Putting the Planning Back into Clean Heat Plans

Stéphanie Breton, Samuel Ross, Adam Epstein &
Charles-Étienne Thifault Taillon, Dunsky Energy + Climate Advisors

ABSTRACT

Clean Heat Plans are seeing increased adoption in jurisdictions across North America. These initiatives typically carry bold targets and big budgets but often lack clarity on precisely how their targets should be met. Jurisdictions often seek to remedy this only after policies are enacted, to chart a path to their new targets. This paper describes, compares, and contrasts the authors' experience modeling clean heat pathways under real-world constraints, covering key aspects such as budgets, adoption rates, policy levers, and technology readiness. Drawing on two contrasting cases—an integrated utility and separate gas/electric utilities with overlapping service territories—we show why static "end-state" policy prescriptions fall short, and how a hybrid approach combining demand-side management (DSM) frameworks, voluntary programs, and mandatory performance standards can be successful. Critically, modeling tools must be able to solve for optimized scenarios while also considering realistic customer adoption forecasting, rather than simply reverse engineering "one possible path among many." This optimization capability is key to answering the big questions facing decision-makers such as:

- How should we balance demand-side efficiency and supply-side transformation?
- Which policies unlock adoption—and which barriers create bottlenecks for progress?
- How much will this really cost? Are current budgets enough—and what is the most cost-efficient way to meet targets?

Within an optimization-capable toolset, it is still critical to model multiple decarbonization trajectories to understand trade-offs and identify viable pathways, and to identify and understand the enabling conditions—policies, programs, and market strategies—required for those trajectories to be actionable in the real world, not just in a spreadsheet. We will share insights into which policy and program mixes show the most potential, and how gas and electric utilities can roll these out collaboratively. In the end, we show how to bridge the gap between targets and effective planning, and the key analytical steps needed to deliver results.

Introduction

Buildings account for a significant share of global energy consumption and greenhouse gas (GHG) emissions, particularly in cold-climate regions where space heating demands are substantial and often met largely through fossil fuel combustion. As jurisdictions pursue decarbonization targets, reducing emissions from buildings has emerged as a policy priority, with commercial and residential buildings responsible for 31% of emissions in the United States (EPA 2026). In response, governments and regulators are increasingly developing Clean Heat Plans (CHPs) and related policies to reduce emissions from space and water heating while managing costs, maintaining reliability, and addressing customer impacts (Specian, Gold and Mah 2022). Figure 1 highlights several states and provinces that have adopted or proposed specific requirements or programs specifically targeting heating sector decarbonization.

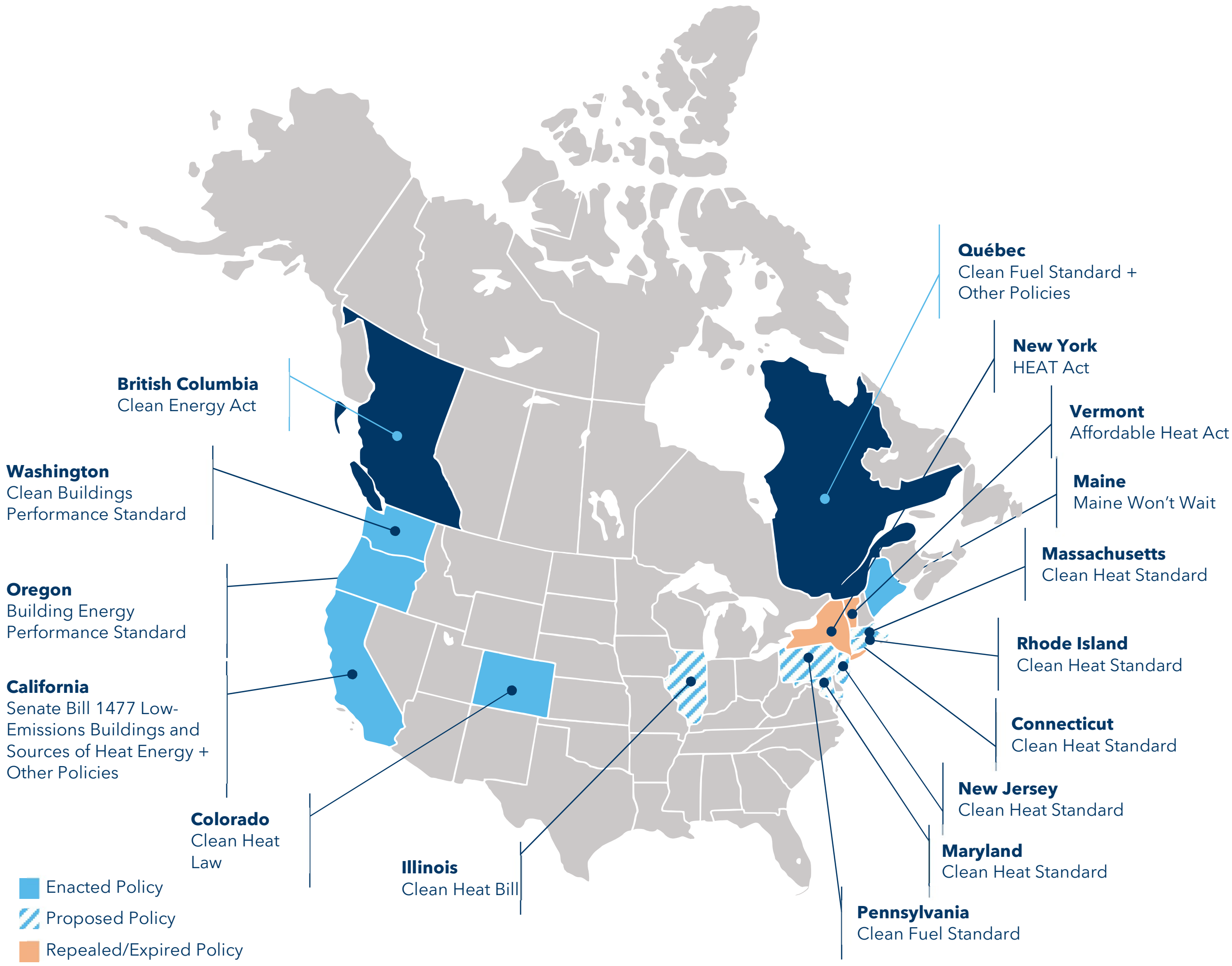

Figure 1. Clean Heat Plans and related policies proposed or enacted in North America.

Across these jurisdictions, CHPs and similar initiatives typically carry ambitious emissions goals, substantial program budgets, and strong policy signals around electrification, energy efficiency, and affordability. Yet many remain more prescriptive than operational. They are effective at describing *what* a jurisdiction wants to achieve, such as accelerated heat pump adoption (RI, MD), emissions reduction targets (BC, MA), reducing natural gas system emissions (CO) and buildout (NY), or a full transition to net zero (QC), but these policies often provide much less clarity on *how* those outcomes will actually be delivered within real-world constraints.

This gap between targets and implementation is becoming one of the defining challenges in building decarbonization. In practice, the transition is shaped by customer economics, technology performance, policy design, regulatory authority, and the physical constraints of gas and electric infrastructure (NREL 2024). A plan that appears feasible in a static end-state analysis may prove difficult or costly to execute once questions of annual adoption rates, incentive budgets, rate impacts, peak demand, and utility coordination are introduced.

Existing policy frameworks have typically established emissions-reduction targets, utility obligations, or broad technology preferences prior to seriously engaging with detailed implementation questions such as eligible measures, customer segments, cost caps, adoption assumptions, infrastructure requirements, and compliance mechanisms, which tend to emerge later. In that sense, the current generation of clean heat planning is still maturing, as the field is moving from target-setting toward implementation planning (Specian, Gold and Mah 2022). In that context, it is increasingly critical to have analytical tools that are up to the challenge of spanning the gap between top-level targets and bottom-up planning.

A consistent theme across jurisdictions is that building decarbonization is more than a technology-substitution problem. It is also a systems planning problem. Replacing fossil heating with electric technologies changes load shapes, affects seasonal peaks, and can shift costs across customer classes and utility systems (Nadel 2023). In winter-peaking regions, rapid electrification of space heating can create substantial new winter capacity requirements on the electric grid. In other systems, electrification can improve energy efficiency and system utilization and reduce emissions, without creating the same degree of seasonal stress, especially in the immediate term. A decarbonization pathway that appears attractive in one jurisdiction may be economically or operationally difficult in another due to differences in building stock, climate, customer usage patterns, and utility structure. Consequently, despite the temptation to paint with a broad brush, or borrow policy structures from other jurisdictions, there is no "one size fits all" solution. Accurate modeling that accounts for this diversity of jurisdiction-specific conditions is a critical tool to identify technically feasible, cost-efficient solutions that best position a specific jurisdiction to meet its CHP targets.

The policy environment adds another layer of complexity. Most building decarbonization plans rely on a mix of tools rather than a single instrument (Regulatory Assistance Project 2024). These can include utility efficiency programs, electrification incentives, appliance and equipment standards, building performance standards, fuel emissions targets, low-income support, and workforce or market development measures. Voluntary programs can build markets and reduce early barriers but may not deliver the scale or pace needed to meet long-term targets on their own, and the large, ongoing budgets typically needed to drive deep penetration of new technologies solely through voluntary programs can be politically challenging to sustain. Mandatory standards can create clearer market signals, but they raise questions about affordability, customer choice, and enforceability. In practice, the most credible CHP implementation plans combine multiple tools and recognize that program design and market transformation are as important as the potential for voluntary technology adoption.

Another shared lesson is that affordability cannot be treated as a secondary issue. As clean heat planning has advanced, cost containment and customer protection have become central design considerations. This is visible in the attention given to rate impacts, bill savings, low-income participation, and the distribution of costs between adopters and non-adopters (Nadel 2023). Even where long-term societal benefits are clear, near-term bill impacts or capital costs can constrain political and regulatory support. For planners, this means that "least-cost" is no longer a purely technical concept. It must account for adoption timelines, budget feasibility, and equity outcomes, not only theoretical system optimization.

Recent policy experience also shows that high-level targets often need to be refined once more detailed planning begins. In some cases, jurisdictions have strengthened or extended targets after technical analysis and implementation progress suggested that a more ambitious pathway was achievable. In others, targets or compliance mechanisms have been delayed, narrowed, or redesigned after more detailed planning exposed data limitations, affordability concerns, legal uncertainty, or implementation barriers. Colorado's clean heat framework illustrates how broad statutory targets can evolve into a more detailed regulatory structure over time. In 2021, Colorado established emissions-reduction targets for gas utilities of 4% by 2025 and 22% by 2030 relative to 2015. In 2025, a proposed target of 41% reduction was established for 2035, showing how such policies can be revisited and revised over time (Colorado PUC 2025). Maine set a target in 2019 to install 100,000 heat pumps by 2025. After surpassing the target two years ahead of schedule, an additional 175,000 installs were targeted by 2027 (Office of Governor Janet T. Mills 2023). In 2023, British Columbia updated the provincial building code, with energy efficiency requirements that progress from the BC Energy Step Code introduced in 2017. The changes are aligned with the CleanBC Roadmap to 2030 for all new buildings to be zero carbon by 2030 and net-zero energy ready by 2032 (B.C. Government 2023).

A more cautionary example was Vermont's Affordable Heat Act, passed in 2023 to help the state reach its goal of 40% emissions reduction relative to 1990. The Act required the Public Utility Commission (PUC) to propose a credit-based marketplace for natural gas and oil providers to offset emissions by implementing clean energy measures such as weatherproofing or fuel switching, with the plan also requiring legislative approval. In its 2025 draft plan, the PUC concluded that the "Clean Heat Standard [was] not well suited to Vermont" due to the added complexity of a new market-based regulatory structure, anticipated problems with fuel-dealer data and identifying obligated parties, and the compressed timeline for program development (Vermont PUC 2025, 73). The PUC recommended expanding existing energy efficiency programs instead of implementing the Clean Heat Standard and closed the case in 2026 after the required legislative authorization was not enacted (Vermont PUC 2026). New York had passed the All-Electric Buildings Act in 2023, which would have prohibited fossil fuels in new buildings, effective December 31, 2025. The Act was challenged in court, and the state has agreed not to enforce the standard until the lawsuit is resolved (NY Department of State 2025).

For practitioners, this has an important implication. Static "end-state" analyses are useful for illustrating ambitious targets, but they are not sufficient for designing actionable decarbonization strategies. End-state analyses often assume that large shares of the building stock can transition by a target year without adequately considering the implications for annual market uptake, customer behavior, budgets, and necessary supporting policies. As jurisdictions move from targets to implementation, these dynamics become imperative to accurately model. Questions about whether customers will adopt at forecasted rates, whether the grid can accommodate incremental load during peak periods, and whether current budgets are adequate, all determine whether a theoretical modeled pathway is actually viable.

This is why the combination of optimized pathway modeling *and* customer adoption modeling is increasingly necessary. Rather than asking only what a decarbonized building sector will look like in 2035 or 2050, our hybrid model asks how a jurisdiction can achieve its targets under realistic conditions covering both supportive policies and customer adoption driven by economically rational decision-making. It evaluates multiple trajectories, compares their costs and trade-offs, and links technical potential scenarios to the policy and program conditions needed to realize that potential. This kind of analysis is particularly valuable where gas and electric systems are closely intertwined. Decisions that reduce building emissions may also reduce gas throughput, affect cost recovery, increase electric sales, alter peak demand, or shift investment needs across separate utilities. Without a planning framework that considers these interactions, it is easy to produce scenarios that are technically interesting but practically difficult to implement.

Successful building decarbonization that meets bold end states requires identifying credible transition pathways. The jurisdictions making the most progress are not necessarily those with the most aggressive headline targets, but those that are beginning to connect targets with delivery mechanisms, cost frameworks, and system planning, as the examples of Colorado and Vermont demonstrate. Across those efforts several themes repeat, including the need to set ambitious yet achievable targets, the importance of combining voluntary and mandatory measures, the central role of affordability and equity, the operational significance of winter and summer peak dynamics, the reality that CHP targets and similar policies often evolve over time, and the need for better coordination between gas and electric planning.

This paper builds on those lessons by drawing on two contrasting cases, one involving an integrated utility and one involving separate gas and electric utilities with overlapping service territories. We show why static end-state analyses fail to answer the questions that matter most to decision-makers. We then demonstrate how a hybrid framework that combines DSM constructs, voluntary programs, mandatory standards, and optimized scenario modeling that accounts for realistic customer adoption can help jurisdictions identify viable pathways under real-world conditions. In doing so, the paper aims to help bridge the gap between targets and implementation, and to clarify the analytical steps needed to move from ambition to delivery.

Methodology

The two case studies presented in this paper were completed using a common planning framework, although the details of each study varied to reflect local market conditions, institutional structures, and planning objectives. A summary of the two case studies is shown in Table 1.

Table 1. Clean Heat Plan study parameters

Case Study	Case Study 1	Case Study 2
Utility Type	Separate Gas and Electric	Integrated Utility
Emissions Target	2050	2030
Current Peak Timing	Winter Peaking	Summer Peaking
Regulation Scope	Jurisdiction-wide net zero target	Natural gas emissions reduction target
Sectors	Residential, Commercial	Residential
Climate Zone[1]	7	5B
Electric-to-Gas Rate Ratio	<2	>4
Grid Carbon Intensity	Low	High
Models	Proprietary Heating Decarbonization Model	Proprietary Heating Decarbonization Model, Proprietary Energy Efficiency Model

[1] Based on the Climate Zone Map from IECC 2021.

Case Study	Case Study 1	Case Study 2
Pathways	1. Minimum Societal Cost 2. Customer Economics 3. Dual Energy 4. Full Electrification	1. Business-as-Usual 2. High Level of Incentive 3. Policy Aligned

We started the study process by establishing the planning scope and identifying the main analytical questions. This included establishing the building sectors and end uses to be covered, the planning horizon, the emissions target, and other policy objectives. The analysis was framed around questions central to clean heat planning, such as the balance between energy efficiency and fuel switching, the role of flexible demand and emerging technologies, the implications of infrastructure and fuel constraints, and the costs associated with different transition strategies.

A set of alternative decarbonization scenarios was then developed. These scenarios were modeled representations of different pathway outcomes. Each reflected a distinct combination of assumptions related to technology uptake, policy levers, and system constraints. Depending on the context, scenarios could vary in their relative emphasis on demand-side efficiency, heating fuel substitution, flexible load management, regulatory requirements, incentive support, or the availability of low-carbon energy sources. They could also reflect changing conditions over time, recognizing that technologies, policies, and market capabilities do not evolve all at once.

The technology and market scope for modeling was then defined. Baseline building conditions were characterized by segment, fuel, and equipment type, and a set of measures was identified for potential adoption over time. These measures included both demand-side and supply-side options, such as equipment replacement technologies, building efficiency improvements, demand management strategies, dual-fuel heating, and renewable natural gas (RNG) penetration. The market was segmented to a level that captures meaningful variation in baseline conditions, customer economics, willingness to pay, and adoption potential across building types and customer groups. For each option, reasonable assumptions were developed for cost, performance, operating characteristics, lifetime, emissions impacts, and market readiness.

A supporting dataset was assembled using available utility information, public sources, technical literature, and engineering assumptions. This included the building stock, baseline energy use, equipment characteristics, technology costs and performance, fuel prices or tariffs, emissions factors, and program incentives and enabling activities. Additional assumptions were incorporated where needed to reflect constraints on technology availability, adoption timing, or system impacts. Given the long-term planning horizon and the uncertainty inherent in clean heat planning, the objective was to establish a fundamental set of inputs that could vary across model runs.

The scenarios were then evaluated using the authors' proprietary heating decarbonization model, which assesses the technical, economic, and achievable potential of clean heat strategies across multiple scenarios. The model was designed to model multiple permutations of replacement case, sizing strategy and control strategy for each combination of baseline heating system, baseline cooling system and low carbon heating technology. The model simulates the baseline and replacement cases to calculate the energy performance and full cost, which allows it to yield the incremental costs and savings for each and every one of the thousands of modeled cases. The general approach for estimating heating decarbonization potential consists of defining valid low-carbon systems for each baseline heating and cooling system configuration modeling equipment performance given prevailing climatic conditions; calculating incremental costs and energy/demand impacts; using those results to calculate measure cost effectiveness and customer economics; and assessing customer adoption under various achievable scenarios.

The model was used to define and compare decarbonization pathways across building segments, end uses, and energy sources, and to estimate their implications for technology adoption, fuel consumption, emissions, costs, and system impacts over the planning horizon. By combining granular market data with technology performance and cost assumptions, the analysis supported a dynamic assessment of how different pathway conditions could shape market uptake over time.

Model outputs were then compiled and compared across scenarios. These outputs typically included technology adoption by segment, changes in energy use by fuel, emissions reductions, peak demand impacts, capital and operating costs, and program costs. The analysis focused on the trade-offs among pathways rather than the identification of a single universally optimal solution, with attention given to the timing of adoption, the relative contribution of different technologies and strategies, the cost implications of alternative approaches, and the extent to which pathway outcomes depended on policy support or market acceleration.

The results were then translated into implementation considerations for the most viable pathways. This included identifying the broad actions required to support delivery in practice, such as financial incentives, regulatory measures, demand-side management approaches, market development efforts, and utility coordination mechanisms.

Taken together, this methodology provided a structured approach for moving from high-level clean heat targets to actionable planning pathways. By combining scenario definition, technology characterization, modeling, and implementation-oriented analysis, it supported the development of decarbonization plans that were both analytically grounded and practical for real-world decision-making.

Case Study: Separate Gas and Electric Utilities in a Winter Peaking System

The first case study examines a jurisdiction served by separate gas and electric utilities that has established a goal of achieving net-zero emissions in the building sector by 2050. The region faces a particular challenge: heating demand already drives winter electricity peaks. As a result, building decarbonization is not simply a matter of replacing fossil fuels with electricity; it also requires reducing and reshaping demand from the existing electric building stock through energy efficiency and demand response.

The electric and gas utilities needed to understand how different decarbonization pathways would affect future energy demand, system costs, and their respective roles in the transition. This study evaluates four pathways to achieving the 2050 target, representing different technological, economic, and policy conditions under which building-sector decarbonization could occur:

1. Minimum Societal Cost: A least-cost pathway from a societal perspective.
2. Customer Economics: An adoption-led pathway reflecting customer-driven decisions based on customer economics.
3. Dual-Fuel: A pathway that exploits the complementarity of electric and gas networks by favoring dual-fuel solutions.
4. Full-Electrification: A full-electrification pathway including widespread adoption of smart peak demand management solutions.

This study examines pathways to decarbonize space heating across the residential, commercial, institutional, and light industrial sectors. Using a bottom-up building model, it simulates equipment replacement decisions over time and evaluates the impacts on energy consumption, peak demand, and emissions. Given the jurisdiction's winter-peaking demand profile, the analysis considers both energy and capacity requirements and assesses the combined role of electrification, energy efficiency (EE), and demand response (DR) in achieving decarbonization goals, while managing the peak demand.

Scenarios were informed by utility and stakeholder data, public statistics, and published research, and incorporated assumptions related to technology performance, fuel prices, and existing and anticipated policies and programs[2].

Results

The study shows that reaching net-zero emissions by 2050 is achievable. As illustrated in Figure 2, the most important question is how utilities can deliver this transition at the lowest cost to society while preserving system reliability and customer affordability. In response, the utilities developed a collaborative approach aimed at balancing emission reductions with system reliability and cost considerations. By aligning incentives and jointly evaluating investment and technology pathways, the framework supports cost-effective emissions reductions while avoiding unintended consequences such as excessive peak demand growth.

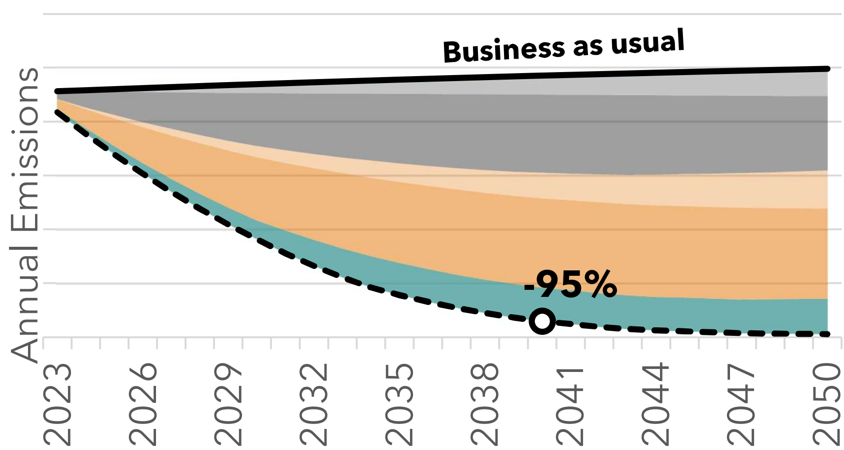

Figure 2. Emissions reduction compared to business as usual, driven by energy efficiency (EE) and fuel switching (FS) from heating oil (EE: light gray, FS: dark gray) and natural gas (EE: light orange and FS: dark orange), along with conversion to renewable natural gas (green) under the minimum societal cost scenario.

The analysis identified five critical market and system transformations required to achieve the 2050 decarbonization target.

A rapid adoption of dual-fuel systems for existing gas customers is required to accelerate emissions reductions while limiting growth in the winter peak. By leveraging both gas and electric infrastructure, this pathway provides a practical transition toward low-carbon heating while maintaining system reliability.

[2] In the optimal societal cost scenario, end-of-life equipment replacements adopt the solution with the lowest total societal cost, accounting for total system (gas and electric) avoided costs, measure costs, and environmental externalities. The model then estimates technology adoption, energy consumption, peak demand impacts, and greenhouse gas emissions under each scenario through 2050.

Complementing the transition to dual-fuel systems, widespread adoption of demand response measures is also required to manage peak demand and reduce system costs. As seen in Figure 3, the optimal scenario results in a 30% lower electricity system peak resulting from conversion of resistive heating and fuel switching to cold climate air source and ground source heat pumps, partial electrification using dual fuel solutions, and the adoption of demand response measures. This avoids significant upgrade costs that would be required to meet the unmitigated peak. Demand-side efficiency remains critical, as reducing existing heating loads can free up additional capacity for further electrification.

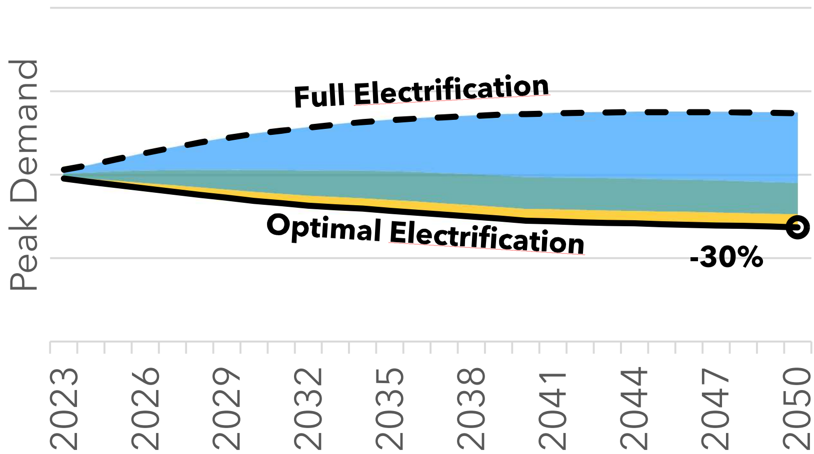

Figure 3. Annual peak demand impacts of optimal (minimum societal cost scenario) versus full electrification. Reductions due to air-source and ground-source heat pumps (blue), dual fuel (green) and demand response (yellow).

Expanding the geothermal market offers significant decarbonization potential. Large-scale deployment of geothermal systems can reduce both energy consumption and peak demand while delivering substantial long-term emission reductions. Given the challenges associated with retrofitting existing buildings, efforts should primarily focus on new construction, where geothermal systems can be more readily integrated. Financial support will be essential to overcome the high upfront costs that remain the main barrier to adoption.

Continued market transformation for air-source heat pumps is critical to achieving long-term decarbonization objectives. As adoption increases and technology continues to improve, particularly for cold-climate models, heat pumps can deliver significant emission reductions while helping to limit the impact of electrification on winter peak demand. Continued investment in market development, customer awareness, and deployment programs will be essential to accelerate adoption.

Finally, the analysis shows that achieving net-zero emissions will require the full decarbonization of the remaining gas supply. As illustrated in Figure 4, after the transition of existing customers to dual-fuel systems and the deployment of geothermal systems in new construction, the remaining natural gas demand can be met with renewable natural gas (RNG).

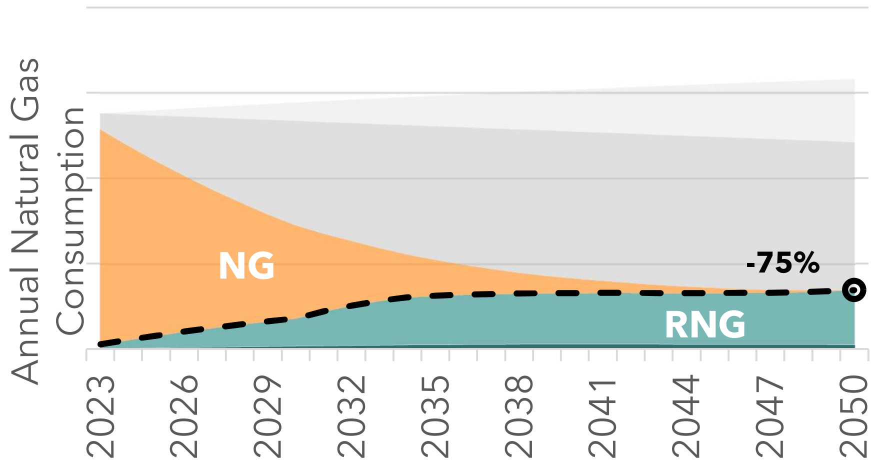

Figure 4. Annual natural gas consumption reduction and adoption of renewable natural gas under the minimum societal cost scenario, with natural gas savings shown in gray.

Moreover, the study highlights that achieving these ambitious, yet attainable, long-term decarbonization goals requires close coordination between utilities and government. Aligned policies, investment strategies, and market transformation efforts are critical to enabling a cost-effective transition. However, delaying action can significantly increase the complexity of the transition and reduce the range of viable pathways available to meet emissions targets. The importance of timely action becomes even more apparent in the second case study, which examines the challenges associated with achieving deep decarbonization within a significantly shorter planning horizon.

Case Study: Summer Peaking Integrated Utility

This case study examines a distinct context involving an integrated utility that distributes both natural gas and electricity. Approximately 65% of the residential heating load is met by natural gas equipment, while electric systems account for only 25%, a key factor contributing to the state's summer-peaking electricity demand profile (EIA 2026).

In this state, gas utilities are required to implement a Clean Heat Plan to reduce their greenhouse gas emissions by 22% by 2030, relative to a 2015 baseline. They are also mandated to develop transition plans that achieve these reductions while minimizing costs to ratepayers and maintaining system reliability.

This study was conducted as part of the utility's effort to evaluate how to achieve the 2030 target and to assess the range of pathways available based on its current portfolio. Three scenarios were developed to assess the extent to which the utility's existing program offerings can drive the adoption of clean heating measures:

1. Business-As-Usual (BAU): The first scenario represents a business-as-usual case, aligned with current programs and calibrated based on historical adoption trends.
2. High: The second scenario assumes increased financial incentives of up to 100% of incremental costs.

3. Policy: The third scenario incorporates a range of enabling measures designed to reduce market barriers and support the achievement of the Clean Heat Plan objectives. The scenario also includes incentives for BE measures covering up to 100% of the equipment costs.

This study's horizon extends through 2045. For this paper, we focus primarily on residential sector modeling between today and 2030, as this is the area the authors directly modeled, and also the sector and time horizon most critical to CHP compliance. Though the study covered electric demand response (i.e., peak load management), electric and gas energy efficiency, and electrification, the outputs relevant to CHP attainment are gas energy efficiency and electrification, so this paper also restricts its focus to those results. Model inputs were primarily derived from client-provided data and market surveys, and are calibrated using publicly available data sources, such as EIA and ResStock data.

The study took advantage of the authors' integrated, cloud-based modeling infrastructure, incorporating analysis within two modules. This enabled the parallel simulation of the adoption of more than 80 energy efficiency measures—including smart thermostats, building envelope improvements, and condensing systems—as well as over 700 beneficial electrification configurations across multiple market subsegments (e.g., single-family and multifamily) and different climate regions. The analysis covers both market-rate and income-qualified customers, across existing buildings and new construction.

Results

The results from this analysis, shown below in Figure 5, indicate that expanding financial incentives through existing program channels is unlikely to drive sufficient voluntary adoption to meet the Clean Heat Plan's 22% emissions reduction target in 2030. Even under the Policy scenario—which includes enabling activities to address market barriers and incentives covering up to 100% of HP equipment costs—the target would be achieved after 2030.

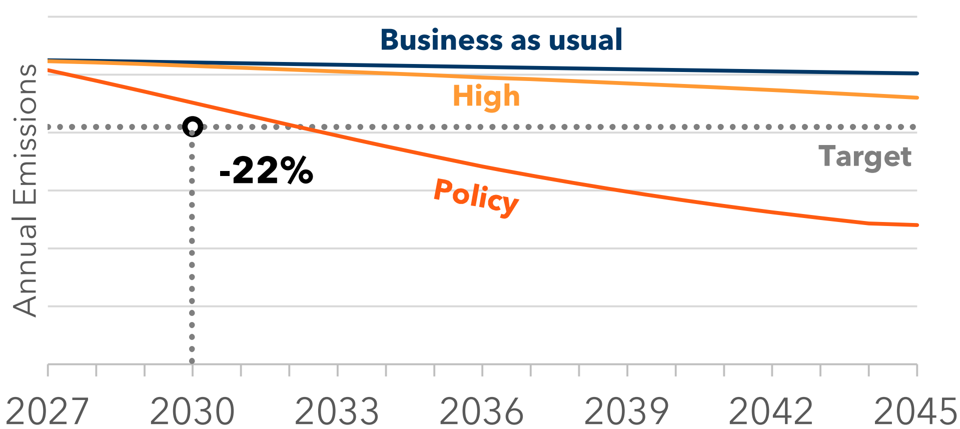

Figure 5. Greenhouse gas emissions reductions from gas energy efficiency (EE) and beneficial electrification (BE) measures under the Business as usual, High, and Policy scenarios, relative to the 2030 CHP target. The High scenario increases incentives, while the Policy scenario combines increased incentives for HP measures with enabling activities.

These findings highlight the importance of setting CHP goals with a clear understanding of both the timeline and tools that will be necessary to achieve them, as well as the power and limitations of traditional, incentive-driven voluntary adoption programs typically available to utilities to drive heat pump and energy efficiency adoption. The study also highlights the challenge of setting and meeting ambitious short- and medium-term goals in a turbulent political context – the relevant Clean Heat Plan legislation was originally passed in the early 2020s. Accounting for the time needed for utilities to file and receive regulatory approval for their plans, this left approximately 6 to 7 years to meet the CHP objectives, which began during a time of significant pullback in the federal government's degree of support for heating electrification and energy efficiency when the administration changed in January 2025.

Because the central results in this study found a notable gap between incentive program impacts and CHP targets, it was determined that a further mechanism would be modeled in addition to the incentive changes already included. Specifically, we modeled a heat pump rate to help overcome challenging customer economics related to ongoing operational costs when heat pumps replace gas-burning equipment. This mechanism was selected in part because it is a strong complement to incentive programs, where one-time payments help overcome the higher upfront cost of purchasing and installing heat pumps.

More specifically, the study team observed that customers of this integrated utility face a high electricity-to-gas price ratio (i.e., "spark gap") exceeding four, driving the finding that heat pumps are rarely cost-effective to operate relative to gas-fired heating systems. As a result, even substantial increases in one-time incentives struggle to overcome this ongoing operational cost differential.

Introducing a preferential electricity rate for heat pumps can improve operating cost competitiveness and provide customers with a clear economic rationale to switch to electric heating technologies. As shown in Figure 6, electricity rates would need to be approximately 50% lower than current levels to materially impact the heat pump economics.

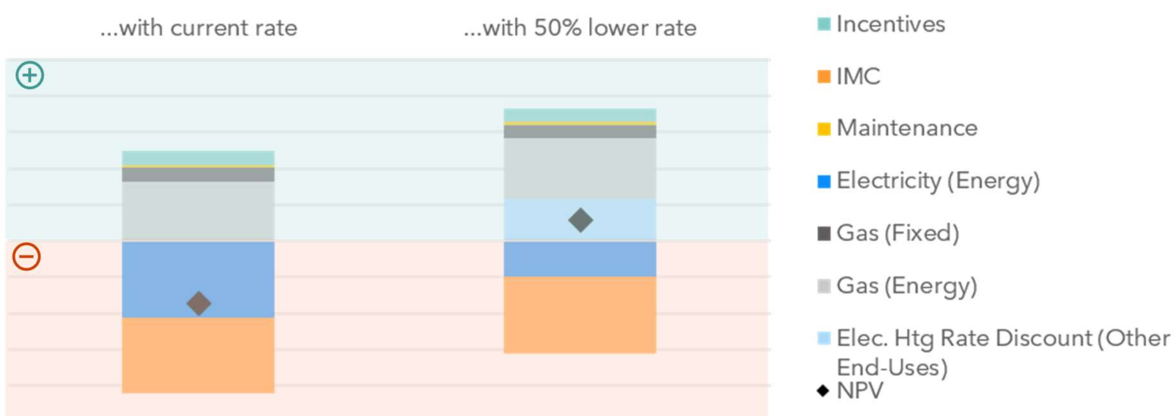

Figure 6. Comparison of participant net present value (NPV) from switching to a gas furnace system with air conditioning to an HP system[3] under the BAU scenario using standard and reduced rates (current rate: left bar; 50% lower rate: right bar).

While not modeled explicitly in this study, another avenue that we considered could help this utility meet its short-term targets would be policies and programs that help accelerate natural gas equipment replacement cycles, which normally occur at the end of the equipment's useful life.

[3] The results represent the average of three configurations: dual-fuel air source heat pump (ASHP), All-Electric ground source heat pump (GSHP) and All-Electric cold climate air source heat pump (ccASHP).

Collectively, our analysis suggests that achieving CHP targets, especially within a relatively short time horizon, will require proactive strategies to accelerate the transition, layering in enhanced customer incentives, other economic drivers for voluntary adoption like preferential rates, and potentially other tools that encourage early replacement of gas-fired systems for both domestic hot water (DHW) and space heating.

Discussion

The two case studies provide an interesting contrast, where applying a similar technical framework to assess how to achieve a target resulted in notably different outcomes. The first case study optimized societal outcomes across both gas and electric utilities to achieve a net-zero objective, while the second case study focused on reducing emissions from natural gas consumption. The longer timeframe in the first case study also enabled measures that would not be economic (or achievable) on the shorter timeframe of the second case study to contribute meaningfully to target attainment. In particular, natural gas demand was able to be reduced to a level that could feasibly be met by future RNG supply. However, this outcome is contingent on RNG availability and competing demand from other, harder-to-abate sectors. Shorter timeframes, as in the second case study, require reliance on immediately deployable measures and limit the ability to scale emerging technologies or develop new supply chains.

A second distinction is the goal of the policies in each jurisdiction. The first case study identifies the least-cost pathway from a societal perspective, requiring coordinated optimization across electricity and natural gas systems. The second adopts a bottom-up approach, using rate design and incentives to reflect customer-driven adoption within the study period. This results in a pathway that is more constrained by near-term economics and behavioral factors.

Understanding the energy system context is also critical when developing a clean heat plan. The first case study had better customer economics for electrified heating, but limited grid capacity to absorb this load. This results in a high value of avoided costs that enables additional solutions to target smart, beneficial electrification while making the best use of low-carbon fuels such as RNG as a peak-shaving service. In the second case study, challenging customer economics for heating electrification is driven by a higher spark gap (i.e., lower natural gas rates relative to electricity rates). Rate design becomes a more important potential tool to encourage adoption since the electricity system has capacity to provide this new load in the near-to-medium term, given the system is summer peaking. This system headroom, somewhat counterintuitively, also creates challenges, particularly by curtailing the ability to treat continued use of the gas system as an electric peak demand reduction strategy, given the notable differences between the electric system avoided costs between the two case studies, thereby limiting the value that can be unlocked through dual-fuel coordination, as in the first case study.

Table 2. Comparison summary of case studies[4]

Similarities	Differences
• Improving customer economics is necessary, particularly through higher incentive levels; however, on their own, incentives are likely insufficient to achieve clean heat targets. • Air-source heat pump (ASHP) technologies play a central role in building decarbonization pathways; therefore, strengthening marketing efforts and improving performance during peak conditions are critical. • Concerns about affordability, while not directly modeled, were central to conversations throughout both study processes. • Both studies relied on realistic, economically-driven customer adoption as a key element of modeling scenarios.	• Differences in grid characteristics (winter-peaking vs. summer-peaking) lead to materially different solutions and modeling approaches. Electric load management emerged as a critical solution in Case Study 1, while rate design did so in Case Study 2. • The nature of the targets influences the strategies required. For example, the carbon neutrality objective in Case Study 1 raises additional considerations, such as the need to address or offset residual natural gas consumption, an issue that is less relevant in Case Study 2. • Because of the societal focus and longer time horizon for Case Study 1, a net benefit maximization scenario played an important role in quantifying the scope of the potential financial 'win-win' from coordinating efforts across the gas and electric utilities. In contrast, in Case Study 2, the near-term nature of the target constrained the set of tools and policies that were considered to only those existing programs and regulatory mechanisms that could be scaled and deployed rapidly.

Conclusion

The case studies presented in this paper clearly demonstrate the value of modeling multiple decarbonization pathways alongside realistic customer adoption forecasting to craft ambitious and achievable clean heat implementation trajectories. Building decarbonization does not follow a one-size-fits-all logic: the most effective approach depends on local market conditions, existing building stock, fuel mix, policy context, and implementation constraints. Evaluating multiple trajectories made it possible to surface trade-offs among strategies and to identify pathways that were technically feasible, but also economically realistic and practically achievable. This was particularly important in avoiding planning approaches that depend too heavily on any single lever like voluntary incentive programs, and in identifying an appropriate, supplemental solution that accounted for jurisdiction-specific context in each Case Study. Additionally, affordability, rate impacts, and program budgets emerged as common key risks that must be managed.

A pathway-based approach also helped clarify the role that different strategies can most effectively play within an overall clean heat plan. Rather than treating energy efficiency, electrification, hybrid systems, and policy supports as competing ideas, the analysis showed the

[4] The final results for Case Study 2 have not yet been published. The following set of measures provides a preliminary overview of the key trends identified during the draft stage.

importance of understanding how and where each can contribute. In practice, this means recognizing that different measures may be more or less effective depending on the segment, timing, and system conditions involved. That level of insight is difficult to obtain through static target-setting alone but is essential for building plans that are both credible and cost-conscious. Finally, the work highlighted that robust pathway analysis is a foundation for implementation planning in addition to being an analytical exercise. By linking decarbonization outcomes to the policies, programs, incentives, and investments needed to achieve them, this approach helps bridge the gap between ambition and delivery. For policymakers and utilities, the key lesson is that clean heat planning is most useful when it does more than define the destination: it should also illuminate the practical routes available to get there, through detailed, jurisdiction-specific modeling that considers multiple decarbonization pathways.

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AI-assisted tools used: ChatGPT
Used for: light editing, drafting sections
Human review: The authors reviewed and verified all content, calculations, and citations.