Leaping Forward:
Local Energy Asset Planning (LEAP)
An Energy Transition Planning Framework

v. 2022.10.14

Michael J. Walsh, Ph.D.

Founding Partner and Director of Policy Research

Groundwork Data

CONTENTS

1 PART 1: EXECUTIVE SUMMARY AND RECOMMENDATIONS FOR POLICYMAKERS

1.1 DOCUMENT PURPOSE

This document presents a framework, methodology, and analytical tools to support local governments, utilities, public utility commissions, and cognate stakeholders in planning and implementing a street-by-street or district-by-district transition of their building stock from the use of natural gas for thermal services to low-carbon alternatives. Its intent is to enable a tactical thermal transition to balance costs, equity considerations, infrastructure needs, and other impacts.

This approach is referred to as *Local Energy Asset Planning* (LEAP). LEAP is a locally focused complement to state and macro-level gas transition planning. It aims to elucidate the opportunities and challenges relating to existing and future local energy assets (Table ES 1).

Table ES 1. ***Examples of Local Energy Assets***

Consumer	***Utility Infrastructure***	***Energy Resources***
Appliances	Pipes	Rooftop solar
HVAC	Wires	Earth and water heat
Building shell	Transformers	Waste heat
EVs & Chargers	Substations	Local load balancing

While effective state-level policies, regulatory frameworks, tariff setting, and other functions are critical to managing the natural gas transition, the building by building, block by block, and neighborhood by neighborhood transition will need to be managed and implemented at the local level.

All thermal decarbonization planning is local!

LEAP can be considered as a focused extension to local *Climate Action Planning,* which has been a broadly focused exercise that has allowed municipalities and their stakeholders to become more familiar with the general dynamics of decarbonization.[1] LEAP now focuses on identifying and prioritizing what *specific* infrastructure changes are needed to support climate, health, equity, resiliency, and energy security goals.

Given the current focus of various policy-making exercises, this report predominantly focuses on the management of gas infrastructure. Still, despite the current centrality of gas, LEAP is a broadly applicable framework.

Local decision-makers can use LEAP to understand alternative gas transition strategies' financial, system, and social impacts and help choose which strategies are the fairest and most cost-effective for which parts of their community. LEAP integrates various utility, building energy use, energy resource, and adjacent infrastructure information to identify and prioritize low-cost transition strategies and understand their impact.

Outputs of LEAP include system investment needs, costs, energy consumption, combustion emissions, methane leaks, labor needs, and broader impacts. Ultimately, LEAP is a long-term utility and building sector simulation framework that can evaluate system planning, regulatory, and financing strategies for managing the gas transition.

This living document is intended to serve as an ongoing resource for stakeholders to understand better and take advantage of LEAP approaches. It encourages regulators to support the development of LEAP by increasing the availability of utility asset data. Further, it seeks to empower organizations marginalized from energy planning, such as municipalities, with a more robust understanding of the analytical approaches to support local energy planning. Finally, it supports equity by providing a framework for evaluating fairness in outcomes across communities.

1.2 THE STRATEGIC CONTEXT

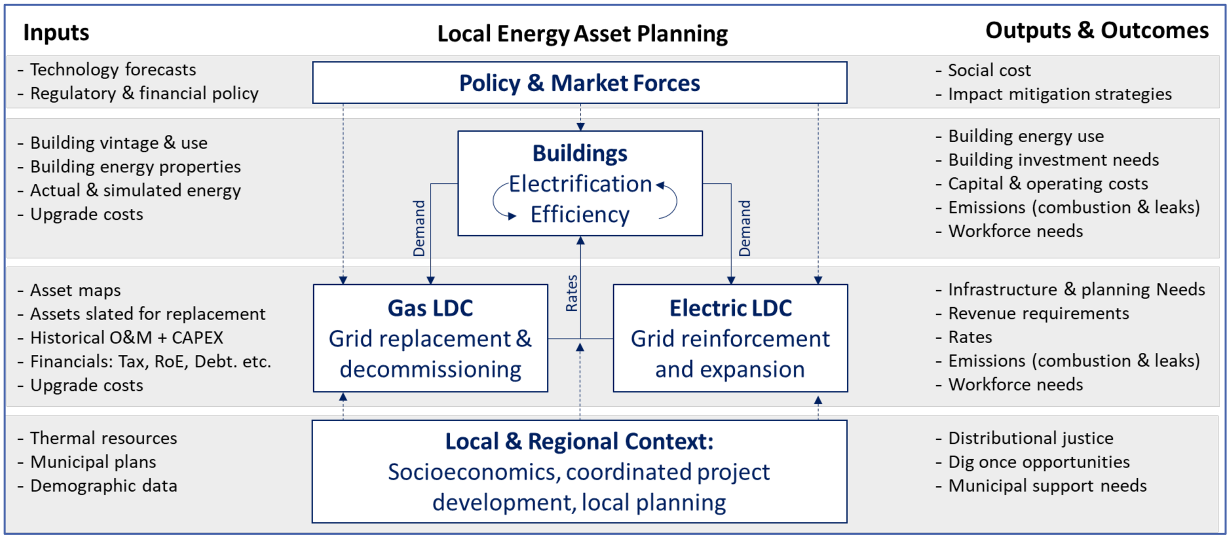
As states and municipalities implement aggressive GHG emissions reduction strategies over the next several decades, the consumption of pipeline-delivered gas and other fuels for building heating will significantly decline as customers transition to alternative, predominantly electric, heating technologies. This transition involves moving from an expansive gas distribution network to various implementations of several distributed heating technologies. Some of these approaches leverage local shared thermal energy resources such as the earth, water bodies, and waste heat.

Gas transition planning is essential for minimizing costs and ensuring an equitable transition by identifying system planning (e.g., pipeline closure, development of a thermal network) and policy strategies (e.g., securitization, rate design) that can be used to manage the transition to achieve such goals.

The gas transition is already underway as cities and states have begun activity to right-size the gas system to be aligned with a net zero emissions future. Notably, Zürich, Switzerland, has already decommissioned part of its gas system in part of the city and is planning to scale back the gas system across the entire city. Entities in California, New York, and Germany have begun efforts to understand the transition and develop management plans. A similar framework being developed in the United Kingdom called Local Area Energy Planning (LAEP) has some similarities to what is being proposed here and will be a model cross-learning. However, the current iteration of this work (LEAP) takes a more technical and methods-development approach focused on Massachusetts and the United States context to emphasize the need for improved and consistent data management at the local level (which is currently less robust in the United States).

1.3 THE LEAP FRAMEWORK

The graphic and table below provide an overview of the LEAP framework.

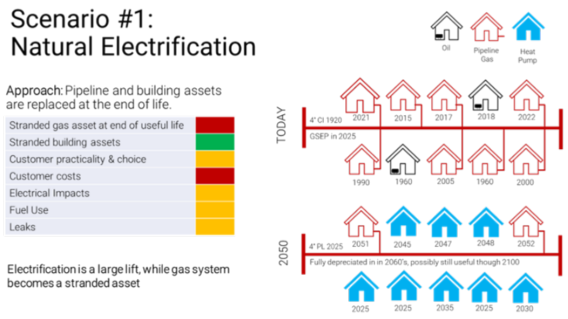


Geographic Focus	Building to utility (distribution-system) scale
Asset Resolution	All energy infrastructure assets with a defined role and lifetime
Time Horizon	Long-term with the ability to represent periods relevant to system design
Primary Accounting Goals	Time-resolved energy consumption by energy source Tracking of costs associated with assets
Secondary Simulation Focus	Emissions, infrastructure changes, customer bill impacts, customer disparities, workforce needs, and health impacts.
Scenario Representation	Customer (building-owner) behavior, systems changes, regulatory policy design.

LEAP leverages existing data to assess the impacts of planning scenarios across these focal areas. The general scope of a LEAP exercise is further defined by:

- **Policy and market forces** create the context within which Local Energy Asset Planning takes place. These include state regulatory structures, thermal technology innovation, and fuel pricing (natural gas and electricity).
- **Buildings** are the structures that consume thermal services. The LEAP process takes building information inputs (age, uses, energy systems, energy consumption, and upgrade costs) and uses them to identify potential future energy uses needed to upgrade investments, capital and operating costs, projected emissions, and workforce needs.
- **Utilities** provide energy distribution systems for natural gas and electricity. LEAP translates transition alternatives into their implications for natural gas and electricity utilities, including needed infrastructure investments, revenue shifts, rate changes, and emissions impacts.
- **The local and regional context** serves as an important background to LEAP planning. This includes the availability of alternative thermal sources, municipal infrastructure plans, municipal support needs, and equity consequences.

1.4 LEAP USE CASES FOR THE GAS TRANSITION

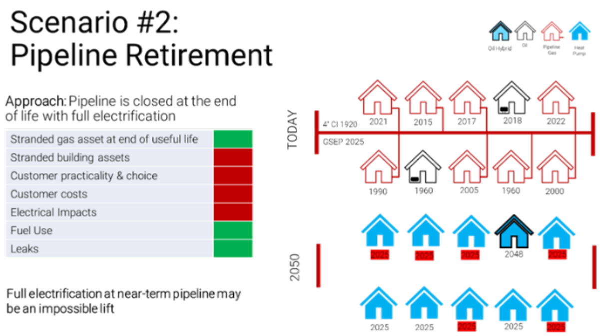


Scenario #1:
Natural Electrification

Approach: Pipeline and building assets are replaced at the end of life.

Stranded gas asset at end of useful life	🟥
Stranded building assets	🟩
Customer practicality & choice	🟨
Customer costs	🟥
Electrical Impacts	🟨
Fuel Use	🟨
Leaks	🟨

Electrification is a large lift, while gas system becomes a stranded asset

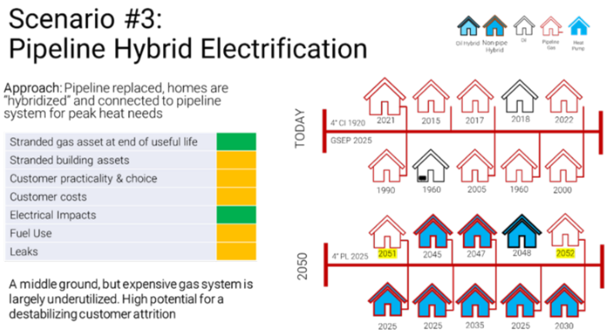


Scenario #2:
Pipeline Retirement

Approach: Pipeline is closed at the end of life with full electrification

Stranded gas asset at end of useful life	🟩
Stranded building assets	🟥
Customer practicality & choice	🟥
Customer costs	🟥
Electrical Impacts	🟥
Fuel Use	🟩
Leaks	🟩

Full electrification at near-term pipeline may be an impossible lift

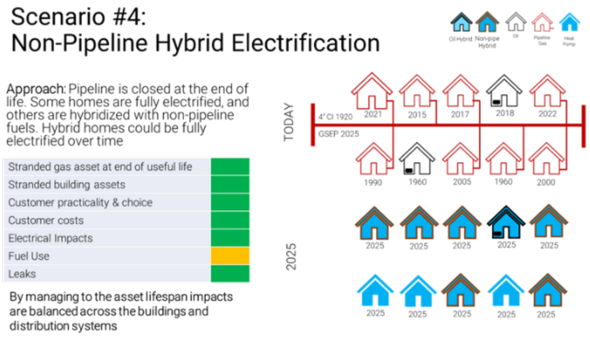


Scenario #3:
Pipeline Hybrid Electrification

Approach: Pipeline replaced, homes are "hybridized" and connected to pipeline system for peak heat needs

Stranded gas asset at end of useful life	🟩
Stranded building assets	🟨
Customer practicality & choice	🟨
Customer costs	🟨
Electrical Impacts	🟩
Fuel Use	🟨
Leaks	🟨

A middle ground, but expensive gas system is largely underutilized. High potential for a destabilizing customer attrition



Scenario #4:
Non-Pipeline Hybrid Electrification

Approach: Pipeline is closed at the end of life. Some homes are fully electrified, and others are hybridized with non-pipeline fuels. Hybrid homes could be fully electrified over time

Stranded gas asset at end of useful life	🟩
Stranded building assets	🟩
Customer practicality & choice	🟩
Customer costs	🟩
Electrical Impacts	🟩
Fuel Use	🟨
Leaks	🟩

By managing to the asset lifespan impacts are balanced across the buildings and distribution systems

There are two overarching immediate opportunities for using the LEAP framework to advance the natural gas transition.

1. **Alternatives to Leaky Pipe Replacement (short term).** LEAP can be used to evaluate alternatives to replacing leak-prone pipe infrastructure. Under the Massachusetts Gas System Enhancement Program (GSEP), the Commonwealth is projected to spend up to $20-$40 billion over the next decade to replace such leaking natural gas pipes. In many instances, the per unit cost of pipe replacement exceeds the per unit cost of installing carbon-free thermal alternatives. LEAP can help utilities and communities decide in what circumstances an alternative heat technology investment strategy makes more economic and emissions-reduction sense than the replacement/repair of old pipes. The figure above shows an illustrative application of LEAP scenarios to GSEP pipes.

2. **Municipal Scale Gas Transition Strategies (long term).** LEAP can also be used for planning neighborhood-to-municipal scale gas transition strategies over a longer time horizon. Such a framework has been called for by several stakeholders in the Massachusetts Department of Public Utilities' (DPU) Future of Gas investigation (Docket #20-80). In the same proceeding, the local gas distribution companies (LDCs) have endorsed the concept of "targeted electrification and networked geothermal" as pillars of their transition strategy. LEAP can help utilities and communities understand where targeted electrification strategies make the most sense from a financial, emissions, and equity point of view.

1.5 CURRENT STATE OF LEAP DEVELOPMENT

The three elements of the LEAP model (framework, methodology, and analytical tools) are in different stages of development. The table below summarizes these development stages.

LEAP Element	Description	Stage of Development
LEAP Framework	A general framework for approaching Local Energy Asset Planning.	Mostly completed, as represented in this background paper.
LEAP Methodology	A detailed description of the process for using LEAP to plan the natural gas transition in a local community.	The basic steps in the process have been defined, but they have not yet been prototyped in a real-life case example.
LEAP Analytical Tools	The analytical and modeling platform used to support data-driven LEAP decision-making. The core elements of the platform include: • Detailed asset, energy, and cost tracking for building and utility infrastructure. • Simulated utility financial operations • Impacts (e.g., emissions, customer bill charges, leaks, health, and employment) sufficiently resolved to assess disparities among different populations. • Representation of policy levers	LEAP analytical tools are currently being developed by a partnership between Groundwork Data and UMass Amherst. The State of California is developing similar tools and approaches, organizations in the United Kingdom, and applied researchers.

1.6 RECOMMENDATIONS FOR POLICY MAKERS AND REGULATORS

This report makes the following recommendations for supporting the evolution and implementation of the LEAP process.

- ***Use State Agencies to Support LEAP Development and Implementation.*** The multiple resources of the Massachusetts state government should be used to advance LEAP as a strategic resource for natural gas transition.

  a. The Department of Public Utilities (DPU). In its gas planning investigations and activities, the DPU should seek to enable local energy planning by municipalities and private sector collaborations to support decarbonization and gas transition goals. It should seek to make relevant datasets and resources accessible to local planners and implementors.

  b. Other State Agencies. State agencies and local government units should begin laying the groundwork for local energy planning by improving data collection, monitoring local transition planning activities in Europe, California, and other states, and convening stakeholders to socialize the evolving understanding of local energy planning. Piloting interventions will help to develop LEAP approaches further.

- ***Explore LEAP as an Alternative to Leaky Pipe Replacement.*** The DPU should investigate near-term gas transition strategies focused on evaluating alternatives to leak-prone pipes currently scheduled to be replaced as part of the GSEP program using local area asset planning. The potential application of such a tool should be a component of the pending GSEP working group.

- ***Support Access to Key Data Sets Needed for LEAP Implementation.*** The LEAP modeling platform is currently set up to integrate many publicly available data sources. As the LEAP practice evolves, it will be necessary for organizations to formalize access to needed data sets. Some of these suggested data support requirements include the following:
    - The **Department of Public Utilities (DPU)** should:
        - Require utilities to submit asset maps periodically for planning purposes and evaluate whether access to such maps should be public or accessible to qualified planning partners (e.g., municipalities, large users, etc.).
        - Establish a standard data format for GSEP reporting that encapsulates labor, overhead and material costs.
        - Require all GSEP filings to include an estimated closure cost as an alternative to the replacement cost.
        - Require utilities to report lost and unaccounted for gas by system segment as gas transfers are recorded (e.g., between city-gate and meters).
        - Seek to develop Open Data Access Frameworks to enable local energy asset planning, following in the footsteps of states like Illinois, which provide utility data to qualified researchers in the state and academia.
        - Establish a minimum geographic reporting level (e.g., census block) for reporting customers on utility discount rates that maintain customer privacy.
    - Municipal **tax assessors' offices** should improve energy asset tracking to support local energy planning.
    - Massachusetts **Division of Local Services** (Dept. of Revenue) should establish best practices in building energy asset tracking.
    - The **Energy Efficiency Advisory Council and MassSave** should establish a reporting framework for tracking costs and labor associated with building energy efficiency and electrification measures.

- ***Deepen Understanding of Alternative Advanced Thermal Resources.*** To understand the potential of advanced thermal resources, the state Department of Environmental Protection (DOER) or other entities should commission a thermal resource assessment study like the ongoing DOER solar siting study. The study should evaluate the availability and economic feasibility of ground-source heat pumps (e.g., NYC's Geothermal Tool); water-source (lakes, rivers, ocean) heating and cooling; waste heat; thermal networks; and organic waste or bioenergy hubs (e.g., a wastewater treatment plant) that could produce local combined heat and power. The resource assessments of emerging technologies should be conducted on a pilot (e.g., municipal) scale before being expanded to the state level to develop how the assessments are conducted and communicated. The assessment will be valuable for both public and private project planners.

- ***Improve Municipal Energy Asset Tracking.*** Municipalities, with coordination from the state, should improve the tracking of energy assets in buildings in a consistent manner as part of their property assessment and permitting functions.

2 PART 2: STRATEGIC CONTEXT

This section discusses the strategic context for natural gas transition planning in Massachusetts. It includes three sub-sections:

1. A framework for thinking about the evolution of the gas transition.
2. An overview of the gas transition in Massachusetts.
3. Best practice examples from other jurisdictions that Massachusetts can learn from, including California, Switzerland, and Great Britain.

2.1 RECOMMENDATIONS RELATED TO THIS SECTION

1. ***Deepen Understanding of Alternative Advanced Thermal Resources.*** To understand the potential of advanced thermal resources, the state Department of Environmental Protection (DOER) or other entities should commission a thermal resource supply and demand assessment study like the ongoing DOER solar siting study. The study should evaluate the availability and economic feasibility of ground-source heat pumps (e.g., NYC's Geothermal Tool), water-source (lakes, rivers, ocean) heating and cooling; waste heat; the viability of thermal networks; and organic waste hubs that could produce local combined heat and power. The resource assessments of emerging technologies should be conducted on a pilot (e.g., municipal) scale before being expanded to the state level to develop how the assessments are conducted and communicated. The assessment will be valuable for both public and private project planners.

2. ***Use State Agencies to Support LEAP Development and Implementation.*** The multiple resources of the Massachusetts state government should be used to advance LEAP as a strategic resource for natural gas transition.

    a. The Department of Public Utilities (DPU). In its gas planning investigations and activities, the DPU should seek to enable local energy planning by municipalities and private sector collaborations to support decarbonization and gas transition goals. It should seek to make relevant datasets and resources accessible to local planners and implementors.

    b. Other State Agencies. State agencies and local government units should begin laying the groundwork for local energy planning by improving data collection, monitoring local transition planning activities in Europe, California, and other states, and convening stakeholders to socialize the evolving understanding of local energy planning. Piloting interventions will help to develop LEAP approaches further.

2.2 A FRAMEWORK FOR THINKING ABOUT THE EVOLUTION OF THE GAS TRANSITION

For decades, the pipeline delivery of natural gas has largely been the cheapest way of providing reliable heating energy to customers due to the relatively low cost of natural gas compared to other fuels and the economies of scale obtained by a utility pipeline distribution network which kept delivery costs low. Along with ongoing marketing to customers, this feature positioned pipeline-delivered natural gas as the highest value and lowest cost energy product for building sector services that could leverage a combustible fuel.

That position is now under threat with significant consequences for the system by two overarching, complementary, and cross-reinforcing forces:

1. **Climate and Energy Policy** – The use of fossil fuels for heat at current scales is incompatible with governmental climate targets seeking to limit jurisdictional greenhouse gas emissions to align with global efforts to avoid extreme climate change. Various incentives, mandates, and transition programs are currently being developed to shift off fossil fuels for heat, emphasizing large-scale adoption of various heat pump technologies, comprehensive energy efficiency, and electrification of other end uses.
2. **Market Competition from Emerging Technologies** – Gas' economic and perceived value is facing unprecedented competition from electric alternatives. Heat pumps create value through lower-cost operation for most heating days, the ability to provide cooling and more flexible heating arrangements.[2] Heat pump water heaters can operate flexibly, allowing the consumer to heat and store water at periods of cheap electricity demand for use later. Further improvements in electric resistance cooking, the growing popularity of induction cooking, and a growing concern[3] about the health impacts of gas cooking are eroding the historical dominance of gas as desirable cooking fuel. All-electric new construction for most building types is now more economically favorable than fuel-based construction.[4] Integrated thermal energy networks can share thermal resources across time and space.[5] These alternatives will lead to a continuous and ongoing displacement of fossil fuels in heating and other applications; however, reliance on these market factors alone will not be sufficient to achieve climate targets.

It is essential to consider policy and market forces in influencing the transition, and market forces alone may cause significant disruption to existing energy systems. Current industry efforts to push back against electrification either naively or intentionally avoid this fact – a likely mixture of two. The increasing optionality and value offered to consumers by electric technologies, from heat pumps to LED fireplaces, is a significant threat to the current market position of combustible fuels.

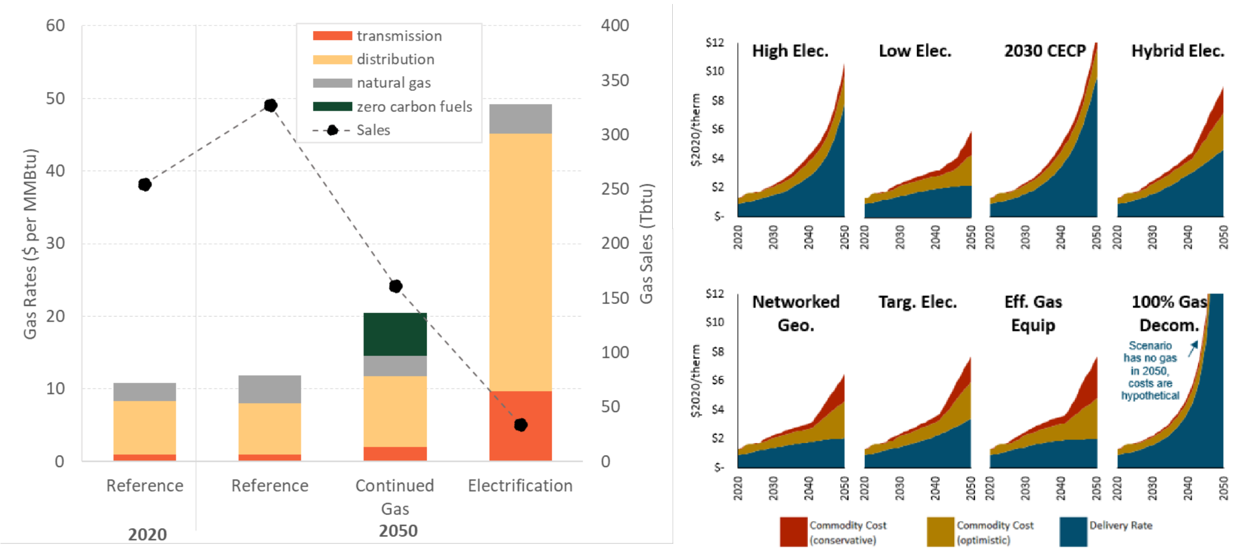


Figure 3. Forecasted gas rates for selected scenarios from the Massachusetts 2050 Decarbonization Roadmap Study[6] (left) and the 20-80 LDC Independent Consultant Report[7] (right). Substitution of fossil gas with renewable gas or hydrogen, alongside increases in delivery rates to cover an increasingly small customer base, drive rate increases in all considered futures.

All scenarios for the future of pipeline gas delivery imply a significant increase in customer gas rates to recover fixed costs and procure low-carbon gas (Figure 3). Utilities that have experienced customer exits – typically a result of regional migration patterns – generally raise rates in response to such exits to maintain the revenue requirement.[8] Further, decarbonized gas and hydrogen will cost more than fossil gas and increase customer costs. Finally, accelerated replacement programs such as the Massachusetts Gas Safety Enhancement Program (GSEP) will likely experience significant increases in expenses in the coming years due to higher project costs.[9] Such near-term replacements may be an opportunity to accelerate the transition to ambient heat, which will be explored in future documents in this study.

Customer sales will decline and be followed by customer exits. All these factors and incentives to electrify will, at minimum, spur partial electrification. Rate increases will be needed to maintain the revenue requirement. The LDC's proposed enablement plans[10–12] acknowledge this but note that equilibrium is possible in which the gas distribution system serves as a "peaking asset" utilizing hybrid gas-electric arrangements. This position will be continuously threatened by the declining absolute and relative cost[9] and increasing practicality of potential "competitors" to the gas system: whole-home electrification, non-pipeline alternatives such as propane retrofits and pellet heating, and various district arrangements. Conceivably strong-handed policy interventions aimed at keeping gas consumers on the gas system could be used to maintain customer levels. However, this approach would drastically constrain customer choice and be anti-competitive.[13]

Market forces are not limited to potential cost savings but include new value propositions that attract consumers. Heat pumps and building thermal improvements will increase the comfort of the occupants' building by reducing drafts and creating increasing opportunities for zoned space conditioning. Coupled with increasing consumer awareness of climate impacts, the desire for home energy improvements may become more attractive despite their higher costs, like how Tesla created the luxury electric car market. Fossil heating systems do not appear poised to deliver similar value propositions to consumers.

The level of electrification and efficiency will improve over time, but deeper levels of electrification and efficiency are likely to experience various implementation barriers which may hinder progress. The thermal transition should be viewed as a continuum of technological progress, reducing the reliance on fuel and the need for a pipeline delivery system while continuously increasing energy use efficiency. Early adoption of heat pumps is heavily favoring hybrid arrangements as consumers and installers gain experience with this emerging technology. Highly efficient thermal energy networks leveraging geothermal ambient heat are being derisked by universities with the technical expertise and access to capital. Energy efficiency practices are becoming more cost-effective across the building stock. Such early adoption is currently tiny, and while it has the potential to scale, access to capital, workforce capabilities, and consumer acceptance may hinder progress, especially with more intensive and comprehensive solutions that will lead to whole-building departure from gas networks.

More specifically, heating electrification faces a trio of cost and scalability difficulties that will complicate the transition:

1. Building retrofit challenges include upfront costs, lack of conspicuous benefits, workforce knowledge and capacity, and implementation feasibility. There is *high certainty* that these factors are especially challenging to whole-building electrification retrofits. Some consumers who value combustion end-uses may also be reluctant to switch.
2. Distribution system challenges include the increasing electrical heating load and need for upgrades and the declining throughput on the gas system. The former is largely interlinked with the need to modernize the grid for vehicle electrification, distributed energy resources, and resiliency. The latter, as noted above, will have consequences for meeting the utility's revenue requirement, likely necessitating rate increases that will spur further electrification and burden those who fail to electrify with higher bills. Additionally, significant uncertainties surround the scalability of new district systems, such as thermal networks that primarily on ambient and waste heat resources.
3. Energy supply challenges are caused by higher peak electricity demands created by heating electrification, while electricity supply becomes highly variable. There is *high confidence* that higher levels of electrification require additional investment in renewable (e.g., wind and solar) and firm (e.g., gas thermal) electric generation capacity. Deep electrification may result in higher levels of peak-day system-wide fuel consumption for electric power generation during cold snaps when heat pump efficiencies approach a coefficient of performance (COP) of 1. The combination of lower efficiency and low renewable energy production requires the use of "gas peakers"[1] that are relatively inefficient compared to heating boilers and furnaces – some of which previously used non-pipeline heating fuels (e.g., heating oil and propane).

---

[1] *Various peaking arrangements may be suitable and include hydrogen peakers, oil peakers (likely supported by short term batteries for ramping support), or some form of long-duration energy storage. Each of these will likely come with cost and implementation tradeoffs relative to the existing gas peaking fleet.*

Utilities and the existing regulatory framework are not currently capable of facilitating a comprehensive and rapid thermal transition. The current regulatory framework incentivizes the expansion of and reinvestment in the gas system, making it difficult for utilities to invest in local energy resources that may run counter to these outcomes. Further, the incongruous territories of Massachusetts' two largest gas *and* electric utilities result in nearly one million customers receiving electric service from a different utility from their gas utility. This currently results in awkward incentives for cross-sector planning.

Under this regime, and as the energy transition becomes more localized, local actors will need to become more engaged in energy transition planning. This requires building both knowledge and capacity to support the local energy transition across a diverse group of local stakeholders.

A rapid and complete decarbonization by 2050 requires simultaneous action to overcome these challenges. These challenges also align with three evolutionary levels of energy system decarbonization (Table 1): the consumer, the distribution system, and the supply. Aggressively pursuing solutions in these areas mitigates the risk associated with insufficient progress in the other areas.

Table 1. Three evolutionary levels of the thermal transition.

	Energy Consumer	Energy Distribution (Local)	Energy Supply (Macro)
Energy Components	Building infrastructure Energy demands Private energy resources	Gas distribution Electric distribution Local public energy resources New distribution networks	Utility-scale generation Transmission City-gate/Substation
Jurisdictional Aspects	State & federal standards State & federal incentives City code enforcement Property owner decisions	Public utility commission regulation City planning where influential	State/Regional generation and transmission policy as influenced by federal regulation
Challenges	Cost and market scalability on building retrofits	Increased need for electric investment coupled with needed rightsizing of the gas system. Uncertain role of new distribution networks.	Buildout of necessary electricity supply infrastructure & need for firm resources such as gas electricity generation.

Prior *pathways* studies seek to illustrate the general dynamics associated with all three levels across a state or region – largely modeling the complex dynamics of electricity supply systems but sacrificing local resolution. Such work helps illustrate broad dynamics but is insufficient for local planning and understating opportunities at the local scale.

This report, and the analytical framework it proposes, primarily focus on the consumer and distribution systems within the situational context of their *macro energy supply system*. By doing so, it intends to more specifically answer the *where* and *when* associated with decarbonization strategies as they relate to specific consumer and distribution system assets.

2.3 THE GAS TRANSITION IN MASSACHUSETTS

Interest and capacity in local energy and decarbonization planning are abundant across the commonwealth. Nearly 160 communities in Massachusetts currently participate in the State's community choice aggregation program, which allows these communities to procure additional renewable energy on behalf of their constituents. Many of these communities have developed their climate action plans and, in doing so, gained an understanding of their limits in achieving ambitious climate targets on their own. Some, such as Brookline, have been more ambitious in attempting to implement bans on new gas connections, only to run into legal resistance.[14] The City of Boston, in partnership with the BPDA, has been pursuing efforts to develop local energy planning for establishing new energy distribution systems in development projects.[15] Such efforts have required the City to submit a home rule petition which has languished in the state legislature.[16]

These communities are hindered by a regulatory framework that has primarily incentivized economies of scale by creating large, conglomerated distribution systems that deliver energy imported from elsewhere. This contrasts with the potential modular approach of local distributed energy resources and strategies.

Low-cost decarbonization strategies can leverage local energy resources. In the case of heat, this includes ambient energy sourced from nearby air, earth, water bodies, and waste heat resources using heat pumps and thermal energy networks.[2] Further, the pursuit of efficiency in energy use is an inherently local activity and investment. Capturing these decarbonization resources requires robust local scale planning conducted in the context of existing energy distribution systems, using transparent, open data and analysis frameworks.

Meeting the state's decarbonization targets will require harnessing such local capacity to produce positive outcomes rather than leaving it to languish under centrally coordinated approaches. Doing so will require empowering communities with data and regulatory structures to help accelerate the deployment of building electrification strategies and local energy planning to meet local energy and decarbonization goals.

Two-thirds of the gas consumed in Massachusetts is consumed by the building sector and is delivered by several investor-owned pipeline distribution utilities. **There is high confidence that the dominance of pipeline-delivered natural gas will be severely eroded in the coming decades by policy and market forces.** Significant uncertainty remains around the degree of electrification at the building and system levels and how residual fuel demand will be decarbonized. Consumers will have an increasingly available set of options for improving the comfort of their homes while reducing reliance on fossil fuels. Some of these options are likely to be more expensive than current building

---

[2] An evolving understanding of district energy technologies has led to some confusion in local energy planning. Despite some interest in the early 2010s, high-temperature gas-fueled CHPs were eventually understood to be incompatible with efforts to nearly eliminate fossil fuels, leading to reduced focus on district energy solutions. Recent successful ambient temperature district projects,[17] proposals to electrify and expand steam production,[18] and potential breakthroughs in deep hot rock geothermal solutions[72] have demonstrated that the provision of low carbon heat through district systems may be a feasible and scalable strategy. However, current regulatory frameworks may hinder the scalability of such systems and, subsequently, the pace of decarbonization.

heating arrangements on both an upfront and ongoing cost basis. However, they will deliver added value to the consumer through more comfortable and healthy buildings that align with climate goals.

2.3.1 Massachusetts 2050 Roadmap, 2025/2030 Clean Energy and Climate Plan Clean Energy and Climate Plan, and Commission on Clean Heat – (Executive Office of Energy & Environmental Affairs)

The transition from a high to a low-throughput gas system will have significant and likely inequitable consequences,[6,7,19] but robust and equitable policy strategies have yet to be developed. A better understanding of the transition dynamics is essential to ensuring a low-cost and equitable transition. The Massachusetts 2050 Decarbonization Roadmap recognized the implications of these factors, noting that:

> *"A strategy reliant on the continued use of pipeline gas for building heat carries asymmetric risks compared to electrification. A future increase in the price of pipeline gas, together with increasing reductions in costs associated with heat pumps, could result in a significant cost-driven market advantage for heat pumps that, regardless of policy, leads to a large, uncontrolled customer exit from the gas system. The potential for an uncontrolled) exit driven by market economics raises significant additional equity concerns."*[20]

The Commonwealth has been understandably focused on two state-wide planning exercises, but as these plans evolve, they need to seek to empower the leveraging of local energy resources. The first was conducted as part of the State's 2050 Decarbonization Roadmap Study [7] and recently augmented as part of the Massachusetts Clean Energy and Climate Plan (CECP) for 2025 and 2030[21] – in which the state called for a "responsible energy infrastructure planning" process for buildings. The 2025/2030 CECP further found that a *phased* approach to transitioning the gas system – one that relies on hybrid fuel and electric heating arrangements in the near term but pursues deep electrification in the long term – achieves the lowest cost transition.

Notably, the 2025/2030 CECP recognized the role of local communities in planning:

> *"Local communities play an increasingly important role in the siting of new renewable energy projects and transmission/distribution system upgrades; implementation of zoning and building ordinances that support the development of high-performance, low-carbon emitting buildings and smart growth; significant expansion of the electric vehicle charging network; increased climate adaptation and resiliency; and equitable implementation of policies that impact residents and businesses in their jurisdictions. Thus, the Commonwealth must work closely with all communities to ensure a just and equitable transition."*[21]

However, despite emphasizing the need for more community engagement[3] and outreach, the technical analysis and policy recommendations of CECP did not make any material advancements in further enabling local communities to develop local energy planning or resources.

The CECP and EOEEA's Commission on Clean Heat has instead focused on a ***Clean Heat Standard*** as a centerpiece of its efforts to mitigate emissions from the building sector. The policy is intended to serve as an "umbrella" framework for emissions reductions from building heat – augmenting other planning that may be necessary. The concept is modeled on adopted legislation in Colorado and proposed-but-vetoed legislation in Vermont. The framework is intended to provide building owners, residents, and utilities with flexibility in the type of heat used. Still, it ignores aspects of a managed transition of gas and associated risks.

2.3.2 "Future of Gas" Docket (20-80) – Department of Public Utilities

The second planning exercise is the Department of Public Utilities' (DPU) "Future of Gas" docket (DPU 20-80[9]). Recognizing the potential consequences of an unmanaged transition, the Massachusetts Attorney General's Office petitioned the DPU to investigate the role of gas in supporting the state's greenhouse gas reduction goals.[24]

Subsequently, the DPU ordered the gas local distribution companies (LDCs) to select an independent consultant to evaluate net zero compliance strategies and pathways for the gas sector as a whole each LDC.,[25] The consultant conducted a comprehensive pathways analysis[7] which informed the utility's proposal to develop a process in which each utility would develop *Net Zero Enablement Plans (NZEPs)*[12] on a triennial basis. Each utility submitted initial plans as part of its filing.

The pathways analysis evaluated several scenarios ranging from continued use of gas at current scales to the complete decommissioning of the gas system. Despite this range, the study was limited by the following factors:

- **Neglect of high-risk scenarios:** The study failed to fully internalize the possibility of an uncontrollable customer exit and how such large-scale customer attrition would be managed.
- **Limited resolution of alternative strategies:** The analysis of *targeted electrification* and *geothermal network* strategies was oversimplified to meet the specifications of the utility-scale analytical approach. These strategies need more granular assessments to understand better their potential and where they should be pursued.
- **Conclusions not backed up by the analysis:** The hybrid electrification scenario assumed continued gas system operation at current scales with declining throughput as heat pumps were installed while still supported by combustion backup. This scenario was found to have the lowest cost and lowest degree of qualitatively assessed transitional barriers. However, cost savings were partly driven by the hybridization of oil-heat, which was not included in

---

[3] The Department of Public Utilities (DPU 21-50)[22] and Energy Facilities Siting Board (EFSB 21-01)[23] are examining the procedural enhancements to promote more meaningful involvement by historically underrepresented communities.

> other scenarios. This gas-agnostic scenario variation serves as a thumb-on-the-scale for this scenario relative to others. While the modeling choice may have been justifiable, the conclusion – that maintaining the gas system at current scales helps to minimize costs relative to other scenarios – is unfounded.

The NZEPs are proposed to be triannual planning exercises evaluating the applicability of different strategies to the utility's net zero compliance and proposing near-term actions for implementing these strategies: renewable gas, hydrogen blending, targeted electrification and retirement, networked-geothermal systems, and enhanced energy efficiency measures. Following the approval of each NZEP, the utility would implement a strategy like how energy efficiency plans are implemented (e.g., MassSave). Utility costs are recovered via a special NZEP tariff, while renewable gas procurement costs are recovered through expansion of the cost of gas adjustment clause.

The pathways analysis and initial NZEP proposals recognized a role for locally focused actions such as targeted electrification and networked geothermal. However, the proposals were largely silent on how to identify, select and plan such projects. **As they stand right now, the utility's proposed Common Regulatory Framework and NZEPs lack a focus on local planning.**

2.3.2.1 AGO's Response

In the AGO's comments on the utility's proposal, the AGO criticized the current state of gas planning as "fractured" and "misaligned and inconsistent with the Commonwealth's climate mandates".[26]

The AGO further called for a more comprehensive review of and an investigation into alternative thermal technologies, submission of system and customer data, alignment of gas and electric planning, and development of frameworks and calculators to evaluate alternatives. Like the state-level planning exercises described above, the AGO's response largely left out an acknowledgment of the local aspects of the gas transition.

2.3.2.2 Department of Energy Resources Response

As part of its comments[27] to the Future of Gas proceeding, the Massachusetts Department of Energy Resources (DOER) recommended that the utilities develop and incorporate geographic marginal cost analysis into their NZEPs.

DOER further specified that the analysis "should incorporate geographic mapping and marginal cost analyses to identify priority investment areas, including potential pipeline upgrades for hydrogen or renewable gas, strategic electrification with decommissioning, and geothermal systems. This analysis should be presented with sufficient detail to identify areas in each LDC's service territory with higher incremental costs of services, opportunities for renewable gas or hydrogen, and opportunities to adopt systematic electrification that allows for targeted decommissioning of the pipeline system."

As it was a response to the utility-focused docket, DOER's comments are offered in the context of utility-focused planning. However, the emphasis on geographic analysis further underscores the potential value and importance of spatially explicit locally focused integrated planning exercises like that presented here.

2.3.2.3 Local Community Involvement

Several communities have been involved in the 20-80 process. Several towns have submitted comments, while the City of Boston has participated in some stakeholder sessions. The Metropolitan Area Planning Commission has been facilitating a forum for communities called the *Multi Town Gas Leaks Initiative,* which meets several times a year to discuss issues related to gas leaks and gas system management.

Notably, on behalf of several municipalities and planning agencies, the Emmett Environmental Law Policy Clinic at the Harvard Law School submitted a comment[28] in the 20-80 process, arguing for an increased focus on towns. The comment states that:

> *"Neither the DPU nor the LDCs should attempt to devise and manage this transition on their own; they need to coordinate with municipalities. Local and regional governments are at the nexus of many issues that will be addressed in this proceeding, including assuring affordable housing stock, reducing environmental and energy justice burdens, scheduling infrastructure projects, promoting public health, and reducing GHG emissions. Municipalities, therefore, have a unique interest in and perspective on this proceeding and should be engaged as partners in promoting and stewarding the transition of buildings to clean energy sources."*[28]

2.3.3 Legislation on GESP and the Future of Gas Docket.

The 2022 Massachusetts Climate Bill (H.5060)[1] established a working group to develop proposals for changes that would help align GSEP with the state's climate targets. The legislation further allowed thermal energy networks to serve as an alternative strategy to pipeline replacement for GSEP-eligible projects. Both developments emphasize the importance of developing a standardized locally focused cost-evaluation framework.

The legislation also prevents the DPU from approving a new regulatory framework without a formal adjudicatory proceeding.

2.3.4 Summary

All gas transition planning must start with the assumption that there is a significant risk of a large customer exit that threatens the financial viability of the gas system. Next, it must simultaneously pursue and aggressively balance the goals of climate mitigation, ratepayer protections, and equity – the current mandate of the DPU.

With these principles established, gas transition planning evolves to be a local issue since, in the near term and long term, significant cost savings will be achieved by the strategic management and potential rightsizing of the gas system. Such management needs to occur within the local context and be informed by the local conditions of the gas system, the building stock, the electric distribution system, local energy resources, and the social-economic context. Further complicating planning in Massachusetts is the 1 million customers in nearly 200 communities served by separate gas and electric utilities (**Figure 1**).

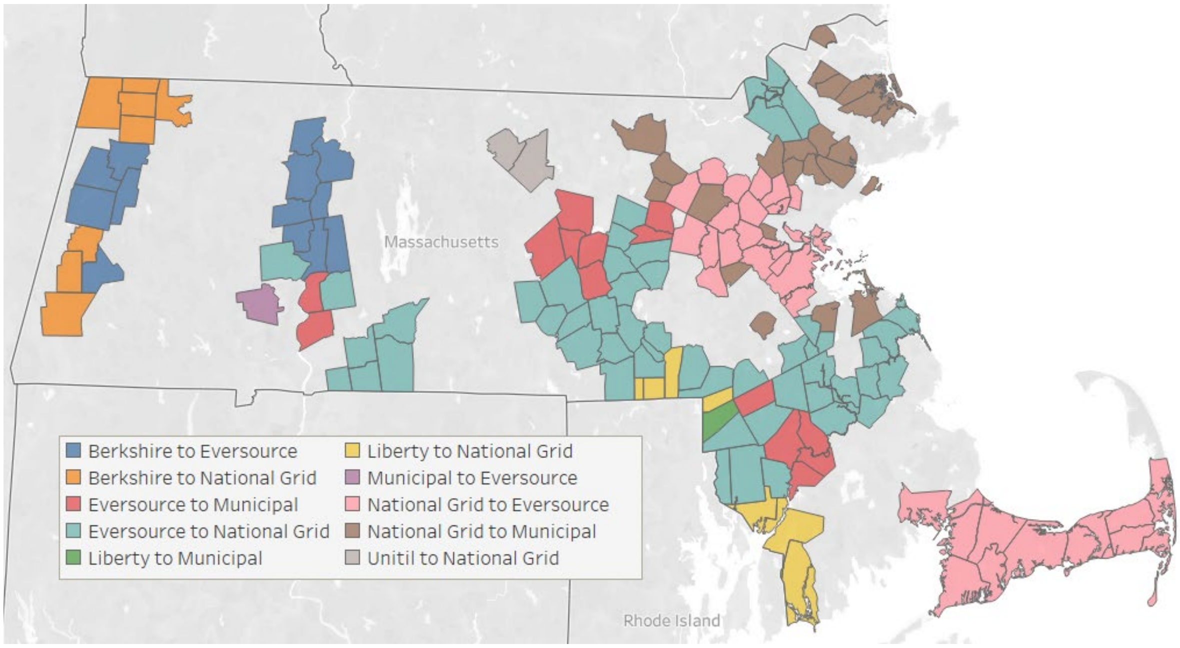


Figure 1. Gas to electric utility service area transitions. The figure excludes towns where the gas to electric energy demand shifts to the same parent investor-owned or municipal utility and towns without gas service.

Solutions, consequences, enablement, funding, synergistic opportunities, equity issues, and consumer adoption will all unfold locally and be influenced by local contexts. This document is based on the premise that local energy planning is integral to state-scale gas planning. Such local planning will naturally happen but be constrained by existing regulatory frameworks. LEAP is a framework, methodology, and set of analytical tools to support this shift from a state and utility-focused transition strategy to one that supports local involvement, decision-making, and innovation.

2.4 BEST PRACTICES IN NATURAL GAS TRANSITION STRATEGIES FROM OTHER JURISDICTIONS

There has been a growing focus on gas transition planning in recent years. This interest has evolved from heating electrification emerging as the consensus strategy to reduce greenhouse gas emissions from the buildings sector and concern about the long-term impacts of customer decline. Despite its potential to substantially reduce emissions, electrification faces potential challenges: the simultaneous need to rapidly scale up renewable energy resources, ensure reliability by maintaining and enhancing firm gas electric generation capacity, and upgrade the electric distribution systems.[6,7,21,29]

Various white papers, reports, and academic studies have begun to consider and evaluate the transition away from gas. The literature is nascent and theoretical, given the lack of examples for system scale back. Several of these have emphasized the potential for a death spiral that may evolve under current ratemaking practices as customers depart the gas system, leaving those who remain with the costs of maintaining the gas system, further incentivizing customer exits.

2.4.1 The Regulatory Assistance Project Natural Gas Transition Framework

The Regulatory Assistance Project (RAP) called for increased local energy planning in its report: *Under Pressure: Gas Utility Regulation for a Time of Transition*.[30] This report lays out a framework for inclusive, cross-sector *gas transition planning* that would be necessary to develop cost-effective and equitable plans for deep emissions reductions (**Figure 2**). The report emphasized that the decarbonization of a utility cannot be conducted in a vacuum, particularly when deep decarbonization strategies such as electrification will have consequences for the gas utility, the electric utility, building owners, utility customers, and local planners.

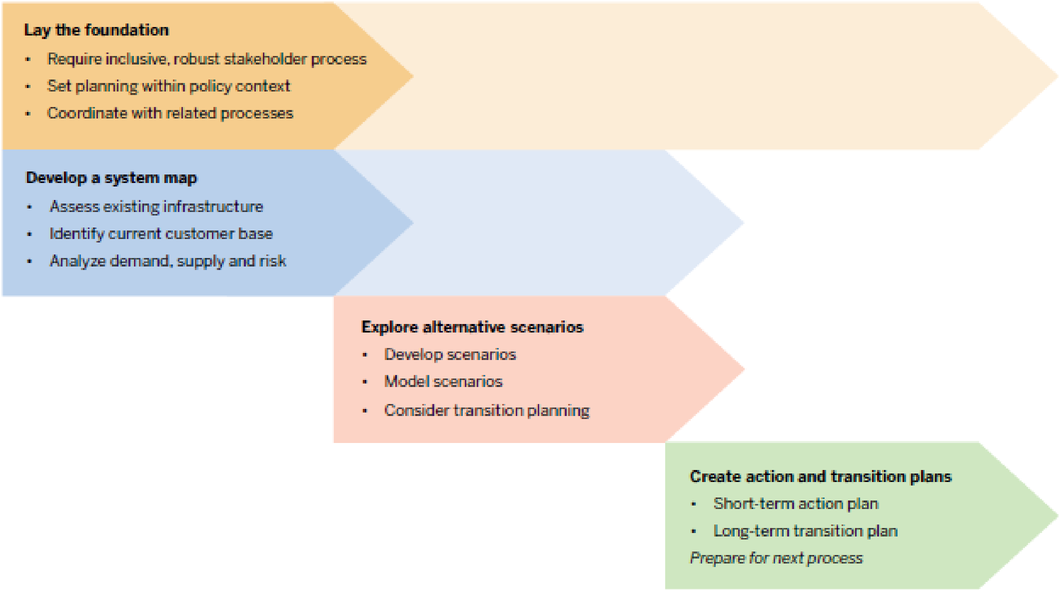


Figure 2. Gas Planning Process as proposed in Under Pressure: Gas Utility Regulation for a Time of Transition[30]

Further, the RAP Report proposed conducting a detailed analysis that included baseline system mapping and forward-looking scenario or pathway planning. Such analysis should evaluate:

1. The existing gas distribution system infrastructure is based on asset age, material, the timing of future replacement, and risks (e.g., leaks). The analysis should also consider the distribution system configuration to identify single feed segments that, if retired, will not impact other areas of the distribution system. The analysis would identify opportunities for early retirement or system reinforcement.
2. The building stock to assess baseline energy demand and potential for efficiency and electrification measures within the stock based upon different building or energy customer classes (residential, commercial, industrial), building energy systems (envelope and HVAC equipment), opportunities for DERs and GSHPs (networked or independent), and other factors that may influence energy demands and decarbonization strategies.
3. The existing electric distribution infrastructure and its capabilities for handling load increases, alongside strategies for mitigating such impacts.

2.4.2 Gas Transition Planning in California

California has been at the forefront of gas transition planning in the United States. In January 2020, the California Public Utilities Commission issued an *Order Instituting Rulemaking to Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and Perform Long-Term Gas System Planning*[31] to investigate the gas transition and its implications for ratepayers. This process has crafted the concept of "*targeted transitioning, decommissioning or electrification.*" These efforts are currently evolving and should be monitored. Recent work is highlighted here.

Influence of Advocacy Organizations: A report[32] commissioned by the Buildings Decarbonization Coalition and authored by Common Spark Consulting provided an overview of strategies for managing the gas transition equitably. The report identified several factors that should be used to prioritize trimming the gas infrastructure, including age and maintenance costs, customer end uses, and broader social and equity impacts. The report also identified several barriers to managing the transition, including the obligation to serve and access to gas planning information.

State Assessment of Issues Related to Gas Planning: The CPUC released a whitepaper titled *Gas Planning and Reliability in California*[33] that evaluated issues related to gas system planning relevant to rulemaking. The whitepaper identified several considerations for gas planning (Table 2), factors influencing gas system decommissioning (**Figure 3**), and transition management strategies.

Table 2. Categories of technical, economic, and other considerations related to Gas Planning Rulemaking[33]

Technical Considerations	Economic Considerations	Other Considerations
A. System condition and needs for reliable operations B. Balancing gas supply and demand in real-time and planning for the long-term C. How to "prune" the gas system?	A. Strategy for continued system investments and operations and maintenance (O&M), including those related to safety B. Stranded assets and cost allocation among customers C. How to "prune" the gas system in the most cost-effective way?	A. Continued GHG emissions B. Alignment of planning processes to broad objectives

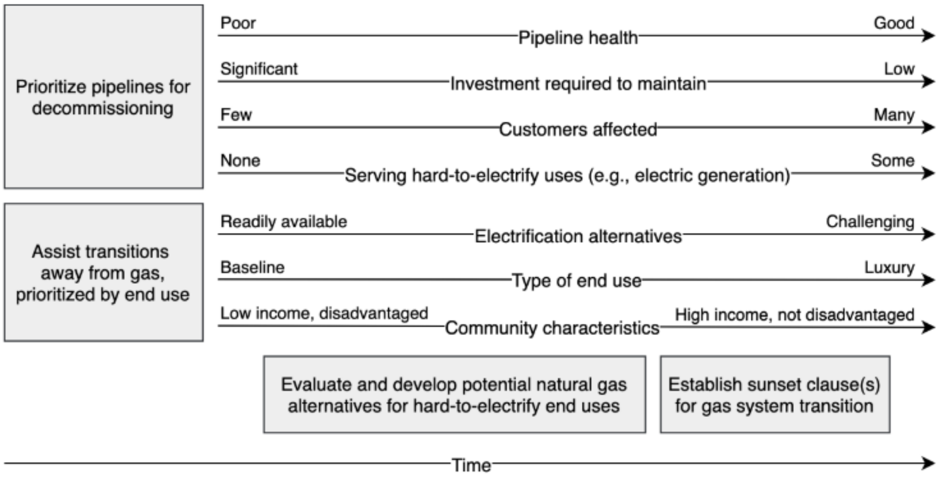


Figure 3. Schematic for the gas system transition.[33]

Utility-Wide Planning Framework Development: The think tank Gridworks facilitated a process in California with stakeholders focused on gas infrastructure planning that established the Gas Resource and Infrastructure Planning (GRIP) Framework.[34] This effort seeks to integrate policy goals, forecasting, assessment of future infrastructure needs, and cost management strategies to inform California Public Utilities Commission decisions.

Notably, the GRIP framework seeks to integrate:

- Utility regulation
- State-wide energy planning, including the availability of gas resources (e.g., biogas)
- GHG reduction goals
- Electric grid operation and reliability

The framework identifies informational and data needs, evaluation criteria, targeted outcomes, and informational outputs. Many of the data components of the planning framework could apply to local planning. However, the framework does not provide sufficient specifications to ensure meaningful local planning.

Analysis of Potential Transition Pilots: Following the Commission's order, the California Energy Commission released a solicitation to support *The Development of Strategic Pathways and Analytics for Tactical Decommissioning of Portions of the Natural Gas Infrastructure*. Two-$1M awards were granted to separate consortia led by E3 and Rand, including utilities and community groups. The awards separately focused on potential project sites in Northern and Southern California. The project seeks to:

- *Develop criteria and a framework for selected decommissioning sites*
- *Explore methodologies and develop deployment plans for strategic decommissioning while balancing decarbonization, consumer acceptance, and safe operations*
- *Identify community priorities, perspectives, and paths forward on electrification and tactical gas decommissioning*
- *Identify opportunities to achieve gas system cost reductions through tactical decommissioning*

The work involves stakeholder engagement, economic and equity modeling, decision analysis, pilot deployment and applications, and developing guidelines and criteria to replicate for project deployment. The first update of the project was held in November 2021, where the project leads discussed their technical and engagement approach[36]

Notably, the state's two major gas utilities (PG&E and SoCal Gas) participate in the effort, providing data and system knowledge. These transition pilots are anticipated to evolve locally and may provide valuable insights for developing local planning analytical frameworks.

Figure 4 shows a draft candidate screening framework for the identification of potential sites for targeted electrification.[35,36]

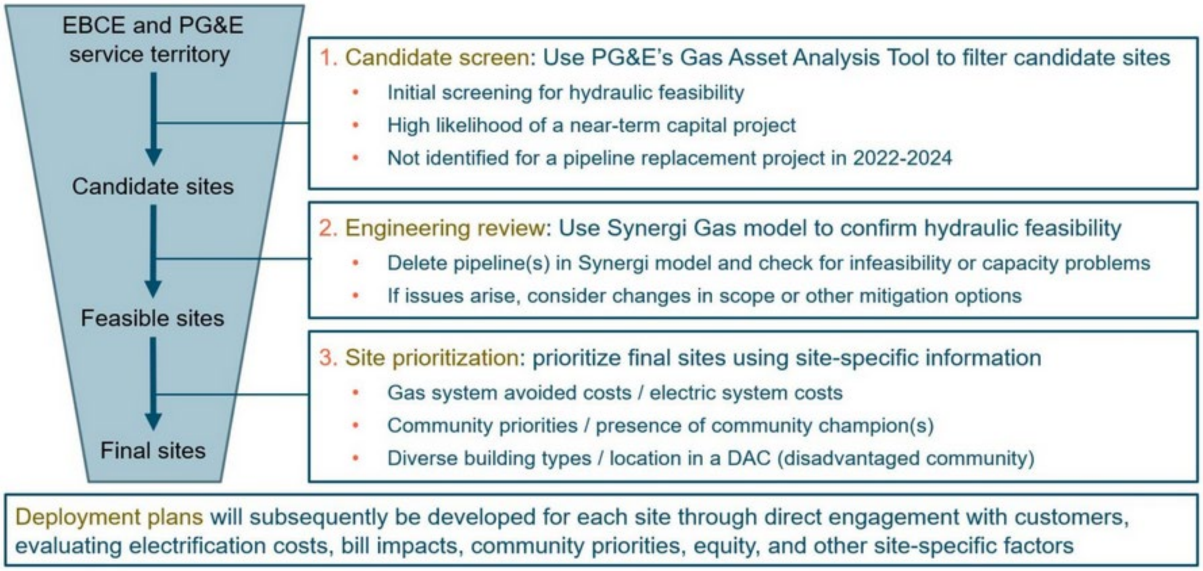


Figure 4. Draft framework for Identifying Potential Gas Decommissioning Projects [35,37]

Analysis Tools: The CA Energy Commission Subsequently issued a $1.5M contract to DNV/GL to develop a *Data-Driven Tool to Support the Strategic and Equitable Decommissioning of Gas Infrastructure*.[37]The project is summarized by the CA Energy Commission:

> *"The data-driven tool developed under this solicitation will provide state agencies, local governments, investor-owned utilities (IOUs), and other stakeholders with valuable information for assessing the technical and economic feasibility of and other issues related to decommissioning specific segments of the gas system. This includes a greater understanding of possible strategic decommissioning pathways to complement emission reductions, avoiding unsustainable significant cost burdens for ratepayers, ensuring that the safety of the gas system is not compromised, and enhancing the capacity of state agencies, IOUs, local governments, and other stakeholders to collaboratively plan and develop a policy for the gas system in California's low-carbon future by identifying promising sites for decommissioning gas infrastructure."*

The California Energy Commission has hosted several workshops to evaluate the analytical framework for the gas transition.[38,39] These workshops covered a variety of analytical approaches ranging from asset modeling to grid-gas interface modeling to physical modeling (power flow and hydraulic modeling).

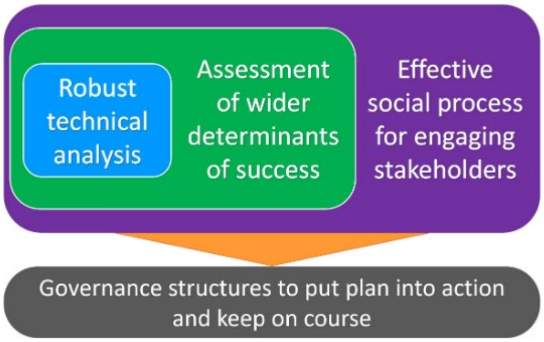
The evolving work in California underscores the importance of multiple layers of analysis to address specific research questions.

Municipal Planning: In 2020, the City of Palo Alto's municipally owned and operated Utilities Department conducted its own internal *Electrification Impact Study*[40] that assumed complete electrification of single-family residences and disconnection and decommissioning of gas assets. The study focused exclusively on single-family homes, leaving behind a skeleton gas distribution system for multifamily and commercial buildings. The analysis was conducted using aggregated utility data and focused on the utility material and labor costs for upgrading transformers and decommissioning gas assets. The analysis did not include the cost of building electrification.

The analysis found that electrification would raise rates by approximately 1.2%-3.8%. However, some of the cost would have been incurred due to vehicle electrification and deployment of distributed energy resources. Further, these estimates do not include the cost savings from avoided investment in the gas system, representing a quarter to a half of the costs of electrification and gas decommissioning. The analysis also included an estimate of staffing needs to facilitate the transition, which was considerable.

It is unclear how prevalent such local scale planning will be in California's state gas planning exercises.

2.4.3 Great Britain – Local Area Energy Planning



The four key elements of local area energy planning

Great Britain's Office of Gas and Electricity Markets (Ofgem) commissioned a report that proposed a Local Area Energy Planning (LAEP) framework to "inform, shape and enable key aspects of the transition to a net zero-carbon energy system."[30] The framework closely mirrors that of the Regulatory Assistance Project's *Under Pressure* report,[31] but goes further in identifying elements of a robust technical analysis to include:

- Scenario modeling
- Representation of local energy resources and networks
- Sufficient detail to capture critical interactions between system components, including geographical features
- An appropriate representation of time
- Appropriate geographic scale
- Incorporate sensitivity analysis of critical uncertainties
- Transparent data inputs
- Validation of models, inputs, assumptions, and application.

The LAEP framework is undergoing further development in the UK and parallels many of the objectives of this report and framework. However, this report's "LEAP" approach is currently distinguished from the UK "LAEP" approach by its methodological focus on energy assets to facilitate the gas transition, whereas the UK LAEP approach is more general. There will be opportunities for cross-learning from the two approaches.

2.4.4 Zurich, Switzerland

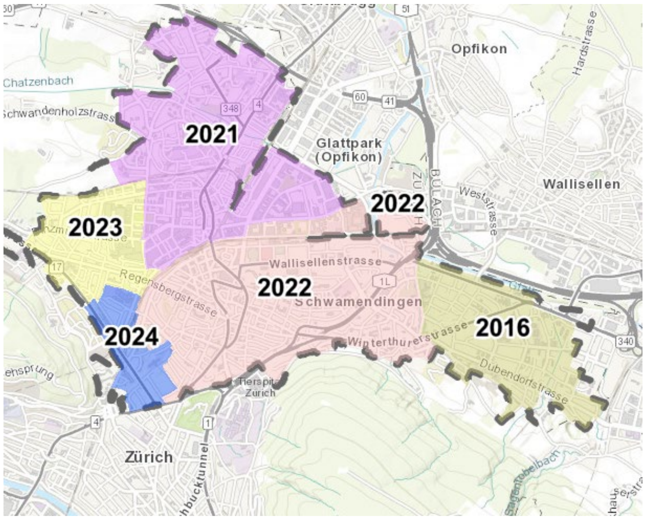


Figure 5. Areas of decommissioning of the Zürich North gas network. The red dot indicates the approximate location of the central heat source in the covered district.

Zürich, Switzerland, is decommissioning parts of its gas distribution network in the northern corner of the city.[38,39] The seeds for this transition were set in the early 1990s when Zürich constructed a district energy system serviced by waste heat from a municipal solid waste incineration facility.[4] With this thermal distribution system in place – and a redundant competitor to the existing natural gas system – the city set forth a strategy to decommission the gas system by the 2020s to have only one heating network in this area.

Zürich relies on the private and public sectors to facilitate this process and provide streamlined transition support for customers. The gas utility (Energie 360°) oversees the disconnection from the gas network by removing the meters and closing the supply line. Customers remove gas equipment and appliances at their own expense, but some are granted residual value compensation.

Customers can either electrify or connect to the district heat system if available.

The transition has not been universally welcomed as some customers protested the costs associated with the transition.[38] The offer of residual value compensation for those who had to install a new furnace in recent years and a five-year delay from the initially planned shutdown date eased some of those concerns. However, the district system is not accessible to a few single-family homes in the gas district.

Zürich is now expanding efforts to transition off gas across the entire city. The climate crisis and national, canton, and municipal goals to reduce energy consumption have prompted the city to pursue alternatives to gas. Over the past five years, the City of Zürich has begun to map out (**Figure 6**) the creation of numerous priority districts for the installation of various thermal energy networks leveraging ambient – locally accessible – thermal energy from lake water, groundwater, and sewage, along with waste heat from municipal solid waste-fed and biomass-fed electric generation plants.

---

[4] The waste heat from this system is considered "zero emissions" because emissions from the facility are attributed to the primary product of the facility: electricity. Such, a facility is a highly efficient energy source, but it may not be compatible with global climate targets. A Swiss-born colleague of the author noted that such systems are publicly operated and maintain the highest emissions standards. Swiss trust in government – the highest in the OECD – enables such an arrangement. In the United States trust in government is half of the Swiss levels and waste incinerators are operated by the private sector.

Once these projects are commissioned in a specific area, these district systems will take priority over the gas distribution system. Here, running two systems is viewed as redundant and uneconomical. Once the decision to decommission a gas zone is made, customers will have 15 years to convert to the district system or go independently electric.

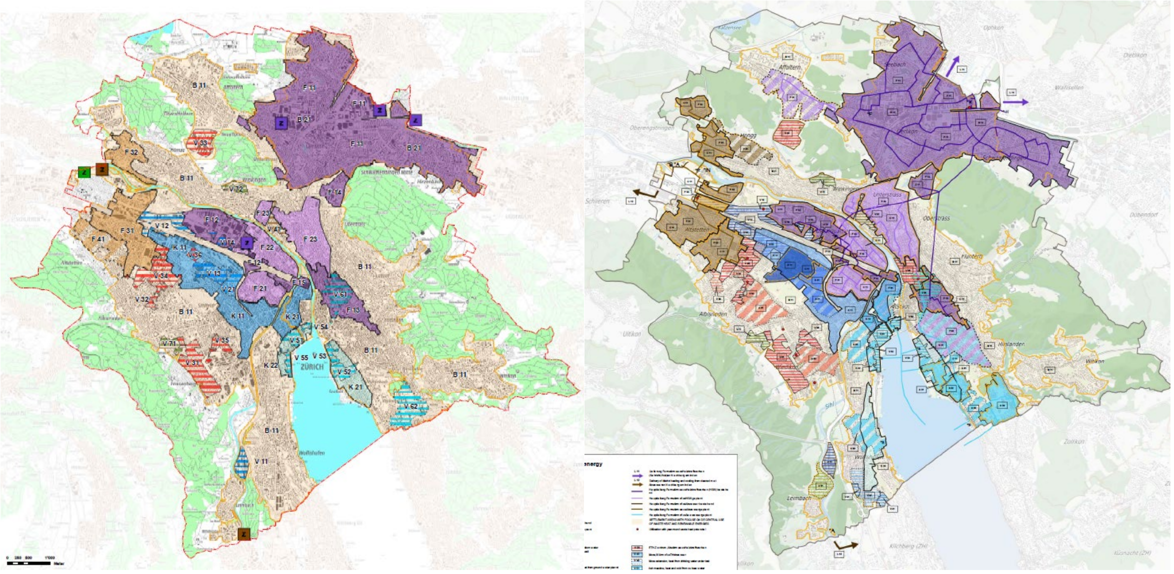


Figure 6. 2017 (left) and 2021 (right) energy planning maps for Zürich. Shaded zones indicate current and planned thermal energy networks utilizing lake water, groundwater, sewage, biomass, and waste-to-energy. The yellow area shows the extent of the gas system. Note growth in planned thermal energy districts between 2017 and 2021

Several factors support this transition, not the least of which is Swiss public engineering and drilling acumen. Zürich's density – predominantly medium multifamily (4+ unit) buildings – and diverse energy loads across the city also make the construction of various modular thermal energy districts practical. The City and all of Switzerland have established robust *local energy asset planning (LEAP) practices*, informed by data (**Figure 7**),[5] made available to private and public stakeholders. Qualified businesses and contractors are given easy access to utility infrastructure maps to facilitate cross-sector planning.

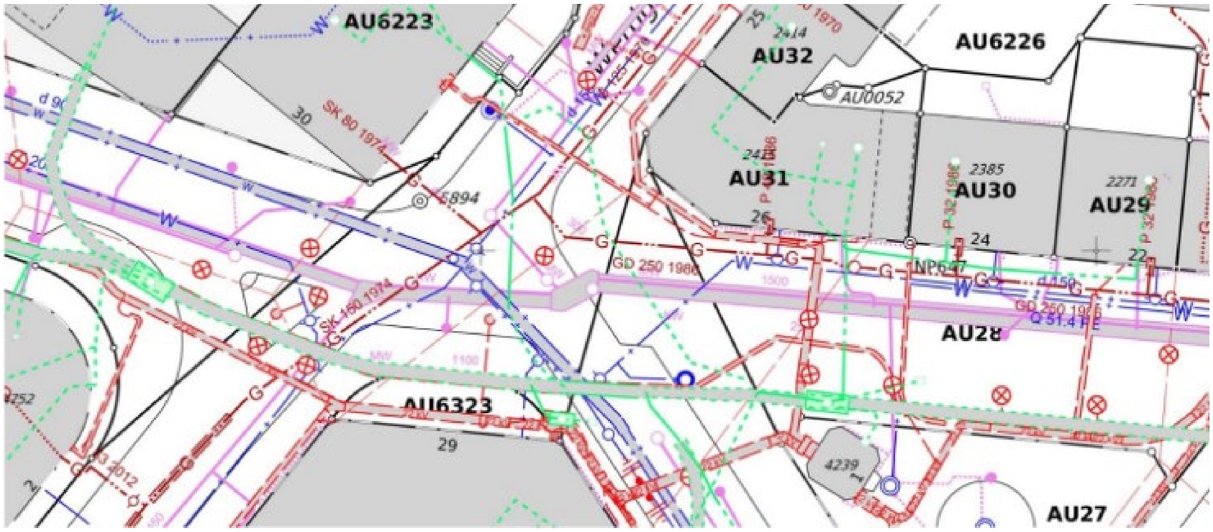


Figure 7. Multi-utility asset planning map and data provided in the City of Zürich, which includes gas, electricity; sewage; district heating; communication.[5]

Zürich has set specific hyperlocal objectives for its thermal transition planning that are anticipated to achieve climate and energy goals. The city's gas transition is being defined by the emergence of a new technology that the public has collectively chosen as its new heat source. Its potential for success rests on its establishment of ongoing local integrated planning.

2.5 IMPLICATIONS OF BEST PRACTICE EXAMPLES FOR LOCAL ENERGY ASSET PLANNING IN MASSACHUSETTS

Table 3 compares aspects of state & utility-scale planning with the needs of local energy planning. Except for electricity supply planning, all aspects of the gas transition are largely centrally planned but locally consequential. Therefore, robust and well-informed local action can help manage the transition for the region as a whole. Local Energy Asset Planning (LEAP) can support this well-informed local action. The following section details the issues and methods that LEAP should focus on.

Table 3. Comparison between state & utility-scale gas planning with local energy planning

	State & utility-scale gas planning	**Local energy planning**
Scale	State-wide or utility-wide	Street, neighborhood, district, municipality
Scope	• Systems focus: Managing system-level gas and electricity demand • Aggregated asset planning by utility territory • Renewable fuels blending and resource availability	• Component and asset focus: Building-electric-gas transition coordination • Granular asset tracking across gas, electric, and building systems • Local energy resource availability
Stakeholders	• State public utility commission (lead) • Cognate state agencies • Utilities • Grid operator • Ratepayer advocates • Environmental justice advocates	• Municipalities (lead) • Utilities • Major energy consumers • Building owners • Ratepayer advocates • Environmental justice advocates
Outcomes	• Prioritization of transition strategies across the utility. • Fulfillment of regulator mandates on providing cost-effective, safe, reliable energy to consumers while meeting climate goals. • Policy adjustments and revisions • Utility infrastructure investment plans • Forecasts of customer costs and transition impacts	• Identify sites for immediate transition off of pipeline gas systems (e.g., leak-prone pipe) • Facilitate gas transition with coordinated infrastructure upgrades, potentially leveraging local energy resources and delivery networks • Local energy infrastructure plans • Forecasts of customer costs and transition impacts
Implementation Examples & Reports	• Gas Resource and Infrastructure Planning (GRIP, California)[27] • Various Public Utility Commission “Future of Gas” Dockets (e.g., initial LDC Study and Net Zero Enablement Framework in Massachusetts) • Long-Term Planning to Support the Transition of New York’s Gas Industry[28]	• Bramberg, Germany (local utility & academic partners)[13,41,42] • LAEP (Ofgem) [30] • Palo Alto Electrification Impact Study[40] • Zürich Energy Planning[43] • Under Pressure[31]

3 PART 3: LOCAL ENERGY ASSET PLANNING (LEAP) DESCRIPTION

This section details the LEAP framework, methodology, and analytical tools. It covers:

1. A description of the LEAP framework
2. LEAP use cases
3. An illustrative example of LEAP in Near-Term Planning
4. The LEAP methodology and analytical tools
5. A summary of the current state of LEAP development

3.1 RECOMMENDATIONS RELATED TO THIS SECTION

1. **Support Access to Key Data Sets Needed for LEAP Implementation.** The LEAP modeling platform is currently set up to integrate many publicly available data sources. As the LEAP practice evolves, it will be necessary for organizations to formalize access to needed data sets. Some of these suggested data support requirements include the following:

    - The **Department of Public Utilities (DPU)** should:
        - Require utilities to submit asset maps periodically for planning purposes and evaluate whether access to such maps should be public or accessible to qualified planning partners (e.g., municipalities, large users, etc.).
        - Establish a standard data format for GSEP reporting that encapsulates labor, overhead and material costs.
        - Require all GSEP filings to include an estimated closure cost as an alternative to the replacement cost.
        - Require utilities to report lost and unaccounted for gas by system segment as gas transfers are recorded (e.g., between city-gate and meters).
        - Seek to develop open data access frameworks to enable local energy asset planning, following in the footsteps of states like Illinois, which provide utility data to qualified researchers in the state and academia.
        - Establish a minimum geographic reporting level (e.g., census block) for reporting customers on utility discount rates that maintain customer privacy.
    - Municipal **tax assessors' offices** should improve energy asset tracking to support local energy planning.
    - Massachusetts **Division of Local Services** (Dept. of Revenue) should establish best practices in building energy asset tracking.
    - The **Energy Efficiency Advisory Council and MassSave** should establish a reporting framework for tracking costs and labor associated with building energy efficiency and electrification measures.

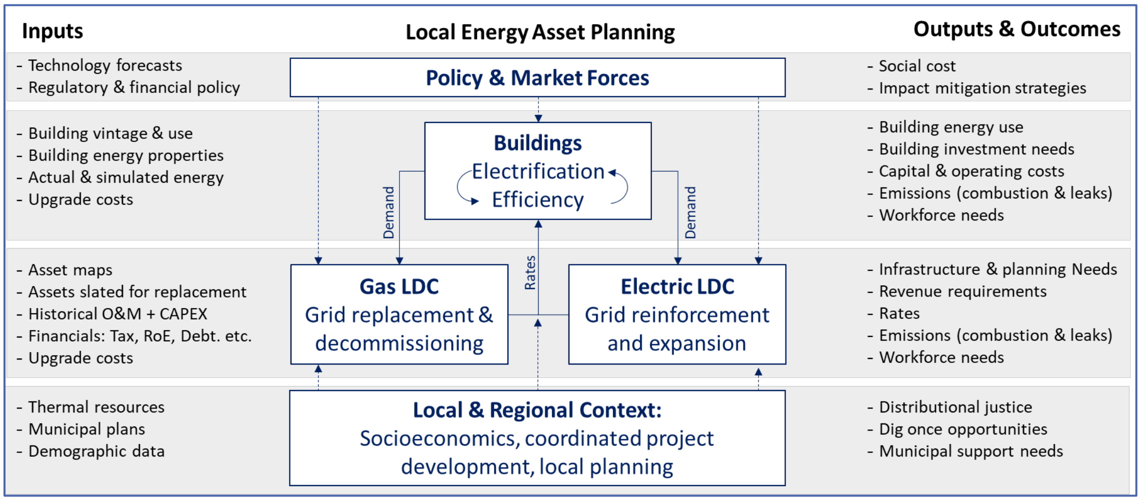
2. ***Explore LEAP as an Alternative to Leaky Pipe Replacement.*** The DPU should investigate near-term gas transition strategies focused on evaluating alternatives to leak-prone pipes currently scheduled to be replaced as part of the GSEP program using local area asset planning.

3.2 THE LEAP FRAMEWORK

LEAP is a locally driven complement to state and utility-scale natural gas transition planning. Ultimately the purpose of LEAP is to shift energy planning away from siloed utilities that, by institutional design, cannot currently be relied on to lead locally focused integrated system planning exercises. Further, it aims to create transparency among local stakeholders to understand the implications of alternative transition strategies to inform shared decision-making.

Local decision-makers can use LEAP to understand alternative gas transition strategies' financial, system, and social impacts and help them choose which strategies are the fairest and most cost-effective for which parts of their community. It integrates various utility, building energy use, energy resource, and adjacent infrastructure information to identify and prioritize low-cost transition strategies and understand their impact. Outputs of LEAP include system investment needs, costs, energy consumption, combustion emissions, methane leaks, labor needs, and broader impacts. Ultimately, LEAP is a long-term utility and building sector simulator that can evaluate system planning, regulatory, and financing strategies for managing the gas transition.

The graphic below provides an overview of the LEAP framework.



Geographic Focus	Building to utility (distribution-system) scale.
Asset Resolution	All energy infrastructure assets with a defined role, cost, energy consumption, and lifetime.
Time Horizon	Long-term (30-50 years) with the ability to represent periods relevant to system design (design day or hour).
Primary Accounting Goals	Time-resolved energy consumption by energy source. Tracking of costs associated with assets.
Secondary Simulation Focus	Emissions, infrastructure changes, customer bill impacts, customer disparities, workforce needs, and health impacts.
Scenario Representation	Customer (building-owner) behavior, systems changes, regulatory policy design.

LEAP leverages existing data to assess the impacts of planning scenarios across these focal areas. The general scope of a LEAP exercise is further defined by:

- **Policy and market forces** create the context within which Local Energy Asset Planning takes place. These include state regulatory structures, technology innovation, and fuel pricing (natural gas and electricity).
- **Buildings** are the structures that consume energy services. The LEAP process takes building information inputs (age, uses, energy systems, energy consumption, and upgrade costs) and uses them to identify potential future energy uses needed to upgrade investments, capital and operating costs, projected emissions, and workforce needs.
- **Utilities** provide energy distribution systems for natural gas and electricity. LEAP translates transition alternatives into implications for natural gas and electricity utilities, including needed infrastructure investments, revenue shifts, rate changes, and emissions impacts.
- All transition plans need to consider the **local and regional context**, including the availability of alternative thermal sources, municipal infrastructure plans, municipal support needs, and equity consequences.

LEAP focuses on integrating forecasting analysis around several asset classes (**Table 4**) related to the use and provision of energy. LEAP can include tracking adjacent non-energy assets to identify opportunities for beneficial coordination. For example, replacing a sewer main may be an opportunity to install a waste heat recovery system.

Table 4. Asset classes and examples included in LEAP

Asset Category	Examples
Building Assets	Shell, appliances, HVAC system, DWH, electric panel, EV charger, distributed solar & storage, private ground ambient heat rights.
Electric System Assets	Meters, service lines, primary and secondary wires, transformers, substations, poles, and underground conduits.
Gas System Assets	Meters, services, mains, regulators, compressors, and storage.
Energy Resource Assets	Public ground ambient heat rights, water bodies, waste heat resources, density to support thermal networks, and local combustion and storage assets.
Adjacent Non-Energy Assets	Street paving, sewers, water, and other utilities.

3.3 LEAP APPLICATION USE CASES

Currently, two promising opportunities exist for using the LEAP framework to advance the natural gas transition. These use cases are currently being used to develop a LEAP calculator:

1. **Near-Term System Pruning Based on Leaky Pipe Replacement Economics**. LEAP can be used to evaluate alternatives to replacing leak-prone pipe infrastructure. Under the Massachusetts Gas System Enhancement Program (GSEP), the Commonwealth will spend $20-$40 billion over the next decade to replace such leaking natural gas pipes. In many instances, the per unit cost of pipe replacement exceeds the per unit installing carbon-free thermal alternatives. LEAP can help utilities and communities decide in what circumstances an alternative heat technology investment strategy makes more economic and emissions-reduction sense than the placement/repair of old pipes. (See more detailed near-term pruning scenario analysis in the following section.)
2. **Long-Term Right Sizing of the Gas System.** LEAP can also be used for planning neighborhood-to-municipal scale gas transition strategies over a longer time horizon (15+ years) as customers exit the system. Right-sizing of the gas system involves decommissioning multi-street zones on a pre-defined schedule. Such decommissioning could proceed *outward in* going from the tendrils of the system, which may correspond with residential neighborhoods that are not foundational to other parts of the system. Alternatively, decommissioning could occur in more dense central business district settings where heating loads could be transferred onto a thermal network. An essential aspect of long-term planning is identifying alternative energy resources (e.g., ground, water bodies, waste heat, biogas) for high and low-temperature thermal services. Similarly, developing sufficient electric infrastructure is a predicate for facilitating the closure of the gas system.

These use cases align with the approach called for by the Massachusetts Attorney General, HEET, RMI, Acadia Center, and several other organizations, which emphasized the need to develop LEAP-like approaches to understand these planning challenges. In their comments on the DPU Docket #20-80 (The Future of Gas), the gas LDCs have endorsed the concept of “targeted electrification and networked geothermal” as one of the critical transition strategy pillars. LEAP can help utilities and communities understand where targeted electrification strategies make the most sense from a financial, emissions, and equity point of view.

LEAP also has the potential to conduct the following analytical tasks:

- **Supporting Infrastructure Alternatives.** Several Massachusetts communities are currently under gas expansion moratoria. LEAP can be used to evaluate non-pipeline alternatives that can be used to meet increasing heating demand. LEAP can also be used to conduct analyses of electric sector strategies for managing growth in electric loads (distribution investment, DERs, flexible loads, etc.).
- **Assessing Gas Pipeline Extension Costs.** In many communities, the cost of extending gas service to new development equals or exceeds the cost of integrating alternative thermal technologies into the standards for new construction or expanding development. (Several municipal utilities in Massachusetts have already made expansion cost tradeoff decisions and prohibited new gas extensions.)

- **Evaluation of priority transition zones or zones supported by alternative thermal resources** (thermal energy networks, water bodies, ground-source thermal, waste heat, organic wastes, etc.) and simulation of the performance of these networks to validate system decisions (power flows, hydraulics, thermal transfers, etc.).
- **Anticipated Customer Exits.** Another type of scenario that supports the LEAP approach is when it is expected that a critical mass of gas users will voluntarily exit the natural gas system for assorted reasons, including cost, improved thermal comfort, or compliance with local emissions performance ordinances. A campus-style development (health care, higher education, corporate, etc., that chooses to transition from natural gas to decarbonized thermal fuels is a particular form of customer exit with consequences that require better understanding. Unplanned voluntary exits can potentially increase rates for remaining customers who must cover the costs of stranded assets. This could be assessed via specific direct assumptions or through simulation of building and operator behavior and decision-making under different incentive and cost scenarios (e.g., agent-based modeling).
- **Aggressive Local Emissions Reductions Mandates.** LEAP makes sense as a standardized planning process in local municipalities that have committed to aggressive emissions reductions and are backing those commitments up with regulatory mandates that require building owners to meet defined emissions standards on prescribed timelines. Boston's BERDO 2.0 ordinance is a prominent example of this. In these cases, local government needs a defined planning process to identify when and how it will decarbonize building thermal services. In many cases, it will make sense to do this on a district-by-district basis rather than one building at a time. (Note that it is highly likely that soon there will be some version of a statewide building emissions performance standard to assure compliance with the Next Generation Roadmap Bill. The Clean Heat Commission is working to make recommendations on the design of this standard. This will create demand for LEAP-like planning across the entire Commonwealth.)
- **Identifications of opportunities for coordinated "dig-once" opportunities**. LEAP energy datasets can be overlayed and integrated with other utility and public assets (water, sewer, etc.) to evaluate opportunities for cost reduction from coordinated planning.
- **Utility-wide and customer-focused analyses of regulatory policies** that manage the financial aspects of energy distribution systems will be essential for managing the natural gas transition. These policies are summarized in **Table 5** below. The customer impact of these policies can be readily represented in a LEAP simulation. The design of utility tariffs or rates will influence the pace, depth, and fairness of electrification and the gas transition. Currently, relatively high electric rates favor gas heating, even given the operational efficiencies associated with heat pumps. Rate design for electrification needs to avoid penalizing electrification but should also create incentives to reduce demand through efficiency and flexibility.

Table 5. Description of non-system planning policy interventions for evaluation in thermal transition planning

Policy	Description
Accelerated depreciation that aligns with climate targets	Allow costs to be recovered over a shorter lifetime, raising rates in the short term. It prevents assets from becoming stranded and reallocates costs to a larger group of ratepayers than those who stay on the system.
Disallow profit	Reduce the allowed rate of return for new or existing assets. Shifts burden of cost to investors.
Segmented tariffs: based on use, location, and income level (Gas & Electric)	Create different tariffs for different end uses or customers. Households, for example, could receive a baseline allotment at one rate, but gas for luxury services or high-square footage homes could be charged a higher rate. Different rates could be assessed by location (urban vs. rural) or income (high income vs. low income.
Time of Use & Demand Rates (Electric)	Design rates are based on usage at a particular time and level of demand.
Other Rate Design	Municipal utility rates are generally lower as they typically achieve a lower cost of capital. Currently, most municipal utility rates in Mass are more favorable to electrification than those offered by investor-owned utilities.
Securitization	Assets are transferred from investors to long-term bonds with lower interest rates than the guaranteed rate of return. This “buys out” the investor, reducing the cost of debt service. Ratepayers may still be responsible – albeit at a lower cost – for the amortization of the securitized asset, or the asset may be more broadly socialized using general funds.

3.4 ILLUSTRATIVE EXAMPLE OF LEAP IN NEAR-TERM PLANNING

Nearly 30% of gas mains and 20% of services are considered leak-prone[40] and have significant health, safety, and climate impacts. While some core gas main "trunks" critical to substantial portions of the distribution system will likely require replacement, the bulk of leak-prone infrastructure comprises many small "branches"[5] that broadly service small residential customers. Many of these buildings also contain leak-prone "behind-the-meter" gas infrastructure, for which there is currently no plan to mitigate and may be responsible for a significant portion of methane emissions from the gas distribution system.[41]

There are likely to be a considerable number of cases where the closure of such pipes and removal of homes from the gas system result in more advantageous societal cost, customer cost, climate, and equity outcomes. A review of GSEP and street segment data highlights several instances where gas main replacement exceeds $60,000 per building on the street, much higher than estimates of building electrification.[42]

The current regulatory framework – notably the legislatively-mandated obligation to serve and the GSEP program – is a barrier to pursuing more cost-effective strategies in such locations. Further, pipe replacement costs are distributed across ratepayers under the GSEP program. In contrast, homeowners directly incur home retrofit costs.

Recognizing this issue, the 2022 Massachusetts Climate Legislation (H.5060)[1] has commissioned a working group to develop recommendations for the regulatory and legislative changes needed to align GSEP with the state's climate goals.

The following pages illustrate several potential approaches to managing leak-prone infrastructure and achieving decarbonization targets on a street segment with a leak-prone pipe scheduled to be replaced in the coming years. In this example, a leak-prone "branch" is scheduled to be replaced in 2025. The housing stock is old enough to exhibit high variability in the age of heating systems – some have been replaced recently. The street segment also includes some houses that use oil. The scenarios for segment management are:

1. **Scenario 1: Natural electrification** of heating equipment at the end of life – over three decades – necessitating the continuation of natural gas pipeline service and pipeline replacement in 2025.
2. **Scenario 2: Pipeline retirement** and immediate electrification of the building stock at the retirement of the pipeline in 2025.
3. **Scenario 3: Pipeline hybrid electrification** of the segment by replacing the pipeline and allowing the households to adopt hybrid heating at a logical transition point for each household.
4. **Scenario 4: Non-Pipeline hybrid electrification** of the segment by removing the pipeline, closing off gas service, and providing a mix of whole home electrification and partial hybrid electrification using a non-pipeline delivered fuel such as propane or wood pellets.

---

[5] Pipes with 6" or smaller diameters that serve mostly residential side streets and ends of the gas system.

Qualitative assessments of each scenario are given for the following impact categories:

- **Stranded gas asset to the end of its useful life** – Does the scenario result in a gas asset being largely underused and possibly stranded?
- **Stranded building assets** – Are appliances and heating equipment prematurely retired?
- **Customer practicality and choice** – Does the scenario constrain customers' appliance choice (e.g., eliminating gas cooking) or create significant implementations burdens (e.g., disruptive retrofits)
- **Customer costs** – Does the scenario significantly increase customer costs?
- **Electric demand** – Does the scenario significantly increase total electricity or peak demand?
- **Fuel use** – Are fossil or renewable fuels still required?
- **Gas leaks** – Are there still leaks from the distribution system and building gas infrastructure?

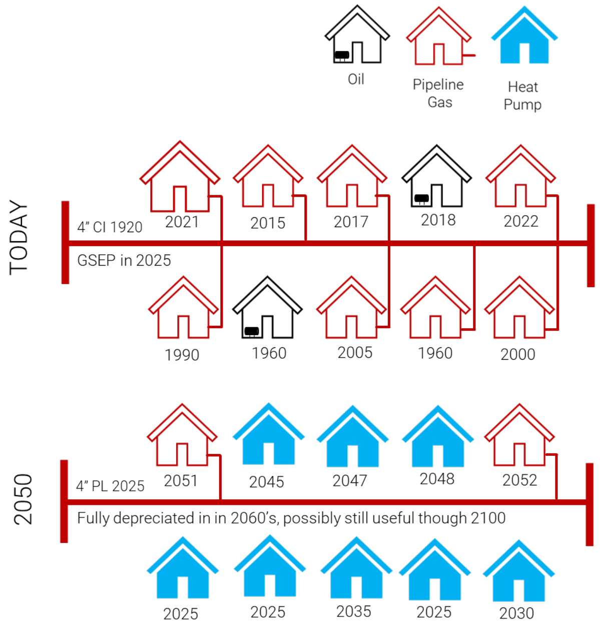
Red is used to denote challenges or undesirable outcomes; yellow is used to denote moderate challenges or mixed outcomes; green is used to denote a low level of challenge or positive outcome. These assessments are intended to be illustrative and ultimately be quantified or rated by a LEAP calculator and assessment.

Scenario #1:
Natural Electrification

Approach: Pipeline and building assets are replaced at the end of life.

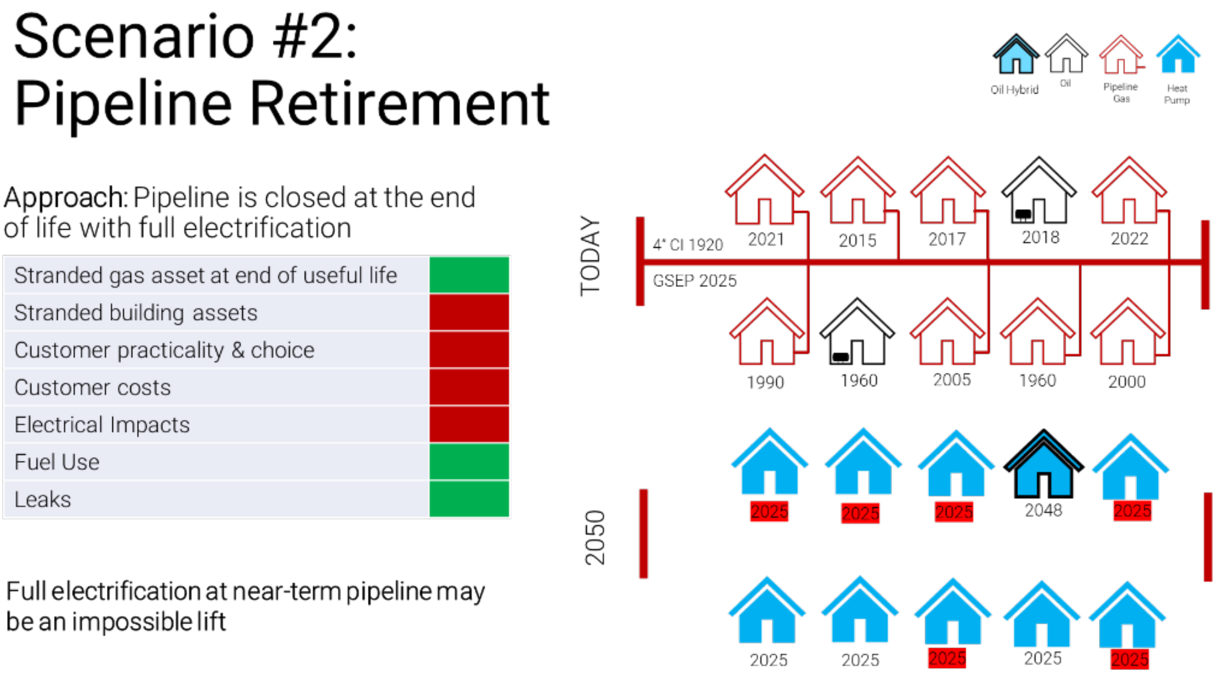
Stranded gas asset at end of useful life	🟥
Stranded building assets	🟩
Customer practicality & choice	🟨
Customer costs	🟥
Electrical Impacts	🟨
Fuel Use	🟨
Leaks	🟨

Electrification is a large lift, while gas system becomes a stranded asset



Scenario 1: Natural electrification of heating equipment at the end of life – over three decades – necessitating the continuation of natural gas pipeline service and pipeline replacement.

Homes are still reliant on a large amount of fuel until the point of *full* electrification. While electrification results in no stranding of assets in the buildings, the replaced gas pipe becomes an underutilized asset as buildings exit the gas system. This pushes costs on those who are slower to electrify. Electric demand is high, but the slow pace of building electrification is presumably manageable for the distribution system.



Scenario #2: Pipeline Retirement

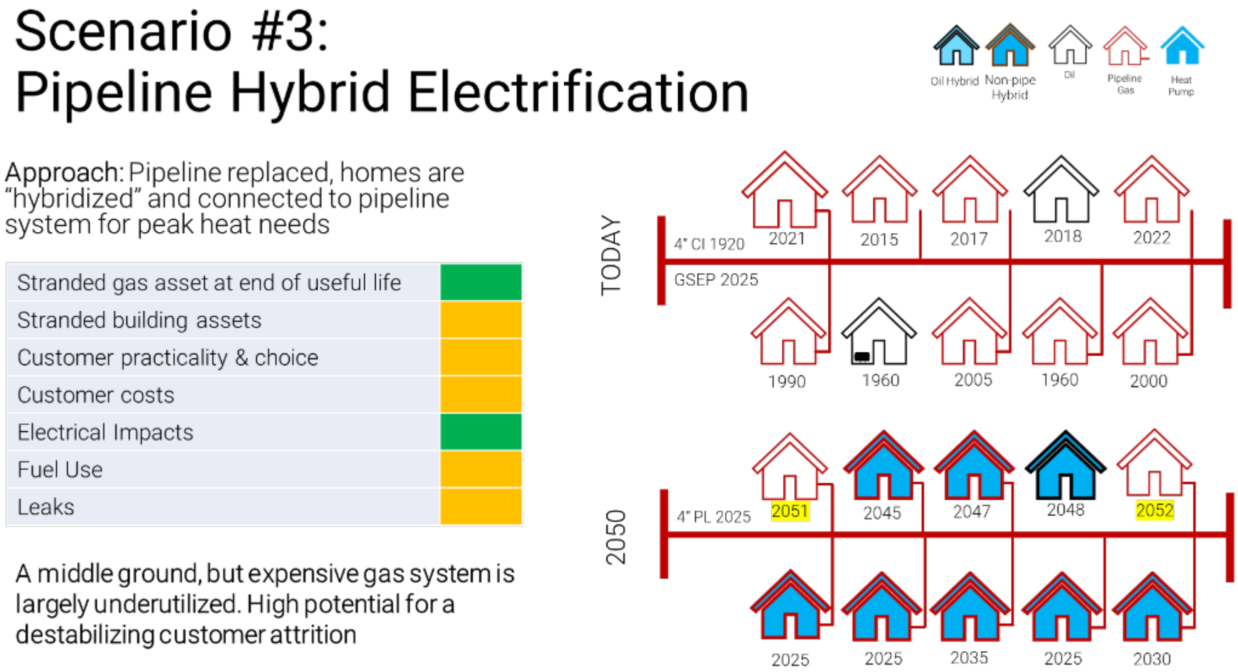
Approach: Pipeline is closed at the end of life with full electrification

Stranded gas asset at end of useful life	🟩
Stranded building assets	🟥
Customer practicality & choice	🟥
Customer costs	🟥
Electrical Impacts	🟥
Fuel Use	🟩
Leaks	🟩

Full electrification at near-term pipeline may be an impossible lift

Scenario 2: Pipeline retirement and immediate electrification of the building stock at the retirement of the pipeline.

This scenario manages the issue of a stranded gas asset by retiring household gas equipment prematurely (see homes with dates of early asset retirement are highlighted in red). Such an approach would likely require compensating building owners for the equipment's residual asset value. Also, the immediate increase in electricity demand would need simultaneous upgrading of the local electrical systems to handle increased electric heating loads; however, this may vary by location. However, if the gas system is old, it is safe to assume the electric system is old.



Scenario #3: Pipeline Hybrid Electrification

Approach: Pipeline replaced, homes are "hybridized" and connected to pipeline system for peak heat needs

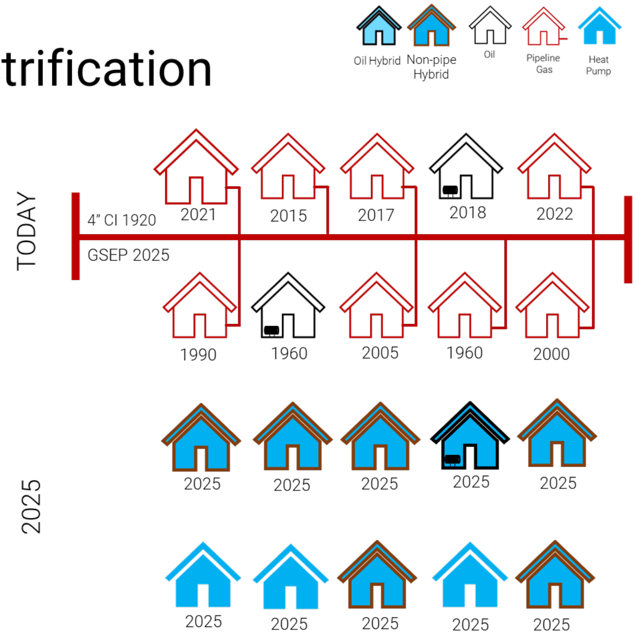
Stranded gas asset at end of useful life	🟩
Stranded building assets	🟨
Customer practicality & choice	🟨
Customer costs	🟨
Electrical Impacts	🟩
Fuel Use	🟨
Leaks	🟨

A middle ground, but expensive gas system is largely underutilized. High potential for a destabilizing customer attrition

Scenario 3: Pipeline hybrid electrification of the segment by replacing the pipeline and allowing the households to adopt hybrid heating at a logical transition point for each household.

Here, electric heating is used at moderate temperatures when heat pumps operate more effectively, and gas is used during colder periods when heat pumps operate less efficiently. This avoids costly investments in the electric system. This approach is the core element of the LDC's net-zero enablement plans filed with the DPU under the 20-80 docket.[12] The gas system may expand to include homes currently heated by oil. All assets continue to be used to some degree. However, the strategy relies on keeping customers and would require coercive rate design to prevent customer attrition.

Scenario #4:
Non-Pipeline Hybrid Electrification



Approach: Pipeline is closed at the end of life. Some homes are fully electrified, and others are hybridized with non-pipeline fuels. Hybrid homes could be fully electrified over time

Stranded gas asset at end of useful life	🟩
Stranded building assets	🟩
Customer practicality & choice	🟩
Customer costs	🟩
Electrical Impacts	🟩
Fuel Use	🟨
Leaks	🟩

By managing to the asset lifespan impacts are balanced across the buildings and distribution systems

Scenario 4: Non-Pipeline hybrid electrification of the segment by removing the pipeline, closing off gas service, and providing a mix of whole home electrification and partial hybrid electrification using a non-pipeline delivered fuel such as propane or wood pellets.

In this case, some homes are fully electrified, while those with recent gas equipment are converted to hybrid arrangements fueled by propane. This avoids stranded assets and near-term stress on the electric distribution system. It also allows for more customer choice in appliances than the other scenarios while avoiding long-term cost increases associated with gas delivery. Finally, it facilitates a smoother transition to various full electrification strategies.

Summary

Impact Area	Natural Electrification	Pipeline Retirement	Pipeline Hybrid Electrification	Non-Pipeline Hybrid Electrification
Stranded gas asset at end of useful life	🟥	🟩	🟩	🟩
Stranded building assets	🟩	🟥	🟨	🟩
Customer practicality & choice	🟨	🟥	🟨	🟩
Customer costs	🟥	🟥	🟨	🟩
Electric demand	🟥	🟥	🟩	🟩
Fuel Use	🟨	🟩	🟨	🟨
Leaks	🟨	🟩	🟨	🟩

Figure 8. An illustrative summary of LEAP results across several impact areas. (Red = high challenge or adverse impact; yellow = neutral challenge or impact; green = low challenge or positive impact impact)

Figure 8 compiles illustrative outcomes of the alternative scenarios. There are clear tradeoffs associated with various building energy assets. As seen in the figure, each scenario presents distinctive tradeoffs, with the non-pipeline hybrid electrification (Scenario 4) yielding the most feasible outcome. The LEAP calculator will quantify these impacts.

A comprehensive LEAP analysis would explore various sensitivities around these scenarios. While the scenarios are designed to be as consistent as possible, some distinct permutations (e.g., the timing of building retrofits) are significant drivers of cost and other impacts.

The following section formalizes the LEAP methodology and addresses the need for robust experimental design when conducting a LEAP analysis.

3.5 LEAP METHODOLOGY

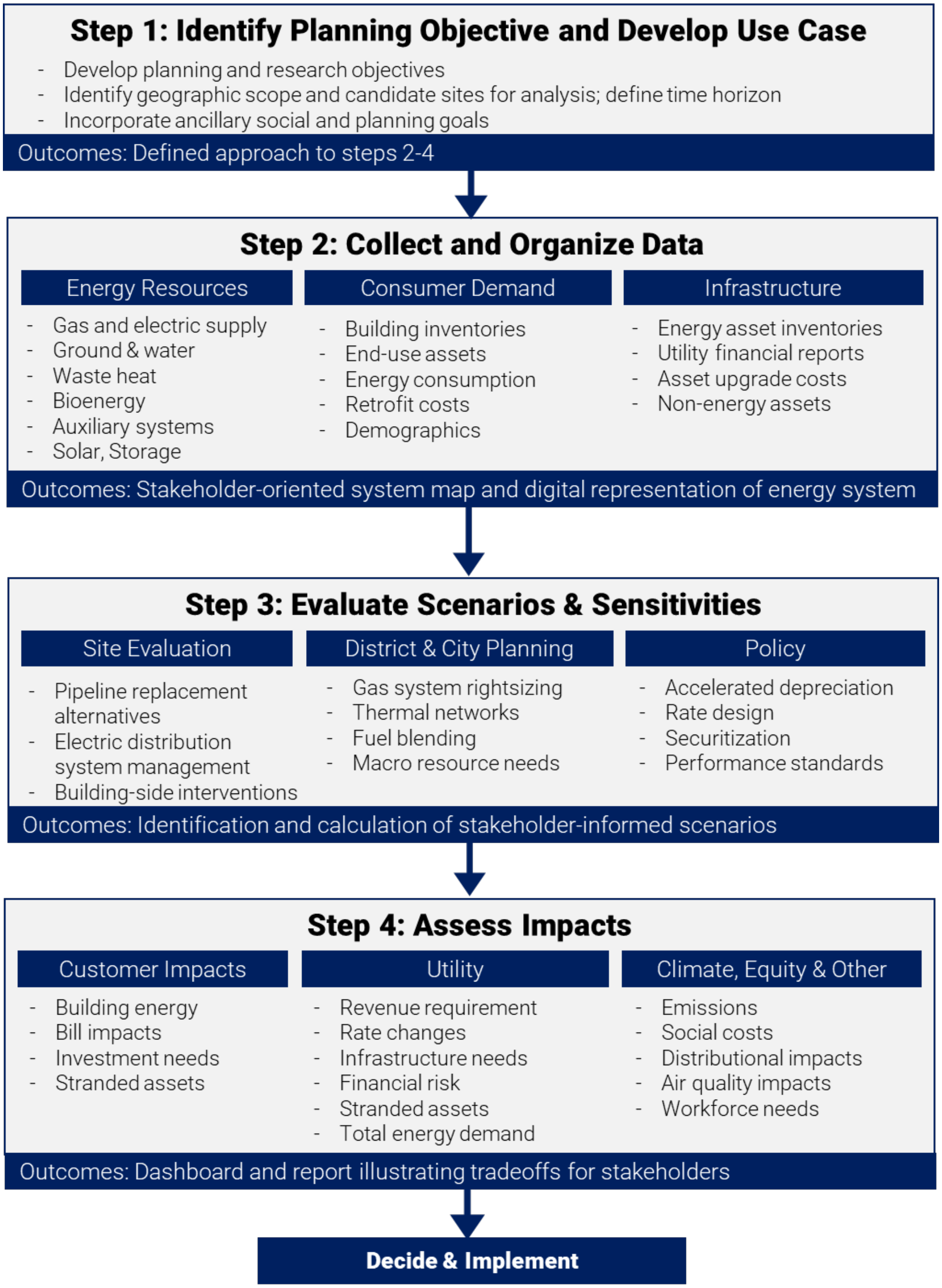


Figure 9. LEAP (v0.1) process flow diagram.

Figure 9 illustrates the general flow of the application of LEAP. The LEAP methodology encompasses an organized set of planning steps that can be used to support local energy system decision-making. The framework is flexible and adaptable to various use cases that span geographic scales, technology solutions, timelines, and research objectives.

The application of LEAP is facilitated by a LEAP accounting tool and calculator. Groundwork Data and the University of Massachusetts Amherst are currently collaborating on developing a modular object- (asset-) oriented approach to represent a network of energy assets across buildings and distribution systems.

3.5.1 Step 1: Identify Planning Objective and Develop Use Case

A LEAP exercise should begin with defining analytical objectives, research questions, indicators, and evaluation scenarios and sensitives that apply to the desired use case and local context.

This step should be conducted with municipal energy planners and local utility network operators to inform the approach and provide local knowledge and experience support.

3.5.1.1 Planning and Research Objectives

Clear research objectives should be defined based on situational needs. Section 3.3 listed potential use cases and the analytical approach should be designed to comprehensively assess alternative scenarios and their impacts.

LEAP can narrowly evaluate alternative pipeline replacement management strategies for a single gas pipeline segment. Research questions and experimental approaches are relatively easy to define in such a simple case. Alternatively, LEAP could be used for city-wide decarbonization analysis, which introduces many additional decision dimensions. A disciplined experimental design based on clear analytical objectives and sufficient scenarios and sensitivities will be necessary to comprehensively understand the decision space.

LEAP can evaluate user-specified *scenarios* or *pathways* that compare defined system planning decisions, end-use changes, or regulatory policies. This requires using a comprehensive set of well and consistently defined scenarios and sensitivities that appropriately map out the option and parameter space to illustrate outcomes using a variety of indicators. The pathway analysis is designed to highlight the tradeoffs between early retirement of distribution system assets versus early retirements of building heating systems connected to such assets.

Alternatively, an *optimization*-based approach – typically more analytically and computationally intensive – can be used to identify the best strategies to minimize costs under a specific emissions limit or other constraints.

3.5.1.2 Identify Geographic Scope and Candidate Sites for Analysis

LEAP is intended to be conducted at scales ranging from a single building to an entire municipality (See section 2.2). The upper bound of LEAP is effectively where energy systems begin to interact with gas or electric transmission and opportunities. LEAP focuses on permutations to energy systems at the local scale but may need to factor in alternative sensitivities relating to the macro energy system (e.g., wholesale energy prices or energy carbon intensity).

The research objective typically informs the geographic scope. Using LEAP to assess electrification of a street segment may focus on a single gas main pipe segment and electrical service up to the local transformer(s). However, the analysis must ensure that major changes to the segment do not have feasibility-challenging ramifications on the rest of the system (see Box 1 below).

As implications get larger, using a broader geographic scope may become more necessary and insightful: An electrification project at a large campus or neighborhood may obviate the need for city-wide gas peak management infrastructure or require increased electric substation infrastructure.

Near-term leak-prone pipe management analysis will largely focus on a single gas segment or similar relatively small projects; long-term transition analysis will focus on the neighborhood to municipal scale. Policy analysis will largely focus on the municipal to utility scale.

Box 1. Integrating gas pipeline transition feasibility criteria

As discussed in section 2.4.2, California is undergoing a similar process to identify and evaluate potential sites for piloting gas decommissioning projects. Figure 4 shows a framework for site selection and characterization. Notably, the first step in this flow is a utility-led *candidate screen* that evaluates hydraulic feasibility and near-term planning aspects to down-select all assets to those deemed feasible for closure.

Hydraulic feasibility, or the level dependency of the gas system on a pipe segment, is an essential element of gas transition planning. Core "trunk" pipes cannot be removed without implications for the remainder of the gas system; many will require repair or replacement, even in a shrinking gas system. Even some secondary pipelines provide the system with necessary redundancies.

This utility-focused approach makes sense from a near-term pipeline management point of view. Determining hydraulic feasibility will undoubtedly be an essential first step in identifying and evaluating pipelines that are currently or soon will be candidates for replacement. However, the broader application of LEAP for site identification should take a more flexible approach. LEAP is intended to integrate the understanding of several systems, not just the gas system. Activity outside the gas system may prompt action on the gas system before such action would be prioritized by the utility. There are also potential alternative strategies for managing pipes with low hydraulic feasibility potential for removal.

3.5.1.3 Time Horizon

Many decarbonization commitments target 2050 as a goal date for achieving net zero greenhouse gas emissions. While this benchmark should inform the design of scenarios to evaluate alternative strategies for achieving emissions reductions by 2050, it should not be used as an analytical bounding date. Further, even if the net zero goal is achieved in 2050, different strategies to achieve that goal will have local implications for several years beyond 2050.

LEAP should seek to use a time horizon of 40-50 years, consistent with the usable lifetime of various energy infrastructure assets.

3.5.1.4 Ancillary goals

A LEAP analysis may focus on changes to ancillary systems such as water, sewer, or other municipal or utility assets. For example, gas pipeline work, electrical undergrounding, and related upgrades may see cost savings from simultaneous street repaving or similar projects.

3.5.1.5 Step 1 Outcomes

Identification of research goals, geographic scope, technical focus, and time horizon will inform the data needs (Step 2), experimental scenario and sensitivity design (Step 3), what and how key indicators and impacts will be assessed (Step 4), and how the findings of the exercise should be applied to implementation.

3.5.2 Step 2: Collect and Incorporate Data into a System Map

The nature of the data required will vary based on the use case. However, some versions of the following data sets will be needed in most cases. A detailed evaluation of sources and limitations with potential recommendations for improvements is listed in Appendix 1: Data Specifications.

A LEAP exercise will need to be prepared to deal with imperfect, missing, and incorrect data sets, although such issues can be rectified by improved data management by data owners. The practitioner must make judgment calls on using actual or syntenic data sources. Often, actual data can offer false precision and require too much effort to obtain; synthetic data may be more advantageous in such cases. In any situation, the LEAP practitioner should be prepared to ensure that data is representative, and that foundational data avoids any elements that may distort or bias the results.

3.5.2.1 Energy Resources

Existing and evolving electric supply context – The analysis should understand the local electricity supply by incorporating a baseline understanding of electricity consumption (aggregate and peak) within the focal area, the existing substation connection point to the grid, and the regional electricity supply context. Deeper electrification and growing use of variable renewable energy resources requires any electric sector impact assessment (e.g., emissions, generation requirements) to use marginal or hourly rather than annual average grid and fuel use factors. Instead best available current and forecasted (e.g., MA 2050 Roadmap Study[20]) hourly generation shapes should be used to inform indirect emissions and fuel impacts.

Existing and evolving gas supply context – The analysis should understand the local gas supply by incorporating a baseline understanding of gas consumption (aggregate and peak) within the focal area, the existing city-gate connection to the gas system, and the regional electricity supply context. Existing gas transmission in the New England region is significantly constrained at the regional and system branch levels. Various local scenarios may exacerbate or relieve problems through direct changes in gas consumption and indirect changes in electricity demands reliant on gas generation.

Local ambient heat resources (ground, water, waste heat) – While not necessary for all use cases, LEAP would benefit from robust local energy resource maps quantifying potential thermal supply and (in the case of ground resources) thermal storage capacity. An example of such a resource map is New York City's geothermal screening tool.[43] Such maps should include hourly thermal potentials. However, accurate representations of such potentials are still being developed.

Auxiliary and backup thermal systems – local heat and electricity generation from fossil or bioenergy sources could be implemented locally to support local distribution networks or buildings under periods of high demand. Can the location support infrastructure such as a fuel tank, a new micro-generator, or a combined heat and power system in a district or neighborhood? Will such shared infrastructure be publicly acceptable? Can that infrastructure be supported by delivered or pipeline fuels? Does such fuel use consistent with climate goals?

Distributed electric resources – include current and potential rooftop solar and assumptions around batteries and vehicle-to-grid or flexible charging.

3.5.2.2 Consumer Demand and Assets

Energy consumption by fuel, end-use, and building unit at an hourly (or sub-hourly) resolution would be the ideal data set to inform a comprehensive LEAP analysis. However, actual data is not available at this scale. At best, utilities may have advanced meter data with hourly and sub-hourly tracking of account energy consumption. Utilities rarely make this data available for external research.

Modeled data can be a good substitute if used properly. Building energy consumption can be simulated by aggregating various datasets. The National Renewable Energy Laboratory has released comprehensive representative building energy use models with 15-minute and end-use resolution for an extensive sampling of buildings in the United States under alternative electrification and efficiency upgrade scenarios.[44]

Building Inventories that include relevant descriptive data about the building (e.g., age, size, etc.) and some tracking of *end-use assets* (e.g., HVAC system, insulation) can be used for population assumptions around the building stock. These are often available from city tax assessor databases, but these can often be several years out of date. Depending on the level of detail modeled, additional assumptions about the buildings stock may need to be made if publicly available data is insufficient.

Building retrofit costs by type of retrofit type and building type are essential for robust cost tracking. Retrofit costs can be broken down by material, supplies, labor, overhead, taxes and fees, and other cost categories. MassCEC[45] and MassSave[46] reported costs, and cost estimates could be used to build this dataset.

Demographic data provides an understanding of the socio-economic context for supporting equity goals, such as understanding potential future energy burdens. Such data includes the identification of:

- Environmental justice communities (using the state's environmental justice mapping tool[47]) in which LEAP is being used.
- Low-income households are defined by census or utility data likely to be on discounted utility rates and fuel assistance.
- The languages which residents speak can help guide future outreach.

3.5.2.3 Utility Asset Data

Access to or robust representation of the following utility data is essential for conducting a comprehensive asset analysis:

- Estimates of operational costs for the distribution network
- Geospatial inventories of utility assets
- Estimates of pipeline replacement costs
- Estimates of pipeline closure and building disconnection costs
- Estimates of methane leak rates
- Estimates of operational costs of the existing distribution system
- Geospatial inventories of electric system assets
- Electric system upgrade costs

In the absence of this data, various assumptions can be made based on the use case and the situational context.

3.5.2.4 Step 2 Outcomes

The data collection, cleaning, and organizing exercise are intended to populate the LEAP calculator tool and generate a stakeholder-focused system map that describes the key features relevant to the use case: description of the assets (age, energy demands, emissions, energy assets), a summary of the energy context (energy supply & decarbonization goals), locational context (e.g., demographic, local long-term planning goals) and data limitations.

3.5.2.5 Recommendations for Improving Data Availability and Quality

The LEAP modeling platform is currently set up to integrate many publicly available data sources. A review of these data sources with detailed recommendations for their improvement is listed in Appendix 1: Data Specifications. As the LEAP practice evolves, it will be necessary for relevant organizations to formalize access to needed data sets. Some of these suggested data support requirements include the following:

- The **Department of Public Utilities (DPU)** should:
    - Require utilities to submit asset maps periodically for planning purposes and evaluate whether access to such maps should be public or accessible to qualified planning partners (e.g., municipalities, large users, etc.).
    - Establish a standard data format for GSEP reporting that encapsulates labor, overhead and material costs.
    - Require all GSEP filings to include an estimated closure cost as an alternative to the replacement cost.
    - Require utilities to report lost and unaccounted for gas by system segment as gas transfers are recorded (e.g., between city-gate and meters).
    - Seek to develop open data access frameworks to enable local energy asset planning, following in the footsteps of states like Illinois, which provide utility data to qualified researchers in the state and academia.
    - Establish a minimum geographic reporting level (e.g., census block) for reporting customers on utility discount rates that maintain customer privacy.
- Municipal **tax assessors' offices** should improve energy asset tracking to support local energy planning.
- Massachusetts **Division of Local Services** (Dept. of Revenue) should establish best practices in building energy asset tracking.

- The **Energy Efficiency Advisory Council and MassSave** should establish a reporting framework for tracking costs and labor associated with building energy efficiency and electrification measures. Further, MassSave should report its activity with more geographic and measure resolution than it currently does. MassSave committed to improving public data resources on these topics in its 2022-2024 Plan,[46] but details on its approach are unclear.

3.5.3 Step 3: Evaluate Scenarios & Sensitivities

The system map and the planning objective should inform the design and selection of scenarios for evaluation. Scenarios should be designed to reflect the potential strategies under consideration by the primary stakeholders. The primary stakeholders should thus be involved in scenario design to have transparent ownership over the analysis and understand the scenarios' limits and applicability to implementation. As discussed in section 3.3, scenarios could include variations in policy, system planning, or alternative consumer behaviors. Section 3.4 includes a detailed description of several example scenarios that could be used to evaluate near-term pipe replacement alternatives.

The analysis should consider relevant sensitivities (Table 6) to represent relevant uncertainties and contextual changes outside the focus of the scenarios.

Table 6. Example sensitivities for improving a LEAP analysis.

Weather	Scenarios should use a consistent weather year. Best practices in the design of energy distribution systems incorporate a representatively extreme weather year – for both heating and cooling – to better represent peak energy demand needs (e.g., hot summer and cold winter). Additionally, if the analysis included an assessment of potential ground-thermal storage options, a scenario where an inter-seasonal (e.g., cool summer, cold winter) imbalance stressed such a system is necessary to model the system's size appropriately.
Climate	Scenarios representing a changing climate may also be insightful to understanding long-term changes in energy demand but are less critical than understanding the system's performance under likely extreme conditions.
Macro Energy Supply Context	The analysis should incorporate sensitivities around the energy supply system, particularly electricity, to capture dynamics surrounding cost and emissions associated with electricity generation. While incorporating these elements will not significantly change the direction of specific strategies, they may become necessary for assessing the value of distributed energy resources and highly efficient solutions for lowering electricity costs and electric sector emissions. Simulations of the macro energy supply should match the weather year.
Cost	Cost is a challenging but essential sensitivity to represent, given significant future uncertainties in the evolution of costs. The application of cost sensitivities is highly situational but typically incorporates a set of optimistic and pessimistic estimates surrounding the core elements of each scenario. For example, heat pump install costs may be used as sensitivity while other cost factors (e.g., wholesale electricity and gas prices) are fixed.

3.5.4 Step 4: Assess Impacts

Table 7 includes a non-exhaustive list of LEAP indicators that can be used to evaluate the impacts of different scenarios. Underlying factors informing the calculation of indicators (e.g., labor needs, costs, leak rates) should be updated periodically to reflect the current best estimates of the factors.

These impacts can be displayed using a standardized reporting dashboard.

Table 7. List of potential indicators that could be incorporated into a LEAP analysis.

	Indicator	Description
Customer Impacts	Energy Consumption	Total and peak demands
	Bill Impacts	Calculated using updated rate
	Investment Cost	Private and public (e.g., rebate) capital investment
	Building resiliency	Presence of cooling, insulation, backup generation
	Stranded assets	Cost of early retirements
Utility Impacts	Revenue requirements	Operational cost and cost of equity
	Rates	Revenue divided by rates
	Infrastructure needs	New equipment. and assets to meet changing demand
	Financial risk	Capital to debt ratios
	Stranded assets	Cost of early retirements
Climate, Equity, and Other	GHG Emissions	Combustion, electricity sector, and fugitive emissions
	Air Quality	Criteria pollutant emissions and monetized impacts
	Job Impacts	*Labor estimates from capital and operational activity*
	Disparities across communities	*Differences in impacts realized by different households across communities and time.*

3.5.5 Decide and Implement

Once local government units select a transition pathway for implementation, the LEAP modeling platform can be used for Monitoring and Verification (M&V) support, including assessing when adjustments in implementation strategies are needed to achieve desired outcomes. In turn, data from implementation experience can be used to refine LEAP analytical tools over time.

3.6 INTEGRATION OF EQUITY AND CLIMATE JUSTICE

A central goal of local energy asset planning is to develop tactics to minimize costs and burdens for society, especially for energy and pollution-burdened communities. While rapid electrification is necessary, it also comes with potential challenges that require a better understanding and inclusive development of equitable strategies to address those challenges and enact solutions.

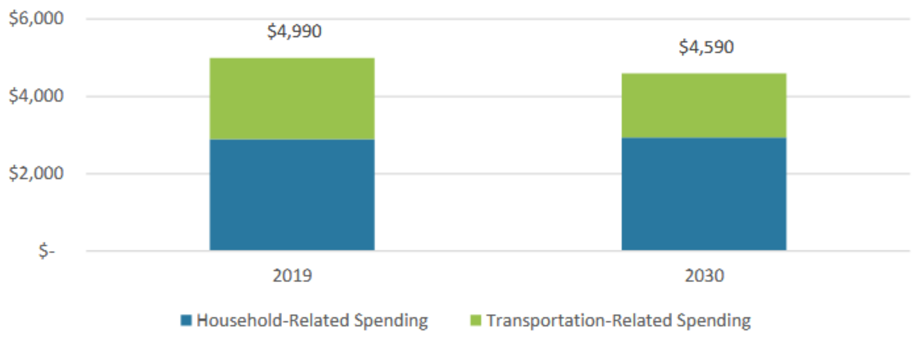
Specific challenges include:

- Potentially higher near-term energy and infrastructure costs for ratepayers or higher costs for challenging transitions (e.g., poorly insulated home with steam heat). While long-term electrification costs are likely to be lower than scenarios that continue to rely on pipeline gas, energy costs may be higher than those experienced today. [6] Further, depending on the penetration and timing of energy interventions, cost savings may be realized disproportionately across communities and households.
- Need for additional electric distribution infrastructure in communities that have historically lacked sufficient energy infrastructure.
- Limited access to implementation and operational information leading to poor understanding of energy infrastructure needs among traditionally marginalized communities of color and language isolation.
- Limited access to capital to implement energy-saving solutions among low-income populations.
- Limited agency over building energy systems in rented spaces.

These challenges are compounded by the complexities of the physical and economic integration of the built environment with multiple energy distribution systems and the need to maintain those systems to be safe, reliable, and cost-effective. Further complicating things is the potential for any

---

[6] The 2025/2030 Clean Energy and Climate Plan[75] forecast a modest decrease in household energy-related costs relative to 2019 and notes that "a household with greater adoption of efficiency and electric technologies will see a greater saving." Further, the plan noted that households in EJ-designated census block groups are estimated to see larger savings (decreases in expenditures of -11%) than households in non-EJ communities (-6%).



transition strategy to have variable impacts that span communities and evolve disparately over time. For example, electrification may be more costly in the near-term while more cost-effective in the long term[7]; specific communities may be optimal for batch electrification based on the age of their energy infrastructure, whereas others could be delayed due to cost or feasibility factors. Substantial social investments at once may mitigate discrepancies across communities but might be a costly solution that comes at an opportunity cost for other social and climate goals.

LEAP can evaluate strategies for equitably distributing the burdens among customers (of different classes), investors, and society by assessing the distributive equity of alternative policy scenarios (e.g., securitization, disallowance of profit on all or new parts of the system, etc.).

Decarbonization policies will improve outcomes for all communities overall. Still, individual strategies and policies may create situations where advancing decarbonization and equity objectives or alternative equity goals may conflict. LEAP aims to elucidate the dynamics of alternative transition strategies and to understand how the transition impacts communities to design the most effective and equitable transition-management policies.

Local energy planning seeks to maximize **fairness in outcomes** in the apportionment of energy and energy infrastructure (*distributive justice*) while redressing energy system harms (*restorative justice*). Fairness can be achieved through several mechanisms:

- Ensuring access to benefits associated with building electrification and efficiency
- Ensuring that energy-burdened populations do not bear transition costs
- Promoting investment that seeks to undo the impacts of redlining, regulatory neglect, and exclusion.

Given the complexities associated with the transition means ensuring **inclusive processes** (*procedural justice*) in local energy planning to define fairness and obtain community buy-in.

The Department of Public Utilities (DPU 21-50) and Energy Facilities Siting Board (EFSB 21-01) are currently examining procedural enhancements to promote more meaningful involvement by historically underrepresented communities. Outcomes of these investigations should be used to inform how, and LEAP can be used to engage the public.

---

[7] A household may undertake a burdensome electrification retrofit now that provides indoor air quality benefits or defer the retrofits until technology costs become cheaper but not be able to realize the benefits until later.

3.7 CURRENT STATE OF LEAP DEVELOPMENT

The three elements of the LEAP model (framework, methodology, and analytical tools) are in different stages of development. The table below summarizes these development stages.

LEAP Element	Description	Stage of Development
LEAP Framework	A general framework for approaching Local Energy Asset Planning.	Mostly completed, as represented in this background paper.
LEAP Methodology	A detailed description of the process for using LEAP to plan the natural gas transition in a local community.	The basic steps in the process have been defined, but they have not yet been prototyped in a real-life case example.
LEAP Analytical Tools	The analytical and modeling platform used to support data-driven LEAP decision-making. The core elements of the platform include: • Detailed asset, energy, and cost tracking for building and utility infrastructure. • Simulated utility financial operations • Impacts (e.g., emissions, customer bill charges, leaks, health, and employment) sufficiently addressed to assess disparities among different populations. • Representation of policy levers	LEAP analytical tools are currently being developed by a partnership between Groundwork Data and UMass Amherst. The State of California is developing similar tools and approaches, organizations in the United Kingdom, and applied researchers.

REFERENCES

1. An Act driving clean energy and offshore wind. https://malegislature.gov/Bills/192/H5060.
2. Lacy Tan & Mohammad Hassan Fathollahzadeh. Why Heat Pumps Are the Answer to Heat Waves - RMI. https://rmi.org/why-heat-pumps-are-the-answer-to-heat-waves/.
3. Lebel, E. D., Finnegan, C. J., Ouyang, Z. & Jackson, R. B. Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science and Technology* **56**, 2529–2539 (2022).
4. Massachusetts Department of Energy Resources. Summary of Stretch Code Study Energy Efficiency Analysis. (2022).
5. HEET & Burro Happold Engineering. Geo Micro District Feasibility Study.
6. Jones, R. *et al. Massachusetts 2050 Decarbonization Roadmap: Energy Pathways to Deep Decarbonization*. https://www.mass.gov/doc/energy-pathways-for-deep-decarbonization-report/download (2020).
7. Energy Environmental Economics (E3). *The Role of Gas Distribution Companies in Achieving the Commonwealth's Climate Goals Independent Consultant Report*. (2022).
8. Davis, L., Hausman, C. & Davis, L. W. Energy Institute WP 317R Who Will Pay for Legacy Utility Costs? Revised version forthcoming in the Association of Environmental and Resource Economists Who Will Pay for Legacy Utility Costs? (2022).
9. Davis, L. W. *et al.* Energy Institute WP 309R. (2022).
10. Eversource. *Eversource Net Zero Enablement Plan*. https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/14633282.
11. National Grid. *National Grid Net Zero Enablement Plan*. https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/14633280.
12. COMMON REGULATORY FRAMEWORK AND OVERVIEW OF NET ZERO ENABLEMENT PLANS.
13. Karas, N. *et al.* Aligning Gas Regulation and Climate Goals.
14. Brookline wants a fossil fuel-free future. With latest ruling, the AG says: Not yet (again). - The Boston Globe. https://www.bostonglobe.com/2022/02/25/science/brookline-wants-fossil-fuel-free-future-with-latest-ruling-state-says-not-yet-again/.
15. Community Energy Planning | Boston Planning & Development Agency. https://www.bostonplans.org/planning/planning-initiatives/community-energy-planning.

16. City Council Committee on Government Operations Hearing on Docket #0340. *Boston.gov* https://www.boston.gov/public-notices/30276 (2017).

17. Geo-exchange Systems | Colorado Mesa University. https://www.coloradomesa.edu/facilities/sustainability/geo-systems.html.

18. eSteam™ | Vicinity. https://www.vicinityenergy.us/products-services/esteam.

19. Aas, D. *et al.* The Challenge of Retail Gas in California's Low-Carbon Future. (2020).

20. Executive Office of Energy and Environmental Affairs. *Massachusetts 2050 Decarbonization Roadmap: Summary Report*. https://www.mass.gov/doc/ma-2050-decarbonization-roadmap/download (2020).

21. *Massachusetts Clean Energy and Climate Plan for 2025 and 2030*. https://www.mass.gov/info-details/massachusetts-clean-energy-and-climate-plan-for-2025-and-2030 (2022).

22. *Notice of Inquiry by the Department of Public Utilities on its own Motion into procedures for enhancing public awareness of and participation in its proceedings.*

23. *Notice of Inquiry by the Energy Facilities Siting Board on its Own Motion into Procedures for Enhancing Public Awareness of and Participation in its Proceedings.*

24. MA DPU 20-80. https://eeaonline.eea.state.ma.us/DPU/Fileroom/dockets/bynumber/20-80.

25. *Vote and Order Opening an Investigation*. (2020).

26. Attorney General's Office. Regulating Uncertainity. www.mass.gov/ago (2022).

27. MA DOER. Comments of the Massachusetts Department of Energy Resources (DPU 20-80). https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/14922528 (2022).

28. Joroff, A. & Lobel, N. DPU 20-80 Comments from Emmett Env. Law Policy Clinic on Behalf of Municipalities (combined signatories).docx.

29. EFI (Energy Futures Initiative) & E3 (Energy and Environmental Economics Inc.). Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future. (2020).

30. Anderson, M., LeBel, M. & Dupuy, M. *Under Pressure: Gas Utility Regulation for a Time of Transition | Enhanced Reader*. (2021).

31. *Order Instituting Rulemaking to Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and perform Long-Term Gas System Planning.*

32. Ralston, M. V. The Flipside Report: A White Paper on Targeted Geographic Electrification in California's Gas Transition Building Decarbonization Coalition.

33. Brockway, A. *Gas Planning and Reliability in California*. https://www.researchgate.net/publication/357636274_Gas_Planning_and_Reliability_in_California/citation/download (2021).

34. *GAS RESOURCE AND INFRASTRUCTURE PLANNING FOR CALIFORNIA A Proposed Approach to Long-Term Gas Planning*. https://gridworks.org/wp-content/ (2021).

35. Preliminary Results: Identifying Gas Decommissioning Pilot Sites. *Gridworks* https://gridworks.org/2022/08/preliminary-results-identifying-gas-decommissioning-pilot-sites/ (2022).

36. Selecting Gas Decommissioning Pilot Locations. *Gridworks* https://gridworks.org/2022/08/selecting-gas-decommissioning-pilot-locations/ (2022).

37. Selecting Gas Decommissioning Pilot Locations. *Gridworks* https://gridworks.org/2022/08/selecting-gas-decommissioning-pilot-locations/ (2022).

38. Zurich turns off gas to fight climate change and Russia : NPR. https://www.npr.org/transcripts/1092429073.

39. Decommissioning of the gas network in Zurich North. https://www-energie360-ch.translate.goog/de/energie-360/wissen/energieplanung/zuerichnord/?_x_tr_sl=auto&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=wapp#:~:text=Das%20Gasnetz%20in%20Z%C3%BCrich%20Nord,von%20ERZ%20Entsorgung%20%2B%20Recycling%20Z%C3%BCrich.

40. Seavey, D. GSEP at the Six-Year Mark: A Review of the Masssachusetts Gas System Enhancement Program. (2021).

41. Sargent, M. R. *et al.* Majority of US urban natural gas emissions unaccounted for in inventories. *Proceedings of the National Academy of Sciences of the United States of America* **118**, (2021).

42. Visualizing the Gas System Enhancement Program (GSEP) - HEET. https://heet.org/gsep/.

43. Geothermal Tools - Department of Design and Construction. https://www1.nyc.gov/assets/ddc/geothermal/index.html.

44. ResStock - NREL. https://resstock.nrel.gov/.

45. Public Records Requests | MassCEC. https://www.masscec.com/public-records-requests.

46. Plans & Updates – MA Energy Efficiency Advisory Council. https://ma-eeac.org/plans-updates/.

47. Massachusetts 2020 Environmental Justice Populations. https://mass-eoeea.maps.arcgis.com/apps/webappviewer/index.html?id=1d6f63e7762a48e5930de84ed4849212.

APPENDIX 1: DATA SPECIFICATIONS

	Description & Approach	*Data Sources & Needs*	*Recommendation to Fill Data Gaps*
Gas Utility Operations	Estimates of utility operational costs are needed to calibrate model assumptions surrounding customer and system costs. Historical trends can be used to establish forecasts.	Gas utility annual returns (annual reports) are filed with the DPU.[33]	None at this point.
Gas System Asset Maps	Accurate geospatially resolved gas system inventories are used to track assets and identify candidate decommissioning sites.	Most utilities track gas system assets using geospatial databases. These datasets include gas mains, regulators, services, meters, compressor stations, and other relevant assets. Tracked information includes install year, install costs, current book value, asset properties (diameter, pressure rating, material), safety rating, and other descriptive data.	The **DPU** should require utilities to submit asset maps periodically for planning purposes. The DPU should evaluate whether access to such maps should be public or accessible to qualified planning partners (e.g., municipalities, primary users, etc.).
Avoided Reinvestment (Gas Pipeline Replacement)	Estimates of planned pipeline replacement costs (labor, equipment, materials) are used for estimating the costs of continued gas reliance. A review of GSEP Data indicates that reinvestment costs may be as high as $60,000 per home in a residential segment.[34]	Estimates of gas pipeline reinvestment costs can be obtained from HEET's aggregation of utility GSEP filing data. The utility, town, and approximate geographic location provide the data.	The **DPU** should establish a standard data format for GSEP reporting that encapsulates labor, overhead and material costs.
Segment Closure Costs	Estimates of pipeline closure costs (labor, equipment, materials) are used for estimating decommissioning costs. The City of Palo Alto's municipal utility drafted detailed estimates of labor, equipment overhead, and materials costs for disconnecting mains, service lines, and meters. The utility estimated that costs would range from $759 to $3,578 per single-family home on average.	Gas system and segment decommissioning are rare and detailed costs are often not reported when it does occur.	**Utility or contractor** expertise may be necessary to determine closure costs. **DPU** should require all GSEP filings to include an estimated closure cost as an alternative to the replacement cost. A third party should validate such reporting.
Leak Estimates	Methane leaks should be estimated by both distribution system (main, regulator, service, meter) and building-level (pipe, appliance) assets using the best available emissions factors that represent the asset (e.g., pipe material, age, etc.). Methane leak factors should be absolute (emissions per foot of pipe/meter/appliance) rather than relative (% methane consumed) to account for large-scale changes in consumption over time while assets are kept in place. This may require deriving leak estimates for changes in equipment use over time (e.g., reduced leaks from on/off cycling of a furnace). Estimates may also need to be harmonized with city-wide estimates.	Statutory estimates of fugitive methane emissions (leaks) are calculated using published emissions factors from the EPA. There is a growing awareness that aggregate estimates of leaks derived using these factors underestimate distribution system leakage. Improved leak measurement from the distribution system and appliances could be used to improve on the EPA's estimates; however, these estimates may be incomplete.	The **DPU** should require utilities to report lost and unaccounted for gas by system segment as gas transfers are recorded (e.g., between city-gate and meters).

	Description & Approach	*Data Sources & Needs*	*Recommendation to Fill Data Gaps*
Electric Utility Operations	Estimates of utility operational costs are needed to calibrate model assumptions surrounding customer and system costs. Historical trends can be used to establish forecasts.	Utility annual returns (annual reports) are filed with the DPU.	None at this point.
Electric System Asset Maps	Accurate geospatially resolved inventories of electric distribution systems are needed to identify current electric distribution capacity and estimate investment needs for electrical system upgrades.	Most utilities track electric system assets using geospatial databases. These datasets include stations, transformers, primary and secondary wires, services, meters, and other relevant assets. Tracked information includes install year, install costs, current book value, asset properties (diameter, pressure rating, material), safety rating, and other descriptive data.	The **DPU** should require utilities to submit asset maps periodically for planning purposes. The DPU should evaluate whether access to such maps should be public or accessible to qualified planning partners (e.g., municipalities, primary users, etc.).
Electric System Upgrade Costs	Electric system upgrade costs are needed for estimating the costs resulting from the need to upgrade distribution infrastructure to meet increasing demands. The City of Palo Alto's municipal utility drafted detailed estimates of labor, equipment overhead, and materials costs for upgrading transformers, service lines, and feeders.	Equipment costs (e.g., transformers) are typically publicly available. Utility filings can also serve as a resource for materials, project and labor costs.	Review assumptions with utility partners.

	Description & Approach	*Data Sources & Needs*	*Recommendation to Fill Data Gaps*
Building Inventories	Various building inventory data can be used to populate the building model and inform building energy, use, and potential retrofit pathways and outcomes. Such factors include: - Building use, size, and physical aspects - Building shell performance (typically associated with age) - Heating system characteristics (e.g., ducted, heat source) - Recent interventions Ideally, a building inventory – based on actual and simulated data – would track building interventions and assets at a granular level (e.g., install year of a gas range)	Municipal tax assessors' data can be used for assembling municipal scale parcel data. They can be a valuable source for building energy asset information that can be used to populate model assumptions. Our initial analysis of several municipal data sets does indicate that many buildings may not have up-to-date data. Utility account and meter data can be used to confirm fuel use or predict other characteristics. Municipal permit data or MassSave rebate data can be used to identify recent energy interventions.	Municipal tax assessors' offices should improve energy asset tracking to support local energy planning. Massachusetts Division of Local Services (Dept. of Revenue) should establish best practices in building energy asset tracking. Census data and building simulation frameworks such as ResStock can be used to fill data gaps.
Simulated Data	Building energy consumption by end-use is needed to evaluate the impacts of various strategies on overall instantaneous and aggregate annual energy consumption. This paper recommends performing forward-looking analysis with simulated rather than actual data. This is recommended to maintain consistency and flexibility and avoid false precision. Simulated data should be used consistently with modeling decisions (e.g., the same weather year is used for building demand simulation as is used with estimates of electric supplies).	NREL's ResStock and ComStock simulations have emerged as the consensus resource for building simulations. These resources use a sampling approach to create many prototypical buildings that can be matched to building inventory data. While they provide a comprehensive set of end users, they have a limited representation of ASHPs and no representation of GSHPs. These models use *tmy3* and *amy2018* as weather years.	These simulations will be anticipated to improve their representation of heat pumps in the coming year. However, analyses may need to be supplemented with additional data from other sources.
Building Energy Consumption	Meter data (ideally interval data from advanced meters) can be used to ground truth and calibrate energy planning simulation data. Further such data could also be used to identify outliers that may be opportunities for strategic management.	Access to utility meter level data is typically restricted due to privacy concerns. However, several research teams at MA University's commonwealth have been provided with utility meter data in the past. Monthly data usage may require adjustments to account for variability in meter read dates.	The DPU should seek to develop Open Data Access Frameworks to enable local energy asset planning, following in the footsteps of states like Illinois, which provide access to utility data to qualified researchers in the state and academia.
Retrofit Costs	Detailed retrofit costs should be modeled by intervention and asset, capturing materials, labor, overhead, and other relevant cost categories. Such detailed tracking can be used to gain insights on major cost drivers and perform scenario analysis.	Estimates of electrification and energy efficiency retrofit costs are essential for forecasting. The MassCEC publishes costs as part of its heat pump incentive and whole home heating program. Utility filings occasionally report MassSave program costs with a detailed breakdown by intervention type.	The **Energy Efficiency Advisory Council and MassSave** should establish a reporting framework for tracking costs and labor associated with building energy efficiency and electrification measures.

	Description & Approach	*Data Sources & Needs*	*Recommendation to Fill Data Gaps*
Tracking Impacts	The thermal transition has the potential to burden households by increasing energy costs for those who transition and for those who remain. Discerning the dynamics of these impacts across individual households and communities is a core part of this work. Further, such analysis can help inform the design and evaluation of impact mitigation strategies. A geospatially resolved planning approach can be valuable for identifying disparate impacts on communities resulting from various thermal transition strategies. Examples that illustrate the impact on prototypical energy-burdened households within the planning area can be used to evaluate household-level impacts.	Census data and the state's environmental justice mapping tool[46] can be used to identify environmental justice communities for discerning disparate impacts in planning that occurs across census blocks.	The planning exercise should develop representative households for impact assessment under various scenarios that include typical examples of energy-burdened households.
Rates and Fuel Assistance	Households below 60% of the state median income and on some special assistance programs are eligible for discounted utility rates and fuel assistance. These rates are typically discounted by 25%. The Low-income Energy Affordability network reports that approximately 10% of Massachusetts residents are on a discount rate. Massachusetts estimates that approximately 5% of households will receive heating assistance in 2021.[47] These populations likely overlap. Estimates of households on discount rates and fuel assistance can provide a more accurate understanding of the impacts of different strategies and changes to utility revenues. Changes to modeled discount rates can also be explored as policy mechanisms.	Utilities and community action agencies track customers on discount rates; however, using such data for planning raises privacy issues. Census data and the state's environmental justice mapping tool can be used to generate estimates of the number of households on discount rates and fuel assistance.	The **DPU** should establish a minimum geographic reporting level (e.g., census block) for reporting customers on utility discount rates that maintain customer privacy. Regional **community action agencies'** datasets also include customers on oil assistance. These can also publish or make such data accessible for local energy planning.
Inclusion in Energy Planning	Ensuring assessment of fairness in outcomes requires developing inclusive planning processes. Planning exercises should ensure that they are performed in a meaningfully inclusive way. Such inclusion can build buy-in to strategies. There is also a need to capture location-specific factors that may influence aspects of an equitable transition, such as siting constraints for energy infrastructure, historical burdens, or existing community perspectives on given strategies.	Local records of participation in previous energy planning exercises can be used to identify gaps in participation.	Local planning exercises with stakeholders should begin with assessing potential gaps in community participation and identifying mechanisms to fill those gaps.
Languages Spoken	Inform the development of outreach materials for public engagement	Census data and the state's environmental justice mapping tool	Local knowledge
Federal Investment	Identification of Justice40 communities that are anticipated to be targeted for federal investment under the Justice40 Initiative.	Climate and Economic Justice Screening Tool	This initiative is still developing and should be monitored.

	Description & Approach	*Data Sources & Needs*	*Recommendation to Fill Data Gaps*
Labor	Several parties have identified workforce needs and workforce transition challenges. Notably, all likely future scenarios require a considerably scaled workforce to retrofit buildings, replace or close pipes, and upgrade electric systems. These needs are significant, maybe disparate depending on the strategy, and require long-term planning. The City of Palo Alto's municipal utility drafted detailed labor estimates for disconnecting mains, service lines, and meters.[20]	Labor requirements (FTE, person-hours) for building retrofits, pipe replacements and closures, electric system upgrades, and operational needs should be included in planning studies. Estimates should be updated periodically to account for changes in output (e.g., streamlined deep energy retrofits).	The **DPU** should require **utilities** to provide estimates of labor needed for GSEP interventions (replacements or closures). MassSave should develop estimates of workforce needs for building interventions in coordination with other state and community workforce planning efforts.
Health & Comfort	Electrification will lead to improvements in both indoor and outdoor air quality. There is an emerging body of literature evaluating impacts on indoor air quality stemming from combustion and leaks. [37,39] The COVID-19 Pandemic highlighted the value of having healthy, well-ventilated buildings. The addition of cooling also improves comfort and occupant resiliency during heat waves. Various retrofit strategies that tighten up the building envelope have the potential to improve air quality and reduce and improve comfort, but they also could create risks if done improperly.	Aggregate health impacts tools such as EPA's COBRA[49] can be used to evaluate the impacts of broad-scale electrification on a regional basis. There is a clear need for developing analytical frameworks for assessing the direct impacts (mortality, morbidity, reduced disease transmission) related costs associated with indoor air quality interventions.	More primary research is needed on the outcomes of issues relating to indoor air quality to estimate impacts appropriately. Air quality experts and regulators (EPA) should aggregate such research as it emerges into tools for assessing impacts. Planning efforts should monitor relevant air quality research and continuously improve model indicators.
Other Loads	Local energy asset planning needs to account for adding other local demand (e.g., EV) and generation (e.g., solar) loads that will impact system investment. These loads should be consistently modeled to ensure that impacts from thermal transition management strategies are appropriately contextualized.	Standard load profiles for electric vehicle demand and local solar generation from NREL. Incorporation of other nontraditional loads may need to be handled on a case-by-case basis.	The local asset planning effort should seek to update load profiles as needed.
Electricity Supply	The cost of electricity supplies will significantly influence the cost of the thermal transition. Forecasts of future electric costs and carbon intestines can be incorporated into planning for calculating costs and emissions impacts. This data could also be used to explore the impact of TOU rates on customers.	A local energy planning effort can use data from previous regional or national studies. Such values need to use weather-year simulations consistent with those used to generate building energy demand.	ISO-NE or the State should provide local energy asset planning efforts with access to data from future grid simulations, such as aggregate and hourly electricity costs and generation profiles.
Fuel Prices	Exogenous forecasts of prices for fossil and renewable fuels can be used to estimate fuel consumption costs.	The Annual Energy Outlook should be used to estimate future gas prices. However, such prices may need to be adjusted monthly for seasonal variability.	The analysis should consider the implications of current events on existing forecasts.

ACKNOWLEDGEMENTS

This work was sponsored by HEET, RMI, and the Boston Green Ribbon Commission.

The following people and organizations generously offered their time and advice to support the development of this work.

Name	Organization
Ben Butterworth	Acadia Center
Jonathan Buonocore	Boston University
Benjamin Miller	MA Energy and Environmental Affairs
Judy Chang	MA Energy and Environmental Affairs
John Cleveland	Green Ribbon Commission
Amy Longsworth	Green Ribbon Commission
Mike Bloomberg	Groundwork Data
Varun Adibhalta	Groundwork Data
Conor Lyman	Groundwork Data
Zeyneb Magavi	HEET
Audrey Schulman	HEET
Dominic Nicholas	HEET
Peter McPhee	MassCEC
Meg Howard	MassCEC
Galen Nelson	MassCEC
Mark LeBel	Regulatory Assistance Project
Mike Henchen	RMI
Sam Lichtin	RMI
Amar Shah	RMI
Sherri Billimoria	RMI
Jonathan Schrag	Taconic Advisory Services
Noman Bashir	UMass Amherst
Prashant Shenoy	UMass Amherst
John Wamburu	UMass Amherst
Vincent McMahon	Wakefield Municipal Gas and Light Department
Peter Dion	Wakefield Municipal Gas and Light Department
Raven Fournier	Wakefield Municipal Gas and Light Department