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The Trouble with STRIDE: **Meeting climate goals and addressing natural gas system stranded costs**



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Preface

This report is concerned with two things: (i) the need to drastically reduce natural gas consumption to meet the climate targets set in the 2022 Maryland law called the Climate Solutions Now Act, including the associated problem of stranded costs; and (ii) the impact of continued investments in existing natural gas system on rates especially, but not only, as they concern low- and moderate-income households.

It builds on a comprehensive report, *Energy Affordability in Maryland: Integrating Public Health, Equity, and Climate*, published by the Institute for Energy and Environmental Research and PSE Healthy Energy in February 2023.¹ That report was funded by the Town Creek Foundation and the Abell Foundation. Part of IEER's agreement with the Abell Foundation was to produce a more detailed report focused on the problem of natural gas rates and stranded costs in the residential sector, given the magnitude of the energy cost burdens and inequities that are emerging due to continuing investments in existing natural gas infrastructure authorized by a 2013 law called the Strategic Infrastructure Development and Enhancement Act (STRIDE). While STRIDE is the focus of this report (which draws heavily on the larger February 2023 report), I want to note that the actual problem of stranded costs is

much bigger since investments in new natural gas infrastructure continue, despite the imperative dictated by the Climate Solutions Now Act of 2022 for Maryland to achieve net zero greenhouse gas emissions by 2045.

I would like to thank Abell Foundation for funding this effort. I especially want to thank its Senior Program Officer, Beth Harber for supporting this work from its inception, including reviewing *Energy Affordability in Maryland*, and sharing her insights with me on a variety of issues. Andrew Green, Vice-President of Abell Foundation, also reviewed the report and provided many useful substantive and editorial suggestions. I am also grateful for important insights from David Lapp, Maryland's People's Counsel. As is clear from the contents of this report, I have found the analysis in the reports of the Office of People's Counsel very useful, insightful, and vigilant in the interests of residential ratepayers. I have benefited from reviews of a draft of this report by Paula Carmody, Joseph Cullen, Laurel Peltier, Emily Scarr, and representatives of Baltimore Gas & Electric. They have all helped improve this report. As is always the case, as the author, I alone am fully responsible for any errors and omissions as well as the contents of this report, including its findings and recommendations.

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President,

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Executive Summary

Baltimore Gas and Electric's replacement of its natural gas infrastructure became a public flashpoint this summer as some Baltimore residents raised loud objections to the installation of regulators on the outside of their homes. The debate about safety, historic preservation, and aesthetics led to threats to cut off gas supplies, litigation, and even the arrest of three protesters in Federal Hill before the Public Service Commission stepped in.

But questions about the replacement of gas lines extend far beyond the dispute between BGE and a few neighborhoods. Rather, it and the state's other major regulated gas suppliers are engaged in a decades-long, state-sanctioned gas infrastructure spending spree that directly contradicts Maryland's legislatively-mandated climate goals and threatens to saddle a dwindling number of ratepayers with billions in costs for decades to come, with the impacts likely disproportionately felt by those least able to afford them.

The replacement of natural gas infrastructure in the name of preventing leaks and promoting safety has been a public policy issue for decades, and in the 2000s and early 2010s, Maryland utilities made several attempts through the Public Service Commission and the General Assembly to follow other states in adopting customer surcharges to expedite

such efforts. In 2013, they succeeded with the passage of the Strategic Infrastructure Development and Enhancement ("STRIDE") Act. Although climate change had been a concern of the General Assembly for years prior to that law, the legislature's debate over the STRIDE Act did not contemplate the possibility that Maryland's greenhouse gas emission reduction goals would require a substantial transition away from the use of natural gas for heating, cooking and other purposes in residential and commercial buildings. Subsequent climate-related legislation—including a 2021 law requiring the Public Service Commission to take climate change into account in its decisions and the 2022 Climate Solutions Now Act, mandating a 60% reduction in greenhouse gas emissions by 2031 and net-zero emissions by 2045—did not repeal or alter the terms of STRIDE. Thus, despite Maryland's stated need to reduce natural gas use in buildings by 90% by 2050 in order to achieve its climate goal, the state's gas utilities continue to spend billions on new and replacement natural gas infrastructure, with customers on the hook to repay those investments plus a rate of return, potentially over the next six decades. Continuing those investments at a time of declining gas use will cause skyrocketing rates by the mid-2030s, threatening the health, well-being, and security of tens of thousands (or more) of Maryland's low- and moderate-income families.

Main findings

- **Maryland is on a course of huge natural gas stranded costs:** More than \$2 billion in STRIDE authorized investments have already set a course for significant stranded costs, assuming achievement of the state's legally mandated climate goals. More than \$4 billion in additional spending is proposed well into the 2040s, whether through the STRIDE provisions or rate cases. If allowed, ratepayers will be paying for these investments for another six decades.
- **There is no evidence that STRIDE has improved the safety of Maryland's natural gas system:** There were no deaths due to material and aging related causes and one serious injury in the nine years before STRIDE; the data show the same in the nine years after STRIDE. State as well as national data show that material and aging-related issues cause a small fraction of serious natural gas-related accidents. The number of serious injuries and deaths from natural gas accidents related to other causes has actually gone up in Maryland since STRIDE—no deaths and four serious injuries in the nine years before STRIDE compared to nine deaths and 58 serious injuries in the nine years since.
- **A 2023 proposal by the state's largest gas utility, BGE, to condition heat pump rebates on customers continuing to maintain natural gas heating as backup is unsound technically and economically:** BGE's proposal would keep customers tied to the natural gas system and saddle residential consumers with high costs. It is based on technically deficient analysis and an approach that was rejected for residential customers by the Building Energy Transition report of the Maryland Commission on Climate Change in favor of essentially complete electrification of that sector.
- **Low-income households, especially low-income renters, would bear the brunt of the skyrocketing rates** because they are the most likely to be stuck with natural gas—and the ill-health and indoor air pollution that often go with it—compounding the inequities they already suffer.
- **Allowing continued investments in the natural gas system will result in a completely unsustainable economic and social situation for all Marylanders,** including non-low-income ones, while natural gas utilities continue to profit handsomely—unless countervailing action is taken.

Recommendations

1. The Public Service Commission should agree to the request of the Office of People's Counsel to initiate a comprehensive proceeding on natural gas so that:
 - The state's climate goals can be achieved equitably and as economically as possible so far as natural gas is concerned.
 - Maryland's expenses (not necessarily investments) made on the grounds of safety are actually reducing the risk of serious accidents.
 - The state's stranded costs are minimized.
2. The STRIDE program as it stands should be ended; so should attempts to continue it by other means—as for instance in the ongoing BGE multi-year rate case.
3. The Public Service Commission should order utilities to identify specific areas where there are material- and aging-related risks of serious accidents and ensure accountability that repairs and investments made actually reduce the rates and severity of such accidents—giving priority to the documented causes and risks.
4. Safety risks in the infrastructure should be specifically identified before investments that would be put in the rate case are authorized. The identified areas should be priorities for complete electrification.
5. A commitment to a fully electric residential sector by 2045 with complementary investments in efficiency, greatly expanded demand response capability, and community solar should be adopted.
6. All low-income homes should be fully electrified as early as possible—at the latest by the mid-2030s.
7. New buildings in the residential and commercial sector should be mandated to be all-electric—by 2025 for the residential sector.
8. It is essential to ensure that efficiency and electrification retrofits are of high quality. This will require contractor and workforce development to expand the state's capacity to properly install and maintain cold climate and geothermal heat pumps.
9. Early integration of demand response capabilities, and the capacity of customers to benefit financially from participation, would spur the energy transition and should be a priority.

The 2013 STRIDE Law on Natural Gas Investments

What is STRIDE?

Natural gas is a household fuel in about half the homes in Maryland; it is the main space heating fuel in about a million of them. The vast majority of them are supplied by three regulated, investor-owned utilities: Baltimore Gas and Electric, Washington Gas, and Columbia Gas; BGE is the largest, supplying almost 60% of gas customers in the state. The fuel itself is procured on the interstate wholesale market by the state's utilities, which then distribute in areas where they own the pipeline infrastructure. In return for the grant of a monopoly in their respective areas and the opportunity to earn a guaranteed rate of return, utilities are subject to regulatory oversight by the Maryland Public Services Commission (hereafter "the Commission").

Starting in the 2000s, Maryland's gas utilities made several attempts to gain permission to place a surcharge on customers' bills to help accelerate the replacement of natural gas pipes, particularly those made of materials now considered obsolete, such as cast iron. The Commission denied these requests, and the utilities turned to the General Assembly, which initially also rejected the idea. However, amid increasing urging from the National Transportation Safety Board (NTSB) for utilities to replace aging gas transmission

and distribution infrastructure after high profile gas line explosions in 2010 in San Bruno, California (eight killed) and in 2011 in Allentown, Pennsylvania (five killed), the utilities' efforts succeeded. Then-Transportation Secretary Ray LaHood visited the San Bruno site in 2011; he promised to improve safety and "fix America's pipeline system," including advocating for new federal legislation.² That year, Mr. LaHood also urged "all parties to step up efforts to identify high-risk pipelines and ensure that they are repaired or replaced."³ Investments in natural gas pipeline distribution infrastructure nationally accelerated in the years that followed, increasing from an average of \$5.2 billion a year during 2002-2012 to \$13.7 billion a year from 2013-2020; a doubling of the annual rate when adjusted for inflation.⁴

Specifically, the Maryland legislature enacted the 2013 Strategic Infrastructure Development and Enhancement Act, which goes by its acronym STRIDE.⁵ An NTSB official testified in favor of the bill's passage in House and Senate committee hearings. In the Senate Finance Committee, she acknowledged that both rates and safety were at issue but said, "I am not here about rates; I am here about safety" and went on to urge the replacement of cast iron pipes.⁶

STRIDE permitted replacement of existing natural gas distribution pipelines and the recovery of the investments plus a rate of return without the utilities having to go through a normal rate case before the Commission. The initial recovery from ratepayers was to be via a surcharge capped at \$2 per month for residential customers, and a proportionally higher surcharge for commercial customers, until the (adjusted) amount was folded into the rate base. The Commission did not oppose the law, but it testified that it already had the authority to allow investments in question to be made and recovered via rates. Indeed, the Commission had considered just such a case in 2011 and allowed the expenditure made to be recovered via rates but denied Washington Gas' request to recover future such investments via a surcharge prior to presenting them in a rate case.⁷

The Office of the People's Counsel, AARP and others objected to STRIDE on the grounds that it would upset Maryland's traditional rate-setting system, and lawmakers engaged in extended debate about it on the floor of both the House and the Senate, but no one raised

the possibility that it could lead to stranded costs amid an eventual shift away from the use of natural gas for heating and cooking.

STRIDE has several features that are important in the context of safety, accountability, and climate:

- It incentivizes pipeline replacements that can be recovered with a profit via rates as distinct from smaller repairs whose costs are passed on to ratepayers and operating maintenance expenses without any return on investment.
- The law lists reducing pipeline leaks of greenhouse gases as a permissible goal for infrastructure replacement under STRIDE. However, no consideration of the eventual need to greatly reduce natural gas consumption is reflected in the law—despite the fact that climate change had been a concern of the state's legislature for many years prior to 2013.
- The commission could deny utilities' proposals on grounds that they were not "reasonable and prudent." Upon such a finding, the utilities would have to refund any collected revenues to ratepayers.





Table 1 shows the six tranches of STRIDE and the actual (for STRIDE I and II) and estimated future capital expenditures, based on an analysis commissioned by the Office of the People's Counsel. The amounts shown do not include

the rate of return that the utilities would earn on the unamortized portion for much of the rest of the century. (Figures are in millions.) Anticipated future spending tranches are italicized.

Table 1: STRIDE investments—actual and projected (future tranches italicized).

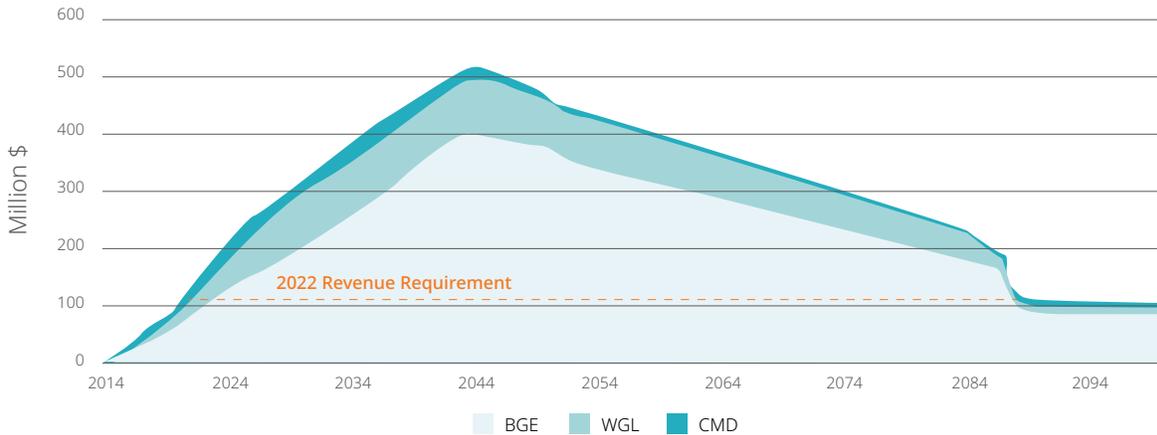
	BGE	WGL	Columbia
Actual STRIDE I, 2014-2018	\$522.73	\$218.50	\$66.19
Actual/authorized, STRIDE II, 2019-2023	\$827.28	\$363.07	\$87.22
<i>Future: STRIDE III, 2024-2028</i>	\$693.39	\$439.44	\$57.38
<i>Future: STRIDE IV, 2029-2033</i>	\$803.83	\$194.82	\$ -
<i>Future: STRIDE V, 2034-2038</i>	\$931.86	\$74.00	\$ -
<i>Future: STRIDE VI, 2039-2043</i>	\$1,034.00	\$ -	\$ -
Total, per utility	\$4,813.58	\$1,302.19	\$210.79
Grand total all three utilities STRIDE I and II			\$2,084.99
Grand total, all three utilities, all STRIDE tranches			\$6,326.56

Source: Office of People's Counsel 2022.⁸

Even if no further investments are made under STRIDE, cost recovery and profits will continue into the 2060s. If the other four tranches are authorized, Maryland gas ratepayers will be paying for STRIDE expenditures and the associated profits until the 2080s.

The Office of People's Counsel (OPC) has estimated how STRIDE would impact revenue requirements in the coming decades if the remaining four tranches are also approved. Figure 1 is reproduced from the 2022 OPC report.

Figure 1: Revenue requirements if all six STRIDE tranches are approved by the Maryland Public Service Commission.



Source: OPC 2022

Those revenue requirements will translate directly to higher gas rates for consumers, with energy cost burdens eventually reaching extreme levels for low-income households. Table 2 shows energy bills in 2021 and 2035 assuming the same usage (since low-income

households may not be able to make significant investments to reduce usage) for a family of three at 50% and 100% of the 2021 poverty level using an estimated rate for 2035 for BGE (See page 18).

Table 2: Estimated energy costs in 2021 and 2035 for Maryland low-income households.

	Annual energy bill		Energy cost burden 50% of 2021 poverty level		Energy cost burden at 100% of 2021 poverty level	
	2021	2035	2021	2035	2021	2035
Natural gas (Notes 1 and 2)	\$950	\$2,430	8.7%	22.1%	4.3%	11.1%
Electricity (Note 2)	\$890	\$890	8.1%	8.1%	4.1%	4.1%
Total energy cost burden	\$1,840	\$3,320	16.8%	30.2%	8.4%	15.1%

Notes:

- Using the estimated average for the year 2035 for BGE natural gas customers (see Figure 5).
- Natural gas use taken as the average per household using that fuel in 2021 in all cases. Average natural gas use in a low-income households (at roughly 100% of the poverty level) is estimated to be slightly higher than the overall average. Electricity use for natural gas heated low-income households estimated at 6,800 kWh/year (rounded), about one-fourth lower than the average (adjusted downward using Makhijani, Mills, and Makhijani 2015, Table III-19). The average household size in Maryland is about 7% smaller than the three-person household assumed in this table. Electricity rates are assumed to be stable in constant 2021 dollars. Rates in constant dollars declined from 2012 to 2022 (including the sudden increase in 2022) but declined slightly over the period since the year 2000.¹⁰

By 2035, natural gas cost burdens alone would increase to extreme levels at 50% of the 2021 poverty level to 22.1%—about two-and-half times the 2021 burden. The total energy burden, including electricity, would increase to more than 30%. At 100% of the poverty level, many households would go from being energy cost burdened to highly cost burdened (defined as burdens greater than 10% of income).

At the high end of natural gas rates in 2050, as estimated by the Office of People’s Counsel,

the natural gas bill alone would be 94% of the entire income of a family of three living at 50% of the poverty level;ⁱ the total energy cost would be about 108% of income. The situation will become intolerable for tens of thousands of Maryland families well before that time; it will also place unsustainable pressures on the rest of society in terms of added emergency room health care, housing support, energy bill payment assistance, and other expenditures.

STRIDE has not measurably improved safety

The federal government continues to urge states to replace aging gas infrastructure for safety reasons, and utility officials testified at the time of STRIDE’s enactment that Maryland had a larger share of cast iron pipes as part of its system than most other states. Since safety is the ostensible purpose for STRIDE investments, one fundamental question to ask, especially given the scale of the expenditures, is whether there has been a measurable decline in serious accidents and their consequences as a result of the law. A “serious accident” is defined as one that involves a death or serious injury. We use the number of fatalities and serious injuries to assess the impact.

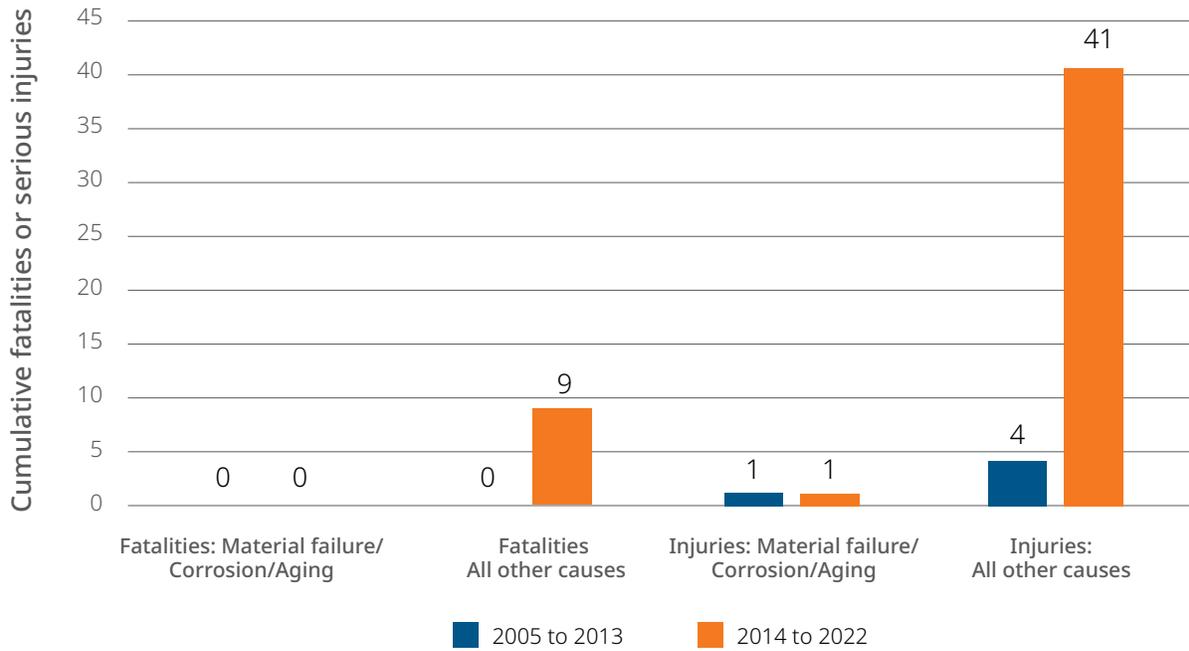
Data from the federal Pipeline and Hazardous Materials Safety Administration (PHMSA) of the U.S. Department of Transportation indicate that about two thirds of serious accidents between 2005 and 2021 (inclusive) nationally were due

to “other outside force damage” (26.6%), “excavation damage” (25%), and “incorrect operation” (14.8%). Approximately 18% were due to “natural force” damage or miscellaneous causes listed as “other causes.” In the most frequent category—“other outside force damage”—69% of the accidents were due to vehicular damage to the infrastructure. Only about one-seventh of the accidents had a material-related cause such as defective welds or corrosion—not necessarily related to aging.

Maryland data from 2005 to 2022 provide insights into whether large STRIDE investments already authorized—\$2.1 billion, or about \$1,750 per gas customer—have made a difference to safety. This period is appropriate since it includes nine years after STRIDE’s enactment (2014-2022, inclusive) and nine years before STRIDE (2005-2013, inclusive). Both periods are long enough to allow a comparison.

ⁱ Both poverty level values and rates are in constant dollars and so have not been escalated for inflation.

Figure 2: Fatalities and injuries due to natural gas distribution system accidents in Maryland before (up to and including 2013) and after the STRIDE law (2014-2022 inclusive).



Sources: Data extracted from PHMSA¹¹

Figure 2 shows accidents in each of these two periods classified into material-related causes (whether due to aging or not) and all other causes.

There were no fatalities due to material-related causes, including aging pipelines, between 2005 and 2022, and only two serious injuries—one before STRIDE and one after. By this measure the system was safe in terms of material defects before the STRIDE law and remained so after it.

Hence, investments under the STRIDE law, which is aimed at addressing material-related issues, have had no demonstrable impact on the frequency of severe accidents.

All nine fatalities were due to other causes—and all were in the period after the STRIDE law was passed. Seven of the nine fatalities occurred in a single accident, a 2016 explosion in an apartment building in Silver Spring (Montgomery County). The accident did not involve the distribution pipeline system. Rather it was due to “the failure of an indoor mercury service regulator with an unconnected vent line....”¹² The other fatalities were also not due to material-related causes. The one in 2014 was due to a gas explosion in a building;¹³ the one in 2021 was due to an excavation accident—one of the most common types of natural gas-related accidents. A worker was killed in that case.

We also considered PHMSA's broader category of "significant incidents," which includes not only incidents involving fatalities and serious injuries but also incidents causing damage in excess of \$50,000. We considered costs of all significant pipeline incidents, including gas and liquid fuel pipelines, and also considered only significant incidents related to the natural gas

system. Table 3 shows the results in constant 2017 dollars. It is clear that STRIDE, besides not reducing serious accidents, has also not reduced the costs of significant incidents. On the contrary, costs of all significant events almost doubled in the post-STRIDE period. The cost of significant natural gas distribution system incidents increased by 50%.

Table 3: Frequency, total cost, and annual average cost of significant pipeline incidents—all significant incidents and natural gas distribution system significant incidents only.

Significant incidents included	Number of significant incidents		Cumulative cost, 2017 dollars		Annual average cost, 2017 dollars	
	2005-2013	2014-2022	2005-2013	2014-2022	2005-2013	2014-2022
All pipeline	19	18	\$9,202,814	\$17,276,025	\$1,022,535	\$1,969,757
Natural gas distribution only	15	10	\$8,477,173	\$13,031,775	\$941,908	\$1,447,975

Note: St. Louis Federal Reserve GDP deflators¹⁴ were used to convert current dollars reported in PHMSA's data to constant 2017 dollars.

The STRIDE law says the Commission may approve a surcharge if it determines that the proposed costs are "reasonable and prudent" and that the proposal is "designed to improve public safety or infrastructure reliability over the short term and long term." The term "safety" is not defined in the law. No metric for the improvement of public safety as a result of the investments is set forth as a marker that would indicate that the billions that ratepayers would be required to pay have measurably yielded a safety return. The term "reliability" is not defined, nor were there any metrics for measuring it set forth in the law. The Commission has the power to "review a previously approved plan," and, if it finds that the investment "no longer meets the requirements" of

improving public safety or infrastructure reliability, it could "alter or rescind approval of that part of the plan."¹⁵ To date, the Commission has not significantly altered or rescinded any gas utility plan it had approved under STRIDE.

The law requires either safety or infrastructure reliability improvements in the short-term and long-term. Safety as measured by serious accidents and their outcomes has, if anything, deteriorated in the nine years since STRIDE went into effect. Costs of significant natural gas distribution system incidents have gone up by about 50%. Is everything to be ascribed to infrastructure reliability without any metrics? What customer benefits correspond to the billions that ratepayers will pay?

Maryland Climate Goals and STRIDE

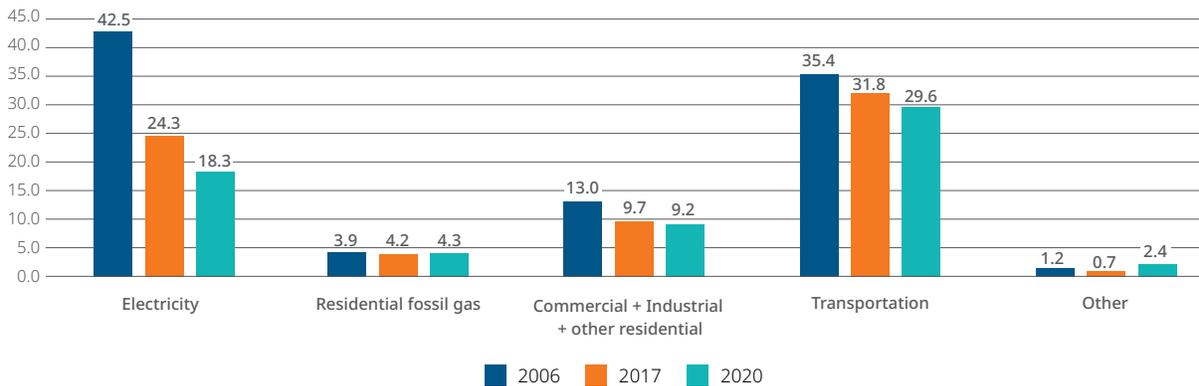
Two laws have been passed since 2013 that are material to revisiting STRIDE. The first is a law passed in 2021 that requires the Public Service Commission to take climate change into account in its proceedings and decisions according to the most recent scientific evaluation of the matter by the Intergovernmental Panel on Climate Change.¹⁶ That science indicates that limiting average global temperature rise to 1.5° C is essential; this indicates global net-zero greenhouse gas emissions by about 2050. Having contributed most to the problem, wealthy countries like the United States have greater responsibilities in meeting that target under the foundational treaty on climate—the

1992 United Nations Framework Convention on Climate Change.

Maryland’s Climate Solutions Now Act of 2022 sets goals that are consistent with recent science. It sets a goal of net-zero greenhouse gas emissions by 2045 and an intermediate term goal of 60% reduction of emissions relative to 2006 by the year 2031.¹⁷

Figure 3 shows the evolution of CO₂ emissions from the energy sector as estimated by the Maryland Department of Environment. It is notable that emissions have been declining in the major sectors of emissions except the residential uses of natural gas.

Figure 3: Maryland energy sector CO₂ emissions by consuming sector for the years 2006 (baseline), 2017, and 2020.



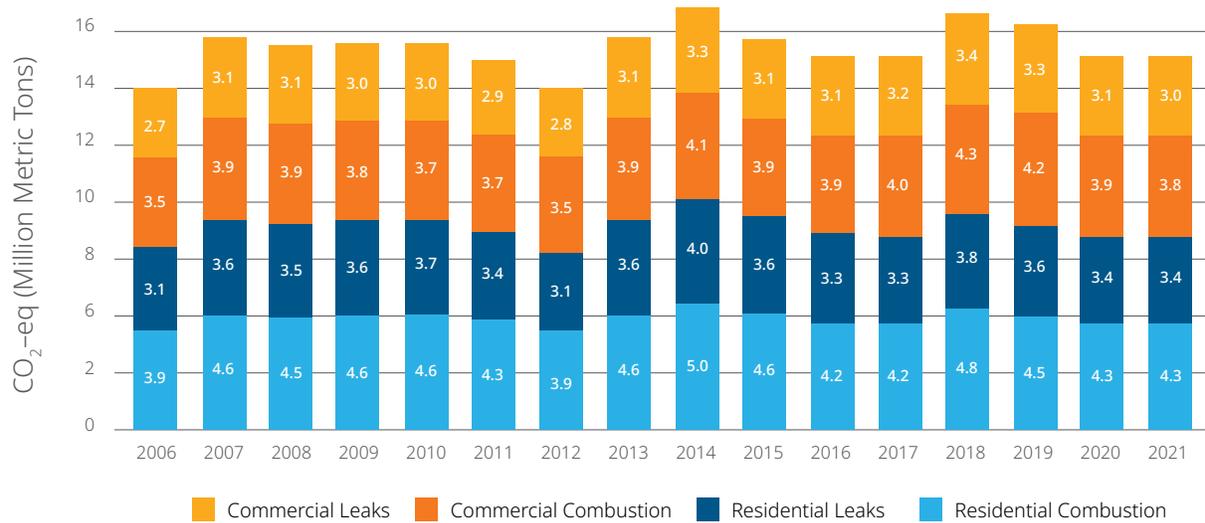
Note: While labeled CO₂-eq in the official inventory, natural gas leaks are accounted for in a separate category called “natural gas industry” not shown in Figure 3.

Source: Maryland Department of Environment greenhouse gas inventories.¹⁸

The emissions shown in Figure 3 do not include the impact of natural gas system (methane) leaks. Figure 4 shows greenhouse gas emissions from residential and commercial

buildings when leaks are factored in using a 20-year global warming potential (GWP) for methane, as required by the 2022 Climate Solutions Now Act.

Figure 4: Residential and commercial sector emissions due to natural gas use. Overall leak rate for natural gas taken as 2.7%.



Source: Reproduced from Makhijani et al., 2023, Figure 4-2, p. 100. Leak rate based on natural gas sold and calculated from the Alvarez et al. 2018¹⁹ rate of 2.3% based on natural gas production.

The STRIDE law includes the reduction of greenhouse gas leaks as one of its goals. BGE has claimed in its recent natural gas rate case before the Commission that STRIDE pipe replacements between 2017 and 2021 reduced natural gas leaks by nearly 47,000 tons of CO₂-equivalent annually.²⁰ This estimate was not based on measurements, but rather calculated based on formulas provided by the EPA for national averages of leaks from different types of pipes, as allowed by federal regulation.²¹ But even taking it at face value, it is a meager return on the vast sums invested.

The 2017-2021 period was a mix of STRIDE I and II—with BGE capital expenditures about \$750 million total in this period.²² Over time, ratepayers would pay roughly \$2.2 billion, including BGE’s profit. The cost of achieving this carbon reduction via leak reduction would depend on how long the gas pipelines were in use. If natural gas or other forms of methane (such as the so-called “renewable natural gas”) were to enable continued use of these pipelines, the 47,000 tons per year might extend for as long as 50 years (assuming no deterioration in the replaced pipes). But if pipelines

become stranded costs, as is more likely if the Climate Solutions Now Act is rigorously implemented, it might be as little as 25 years, possibly less depending on the geography and pace of distribution system retirement.ⁱⁱ Using this range, the cost to ratepayers of avoiding CO₂-equivalent emissions would be between \$1,000 and \$1,900 per ton (rounded). This is extremely expensive greenhouse gas mitigation. For instance, the cost of one of the most expensive methods—capture from the air (known as direct air capture)—is estimated to be in the range \$250 to \$600 per metric ton.²³ Far cheaper methods of mitigation are widely available. Thus, even by the leak mitigation metric, STRIDE investments cannot be said to be successful—much greater carbon reductions could be had for the same investment.

The relatively constant, or even slightly rising emissions due to natural gas use since 2006 in the buildings sector present a contrast with the other major sectors, where there have been moderate to large reductions in emissions since 2006. Given that there are difficult sectors for emissions reduction, such as cement production, high temperature industrial heat, and aircraft fuel, the elimination of natural-gas-related emissions from the buildings sector will have

to be nearly if not entirely complete to meet the requirements of the 2022 Climate Solutions Now Act. Reinforcing that case is the stark fact that phasing out natural gas will occur as an economic imperative in the medium term—well before 2045—as discussed below.

The need to reduce natural gas-related emissions from the buildings sector almost completely has been recognized as a climate imperative in the most recent study commissioned by the Maryland Department of Environment. Maryland's Climate Pathway,²⁴ published in 2023, estimates that the Climate Solutions Now Act will require actions in the buildings sector such as replacing appliances that use natural gas with those that use electricity and electrifying heating, in addition to making efficiency improvements for these end uses. The study estimates that to meet the targets of the Climate Solutions Now Act, natural gas-related greenhouse gas emissions in the buildings sector would decline by about 90% between 2006 and 2050, with the corresponding declines in natural gas use in commercial buildings estimated to be close to 100% and that in the residential sector estimated to be about 80%.^{25,iii}

ⁱⁱ As discussed below, retirement of gas infrastructure is and should be an option. For instance, that is the purpose of a pilot project proposed by Public Service Company of Colorado in a commercial area in Boulder.

ⁱⁱⁱ The analysis in this report shows that retaining any significant natural gas use, much less 20%, would result in serious negative economic and social impact, so that essentially complete electrification of the residential sector is essential.



Natural gas rates

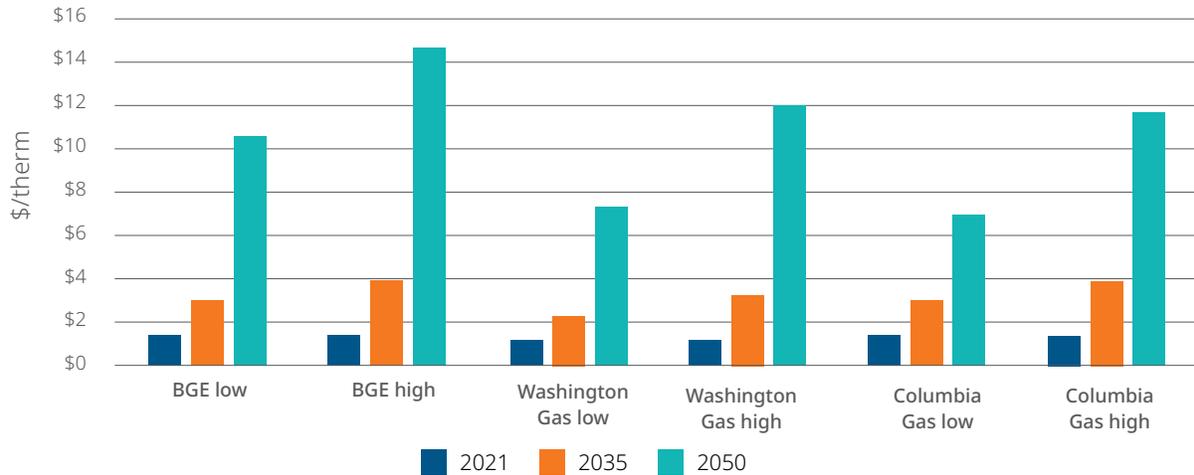
In the absence of affirmative policy action, declines on the order of 90% in residential natural gas use in the next 25 years or so will entail significant stranded costs, skyrocketing rates, or both. For instance, Figure 1 above shows that if STRIDE investments continue, natural gas ratepayers will be paying for them for another six decades. The same dynamic applies to new pipelines and new natural gas connections. Maryland's Climate Pathway, commissioned by the Department of Environment to inform the state's "thinking and next steps to confront the climate crisis" recognized the problem in a section entitled "System Fragility Under Rapidly Declining Usage" of natural gas. But the study did not substantively address how to solve the problem; it only called for future research:

A rapid decline in natural gas consumption means that natural gas customers remaining in the system would likely experience higher utility bills due to infrastructure costs being spread over a smaller customer base. This would have a disproportionate impact on LMI [low- and moderate-income] consumers and renters who are unable to switch to alternative energy sources because they don't own their own equipment or can't afford to electrify their equipment.

Mitigation of cost impacts for LMI customers will become essential in these circumstances to ensure an equitable transition. Research on methane leak detection and prevention strategies has also highlighted the challenges faced in pursuing these strategies as the system loses customers and has limited capital resources. However, continuously expanding natural gas infrastructure would delay the inevitable transition to clean energy and could cause major economic losses from stranded assets. Further research is needed on mid-transition system dynamics to address these issues effectively and determine the rate impacts on customers of lower system throughput.²⁶

This is an excellent problem statement—with one important omission. It does not mention the vast STRIDE investments in existing infrastructure; since these are recoverable through rates with a return on investment until fully depreciated, the impact on rates will be compounded, as has been demonstrated in a 2022 study by the Office of People's Counsel (OPC). Figure 5 shows the impact on rates as estimated by OPC's modeling of natural gas use reduction compatible with the Climate Solutions law.

Figure 5: Natural gas residential rate changes with continued STRIDE investments between 2021 and 2050.



Note: \$/therm calculated in constant 2020 dollars

Source: OPC 2022²⁷ p. 19

Makhijani et al. (2023) found very similar results when they analyzed the problem in a comprehensive study examining the policies needed to achieve equity in the energy transition for low- and moderate-income households—and the severe increases in energy cost burden of a failure to achieve equity. The study also found that “renewable natural gas” and other fuels claimed to be low-emissions replacements for natural gas would result in an even worse problem because these fuels are more expensive than natural gas.²⁸

STRIDE is not the only mechanism through which customers are threatened with long-term costs associated with replacing natural gas infrastructure that Maryland’s climate goals will render obsolete. BGE has now shifted its pipeline replacement program to its 2023 long-term rate case where that activity is mixed up with a range of other investments, including the replacement of regulators. BGE’s pipeline

replacement program includes supply of gas at higher pressures. As a result, BGE is now replacing gas regulators to match the pressure changes on the grounds of safety, reliability, and reducing leaks. The regulators alone have cost about \$81 million in the period 2020-2022 (inclusive)—an average of \$27 million per year, or more than \$6,000 per residence.²⁹ Like the STRIDE pipeline replacements, the regulator replacement costs would be added to the rate base, adding to the already huge stranded cost risks of the STRIDE program.³⁰ It is not that replacement of specific regulators (or pipe sections for that matter) does not have the potential to increase safety. But the failure of STRIDE investments to improve safety generally shows that risk should be identified in the specific instance where the replacements are made.

Despite the above, gas utilities are proposing to increase the pace of investments in replacing natural gas infrastructure relative to the STRIDE

proposals previously filed with the Commission, according to a report by the Office of People’s Counsel. For instance, Washington Gas’s updated STRIDE proposals indicate a 33%

increase in revenue requirements compared to the prior plan.³¹ These utility plans have not yet been approved by the Commission and have therefore not been analyzed in this report.

Energy cost burdens

The average use of natural gas in households that have natural gas in Maryland is about 710 therms (71 million Btu) per year. This means that an average natural gas bill for a BGE customer in 2021 would have been about \$950 per year. The bill would increase to about \$2,100 per year by 2035 and \$7,500 per year by 2050 in the absence of countervailing action(s) as per the OPC “low” estimate of BGE rates. At the “high” end, the corresponding bills in 2035 and 2050 would be about \$2,800 and \$10,300, respectively (in constant 2020 dollars).^{iv} At the high end the estimated natural gas bill in 2050 would be almost equal to half the federal poverty level for a family of three in 2021. In other words, for tens of thousands of Maryland families with very low incomes, natural gas bills alone would equal or exceed their entire income (see below for details). Electricity bills would be on top of that.

Rising costs would—as is generally recognized, and as was noted in the Maryland’s Climate Pathway study quoted above—spur a conversion to electricity. Initial costs of heat pumps for space heating and water heating are estimated

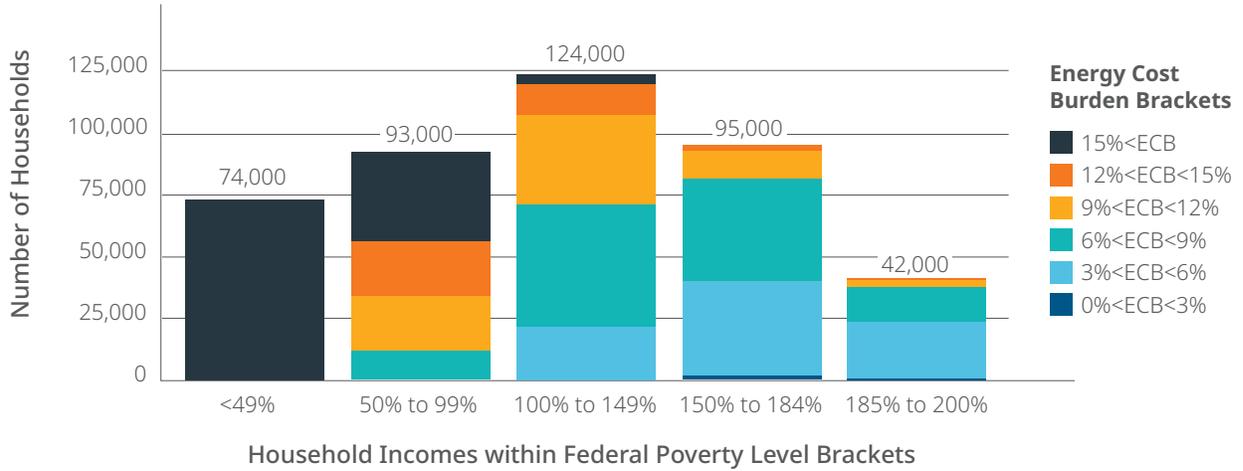
to be somewhat lower than comparable natural gas systems for both new housing and retrofits. At the 2020 rates used in the study, the energy cost of electricity would typically be a few dollars per month higher in case of heat pump retrofits (\$600 over the life of the system).³² These small cost differences would be quickly overwhelmed by rising natural gas rates in the 2030s. This would likely cause a mass exodus from the gas system for homeowners who could afford it. Renters, especially low- and moderate-income renters, would be left facing bills they could not afford because they would not be in a position to make the shift to electrification or even to invest heavily in improving building envelope performance. The classic “split incentive” problem in which the landlord has no incentive to invest because the renter benefits from efficiency investments would become a gaping inequity; large numbers of households would fall into economic distress, ill-health, and all too often homelessness.^v

Figure 6 shows energy cost burdens of low- and moderate-income households in Maryland as estimated in Makhijani et al. 2023.

^{iv} All values are rounded to the nearest \$100. The calculations assume no efficiency improvements in natural gas use and no deterioration of equipment relative to 2021. Since the poverty level is adjusted for inflation, no adjustment in the 2021 dollar levels are necessary since all calculations are in constant dollars.

^v The severe damage to families from unaffordable energy bills is discussed at length in Makhijani, Mills, and Makhijani 2015 and also in Makhijani et al. 2023.

Figure 6: Energy cost burdens of households with incomes below 200% of the federal poverty level.



Note: About 50,000 households with burdens >6% and income >200% FPL not shown.

Source: Makhijani et al. 2023, Chapter 2.

Tens of thousands—and potentially hundreds of thousands—of Maryland households could fall into energy poverty in the 2030s in the face of rising heating bills. By 2035, energy cost burdens for a family of three at the poverty level would increase by seven percentage points if they had average natural gas use.^{vi} As a result natural gas bill increases alone would cause the energy affordability threshold of 6% of income to be exceeded for tens of thousands of families before 2035.

Another way to look at it is that a rise of about \$1,500 in typical natural gas bills^{vii} would more than wipe out the entire benefit of energy assistance programs.³³ The rise in natural gas costs would effectively mean some

combination of a downward economic spiral for low-income and many moderate-income families, increasing need for energy assistance (with corresponding burdens for other ratepayers and/or taxpayers), or some combination of the two. In contrast, gas companies, guaranteed a return on investments approved by regulatory authorities, would, in theory, continue to be made whole.

This is an unsustainable scenario in which almost the entire society suffers serious adverse consequences for the sake of maintaining the profits of a line of business that state law and sound science require to be retired and replaced with cleaner fuel.

^{vi} Using the average of low and high estimates for BGE shown in Figure 5.

^{vii} Using the average of the low and high estimates of rates in 2035 cited above.

Indoor air pollution and natural gas health risks

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. The issue is illustrated by the fact that Baltimore low-income homes have a considerable problem of indoor carbon monoxide (CO) pollution due to natural gas use.

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; it is associated with various adverse health effects at lower levels according to the Agency for Toxic Substances and Disease Registry of the Centers for Disease Control and Prevention, including:³⁴

- Miscarriage at higher levels.
- Permanent harm to the heart and brain even at lower levels.
- Harm to children's mental development when breathed in during pregnancy even at lower levels.

CO is also one of the criteria air pollutants for which the U.S. EPA establishes air quality standards—but only for outdoor air. Thus the public is unprotected by any government regulation or standard from indoor air pollution, including from among the most serious air pollutants like carbon monoxide.

Outdoor air standards nonetheless provide metrics for the levels that could produce harm:

- Nine parts per million of CO should not be exceeded for eight hours more than once a year.
- Thirty-five parts per million should not be exceeded for an hour more than once a year.
- Seventy parts per million requires evacuation.

All of these levels have been exceeded in some low-income Maryland homes. Table 4 shows the data from low-income homes in Baltimore that were retrofitted. The measurements were taken as part of the retrofit procedure; the retrofit would, among other things, remediate the high CO problems.

Table 4: Carbon monoxide pollution frequency (and percentage) in low-income Baltimore homes being retrofitted.

Appliance Type	> 9 ppm (%)	> 35 ppm (%)	> 70 ppm (%)	Maximum
Cook stove	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%)	-

Source: Maryland DHCD data as compiled by and analyzed in Makhijani et al. 2023, op. cit., Chapter 3.

These are high frequencies of a problem that may well be causing many serious adverse health outcomes in Baltimore City. Perpetuating natural gas use will tend to perpetuate

these problems, which would be aggravated by the disproportionate and severe adverse economic impact of rising natural gas rates on low-income households and renters.

Retaining back-up residential natural gas heating is unnecessary

BGE, by far Maryland’s largest natural gas company, recently filed a multi-year rate case that includes a proposal to help households with natural gas heating convert to electric heat pumps. The company proposes to provide rebates—up to \$7,500 per household—for converting natural gas to heat pump heating. There is general agreement that such conversions are necessary to fulfill climate goals. But BGE’s proposal has a catch: the customer would have to keep their natural gas heating system as a supplemental source of heat for the coldest hours. BGE’s

reason: Relying only on air-source heat pumps would require electrical resistance supplemental heat, which would aggravate electric peak loads and require costly investments.

The full text and context of BGE’s testimony is worth quoting because it flies in the face of concerns about this very approach raised by the Mitigation Working Group of the Maryland Commission on Climate Change, which is the state’s official advisory body on climate-related matters. BGE’s rationale in its rate case for

requiring natural gas heating in the context of electrification is as follows:

It is important to note, however, that today's ASHP [air-source heat pump] technology is limited in home heating effectiveness below certain temperatures. ASHPs operate less efficiently at low temperatures, i.e., using significantly more electricity per degree of heating as they attempt to provide heat required for a home at those extreme temperatures. Thus, in our region ASHPs typically require a backup heat source to ensure customers' winter safety and comfort, which backup may be either electric—in the form of more inefficient electric resistance heating—or gas. The State's ambitious CSNA [Climate Solutions Now Act] goals will require broad deployment of ASHPs throughout Maryland and BGE's territory, specifically, so inefficient backup electric-sourced heating with ASHPs threaten to significantly impact our electric grid during winter peaking periods. In order to avoid more expensive grid infrastructure upgrades and overall higher costs to our customers, BGE therefore proposes that customers supplementing natural gas furnaces with ASHPs must maintain a natural gas furnace as the backup heating system to receive BGE's BE Program rebates.³⁵

The technical reference for this reasoning is a report commissioned by BGE that was published in October 2022.³⁶ A similar study published a year before, commissioned by the Maryland Department of Environment from the same company (“E3”)—with the same two principal authors—had recommended the same approach for the same reasons; that study also concluded hybrid heat pump-natural gas heating would be the lowest cost approach.³⁷ The Mitigation Working Group (MWG) of the Maryland Commission on Climate Change

concluded that such a policy would be complicated to implement and raised equity concerns; in response E3 developed a new “MWG Policy scenario” in which essentially all residential buildings would be electrified by 2045 while commercial buildings would retain some flexibility. The scenario was described in the Building Energy Transition report of the Maryland Commission on Climate Change as the lowest cost scenario.

The “lowest cost” claim for the MWG Policy scenario is based in part on allowing substantial continued use of natural gas in the commercial sector and the purchase of offsets to supposedly compensate for those emissions—a dubious proposition at best and one that E3 did not model for other proposed net-zero scenarios to provide an apples-to-apples cost comparison. The analysis in this report shows clearly that the residential sector would confront a grave crisis of affordability and equity should natural gas infrastructure remain in place as most households electrify. The commercial sector would likely confront very similar issues due to inexorable arithmetic of drastically declining natural gas use. However, the commercial sector is beyond the scope of this report and deserves a much more detailed analysis in its own right. The Maryland's Climate Pathway report posited essentially a total phase out of natural gas in the commercial sector by 2050; it did not detail costs and acknowledged the challenges of converting old buildings.³⁸

Maryland is not alone in confronting this issue. The Public Service Company of Colorado, which supplies gas and electricity (and can be regarded as a Colorado equivalent of BGE), evaluated natural gas infrastructure upgrades versus full electrification and elimination of the

gas infrastructure in a commercial section of Boulder, Colorado; it recommended the electrification option as a pilot project. The company also stated, in its regulatory filing justifying the expenditure, that the project was “scalable, and results are applicable to other customers with gas loads that are traditionally viewed as hard to electrify.”³⁹

The analysis in this report shows that electrification of the residential sector is the more economical option and also the more equitable one. It is in accord with the residential sector analysis of the MWG Policy scenario according to which natural gas use would end totally or nearly completely by 2045. Low-income households would be retrofitted and electrified with higher priority. Specifically the Buildings Energy Transition Plan recommended the following:⁴⁰

- An all-electric construction code with “zero direct emissions” should be put in place for residential buildings by 2024.
- All existing homes should have “zero direct emissions” by 2045.
- All low-income homes should have “comprehensive retrofits” by 2030.
- “The state assist households with high energy burden to transition off the gas system before gas rates increase above current levels.”

It is critical to note that the recommendations distinguish between “zero direct emissions”—that is zero emissions at the point of use—from “net-zero emissions” with considerable leeway for offsite offsets for onsite emissions. The recommendations include the possibility of “net-zero emissions” in existing commercial buildings but not in existing residential sector buildings. These findings were endorsed by

the Maryland Climate Commission in its 2022 report to the state’s legislature; the commission attached the Buildings Energy Transition Plan to its report.

The BGE proposal in its 2023 rate case is especially noteworthy—and problematic. BGE, in effect, rejected the residential recommendation of zero residential emissions and support for early full electrification and disconnection of natural gas from low-income homes. Rising costs, especially for low-income Marylanders, were a central concern that was reflected in the report’s recommendations for existing buildings in the residential sector.

The BGE-commissioned E3 study has extensive discussion of the winter peak demand that would be created by electrification of heating. The BGE-commissioned study downplays the potential of demand response to further reduce peak electric demands, despite the fact that it is considered on a par with dispatchable electric generation resources by the Federal Energy Regulatory Commission.⁴¹

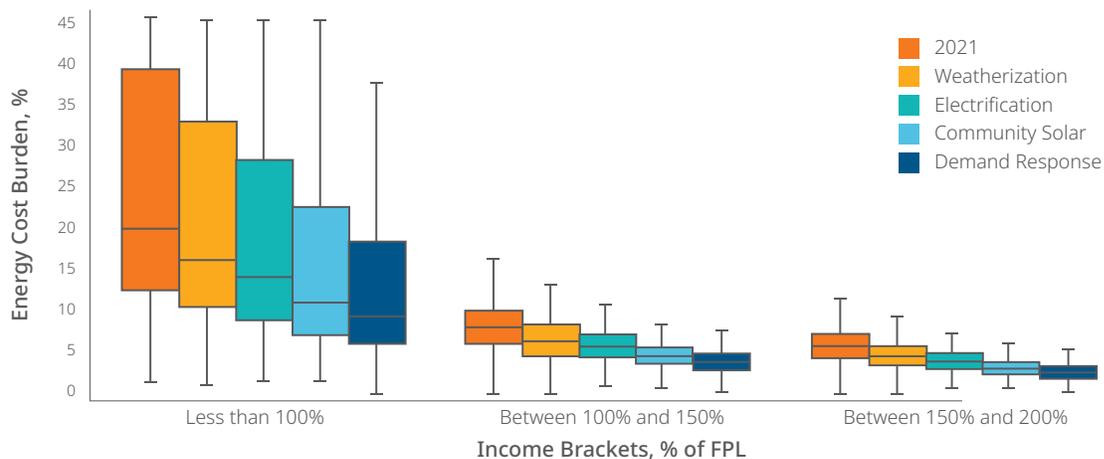
The issue of hybrid systems was also analyzed in Makhijani et. al. (2023) report, which concluded that it would be cheaper to install geothermal heat pumps than to use natural gas as supplementary heat to avoid utility system peaks. Even that is not necessary, given the advances in air-to-air heat pumps that are incorporated in what have come to be called “cold climate heat pumps.” Energy Star has even developed certification or cold climate heat pumps optimized for winter performance.⁴² They have been demonstrated to work *without auxiliary heat* in Minnesota and North Dakota at temperatures below -20° F⁴³—far lower than anything that would be encountered in Maryland.

On a deficient and incomplete analysis, BGE proposed *requiring* households to have natural gas supplemental heat in return for rebates for heat pumps. Egregiously, BGE sought to add the rebate amounts to its rate base so that it could earn a profit on rebates and property that, in the vast majority of cases, would not be owned by BGE but by its customers. In all \$272 million was proposed to be added for electrification rebates, of which 96%, or about \$262 million, was in the buildings sector. The utility rebates in efficiency programs are recovered at cost from ratepayers as part of Maryland's EMPOWER program. Charges for arrears in recovery have been added, but as these mounted the commission ruled that recovery should occur in the same year. These facts were among the reasons that the Office of People's Counsel petitioned the commission to reject that part of BGE's rate case filing.⁴⁴ In deciding in the Office of People's Counsel's favor, the commission noted that the total amount would be large—about \$400 million—and so

in part for that reason should be taken up in a separate proceeding where stakeholders could present alternatives.⁴⁵

Indeed, more economical, equitable, and environmentally responsible alternatives have already been identified. A comprehensive energy equity study analyzing the energy transition in the Maryland residential sector published by the Institute for Energy and Environmental Research and PSE Healthy Energy in 2023⁴⁶ showed that a combination of building envelope improvements, efficient electrification of space and water heating, community solar, and demand response coupled with energy assistance could fully address both climate and equity goals (Figure 7). A remarkable result is that even before the full transition is complete, the funds needed for energy assistance would be less than those available in 2021 while all households would have affordable energy. Only the lowest income households would need bill-payment assistance.

Figure 7: Components of achieving climate and equity goals for low- and moderate-income households in Maryland.



Source: Makhijani et al 2023

Conclusions

Declining natural gas use, skyrocketing rates, and stranded costs are poised to place enormous economic pressures on a dwindling number of natural gas customers. Without strong countervailing action, this problem is on course to become severe in the early to mid-2030s, especially for low- and moderate-income households unable to convert from natural gas to electricity because they cannot afford it or because they are renters.

An increase in bills of \$1,000 to \$2,000 per year by the mid-2030s would devastate tens of thousands of households and seriously increase financial stress for hundreds of thousands more. As it is, large percentages of energy burdened households suffer ill-health because they cannot afford to keep their homes warm enough, among other reasons. Nationally, about 5% of households who receive federal heating bill assistance lose their homes each year due to rent/utility bill payment conflicts. While there are no comparable statewide data for Maryland, there were about 6,400 evictions in Baltimore City alone in the year between July 2018 and June 2019, representing roughly one in 12 low-income renters.⁴⁷ While it is difficult to disentangle all the financial pressures that result in evictions, national data make it clear that rent payment conflicts with utility bills are among the major reasons.⁴⁸

The middle estimate of natural gas rate increases (discussed on pp. 16-18) would increase the energy cost burden of a family of three at 50% of the poverty level by a devastating 13.5 percentage points. The cost to them in terms of economic and social dislocation and ill-health would be incalculable. The cost to society could run into tens of millions of dollars in the form of needs for housing support, more emergency room visits, and dislocation of families.⁴⁹

The Maryland's Climate Pathways study (quoted on p. 16) called for research on and analysis of the problem of rising rates and stranded costs in the middle of the energy transition period—which would be the 2030s. *But the core of the needed research has already been done.* The Office of People's Counsel published two studies on the topic in October 2022 and November 2022; it was also addressed in detail in Makhi-jani et al. (2023).^{50,viii}

The math is straightforward; so are the conclusions. It is an economic, social, and political imperative that natural gas use in the residential sector be phased out as early as possible and at the latest by Maryland's net-zero date of 2045. To insulate low-income households from catastrophic economic consequences of declining natural gas use, electrification with disconnection of gas should be completed before 2035 to the greatest extent possible.^{ix}

^{viii} Interestingly, Maryland's Climate Pathway also does not address the STRIDE law or the investments in it that are a principal part of the state's stranded cost problem.

^{ix} The Buildings Transition report of the Mitigation Working Group recommended completion by 2030. While this would be desirable, it also critical to ensure quality installation and educational efforts of both the contractor and consumer communities. In the latter case, demand response participation and education for that should be integrated into the installation process.

To achieve this, state policymakers need to take several steps:

- The STRIDE program must be repealed.
 - STRIDE investments have not prevented or mitigated natural gas system-related fatalities. Rather, all fatalities in 2005-2022 timeframe occurred in the post-STRIDE period. None were related to material causes such as aging, corrosion, or defective welds.
 - The STRIDE law creates an economic landscape in which continued large-scale use of natural gas would be necessary to avoid huge stranded costs and steep natural gas rate increases in the 2030s.
 - STRIDE law and other continued major investments in the regulated gas infrastructure are in serious conflict with state's climate and equity goals, which require a near total elimination of the use of natural gas in residential (and in some scenarios, commercial) buildings by 2045.
- Efforts to achieve the same ends as the STRIDE program through other means—for example, BGE's current rate case—should also be blocked.
- The PSC should order an urgent and detailed identification of specific geographic areas with clear safety issues, with actual field data and gas company records.
 - The most urgent specific safety problems should be addressed by appropriate combinations of repairs and investments.
 - At the same time these very areas would be targeted for priority electrification especially if there are investments with profits attached rather than repairs.

- All low-income homes should be fully electrified as early as possible—at the latest by the mid-2030s.
- Maryland should require new residential and commercial buildings to be all-electric by 2025. Electric technologies, especially for home heating, are now more cost-effective for customers, and new federal incentives can reduce costs further.
- The Maryland Public Service Commission should agree to the February 2023 request of the Office of People's Counsel to initiate a broad proceeding on natural gas that includes economic and climate considerations and that considers both the steps needed in the short-term as well as the long-term climate and economic imperatives discussed above.⁵¹

It is now widely recognized that all-electric, efficient new residential construction as well as all-electric retrofits (along with efficiency improvements) are central to meeting climate goals efficiently, expeditiously, and economically. Yet Maryland follows a course set out by the General Assembly a decade ago that actually accelerates investment in gas infrastructure and directly conflicts with its more recently adopted climate goals, threatens consumers with exploding costs, and perpetuates health and economic disparities. With each passing year, this problem gets worse, both because of continued STRIDE-related investments and investments in expanding natural gas infrastructure with more long-term economic threats to consumers and a greater challenge to meet Maryland's climate goals. State policymakers must step in—and soon.

Endnotes

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³⁷ Tory Clark et al., 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

³⁸ Maryland's Climate Pathway 2023, op. cit., Figure

³⁹ Public Service Company of Colorado, Market transformation Portfolio: 2024-2028 Clean Heat Plan, 2023, pp. 11-12 at https://www.dora.state.co.us/pls/efi/efi_p2_v2_demo.show_document?p_dms_document_id=1002254&p_session_id=

⁴⁰ 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, pp. 9-10, 18, and 20 at <https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Commission/Building%20Energy%20Transition%20Plan%20-%20MCCC%20approved.pdf> pp. 7-10.

⁴¹ Federal Energy Regulatory Commission, Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators, FERC Order 2222, Final Rule, Department of Energy, published on 17 September 2020 at https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf

⁴² Energy Star, ENERGY STAR® Program Requirements Product Specification for Central Air Conditioner and Heat Pump Equipment Eligibility Criteria Version 6.1 (Rev. January—2022) , at <https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%206.1%20Central%20Air%20Conditioner%20and%20Heat%20Pump%20Final%20Specification%20%28Rev.%20January%20%202022%29.pdf>

⁴³ A Minnesota video—“Heat Pump Extreme Cold: Tested” with thermal imaging and temperature data is at <https://www.youtube.com/watch?v=wCZrBI3PFag> ; a similar North Dakota video—“MrCool Heat Pump Heats at -24oF”—is at <https://www.youtube.com/watch?v=v8vizQXwss>

⁴⁴ Office of People's Counsel, Motion to Strike or in the Alternative Dismiss BGE's Proposed Customer Electrification Plan, Case 9692, Before the Public Service Commission of Maryland, 20 June 2023 at <https://webpsc.psc.state.md.us/DMS/case/9692> item 47 in the case log ML 303632.

⁴⁵ Maryland Public Service Commission, Order No. 90755 Baltimore Gas and Electric Company's Application for an Electric and Gas Multi-Year Plan—Order on the Office of People's Counsel Motion to Strike, 9 August 2023 at <https://webpsc.psc.state.md.us/DMS/case/9692> Listing No. 75 in the case number, file number 304507_14718.

⁴⁶ Makhijani et al. 2023, op. cit.

⁴⁷ Tim Thomas, Malcolm Drewery, Meredith Greif, Ian Kennedy, Alex Ramiller, Ott Toomet, and Jose Hernandez, Baltimore Eviction Map, The Eviction Study, 8 May 2020 at <https://evictionresearch.net/maryland/report/baltimore.html>

⁴⁸ Based on a federal survey as analyzed in Makhijani et al. 2023, Sections 5.2 and 5.3

⁴⁹ See Makhijani, Mills, and Makhijani 2015, op. cit., and Makhijani et al. 2023, for detailed explanation of the costs to non-low-income households as a result of dislocation of low-income families to utility bill and other financial stresses.

⁵⁰ OPC October 2022, op. cit. and OPC November 2023, op. cit. , and Makhijani et al. 2023, op. cit.

⁵¹ Office of People's Counsel, Petition of the Office of People's Counsel for Near-Term, Priority Actions and Comprehensive, Long-term planning for Maryland's Gas Companies, 9 February 2023.

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