERATIONSPLAN_2022.pdf*

The biggest problem is the low level of participation: most recently, only about 22 percent of the eligible population receive utility bill payment assistance. Within the eligible population, the lowest income group with income below the federal poverty level is also served at a low rate. Only about one-fourth of the families with incomes below the federal poverty level receive any energy assistance,[324] leaving well over 100,000 of the most vulnerable households with unaffordable bills.

Maryland is typical of many other states in its low level of participation in energy bill payment assistance programs. As noted in **Chapter 1**, the number of assisted households has generally declined over the past decade from a high of more than 130,000 in 2011 to just above 80,000 in 2021 and the rate of denials for those who do apply has been rising (**Figures 1-3** and **1-4, Chapter 1**).

Maryland's low participation has many potential causes.[325] Among them:

- Cumbersome documentation requirements, including income and social security numbers;
- Lack of access to broadband;
- Lack of easy access to physical offices for those who prefer that option due to distance or illness for instance;
- Linguistic barriers;
- Presence of undocumented immigrants in the household;
- Lack of information;
- Lack of adequate customer service to assist applicants (exacerbated during the COVID-19 pandemic);
- The general stigma associated with receiving government assistance, particularly for older persons.

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[324] Estimated from Table 6, Office of Home Energy Programs, *Electric Universal Service Program (EUSP) Proposed Operations Plan for Fiscal Year 2022,* , Maryland Department of Human Services, submitted to the Maryland Public Service Commission Docket No. 8903, July 2021, Item # 569, at https://webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?filepath=//Coldfusion/Casenum/8900-8999/8903/Item_569\EUSP_OPERATIONSPLAN_2022.pdf The Office of Home Energy Programs uses unusual categories of income brackets: 0 to 75 percent and 75 to 110 percent of the federal poverty level, so that the exact number of households below the federal poverty level who were assisted needs to be estimated. We did this by assuming a uniform distribution of households assisted within the 75 to 110 percent bracket.

[325] A report based on interviews with experts describes many of these issues nationally. See "Challenge 3, p. 16 onward in Zully Juarez*, Energy Burden & the Clean Energy Transition: Challenges and just solutions from energy assistance practitioners and advocates from around the country*, Just Solutions Collective, 2022, at https://assets-global.website-files.com/5fd7d64c5a8c62dc083d7a25/6246ab05aca2107884fb1632_Energy%20Burden%20and%20the%20Clean%20Transition%20-r4.pdf

Many of these problems are reflected in Maryland's program requirements and application process, resulting in high denial rates and low participation. For instance, Maryland has a rather forbidding list of application requirements, including "PROOF" (caps in the original) of a highly specific large itemized list of sources of income, including:

- Wages;
- Self-employment;
- Social Security;
- Tips;
- Interest from bank accounts;
- Dividends;
- Rental income;
- And 20 other items.[326]

In addition, the income eligibility limits vary according to who lives in the household. The general income eligibility limit is 175 percent of the federal poverty level; but it is 200 percent for households with at least one member who is 67 years old or older. Besides making the application more complex, there is also an element of arbitrariness in it. While the added eligibility is a positive for families with an older member, it excludes other households with similar levels of vulnerability, such as families headed by a single mother. It is well-documented that such households are more vulnerable and more at risk of poverty, among other disproportionate risks.[327]

If an adult in the household had no income, a signed declaration to that effect is required. Thus, potentially 28 different attestations (including the no-income attestation) are required just for the income portion of the application. A social security number must be submitted for each household member. Birth dates and citizenship status for each household member are also required. Energy bills must be submitted, rather than just the utility account number. The form must be signed and its contents declared to be true and correct under penalty of perjury. There are explicit cautions about fraud, intentional misrepresentation, and punishment in such cases. Assistance information is available in English and Spanish. The application runs into six pages; documentation requirements are over and above the length of the application. To top it all, the application is explicitly punitive in its tone, reminding applicants that they may face "punishment" for "misrepresentations" or "not telling the truth" in the application.

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[326] Office of Home Energy Programs, State of Maryland, assistance application at dhs.maryland.gov/documents/DHR%20Forms/FIA%20Forms/English/OHEP/OHEP_-Application_2023_EN_Fillable.pdf viewed on October 28, 2022.

[327] Sarah Damaske, Jenifer L. Bratter, and Adrianne Frech, Single Mother Families and Employment, Race, and Poverty in Changing Economic Times, Social Science Research, Vol. 62, February 2017 at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5300078/

The searching, detailed, punitive tone of the application entails a loss of dignity in just applying for aid; it appears designed as much a deterrent as an application for assistance. Certainly, many households would be ruled out automatically; for instance, mixed status households in which some have social security numbers and some do not, would be deterred from applying.

The application also presents logistical hurdles. The voluminous documentation must be found and collected; if applying online, the documents must be scanned and uploaded. In the absence of facilities at home; a trip to a commercial facility would be required. In case of a mail-in application, copies would need to be made.

As noted in **Chapter 1**, the number of households helped has been declining over time. The most recent fiscal year, FY 2022, ended on June 30, 2022, is no exception. The number of households helped with bill payment assistance through the first ten months declined again by seven percent to a low of 65,600. Expenditures on the Electric Universal Service Program were only $64.2 million, despite the fact that revenues were $118 million,[328] even as hundreds of thousands of eligible households received no help.

Given the complex application and documentation process, the way applicants are served and helped through the process becomes more critical. While direction rests with a central state office, the Office of Home Energy Programs, services are delivered via a network of 25 local offices; about half are local government offices and the rest are “Community Action Partnerships” or non-profit offices. The evident upside is that residents are served by local offices that may know their needs better. The downside is inconsistency of services; for instance, some offices provide in-person help while others do not. There are also inconsistencies in the rates of denial of assistance, since applications are screened by the local offices.

Maryland has made an effort to streamline the process of applying for and receiving various types of assistance by creating a one-stop portal. This site, known as myMDThink,[329] started several years ago. People can apply for food benefits (Supplemental Nutrition Assistance Program), Temporary Cash Assistance Program, Child Protective Services, OHEP, Jobs and Unemployment, Adult Services, and, more recently, utility bill payment assistance, all through a single portal.

Despite the availability of the one-stop shop portal, the long list of requirements has not changed. While the single application process is a big plus, the hurdles of navigating an online

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[328] Office of Home Energy Programs. Electric Universal Service Program: Proposed Operations Plan for Fiscal Year 2023. Baltimore, Maryland: Maryland Department of Human Services, July 2022, pp. 2-3, Case No. 8903, Maillog 2416781.
[329] myMDTHINK. https://mymdthink.maryland.gov/home/#/

application process with extensive documentation requirements remain. There are, inevitably, glitches in the new software, creating additional hurdles.

California provides a welcome contrast. It has close to a 100 percent participation rate in its electricity bill assistance program—essentially all those who are eligible apply and get assistance. Indeed, during the initial period of the COVID-19 pandemic, when unemployment skyrocketed, participation climbed to more than 100 percent because economic dislocation made more people eligible. The participation is so remarkable that the data, by utility, are reproduced in **Table 5-2** below.[330]

Table 5-2: Participation in California's electricity bill assistance program, California Alternate Rates for Energy (CARE).

2021 Enrollment and Penetration YTD through July 31						
Utility	Total Residential Customers	Estimated Eligible Customers	Eligible Rate	Customers Enrolled	Penetration Rate	Newly Enrolled Customers
PG&E	5,583,279	1,447,571	26%	1,609,223	111%	139,161
SCE	4,497,048	1,349,716	30%	1,482,236	110%	133,871
SDG&E	1,372,319	293,584	21%	342,851	117%	35,253
SoCalGas	5,672,733	1,712,462	30%	1,839,181	107%	157,818
Total	17,125,379	4,803,333	28%	5,273,491	110%	466,103

Source: Pacific Gas & Electric, Southern California Edison, San Diego Gas & Electric, and SoCalGas, Joint IOU Report of the CARE and ESA Programs, slides presented at the Low-Income Oversight Board Meeting, September 29, 2021.

A key to the high participation rate is that no documentation is required with the application. The application asks for the account holder's name and address as well as the utility account number. No other personal identifying information is required; names of other household members or their social security numbers or driver's license numbers are not required. So far as other household members are concerned, the only information needed is the number of adults besides the applicant and the number of children in the household. A simple signature suffices—without further attestation or legal jeopardy attached to that signature. The applicant can choose from nine languages for communications from the utility, including English, Spanish, Mandarin, Cantonese, Vietnamese, and Hmong. The form, including eligibility information, is just two pages long; the application part is just one page.

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[330] Pacific Gas & Electric, Southern California Edison, San Diego Gas & Electric, and SoCalGas, Joint IOU Report of the CARE and ESA Programs, Slide Deck presented at the Low Income Oversight Board Meeting, September 29, 2021, at https://liob.cpuc.ca.gov/wp-content/uploads/sites/14/2021/09/Item-9-IOUs-Consolidated-Template-revised. pdf

It is not that California's program is without its difficulties or complexities. Post-assistance verification is done for selected assistance recipients. The requirements for documentation of income are extensive and comparable to Maryland, though other documentation requirements are not as extensive or intrusive. For instance, social security numbers are not required. While the applicant must certify that the information provided is true, there is no mention of "punishment."[331] Assistance recipients do get excluded from the program *post facto* for failing to provide adequate documentation.

Asking low-income people who are going to be bumped from assistance for refunds post-facto is a tall order—and complex on both sides of the equation. Moreover, assistance in California is provided in the form of lower rates; it does not guarantee that the resultant bill at the lower rate will be affordable. It is much more likely to be so for people at the higher end of the eligibility range (i.e., closer to 200 percent of the federal poverty level) than, say, at 50 percent or 100 percent of the poverty level. While overall participation is high, it can be, and is, low in some rural areas with very low population density.[332] But these are mere quibbles compared to the massive failure of enrollment in Maryland's program and the failure to assist tens of thousands of families who do apply.

California is not the only state that makes it easy to apply for assistance. For instance, the energy utility in the Portland, Oregon area can be approached in 15 different languages (including English and Spanish) to get a discount on the household energy bill of up to 25 percent over and above whatever other assistance the family may be getting. The webpage is welcoming: it says it is "super easy" to apply. The application form is very similar to the one used in California. While there is an explanation of what income sources should be counted in providing the statement of household income, it says clearly that "no financial documents are required."[333] This new supplemental assistance plan was launched in 2022.[334]

The best experience with self-attestation appears to be in Maryland itself. Civic Works, based in Baltimore, is a non-profit organization; it has been carrying out weatherization and efficiency programs in low-income households since 2009 in cooperation with both state and Baltimore City agencies. Civic Works uses self-attestation as part of the qualification process for eligibility. It does have a random post-weatherization income check; customers are

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[331] Pacific Gas & Electric, CARE Post-Enrollment Verification Request Form at https://www.pge.com/pge_global/common/pdfs/save-energy-money/help-paying-your-bill/EN_pev_request_form.pdf viewed on November 1, 2022.

[332] Ibid. pp. 4-5.

[333] See PGE's assistance webpage at https://portlandgeneral.com/income-qualified-bill-discount. The application form is at https://portlandgeneral.com/income-qualified-bill-discount-form,viewed on October 30, 2022.

[334] PGE News Release, "PGE Launches New Income-Qualified Bill Discount Program, Portland General, April 18, 2022 at https://portlandgeneral.com/news/pge-launches-new-income-qualified-bill-discount-program

informed in advance that there may be such a check. Over all these years, *Civic Works has not found a single case of fraud*; only minor discrepancies have been discovered.[335]

There are four principal issues associated with providing low- and moderate-income households with assistance sufficient to make household energy costs affordable:

- What are the policies, regulations, incentives, and procedures needed to have essentially universal enrollment in assistance programs of all the households that are income-eligible to do so?
- What is the best way to ensure that the energy cost burden for all eligible households is made affordable (defined in this report as six percent of income or less)?
- What level of assistance funds would be required to meet a universal affordability goal and, as a corollary question, where might these funds come from?
- Since the funds needed for universal affordability are far greater than those available now, are there systemic ways to reduce funding requirements, while maintaining the affordability goal? This is the question where affordability connects with the transition to a clean, renewable, efficient, and affordable energy system.

Self-attestation would be a big step but it is not a cure-all. A part of the assistance money is from the federal government's LIHEAP program; those funds require documentation before they can be disbursed to recipients. In California, the reduced rate program is administratively separate from the utility-run programs that provide discounted electricity (30 to 35 percent less than the normal rate) and discounted natural gas (20 percent less than the normal rate).[336] However, even in this case, the application is much simpler than the one used in Maryland. For instance, only the applicant is required to provide a social security number. It is also more respectful of the dignity of the applicant who is not sternly reminded about punishment even though they are required to attest to the contents of the application under penalty of perjury.[337]

It should also be noted that, in contrast to essentially 100 percent participation in the utility program, participation in California's LIHEAP program is very low—just six percent in 2019 (**Figure 1-1, Chapter 1**). We have not examined the causes for this, but note that the rebate in the utility gas rate serves a similar function of reducing heating bills without the obstacles presented by LIHEAP documentation requirements. Maryland, which is typically colder than California, has no comparable program.

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[335] Schwartz, E. Civic Works, personal email communication, December 17, 2021.

[336] California Public Utilities Commission, California Alternate Rates for Energy,

[337] CALIHEAPApply.com - California's Online LIHEAP Application includes a very simple, easy to follow step-by-step instruction video, at https://www.caliheapapply.com/ viewed on November 11, 2022.

In addition, there are also related approaches that would systemically reduce bills and enable all people, including low- and moderate-income households, to participate in the energy transition; we will cover these in this chapter as well.

5.2.2 Approach to Assistance

Different approaches are used to directly reduce the energy cost burdens of low- and moderate-income families:

- **Direct bill payment assistance**: This is the model used in Maryland, where assistance is used to provide a credit on utility bills and reduce the amount payable by the customer. Ratepayer and RGGI-funded electricity bill assistance (EUSP) and federal heating bill assistance (MEAP) are disbursed in this way. Periodic clearance of long-accumulated arrears is also done by bill credits.
- **Discounted rates**: This is the California model, whereby a lower electricity or gas rate for eligible households reduces energy bills. Known as CARE (California Alternate Rates for Energy), the "program offers a 30-35% discount on your electric bill and a 20% discount on your natural gas bill."[338]
- **Percentage of income payment plan (PIPP):** This approach aims at making energy bills affordable by providing bill assistance sufficient to lower the energy cost burden to a specified percentage of income, usually six percent.

Each plan has its advantages and disadvantages. The discounted rates approach has the merit of great simplicity of concept and administration. It does not require legislative or regulatory action to raise the amount of funds when the need increases. In addition, California's simple application procedure with self-attestation of income, makes for high participation without high overheads for aiding people to fill out the forms, find, copy, and upload documents to achieve it. The California program also makes provision for encouraging efficiency among high electricity users by stating that a utility may require a CARE program participant whose electricity consumption is more than 400 percent of a "baseline" amount to "to participate in the Energy Savings Assistance Program (ESAP), which includes a residential energy assessment, in order to provide the CARE program participant with information and assistance in reducing his or her energy usage."[339]

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[338] California Public Utilities Commission, CARE?FERA Program: California Alternate Rates for Energy," at www.cpuc.ca.gov/lowincomerates/ viewed November 11, 2022. www.cpuc.ca.gov/consumer-support/financial-assistance-savings-and-discounts/california-alternate-rates-for-energy, viewed November 1, 2022. The 30 to 35 percent electricity rate discount applies to utilities with more than 100,000 customers. For those with fewer customers, a 20 percent discount is offered.

[339] California Public Utilities Code 739.1(i) at https://california.public.law/codes/ca_pub_util_code_section_739.1 viewed November 1, 2022.

One disadvantage of rate discount plans is that, for a given percentage rate discount, utility bills become less affordable as rates rise. Thus, even as low- and moderate-income customers receive a deteriorating level of assistance from the point of view of energy cost burden, the costs to ratepayers of providing that assistance increases. For instance, a regular rate of $0.20 per kilowatt-hour, discounted 33 percent to $0.133 per kWh would result in an energy bill of $1,000 for a low-income customer using 7,500 kWh a year. At an income of $20,000 per year, the energy cost burden would be reduced from 7.5 percent to five percent. The cost to other ratepayers would be $500.

If the rates rise to $0.30 per kWh (as they have done in some cases), the same percentage discount would now result in the low-income customer having a bill of $1,500 per year, which means an energy cost burden of 7.5 percent, the same as before assistance when the rate was $0.20/kWh. Even as the bill becomes unaffordable for the household receiving assistance, the cost to other ratepayers increases by 50 percent, from $500 to $750 per year. Thus, neither the party getting assistance nor the party funding it are insulated from the affordability consequences of rising rates.

Another feature that could be seen as a drawback is that a rate discount lowers the bill of households with very different incomes but same electricity use by the same amount. In the example above the electricity cost burden for a family with an income of $20,000 is reduced from 7.5 percent to five percent, which is possibly affordable (depending on whether there is a natural gas or propane bill or not). For a household with $10,000 income, the percentage burden drops by more, from 15 percent to 10 percent, but the final bill remains unaffordable.

The Maryland model of direct bill payment assistance that is paid to utilities is similar to the rate discount program in one way: by crediting the assistance amount to the customer’s bill, the low-income assistance recipient sees a lower, more affordable bill than would be the case without assistance. In many cases, the energy cost burden is reduced to less than six percent, which is the affordability threshold.

Two other advantages over the rate-discount program are noteworthy.

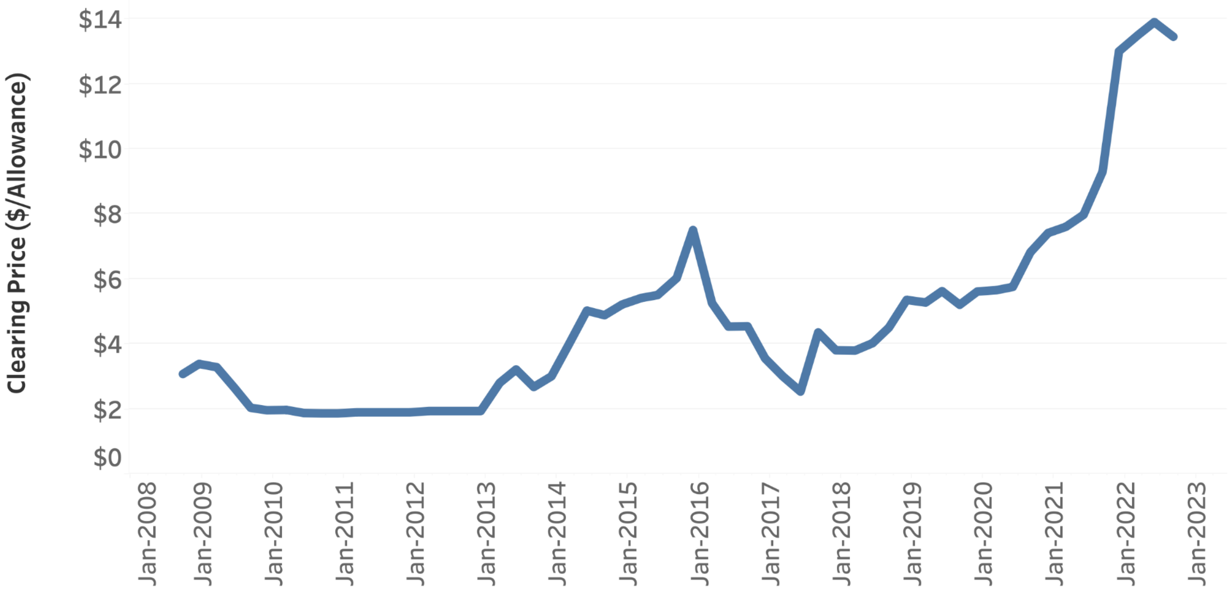
First, the federally-funded LIHEAP heating program can include households that use non-regulated fuels for heating, notably fuel oil and propane. Energy cost burdens for households using these fuels are generally higher (other things being equal), since they are more expensive fuels. Maryland, like other mid-Atlantic and northeastern states, has a significant number of households using these fuels; they are generally in rural areas. Their inclusion in energy assistance is an element of urban-rural equity that is important for both assistance and energy transition policies to take into account.

Second, the programs can be designed so that assistance can be preferentially directed towards households at the lower end of the income spectrum, families with disabled or ill members, and families with children. On the other hand, the funds available for bill assistance are limited and participation is low. High participation would reach more families but reduce the impact per family, since the amount of assistance funds available does not increase with the number of applicants or eligible households.

Specifically, in Maryland, EUSP, the electricity bill assistance program, is funded in part by a per-kilowatt-hour charge on electricity sales; the amount available is thus automatically limited by the total sales. Unlike the discounted rates approach, the available funds do not increase as rates rise and electricity bills become less affordable.

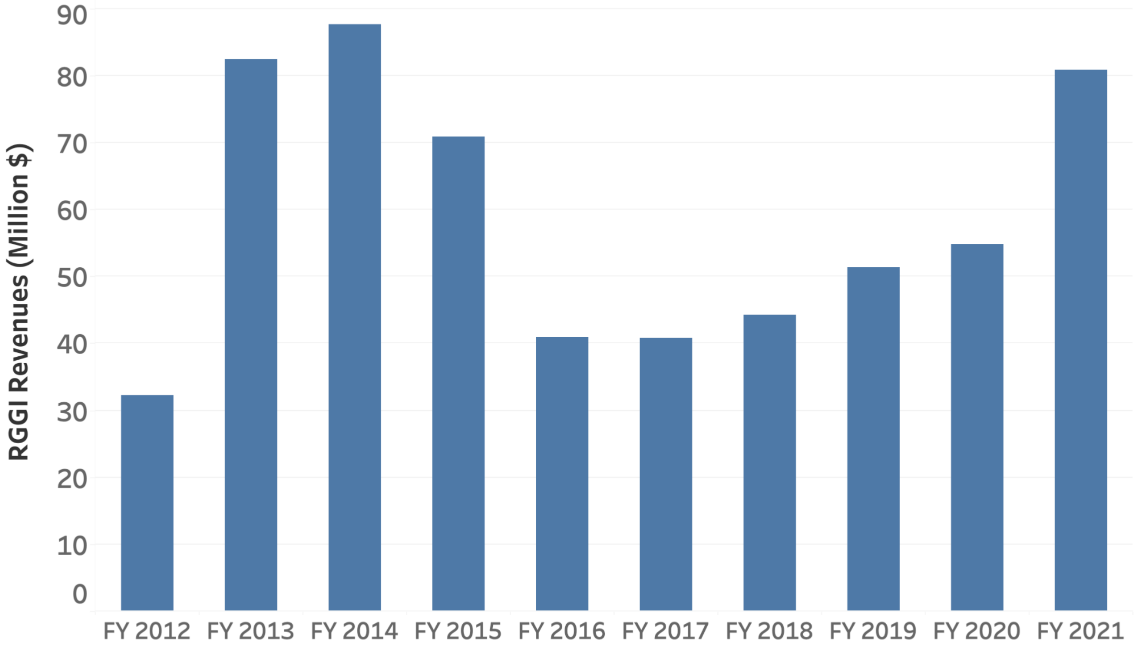
A part of the revenues from the sale of allowances under the Regional Greenhouse Gas Initiative (RGGI) is also devoted to electricity bill assistance in Maryland; it is the other major source of funds (see **Chapter 1**). The amount of this funding depends on the market price of each unit, which represents a metric ton of CO_2; allowances must be purchased at auction by electric utilities that have CO_2-emitting power plants. **Figure 5-1** shows the auction clearing prices of permits over time, with each permit representing a metric ton of CO_2 emissions.

Figure 5-1: Auction Clearing Prices of CO_2 permits in the Regional Greenhouse Gas Initiative. An allowance represents a metric ton of CO_2. *Source: Regional Greenhouse Gas Initiative, Allowance Prices and Volumes, at* www.rggi.org/auctions/auction-results/prices-volumes.



The available funds fluctuate with each auction; hence funding increases are not necessarily aligned with funding needs. Prices rose from 2012 to 2015 and then fell sharply for the next two years. A reduction in the total number of permits available (to restrict electricity sector CO_2 emissions) has resulted in an increasing permit clearing price tendency since late 2017. Of course, total revenues rise less than the allowance price when the number of allowances declines. **Figure 5-2** shows the annual revenues that accrued to Maryland from the sale of RGGI allowances, indicating the volatility of RGGI revenues.

Figure 5-2: Maryland annual revenues from the sale of Regional Greenhouse Gas Initiative allowances by fiscal year (from July 1 to June 30 of the next year). *Sources: Data compiled from Annual RGGI reports for FY 2016, FY 2018, FY 2020, and FY 2021, downloaded from https://energy.maryland.gov/Pages/reports.aspx*



Unlike the rate-discount approach used in California, the available funds in the bill-payment assistance model do not increase with the need, as for instance when electricity or natural gas rates increase, pushing up energy cost burdens.

Our estimate of the total affordability gap (**Chapter 2**) is about $360 million per year (based on Standard Offer Service rates for electricity and gas), but only about $120 million or so is available from current assistance sources—far short of meeting the need. The gap for fully funding a PIPP is therefore about $240 million per year. This includes all households with energy cost burdens over six percent; current eligibility criteria for assistance would leave out tens of thousands of them.

It should be noted that the administrative expenses associated with Maryland's program are significant. The allocation for administrative expenses for Fiscal Year 2022, including for the local offices accepting and processing assistance applications, was $11.5 million[340]—about $130 per assisted household. Much of this expense is the cost of processing applications that have voluminous documentation requirements, including verification of income, social security numbers, etc. Simplification of this process would free up funds for expanding participation.

A smaller, but still significant problem is the different income qualification levels for different programs and income groups. As noted in **Chapter 1**, the general income eligibility level for qualifying for assistance is income equal to or less than 175 percent of the federal poverty level. A recently enacted law has increased the income threshold to 200 percent for households with at least one member who is at least 67 years old. The threshold for weatherization assistance is 200 percent of the federal poverty level or 80 percent of the Area Median Income, whichever is higher in a particular county. This is the most expansive income qualification criterion. It is even more confusing because assistance for all these households is handled through a common application.

Expanding eligibility to be the same as for weatherization, up to 200 percent of the federal poverty level or 80 percent of area median income, whichever is higher, would cover essentially all cost burdened households and simplify the full integration of assistance with energy transition for cost burdened households.

We turn now to the Percentage of Income Payment Plan (PIPP), which combines the strengths of the rate-discount approach and the bill reduction approach. However, the path to securing such a program is not without its obstacles.

5.2.2.1 Percentage of Income Payment Plan

Percentage of Income Payment Plans (PIPPs) limit the total energy cost burdens of eligible low- and moderate-income households to a certain percentage of household income—usually

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[340] Office of Home Energy Programs, *Electric Universal Service Program (EUSP) Proposed Operations Plan for Fiscal Year 2022,* , Maryland Department of Human Services, submitted to the Maryland Public Service Commission Docket No. 8903, July 2021, Item # 569, Attachment A, p. 31, at https://webapp.psc.state.md.us/newIntranet/Casenum/NewIndex3_VOpenFile.cfm?filepath=//Coldfusion/Casenum/8900-8999/8903/Item_569\EUSP_OPERATIONSPLAN_2022.pdf

six percent. In theory, PIPPs combine the advantages of the rate-discount approach and the bill-payment approach to reducing energy cost burdens.

The biggest advantage is that a reduction of energy cost burden to the defined affordable amount is guaranteed under the program. That does not reduce the obstacles to enrollment, but it does assure that those who do enroll have a legally defined maximum energy cost burden. This guarantee will become increasingly important as climate extremes drive up energy bills—especially for cooling, but also for heating in some years and places. As is clear by now, average temperature increases can be and are accompanied by more severe winters or more severe periods (such as "polar vortex" periods) within a winter that is warmer on average. Thus, heating bills may also rise, disrupting a family's finances. Given that low-income household finances are usually precarious, there is an asymmetry of consequences—the surpluses when bills are lower are absorbed by other unmet needs, but the deficits can result in food-medicine-rent-utility bill payment conflicts that can lead to disastrous consequences including ill-health and becoming unhoused.

As we discuss below, weatherization is one way to reduce energy cost burdens by lowering overall energy demand. However, access to weatherization is considerably more difficult for renters, since audits and retrofits require the landlord's permission for access to the property. This is sometimes denied.[341] If a PIPP is in place, renters can still have affordable bills, though the cost would be higher than with weatherization. Those additional costs are borne by the non-low-income part of society—some combination of ratepayers and taxpayers. As a result, a PIPP creates a financial interest in the economically better-off sections of society to invest in weatherization and other means of systemically reducing energy bills because that also reduces assistance requirements.

The seriousness of the energy cost burden problem and the inadequacy of an assistance program that neither reaches most eligible households nor makes energy cost burdens affordable for all the households it does reach has been recognized in Maryland for many years. Specifically, the Public Service Commission opened an inquiry in 2011 into a PIPP for low- and moderate-income households in the state. Under such a plan, an eligible household would get sufficient assistance to bring its energy cost burden down to six percent, independent of how much above that threshold it might be initially. The Technical Staff of the Commission and the Office of People's Counsel, the official ratepayer advocate, worked together to examine the program. In 2012, both the Commission Staff and Office of People's Counsel recommended that Maryland adopt such a plan under the rubric of the Affordable

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[341] Arjun Makhijani, Christina Mills, and Annie Makhijani, *Energy Justice in Maryland's Residential and Renewable Energy Sectors*. Takoma Park Maryland: Institute for Energy and Environmental Research, 2015, p. 66, at https://ieer.org/wp/wp-content/uploads/2015/10/RenMD-EnergyJustice-Report-Oct2015.pdf

Energy Program, which was the phrase adopted for a PIPP proposed for Maryland. Its main features were to be:[342]

- The energy cost burdens of households with incomes equal to or less than 175 percent of the federal poverty level would be limited to six percent by providing direct bill credits to electricity and, if applicable, natural gas bills. Since propane and fuel oil are not regulated by the Commission, they were not covered by the recommendation. In case a household had both gas and electric service, a three percent limit would be applied to each bill.
- The pre-program arrearages would be cleared through special one-time grants at the start of the program, requiring some contribution from most households, with the rest provided by assistance funds.
- The Affordable Energy Program would be coordinated with weatherization programs so as to reduce energy bills and, hence, the amount of assistance needed to meet the six percent affordability criterion. Households with very high energy consumption would be prioritized.
- Routine periodic clearance of arrearages would be ended.
- Arrearage clearance would be considered if there were an extraordinary circumstance such as the loss of a job or a severe illness.

The overall cost of the program was estimated at $250 million.[343] While regulated utilities did not oppose the program outright, recognizing its benefits in making bills more affordable, they asked that the program not be enacted until there was much more study and examination of a variety of issues, including impacts on non-income ratepayers, conversion of an assistance program to an entitlement program, and assistance costs much above assistance levels at that time (2012). Baltimore Gas and Electric also made a remarkable statement about personal responsibility and root causes of failure to pay utility bills in full:[344]

> BGE said then [in March 2012] and reiterates now [November 2012] that assistance is more likely to help move customers toward self-reliance if it is tied

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[342] Maryland. Public Service Commission. Staff. *Affordable Energy Program ("AEP") Proposal*. Before the Public Service Commission, In the Matter of Low-Income Energy-Related Customer Arrearages and Bill Assistance Needs of Maryland: PC 27 [Public Conference PC 27]. Baltimore: PSC, November 1, 2012, p. 4, at https://webapp.psc.state.md.us/newIntranet/AdminDocket/NewIndex3_VOpenFile.cfm?FilePath=//Coldfusion/AdminDocket/PublicConferences/PC27//12.pdf

[343] Ibid. p. 28.

[344] *Comments of Baltimore Gas and Electric Company: In the Matter of Low-Income Energy-Related Customer Arrearages and Assistance Needs*, filed as part of Public Conference 27, Maryland Public Service Commission, November 30, 2012, pdf pp. 2-3, https://webapp.psc.state.md.us/newIntranet/AdminDocket/NewIndex3_VOpenFile.cfm?FilePath=//Coldfusion/AdminDocket/PublicConferences/PC27//16.pdf

> to some elements of personal responsibility, energy efficiency and conservation, and financial literacy/budget counseling.
>
> In addition to enhanced conservation and efficiency measures, BGE argued this might entail some customer requirements for ongoing receipt of assistance, such as a history of utility payments and attendance at some prescribed set of energy education and/or financial literacy or budgeting programs, to address some of the root causes of insufficient bill payment.

The “root causes of insufficient bill payment” were not further discussed in the company’s comment. Yet, they are well known. Generally, the causes include low wages, high rents, lack of health insurance with employment, ill-health due to a variety of factors, including living in food deserts, and the well-documented conflicts between the various financial needs. The most frequent and important conflicts are that families are forced to choose between paying rent, paying utility bills, and buying food and medicines. Almost five percent of those who have received heating bill payment assistance at least once in five years lose their homes due to such conflicts; there are about 7,000 evictions a year in Baltimore City alone (see below). Budgeting programs and financial literacy cannot address these fundamental problems, though they might rearrange them.

As is well and widely understood, most low-income households are renters; weatherization, more efficient appliances, and more efficient heating systems are therefore typically beyond their control. The “split-incentive” problem—costs to the landlord, benefits to the renter—is well understood as a structural obstacle, also outside the control of renters. Living in poorly insulated rental housing is also a cause of high energy bills. The 2015 IEER energy justice study estimated that on average, low-income households have about 50 percent more heating consumption per square foot than the average; as is well understood, the average can be improved significantly, with obvious implications for the greater potential for savings for low-income households. To imply that “insufficient bill payment” was somehow a failure of personal responsibility in the context of these well-known causes is to deflect attention from the causes, and hence also the solutions.

Finally, third party supply in Maryland’s deregulated electricity and gas sectors also significantly increases energy bills of residential subscribers in general, and of low-income households in particular. The problem has become particularly acute since the “Purchase of Receivables” regulation that put the risk of failure to pay due to high rates on ratepayers instead of the vendors of third-party supply. High third-party energy supply rates actually siphon off millions of dollars of assistance funds that go to the suppliers instead of reducing energy cost burdens. As noted in a 2018 Abell Foundation report, the Purchase-of-Receivables regulation left the third-party suppliers free to charge high rates without fear that the subscribers would fail to pay; the third party suppliers were guaranteed payment because the utilities paid them automatically, whether the customer paid the bill or not. The problem ballooned once this “moral hazard” was created.[345] A rough estimate of the added energy cost burden on low- and moderate-income households for the year 2021 is on the order of $30 million for electricity bills and $7 million for natural gas bills.

The impact on energy cost burdens of low-income subscribers of high third-party energy supply costs has been serious enough that the Maryland General Assembly passed a law in 2021 prohibiting third party supply rates above the utility “Standard Offer Service” for low- and moderate-income households receiving energy bill assistance.[346] That is only a partial solution; it leaves the majority of the problem unsolved, however, since almost 80 percent of low- and moderate-income households do not get assistance even though they are eligible.

PIPPs that have near-universal enrollment will, in general, be more expensive than other assistance plans. This is because the various present-day combinations of low-enrollment and insufficient assistance to enrollees means the current budgets fall far short of filling the actual affordability gap. Funding PIPP adequately and ensuring essentially universal enrollment are the two major challenges in generally lowering costs to affordable levels. We have discussed lowering the barriers to enrollment. The political will for appropriating sufficient funds can be increased in two ways:

a. Quantifying, so far as possible, the very substantial non-energy benefits of affordable energy to non-low-income households;

b. Reducing energy bills of low- and moderate-income households significantly by weatherization, community solar investments, electrification, and demand response sufficiently to greatly decrease the amount of assistance needed to make energy bills affordable and, so far as possible, reducing the amount of assistance needed to zero in all cases except the very lowest income brackets, where increases in income would be the most basic remedy.

We cover the systematic reduction of bills below and then show how the assistance and bill reduction aspects work together. In the rest of this section we estimate some of the quantifiable benefits of universally affordable energy and the funds needed in case universal enrollment is achieved.

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[345] Laurel Peltier and Arjun Makhijani, *Maryland’s Dysfunctional Residential Third-Party Energy Supply Market: An Assessment of Costs and Policies*, Abell Foundation, Baltimore, Maryland, December 2018, p. 12 at https://ieer.org/wp/wp-content/uploads/2018/12/Third-Party-Energy-Report-final-121718.pdf

[346] Maryland Senate, “Electricity and Gas – Energy Suppliers – Supply Offers,” Senate BIll 31, 2021, (cross-filed with House BIll 397) at https://mgaleg.maryland.gov/2021RS/bills/sb/sb0031E.pdf

5.3 Non-energy Benefits of Affordable Energy

Making energy affordable for all would have significant health and economic benefits for non-low-income households and for society at large. Many of these can be considered under the rubric of non-energy benefits, such as improved health and reduced costs associated with emergency room visits and homelessness. Taking such benefits into account was not a regulatory norm in 2012, when the proposed Affordable Energy Program was set aside. However, in 2015, when considering energy efficiency program costs and benefits, the Maryland Public Service Commission decided that if societal costs of efficiency programs were going to be considered then societal benefits—including "non-energy benefits"—should be included as well. While the Commission did not state that non-energy benefits should be considered for energy assistance programs as well, the reasoning clearly applies to any energy program on which public funds—ratepayer or taxpayer funds—are spent; the former are under the purview of the Public Service Commission; the latter under the Executive branch (for spending) and the legislature (for accountability).

Affordable energy and healthy homes will not remove all financial conflicts, but there is evidence that they could be significantly diminished. Maryland-specific data can help us identify order of magnitude estimates of at least some of the non-energy benefits of PIPPs.

Consider the following example provided by a pilot program in Baltimore. It implemented a holistic approach, as adopted by the Green and Healthy Homes initiative, in its retrofits. The result was a dramatic reduction in mortgage foreclosure notices, indicating much greater housing stability, as recounted in Makhijani, Mills, and Makhijani 2015:

> Out of a total of 580 houses pre-intervention, there were 57 total foreclosure notices to 49 different households (some received more than one notice in the study period). Post-assistance, the numbers were 7 total notices to 6 households out of a total of 580. **This means over 8 percent of the households received notices prior to participation and only about 1 percent received such notices after participation—more than an eight-fold decrease.**[347]

It is difficult or impossible to untangle the various financial stresses that lead to a particular eviction or foreclosure. However, the rent-energy bill conflicts are significant in the picture. For one thing, tenant payment of utility bills is a common part of many rental contracts.

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[347] Arjun Makhijani, Christina Mills, and Annie Makhijani, *Energy Justice in Maryland's Residential and Renewable Energy Sectors*. Takoma Park Maryland: Institute for Energy and Environmental Research, 2015, p. 91 (emphasis in the original), at https://ieer.org/wp/wp-content/uploads/2015/10/RenMD-EnergyJustice-Report-Oct2015.pdf

Low-income families who get federal Section 8 vouchers to assist with rent payment must stay current on their energy bills.[348]

There is direct evidence of the rent-energy bill conflicts from the detailed study on evictions done in Milwaukee, Wisconsin by Matthew Desmond. Since families are protected from utility shut-offs in the winter, many low-income families put off paying their utility bills, including in the effort to stay current on rent. The prohibition of utility shut-offs ends in the spring, with many families having accumulative significant arrears. As they start paying these off, they fall behind on rent. Summer becomes a tragic season of increasing evictions.[349]

There is no data specific to the state of Maryland on the various impacts of the conflicts between unaffordable energy bills and other needs like paying rent and buying medicines. However, some indication of the magnitude of the results of such conflicts can be found in data from Baltimore City, where landlords evict 7,000 families each year.[350] The court that adjudicates these cases deals with 150,000 cases each year[351] in a city that has only about 126,000 households who rented their homes, amounting to 52.3 percent of the occupied houses in the city; 20 percent of people in the city live with incomes below the poverty line.[352] We estimate that three-fourths of those households with incomes less than the federal poverty level rent their homes. Moreover, the median income in this majority-Black city ($52,000 per household[353,354]) is only about 60 percent of the median of the state as a whole ($90,000 per household)).

The rate of eviction notices average more than one per year per residential rental property in Baltimore City. Since the majority of low- and moderate-income households are renters, we estimate that on the order of one in ten low- and moderate-income households in Baltimore

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[348] The federal program that provides vouchers to assist eligible households with rent, known commonly as the "Section 8 program," is governed by federal regulations promulgated by the Housing and Urban Development Department at 24 CFR Part 982. The tenant obligations include "maintain[ing] the unit in accordance with HQS [Housing Quality Standards" (24 CFR 882.404a); that obligation includes the requirement to "pay for any utilities that the owner is not required to pay for, but which are to be paid by the tenant" (24 CFR 982.404(b). Failure to do so could result in the termination of the assistance. The full regulation is at https://www.ecfr.gov/current/title-24/subtitle-B/chapter-IX/part-982

[349] Matthew Desmond. *Evicted: Poverty and Profit in the American City.* New York, New York: Crown Publishers, 2016, pp. 15-16.

[350] Public Justice Center, Rent Court and Eviction Reform, at http://www.publicjustice.org/en/rent-court-and-eviction-reform/ viewed on October 26, 2022.

[351] Dan Pasciuti and Michele Cotton, How Renters Are Processed in the Baltimore City Rent Court. Baltimore, Maryland: Public Justice Center, December 23015, p. iv at http://www.publicjustice.org/wp-content/uploads/2019/09/JUSTICE_DIVERTED_PJC_DEC15.pdf

[352] Calculated from Baltimore City, Quick Census Facts, at

[353] Data USA: Baltimore City, at https://datausa.io/profile/geo/baltimore-city-md/ viewed on October 26, 2022.

[354] In **Chapter 2** we present that the BIPOC population in Baltimore City has an even lower median income of $44,000

City experience an eviction each year and that these households would typically receive multiple eviction notices.

IEER's energy justice report also estimated that each homelessness event, besides being very harmful to the family evicted, would also cost the rest of society about $28,000 in costs of shelter and added emergency room visits;[355] in 2022 dollars, it would be well in excess of $30,000. Assuming 1,000 homeless families (just 15 percent of the evictions in Baltimore), the added cost of these two items alone would be $30 million. If the costs of dislocation, loss of educational opportunity, and loss of jobs, and other impacts are taken into account, the statewide impact would be considerably larger.

This accounting of non-energy costs does not take into account the majority of families who become unhoused because they take shelter with family or friends. They would be counted as "homeless" in the broader definition of that term by the federal Department of Health and Human Services. That term includes people who do not have "a fixed, regular, and adequate nighttime residence" and people who "will imminently lose their housing" including if they have an eviction notice to vacate the home within 14 days. By this definition, the number of homeless people in Maryland could total many thousands of families each year, given that there are about 7,000 evictions each year in Baltimore City alone.

There are many other costs as well. A 2015 survey of the consequences of eviction found increased depression, increased material deprivation, and increased stress for two years or more after an eviction. Homeless people experience increased assault and unemployment. The latter involves loss of income to the person and loss of tax revenue to the government. More complete estimates of quantifiable costs of homelessness range from $35,000 to $111,000 *per person per year*[356]—an average of over $70,000 per year. Lower stress, being able to buy medicines and take the full dose are examples of non-energy health benefits that are likely to be realized in at least partial measure due to affordable bills.

The average duration of homelessness due to evictions is about seven months.[357] Typically, an eviction means that more than one person loses their home. Assuming an average of two people become homeless for seven months per eviction or foreclosure, a more complete cost estimate per eviction or foreclosure is about $80,000 (rounded). Of course, the loss of a sense

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[355] Ibid. p. 90.

[356] Arjun Makhijani, Christina Mills, and Annie Makhijani, *Energy Justice in Maryland's Residential and Renewable Energy Sectors*. Takoma Park Maryland: Institute for Energy and Environmental Research, 2015, pp. 90-91. Seven months was the weighted average period between homeless families and single people. at https://ieer.org/wp/wp-content/uploads/2015/10/RenMD-EnergyJustice-Report-Oct2015.pdf

[357] Ibid., p. 90. Seven months was the weighted average period between homeless families and single people. at https://ieer.org/wp/wp-content/uploads/2015/10/RenMD-EnergyJustice-Report-Oct2015.pdf

of security and safety, the loss of dignity, and the consequences of constant stress upon relationships and family cannot be quantified in money terms. Applied to 1,000 households, the total amounts to $80 million per year. The entire $80 million cannot be attributed to rent-mortgage conflicts with energy bills alone; yet there are also many costs not taken into account. For instance, it does not include the people who lose their homes who take shelter with family and friends, or the increased crowding, health risks, stresses, and dislocation involved. Nor does it count the increased pediatric asthma from indoor air pollution, the ill-health caused when people take partial doses of medicine to save money to pay their utility bills or rent or when they go hungry for the same reason. It does not take into account loss of workdays or the resultant lost tax revenue. The non-energy benefits are likely to be much larger than the very partial accounting above. In the following calculations, we use $120 million per year (i.e., 50 percent more than the estimate for homelessness alone) to estimate the avoided costs from 2038 onward of having healthy, affordable energy.[358]

In brief, the consequences to the affected low- and moderate-income families as well as to the non-low-income part of society are severe and large. An order of magnitude estimate (present value at a three percent discount rate) of avoided damage is about $3 billion. This is about the same as the present value of the net cost of assistance and full integration into the energy transition to the year 2100 (see **Sections 5.3 and 5.4.6**).

In the following sections we will use typical energy consumption values for a natural gas- and a fuel oil-heated household at three different income levels in order to illustrate the economics of integration of low-income households into the energy transition. We will use a three-person household at 50 percent, 100 percent, 150 percent, and 200 percent of the federal poverty level to estimate the evolution of energy cost burdens. We will examine cost burdens for each facet of energy transition integration for households with the current rate/cost structure and in cases where low-income households are stranded on the fossil fuel system when non-low-income households have transitioned to an all-electric mode. Fuel oil-heated homes are assumed to have electric water heating and cooking, hence the larger electricity consumption relative to natural gas heated homes. The economics of propane heated homes will be similar. **Table 5-4** shows the possible evolution of the energy costs of typical fossil fuel heated households from 2021 to 2040.

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[358] This is admittedly an order of magnitude calculation that should be refined with a fuller accounting of the non-energy benefits of affordability, housing security, and better health both for the households concerned and or society at large. It should be noted, however, that the cost calculations in Chapter 5 include substantial amounts for making homes healthier over and above the direct investments in weatherization, ventilation, and electrification.

Table 5-4: Typical energy costs and burdens of a fossil fuel heated household in 2021 and 2040.

Typical Household In 2021		
	Gas-heated household	**Fuel oil-heated household**
Fossil fuel consumption, MMBtu	70	50
Electricity consumption	7,000	12,000
Fossil fuel rate, $/MMBtu	$12	$20
Fossil fuel cost, $/year	$840	$1,000
Electricity rate, $/kWh	$0.13	$0.13
Electricity cost	$917	$1,572
Total energy cost $/year	**$1,757**	**$2,572**
Energy cost burden 50% FPL	16%	23%
Energy cost burden 100% FPL	8%	12%
Energy cost burden 150% FPL	5%	8%
Energy cost burden 200% FPL	4%	6%
Stranded Hydrocarbon Fuel Household, 2040 (See Chapter 4)		
Fossil fuel rate $/MMBtu	$70	$40
Total energy cost $/year	**$5,817**	**$3,572**
Energy cost burden 50% FPL	53%	33%
Energy cost burden 100% FPL	26%	16%
Energy cost burden 150% FPL	18%	11%
Energy cost burden 200% FPL	13%	8%

5.4 Interventions and Financial Policies to Reduce Bills

In addition to bill assistance, affordability can be improved by means of a variety of interventions that reduce home energy bills and, in many cases, provide co-benefits to health and comfort as described in **Chapter 3.** As discussed above in this chapter, a reasonable accounting of the non-energy co-benefits indicates that they may well be of the same order of magnitude as the investments, to the extent that the co-benefits can be even roughly quantified.

We investigate here the potential of four promising interventions to reduce energy cost burdens: weatherization, electrification, community solar, and demand response. For each intervention, we estimate the costs and bill impacts of the intervention for all homes. Currently, retrofits are free to eligible households—that is, those with income less than 200 percent of the federal poverty level or 80 percent of the area median income. Landlords are required to contribute 50 percent of the cost of major equipment like heat pumps.[359] Weatherization, in the strict sense of improving the building envelope, proceeds as grants when the tenants are income-eligible.

5.4.1 Weatherization

For decades, weatherization and improved efficiency have served as cost-effective methods to reduce energy bills. Weatherization most often entails sealing the envelope of a home through methods such as attic insulation while efficiency often entails maintenance and replacement of inefficient appliances so as to reduce energy consumption for the same energy services.

In **Chapter 1**, we noted that participation in weatherization is very low (**Figure 1-7**); on average only about one percent of eligible households have their homes weatherized each year. However, Maryland's Department of Housing and Community Development is trying to ramp up weatherization and efficiency improvements rapidly.[360] The aim is to reach ~26,000 homes per year with a range of measures ranging from energy kits to full retrofits; the vast majority are not full retrofits. Therefore the ramp up involves both numbers of retrofits and their scope. This would be satisfactory, if achieved and if it covered the entire range of retrofits to be made, including electrification of fossil fuel-heated homes. Currently, fuel-switching retrofits are not permitted for low- and moderate-income households under Maryland's EmPOWER efficiency program. Further, based on data as of November 2022, the actual achievement is falling considerably short of the ambitious target: the rate of retrofits in the first half of the program, though mid-2022, was only about one-fifth of the targeted rate of about 23,000 homes per year.[361] This may have been in part due to COVID-19 pandemic-related difficulties.

Historically, low participation in weatherization has a number of causes. The split incentive for rental property is chief among them. A substantial majority of low- and moderate-income households are renters and the vast majority of these units are individually metered so that

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[359] Housing and Energy Programs, Energy Efficiency Program Operations Manual v.3, Department of Housing and Community Development, 2021, pp. 48-50, at https://dhcd.maryland.gov/Residents/Documents/wap/EnergyEfficiencyProgramOperationsManualv.3-2021.pdf

[360] The plan for the current 2021-2023 period is to reach almost 77,000 homes in all, compared to just 17,000 in the 2018-2020 period. 2021-2023 EmPOWER Maryland Program: Limited Income Program, Department of Housing and Community Development, August 31, 2020, p. 9.

[361] EmPOWER Maryland Limited Income Programs: Semi-Annual Report Q1Q2 2022, Department of Housing and Community Development, August 15, 2022, pdf p. 45

the renters pay the utility bills. Landlords often do not allow access to their properties for the energy audits that are a necessary first step for weatherization measures to be implemented. Indeed, a pilot project in Baltimore found that "the landlord is a unique and major barrier [to weatherization] for renters," and the refusal of permission to enter was the biggest problem: "Nearly half (46%) of all tenants who applied could not get permission for audit despite qualifying for weatherization otherwise."[362] More recently, the Department of Housing and Community Development, which administers the low- and moderate-income weatherization programs has noted that the vast majority—80 to 85 percent—of the applicants for assistance who indicate they want to participate in weatherization do not receive actual retrofits. This occurs "for various reasons—clients may become unresponsive or do not fully understand the value in energy efficiency programs, and many renters cannot gain landlord consent for participation."[363]

The failure of rental housing to meet required building standards may be one reason for landlords to refuse access. When audits were conducted during the Baltimore City pilot, 88 percent of rental units that are subject to annual inspections passed the audit; for units that were not subject to such inspections, only 43 percent passed. In addition, the pilot project reported that many homes, both rental units and owner-occupied structures, were not up to building codes, with mold and bad roofs being among the common problems observed; wet basements were another frequent issue.[364]

Generally, the cost of maintaining properties in compliance with codes is borne by the property owner. In principle, therefore, it is not strictly a cost that should be attributed to the energy transition. However, weatherization and other major retrofits cannot be done unless issues of non-compliance with codes are addressed. In the case of rental units, this is an issue that relates to enforcement.

In the case of low- and moderate-income homeowners, the financial implications more directly impact the ability to carry out the retrofits needed as a part of the energy transition. For them, the financial implications of a holistic approach, such as that recommended by the Green and Healthy Homes Initiative, must be included in the cost of the transition. Those

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[362] Green and Healthy Homes Initiative as quoted in Arjun Makhijani, Christina Mills, and Annie Makhijani, Energy Justice in Maryland's Residential and Renewable Energy Sectors. Takoma Park Maryland: Institute for Energy and Environmental Research, 2015, p. 66 (emphasis in the original), at https://ieer.org/wp/wp-content/uploads/2015/10/RenMD-EnergyJustice-Report-Oct2015.pdf

[363] Ibid. p. 12.

[364] Green and Healthy Homes Initiative as quoted in Arjun Makhijani, Christina Mills, and Annie Makhijani, Energy Justice in Maryland's Residential and Renewable Energy Sectors. Takoma Park Maryland: Institute for Energy and Environmental Research, 2015, p. 66 (emphasis in the original), at https://ieer.org/wp/wp-content/uploads/2015/10/RenMD-EnergyJustice-Report-Oct2015.pdf

costs could be substantial. For instance, the following issues were discovered during the retrofitting of a detached residential structure in Baltimore:

- A leaking roof;
- Mold in the basement due to water leaks from a “defective air conditioning system”;
- Hot water heater pipe corrosion (which also created the risk of carbon monoxide); and
- A clothes dryer vent that was blocked, creating a fire hazard.

Fixing all these problems, making the home safer for an older person, and installing a new heating and cooling system cost a total of $27,000. The cost of the entire retrofit was covered by a federal grant to Green and Healthy Homes Initiative, a national organization, based in Baltimore City.[365]

Thus, in extreme cases such as this, it may take $10,000 or more to bring the house up to the point where an energy-related retrofit in the narrow sense of that term could be reasonably done. We do not have an estimate of the total number of homes that will need retrofits for health and safety that are not directly related to weatherization and electrification.

The Department of Housing and Community Development recognizes the value of the whole house approach and implements it within the constraints of limited funding and the limitations of its mandate. For instance, DHCD weatherization funds can be used to resolve relatively minor problems of mold or moisture but more serious levels may result in a deferral or denial of the retrofit.[366] The same approach, including for multifamily housing, is described in its 2021-2023 plan:[367]

> The Department’s core programs, Whole Home Efficiency and MEEHA [Maryland Energy Efficiency and Housing Affordability], continue the tradition of a whole-home approach, providing limited-income families with all cost-effective energy upgrades, limited health and safety measures, and incidental repair measures at no additional cost to them.

For the direct energy-related retrofits we have taken the following into account:

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[365] A description of the problems and the solutions is in Elizabeth Shwe, “Feds Direct Millions to Reduce Lead and Asthma Triggers in Low-Income Homes in Md.,” Maryland Matters, January 24, 2022, at https://www.marylandmatters.org/2022/01/24/feds-direct-millions-to-reduce-lead-and-asthma-triggers-in-low-income-homes-in-md/

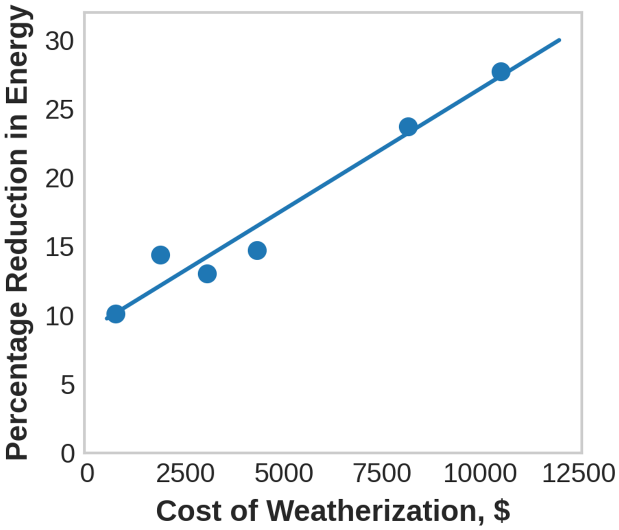
[366] Housing and Energy Programs, Energy Efficiency Program Operations Manual v.3, Department of Housing and Community Development, 2021, p. 70, and pp. 72-73, at https://dhcd.maryland.gov/Residents/Documents/wap/EnergyEfficiencyProgramOperationsManualv.3-2021.pdf

[367] 2021-2023 EmPOWER Maryland Program: Limited Income Program, Department of Housing and Community Development, August 31, 2020, p. 22.

- The direct costs of retrofits (weatherization and heat pumps);
- Federal funds available for retrofits, particularly in reference to the rebates under the 2022 Inflation Reduction Act;
- Required landlord contributions;
- Incentives for landlords;
- Funds for a holistic approach to retrofits for income-eligible homeowners.

In order to account for health- and safety-related changes, we have added $5,000 in grants to the cost of retrofits for half of the owner-occupied homes with income less than 200 percent of the federal poverty level. Not all homes will need healthy-home remediation and those that do may cost more than $5,000 (as is often the case). As a reference point, the national average cost of mold removal is $2,325.[368]

Figure 5-3: Reduction of energy use and cost of weatherization.



After the costs of remediation, we estimate the cost and energy savings of weatherization. Using data from a report tracking energy savings after intervention,[369] we plot the percentage savings in 2021 dollars[370] for a given investment (blue dots in **Figure 5-3)**. The costs of weatherization were roughly uniformly distributed from $500 to $10,000, so we use the same

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[368] "How much will your mold removal cost?" Home Guide, homeguide.com/costs/mold-removal-cost viewed 11/17/22.

[369] Michael Blasnik, Greg Dalhoff, David Carroll, Ferit Ucar, Dan Bausch. Evaluation of the Weatherization Assistance Program During Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impacts for Single-Family Homes 2009-2011, Oak Ridge National Laboratory, March 2015, at https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2014_582.pdf

[370] All 2008 dollar values from the Blasnik et al. 2015 report adjusted to 2021 dollars using the core inflation index; data from the St. Louis Federal Reserve Bank at https://fred.stlouisfed.org/series/PCEPILFE

trend for the analysis presented here. The average amount of investment in weatherization is then $5,250, which then becomes $10,250 when combined with the healthy-home remediation costs. We then reduce their energy consumption by the corresponding percentage shown by the blue line.[371]

5.4.2 Beneficial Electrification

Electrification using rates from the year 2021 nearly always decreases energy bills as discussed in **Chapter 2**. The recently-passed Inflation Reduction Act (IRA) provides substantial grants for electrifying most energy needs for low- and moderate-income homes, as shown in **Table 5-5**. These IRA grants drastically change the cost-benefit analysis for electrification and, to a lesser extent, weatherization. In Maryland, since practically all homes with energy cost burdens greater than six percent have incomes less than 80 percent of the area median income, they are eligible for up to 100 percent of these conversion costs. While there exist smaller additional benefits available for both weatherization and electrification using more complicated mechanisms such as tax credits, we do not include those here. We can safely assume the following range of net costs for electrification, assuming a replacement at the end of lifetime for the respective appliance: $1,000–$5,000 for air source heat pump conversion depending on the current energy usage for space heating and retirement of either end-of-lifetime air conditioner, space heater or both; $500–$1,500 for hot water heater conversion depending on the current energy needs for water heating; $6,500 set aside for electrical upgrades; and $850 each for quality induction electric stoves or heat pump gas dryers without even considering replacement cost. We see that conversion is nearly entirely paid for in the majority of cases. For many homes that are retiring old furnaces, hot water heaters, stoves or dryers, electrification may in fact provide a net savings in the up-front investment cost since retirement of fossil fuel powered technologies will be nearly entirely paid for with IRA grants while a non-electric replacement would need to be paid for fully by the household. These negative net costs are not included in the estimated savings for this analysis. To estimate the impacts on energy usage, we use the same estimates for bill changes described in **Chapter 2**. With the introduction of the HEEHRA component of the IRA, recent increases in gas prices and their expected continued increase, and improvements in heat pump technology, we can now safely say that all homes with energy cost burdens greater than 6 percent will see immediate savings once electrified. This was not true for all low- and moderate-income households as of just a few years ago.

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[371] Note that the y-intercept of the blue line is not zero, so we set a minimum spending of $500. This captures the reduced efficiency gains for increased levels of spending.

Table 5-5: Grants for electrification in the Inflation Reduction Act. *Source: Adapted directly from Rewiring America.*[372]

High-Efficiency Electric Home Rebate Act: Rebate Levels	
Income Eligibility	**% of Costs Covered**
Low-income (<80% Area Median Income)	100%
Moderate-income (80-150% Area Median Income)	50%
Overall Incentives	
Maximum consumer rebate	$14,000
Maximum contractor rebate	$500
Rebates for Qualified Electrification Projects	
Heat pump HVAC	$8,000
Heat pump water heater	$1,750
Electric stove/cooktop	$840
Heat pump clothes dryer	$840
Breaker box	$4,000
Electric wiring	$2,500
Weatherization (insulation, air sealing, ventilation)	$1,600

5.4.3 Community Solar and Demand Response

We assume community solar provides a 20 percent discount on low- and moderate-income household electric rates. After electrification, this rate reduction provides increased savings. We emphasize community solar because it is accessible for those who do not own their own rooftops and can be more cost effective than rooftop installations owned by the homeowner.

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[372] Adapted from Rewiring America: High-Efficiency Electric Home Rebate Act (HEEHRA). https://www.rewiringamerica.org/policy/high-efficiency-electric-home-rebate-act

Given the importance of community solar in achieving lower costs, it is important to note some key points essential to achieving the necessary level of subscriptions:

- Maryland has a pilot community solar program of about 418 megawatts. Customers can acquire contracts for discounted electricity on a virtual net metering basis. The program was enacted by the General Assembly in 2015; it "…require[s] 30% of the solar capacity be assigned to low- and moderate-income projects, with 10% of the total array energy to be used only for the Low Income participants"; moderate income for the purposes of community solar is defined as less than 80 percent of area median income; low-income is defined as less than 175 percent of the federal poverty level.[373] While 125MW of the 418MW are reserved for projects that serve low- to moderate-income subscribers, the total number of low-income households served to date is believed to be in the hundreds (data has not been made public). This is because low- and moderate-income project economics are not favorable to solar financiers and investors without proper incentives in place. Specifically, the risk profile of low- to moderate- income households with varying credit histories, combined with higher marketing and customer management costs, means that it is currently more expensive for community solar developers to serve low- and moderate-income households than non-low- and moderate-income households. Contract default backstops, provided by green banks or non-government organizations are one way to address this issue. Grants, added tax incentives and/or low-cost financing for projects serving low-income subscribers, such as those currently provided in small numbers by the Maryland Energy Administration and included in the Inflation Reduction Act, would also provide solar developers with the financial assurance needed to elect to sell to low- and moderate income subscribers. Such measures are necessary if community solar is to increase by the roughly two orders of magnitude needed to meet the requirements of needs of all low- and moderate-income households (by the expanded definition in the community solar program), once their space and water heating is electrified.[374]

- The usual guaranteed discount relative to residential rates (Standard Offer Service) is 10 percent. According to Lynn Heller, CEO of the Climate Access Fund, a statewide green bank that provides financing and bill payment default guarantees for low- and moderate-income community solar projects in Maryland, a discount of at least 20

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[373] Maryland Energy Administration, "Community Solar for the LMI Community," no date but circa 2020 inferred, at https://www.google.com/url?client=internal-element-cse&cx=007821330218074952993:n0vbm89nrde&q=https://energy.maryland.gov/residential/SiteAssets/Pages/CommunitySolarLMI-PPA/Community%2520Solar%2520for%2520the%2520LMI%2520Community.pdf&sa=U&ved=2ahUKEwi6s-i0yL_7AhW0LFkFHc1xCP0QFnoECAgQAQ&usg=AOvVaw15vpsovZkudGv-3cx7MD1L viewed on November 21, 2022

[374] Assuming 11 MWh per year per household, 750,000 households, and 1,600 MWh/MW-dc solar generation, about 5,000 MW-dc capacity of community solar would be required.

percent is needed to make it worthwhile for low- and moderate-income subscribers to sign contracts, especially given that they currently need to pay two electricity bills—one to the community solar owner and one to the electric utility.[375] The cost of this additional discount, combined with the added cost of recruiting low-income customers, makes it significantly more expensive for community solar developers to serve low- to moderate- (and especially low-) income customers. Without low-cost financing through green banks, investment tax credits like those included in the Inflation Reduction Act, and/or grant funding from the Maryland Energy Administration, community solar projects will likely continue to serve predominantly non- low- to moderate- income households.

- Utility Consolidated BIlling with Purchase of Receivables, which is available to all other third party suppliers, is not available to community solar providers. Under a Purchase of Receivable policy, the utility purchases the debt owed by the community solar subscriber to the owner of the solar by paying the owner the amount due. The amount due for the solar energy is consolidated with the amount due to the utility for the electricity it supplied, plus the connection charges. Thus the risk of contract default, now borne by the owner of the community solar project, is transferred to the utility, as is the case for all other third party suppliers where the utility (and hence ratepayers) assumes the risk for a small fee charged to the third party supplier.
- The Maryland Energy Administration provides two kinds of financial support for promoting low- and moderate-income household community solar subscriptions: a) grants to organizations such as the Climate Access Fund to enable them to provide solar developers with guarantees against contract default, and b) direct cash grants to solar developers who provide an additional discount to low- and moderate-income subscribers relative to utility residential rates.
- There are a number of creative models for increasing low- and moderate-income households' participation in community solar. The Silver Spring, Maryland rooftop community solar promoted by Groundswell, a non-profit, provides one example. It is a 273-kW rooftop community solar project, known as Paddington Square. There are 63 regular subscriptions of 3 kW each, roughly at regular utility rates; they subsidize 28

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[375] This bullet point and the next three are based on Lynn Heller, CEO and Founder, Climate Access Fund, personal communication, November 7, 2022; cited with permission.

low income households to get free subscriptions of 3 kW each. The project is underwritten by Montgomery County Green Bank.[376]

- The amount of the electricity bill directly impacts payment assistance in Maryland. Without Utility Consolidated Billing with Purchase of Receivables, the cost of community solar is not included in the utility electricity bills; as a result many low- and moderate-income households are at risk of losing bill payment assistance, in whole or in part, deterring subscriptions.

We further assume demand response provides a $150 reduction in annual energy bills.[377] Demand response programs are a method to decrease the total generation capacity needed by minimizing peak electricity needs. Building enough available capacity for the highest demand hours is one of the greatest costs and challenges to providing reliable electricity. Demand response includes installing devices or thermostats to minimize electricity consumption for short periods of time when the demand across a utility is at its highest. For example, hot water heaters can be turned off for a few hours or smart thermostat temperatures shifted by a few degrees with minimal inconvenience to customers. Demand response programs have been available[378] in Maryland and should be expanded, especially for low-income households. Demand response payments should be in the form of utility bill credits so that there is a direct impact on reduction of energy cost burdens.

Moreover, when demand response programs have high enough participation, they can offset the need for utilities to rely on costly generation sources that are only needed for a small fraction of the time—such as peaker power plants—and thus can pass these savings into rates, decreasing energy bills for all.

5.4.4 Proposed Suite of Grants

To ensure that integration of low- and moderate-income households with the energy transition is affordable, the retrofits themselves must be affordable. Current policy is appropriate in that regard; the main issue is that the pace of retrofits and the depth of most of them must both be intensified.

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[376] Calculated from data at "Paddington Square Apartments in Silver Spring [Maryland]," Groundswell, at https://groundswell.org/project/paddington/ viewed on November 23, 2022 and personal communication with Groundswell staff November 23, 2022 for generation per kW [written confirmation coming]

[377] Inferred from 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 and the range $50 to $100 per kilowatt-year (pdf p. 26), at https://eta-publications.lbl.gov/sites/default/files/ca_dr_potential_study_-_phase_3_-_shift_-_final_report.pdf

[378] BGE. (2019). Demand Response Service. https://www.bge.com/MyAccount/MyBillUsage/Documents/Electric/Rdr_15.pdf

As discussed in **Chapter 1**, retrofits, including deep retrofits, are available to income-eligible homeowners at no cost to them—that is, the entire cost of the retrofit is a grant. Various sources of funds are used for these grants, which are made in most cases by the Department of Housing and Community Development and also by the Maryland Energy Administration. In the case of rental housing, landlords are required to put up half the cost of major appliances like heat pumps, air conditioners, or refrigerators. Our proposals are to:

- Retain the present basic approach for retrofits, including the DHCD income-eligibility level;
- Provide an additional incentive to landlords; and
- Expand the income eligibility of bill payment assistance to be the same as for DHCD weatherization: 200 percent of the federal poverty level or 80 percent of the area median income, whichever is greater.

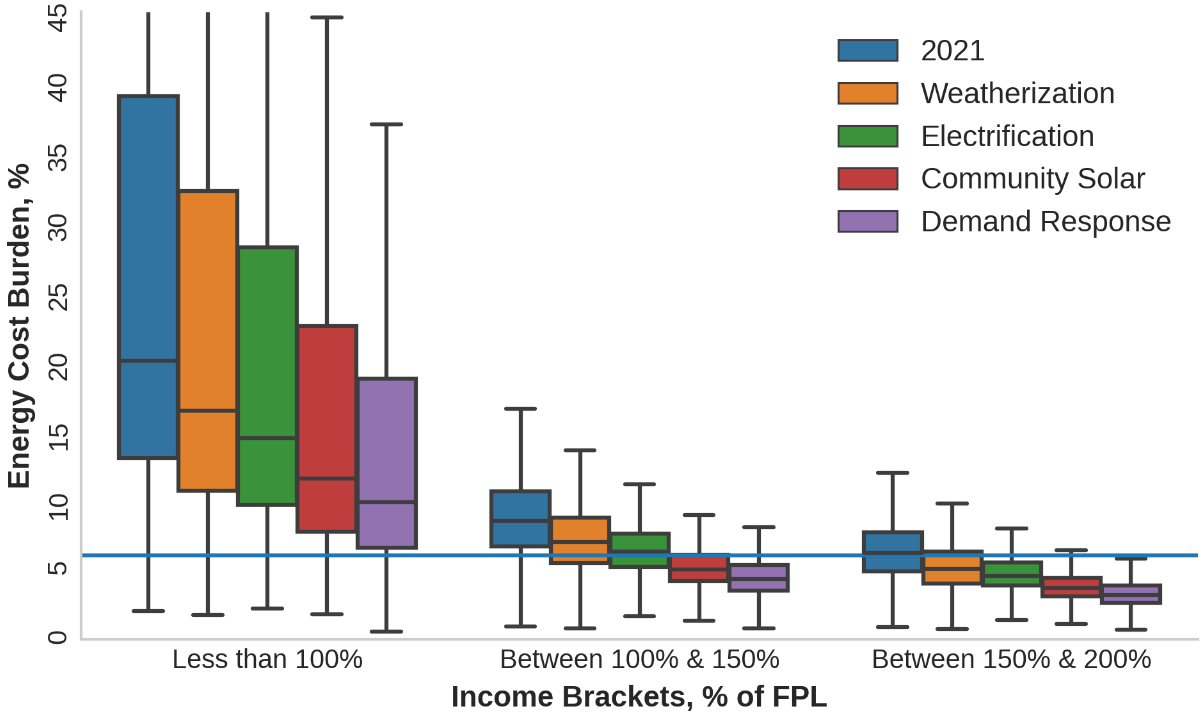
Any costs not covered by grants can be effectively added to energy bills in the form of loans or from other sources, notably from the federal government's Inflation Reduction Act.

An essential condition for success is that the capacity of the implementing agencies, mainly DHCD but also the Maryland Energy Administration, will need to be strengthened to enable an effective expansion of the retrofit programs.

5.4.5 Bill Impacts from Home Interventions

When implemented sequentially, the four above interventions with proposed financing can drastically reduce energy bills as shown in **Figure 5-4**. The topmost box and whisker plots represent the current distributions of energy cost burdens within each income bracket. The shaded portion—the box—represents households in the middle 50 percent of the energy cost burdens; 25 percent have values above the top of the box and 25 percent have burdens below the lowest value shown for the box. Proceeding to the right for each income group, we see how each sequential intervention applied to all households impacts these distributions. Weatherization includes both financed payments for weatherization using 15-year loans and reduced energy use for heating and cooling, with the associated bill reductions. Weatherization will typically pay for itself for most homes over a 15-year period with benefits that will persist for many more years after. Households with incomes below the federal poverty level see the greatest reduction in energy costs due to the proposed grants discussed above. After weatherization, homes are electrified. At this point, all energy is electric. Next, through use of discounted community solar programs, and then demand response, we see further reductions of energy cost burdens. At this point, the majority of homes with incomes above the federal poverty level have energy cost burdens below the six percent affordability threshold, but roughly three fourths of households earning below the federal poverty level are still cost-burdened. We further investigate how the affordability gap would change as the interventions are applied to each home in **Figure 5-5**.

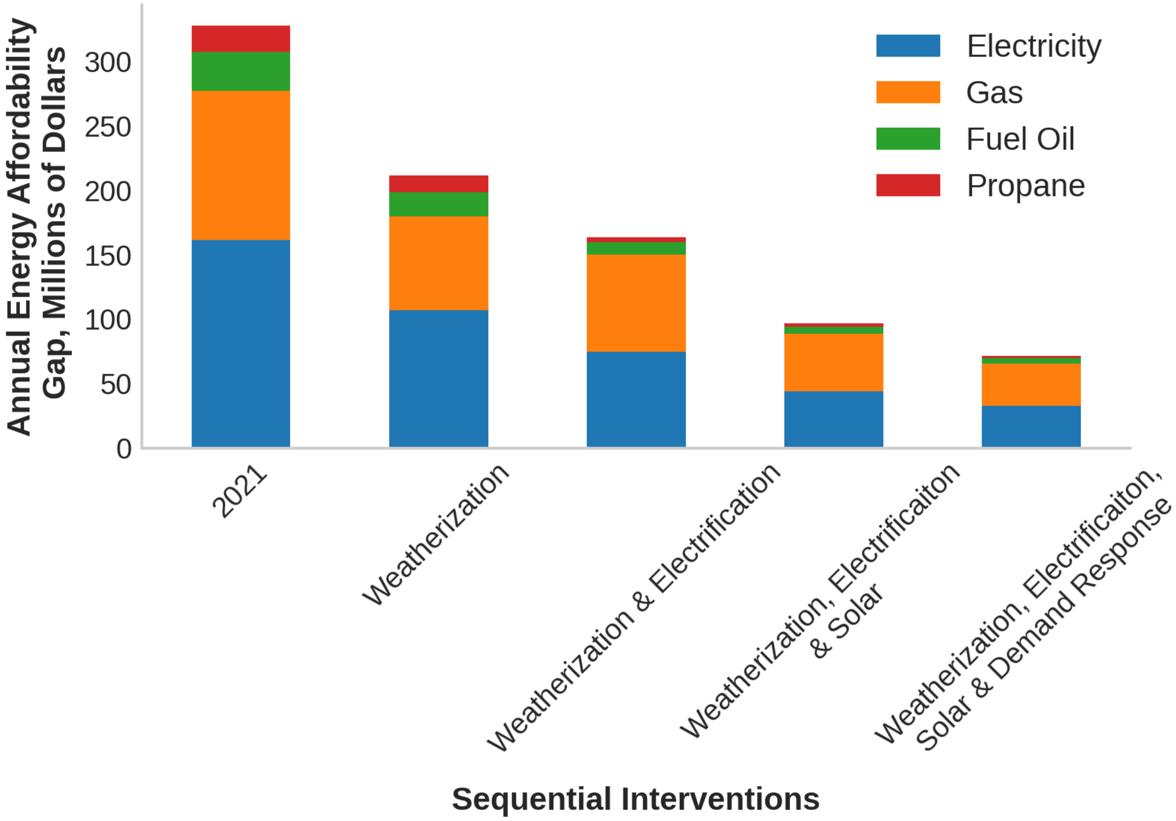
Figure 5-4: Box and whisker plot showing impact of various measures by income group.



The box and whisker plot and the bar chart (**Figures 5-4** and **5-5**) show that electrification coupled with discounted community solar provide the most significant reductions in the need for assistance funds by systemically reducing energy bills. Weatherization (including ensuring healthy retrofits) creates the foundation on which electrification takes place.

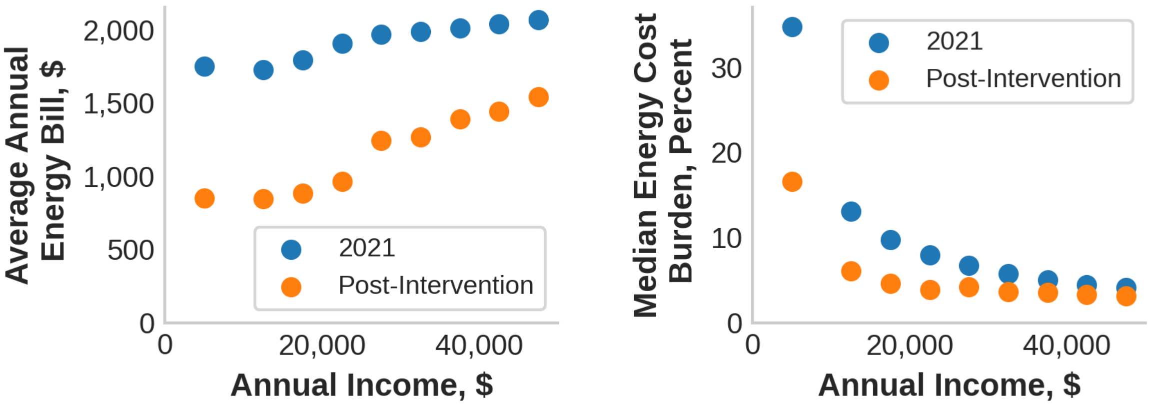
Energy cost burdens, though lower with the above measures, will tend to remain high for most of the 100,000 households whose annual income is less than $10,000. We see in **Figure 5-6** both energy cost burdens and annual spending as a function of annual income. The figure only shows the cost to the household, and does not include grant amounts, which are included in **Figure 5-8** below showing the overall picture as it would evolve over time. We see that the lowest-income households use the least energy, as expected since they live in smaller homes. Using the proposed suite of interventions, mean energy bills for the lowest incomes were reduced drastically from $1,750 to $700. The greater proportional decrease in energy bills for lower income households arises due to an increased reliance on resistive electric space heating and other more costly fuels for space heating among the lowest-income households.

Figure 5-5: Reduction in the affordability gap with sequential measure implementation.



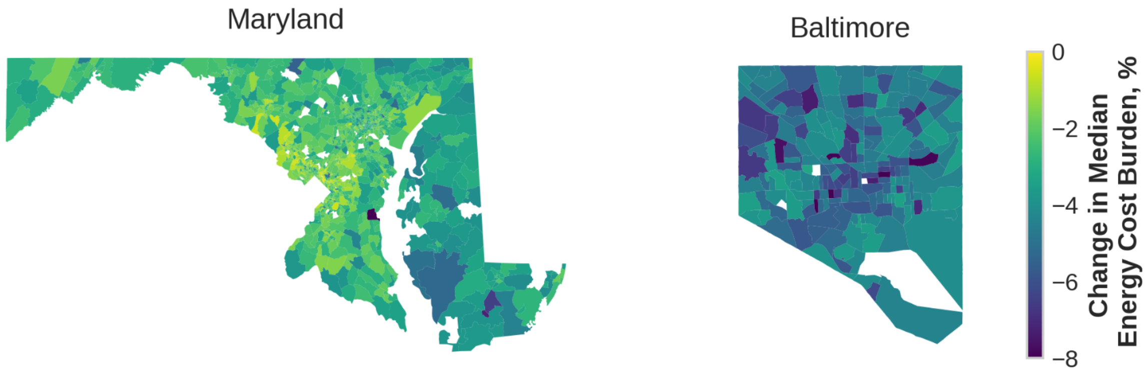
This decrease in energy bills results in a correspondingly drastic decrease in median energy cost burden from 35 percent to 14 percent, but still far from the target value of six percent. In other words, full integration into the energy transition would make energy bills affordable by themselves, without the need for assistance except for the lowest income households. But with an income at 20 percent to 30 percent of the federal poverty level, it is difficult to imagine how energy-related measures alone could accomplish the energy affordability goal. Only an increase in income can do that. There is a range of approaches to increasing income, from guaranteeing families a minimum income to increasing the minimum wage to providing child care, for instance, to enable the family to increase their income-earning hours. These broad issues, while critical, are beyond the scope of the present report.

Figure 5-6: Impact of combined measures on energy bills and energy cost burden as a function of income.



Under the proposed scenario above, households will experience different degrees of benefits depending on where they are geographically. As discussed before, this is dependent on climate, which determines the amount of energy used for heating and cooling, fuel types used, local fuel prices, type of home, and incomes. We map the impact on median energy cost burden geographically to portray the cumulative effects of the proposed scenario in **Figure 5-7**. We see the greatest changes in cost burdens arise in neighborhoods with high numbers of low-income households in Baltimore and along the Eastern Shore.

Figure 5-7: Geographical variation in impact of combined measures on energy cost burden.



5.4.6 Financial Implications Over Time

Implementation of these interventions can begin to provide net savings over a bill assistance approach. Specifically, in **Figure 5-8** we imagine a scenario over a 15-year time period after which all low- and moderate-income homes have been provided the interventions described above with the households with the highest energy cost burdens prioritized first and equal numbers of homes are implemented each year.

In **Figure 5-8(a)**, the black dotted line assumes business as usual, with a constant energy affordability gap being filled by the amount indicated by the line ($360 million per year).[379] The gray shaded area represents the amount of bill assistance under the proposed set of policies. It also starts at $360 million per year but decreases to $80 million per year by the end of the 15-year period, which is $40 million less that the $120 million per year currently available. The solid black line assumes the current affordability gap plus the proposed total additional grants for all households eligible for assistance until 2038 under our recommendation for expanding eligibility. By 2038, the energy cost burden of the vast majority of households with incomes above 100 percent of federal poverty level will have been reduced to below six percent, often well below that level (see **Figure 5-4** above). At that point the basic investments in healthier homes, electrification infrastructure, building envelope improvements, and landlord incentives to enable them will have been made. Some weatherization funds will be needed to replace the heat pumps after their 15-year estimated life for those with energy cost burdens still above six percent. We estimate this amount to be just above $20 million a year—or almost $30 million less than currently available state and federal weatherization funds (excluding the Inflation Reduction Act).

Figure 5-8(a) shows the purposes for which the funds would be used; **Figure 5-8(b)** shows the sources of the funds, including new funds that Maryland will have to raise until 2038 to meet the goal of universal energy affordability and universal integration into the energy transition. The solid black line in **Figure 5-8(b)** shows existing resources available at $170 million per year: $120 million for assistance and $50 million for weatherization (**Chapter 1**). The amount needed for both in 2039 and after will however be about $100 million per year (rounded), for an annual savings of $70 million relative to 2021 outlays.

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[379] For the purpose of these calculations we assume a constant affordability gap; this implicitly means a constant number of households helped and constant energy costs. In practice, changes in income, housing standards for new housing, changes in the cost of renewable energy, and changes in utility rates will affect the affordability gap—in both directions. The estimates derived from this exercise are approximate, but satisfactory for setting policy directions and determining the magnitude of resources needed to meet a universal affordability criterion.

Figure 5-8 (a): Uses of funds for universal affordability and energy transition integration and **(b)** potential sources of funds for achieving that goal.

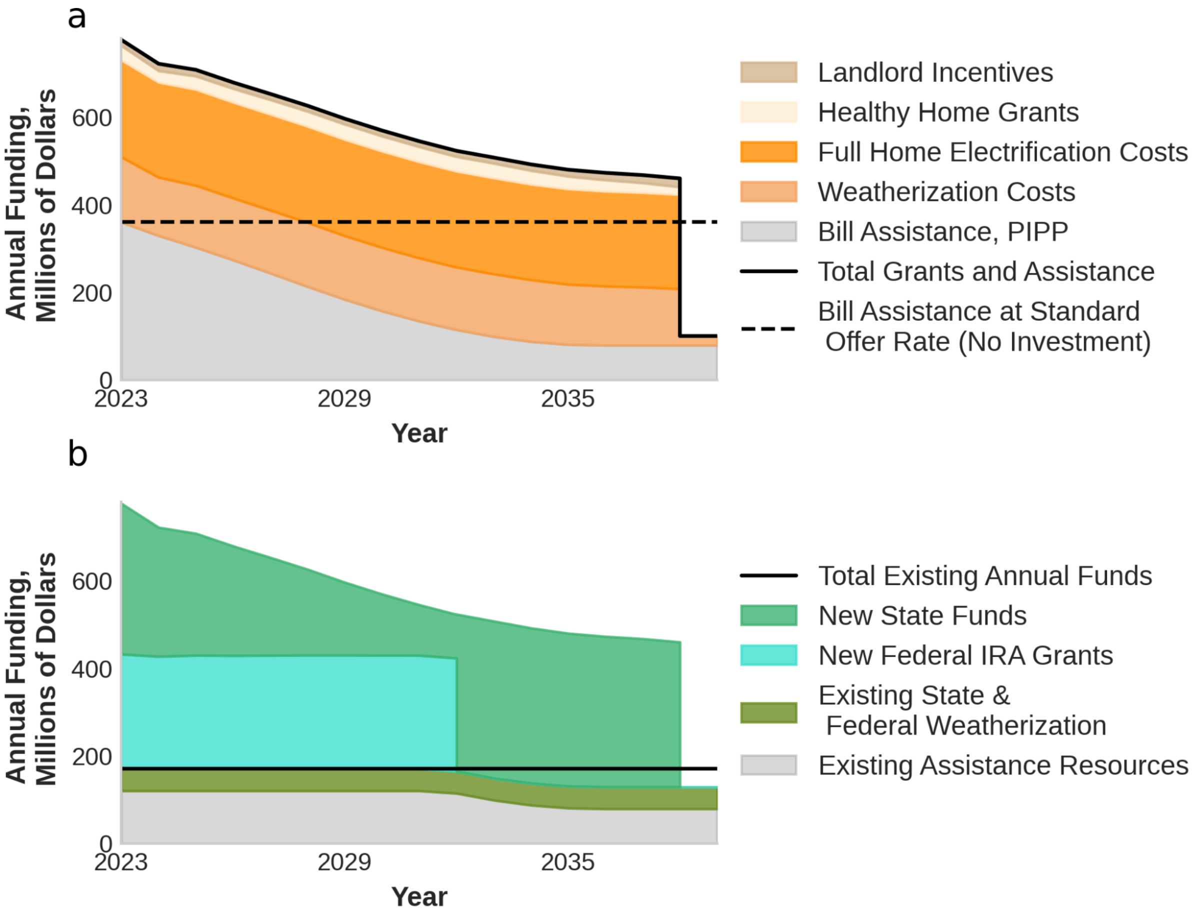

Figure 5-8 above shows the total funds that would be required to maintain universal affordability in a heuristic manner, positing full affordability in the very first year. The dashed straight line shows the funds needed for universal PIPP enrollment only, assuming no adoption of clean energy technologies. The solid black line shows the funds required if PIPP is combined with clean energy investments. The latter approach is compatible with the Climate Solutions Now Act; it is also much lower in cumulative cost to Marylanders. The cumulative cost for an assistance-only mode over 15 years would be $5.4 billion; cumulative funds needed, excluding Inflation Reduction Act funds, over the same period would be about $4.3 billion. Even more important, the need for $360 million in assistance funds would continue indefinitely after 2038. In contrast, after the investments are made, the total funds needed for universal affordability will be about $80 million per year, or $90 million less than currently available assistance and weatherization funds.

A present value calculation with a three percent discount rate out to the 2100 yields the following results:

- The present value of the cost of an assistance only approach to affordability is about $10.8 billion.
- The net present value of the cost of the assistance plus integration approach is about $3.1 billion. This takes into account the savings in assistance, relative to present resources, from 2039 to 2100, amounting to about $1.2 billion and the $4.3 billion present value of new state funds from 2023 to 2038. Compared to assistance alone, the net savings of pursuing an equitable clean energy transition would be almost $8 billion out (rounded) to the year 2100 (where climate calculations usually stop).[380]

The initial costs are higher because there are retrofit grants in addition to PIPP expenses. But the retrofits reduce bills and total costs decline over time. To recapitulate, the following elements have gone into the calculation of the annual funds needed to make energy bills affordable for all-low and moderate-income households, up to 200 percent of the federal poverty level:

- Bill assistance funds needed to fill the affordability gap between energy bills and six percent of household income;
- Grants for weatherization of all households;
- Grants for electrification of space and water heating using efficient heat pumps for all households, including funds available from the Inflation Reduction Act;[381]
- Community solar subscriptions at a 20 percent discount relative to utility rates, starting at the time when retrofits, including electrification investments, are completed;
- $150 per year electricity bill reduction due to demand response participation.[382]

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[380] The net present value of $8 billion for cumulative savings is sensitive to the discount rate. We have used the usual social discount rate of 3 percent in constant 2021 dollars. Using a zero percent discount rate (i.e. costs and savings are not discounted), the savings to the year 2100 rise to $28 billion. A five percent real discount rate reduces the savings to $3.3 billion, still very substantial. The savings stay positive till a real discount rate of almost 9 percent—a rate never used in such calculations when there are substantial long-term social and environmental benefits involved.

[381] Under present policy, landlords would be required to contribute 50 percent of the funds for major equipment like heat pumps. Essentially all of this amount would be covered by the Inflation Reduction Act.

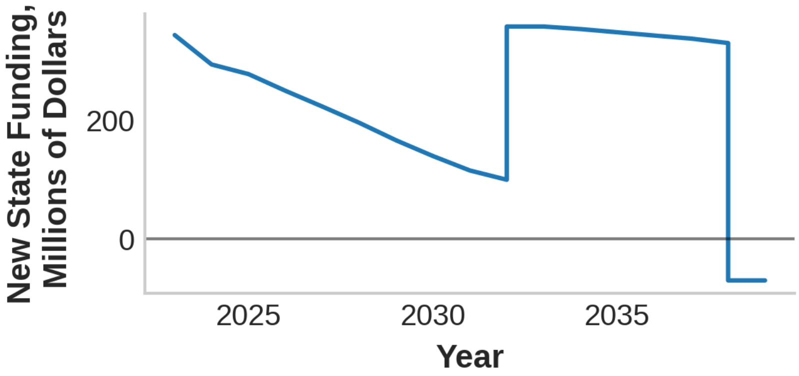
[382] Demand response participation across numerous appliances will require broadband availability. The cost of broadband has not been included because the need and utility of universal broadband is general and goes far beyond the issue of demand response participation. We assume smart appliances will become the norm and will therefore also be installed in low- and moderate-income housing.

5.4.6.1. Sources of Funds

Figure 5-8(b) shows that the funds required over the 15 years during which all low- and moderate-income households are fully integrated to the energy transition will require funds well above the $170 million a year available for assistance and weatherization 2021. A substantial portion of the additional funds, including for electrification of space and water heating and cooking (where fossil fuels are now used) will come from grants, rebates, and tax incentives contained in the 2022 Inflation Reduction Act. However, ensuring affordability for all will also require the institution of a Percentage of Income Payment Program with universal enrollment that is not covered by any new federal legislation. Substantial funds over those available for making homes healthy and to incentivize landlords participation are also likely to be needed. Thus significant new state-generated funds will also be needed.

The need for state funds will vary over time. Until 2032, the Inflation Reduction Act could fund almost the entire electrification effort, including the landlord's 50 percent share now required for major equipment, and also assist with weatherization. The need for PIPP funds will decline over time, since weatherization, electrification, community solar, and demand response will reduce bills in most cases below six percent of income thus eliminating the need for assistance funds for those households. After 2032, state funds will be needed to replace Inflation Reduction Act funds until 2038 (assuming IRA is not extended), as can be seen in **Figure 5-8(b)**, at which point all low- and moderate-income homes would be retrofitted in this scenario. After 2038 the needed funds would decline sharply to remaining assistance for households with energy cost burdens still above six percent and heap pump replacement costs for the same households. There will actually be an estimated savings of $90 million a year in savings from 2039 onwards relative to funds available in 2021 for assistance and weatherization. **Figure 5-9** shows how the need for state funds will vary over time.

Figure 5-9: Variation of new state funds needed for PIPP and other energy transition efforts (assuming the Inflation Reduction Act is not extended past 2032); there is a surplus after 2038.



It may be difficult to raise the funds that would be needed to match these expenses via an annual tax, such as on income, CO_2 emissions, or gasoline. The funding requirements will vary a great deal from year to year, and may depend on future allocations of funding from the federal government. Another option would be a graduated tax, but this would also have to vary if federal funding is discontinuous. For instance, a tax of the highest earning five percent of Marylanders would start at about 0.6 percent in 2023, decline to 0.2 percent in 2032, rise to 0.6 percent again from 2033 to 2038 and then go to zero in 2039. Taxes on fossil fuels or CO_2 would gyrate similarly. Another option would be a one-time wealth tax is an option that would raise all the necessary funds in the very first year and go to zero thereafter. A one-year tax of about 1 percent on the wealthiest 0.1 percent of Maryland households would raise the needed $3 billion.[383] The tax could automatically go to zero in the second year and stay zero.

The above assessment only covers the direct costs on a business-as-usual basis without considering the Climate Solutions Now Act of 2022, health costs, and non-energy benefits such as reduced illness and greater housing stability—that is the factors that were explored in detail in **Chapter 3** (health) and **Chapter 4** (fossil fuels and the energy transition). We now examine these issues from a policy point of view.

5.4.7 Indoor Air Pollution

Combustion of fossil fuels and wood for space, water heating, cooking creates contributes to poor indoor air quality. As discussed in **Chapter 3**, it is well established that residential combustion-based appliances are a source of indoor CO,NO_2, $PM_{2.5}$, and VOCs, including formaldehyde and benzene. Indoor air pollutant concentrations associated with combustion appliance leaks and emissions can reach levels that exceed health-based guidance values—even when the appliances are not being used. Exposure to these pollutants is associated with a variety of adverse cardiovascular and respiratory health effects, particularly for those with underlying health conditions (e.g., asthma).

When such health burdens are not considered, natural gas is often the lowest-cost fuel for space and water heating; most such households also cook with natural gas. Low-income

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[383] This assumes that the balance of the fund, i.e., after deducting each year's expenses for PIPP and the investments in the transition, will earn five percent per year. We estimate the 2021 wealth of the top 0.1 percent of Maryland households at about $300 billion. This estimate was derived from Isabel Sawhill and Christopher Pulliam, Six Facts about Wealth in the United States, Brookings Institution, June 25, 2019, at https://www.brookings.edu/blog/up-front/2019/06/25/six-facts-about-wealth-in-the-united-states/ , Todd Burnaford, What is the Average Net Worth by State, Personal Capital, June 15, 2021, at https://www.personalcpital.com/blog/family-life/what-is-the-average-net-worth-by-state/ and Emmanuel Saez and Gabriel Zucman, Letter to Senator Elizabeth Warren, January 18, 2019, at https://www.warren.senate.gov/imo/media/doc/saez-zucman-wealthtax.pdf

households and renters are more likely to lack range hoods for their stoves. In some cases, gas stoves are used for space heating, which increases indoor air pollution. As discussed in **Chapter 3**, indoor levels of NO_2 are often at levels that are associated with statistically significant increases of a variety of respiratory symptoms in children. (See the box on Baltimore-specific studies in **Chapter 3**.) Despite the relatively low cost of natural gas, the very same areas also tend to have high energy cost burdens (**Figure 2-4**, **Chapter 2**); these same areas also have higher concentrations of Black populations in Baltimore and higher prevalence of asthma (**Figure 3-2**).

The health costs of natural gas use have not yet been integrated into either regulatory or legislative perspectives. Unless they are factored in, natural gas provides the illusion of being cheaper in dollar terms while negatively impacting the health of large numbers of Marylanders, causing added expenditures and distress to them, with a disproportionate impact on BIPOC communities and low-income households. Of course, the increase in medical expenses occasioned by natural gas-related medical expenditures would exacerbate the frequently noted financial stresses between paying utility bills and rent or buying food and medicine. There are also impacts on non-low-income households, for instance in the form of costs of increased emergency room visits and an increased need for utility bill payment assistance.

Electrification is an obvious, if incomplete, solution to these public health challenges. In the prior section, we have shown that energy cost burdens can be greatly reduced when weatherization, electrification, and community solar supply are combined. There are advantages to implementing changes as a package. For instance, weatherization alone can reduce ventilation and/or change its patterns in a home, which can adversely impact indoor air quality, as discussed in **Chapter 3**. The replacement of a gas stove with an induction stove can reduce fossil fuel-related emissions, but cooking still produces air pollutants such as particulate matter and ventilation—such as a fume hood—is likely still necessary. As a result, it is essential to evaluate whether and how much additional mechanical ventilation is needed to maintain or improve ventilation when homes are weatherized. Measurement of post-retrofit air quality as well as energy cost burdens must become a routine part of retrofits and improvement of quality of life. A holistic approach to retrofitting buildings is needed to join climate, economic, and public health goals. From a health and efficiency point of view, it is best if weatherization, ventilation, health hazard remediation, and electrification of space and water heating and cooking were carried out in a single major retrofit.

5.4.8 Natural Gas Rates and Energy Burdens

While natural gas is a relatively low-cost fuel today, it will likely not stay that way in Maryland. We showed in **Chapter 4** that, absent policy action, natural gas rates will begin to rise steeply in the 2030s due in part to the 2013 STRIDE law allowing pipe replacements and the addition of the investment cost to the rate base post facto. The Climate Solutions Now Act and the imperative of reducing natural gas use will likely drive electrification; those who can afford it will electrify, leaving the remaining ratepayers, including lower-income households, stuck with paying for the entire natural gas distribution infrastructure. By 2040, the natural gas rates would more than triple to roughly $40 per MMBTUcompared to $12 or so in 2021. Thus, while natural gas is at least nominally an economical fuel today, it will not remain so.

Proposals to maintain the natural gas infrastructure and putting synthetic methane and biogas in it will make matters worse. As discussed in **Chapter 4**, the cost of commodity gas would increase many fold from under $10 per MMBTU to the range of $30 to $70 MMBTU. Even if it is used as a supplement to heat pump electric heating (the supposedly lower cost option), heating bills would increase significantly. The drawbacks of a mixed electrification with a gas supplement are discussed in **Chapter 4**; suffice it to say here that even the E3 study that suggests it as the lowest cost option estimates that heating bills would go up by several tens of dollars a month as compared to an all-electric option.[384] As a result, energy costs and the need for assistance would rise by tens of millions of dollars a year—a consideration that was not taken into account.

Minimizing stranded costs also will require minimizing natural gas connections to new buildings, whether residential or commercial.

Finally, the negative health impacts of indoor air pollution from use of gas as a fuel would remain; so would the climate impacts from methane leaks.

5.5 Conclusions

Making energy affordable for all Marylanders as part of the energy transition is a necessary element of economic and environmental justice. It should be unacceptable that there are hundreds of thousands of Maryland families with very high energy cost burdens that routinely impose impossible choices on low- and moderate-income families. Pay the rent or the electric

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[384] Tory Clark, Dan Aas, Charles Li, John de Villier, Michaela Levine, and Jared Landsman, Maryland Building Decarbonization Study: Final Report, Energy + Environmental Economics, October 2021, slide 35 at https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MWG_Buildings%20Ad%20Hoc%20Group/E3%20Maryland%20Building%20Decarbonization%20Study%20-%20Final%20Report.pdf

bill? Buy medicines or pay the natural gas bill? Buy food and risk an electricity shut-off or pay the bill and go hungry? These privations also impact non-low income households and the state's society at large; the quantifiable costs alone are very large and of the same order of magnitude as the additional resources it would take to reduce energy cost burdens universally to six percent or less.

Maryland's Climate Solutions Now Act presents a huge opportunity to do affordability well. A full integration of low- and moderate-income households into the energy transition with high priority would reduce assistance requirements while keeping their energy cost burdens low and allowing them to participate in the transformation of the state's energy sector. Eliminating fossil fuels will also improve both indoor and outdoor air quality—and hence health—on average. But specific attention needs to be paid to the disadvantaged and more vulnerable demographic groups to ensure that they are included—without that inclusion, matters could deteriorate for them even as things improve on average. This inclusion means not only ensuring that these populations receive the benefits of the clean energy transition, but also that there are mechanisms (e.g. funding, outreach efforts) to enable historically excluded populations to participate in the process of designing, implementing, and evaluating the relevant policies and programs.

The challenges are as daunting as the prize is attractive. The pace of weatherization and electrification of low- and moderate-income homes will have to increase by five to ten times compared to recent years. A much better, more inclusive infrastructure for assistance application and provision that respects the dignity of low- and moderate-income households will need to be put into place. Much of the effort now spent on verifying documentation will need to be shifted to outreach and enrollment of households into a program such as a PIPP. A coordinated holistic approach will be needed. That means more resources. While the amount of assistance needed in the long term will be the same order of magnitude as currently available resources, about $300 million a year in additional resources will be needed in the initial years. This includes grants for a holistic approach to retrofits and incentives for landlords, and weatherization grants for all households below the federal poverty level.

5.5.1 Findings

1. **The highest cost burdens tend to be in the lowest income areas—and are geographically concentrated in Baltimore City, which is also majority Black, and in rural areas in Western Maryland and the Eastern Shore (Chapter 2).**
2. Maryland's energy assistance programs are effective in reducing energy costs burdens, but these burdens remain high for many assistance recipients.

3. The largest problem with the assistance programs is that they do not reach the vast majority of recipients for a complex set of causes:
    a. The application process is complex, replete with obstacles, and literally punitive in its tone;
    b. The types and extent of documentation required—such as social security numbers and citizenship status of every household member—presents barriers to application for large numbers of families;
    c. The extent of proof required is onerous: twenty-seven different types of income must be documented for each earning member; a sworn attestation is even required for household members with zero income.
    d. Maryland's decentralized administration of assistance programs has the advantage of being community-centered, but its implementation lacks uniform standards, resulting in varying rates of denial. Given the documentation and verification requirements it is also costly and cumbersome.
4. Self-attestation of income has been shown to be a success not only in California, but in Baltimore City, where random audits have not found even a single instance of a fraudulent income declaration in applications for retrofit programs carried out by the non-profit Civic Works.
5. Since Maryland has combined the application process for a variety of different benefits, including energy bill payment assistance, eliminating documentation requirements could benefit several state and local assistance programs. In any case, up-front documentation requirements should be eliminated in favor of self-attestation, and the amount of information required should be reduced and made comparable to the minimal approach in California.
6. A simpler application process, used in some other states like California and Oregon, would go a long way in increasing participation. For instance, California requires no documentation up front, no names other than those of the applicant, and no social security numbers. This will require separation of federal heating program assistance (LIHEAP) from state assistance funds. However, LIHEAP can be disbursed via the new MDThink application process that combines applications for a variety of programs that include federal monies.
7. A PIPP with near universal enrollment and eligibility up to 200 percent of the federal poverty level would require about $200 million per year in funds above those currently

available. These funding needs would decrease over time, however, as bill-saving investments in weatherization and electrification begin to bear fruit.

8. A variety of sources of revenue with zero or low impact on the vast majority of Marylanders are available to meet the funding requirements of a PIPP with universal enrollment and retrofit grants.
9. High rates for electricity and gas charged by third party suppliers would increase the assistance requirements by tens of millions of dollars each year.
10. The quantifiable non-energy benefits to non-low-income households will be very large. Data are not available to enable precise estimates of statewide positive non-energy benefits but they may well be of magnitude comparable to the added cost, even if one counted only the benefits to non-low-income households.
11. Combustion of fossil fuels and wood in cooking and heating appliances contribute to poor indoor air quality, particularly when the appliances are not vented outdoors. Furthermore, gas-based appliances can leak when not in use and can contribute to hazardous air pollutant concentrations indoors. Appliances reliant on electricity do not require indoor combustion and therefore do not emit combustion-related emissions indoors. However, the use of electric or induction ranges and ovens may still contribute to indoor air pollutant emissions related to types of foods being cooked.
12. Energy efficiency retrofits focused on weatherization without ventilation may contribute to poor indoor air quality. Combinations of weatherization and ventilation retrofits, electrification programs, and educational programs are more likely to provide simultaneous energy efficiency and indoor air quality benefits.
13. The amount of assistance required to make energy cost burdens affordable will increase significantly if current policies allowing expansion of gas infrastructure and replacement of existing infrastructure are allowed to continue.
14. Virtually net-metered discounted community solar electricity is one of the keys to reducing energy assistance requirements, all the more so once space and water heating have been electrified. It is also an essential aspect of harmonizing equity goals with the greenhouse gas emission reduction targets of the Climate Solutions Now Act.
15. Current regulations do not permit community solar developers and subscribers the benefit of Purchase of Receivables, by which the utility purchases the debt owed by the solar subscriber to the developer, enabling a single consolidated electricity bill to be sent to the subscriber. Many low- and moderate-income subscribers risk the loss of

electricity bill payment assistance because their full energy usage is not seen by the utility.

16. The added funds required for a PIPP would decline steadily if low- and moderate-income households are fully integrated into the energy transition required by the Climate Solutions Now Act. Full integration includes weatherization (including of rental properties), conversion of fossil fuel space and water heating to efficient electric heat pumps, provision of community solar electricity at a significant discount (20 percent or more) relative to residential utility rates, and enabling all households to effectively participate in demand response programs. A holistic “green and healthy homes” approach is needed for energy retrofits to result in economic and health benefits—and, in many cases, for energy retrofits to be implemented at all. The detailed estimates made in this report indicate that:
    a. The energy cost burdens of the vast majority of low- and moderate-income households can be reduced below the six percent affordability threshold by integration in the energy transition; these households would therefore no longer require assistance for paying their energy bills.
    b. Assistance would still be needed for 60 percent of households earning incomes less than the federal poverty level, but the total amount of assistance needed for these households with the lowest incomes would be about $40 million less than the assistance resources available in 2021.
17. The pace of weatherization and retrofits of low- and moderate-income homes would need to be increased by five to ten times to protect low-income households from the impact of rising natural gas rates; efficient, complete electrification is essential to achieving this goal. Partial electrification that leaves gas infrastructure in place will increase energy cost burdens and deprive households of the full health benefits of electrification.
18. The greatest benefits of interventions aimed at improving indoor air quality and health will be derived when targeted programs are implemented carefully and focus on populations vulnerable to poor indoor air quality, such as children, pregnant people, and those with preexisting cardiovascular and respiratory disease.
19. The lack of Purchase of Receivables for community solar subscriptions is a significant hindrance to getting low- and moderate-income subscribers, since without it they must pay two bills. Some of them may also be at risk of losing electricity bill payment assistance money, since such assistance is only provided in consideration of the

electricity bills, which, without Purchase of Receivables, are reduced by the full amount of payment due to the solar developer.

20. Maryland passed a law in 2021 requiring the Public Service Commission to take climate impacts into account in its regulatory actions. If vigorously applied, this could be a powerful instrument in achieving the ambitious targets of the 2022 Climate Solutions Now Act: 60 percent greenhouse gas emission reductions by 2031 and net zero emissions by 2045.

5.5.2 Recommendations

1. It is essential to put in place a bill assistance program such as a Percentage of Income Payment Plan that has near-universal enrollment to make energy cost burdens affordable for all Marylanders. This will require significant additional funding in the near term but not in the long term if coupled with clean energy investments.

2. A thorough simplification of the application process that respects the dignity of low-income households is urgent and an essential foundation of affordability. It should be based on self-attestation—that is, *up-front documentation requirements should be eliminated*. Near universal enrollment within three years should be the goal.

3. There are varied income eligibility criteria from different segments of the low- and moderate-income population, with 175 percent of the federal poverty level being the requirement for most households. This leaves tens of thousands of households with energy cost burdens more than six percent. Further, the DHCD weatherization program, which gets most of its referrals from the assistance program, is available to households with up to 200 percent of the federal poverty level or 80 percent of the area median income, whichever is higher. The eligibility requirement should be made uniform and set at the DHCD weatherization level.

4. Third party supply of electricity or natural gas to any household eligible for bill payment assistance at rates above Standard Offer Service should be prohibited, extending the prohibition from only those who actually get assistance to all customers.[385]

5. A vigorous program of retrofitting all low- and moderate-income households should be implemented with the pace increasing ~ten times above the rate in the last decade.

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[385] "Standard Offer Service" is the rate for commodity electricity or natural gas supply acquired by regulated utilities on wholesale markets for resale to retail customers within Maryland. This rate changes periodically since Maryland's commodity electricity and natural gas supply are acquired on wholesale interstate markets under the supervision of the Public Service Commission. As of 2022, state law only prohibits above SOS third party rates for low- and moderate-income households that get assistance, leaving the vast majority still vulnerable to unnecessarily high bills.

6. Priority in retrofits should be given to those areas where relatively large proportions of the population have high energy cost burdens or high risk of indoor air pollution. These areas are mainly on the Eastern Shore, in Baltimore City, Western Maryland, and certain parts of Southern Maryland. Priority to these areas would reduce environmental injustice—Baltimore City is majority Black and has much lower income on average than the rest of Maryland (see Baltimore City maps in **Chapters 2** and **3**). Early electrification and healthy home retrofits in these areas may also provide health benefits, since these are also the areas with high asthma prevalence (**Figure 3-2**).
7. In its 2021 Annual Report, the Maryland Commission on Climate Change made a number of recommendations that are especially pertinent to equity in the energy transition, including retrofitting "100% of low-income households by 2030," encouraging fuel switching away from fossil fuels, mandating that 95 percent of residential heating system sales should be heat pumps by 2030, incentives for all-electric buildings, specifically including "incentives for net zero energy all-electric new buildings".[386] These recommendations were made before the Climate Solutions Now Act of 2022—and hence before the large potential impact of the law on natural gas costs could be estimated. The following recommendations, applicable to the residential sector, are consonant with the spirit of the 2021 Climate Commission recommendations, but made more stringent in light of the needs and exigencies of the Climate Solutions Now Act of 2022 (see **Chapter 4** in particular for details on impacts):
    a. Weatherize, electrify with efficient space and water heat pumps, and disconnect natural gas service from all low- and moderate-income households by 2030 if a PIPP is not in place by 2025, and by 2038 at the latest if it is. (A PIPP will insulate low- and moderate-income households from the impact of natural gas rate increases implicit in current policies (**see Chapter 4**). All fuel oil- and propane-heated households should be prioritized for conversion by 2030, since that will have a disproportionately large impact in reducing energy cost burdens and the scale of assistance needed.
    b. All new detached residential construction starting on January 1, 2025 should be all electric and net-zero in terms of electricity consumption based on annual rooftop solar generation.[387]

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[386] Maryland Commission on Climate Change, 2021 Annual Report, Maryland Department of the Environment, 2021, p. 8, at https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Documents/2021%20Annual%20Report%20FINAL%20%282%29.pdf

[387] For the economics of such construction and an analysis of what a net-zero mandate is preferable to a "solar-ready" policy see Arjun Makhijani, *Gold on the Roof: The Economics of a Net-Zero-Energy Rooftop Solar Mandate for New Residential Housing*

    c. All other new residential construction should be all-electric starting in 2025.
    d. No new natural gas connections to buildings should be permitted starting on January 1, 2025; this is important for all customers on the natural gas system because they all pay for the distribution system costs that are in the rate base of regulated natural gas companies.
    e. All incentives for new natural gas appliances should be ended by the end of 2023.
    f. Incentives should be provided to landlords for weatherization and electrification of their properties, subject to the benefits of lower energy bills accruing to the tenants (via lower rent in the case of master-metered buildings);
    g. Landlords should be required by law to give access to their properties for the purpose of energy audits.

8. A "green and healthy homes" approach should be adopted for retrofits; this will enable all low-and moderate-income homes to be eligible for weatherization assistance program grants and all such homes to be weatherized to improve both the economic and health outlook of families at the same time.
9. Caution should be exercised when implementing energy efficiency retrofits to ensure that programs do not reduce household ventilation, resulting in degraded indoor air quality. This is in line with the existing DHCD approach to retrofits. Energy efficiency programs should be coupled with electrification and/or ventilation and filtration programs for climate and health benefits to be realized. Educational campaigns should promote activities that increase ventilation during cooking (e.g., using range hood, opening windows) as a precaution whenever cooking occurs.
10. Electrification of household appliances, particularly those located within the living space, e.g., stoves, ovens, space heaters, can eliminate combustion-related emissions that contribute to poor indoor air quality and increased health risks. Policies and programs that support electrification of household appliances can help people who want to transition to electric, but cannot afford to do so.
11. Institutions such as the Maryland Clean Energy Center, a state-chartered non-profit, and the Montgomery County Green Bank, and the non-profit, Climate Access Fund, can

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in Montgomery County, Maryland, Institute for Energy and Environmental Research, December 2020 at ieer.org/wp/wp-content/uploads/2020/12/Gold-on-the-Roof-Economics-of-New-Detached-Net-zero-Energy-Homes.pdf be among the vehicles for providing low-cost financing for low- and moderate-income household needs.

12. Net metering for rooftop and community solar subscriptions should be maintained for low- and moderate-income households who have benefited very little from Maryland's solar policies and expenditures so far.
13. Purchase of Receivables should be made available for community solar subscriptions to enable subscribers to receive a single bill and avail themselves of any bill payment assistance for which they may still be eligible.
14. Most low-and moderate-income households will have an incentive to subscribe to community solar after electrification because it would enable them to reduce their energy cost burden to well below six percent. Many households at the lowest income levels will likely still have energy cost burdens over six percent even after weatherization and electrification. Subscriptions to community solar (discounted by at least 20 percent) should be part of an application for assistance under a PIPP program, provided subscriptions are available at that time.
15. Maryland should put in place a comprehensive effort to measure indoor air pollution before and after electrification, especially where it concerns cooking and use of portable fossil fuel heating devices. The benefits of reducing indoor air pollution should be added to the non-energy benefits of electrification and ending the use of natural gas in residential settings.
16. The state should issue guidelines for indoor air pollution that are comparable to or more stringent than outdoor air pollution standards. While guidelines would not be enforceable at first, consistent exceedance should trigger their conversion into requirements for landlords to provide ventilation hoods and properly tuned equipment in rental housing.
17. The Maryland Public Service Commission has ruled that non-energy benefits should be taken into account when evaluating the costs and benefits of ratepayer expenditures on energy efficiency. The same reasoning should be comprehensively applied to estimating the non-energy benefits of a PIPP and of full and rapid integration of low- and moderate-income households into the energy transition that is required to meet the targets of the Climate Solutions Now Act.

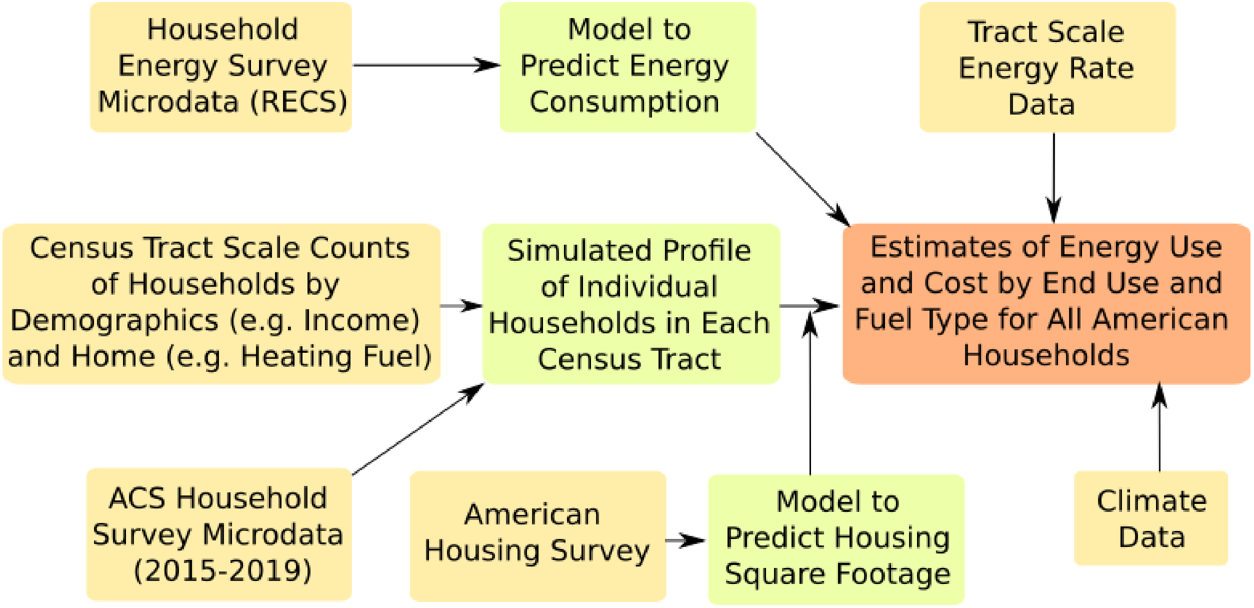
Appendix

A.1 Energy Affordability Estimates

A.1.1 Methodology

To estimate energy bills, we use models to integrate data from multiple publicly available sources. These methods build upon methods recently used for a similar analysis for the state of Colorado.[388] We outline the method here along with comparisons with available datasets for validation purposes. Code for generating these estimates are available upon request.

Figure A-1: Flowchart of modeling for estimation of household energy spending.



Our model roughly follows the flowchart shown in **Figure A-1**. We break the flowchart down into steps as follows:

1. ***Predictive model of energy by end use and fuel type.*** The Residential Energy Consumption Survey (RECS),[389] provides a detailed profile of over 5,000 homes in the

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[388] B. Lukanov, Makhijani, A., Shetty, K., Kinkhabwala, Y., Smith, A. and Krieger, E. Pathways to Energy Affordability in Colorado. (2022). *PSE Healthy Energy.*

[389] U.S. Energy Information Administration (2015). Residential Energy Consumption Survey. https://www.eia.gov/consumption/residential/data/2015/

year 2015 and their energy use. RECS was designed to capture the wide diversity of homes across the United States and uses bill data obtained directly from utilities to survey the energy usage. This utility-reported data is more reliable than relying on self-reported data such as the American Community Survey (ACS), but is not as extensively sampled. The predictor variables we choose are home type, fuel type, cooling degree days, heating degree days, number of household members, square footage, and the number of rooms. These are chosen because they correlate with energy usage and, for most of them, are available at the census tract scale. The dependent variables we estimate are the total energy as well as the energy used for water heating, space heating, appliances, and space cooling. This builds upon previous methods in the literature, but uses a random forest model as opposed to linear models to avoid issues such as over-fitting or unrealistic estimates outside the domain of what has been observed. This model trained on RECS data can then estimate energy consumption when given a set of predictor variables.

2. ***Building a portfolio of household scale data.*** The U.S. census provides the counts of households in census tracts by demographic attributes and home attributes such as the fuel used for space heating. We use American Community Survey (ACS)[390] data for the period 2015-2019. Due to privacy concerns, however, the number of cross tabulations are limited. For example, while we may know the total number of households in detached homes, race, and the number of households that rent, we cannot know the number of households that rent, are in detached homes, and identify as White. However, we expect these variables to be correlated. Correlations between these variables can be found in the detailed responses for each survey as found in the ACS microdata that are available in Public Use Microdata Area (PUMA) geographies. We detailed cross tabulations through integration of these data using methods from combinatorial optimization. Broadly speaking, we use optimization methods to select households from the ACS survey microdata in Maryland and neighboring states for each census tract so that the total number of households matches the tallies reported by the ACS. This preserves correlations between variables, such as the fact that low-income households are more likely to be renters. We additionally use American Housing Survey (AHS)[391] and RECS data to build models that predict the home square footage, fuel used for water heating, and the fraction of appliance energy use broken down by fuel type since these are not provided by the U.S. census but are available and can be useful for modeling. Using this method, we are able to get a simulated

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[390] United States Census Bureau. American Community Survey Microdata (2015-2019). https://data.census.gov/mdat/#/

[391] United States Census Bureau. American Housing Survey. https://www.census.gov/programs-surveys/ahs.html

profile for each household in every census tract. We do not expect these tallies to be exact at the household scale. For example, multifamily housing in one tract may be high-end luxury housing while another tract may be dominated by low-income multifamily housing. However, aggregate statistics across multiple tracts are reliable and interpretable. Importantly, the disaggregation of tracts into households is vital to reaggregation as demonstrated throughout this report to calculate the affordability for homes according to a given variable such as the fuel type used for heating.

3. ***Estimating energy consumption for households*.** We take the households simulated in step 2 and enter them into the model built in step 1 in order to estimate the total energy and the energy used for each of the four end uses for each home. We also incorporate estimates of the heating and cooling degree days from nearest weather stations that provide such data.

4. ***Calculating spending*.** To translate energy use into total annual energy bills, we need the price of each fuel. Due to limited data availability for the delivered fuels, we rely on statewide estimates provided by the EIA for fuel oil and propane costs. More data, however, is available for the electric and natural gas utilities as surveyed by the EIA forms 861 and 176 respectively. We use these to calculate energy rates for each large utility. We then use geospatial methods to assign homes in census tracts to utilities while aligning the total number of customers. This is inexact due to overlapping utility service areas and a lack of alignment of service areas with census tracts, but can be relied upon to capture the regional differences in natural gas and electric rates. We then use these rates to calculate total energy spending and spending broken down by end use.

A.1.2 Validation

No data set of residential energy affordability currently exists at the household scale for all households in Maryland. To perform comparisons of our data with other estimates, then, we shall aggregate it according to data sets and modeled data that do exist and perform comparisons.

A.1.2.1 Average Bill Comparisons

The RECS survey from 2015 reports average energy bills by census division[392] shown in **Table A-1** corrected by an energy-based inflation factor of 17 percent to the year 2021.[393] For Maryland, the average of the energy bills we estimate is $2,233 and $2,035 for just low- and moderate-income households. Maryland is situated in the northmost part of the South Atlantic Region whose average annual energy bill is $2,297, a 3 percent difference than estimated values here. The LEAD tool estimates $2,386. However, a recent APPRISE report estimated the average Maryland bill for households with incomes less than twice the federal poverty level to be $2,647, 27 percent greater than the bills estimated for low- and moderate-income used in this report.

Table A-1: Average Annual Energy Bills from RECS.

Census Division	Annual Energy Bill Adjusted for 2021
Northeast - New England	$2,973
Northeast - Middle Atlantic	$2,537
Midwest - East North Central	$2,061
Midwest - West North Central	$2,055
South - South Atlantic	$2,296
South - East South Central	$2,231
South - West South Central	$2,156
West - Mountain North	$1,855
West - Mountain South	$1,974
West - Pacific	$1,709

A.1.2.2 Affordability Gap and Cost Burden Comparisons

The Low-Income Energy Affordability (LEAD) Tool developed by the Department of Energy provides energy affordability data down to the census tract scale and allows for granular comparisons of affordability. In fact, the second step in the methodology described above is

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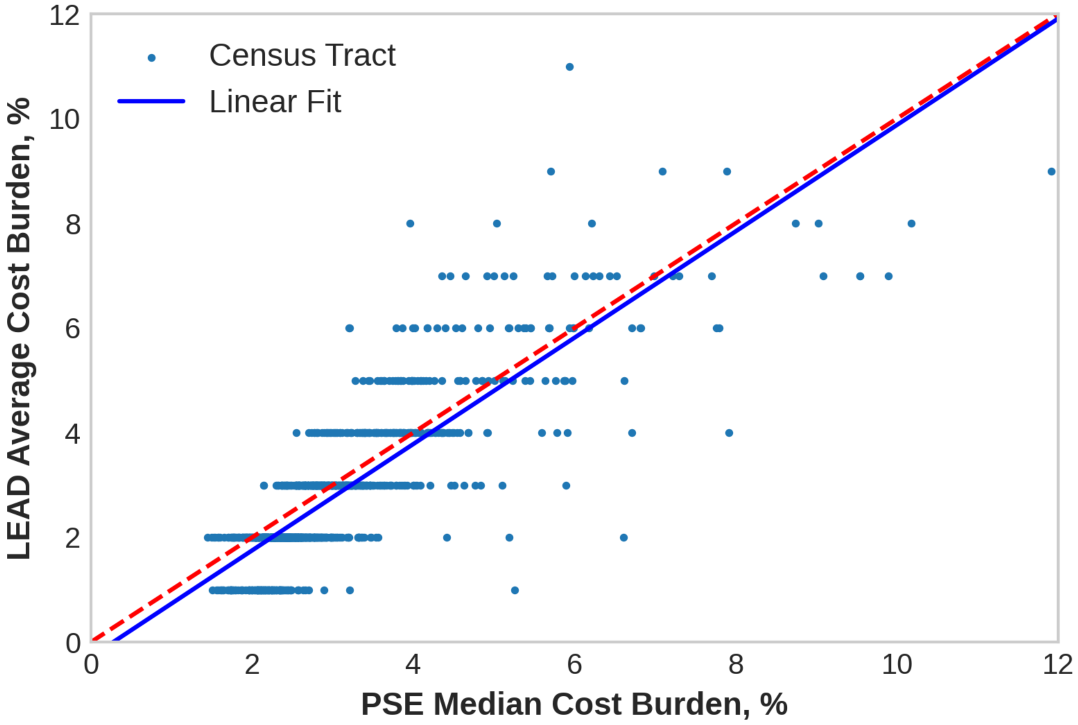
[392] U.S. Energy Information Administration (2015). Residential Energy Consumption Survey. Table CE1.1. https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce1.1.pdf

[393] Energy Inflation Calculator. https://www.in2013dollars.com/Energy/price-inflation/2015-to-2021?amount=1

similar between our methods and that of the LEAD tool. The biggest difference is that we also use a model for predicting energy consumption while the LEAD tool uses surveyed data of energy bills from the ACS to estimate bills. While the LEAD data is very useful, it does not make public household scale estimates nor their intersections with demographic variables and so we chose to perform our own estimates in order to build custom aggregations and to have available the energy use data in addition to the bill data. In **Figure A-2**, we provide a comparison between the energy cost burdens reported by the LEAD tool and the median cost burdens we estimate. As shown by the blue linear line of best fit, the general trend of our estimates are in agreement with the LEAD tool, however, there is still noise that results from many factors such as the different sources of energy data and different statistical methods used to aggregate burdens at the tract scale.

Figure A-2: Comparison between PSE and LEAD tool reported census tract energy cost burdens. Points on the red dashed line have identical values between the two estimates. Solid blue line is the linear line of best fit for the blue scatter points.



Fisher, Sheehan, and Colton first introduced the energy affordability gap metric and have provided estimates of these gaps down to the county scale across the U.S. for years. These estimates have been widely used, providing critical quantification of the gaps of the types we estimate here and steering decision-making into energy affordability. However, our estimates of energy cost burdens tend to be lower than the estimates of Fisher, Sheehan, and Colton. This is most likely due to differences in estimates of energy bills which is the data that must be estimated. For 2021, the year under consideration in this report, we present a comparison between the gaps and energy cost burdens at the county scale in **Table A-2**. One explanation for the much higher energy cost burden for the income groups below 50 percent of federal poverty level is that our estimate is based on a house-to-house energy and income analysis, while Fisher, Sheehan, and Colton calculated the median energy cost burden assuming a single income value set at 40 percent of federal poverty level. In effect, the median income within the group of households that have less than 50 percent of federal poverty level is considerably less than 40 percent of federal poverty level.

Another potential reason estimates made by Fisher, Sheehan, and Colton are higher than ours is due to an additional stringent affordability limit for heating alone of two percent of income. This criterion may add a considerable amount to the affordability gap for the same energy bills. We have not included the additional affordability criterion in our affordability gap estimates.

Table A-2: Comparison of energy cost burdens by income groups.

Income Group *Percent of Federal Poverty Limit*	**Fischer, Sheehan, and Colton Home Energy Cost Burden**	**PSE Median Energy Cost Burden**
Below 50%	35%	45%
50-100%	19%	14%
100-125%	12%	9.4%
125-150%	10%	7.8%
150-185%	8%	6.4%
185-200%	7%	5.6%

A.1.2.2 Total Maryland Consumption

The EIA reports the total residential energy consumption by fuel type across Maryland[394] shown in **Table A-3**.

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[394] U.S. Energy Information Administration. State Profiles and Energy Estimates. https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_btu_res.html&sid=US

Table A-3: Comparison of total energy consumption reported by the EIA and estimated by PSE.

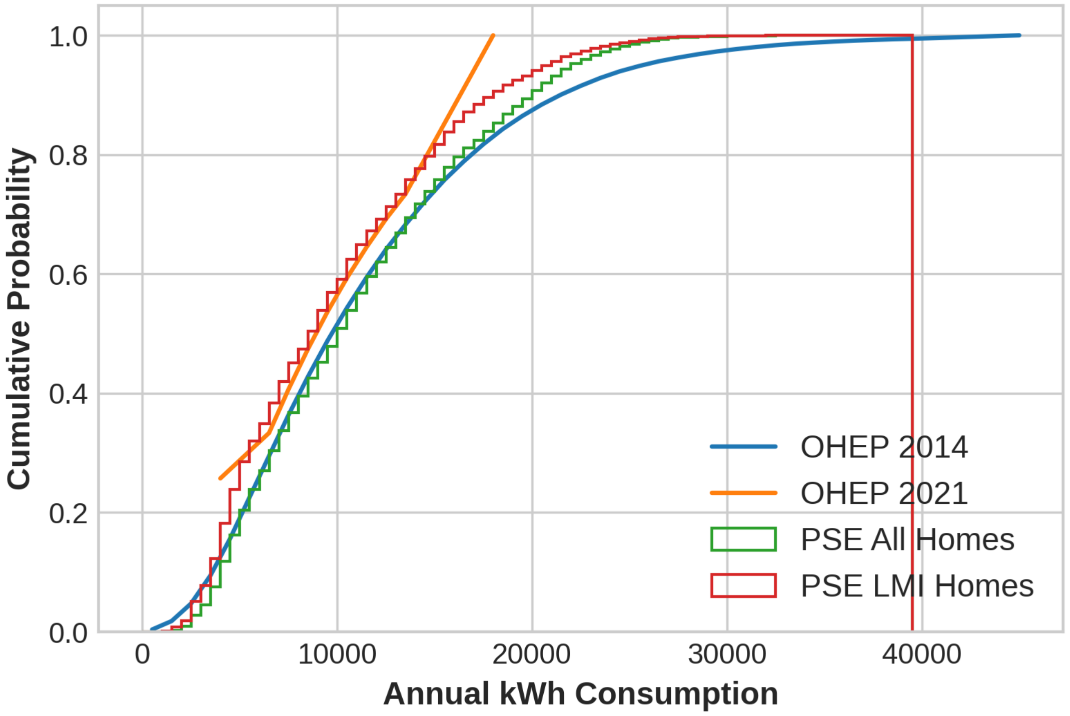
Energy Source	**EIA SEDS (2020)** *Trillion BTU*	**PSE Estimate** *Trillion BTU*
Fossil Gas	80.4	79.8
Electricity	93.2	88.7
Fuel Oil	10.7	9.0
Propane	7.3	4.9

Estimates from our model are lower for each of the fuels but within a few percent for the most commonly used fuels. Propane has the greatest proportional discrepancy of 30 percent. For scale, however, we note that the energy difference between EIA's reported value and PSE's estimated value is the equivalent of roughly 5,000 small tanks of propane of the type typically used for outdoor grills, an end-use common across all homes that may not be fully accounted for in our data. Discrepancies for other fuels could have multiple causes. It could be caused by homes that have outlier usage such as very leaky or very large homes as discussed in **Section 2.7.2**. This discrepancy could also be a systematic difference for Maryland in which homes systematically use slightly larger amounts of energy than our model predicts. Likely, it is due to a combination of such factors and so we choose to use the data as is and advise that there exist homes with especially high bills that are not fully accounted for in this analysis.

A.1.2.3 OHEP Energy Usage Statistics

The Office of Home Energy Programs (OHEP) has collected surveys of energy bills for low-income households. Within these data, they provide the total number of homes within electricity usage brackets. We compare the distributions of electricity usage from our estimates with values reported by the OHEP for the years 2014 and 2021 in **Figure A-3**. The year 2021 had fewer brackets and so the curve is limited to a smaller range. In 2021, energy use was less due to differences in weather and possibly improvements in efficiency.

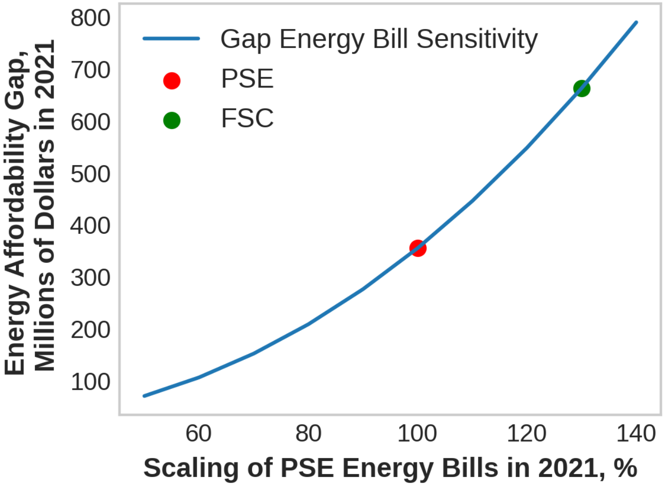
Figure A-3: Cumulative distributions of annual electric energy for surveyed homes from two OHEP reports (2014 and 2021) and from estimates used in this report for all households and for just low- and moderate-income households.



A.1.2.4 Sensitivity Analysis

A part of the difference in the aggregate estimate of the affordability gap of about $400 million in this report and the Fisher, Sheehan, and Colton gap of $709 million is due to the latter's use of an additional 2 percent affordability threshold for heating. We have not included this additional threshold in our analysis. However, a part is due to the higher energy bill estimates in Fisher, Sheehan, and Colton relative to the ones in this report. **Figure A-4** shows the non-linear sensitivity of the affordability gap to energy bill estimates assuming it is due to energy bills alone. As bills increase, the affordability gap increases more rapidly due to additional households being pushed beyond the 6 percent affordability threshold. The actual discrepancy between our affordability gaps estimate and that of Fisher, Sheehan, and Colton is likely less than that indicated in **Figure A-4**.

Figure A-4: Sensitivity analysis of the total affordability gap on the scaling of energy bills estimated in this report.



A.1.2.5. Discussion of Potential Sources of Discrepancy in Energy Usage and Bills

Energy usage differences between reported values from the EIA, OHEP, and RECS and those estimated here are in general agreement and not sufficient to describe disparities between our estimated annual bills and affordability metrics as those provided by APPRISE or Fisher, Sheehan, and Colton. In the absence of more detailed information about the estimation methods and underlying data sources, we can only speculate about the source of these different estimates.

One possible reason for the different energy bill estimates is a difference in the choice of the underlying data. In our analysis, energy related consumption was estimated from RECS and then merged with rates estimated from reported sales and revenues, other estimates often rely on the ACS self-reported energy bill data. These data ask respondents to report their last month's energy bill. This data must then be integrated and modeled in order to determine the full year's energy bill, but it has the advantage of a greater sample size and spatial granularity compared to the RECS data. It has been observed, however, that responses tend towards higher estimates of energy bills that must be corrected for.

Different accounting methods of energy consumption variations between low-income households and the remainder of the population may also be a factor. For example, randomly assigning energy bills to households regardless of income results in an increase of the total energy affordability gap from roughly $350 million to $510 million. This is because, after shuffling energy bills, low-income households will be spending as much as higher-income households on average.

A.1.3 Energy Estimates Summary

Given above comparisons and the comparisons between our estimates and EIA data in Table A-3 above, our estimate of an affordability gap of $350 million is likely to be underestimated by about $50 million. This captures the differences in energy usage reported by the OHEP bills and EIA combined with rough estimates of climate sensitivities. We have accordingly adjusted our total estimate of the gap to $400 million.

We recommend more reporting from utilities to resolve discrepancies discussed here and to allow a finer scale of analysis while still protecting customer privacy. It is challenging to make more accurate estimates of the affordability gap with publicly available data. Lack of utility data (appropriately anonymized) presents unnecessary obstacles to the analysis and design of programs and public policies. One simple solution would be clear and accessible reporting of utility rate structures for gas and electricity. This would additionally clarify what portion of bills are fixed connection fees and what portions are consumption based and allow for better modeling of the impacts of rate structures on affordability. Additionally, consumption and revenue data at a finer scale than that reported by the EIA-861 and EIA-176 forms would be useful. For example, these same data could be reported not just by utility but also by county. This would be especially useful for understanding the impact of retail choice services that have no utility service area and thus provide no way of locating where their customers live and how much beyond the local base rate they are paying.

Energy Use, Indoor Air Quality, and Health Methodology

We conducted a brief review of relevant literature that demonstrated the impacts of residential energy efficiency, household fuel combustion, ventilation, and electrification retrofit measures on indoor air quality and health in residences across the United States. We conducted a literature search of peer-reviewed journal articles published from January 1, 2010 to June 13, 2022. We also considered selected additional studies published after this timeframe as well as government reports and white papers from federal agencies and Maryland-based institutions in our review. We prioritized peer-reviewed literature focused in Maryland, Baltimore City, and the Northeast, United States, but considered all U.S.-based studies. Although other factors can contribute to indoor air quality and are relevant to consider in a health context (e.g., off-gassing of household products, mold), in this review, we restricted our literature search to studies focused on energy use (fuel types and appliances), energy retrofits (efficiency measures such as weatherization), and the availability, efficiency, and utilization of mechanical ventilation (hood fans) and filtration systems (HVAC). As such, we excluded studies not focused on the United States and studies that focus on indoor air quality but that did not evaluate the impacts of appliances, energy use, and/or energy retrofits on indoor air quality or health.

While this report is not a comprehensive review of available peer-reviewed literature, we relied upon the following set of search terms in Web of Science to help identify articles relevant to this assessment. The search, conducted on June 13, 2022 was restricted to articles published on January 1, 2010 or later.

> TS=("residential" OR "household*" OR "home*" OR "apartment*" OR "single-family*" OR "multifamily*" OR "multi-family*" or "housing*") AND TS=("healthy home*" OR "retrofit*" OR "energy use" OR "indoor energy use" OR "energy usage" OR "energy upgrade*" OR "electrification" OR "energy transition" OR "electrify" OR "energy efficiency" OR "weatherization" OR "weatherize" OR "efficiency upgrade*" OR "appliance upgrade*" OR "fireplace*" OR "wood stove*" OR "pellet stove*" OR "ventilation" OR "hood fan*" OR "vent hood*") AND TS=("Formaldehyde" or "indoor ambient air" OR "indoor air quality" OR "indoor air*" OR "indoor air pollutant*" OR "indoor air contaminant*" OR "indoor air pollution" OR "IAQ" OR "carbon monoxide" OR "benzene" OR "formaldehyde" OR "ultrafine*" OR "polycyclic aromatic hydrocarbon*" OR "PAH*" OR "particulate matter" OR "PM" OR "PM1" OR "PM2.5" OR "PM10" OR "NOX" OR "NO2" OR "nitrogen oxide*" OR "nitrogen dioxide" OR "hazardous air pollutant*" OR "hazardous*" OR "toxic air contaminant*" OR "TAC" OR "air toxic*" OR "health damaging" OR "air pollutant*" OR "volatile organic compound*" OR "VOC" OR "respiratory" OR "pulmonary" OR "cardiopulmonary" OR "cardiac" OR "neurologic*" OR "disease" OR "health" OR "epidemiological" OR "symptom*" OR "health risk*" OR "physiological" OR "hospitalization" OR "asthma" OR "injury" OR "mortality" OR "cancer" OR "morbidity" OR "adverse pregnancy outcomes" OR "birth" OR "congenital" OR "birth defects" OR "birth weight" OR "low birth weight" OR "preterm birth" OR "premature birth" OR "preterm delivery" OR "small for gestational age" OR "LBW" OR "PTB" OR "PTD" OR "SGA" OR "fetal death" OR "cardiovascular" OR "exposure") AND TS=("Maryland" OR "Baltimore City" OR "Baltimore" OR "United States" OR "US" OR "U.S." OR USA OR Alabama OR Alaska OR Arizona OR Arkansas OR California OR Colorado OR

Connecticut OR Delaware OR Florida OR Georgia OR Idaho OR Hawaii OR Illinois OR Indiana OR Iowa OR Kansas OR Kentucky OR Louisiana OR Maine OR Maryland OR Massachusetts OR Michigan OR Minnesota OR Mississippi OR Missouri OR Montana OR Nebraska OR Nevada OR "New Hampshire" OR "New Jersey" OR "New Mexico" OR "New York" OR "North Carolina" OR "North Dakota" OR Ohio OR Oklahoma OR Oregon OR Pennsylvania OR "Rhode Island" OR "South Carolina" OR "South Dakota" OR Tennessee OR Texas OR Utah OR Vermont OR Virginia OR Washington OR "West Virginia" OR Wisconsin OR Wyoming OR "Washington DC" OR "Washington D.C." OR "D.C." OR "District of Columbia" OR "Appalachia" OR "northeast" OR "southeast") NOT TS=("China" OR "Switzerland")

Acronyms and Abbreviations

BIESAK	Baltimore Indoor Environment Study of Asthma in Kids
CalEPA OEHHA	California Environmental Protection Agency Office of Environmental Health Hazard Assessment
CAAQS	California Ambient Air Quality Standards
CHD	coronary heart disease
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent
COHgb	carboxyhemoglobin
DHCD	Department of Housing and Community Development
ECB	energy cost burden
EJ	environmental justice
FPL	federal poverty level
HAP	hazardous air pollutant
HI	hazard index
HVAC	heating, ventilation and air conditioning
IAQ	indoor air quality

IRA	Inflation Reduction Act
LMI	low- and moderate-income
MD	Maryland
mg/m^3	milligrams per cubic meter
NAAQS	National Ambient Air Quality Standards
NO	nitrogen monoxide, nitric oxide
NO_X	nitrogen oxides
NO_2	nitrogen dioxide
NYS HNP	New York State Healthy Neighborhoods Program
OHEP	Office of Home Energy Programs
PAH	polycyclic aromatic hydrocarbon
PM	particulate matter
$PM_{1.0}$	ultrafine particulate matter less than or equal to 1.0 micron in diameter
$PM_{2.5}$	fine particulate matter less than or equal to 2.5 microns in diameter
$PM_{2.5\text{-}10}$	particulate matter equal to 2.5-10 microns in diameter
ppb	parts per billion
ppm	parts per million
REL	reference exposure level
SO_2	sulfur dioxide
$\mu g/m^3$	micrograms per cubic meter
$\mu g\ m^{-3}$	micrograms per cubic meter
U.S.	United States
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic compound
WHO	World Health Organization