Energy+Environmental Economics

PGW Diversification Study

Draft Materials

April 2021

Energy & Environmental Economics (E3)
Portfolio Associates
Econsult Solutions Inc. (ESI)

Content

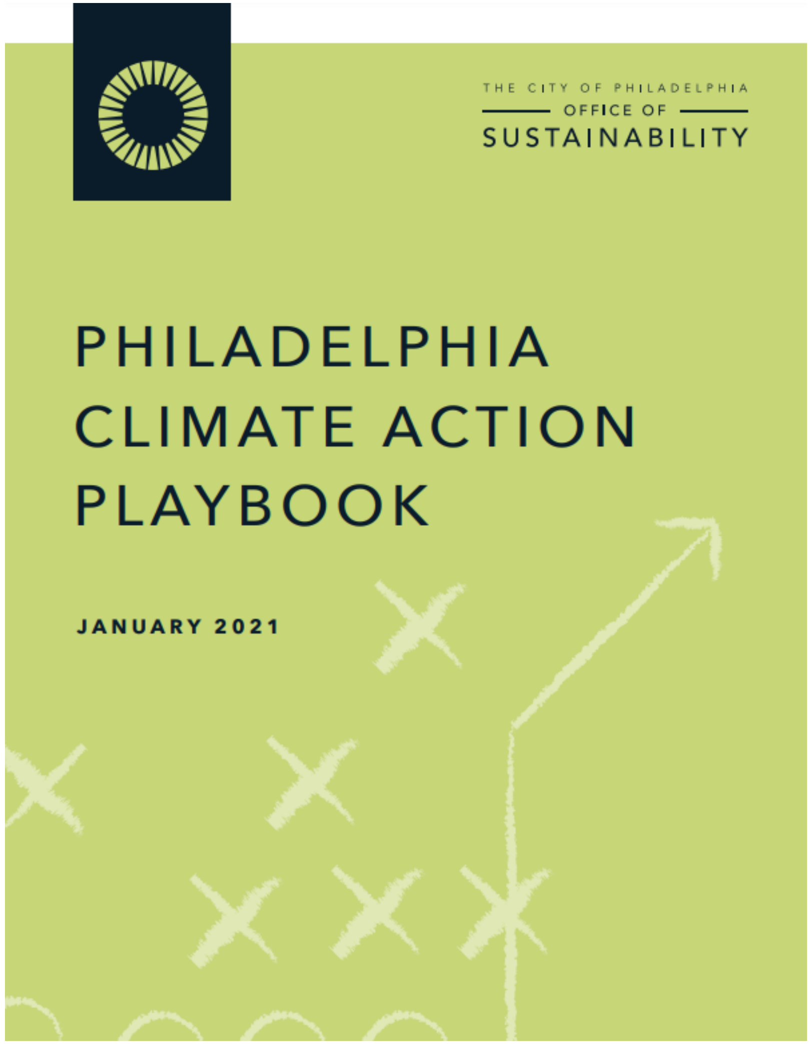
Glossary of terms

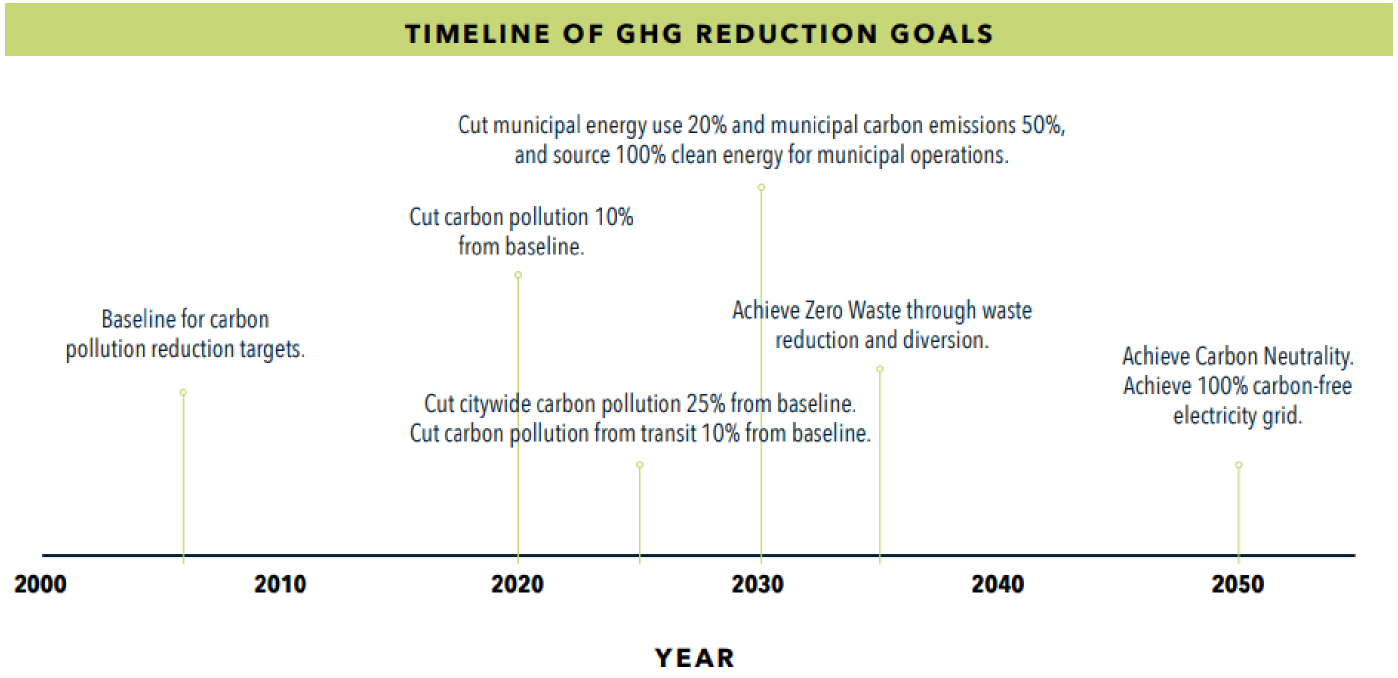
Term	Definition
Decarbonization	The reduction of Greenhouse Gas (GHG) emissions through measures including energy efficiency, decarbonized fuels and fuel substitution.
Greenhouse Gases (GHG)	Gases that contribute to the greenhouse effect. GHGs referred to in this report are carbon dioxide (CO_2) and methane (CH_4).
Carbon Neutrality	Achieving a net-zero society by eliminating or offsetting GHGs.
Renewable Natural Gas (RNG)	Types of gases alternative to natural gas that are considered low-carbon or zero-carbon. This report uses RNG as a catch-all for biomethane, hydrogen and Synthetic Natural Gas (SNG).
Synthetic Natural Gas (SNG)	Type of Renewable Natural Gas produced from hydrogen in combination with a carbon-neutral form of CO_2.
Clean Energy Standard	A market-based electricity portfolio standard that requires a certain percentage of retail electricity sales to come from zero greenhouse gas sources.
Air Source Heat Pump	Electric heating appliance that transfers heat absorbed from the outside air to an indoor space.
Ground Source Heat Pump	Electric heating appliance that transfers heat absorbed from ground (geothermal energy) to an indoor space.
Geothermal MicroDistrict	Network of Ground Source Heat Pumps that connect multiple buildings to a connected infrastructure, in this case piped hot water.
PJM Interconnection	The Regional Transmission Organizations (RTO) in the Eastern U.S. that coordinates the movement of wholesale electricity supplied to Philadelphia.

Energy+Environmental Economics

About this Study

The City of Philadelphia aims to achieve carbon neutrality by 2050 to help avoid the impacts of climate change



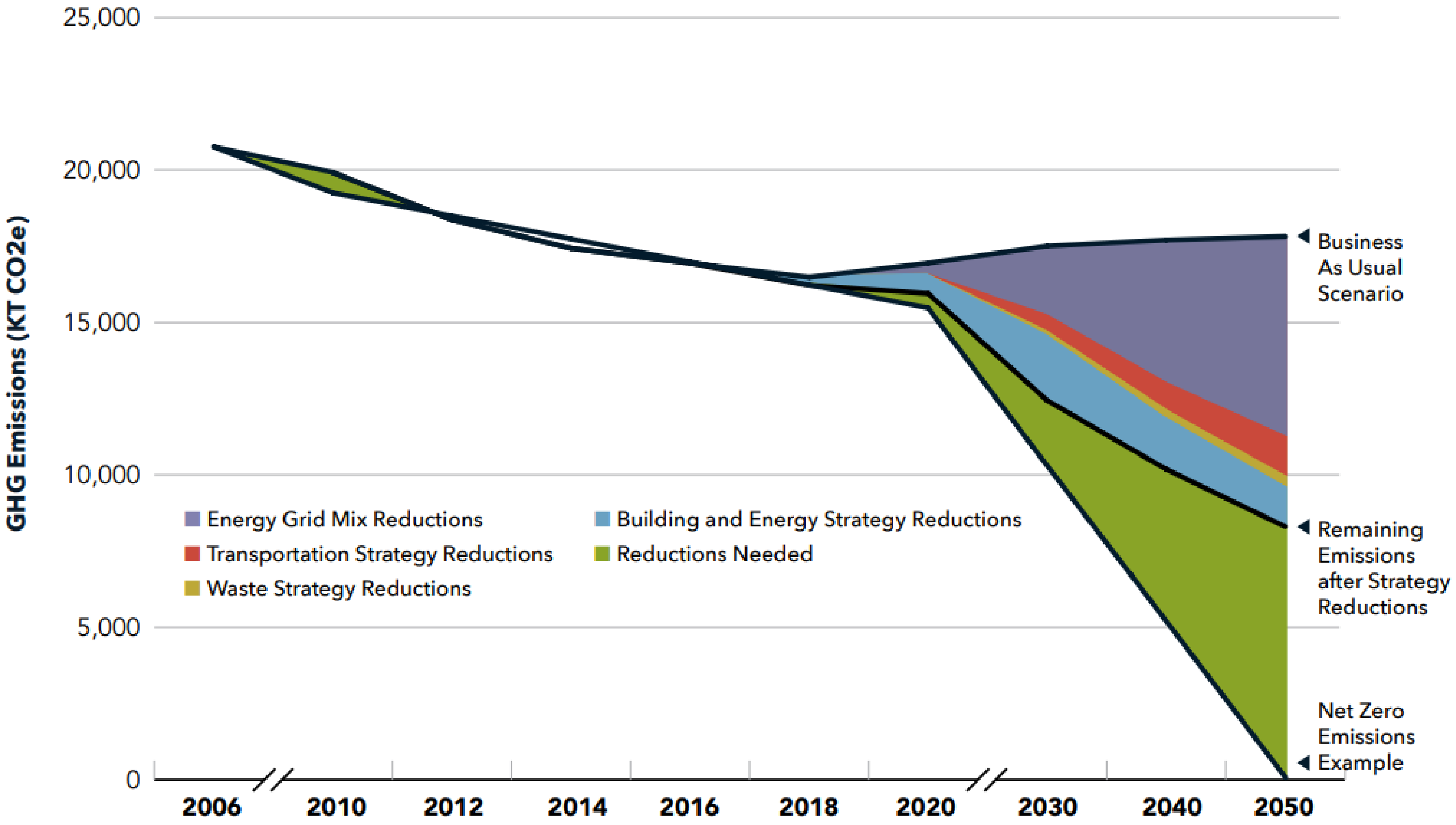


Source: City of Philadelphia (2021). Philadelphia Climate Action Playbook.

72% of GHG emissions in Philadelphia are accounted for by Buildings & Industry

Source: City of Philadelphia (2021). Philadelphia Climate Action Playbook.

The City's carbon neutrality goal requires transitioning away from fossil fuels such as natural gas



Source: City of Philadelphia (2021). Philadelphia Climate Action Playbook.

Philadelphia Gas Works (PGW) is the largest municipally owned gas utility in the U.S.

About PGW

- The largest municipally-owned gas utility in the U.S.
- Delivers natural gas to 500,000 customers in the City
- Manages & maintains over 6,000 miles of gas mains and service pipes
- Employs around 1,600 employees

The Challenge

- **How to decarbonize PGW's system while:**
  - Safeguarding ratepayer interests, especially low-income households
  - Maintaining reliable energy services in the City
  - Retaining PGW's workforce and creating new opportunities for jobs and economic growth
  - Ensuring health and safety of Philadelphians

What challenges does PGW face in transitioning to a low-carbon future?

In a low-carbon future, PGW will need to identify strategies that both reduce Greenhouse Gas emissions and safeguard ratepayer interests. Key challenges include:

Aging Gas Infrastructure

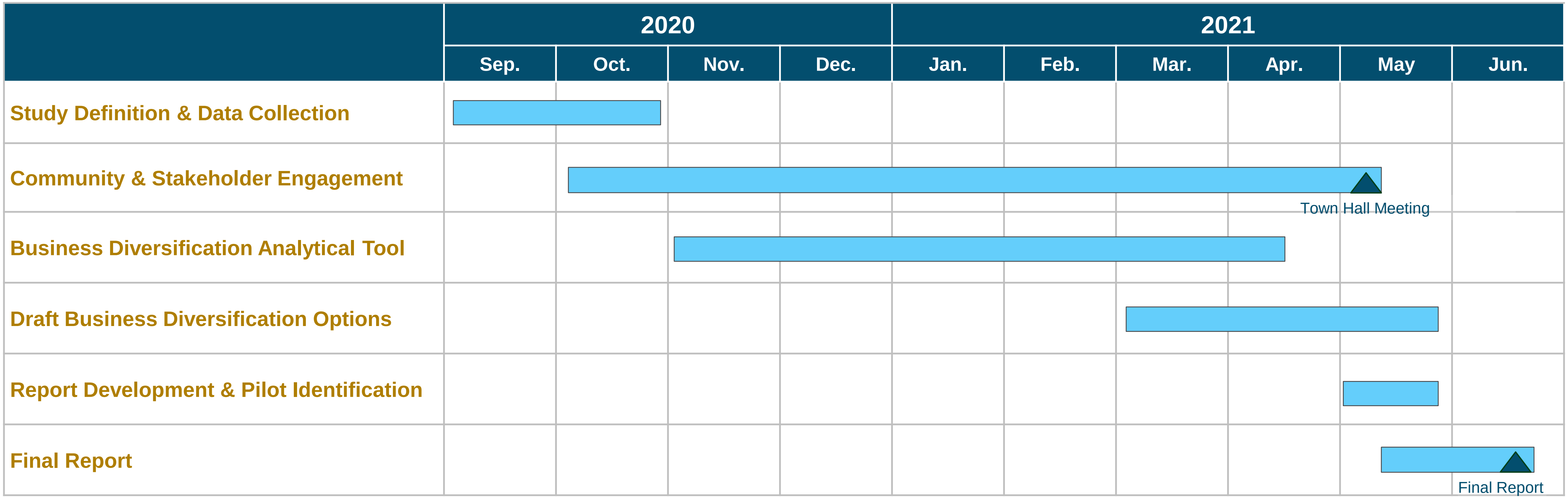
Uncertainties in gas demands

Providing and retaining jobs

Health, safety and equity challenges

The PGW Diversification Study aims to investigate different business strategies for PGW to facilitate GHG reductions

The **aim** of the Diversification Study is to **identify equity-focused strategies** for PGW that **reduce Greenhouse Gas (GHG) emissions** and **maintain competitiveness**



The scope of this study

Key deliverables of this project

- **PGW Diversification Analytical Tool** – *Excel-based tool that examines different (energy) futures for PGW*
- **Business Diversification Study** – *Identifying feasible Diversification Options for PGW*
- **Identification of Pilot Program**

Resulting in…

An overview of Diversification Options and their impacts on PGW and customers

About the Consulting Team

- **Prime contractor**, project manager
- Lead on **data collection** and **development of business diversification analytical tool**
- Lead on development of business diversification study

PORTFOLIO ASSOCIATES INC.

- Translate PGW/City and **community outreach** and analyses into this project
- Support on **drafting Business Diversification Strategy**
- Support report out of study findings

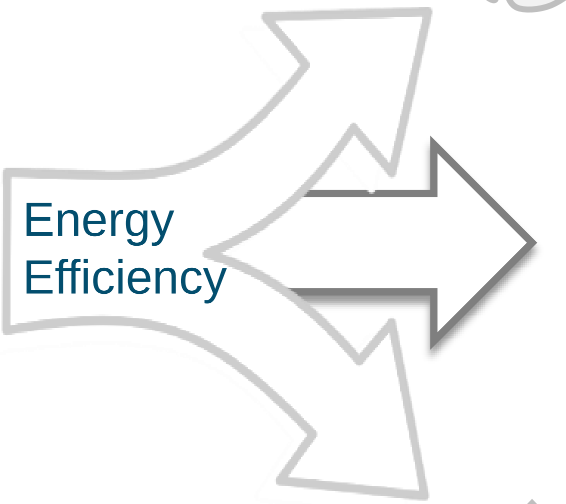
ESI ECONSULT SOLUTIONS INC.
economics | policy | strategy

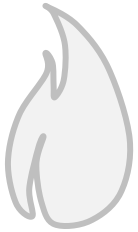
- Consolidate **existing internal and external research** from the City and other resources
- Assist in **evaluation of alternative energy service business models**
- Assist in identifying **carbon reduction and strategic business goals**

Energy+Environmental Economics

Options to decarbonize gas end-uses in Philadelphia: high-level overview

Several strategies can transition PGW and its customers to a low-carbon future



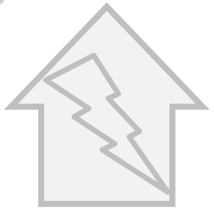


Decarbonized gas

Injecting Renewable Natural Gas (RNG), consisting of biomethane, hydrogen or Synthetic Natural Gas* into the existing pipeline.

Hybrid electrification

Customers adopting heat pumps paired with a gas furnace to meet "peak heat" demands during the coldest periods of winter.



Electrification

Customers adopting electric heat pumps or connecting to geothermal micro-districts, plus induction stoves.

**Synthetic Natural Gas (SNG) consists of hydrogen (H_2) with CO_2 from biogenic sources (SNG-bioCO_2) or from Direct Air Capture (SNG-DAC)*

What is a decarbonized gas scenario?

In a decarbonized gas scenario, customers keep their existing gas furnaces. Heat is supplied by Renewable Natural Gas from a variety of sources.

Waste biogas

Sources:
Municipal waste, manure, landfill gas

Gasified biomass

Sources:
Agriculture/forest residues and purpose grown crops

H_2 Hydrogen

Sources:
Produced from renewable electricity (wind/solar)

Synthetic Natural Gas

Sources:
Produced from hydrogen in combination with CO2 from biowaste or Direct Air Capture

Decarbonized gas

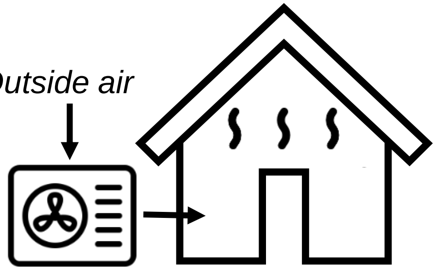
Injecting Renewable Natural Gas (RNG), consisting of biomethane, hydrogen and Synthetic Natural Gas into the existing pipeline.

What is an electrification scenario?

In an electrification scenario, customers replace their gas furnace with a heat pump. The heat pump uses (clean) electricity to provide heat to the home.

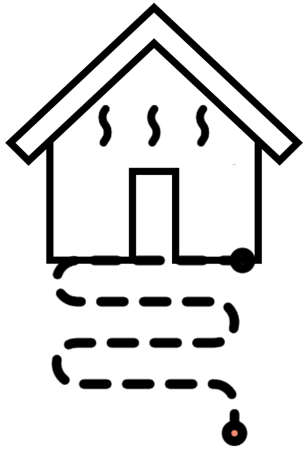
Air-Source Heat Pump

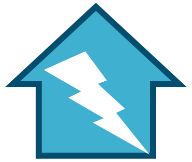
Transfers heat absorbed from the outside air to an indoor space.



Ground-Source Heat Pump

Transfers heat absorbed from the ground to an indoor space. Pipes from neighboring homes can be connected to form a “Geothermal MicroDistrict”. This concept has been studied in Massachusetts.*



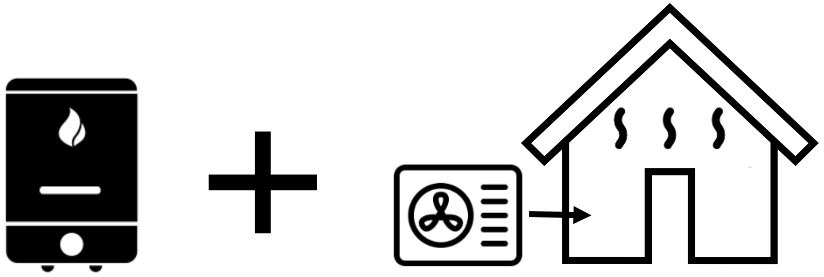


Electrification
Customers adopting electric heat pumps or connecting to geothermal micro-districts, plus induction stoves.

*See: GeoMicroDistrict Feasability Study (HEET & BuroHappold, 2019)

What is a hybrid electrification scenario?

In a hybrid electrification scenario, customers keep their existing gas furnace, but adopt a heat pump to supply heat throughout most of the year.



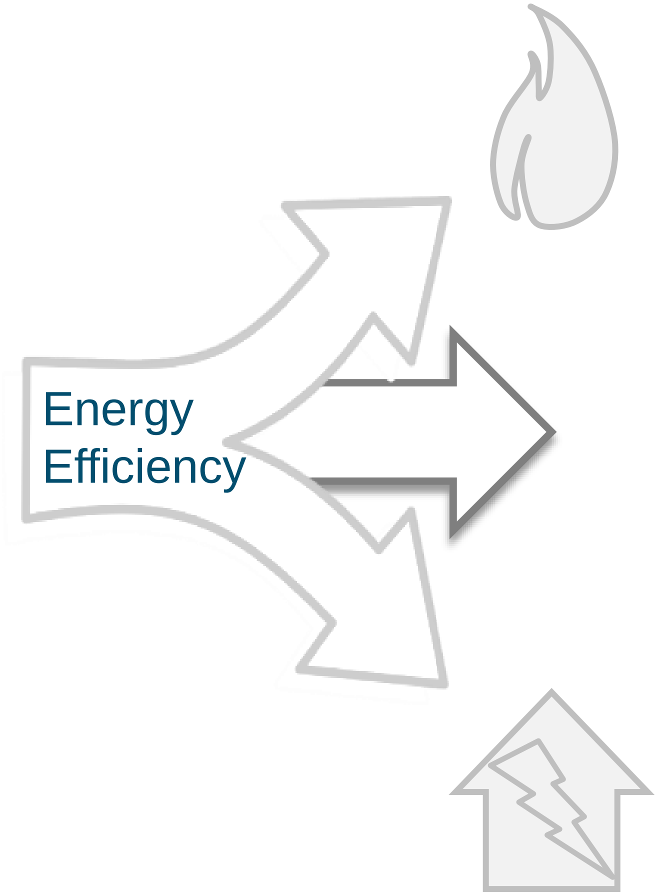
Heat Pump + Decarbonized Gas Back Up

(Air-Source) Heat Pumps are sensitive to outside temperature. In a hybrid scenario, heat is supplied by the heat pump throughout most of the year. When the temperature drops below a certain degree, the gas furnace “jumps in” as a backup source of heat.

Hybrid electrification

Customers adopting heat pumps paired with a gas furnace to meet “peak heat” demands during the coldest periods of winter.

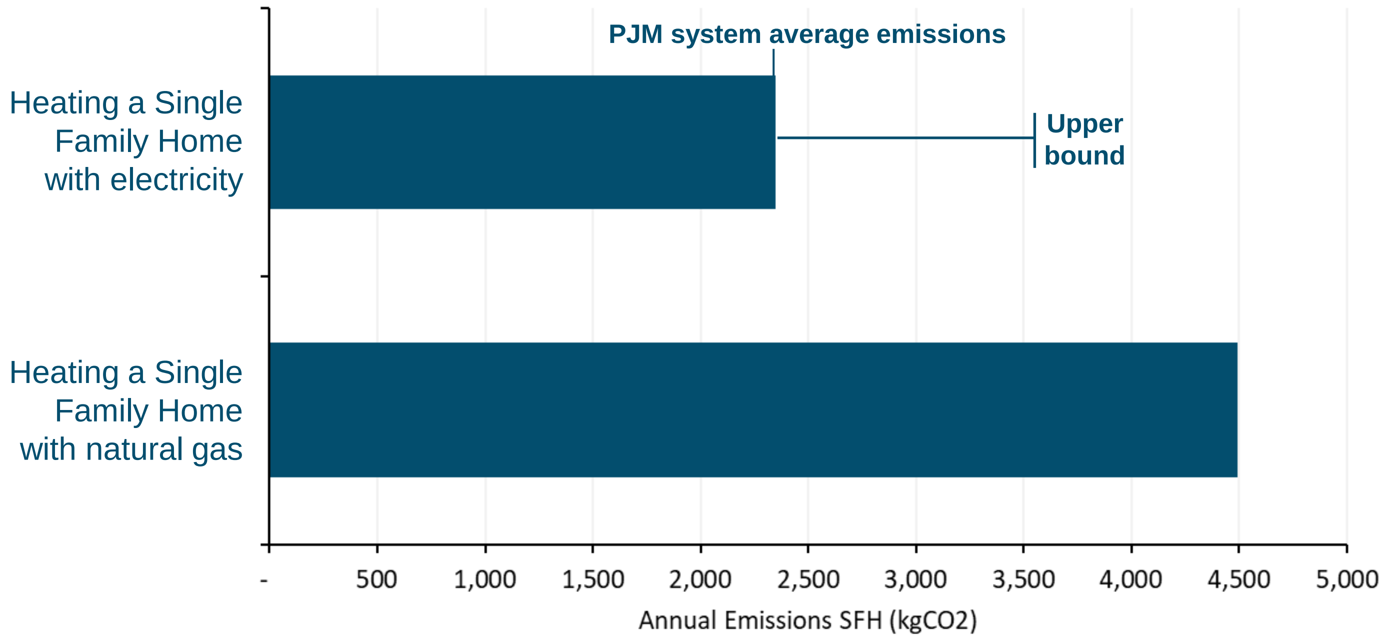
What are advantages and trade-offs of each scenario?



	Potential advantages	Potential drawbacks
Decarbonized gas	Repurposes existing infrastructure with minimal consumer disruption.	High fuel costs, availability of resources, land-use, not commercial at scale.
Hybrid electrification	Utilizes existing infrastructure, reduces demand for more expensive gas, mitigates electric grid impacts.	Requires different utility rate structures, not well studied in the U.S. (though an emerging strategy in Europe).
Electrification	Commercially available products, complementary to decarbonized electricity, improves indoor air quality.	Requires building retrofits, potential electric peak load impacts, may result in stranded assets and future gas workforce reductions.

Replacing gas furnaces with heat pumps results in a reduction in GHG emissions today

Annual emissions resulting from heating a Single Family Home with electricity versus natural gas (includes space heating, water heating, cooking & clothes drying)



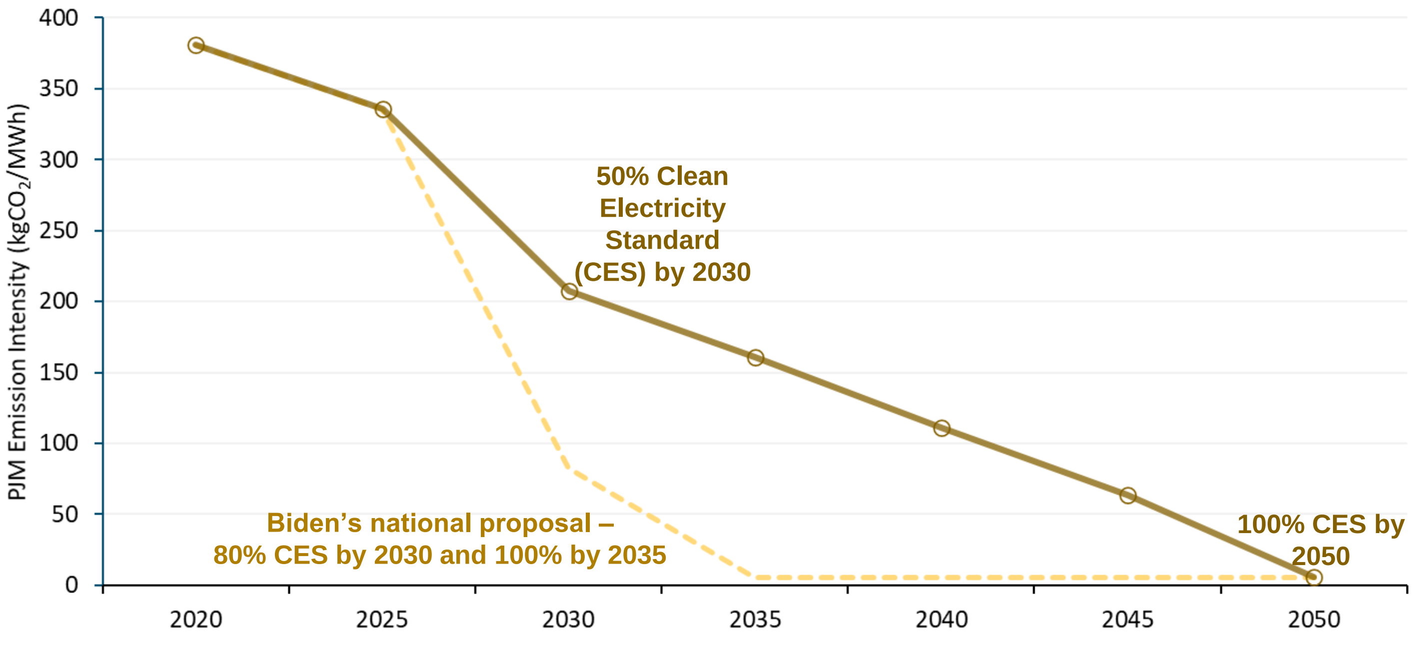
Electricity GHG emission intensities are derived from PJMs annual emissions report. The upper bound represents the marginal on-peak emission intensity, i.e. the emissions of a unit that would provide additional energy to the grid during peak periods. The system average is a weighted average accounting for higher loads during the summer and winter months. The emissions are based on the average heating demand of a Single Family Home in Philadelphia (equivalent to 82 mcf/year). Figure includes emissions for water heating, cooking & clothes drying. Natural gas is assumed to have an emissions coefficient of 53.06 kgCO2/MMBtu

- **The emissions from a customer heating their home with electricity from the grid in 2020 are lower than the emissions of a customer using a gas furnace.**
  - ~43% of electricity generation supplied to Philadelphia comes from zero-GHG energy sources (35% from nuclear resources).
  - Heating a home with a heat pump is significantly more efficient on a site-energy basis than with a gas furnace.
- **By 2050, electricity consumed by heat pumps needs to come from 100% clean sources to align with the City's net-zero goal.**

Source: PJM 2020-emissions-report; E3 analysis.
Heat Pumps are assumed an efficiency of 300%

The emissions benefits of electrification over time will increase as the PJM system decarbonizes

PJM Emission Trajectories Under Potential Future Policies



- In a 100% CES by 2050 scenario, 100% of retail sales is met by clean electricity and 100% reduction in emissions as compared to 2005 levels.
- The Biden Administration has called for an 80% CES by 2030 and 100% CES by 2035.

- **The average emissions intensity of PJM decreased by 23% between 2014 and 2019.**
  - Ongoing coal retirements and renewable energy additions will further reduce PJM emissions over time.
- **Regional or national policy would accelerate the pace of electric sector decarbonization in PJM.**
  - Research by E3 and others finds that deep electric sector emissions reductions can be achieved via policy at relatively low incremental costs.

See, for example:
E3 Least-Cost Carbon Reduction Policies in PJM States – EPSA.
UC Berkeley/LBNL-2035 Report

Energy+Environmental Economics

Integrating stakeholder perspectives: initial outcomes of stakeholder engagement

This Study has (so far) gauged input from stakeholders through three engagements

Stakeholder Workshop

- Workshop Participation
  - 70+ invitees sent Fact Sheet and Registration Link
  - 58 registrants; 43 attendees + OOS/E3/ESI/PAI project team
- Live Polling & Discussions in breakout rooms

Online Survey

- Open 3/24 Wed – 4/12 Mon
  - 391 total responses; 259 completed responses (submitted all pages)
  - 10 Questions
    - 6 multiple choice w/ open-ended option; 4 open-ended
    - >1,000 open-ended comments

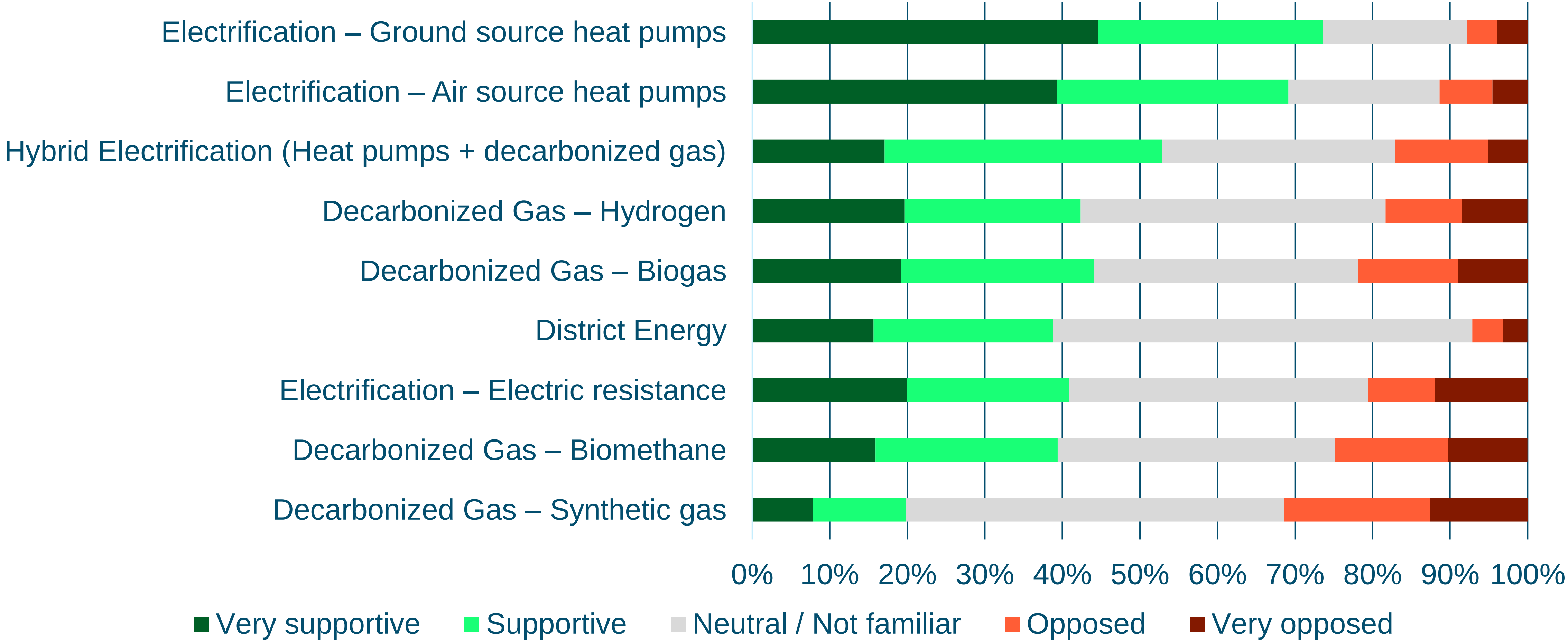
Energy Burden Conversations

- Conversations organized by the Office Of Sustainability* in partnership with the Philadelphia Association of Community Development Corporations (PACDC) and other community groups
- 6 of the most energy burdened communities; 3 focus group discussions per community

Initial results of the energy burden conversations are included in the appendix.

Survey Results Example – Q3: Energy Directions

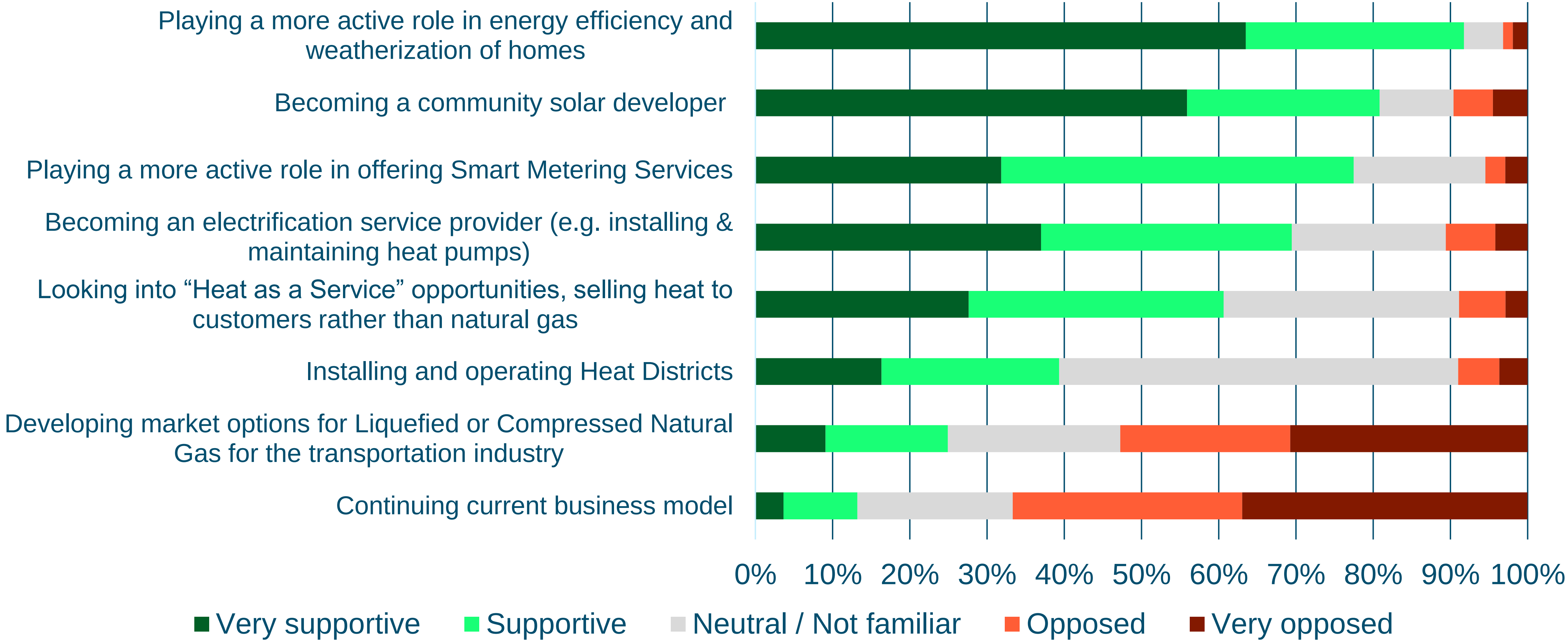
Which of the following potential energy directions for PGW do you support?



n = 324

Survey Results Example – Q4: Business Operations

Which options for diversifying PGW's business operations do you support?



n = 324

Stakeholders were asked to rank different evaluation criteria for the PGW Diversification Study

SOCIETY ORIENTED

GHG emission reductions	*A portfolio that minimizes GHG emissions*
Societal costs	*Aiming for lowest societal costs*
Inclusive workforce opportunities	*Focusing o diversion & inclusion*
Public health & environment	*A portfolio that supports healthy communities*

BUSINESS ORIENTED

PGW generated revenues	*Aiming for sustained revenues*
Infrastructure utilization	*Making optimal use of existing infrastructure*
Regulatory boundaries	*Aligning new business models with current or expected regulation*
Workforce retention	*Aiming to keep the PGW workforce in place*

CUSTOMER ORIENTED

Customer affordability	*Aiming for stable rates & focus on equity*
Consumer disruption	*Solutions that provide the least disruptions for customers*
Energy safety & reliability	*Continuation of safe and reliable energy supply*
Customer choice	*Providing for customer choice and open to competition*

PORTFOLIO ORIENTED

Resilience	*A dynamic portfolio that is able to adapt to unknown variables*
Technology Readiness	*A portfolio with established technologies*
Availability of resources	*A portfolio that makes optimal use of local resources*

Based on stakeholder ranking, the four criteria that ranked the highest were selected for the analysis

Evaluation Criteria	Goal
Impact on GHG emissions	Reduce GHG emissions consistent with City climate policy ambitions
Impact on air quality	Improve outdoor and indoor air quality consistent with City ambitions and stakeholder interests
Impact on rate affordability	Decrease or stabilize rates/bills and reduce energy burden
Impact on revenues & workforce	Maintain a financially sound utility that can continue to maintain safety and reliability, sustain good union jobs in Philadelphia

+ **Impact on GHG emissions, rate affordability & PGW revenues are quantitatively assessed by E3 in this Study. Impact on air quality & workforce are qualitatively assessed.**

Energy+Environmental Economics

Evaluation of PGW decarbonization options: draft findings

E3 evaluated four scenarios across the four evaluation criteria

Overview of decarbonization scenarios	*Quantitative* **Impact on GHG emissions**	*Qualitative* **Impact on air quality**	*Quantitative* **Impact on affordability**	*Quantitative & Qualitative* **Impact on revenues & workforce**
Decarbonized gas				
Electrification				
Hybrid electrification				
Hybrid electrification with Geo MicroDistricts*				

**The Hybrid Electrification with Geothermal MicroDistricts option was added as a potential fourth option as a reaction to stakeholder interest in the Stakeholder Workshop. This option is explained in more detail on page 34.*

Each decarbonization scenario results in both positive and negative impacts

Overview of (full) decarbonization scenarios	*Quantitative* **Impact on GHG emissions**	*Qualitative* **Impact on air quality**	*Quantitative* **Impact on affordability**	*Quantitative & Qualitative* **Impact on revenues & workforce**
Decarbonized gas	✔ Reduces emissions	– No significant change	✘ Pressures long-term gas costs	✔ Current system maintained
Electrification	✔ Reduces emissions	✔ Improves air quality	– Mixed, depending on customer	✘ Large revenue reduction
Hybrid electrification	✔ Reduces emissions	✔ Improves air quality	– Lowest impact option	✔ Current system maintained
Hybrid electrification with Geo MicroDistricts	✔ Reduces emissions	✔ Improves air quality	? Dependent on cost allocation	✔ Additional workforce opportunities

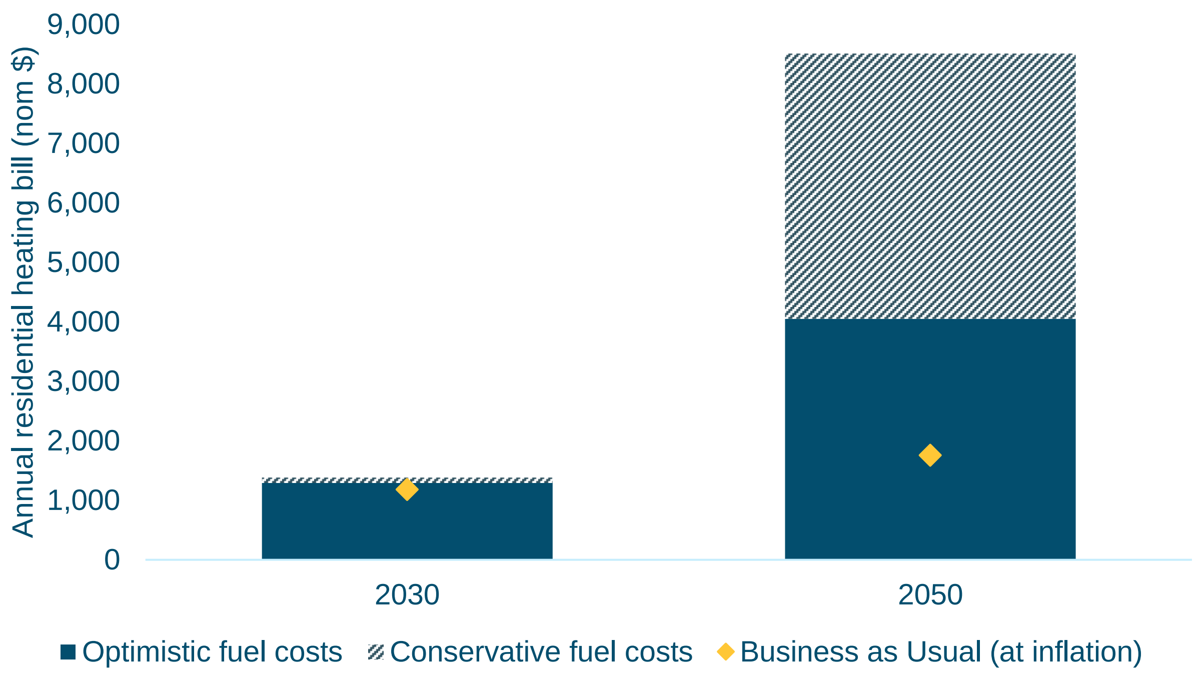
Carbon neutrality achievable in all scenarios (guiding principle)

Proceeding slides will focus on these two criteria

Decarbonized gas: bill comparison without diversification strategies for PGW

	Impact on GHG emissions	Impact on air quality	Impact on affordability	Impact on revenues & workforce
Decarbonized gas	Reduces emissions	No significant change	Pressures long-term gas costs	Current system maintained

Bill comparison without diversifying strategies for PGW: 2030 vs. 2050



+ By 2030:

- A limited blend of Renewable Natural Gas in the pipeline keeps short-term customer bills relatively stable.

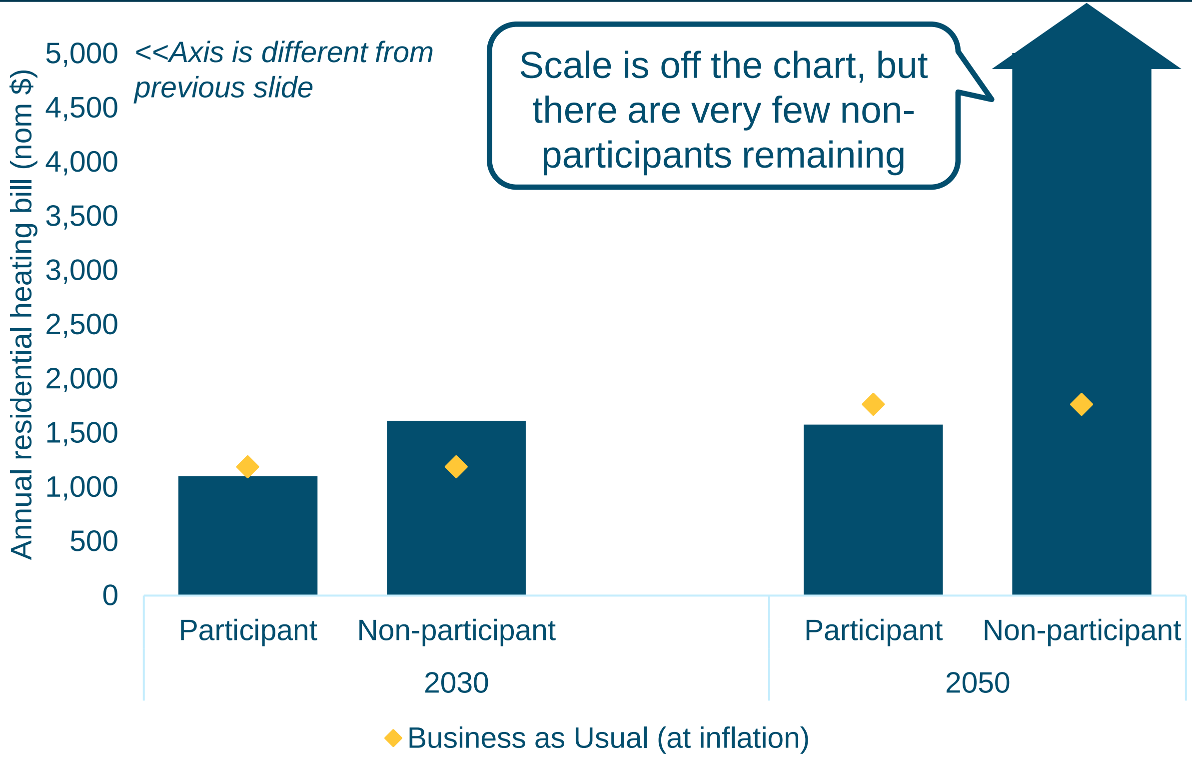
+ By 2050:

- High blending volumes of RNG will result in significant costs as supply relies on expensive types of gas.
  - The magnitude of cost impacts depends on whether RNG follows a "Conservative" or "Optimistic" cost trajectory.
- These cost increases would create an incentive for customers to electrify (for those who are able to do so).

Electrification: bill comparison without diversification strategies for PGW

	Impact on GHG emissions	Impact on air quality	Impact on affordability	Impact on revenues & workforce
Electrification	Reduces emissions	No significant change	Mixed, depending on customer	Current system maintained

Bill comparison without diversifying strategies for PGW: 2030 vs. 2050



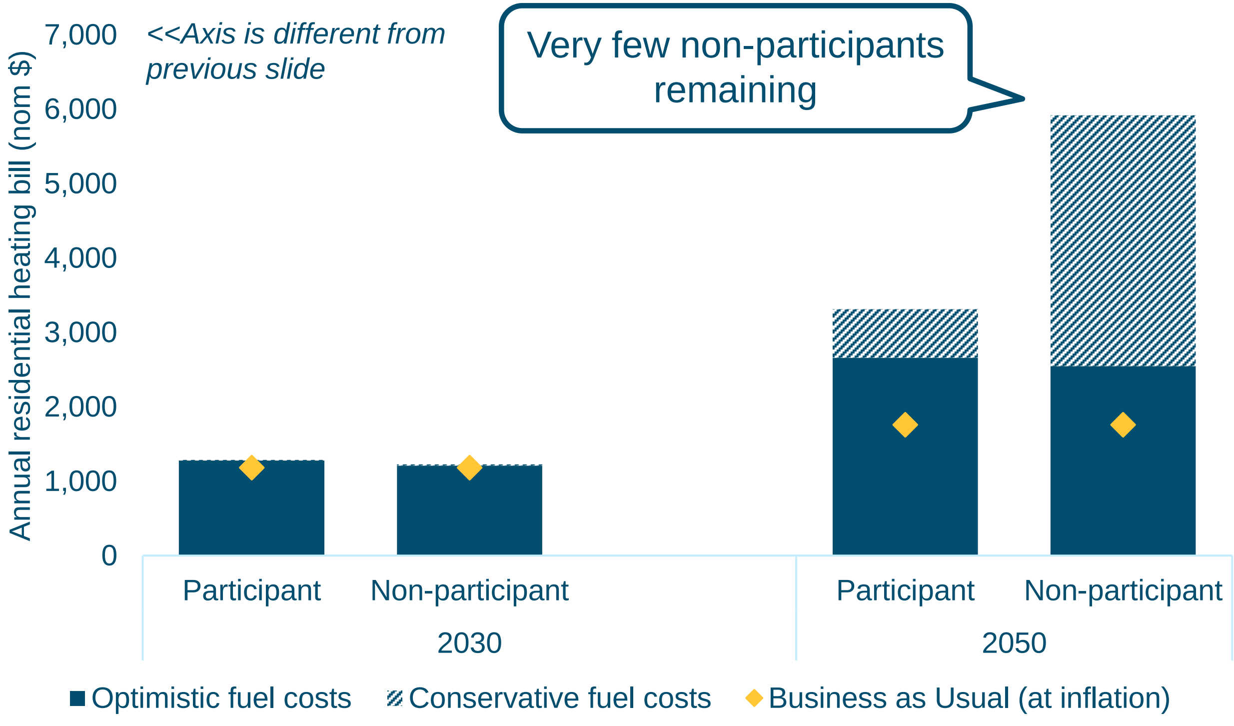
- **By 2030:**
  - Electrification customers have relatively low bills compared to other scenarios, but face higher upfront costs (discussed later).
  - Electrification causes a shift of fixed gas system costs to customers who are not able to electrify ("non-participants").
- **By 2050:**
  - Electrification raises the need to ensure equitable access to electrification benefits to make sure homes are not left with the cost impacts from others shifting away from gas.

Hybrid electrification: bill comparison without diversification strategies for PGW

Impact on GHG emissions	Impact on air quality	Impact on affordability	Impact on revenues & workforce
Reduces emissions	No significant change	Lowest impact option	Current system maintained

Hybrid electrification

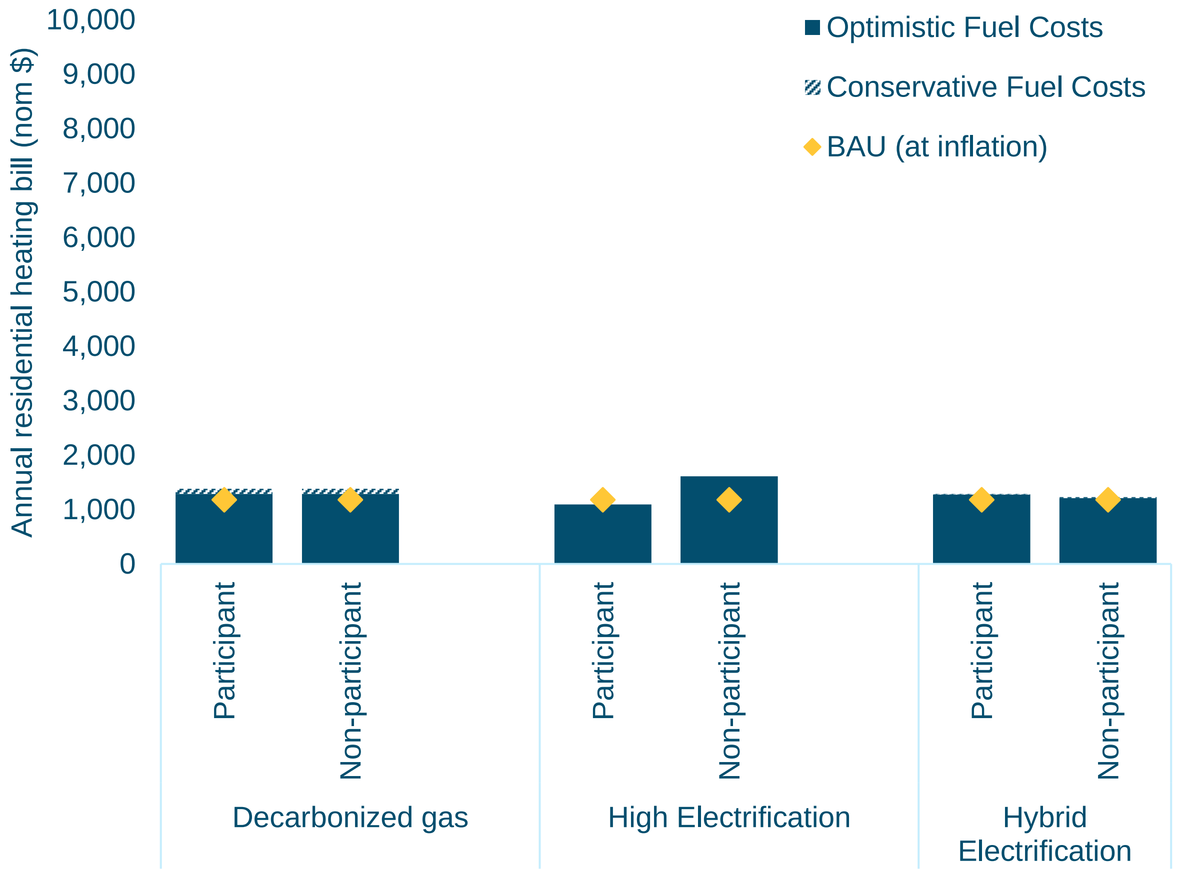
Bill comparison without diversifying strategies for PGW: 2030 vs. 2050



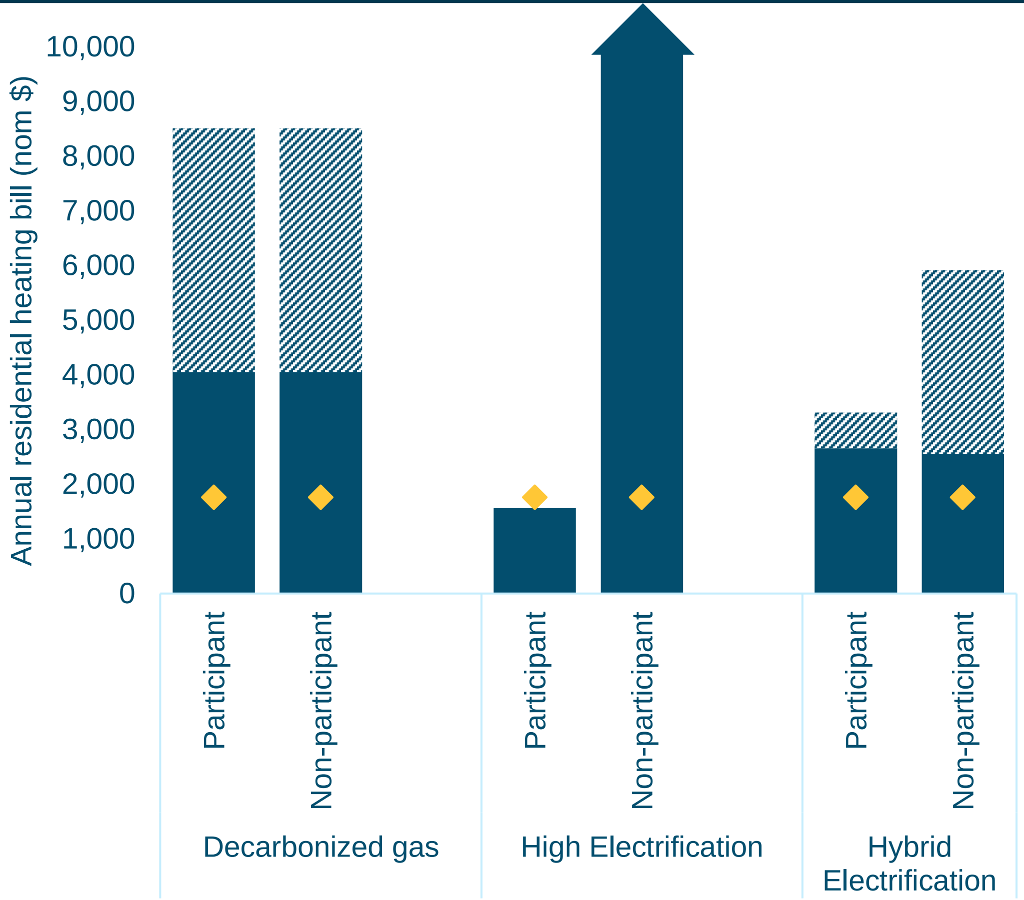
+ **By 2030:**
  - Costs are similar to a Business as Usual case, both for participants (customers adopting a hybrid electrification strategy) and non-participants (customers without hybrid electrification strategy).
+ **By 2050:**
  - Although cost differences are still visible, hybrid approach creates a more equitable outcome between participants and non-participants.

Scenario bill comparison: 2030 vs. 2050

2030 bill comparison across scenarios: participants & non-participants



2050 bill comparison across scenarios: participants & non-participants

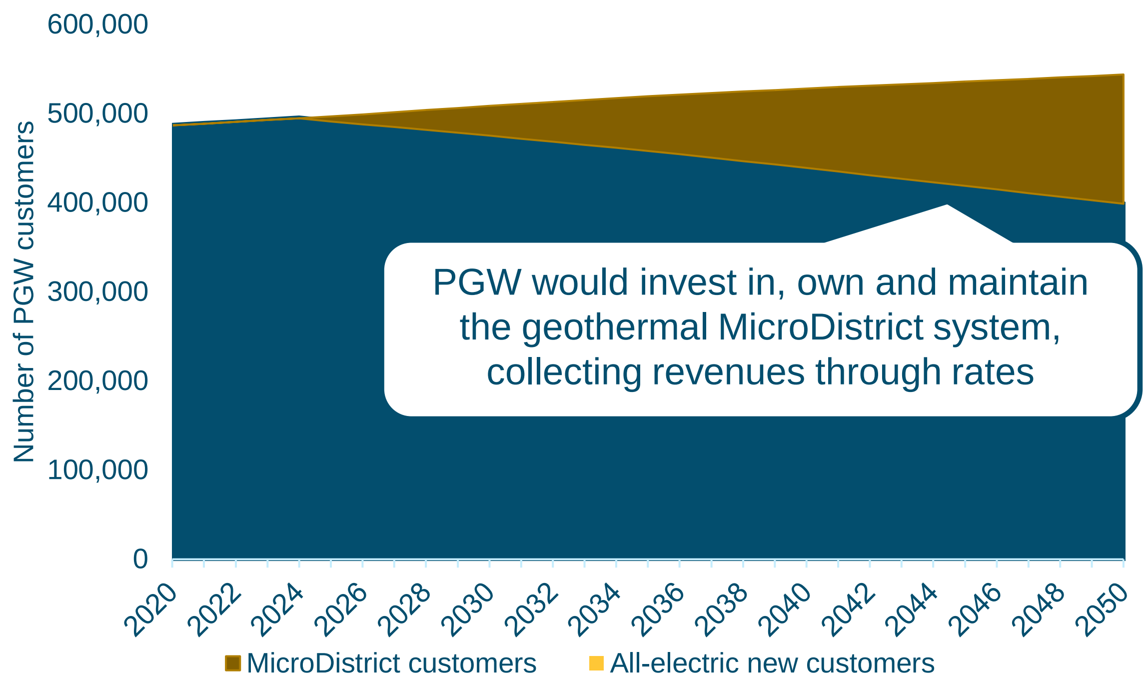


Electric bills are based on customers adopting an Air Source Heat Pump, with a Coefficient of Performance (COP) of 3 for ASHP and 3.5 for ASHP with Gas Back Up. Electric rates are calculated taking incremental electricity (peak) demand into account, and amount to 17.4 cts/kWh in 2030 and 26.3 cts/kWh in 2050 (in nominal dollars). Hybrid bills include both electric and gas costs. Renewable Natural Gas costs are calculated using E3's fuel optimization model (see Appendix). For optimal comparison with BAU, operating costs do not include building shell upgrades.

What about Geothermal MicroDistricts?

	Impact on GHG emissions	Impact on air quality	Impact on affordability	Impact on revenues & workforce
Hybrid electrification + MicroDistricts	Reduces emissions	No significant change	Dependent on cost allocation	Current system maintained

Example: customers switching to Geothermal MicroDistricts



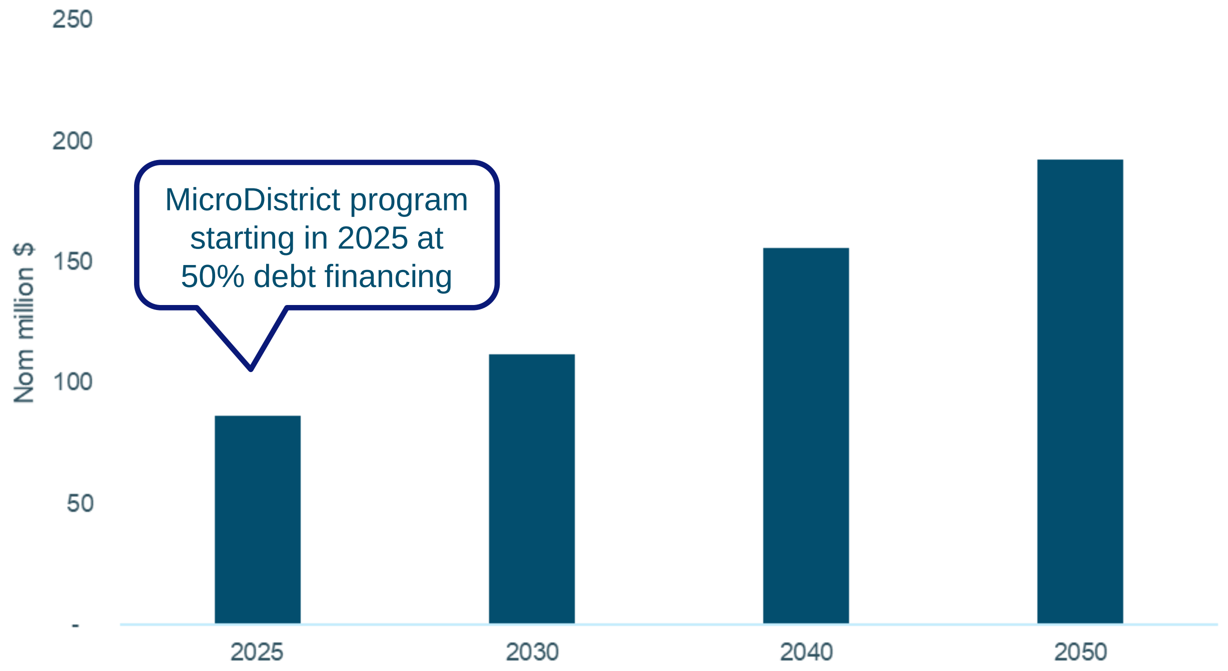
+ **Geothermal MicroDistricts are geothermal heat pump systems that connect several homes to a central infrastructure**
  - PGW could potentially shift its cast iron replacement program to support these systems
  - This effort would involve block or even neighborhood-level retrofits of both PGW's infrastructure and the heating systems used in buildings

Figure represents a high-level estimation of number of customers that could switch over to Geothermal MicroDistricts, assuming cast iron pipes would be replaced by MicroDistricts from 2025 onwards. Additional research on this concept is required.

Geothermal MicroDistricts could provide customer benefits, but are expensive to install

	Impact on GHG emissions	Impact on air quality	Impact on affordability	Impact on revenues & workforce
Hybrid electrification + MicroDistricts	Reduces emissions	No significant change	Dependent on cost allocation	Current system maintained

Incremental (annual) Revenue Requirement with GeoMicroDistricts

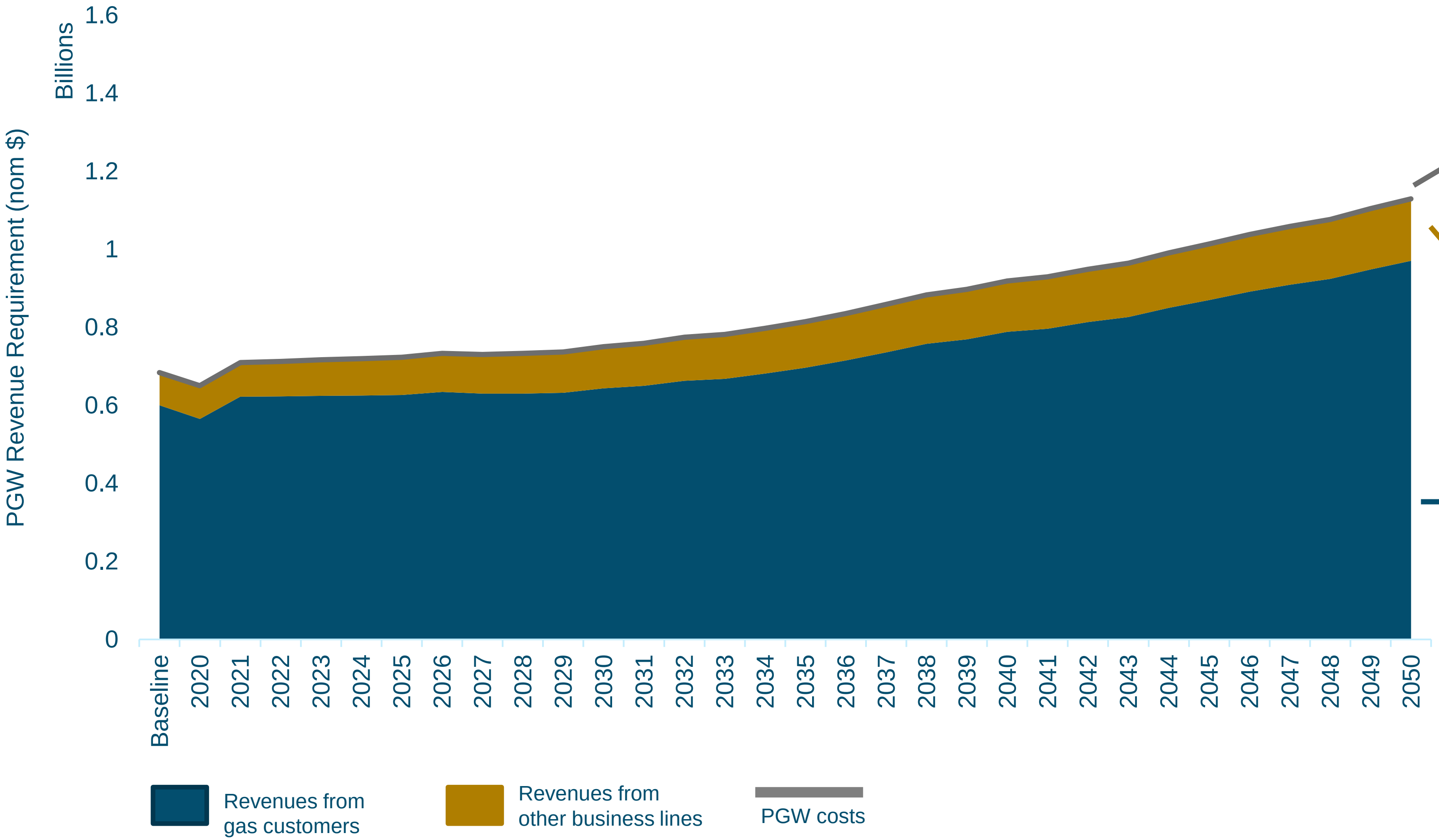


+ **Because MicroDistricts are efficient in operation, monthly fuel (electricity) costs are low for customers connected to the system**
+ **However, the costs of installing the system are high, and "delivery costs" per customer depend on financing & allocation options:**
  - Costs can be socialized over the entire customer base, or allocated to district system customers only;
  - Annual incremental revenue requirement impacts depend on how capital expenditures are financed.

Installation costs are assumed at 13,000 $/ton, which is the average of installed geothermal district systems in Massachusetts (based on the GeoMicroDistrict Feasability Study (HEET & BuroHappold, 2019). However, these costs are highly uncertain and dependent on local characteristics, such as geology & building typology. Sizing of the system is conservative and does not take smoothened demand patterns into account.

Customer bill impacts depend on the recovery of costs from PGW's system

PGW's revenue requirement in a Business as Usual case



The gray line represents the costs PGW needs to collect to maintain the gas system, retain its workforce and procure the gas needed to supply its customers

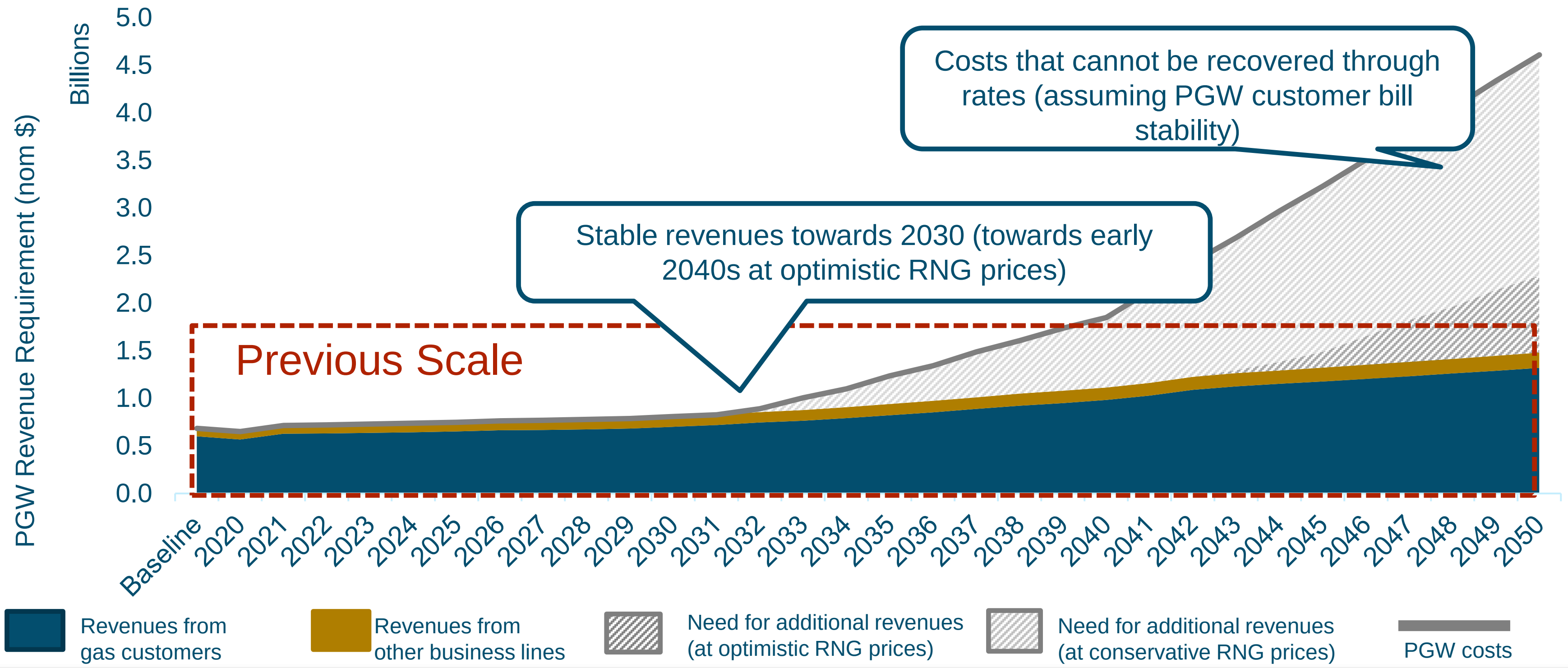
This area represents revenues from PGW from sources other than customer bills. This includes Gas Transportation Services and, for instance, PGW's LNG facilities.

Remaining costs are divided over PGW's customers and determine customers' bills.

Decarbonized gas: what if we assume stable bills? The need for additional revenues for PGW arises

	Impact on GHG emissions	Impact on air quality	Impact on affordability	Impact on revenues & workforce
Decarbonized gas	Reduces emissions	No significant change	Pressures long-term gas costs	Current system maintained

Need for additional revenues in decarbonized gas scenario (at stable customer bills)

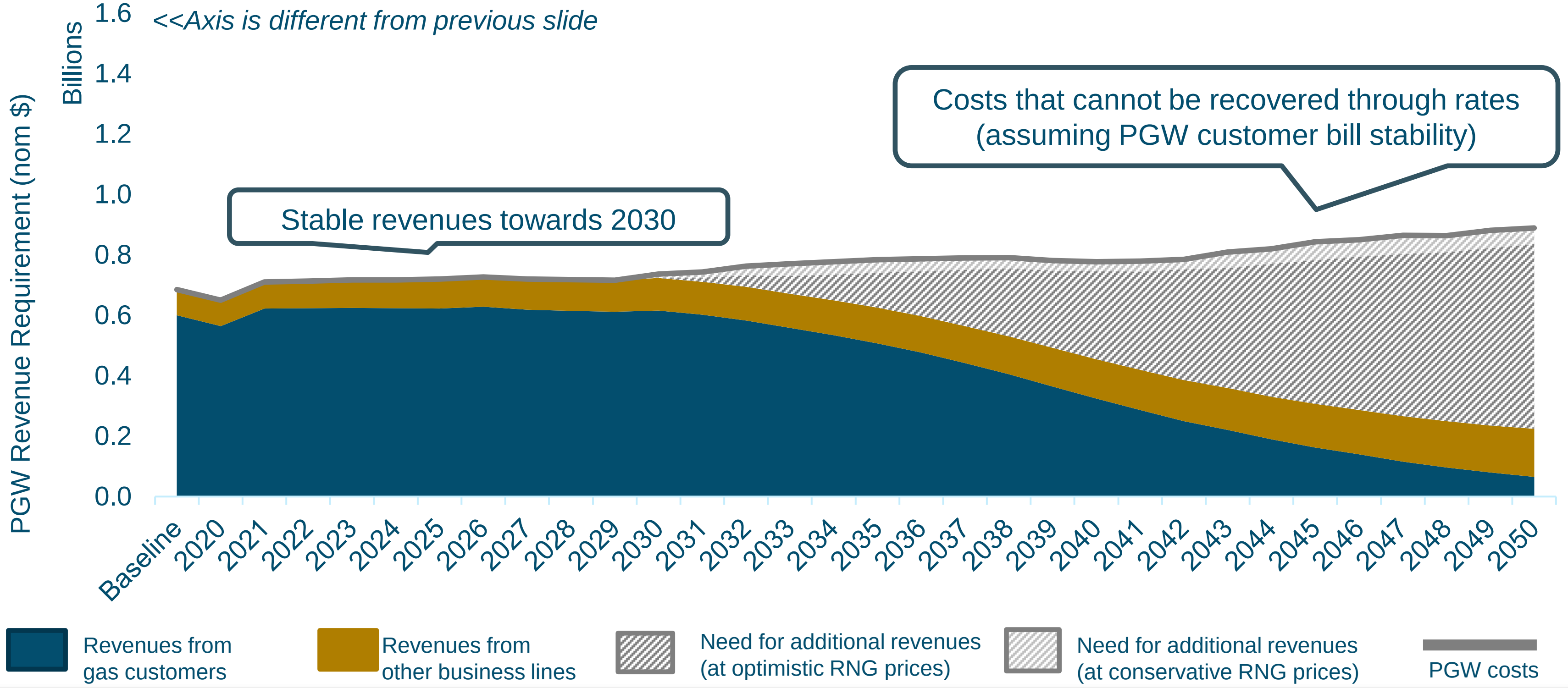


- **Relatively stable revenues may be possible until the early 2040s with energy efficiency and optimistic RNG prices**
- **In the long run, additional revenues through diversifying strategies are required to retain PGW's workforce, i.e.:**
  - Weatherization & Energy Efficiency services
  - LNG & CNG facilities
  - Utility-led financing solutions
  - Community solar operations
  - Geothermal MicroDistricts

Electrification: what if we assume stable bills? The need for additional revenues for PGW arises

	Impact on GHG emissions	Impact on air quality	Impact on affordability	Impact on revenues & workforce
Electrification	Reduces emissions	No significant change	Pressures long-term gas costs	Large revenue reductions

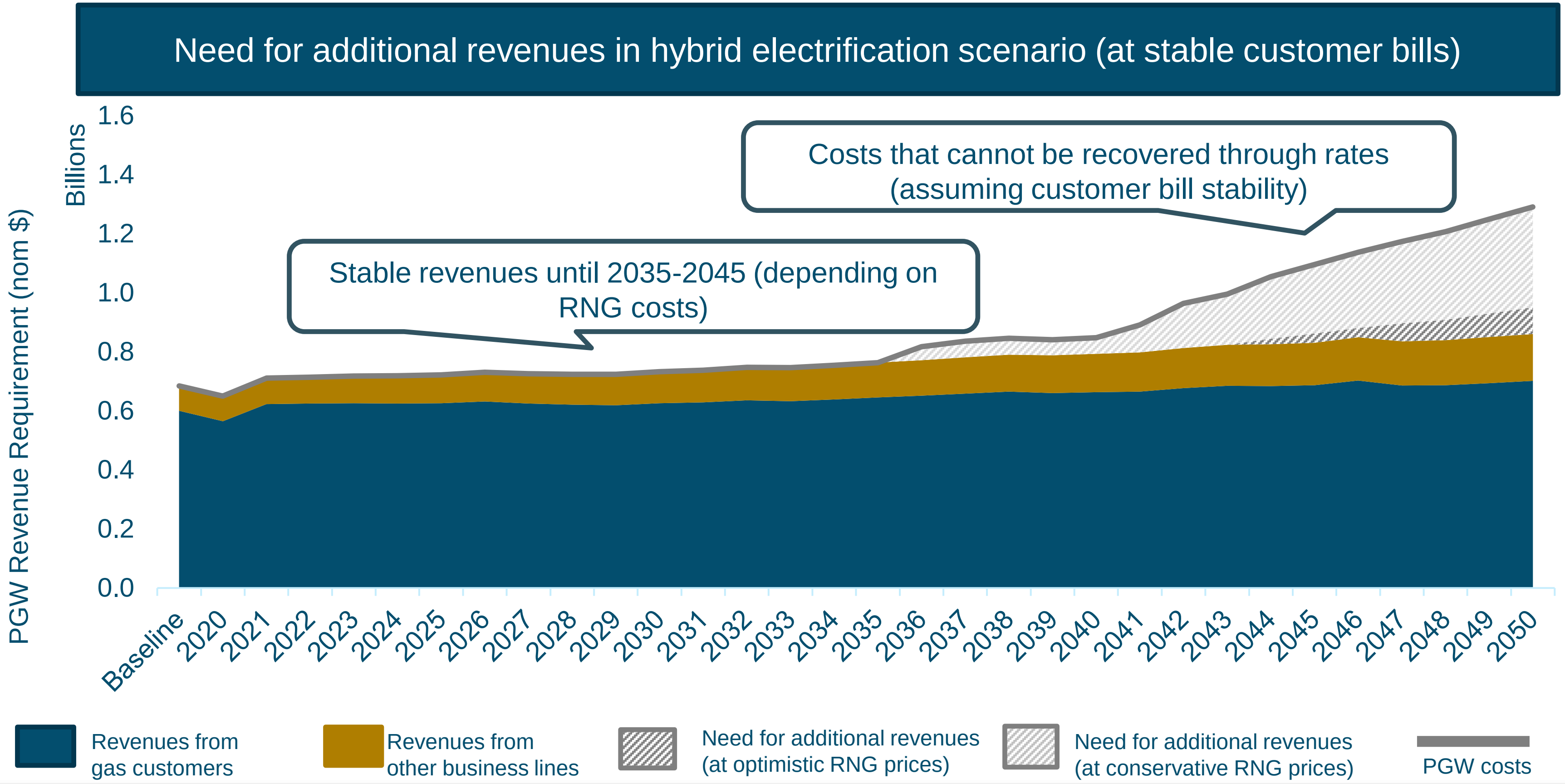
Need for additional revenues in electrification scenario (at stable customer bills)



- **In the long run, as more customers leave the system, new revenue sources and business models will be required to cover system costs**
- **Potential diversification options where PGW has a role in electrification:**
  - Heat as a Service
  - Weatherization & energy Efficiency services
  - Strategic electrification
  - Utility-led financing options
  - Geothermal MicroDistricts

Hybrid electrification: what if we assume stable bills? The need for additional revenues for PGW arises

	Impact on GHG emissions	Impact on air quality	Impact on affordability	Impact on revenues & workforce
Hybrid electrification	✓ Reduces emissions	— No significant change	✗ Pressures long-term gas costs	✓ Current system maintained

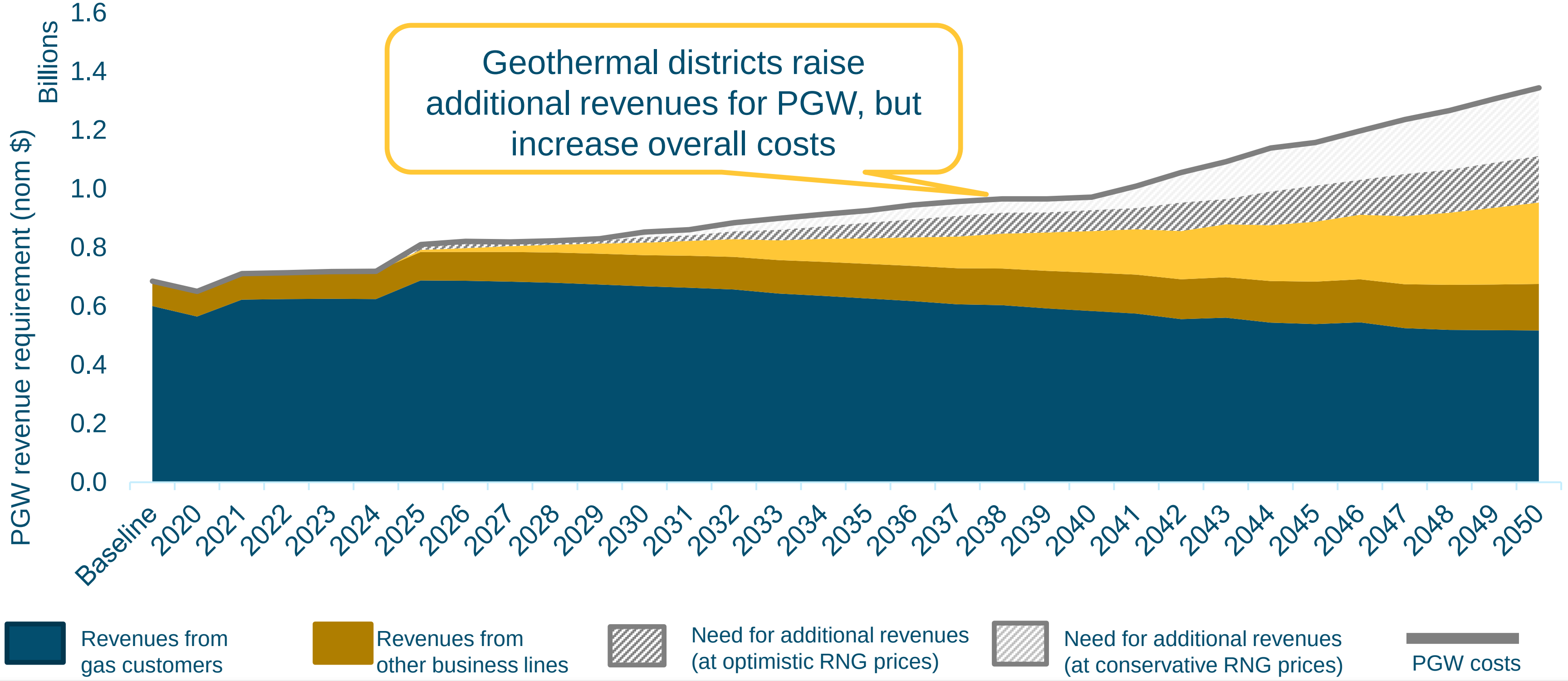


- **The revenue "gap" in the hybrid scenario is smaller than in the preceding energy option scenarios**
  - PGW infrastructure continues to be used, but at lower volumes. This reduces exposure to high RNG costs.
- **A smaller revenue challenge reduces, but does not eliminate, the need for diversification options.**

Hybrid electrification with MicroDistricts: what if we assume stable bills?

	Impact on GHG emissions	Impact on air quality	Impact on affordability	Impact on revenues & workforce
Hybrid electrification + MicroDistricts	Reduces emissions	No significant change	Pressures long-term gas costs	Current system maintained

Need for additional revenues in hybrid electrification with MicroDistricts scenario (at stable customer bills)



- **Geothermal MicroDistrict reduce the “revenue gap” and allows PGW to continue to play a core role in heating Philadelphia’s buildings**
- **However, MicroDistricts are costly compared to existing infrastructure and requires a coordinated block- or neighborhood-level retrofits**
- **The economics of neighborhood level retrofits are uncertain.**

Scenario comparison: need for additional PGW revenues arises after 2030 in all scenarios

Comparison of long-term cost recovery across scenarios – total costs include commodity costs (at optimistic RNG costs).

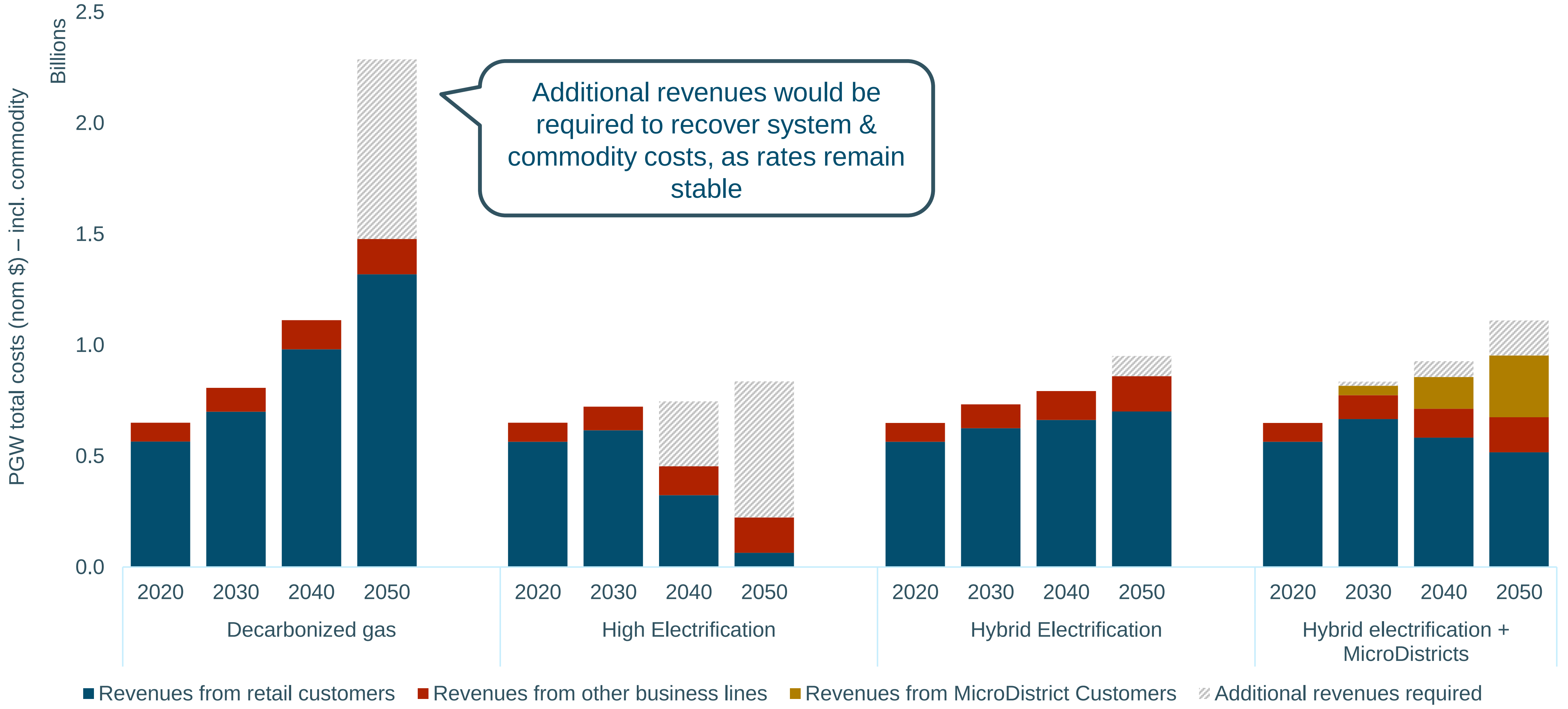


Figure includes commodity costs and is based on the optimistic RNG cost range. Analysis assumes no significant long-term cost reductions take place and revenues from existing business lines remain stable. Rate stability assumes 2% annual inflation.

In all cases, decarbonization raises the need for mitigating strategies for PGW

Business as Usual

PGW system & operating costs

Collected Revenues from retail gas volumes

Collected revenues from other business lines

Total system costs are shared between the gas volumes of all customers

= ***Annual customer bill (~1,100 $/year)***

Decarbonization – Electrification Example

PGW system & operating costs

Additional decarbonization costs

Collected Revenues from customer gas volumes

Collected revenues from other business lines

Additional revenue required to maintain current bill levels

Potentially lower gas volumes/fewer customers with more electrification & energy efficiency

= ***Annual customer bill significantly increase without additional revenue sources or policies***

Additional sources of revenue <u>could</u> help to maintain current energy bills

Business as Usual

PGW system & operating costs

Collected Revenues from retail gas volumes

Collected revenues from other business lines

Total system costs are shared between the gas volumes of all customers

= ***Annual customer bill (~1,100 $/year)***

Decarbonization – Electrification Example

PGW system & operating costs

Additional decarbonization costs

Collected Revenues from customer gas volumes

Collected revenues from other business lines, other sources of external funding or potential cost reductions

To avoid increasing customer bills, revenues from additional business lines would be required

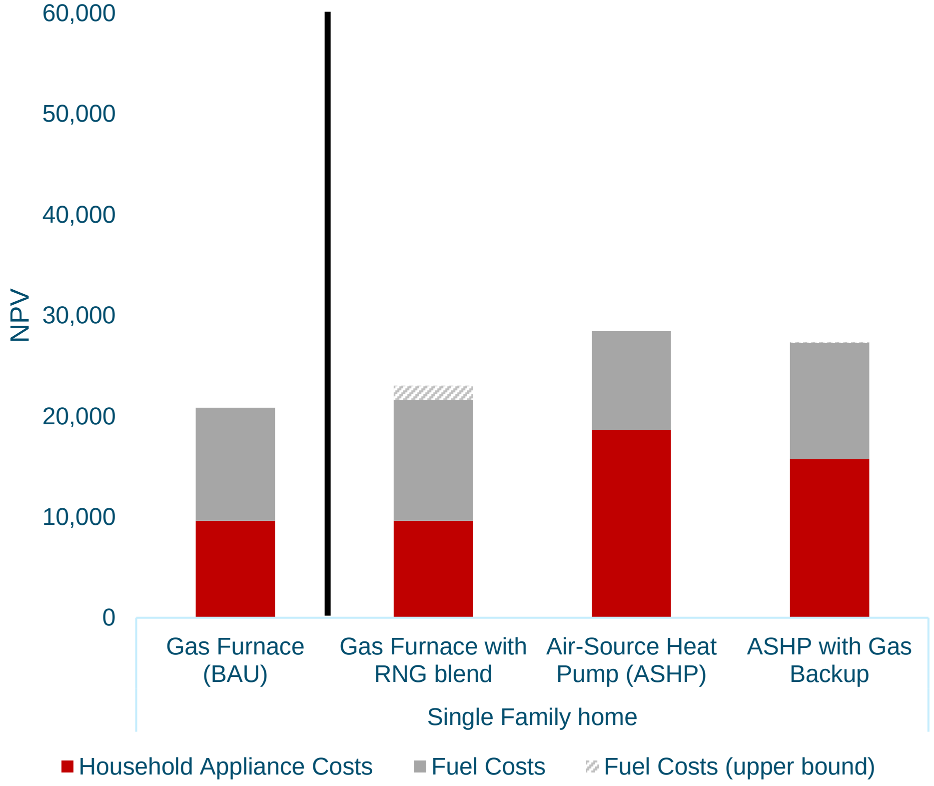
Potentially lower gas volumes/fewer customers with more electrification & energy efficiency

= ***Annual customer bill (~1,100 $/year)***

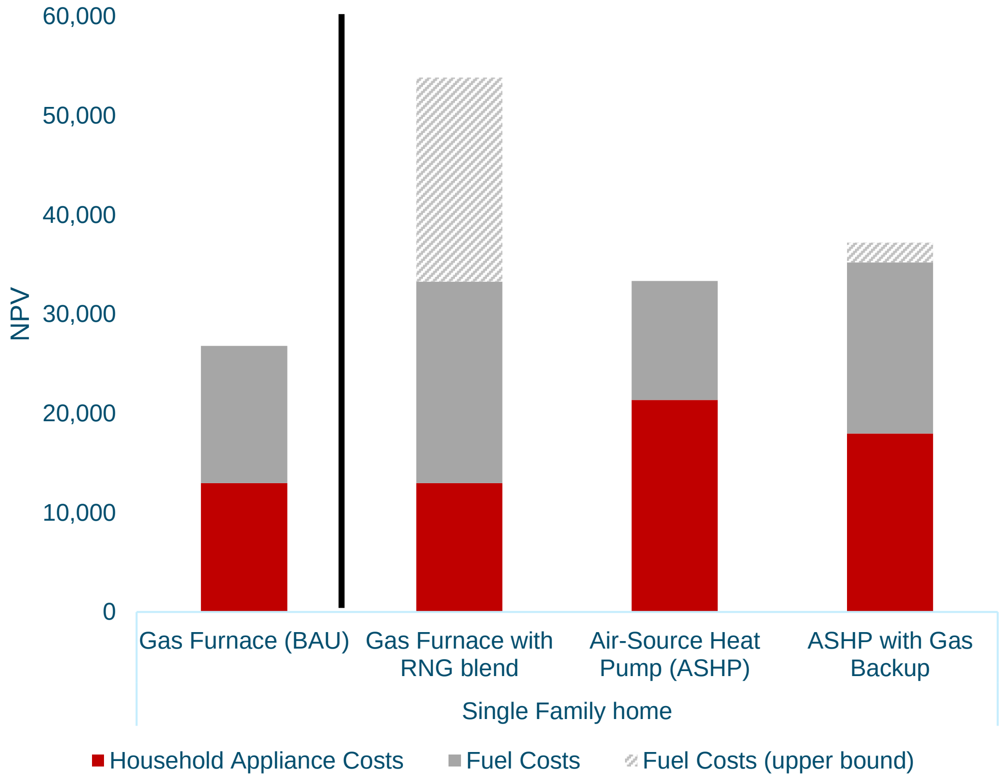
Ultimately, customer decision-making will determine how decarbonization occurs in Philadelphia

+ **Diversification options will need to be robust against uncertain consumer decisions on purchasing heating appliances. Consumer decisions on how to heat their homes and businesses are largely outside of PGW's control.**
+ **Upfront costs are a challenge for electrification options, even though they may produce bill savings. PGW could potentially play a role in supporting financial solutions to address that challenge.**

Lifecycle costs for appliances purchased in 2021



Lifecycle costs for appliances purchased in 2035



To ensure bill stability and workforce continuity, several diversifying strategies for PGW are under consideration

	Business Model	PGW playing a role in….
Options as extension of current business	RNG operations	Operating or procuring Renewable Natural Gas (biomethane, hydrogen, etc).
	District Heating	Distributing heat from geothermal heat pumps to buildings that are connected to a shared infrastructure.
	Weatherization	Facilitating and/or installing building energy efficiency & weatherization services.
	LNG & CNG supply	The operations and sales of Liquefied Natural Gas (LNG) or Compressed Natural Gas (CNG) to regional customers
Potential new business models	Strategic electrification	The customer transition to electrification (i.e. installation/maintenance of heat pumps).
	Heat as a Service	Selling heat to customers under the provision of agreed room temperatures at certain times for a fixed fee, instead of charging for energy use on a per-unit basis.
	Utility-led financing	The facilitation of investments in customer-side energy upgrades, for instance through tariffed on-bill financing.
	Smart meters	Facilitating “Smart metering as a service”, helping customers gaining control of their energy use.
	Microgrids	Facilitating integrated energy systems consisting of interconnected loads.
	Community solar	Installing and operating shared solar systems.

Preliminary conclusions & next steps

Overview of preliminary findings from scenario analysis

- Decarbonizing PGW is a priority for achieving the City's climate goals, and will require innovation and (likely) new sources of revenues to address energy affordability challenges in Philadelphia.
- Exclusive reliance on decarbonized gas is risky and poses unsustainable bill impacts to all PGW customers in the long-run, and does not address other City and stakeholder priorities (i.e. improving air quality).
- Exclusive reliance on electrification can reduce energy bills for households that electrify, but increases energy bills for customers remaining on the gas system, posing equity challenges unless mitigated.
- Hybrid electrification options may present a feasible decarbonization path that balances impacts on customers who electrify, and customers who do not ("participants" and "non-participants").
- Geothermal micro-districts represent a promising option for some customer types, but their cost and feasibility in Philadelphia are uncertain. More data are needed on real-world cost of these systems and their suitability given Philadelphia's geology, housing density and infrastructure.

What are other potential promising considerations?

+ Energy efficiency & weatherization

- Weatherization increases customer comfort and lowers bills. PGW could expand its current role in helping customers weatherize their homes

+ Continued focus on leakage detection

- Increases safety, reduces costs and GHG emissions

+ Low-cost RNG procurement and blending

- At limited volumes, Renewable Natural Gas is relatively inexpensive and has a small effect on rates

+ All-electric options for new construction homes

- Electrification in newly constructed homes is much cheaper than retrofitting existing homes

+ Ductless mini-splits for (multi family) homes w/o AC

- Ductless mini-splits increase customer comfort, are easy to install and relatively inexpensive

+ Supporting current non-retail customers with decarbonization

- Collaborating with GTS customers (i.e. the current steam loop) to partner in decarbonization plans

Next steps for the Diversification Study

+ Research on the potential for diversification options to provide additional revenue streams to PGW and ensure affordability for PGW's customers.
+ Research on the legal and regulatory feasibility of new business models that would be required to implement diversification options.
+ Incorporating stakeholder feedback on this preliminary report.
+ Identifying and evaluating potential pilot project opportunities that PGW could implement to further explore diversification options.
+ Developing a final report that describes the key findings and conclusions of the Diversification Study.

Energy+Environmental Economics

Appendix

Energy+Environmental Economics

Appendix A
Results of Energy Burden Conversations

Context and Purpose

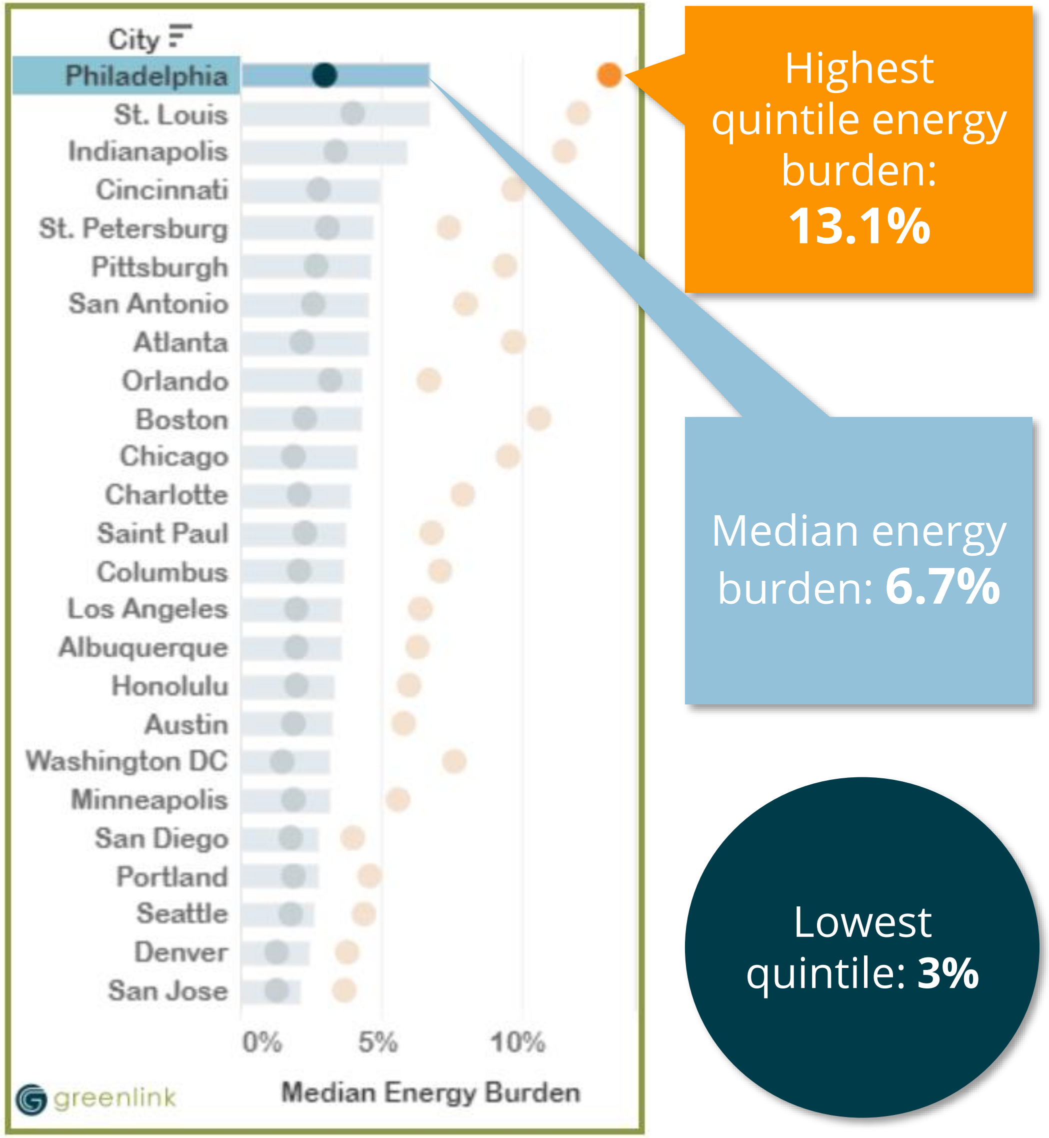
- Philadelphia has an affordability crisis, a housing quality crisis, and a climate crisis.
- Addressing these inter-related issues requires hearing from and raising the voices of those most vulnerable to these them.

The Energy Burden Focus Groups provided a forum to hear from local community members, discuss their relationship with energy services, and learn from their lived experiences.

Energy Burden:
The percentage of household income that goes toward utility energy bills

Philadelphia is one of the most energy burdened cities in the U.S.:

- Philadelphia's median energy burden is 86% higher than the national average
- 233,000 households have a high energy burden (>6%)
- 111,000 households have a severe energy burden (>10%)



Energy Burden Focus Groups Approach and Partners

The Office of Sustainability, in partnership with six community-based organizations, PACDC, the American Cities Climate Challenge, and the Greenlink Group, held conversations with:

6 of the city's most energy burdened communities

3 focus group discussions per community

Energy Burden Focus Groups Key Findings

- The majority of participants (54%) who are PGW customers consider their **monthly heating bills too expensive for them to afford**.
- All participants agreed that **energy assistance programs are too exclusive**. Many who are not eligible for programs are still in need of assistance. Others mentioned **challenges navigating PGW billing processes**, **program applications, and customer service**.
- There is **interest in home building repairs**, including weatherization and other energy efficiency improvements that will reduce energy utility costs, in addition to whole building repairs.
- **Safety of natural gas equipment is not a concern** for the majority of participants, and most feel comfortable with having PGW employees or contractors into their homes to implement energy measures.
- There is also interest in learning about natural gas alternatives; for most, the **understanding of these alternatives is limited**. Where there is a greater understanding of them, interest in electrification is higher.
- Participants are interested in **solutions that reduce/stabilize bills, improve health, and put people** in their communities to work, but they are skeptical that new policies and programs will provide them with real benefits as they have been disappointed by previous claims.

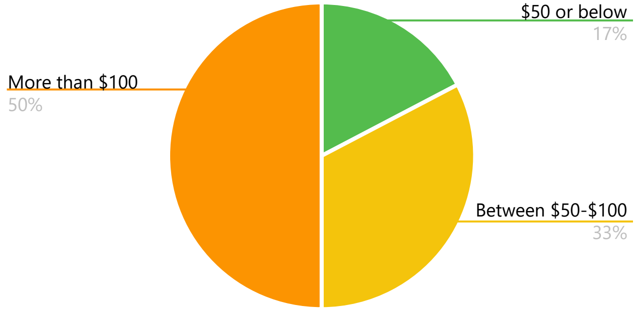
Most participating PGW customers consider their monthly heating bills too expensive

- Half the participating PGW customers pay >$100 per month in the winter.
- More participants found their winter heating bills too expensive compared to summer electric bills
  - 54% find their winter heating bills too high
  - 47% find their summer electricity rates too high

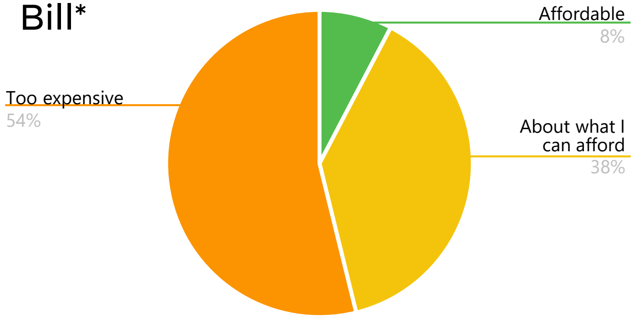
What we heard:

- *"During the winter, I tell the kids to put socks, sweatshirts on and to use extra blankets because we can't afford to turn the heat up."*
- *"When it's cold, we use space heaters because the gas heat is not enough to warm up the house; even though this increases the bills, we would be freezing without it."*
- *"Our winter costs are three to four times as high as our summer bills."*

Participant Monthly Winter Heating Bills *



Participant Attitudes Towards PGW Bill*



* Includes participants who are PGW customers. Approximately 10% of participants indicated they do not pay a PGW bill and are not included in this chart. Data based on participant response to poll questions.

Despite being ineligible for PGW bill programs, many are still in need of assistance

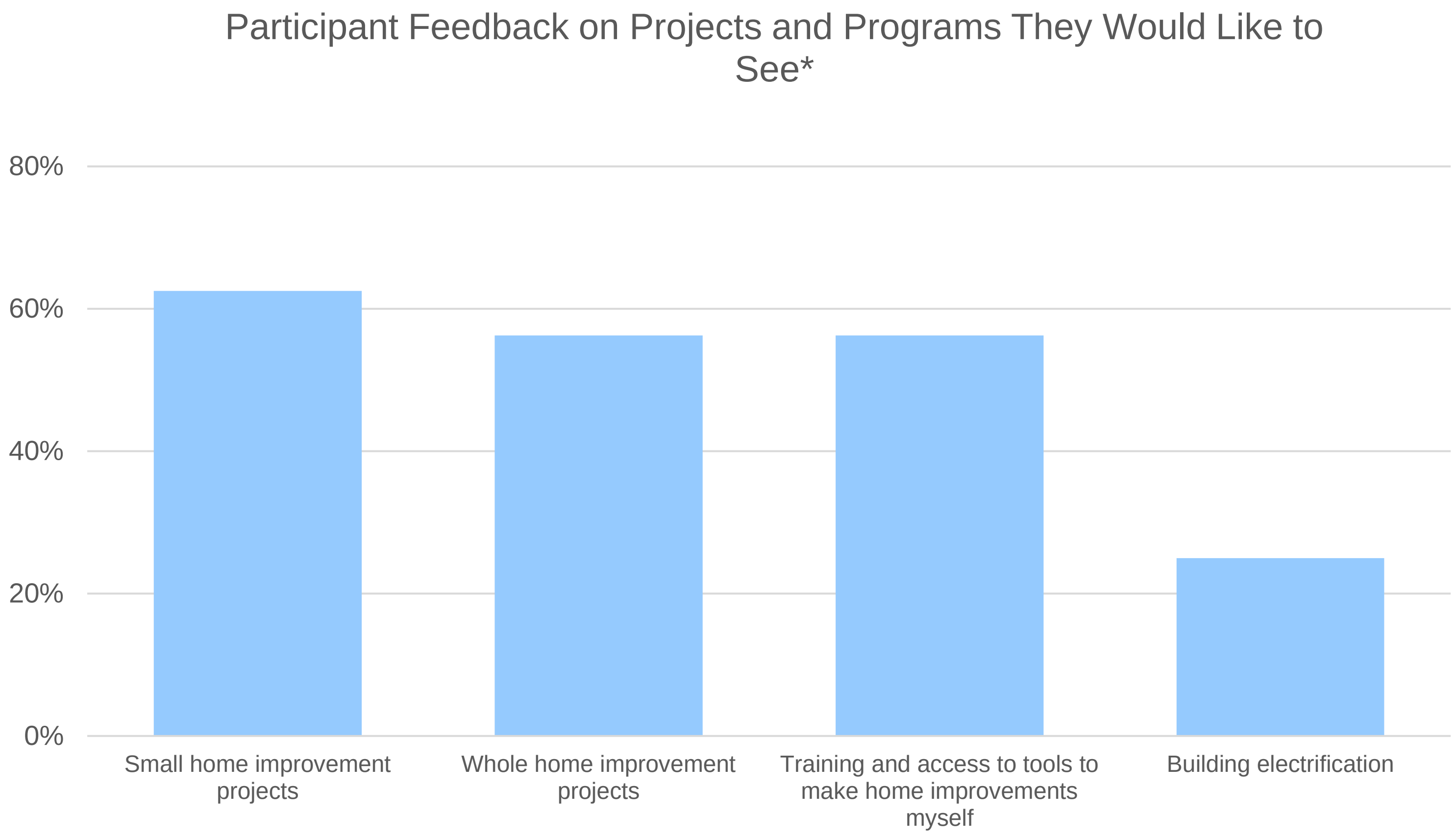
Common feedback on assistance programs:

- Income eligibility is too exclusive
- Poor residents with jobs are not eligible for assistance programs, even though they cannot afford their heating bills.
- There is a need for more outreach around available assistance programs, including for non-English dominant speakers.

What we heard:

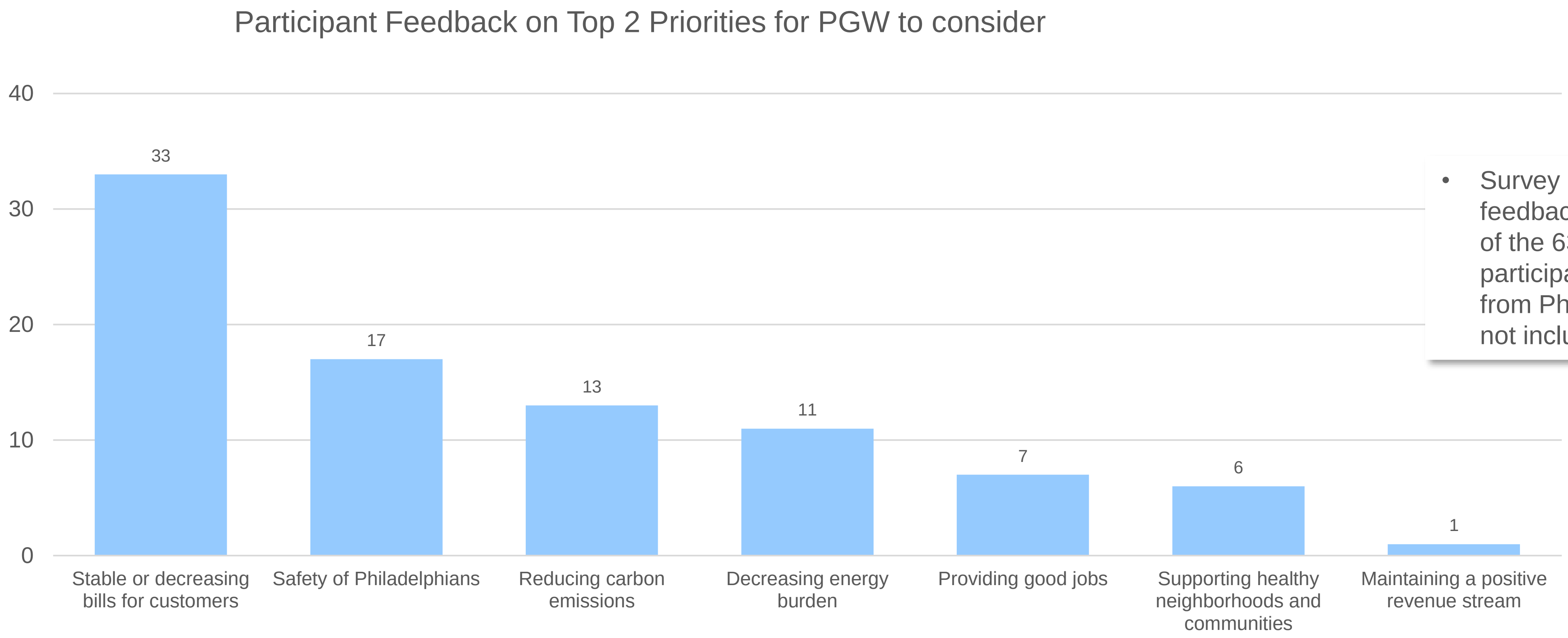
- *"I am poor, but not poor enough for them."*
- *"There shouldn't be income guidelines [for programs]; if we have a need, like a broken heater or high bills, we should be eligible."*
- *"The main problem is that those of us who would benefit the most from these programs have never heard of them."*

There is **interest in home building repairs**



- 48 out of the 63 total Energy Burden Focus Group participants participated in this survey.
- Philly Thrive participants did not complete this survey; however, during discussions, the majority of Philly Thrive participants mentioned an interest in building electrification.
- Some participants noted they did not have enough information to evaluate natural gas alternatives, including building electrification, as options.

Participants are interested in solutions that address air pollution, improve health, and create access to jobs



- Survey includes feedback from 48 out of the 63 Focus Group participants. Feedback from Philly Thrive is not included.

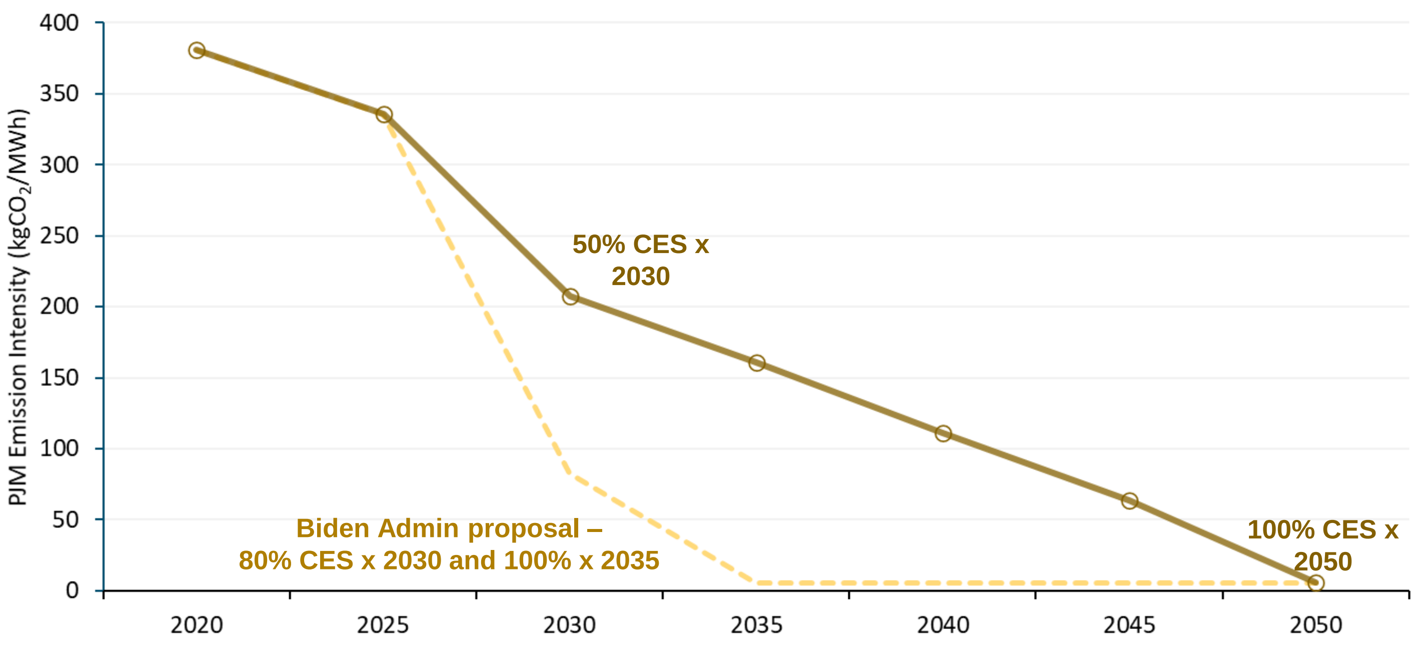
Energy+Environmental Economics

Appendix B
E3 analysis assumptions

The emissions benefits of electrification will increase over time as the electric grid decarbonizes

- **In scenarios that focus on electrification, electricity consumed by heat pumps needs to come from 100% clean sources to align with the City's net-zero goal.**
- In a separate recent study, E3 performed a reliability and cost-effective analysis to assess decarbonization and reduction emission goals in the PJM Interconnection, the regional grid that Philadelphia relies upon for power.
- That study included a "100% CES by 2050" scenario that is ambitious relative to today, but conservative relative to current national proposals.
  - CES = Clean Energy Standard, meaning 100% of retail sales is met by clean electricity
- E3 used results from the "100% CES by 2050" scenario as the basis for our electricity costs and emissions in this study.

PJM Emission Trajectory Under Two Potential Policy Trajectories

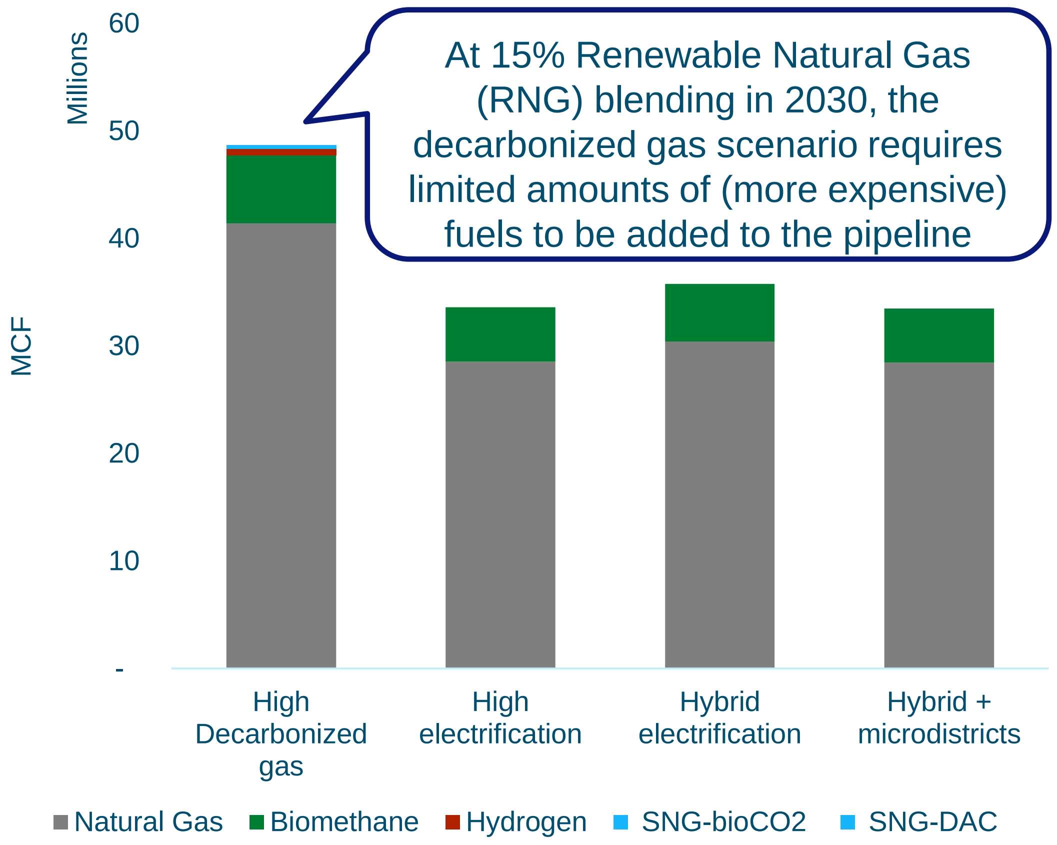


- **In the 100% CES by 2050 scenario, 100% of retail sales is met by clean electricity and 100% reduction in emissions as compared to 2005 levels.**
- **The Biden Administration has called for an 80% CES by 2030 and 100% CES by 2035.**

Source: E3 Report: Least-Cost Carbon Reduction Policies in PJM States – EPSA. The alternative policy cases assessed by E3 use different combinations of coal retirements, renewable additions, and nuclear retention to achieve policy goals

All scenarios assume a 15% blend of Renewable Natural Gas by 2030

Gas volumes across scenarios in 2030

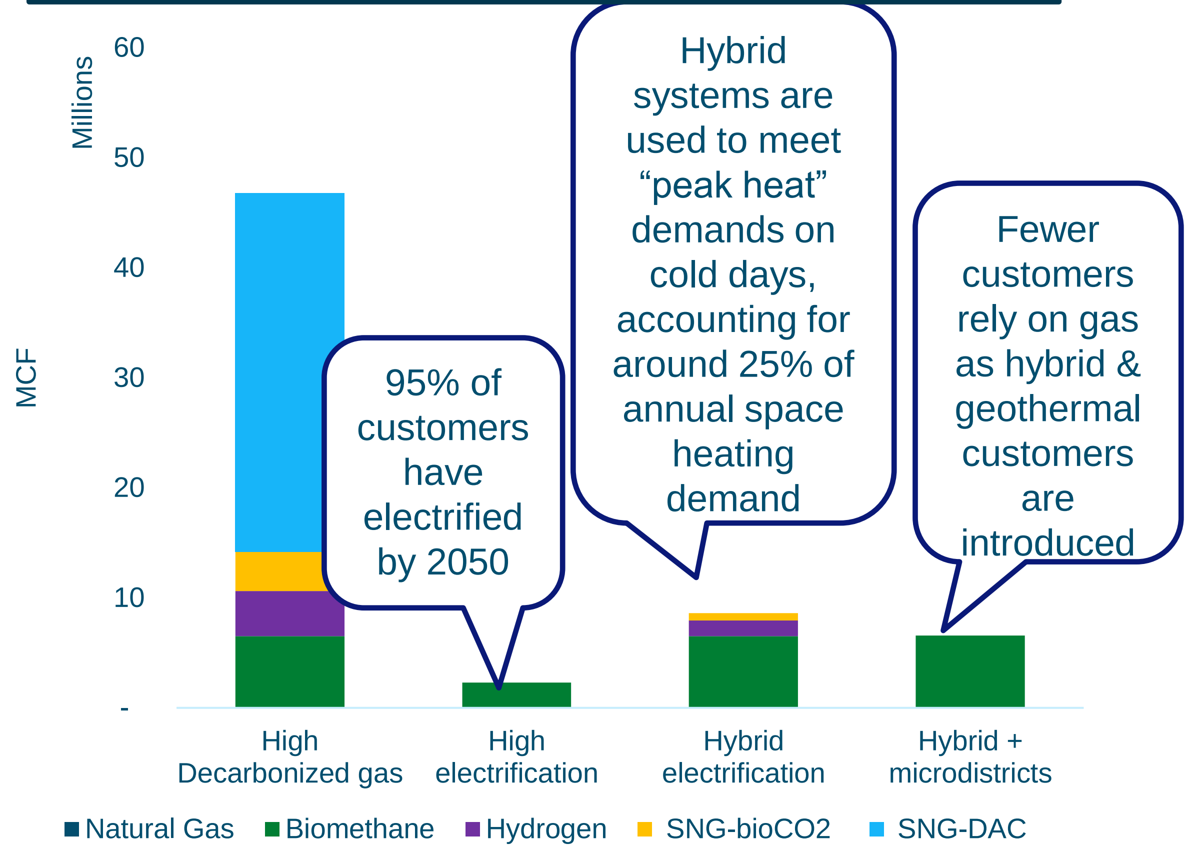


+ **By 2030:**
  - **Decarbonized gas:** Because all of PGW's customers still rely on gas, volumes are higher than in other scenarios. Small amounts of more expensive types of hydrogen and SNG are required to achieve a 15% blend.
  - **Electrification:** Gas volumes in the electrification scenarios are lower as part of PGW's customer base gas already transitioned to heat pumps
  - **Hybrid Electrification:** Gas volumes in the hybrid electrification scenarios are higher than in the electrification scenario as customers rely partly on gas
  - **Hybrid + Microdistricts:** Gas volumes are lower as part of PGW's customer base has transitioned to microdistricts

Volumes of Renewable Natural Gas are determined based on the US Billion ton study, which determines the availability of different sources of biomethane per year taking into account Philadelphia's weighted population share (results shown are based on a conservative scenario). In scenarios with higher gas demand, RNG needs to be supplemented by more expensive types of gas. The 15% blend in 2030 is based on a benchmark of gas utility targets across North America. SNG-DAC = Synthetic Natural Gas with Direct Air Capture. SNG-bioCO2 = Synthetic Natural Gas with Direct Air Capture with CO2 from bio-sources. Figures excludes volumes from Gas Transportation Services (GTS).

In the long term, the scenarios result in substantial differences in gas demand

Gas volumes across scenarios in 2050



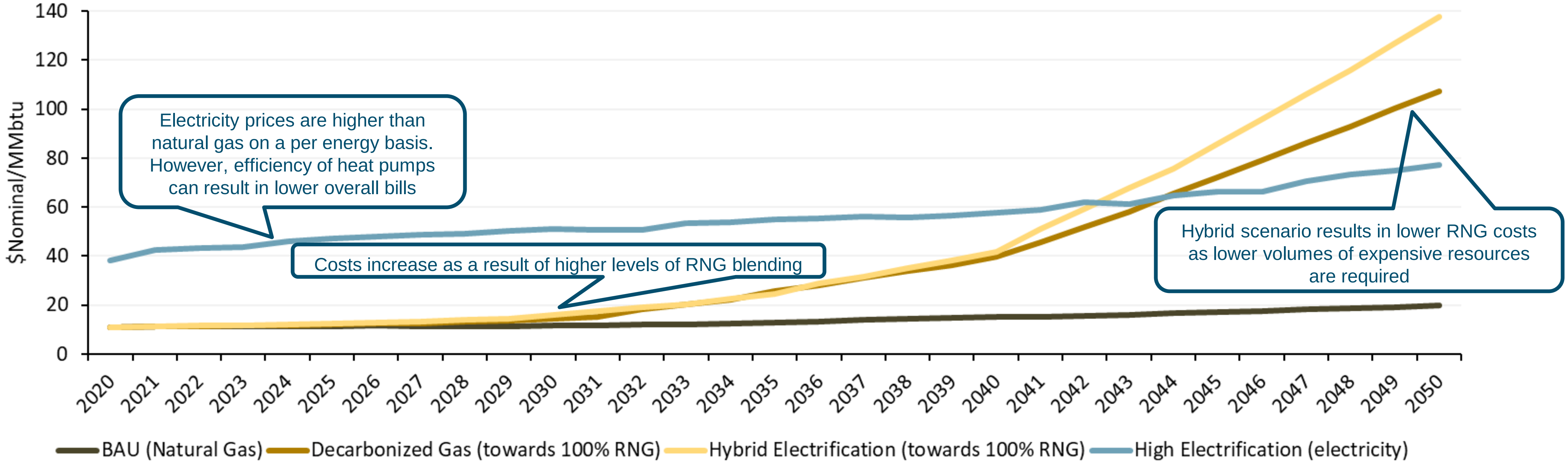
+ By 2050:

- **Electrification:** relatively low amounts of gas consumption as most customers have shifted from gas appliances to electric ones
- **Hybrid electrification**: gas demand is slightly higher than in the Electrification scenario because customers rely on gas during winter peaks
- **Hybrid + geothermal microdistricts:** A subset of PGW customers are assumed to transition to (electric) geothermal energy, lowering the need for gas
- **High decarbonized gas**: Because there is limited availability for biomethane , this scenario relies heavily on (not yet commercialized) Synthetic Natural Gas resources and assumes a 7% hydrogen pipeline blend.

Volumes of Renewable Natural Gas are determined based on the US Billion ton study, which determines the availability of different sources of biomethane per year taking into account Philadelphia’s population weighted share (results shown are based on a conservative scenario). In scenarios with higher gas demand, RNG needs to be supplemented by more expensive types of gas. SNG-DAC = Synthetic Natural Gas with Direct Air Capture. SNG-bioCO2 = Synthetic Natural Gas with Direct Air Capture with CO2 from bio-sources. Figures excludes volumes from Gas Transportation Services.

Customer economics and rate affordability depend on fuel prices of RNG and electricity

Energy Cost Comparison by scenario (includes delivery component)

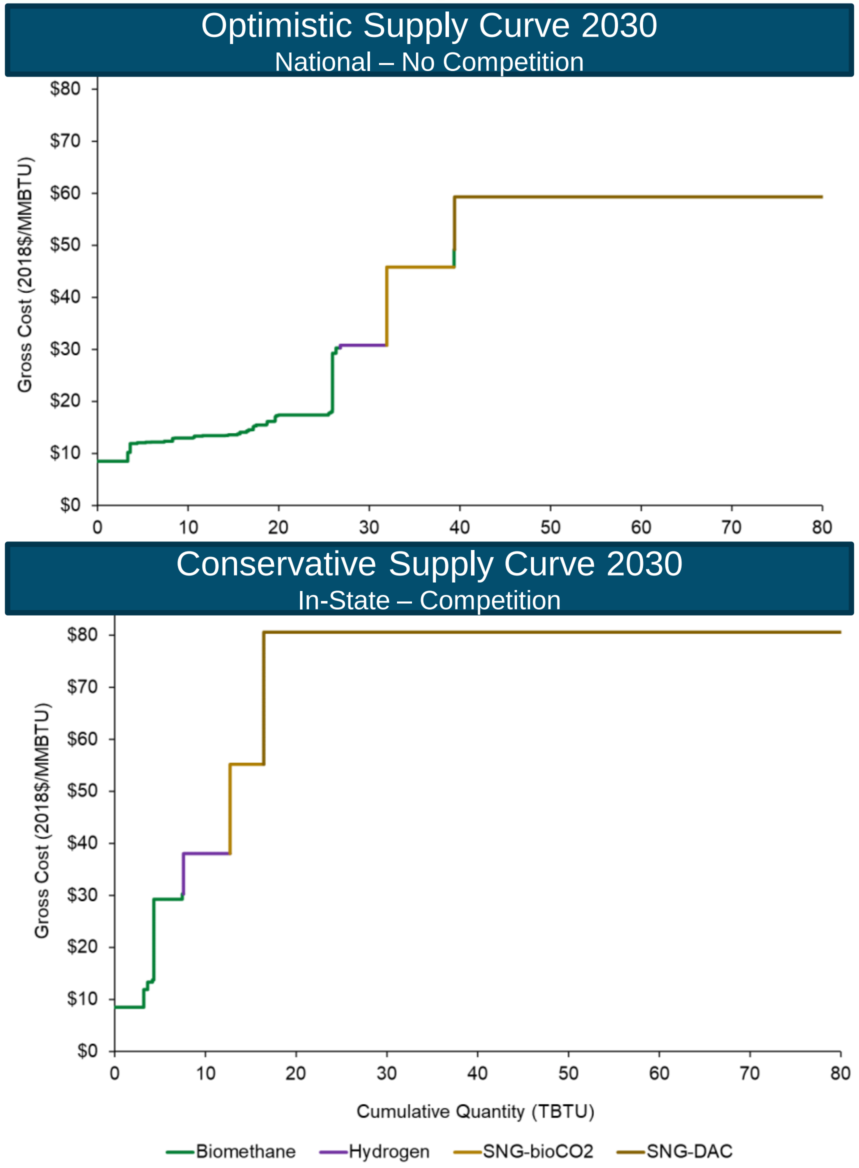


- **Under all scenarios other than the Business As Usual case, fuel prices are expected to increase due to the level of RNG blended into the pipeline.**
- **Renewable Natural Gas prices will remain cheaper than electricity on a per energy basis in the short term, but the efficiency of electric heat pumps may result in lower overall bills for customers adopting a heat pump**
  - Note that the decarbonized gas rates incorporate alternative fuel mixes (15% x 2030, 40% x 2040, 100% x 2050); decarbonized gas becomes more expensive as expensive gases are added to the mix at higher blending levels.

Gas costs do not include fixed monthly customer charge.

E3's Biofuel optimization module determines the costs and availability of RNG resources

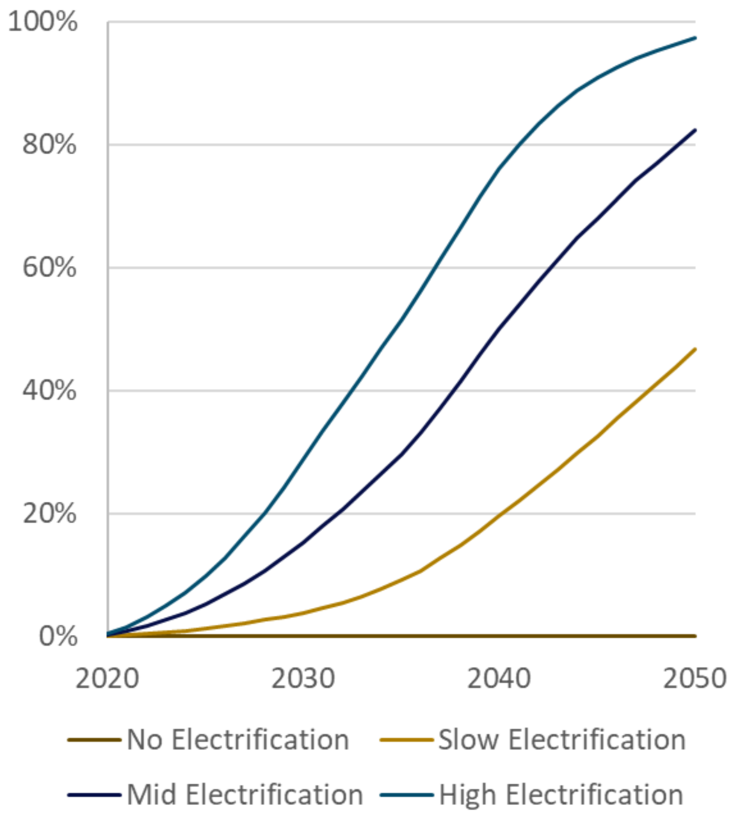
+ **RNG supply assumptions are developed from E3's biofuels optimization module, which determines the most cost-effective way to convert biomass into biofuels across all sectors.**
+ **Biofuels optimization bookends**
  - Optimistic: Access to nationwide supply of biofuels and no competition with other sectors (i.e. gasoline, diesel, jet fuel)
  - Conservative: Access to only state supply of biofuels and competition with other bio demand sectors.
  - Both cases scale the total available supply of biofuels to PGW by taking the share of PGW customers to the PA state population
+ **Optimistic and conservative costs for hydrogen and SNG are dependent on technology cost trends (i.e. electrolyzers)**
  - Optimistic: A global industry for hydrogen and synthetic fuels emerges over time, reducing technology costs via learning by doing
  - Conservative: Hydrogen and synthetic fuels are a niche industry, so there is less technology learning.



Building energy demands are based on a stock rollover approach

+ **Baseline energy demands are based on a variety of sources**
  - Characterization of existing building stock from US Census data
  - Gas consumption data from EIA Residential and Commercial Energy Consumption Surveys
  - PGW gas throughput and customer class breakdown from PGW Annual Financial report
+ **Building electricity and gas demands change over time based on a simplified stock rollover model**
  - Building appliances are long-lived and their replacement with efficient or electric devices is assumed to only occur at their natural retirement (end of useful life)
  - Stock rollover scenarios describe the likelihood that a device would be replaced by an efficient or electric device upon retirement, and these likelihoods change over time
  - *E.g.*, in a "High Electrification" scenario, 100% of new HVAC units sold are assumed to be electric by the year 2040. However, some existing gas furnaces will remain in service in 2050

Adoption of Heat Pump HVAC by scenario



Building energy demands – assumptions on efficiency, building shell, and climate change

In addition to electrification, several other factors influence how building energy demands change over time

- **Steady growth in building stock**
  - Residential building stock grows by 10% through 2050 (EIA Census Data)
- **Reference gas devices are replaced by efficient gas devices**
  - Device efficiencies from EIA NEMS
- **Building shell upgrades reduce demand for space heating**
  - Gradual rate of upgrades for existing buildings
  - New buildings are assumed to have upgraded building shell
- **Climate change is assumed to gradually reduce the demand for space heating**
  - 0.3%/year reduction in space heating demand from EIA AEO 2020
- **Scenario-specific adjustments**
  - *E.g.*, growth of MicroDistricts will reduce gas demand as homes are added to new MicroDistricts

Customer Cost Assumptions

- **Customer costs takes the full NPV lifecycle (15 yrs) cost of the building heating mechanism into account, which includes upfront capital costs and fuel costs**
  - Existing gas furnace + AC, water heater, stove and dryer upfront costs are based on average HomeAdvisor[1] costs and EIA NEMS model data.
  - Electric heating capital costs are based off of EIA NEMS except for ASHP and ASHP with gas back up costs, which are derived from the Energy Trust of Oregon dataset (based on similar climate).
  - Annual Fuel costs take the required fuel demand per scenario (whether it be electric, natural gas, alternative fuels) and the expected fuel rates (which will differ by scenario)

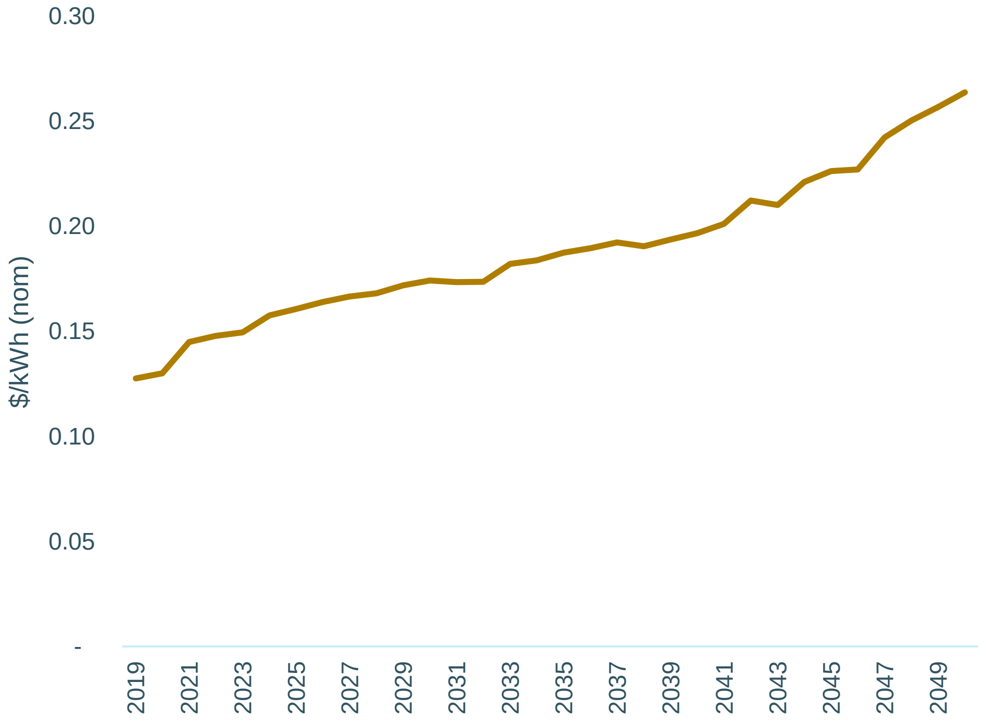
Cost assumptions for a Single Family (attached) home	Capital Cost ($)	Source
Gas Furnace + AC	$ 7,450	Based on HomeAdvisor costs (furnace + AC)
Gas Water Heater	$ 1,070	Based on HomeAdvisor costs
Gas Stove	$ 350	Based on EIA NEMS
Gas Dryer	$ 760	Based on EIA NEMS
Air Source Heat Pump	$ 14,200	Based on Energy Trust of Oregon dataset (assuming heat pump size of 4 ton)
Air Source Heat Pump with Gas Backup	$ 11,350	Based on Energy Trust of Oregon dataset (assuming heat pump size of 2.6 ton)
Electric Water Heater	$ 3,225	Based on EIA NEMS
Electric Stove	$ 350	Based on EIA NEMS
Electric Dryer	$ 838	Based on EIA NEMS

[1] *https://www.homeadvisor.com/cost*

Electricity Cost Assumptions

- **E3 performed a high-level Revenue Requirement analysis for PECO to forecast electricity costs for the next 30-year period.**
- **The forecast takes incremental peak capacity as a result of building electrification into account**
  - Baseline Energy, Capacity & T&D costs are forecasted based on EIA AEO 2021 data (reference case), with a cost premium for zero carbon generation from E3 RESOLVE data.
  - Incremental Capacity, Transmission & Distribution costs are based on PJM's Cost of New Entry Study (2018) and the Cost Effectiveness Screening Tool for Energy Efficiency Program Administrators (Synapse, 2015). Baseload electricity load is forecasted to increase by 0.1%/yr, taken from PJM's 2020 Load Report.
  - Annual baseline revenues and sales for PECO for residential, commercial & industrial customers are taken from S&P Global; the allocation of costs by component from Carnegie Mellon (2019): The Value of Solar for PECO and its ratepayers.

Residential forecasted electricity price under a high electrification scenario



Energy+Environmental Economics

Thank You

Energy & Environmental Economics (E3)
Portfolio Associates
Econsult Solutions Inc. (ESI)