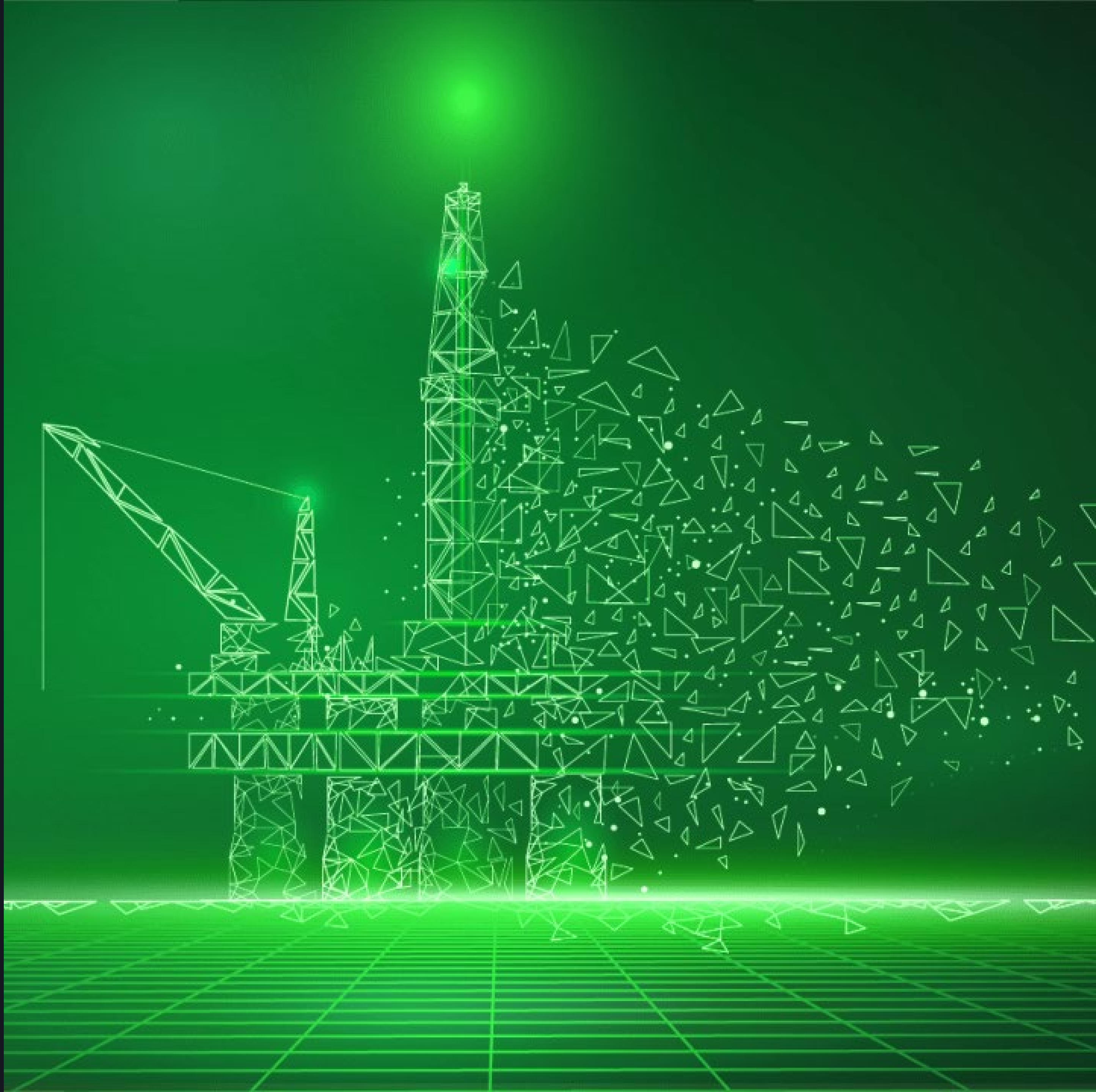
Natural Gas Decarbonization Strategies and Impacts

Charging Ahead Webinar

October 22, 2024

ENERGEIA



Agenda and Housekeeping

Agenda

- United States CO2 Pathways
- Natural Gas Sector Decarbonization Pathway Options
- International Best Practices
- Optimizing Gas Sector Decarbonization
- Takeaways and Recommendations
- Next Charging Ahead

Housekeeping

This webinar is being recorded and distributed to all registrants along with this presentation

Add your questions to the chat. My colleague, Sara, is monitoring the queue for the Q&A session

Speaker – Ezra Beeman, Energeia

Ezra Beeman

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Formerly, Pricing Strategy Manager for EnergyAustralia (now Ausgrid), the largest utility in Australia with 1.8 million customers serving Sydney

Empower Energy develops solar-batteries for virtual power plants, utilizing Ezra's patented battery optimization algorithm

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United States CO2 Pathways

Targets

Emissions Outlook

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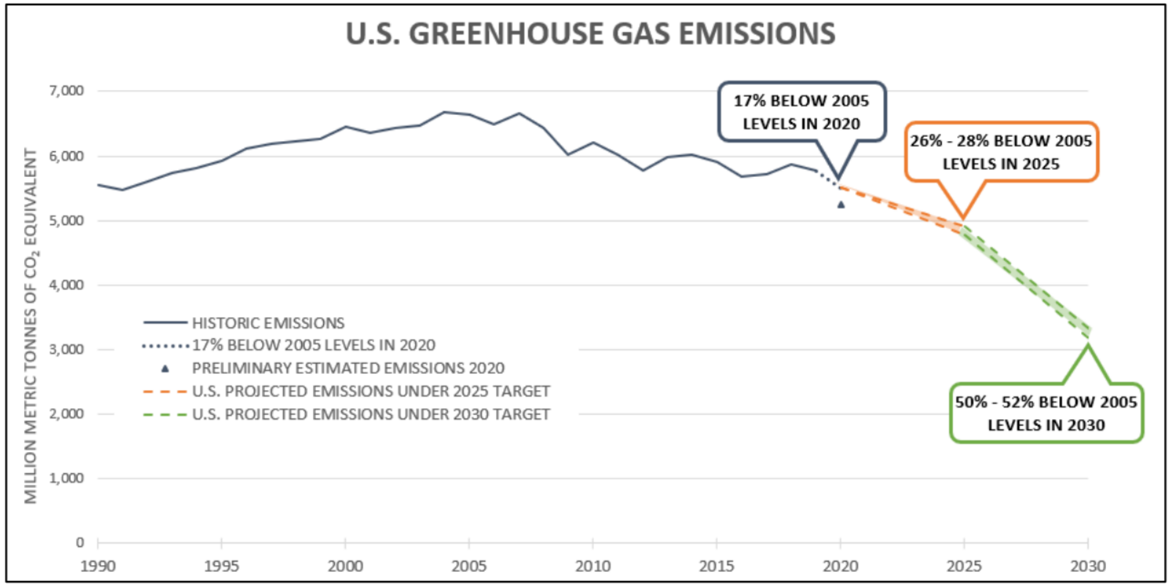
Paris Agreement and the US

US Historic and Projected Emissions Under 2030 Target



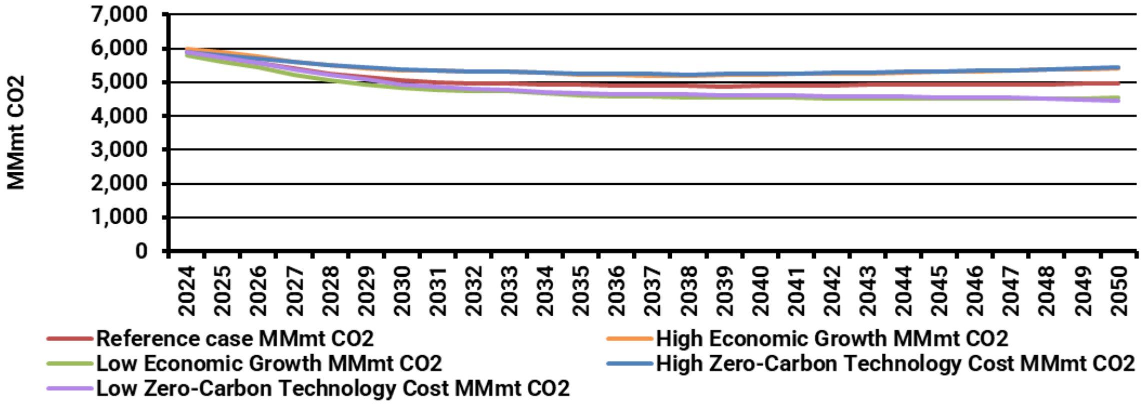
- The Paris Agreement targets limiting global warming to below 2°C, with an additional goal to keep global temperatures below 1.5°C, from pre-industrial levels
- The US rejoined the Paris Agreement in 2021, signaling a commitment to global climate action
- US targets include a 50-52% reduction in 2005-level (baseline) emissions by 2030, and a net-zero goal for 2050
    - Energeia notes that the UNFCCC has since modeled US targets to be insufficient to achieve those temperature goals
- Every 5 years, each country must submit a climate action plan, known as a Nationally Determined Contribution (NDC)
- The United States NDC highlights key roles for renewable energy, efficiency improvements, transport electrification, carbon capture, and aiming to curb methane emissions
- Some US States, which are detailed later, have committed to more ambitious emissions reduction targets

Source: United Nations Framework Convention on Climate Change (2022)

Source: The Paris Agreement, United Nations (2015)

United States Emissions Projections

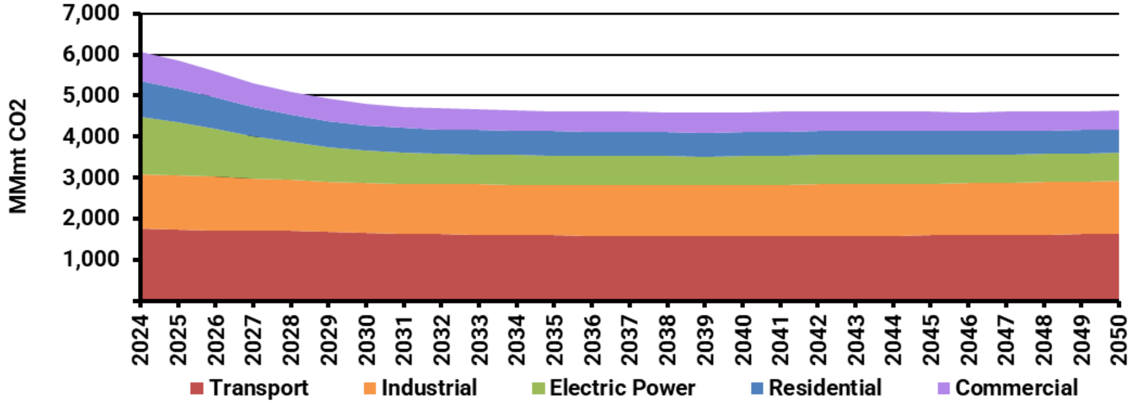
US Baseline Emissions Projections by Scenario



Source: Energeia Research, US EIA Annual Energy Outlook (2023)

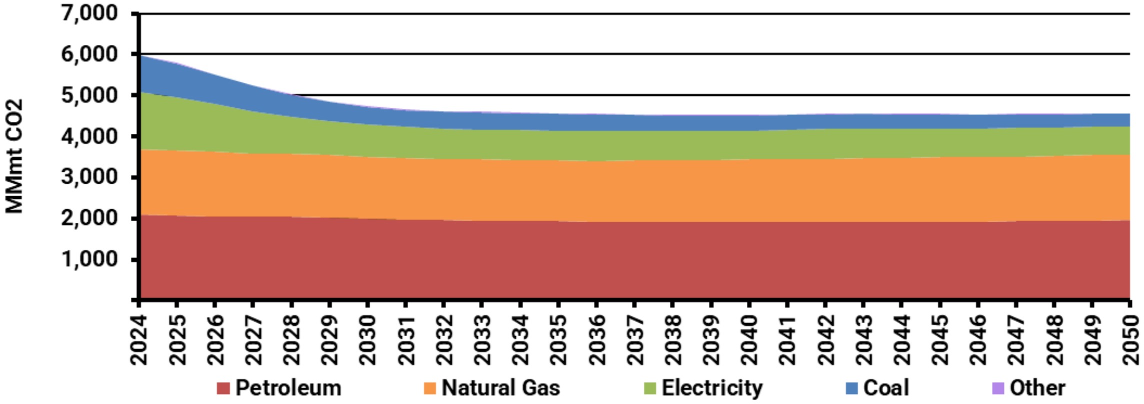
- Baseline US emissions projections show a steady increase or minimal change, even with high development and adoption of new technology
- Majority of US emissions from transport and industrial usage, however, residential and commercial combined is about the same size
- Natural gas is the second largest source of emissions, only slightly less than petroleum

Reference Case Emissions Projections by Sector



Source: Energeia Research, US EIA (2022)

Reference Case Emissions Projections by Fuel



Source: Energeia Research, US EIA (2022)

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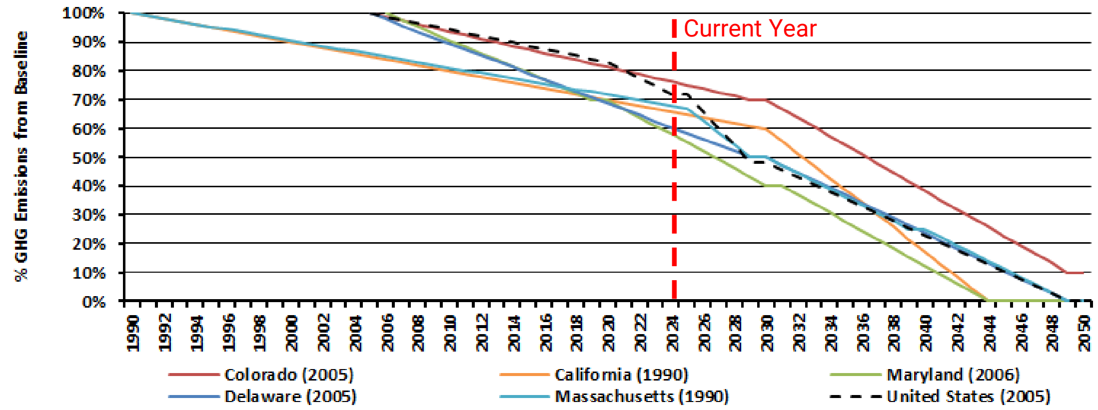
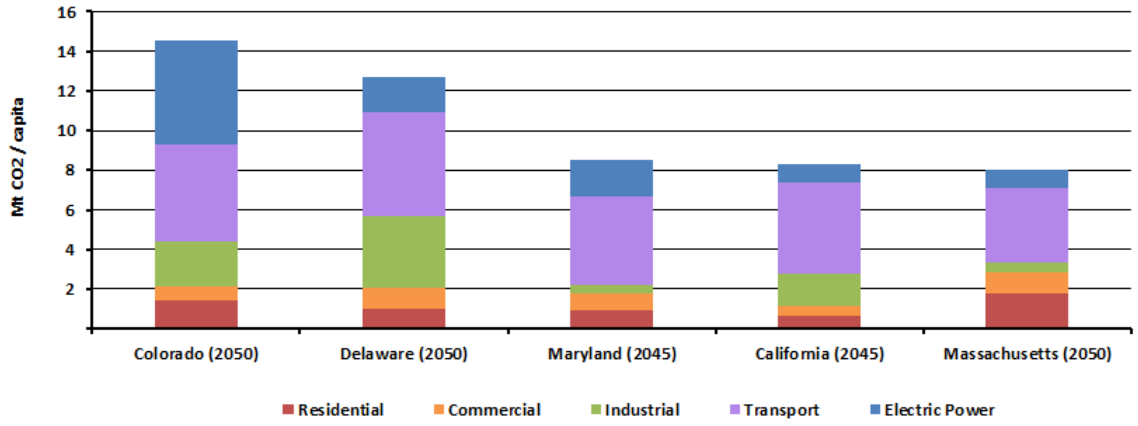
United States CO2 Targets by Key State

Leading State and Federal CO2 Targets



Source: Energeia Research, US EIA (2022), Note: legend includes "State" ("Baseline Year")

Leading States Emissions per Capita by Sector



Source: Energeia Research, US EIA (2022), Note: labeling includes "State" ("Target Year")

- The United States has adopted a trajectory to reduce emissions by 50-52% of 2005 baseline levels by 2030 under its NDC to the Paris Agreement
- The Federal Government has also developed a net-zero goal by 2050 via executive order[1], though this target was not included in its 2021 NDC
- State CO2 targets vary substantially in terms of baseline year, target sectors, and trajectory, with California, Colorado, Massachusetts, and Maryland undertaking some of the most comprehensive climate action plans, driven by state policy
  - States with most comprehensive CO2 roadmaps have been included, but may not represent the states with the most stringent targets
- *Key questions for policymakers and stakeholders include how much each of these trajectories will cost to achieve and how costs can be minimized*

[1] Executive Order 14057: Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability

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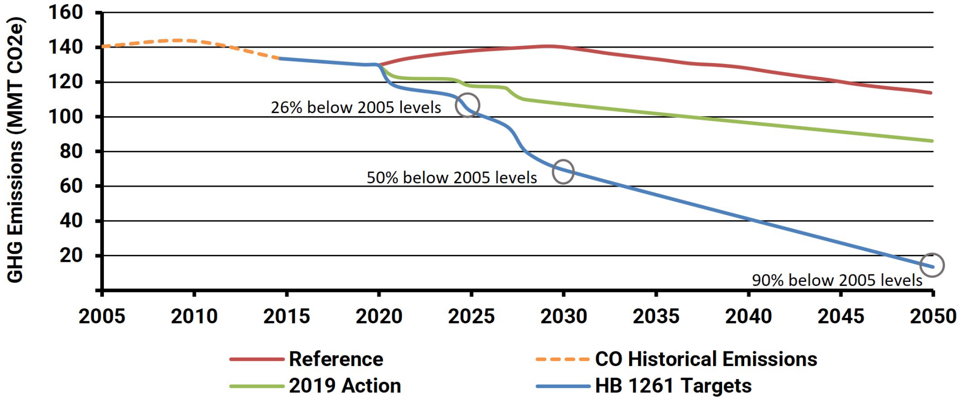
Detailed Emissions Inventories by Sector – Colorado Example

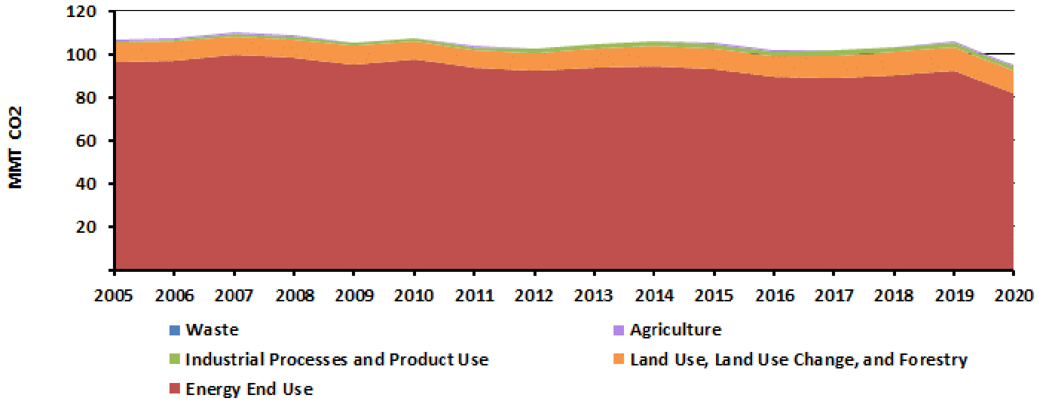
Colorado's Potential Pathways to CO2 Targets



Source: Colorado Energy Office (2019)

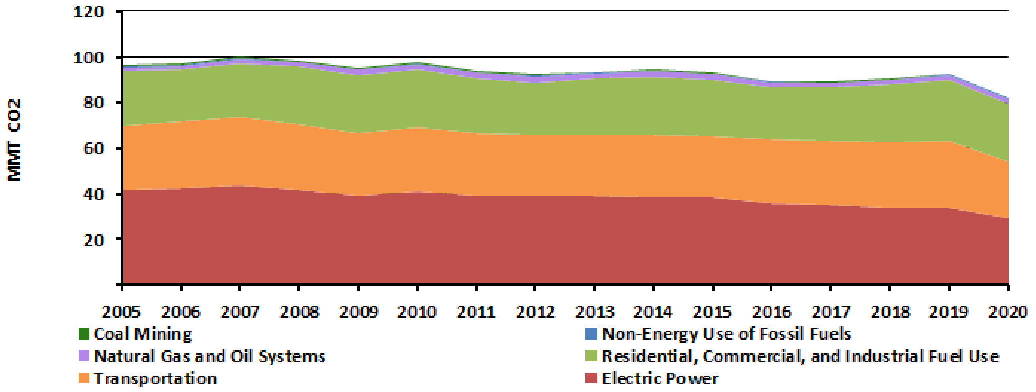
- Colorado translated international warming scenarios into emissions targets under HB19-1261, CO Climate Action Plan
- Detailed emissions inventories are being used to target key emitting sectors and inform policy
- Identifying the cost of reducing CO2 over time by sector, and how to minimize costs, requires detailed, segment level analytics

Emissions Inventory by Sector



Source: Colorado Energy Office, Dept. of Public Health and Environment (2023)

Emissions Inventory by End-Use Segment



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Key Gas Sector Decarbonization Pathways

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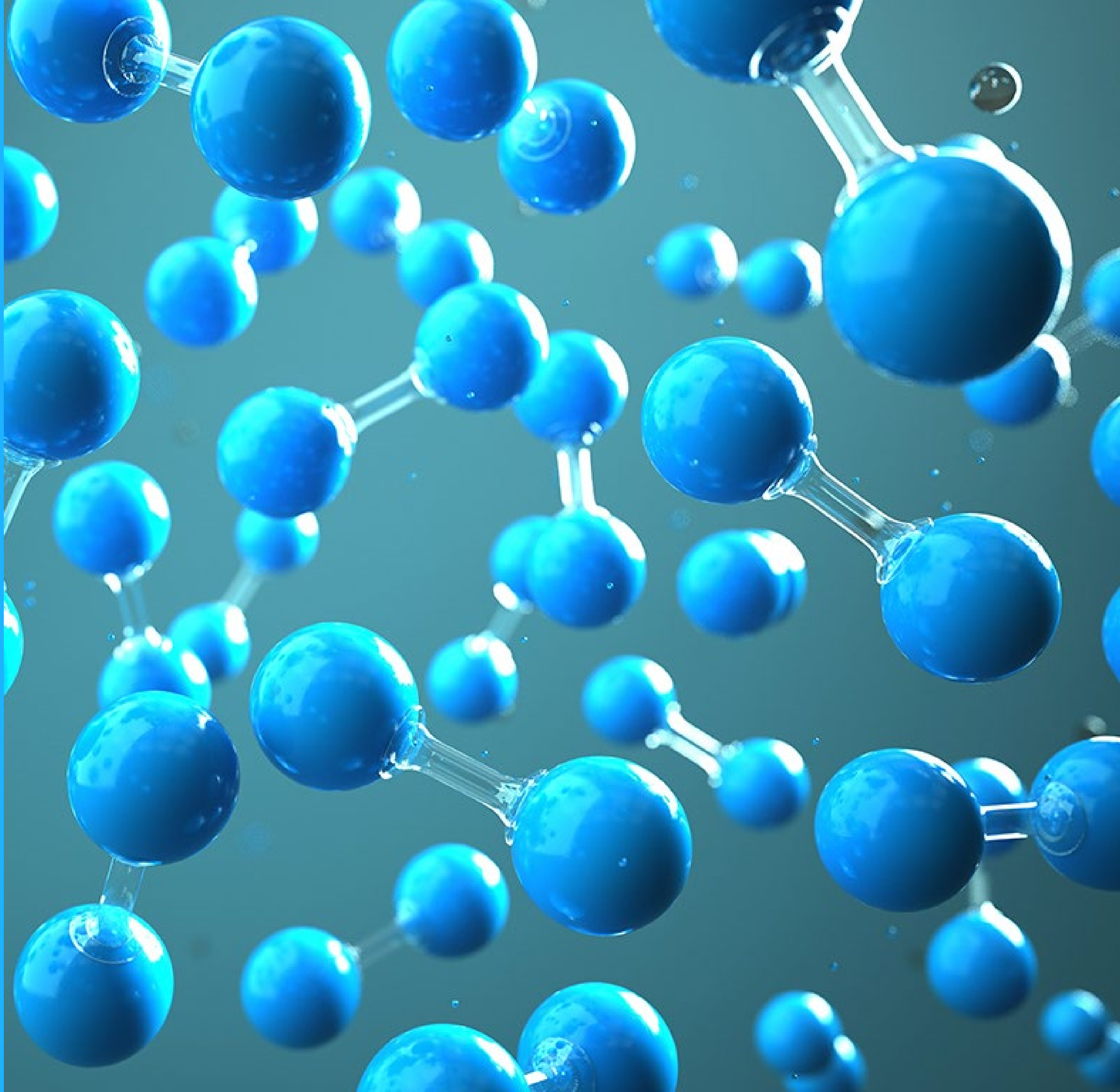

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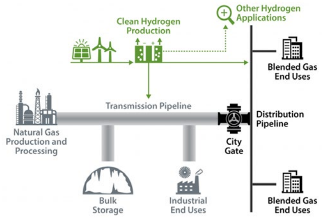
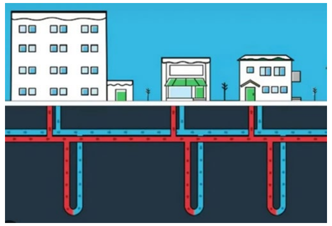
Key Gas Sector Decarbonization Pathways

Summary of Key Pathways

Key Pathway	Summary	Schematic
RNG or Hydrogen Blending Pathway	• Blends zero carbon, green hydrogen or Renewable Natural Gas (RNG) with natural gas (NG) in existing delivery networks • Recent feasibility studies have found ~5-20% hydrogen blends can be accommodated by most existing NG networks and appliances • Involves establishment of a green RNG and/or hydrogen supply chain including production, storage, and transport	
Thermal Energy Network (TEN) Pathway	• Uses TENs to distribute zero carbon heat generated from a geothermal network, waste heat, waterbodies, or sewer heat recovery • Involves developing a new system of pipelines to deliver thermal energy, as well as installation of space, water, or industrial process heating heat pumps	
End Use Electrification Pathway	• Replaces fossil fuel-based appliances, equipment and systems with electric alternatives powered by renewable energy • May require investment in renewable energy, grid infrastructure, and energy storage to handle increased electricity demand	
Hybrid Approach	• Combines hydrogen and RNG blending, TENS, and end-use electrification • Can help address economic and technical limitations in RNG/hydrogen blending as well as TENs, which offers most advantage in cold climates • Can enable a more flexible, lower risk, and lower cost NG sector Decarbonization pathway than any single pathway	

Source: Energeia Analysis

- Energeia's research has identified a few key natural gas sector decarbonization strategies
- Each has their relative strengths and weaknesses, giving rise to a hybrid approach in many jurisdictions
- Each of the primary pathways is discussed in greater detail in the following slides

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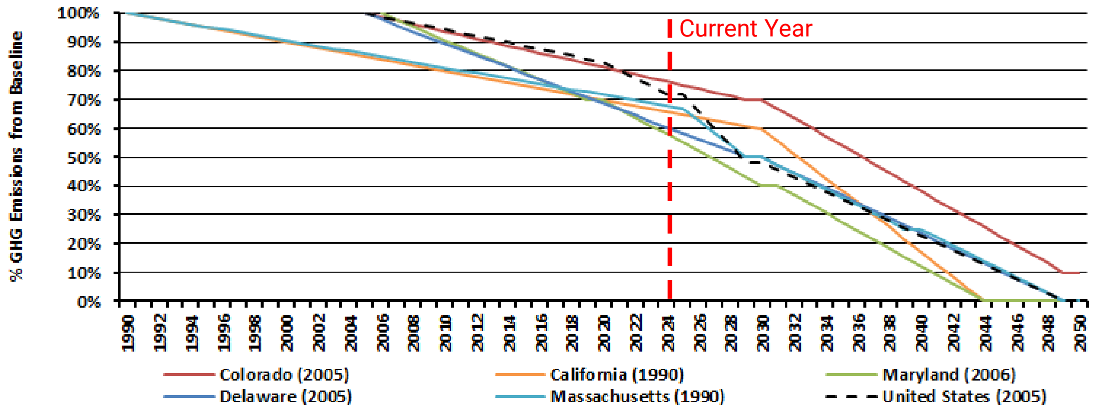

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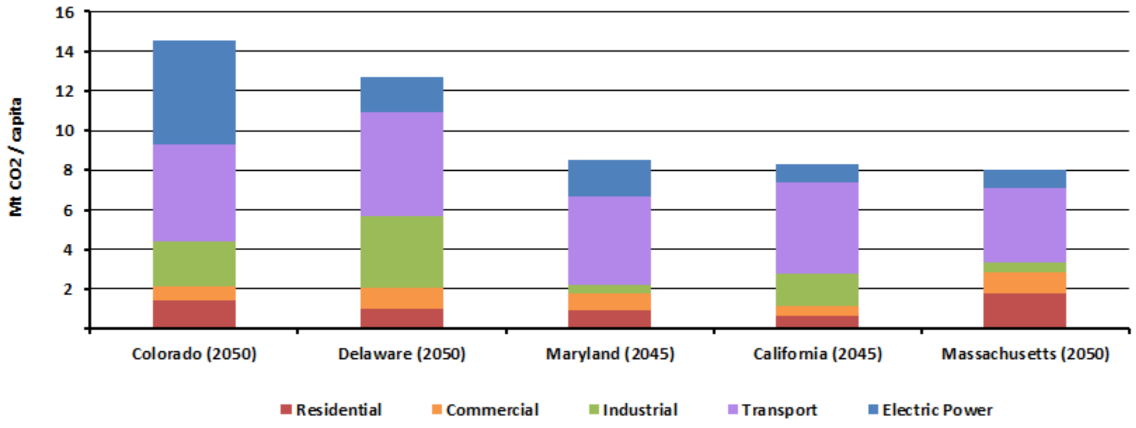

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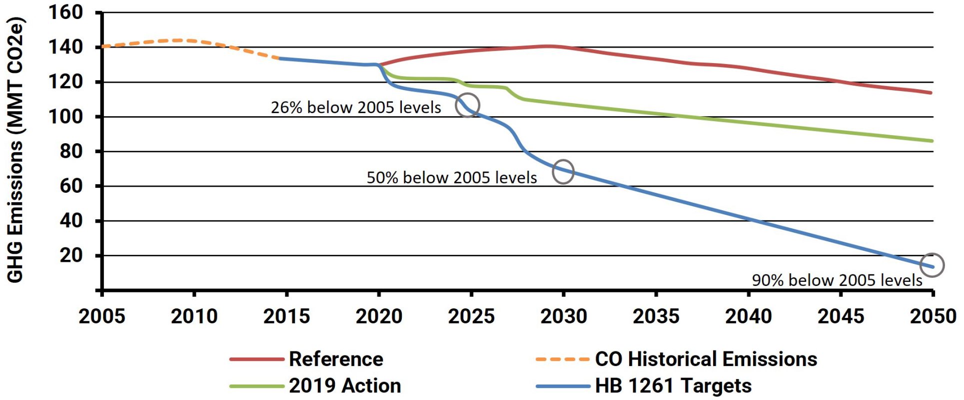

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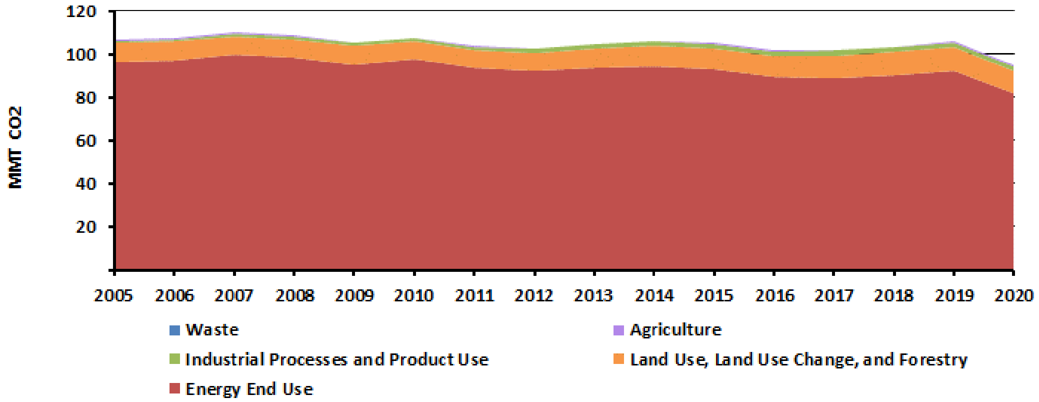

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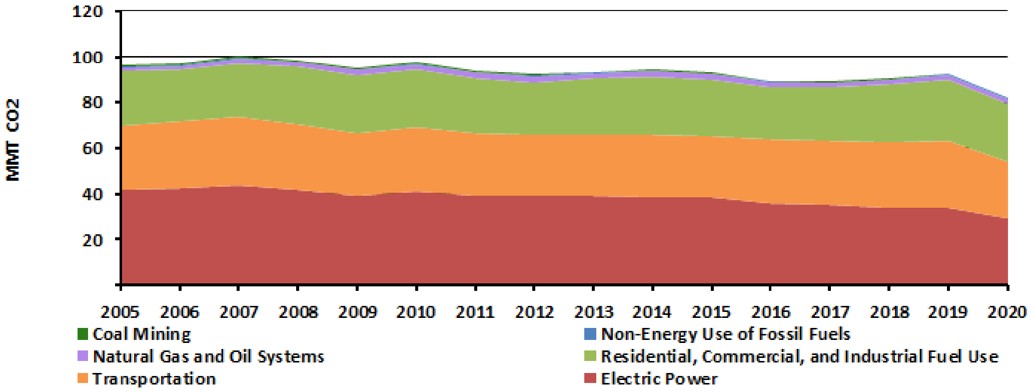

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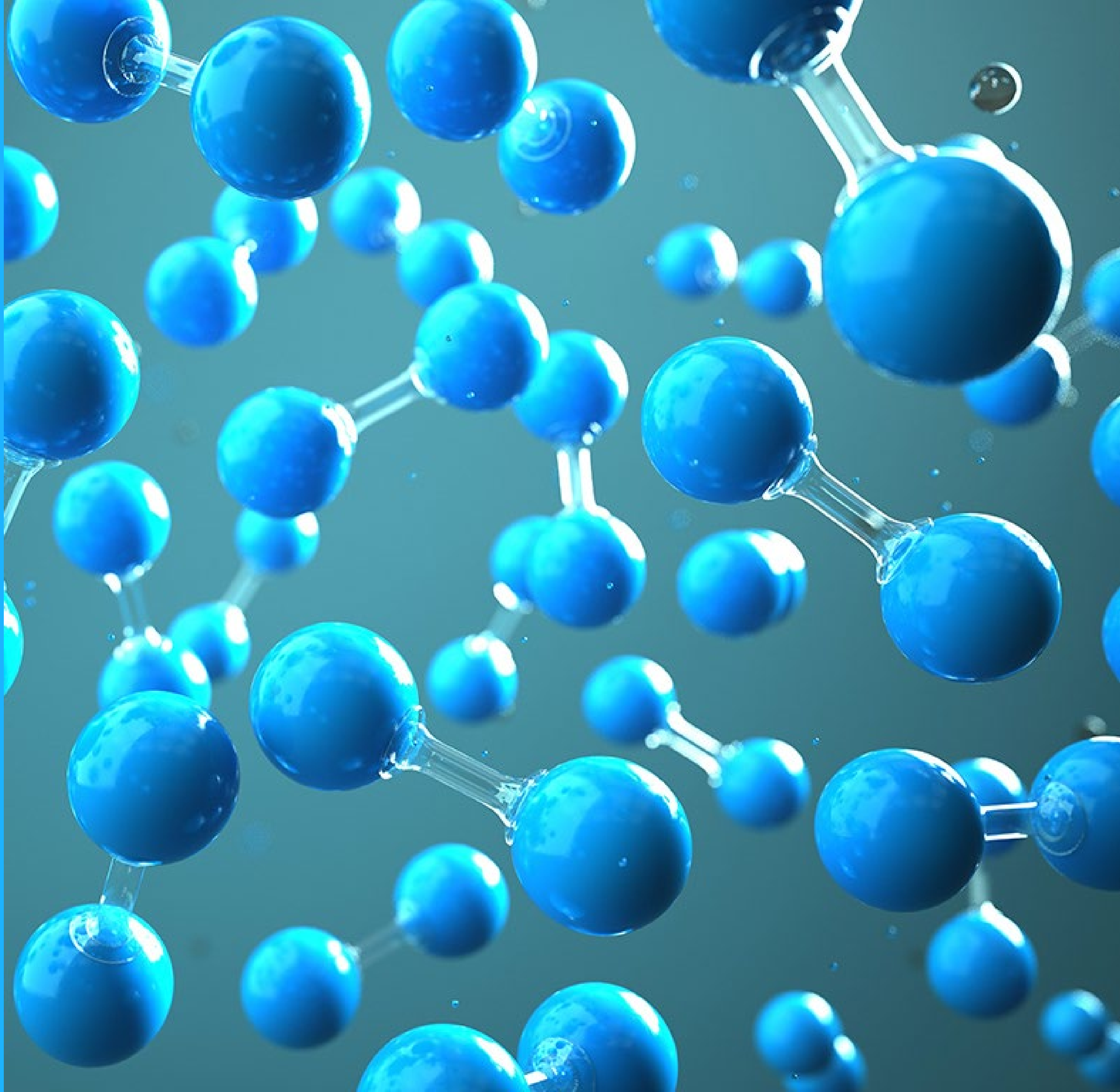

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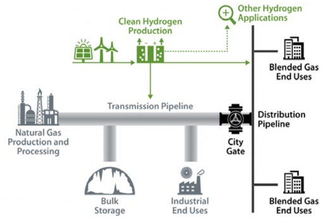
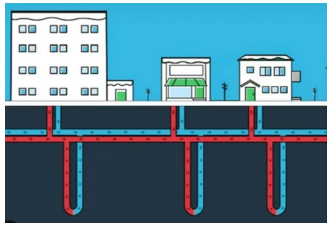
RNG or Hydrogen Blending Pathway	• Blends zero carbon, green hydrogen or Renewable Natural Gas (RNG) with natural gas (NG) in existing delivery networks • Recent feasibility studies have found ~5-20% hydrogen blends can be accommodated by most existing NG networks and appliances • Involves establishment of a green RNG and/or hydrogen supply chain including production, storage, and transport	
Thermal Energy Network (TEN) Pathway	• Uses TENs to distribute zero carbon heat generated from a geothermal network, waste heat, waterbodies, or sewer heat recovery • Involves developing a new system of pipelines to deliver thermal energy, as well as installation of space, water, or industrial process heating heat pumps	
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US Hydrogen Roadmap

United States Hydrogen Blending Pathway

Actions and Milestones for the Near-, Mid-, and Long-Term

	2022-2025		2026-2029		2030-2035
Clean Hydrogen Production	Catalyze RD&D in electrolysis, thermal conversion, & new pathways to meet Hydrogen Shot	Demonstrate replicable, scalable production from renewables, nuclear, & fossil and waste with CCS	Deploy gigawatt-scale electrolyzers and develop domestic supply chains	Scale up electrolyzer manufacturing and recycling/reuse capacity	Achieve 10 MMT production capacity and $1/kg target
Delivery and Storage Infrastructure	Identify and prioritize barriers to infrastructure roll out	Initiate supporting infrastructure for regional hubs	Demonstrate advanced and efficient infrastructure components	Develop sustainable regional clean hydrogen networks	Deliver hydrogen at scale
End Uses and Market Adoption	Engage regulators to lay groundwork for strategic adoption across sectors	Initiate industrial projects and develop offtake agreements	Deploy regional clean hydrogen hubs	Deploy technologies that lower pollution and provide resiliency	Scale up hydrogen hubs and prepare export opportunities
Enablers	Engage stakeholders; address safety codes and standards; develop critical supply chains	Develop and expand workforce, talent pools, and apprenticeship programs	Ensure 40% of benefits flow to disadvantaged communities impacted by DOE-funded clean H2 projects	Demonstrate business cases and activate private capital	Achieve Justice 40, create good-paying jobs, and ensure public health and safety

- The US DOE's National Clean Hydrogen Strategy and Roadmap estimates 4 MMT H2 system-wide blending by 2050, or *less than 2%* of US natural gas consumption in 2023
- Recent feasibility studies have found that blends of approximately 5-20% hydrogen can be accommodated by most natural gas networks with little increased risk
    - Equipment conversion needed for >20% blending
- National Renewable Energy Laboratory (NREL) did Techno-Economic studies of hydrogen blending in natural gas pipelines
    - The total cost of the conversion is highly dependent on the amount of hydrogen blended and the design factor of the pipeline

Source: US DOE

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US Hydrogen and Key Gas System Impacts

Natural Gas System Impacts by Hydrogen Blending Level

Limitation Area	10% Hydrogen Blending	100% Hydrogen Blending
Network Capacity	2-4% reduction in network capacity	13% reduction in network capacity
Distribution Piping	No changes required. All distribution piping in Victoria and South Australia is suitable for 10% blended gas and 100% hydrogen supply	
Joint Types	No changes required	Potential replacement of some specific joints
Metal and Plastic Components	Most components are suitable for 10% and 100% hydrogen supply. Potential replacement of some specific components if further testing proves them unsuitable	
Facility Piping	Stress analysis of piping layouts at each facility should be undertaken. Some field regulators may benefit from modification of pipe supports	
Operational Procedures	Some potential changes should be considered; these would not be major step changes to current procedures. A list for each scenario can be found in the full State-wide reports	
End Uses	Existing home appliances can work safely, reliably, and effectively	New appliances or burner parts will be required

Source: Australian Hydrogen Council

- The total cost of the conversion is highly dependent on the amount of hydrogen blended and the design factor of the pipeline
- Note that this study does not compare against the economics of building new dedicated hydrogen pipelines but rather assumes that upgrading existing infrastructure

Key Capex and Opex Impacts of Blending by Design Factor

Blending Hydrogen	Reduced Capacity	Design Factor	% Increased of total cost
5%	1-2%	0.5	480%
5%	1-2%	0.6	<1%
10%	2-4%	0.5	500%
10%	2-4%	0.6	68%

Source: NREL

- Design factor is a safety coefficient applied to pipeline design to account for different environmental and situational risks, ensuring the pipeline operates safely under specified conditions
- Hydrogen blending cost impacts very sensitive to design factor assumptions, moving from <1%-68% to 480%-500%

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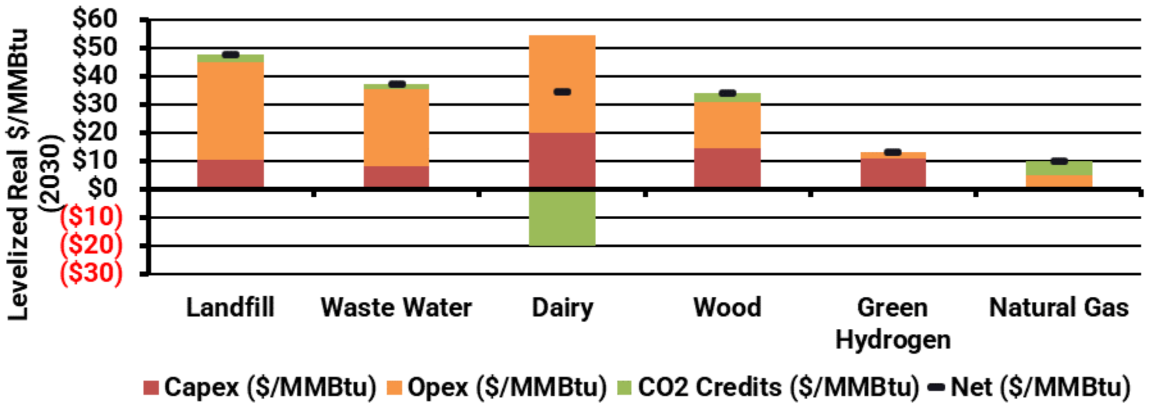
Hydrogen and RNG Fuel Costs

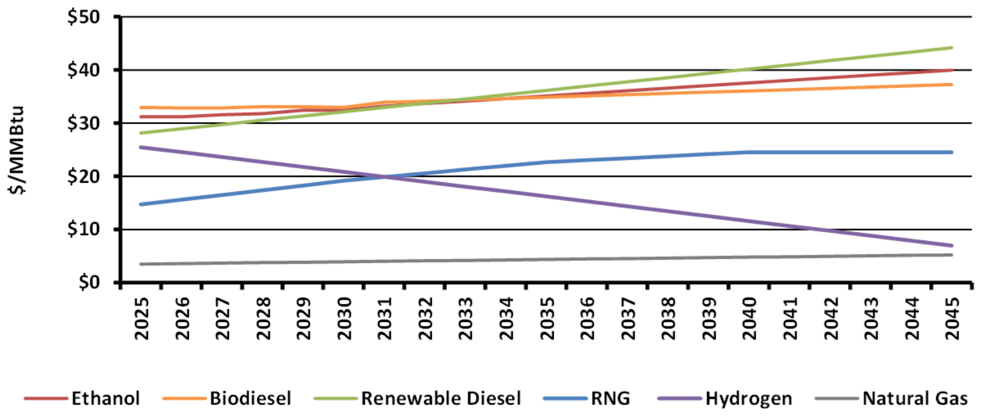
2030 Levelized Cost of Fuel by Type and Source in US



Source: CEFC (2021), Energeia

Note: All fuel types were forecasted forward using US price trends. Base Year: 2010.

Forecast Fuel Production Costs



Source: Energeia (2021)

- Energeia's forecast Levelized Cost of Energy (LCOE) in MMBtu terms shows green hydrogen to be the most cost-effective alternative to natural gas in 2030
  - RNG from wood waste estimated to be the next lowest cost source of supply, assuming no marginal increase in site costs
  - Dairy is next lowest cost option, based on forecast CO2 prices and the marginal project cost curve used
  - Lowest cost zero carbon fuel expected to be ~30% higher than the cost of natural gas
- Hydrogen prices expected to fall with input costs, but forecasted price declines have yet to materialize
- RNG prices expected to rise to bring in higher cost sources of limited supply
  - Key questions include how much feedstock is available and at what price?

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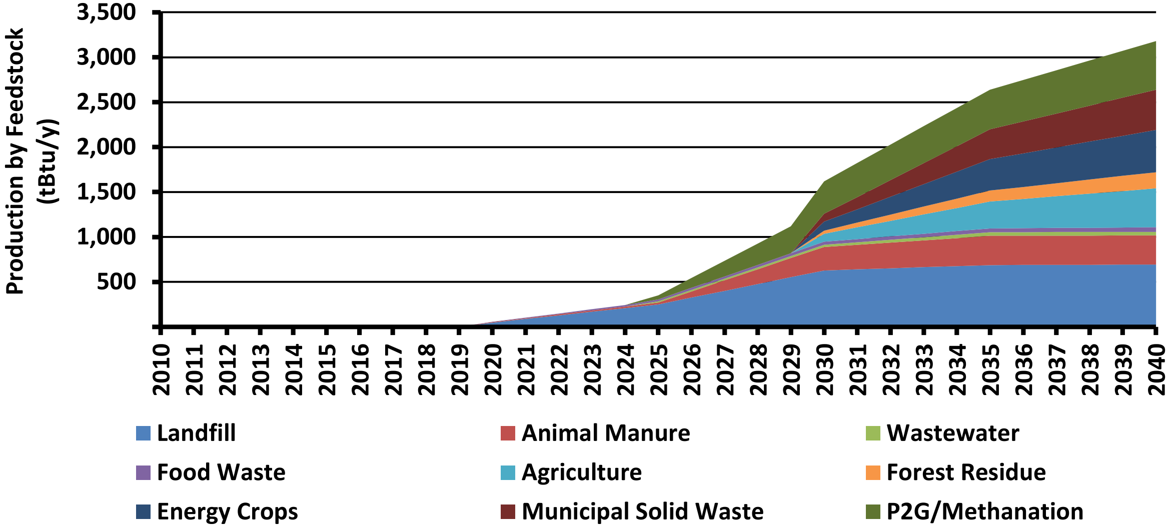
RNG Feedstock Production by Type

RNG Production Potential by Feedstock



Source: Energeia, US EPA (2021)

- US RNG production is currently estimated to be approximately 85 tBtu per year, which represents half of current nationwide technical potential in 2024, but less than 5% of US potential in the long-term
- Landfills are the largest resource opportunity for developing the industry in the short term
  - This represents 73% of the US current potential
- What is lacking in this analysis is a supply cost curve so that prices can be estimated from demand and supply

Source: US EPA, Argonne National Lab (2023)

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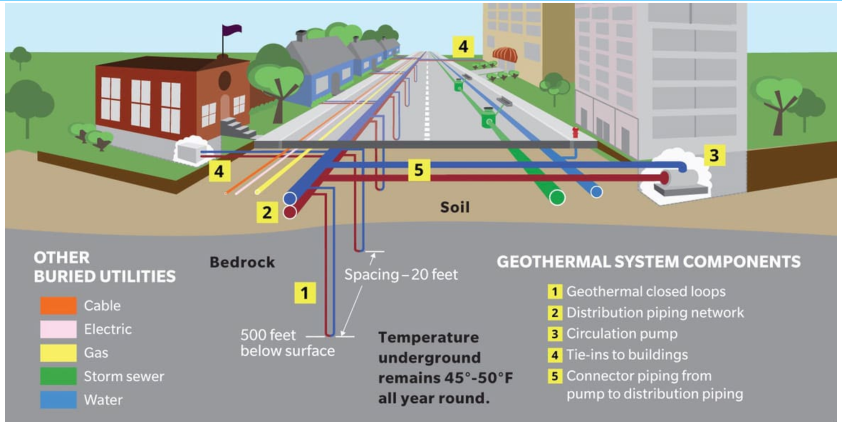
Thermal Energy Networks (1 of 2)

Overview of a TEN



Source: Building Decarbonization Coalition (2023)

- A typical residential and commercial area TENs system is shown to the left
- It can draw heat from several zero carbon sources, the most common of which are shown below left
  - Pilot data shows geothermal networks to be the most common
- Energeia's research has found that TENS have not yet been rolled out at scale in the US
- Pilot data shows a wide range of site types and both water and space heating applications

Thermal Energy Sources for TENs

Types of TENs	Description
Geothermal Networks	Shallow boreholes are used to harness the relatively constant temperature of the Earth
Direct Use Geothermal	Underground pipes are used to directly heat buildings or melt snow on roads and footpaths by heat conduction
Sewer Heat Recovery	Heat from sewer water is used for space and water heating in buildings
Waterbodies	Heating and/or cooling is extracted from nearby oceans, seas, lakes or rivers
Waste Heat without Boreholes	Heat exchangers are used to share heating and cooling between multiple buildings

Source: Building Decarbonization Coalition (2023)

TENs Pilots

Developer	Year	Location	TEN Type	Sites	Types of Sites	Types of End Uses	Funding Source
National Grid	2024	Lowell, Massachusetts	Geothermal Networks	40	Residential Commercial	Space Heating	National Grid
Eversource Energy	2021	Framingham, Massachusetts	Geothermal Networks	36	Residential Commercial	Space Heating Water Heating	Eversource Energy
Yale Acres	2020	Meriden, Connecticut	Geothermal Networks	162	Residential	Space Heating Water Heating	The Meriden Housing Authority
CO Mesa University	2008	Grand Junction, Colorado	Geothermal Networks	16	Classrooms Dormitories	Space Heating Water Heating	Colorado Energy Office
Weber State University	2015	Ogden, Utah	Geothermal Networks	Not found	Campus Buildings	Space Heating	Weber State University
West Union	2012	West Union, Iowa	Geothermal Networks	70	Urban Commercial	Not found	Iowa Economic Development Authority

Source: Energeia Research

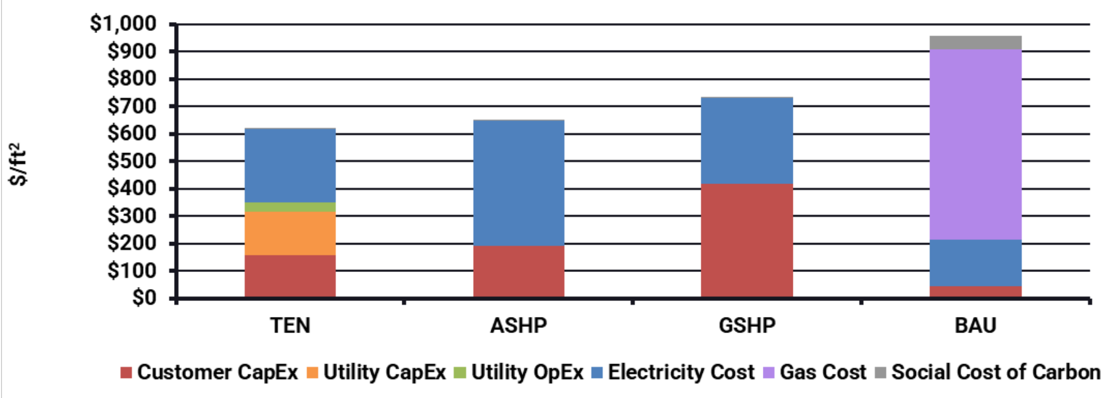
Thermal Energy Networks (2 of 2)

TENs Setup and Ongoing Costs by Category

Trial Name	Year	Sites	New or Retrofit	Customer Class	CapEx ($USD/m2)	OpEx ($USD/Year)
National Grid USA	2024	40	New	Mixed	$969	Unknown
Niagara Mohawk Power Corporation	Unknown	Unknown	New	Mixed	$538	Unknown
Buro Happold - Low Density	Unknown	Unknown	Retrofit	Residential	$178	$2,800
Buro Happold - Medium Density	Unknown	Unknown	Retrofit	Mixed	$178	$8,550

Source: Canstar Blue (2023, 2024), ACT Government (2023), Endeavour Energy (2024), EIA (2023), Energeia

Lifecycle Cost Analysis for TENs Pilot

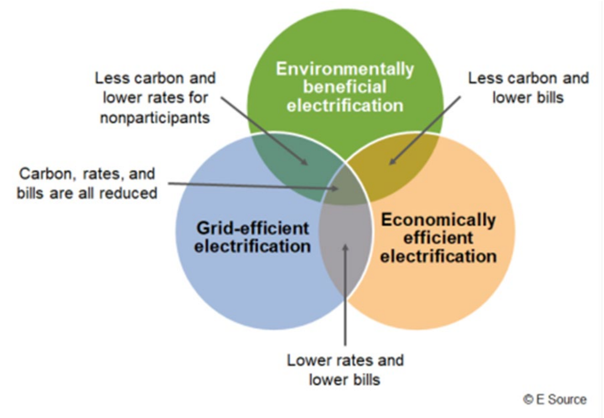


Source: ConEd (2023), Notes: ASHP = Air Source Heat Pump, GSHP = Ground Source Heat Pump, BAU = Business as Usual

- Data on TENs costs and competitiveness with other sources of water and space heating is not widely available
- Energeia has identified some published costs, but these are mainly at pilot scale and likely to be overstated
- Analysis in bottom left (based on a ConEd study) shows that TENs are 62% cheaper than installing a standalone ground source heat pump (GSHP) and typically use 14% less energy than standalone systems
  - BAU illustrates costs associated with remaining on existing natural gas system

End Use Electrification

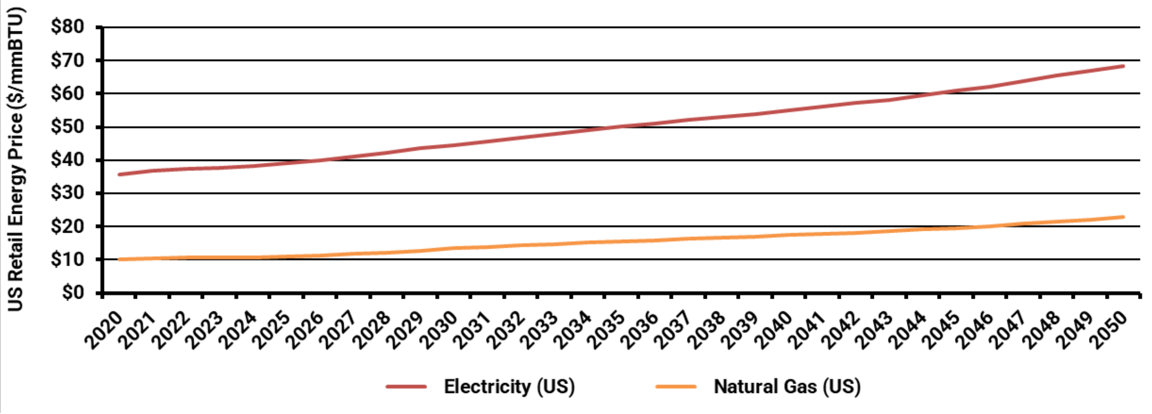
Overview of Electrification



Source: DISER (2024), IEA (2023)

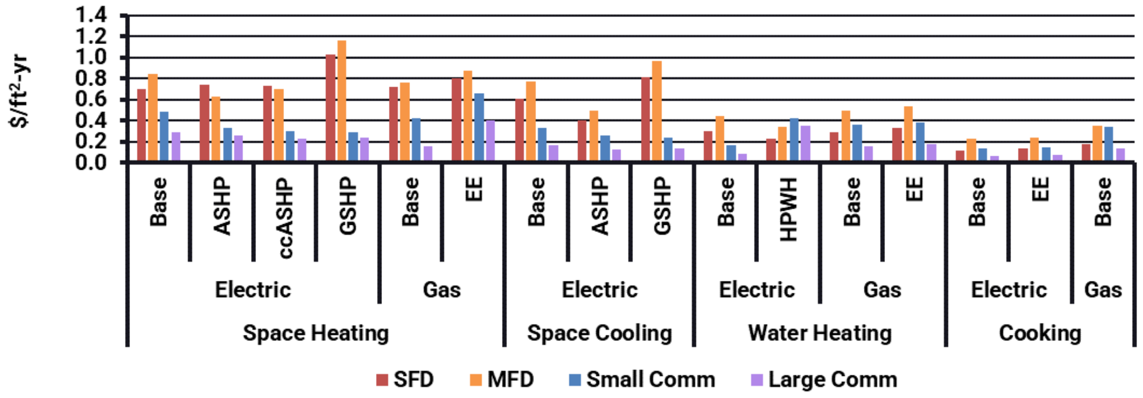
- The whole of system costs of electrifying include impacts on the electricity wholesale market and infrastructure
  - Wholesale market costs include renewable energy and firming resources such as battery storage
  - Transmission costs are driven by renewable connections, while distribution costs are driven by peak demand
- Electric heat pumps tend to be less expensive to the customer on a levelized basis, partially due to government subsidies
  - Standalone GSHPs are more expensive due to higher installation costs

US Retail Energy Price Forecasts ($/mmBTU)



Source: EIA (2023)

Annualized Tech Costs by End Use and Segment



Source: NREL (2024), EIA (2023), Energeia
Note: ASHP = Air Source Heat Pump, cc = Cold Climate, GSHP = Ground Source Heat Pump, HPWH = Heat Pump Water Heater, EE = Energy Efficient

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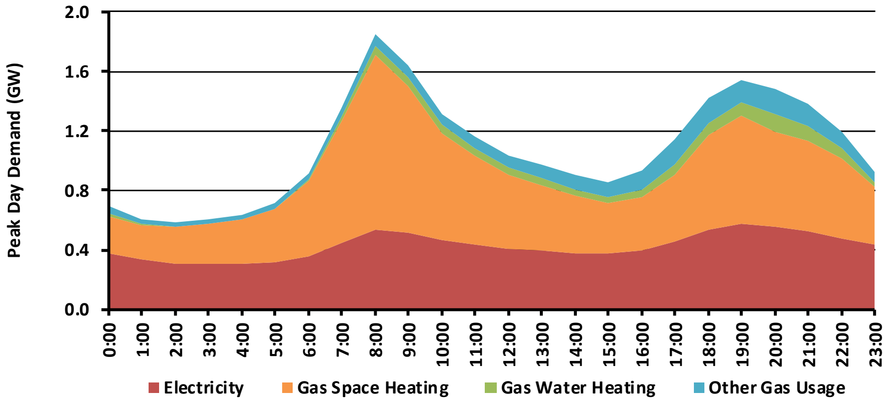
Gas Peak Demand Impacts by Sub-load on Peak Electricity Day

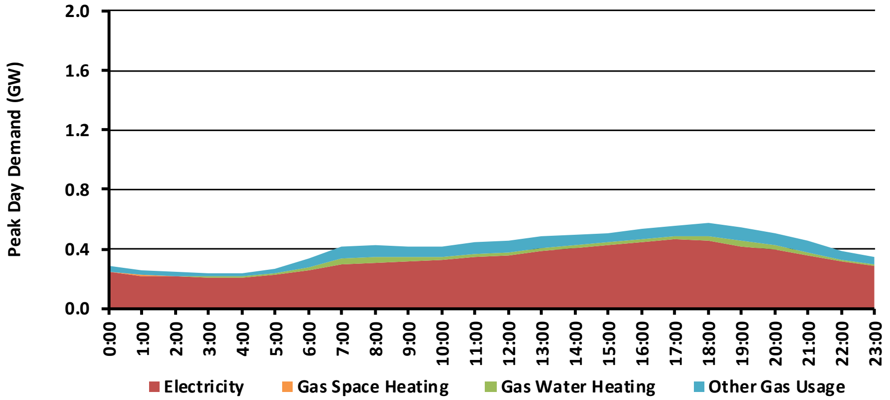
Winter Electricity Peak Day Load Profile



Source: Energeia Modeling, Note: Gas to electricity conversion assumes 100% energy conversion; Peak day is the average of the top 2.5% of peak days in Summer

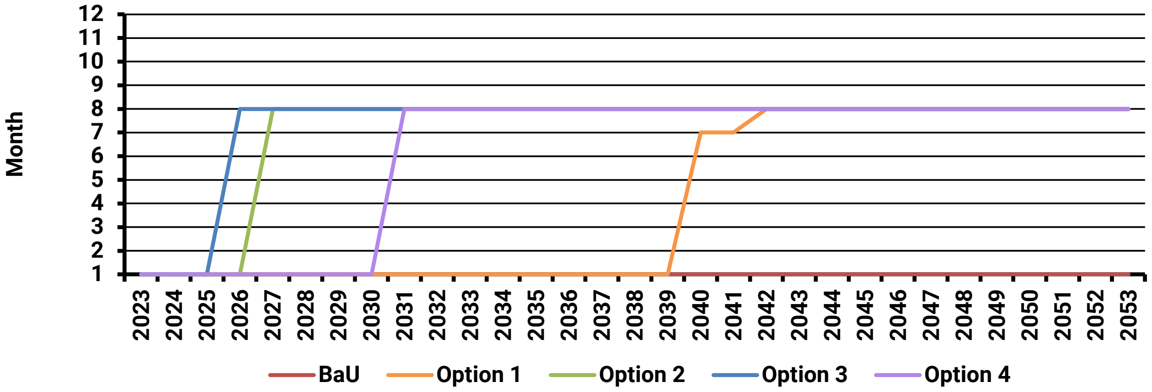
- Gas demand varies significantly by state and by season
  - Winter demand driven mainly by space heating
  - Summer demand driven mainly by water heating and other
- Example peak day load impact estimates based on wholesale gas consumption data at the total level for the given jurisdiction
- Bottom right example shows different timing of a change in the peak month depending on the policy settings assumed

Summer Electricity Peak Day Load Profile



Source: Energeia Modeling, Note: Gas to electricity conversion assumes 100% energy conversion; Peak day is the average of the top 2.5% of peak days in Winter

Changes in the Timing of Peak Demand (Example)



Source: Energeia Analysis

International Best Practices

Targeting, Prioritization and Piloting

Removing Key Consumer Barriers

Tariff Design and Cost Allocation

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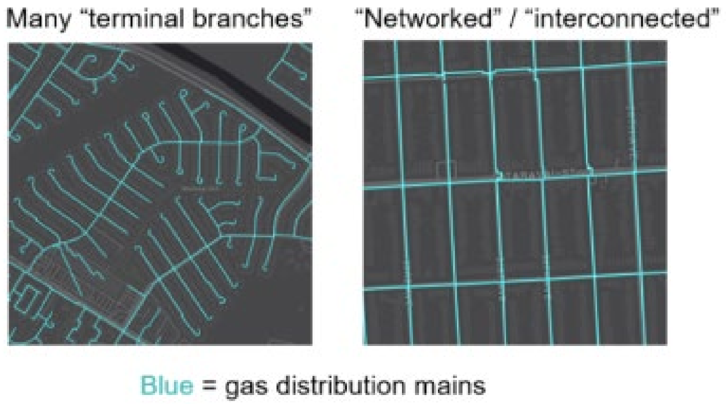
International Best Practices – Targeting, Prioritization & Piloting

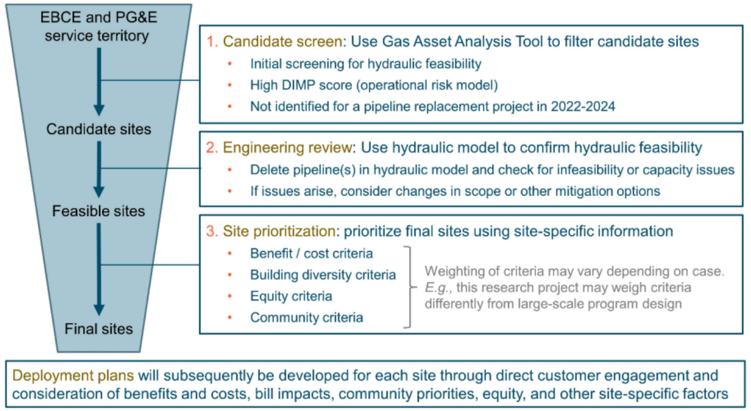
Targeting Least Cost Elements (Spurs)



Source: Gridworks (2022)

- Top left shows a zoomed in view of distribution main gas pipeline topologies
  - ‘Spurs’ in the left example, provide lower risk, lower cost decommissioning opportunities vs. ‘networked’ areas
- In addition to targeting an appropriate technical granularity and type of network grid element, key economic criteria are used
  - Gas consumption
  - Planned (avoidable) capex
- This prioritization system is then tested via a series of pilots, such as those listed in the table below

Targeting Criteria



Source: Gridworks (2022)

Piloting

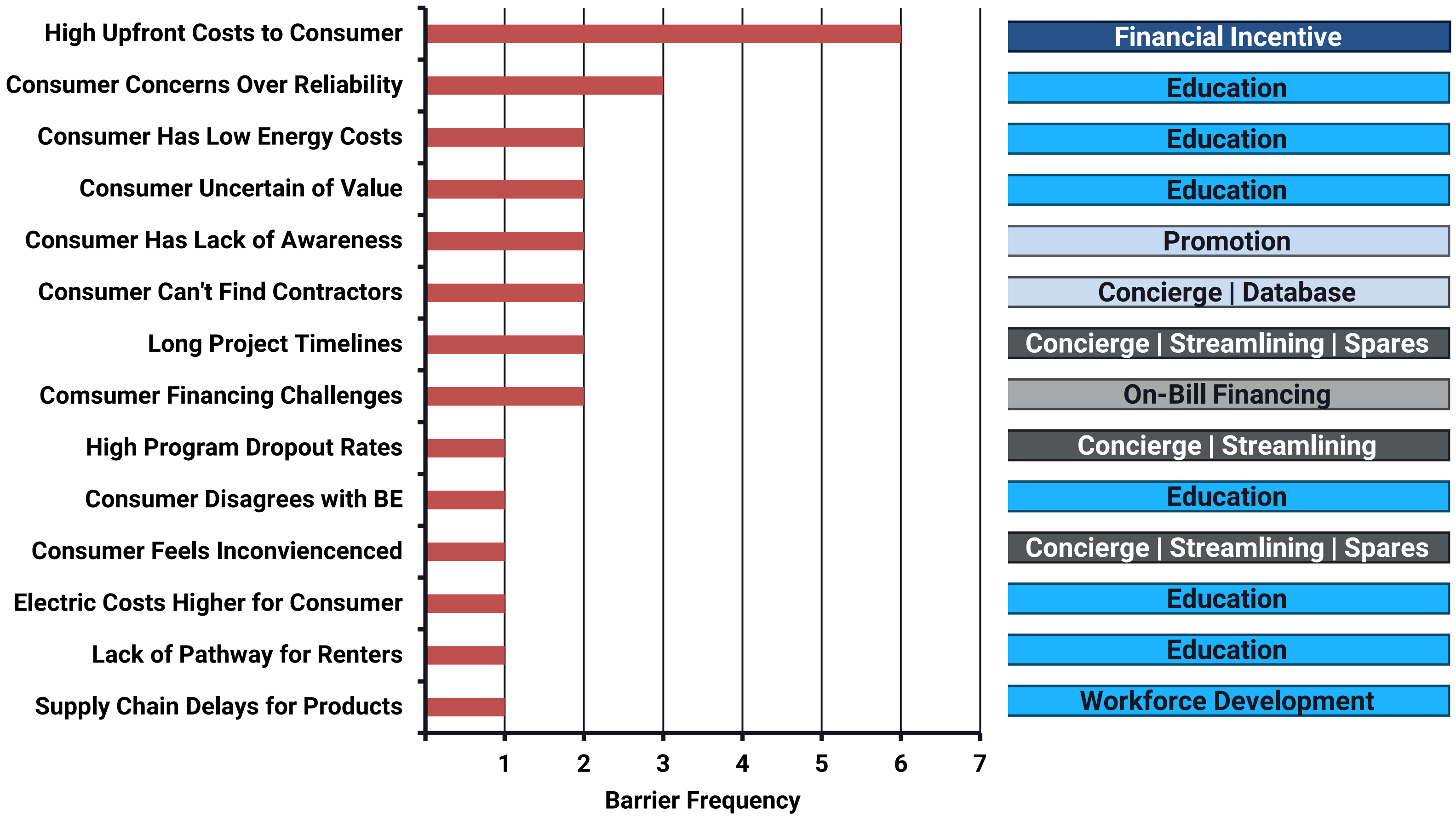
City	1 **Initial candidate sites** *Terminal branch + high capital project likelihood*	2 **Updated candidate sites** *Also includes "networked" non-residential sites with high capital project likelihood*	3 **Final Candidate Sites** *Excludes sites where a pipeline replacement project is planned through 2024*	4 **Building Types**	5 **Buildings per Site**
Oakland	8	12	**11**	SF, MF, Non-res	5-300
San Leandro	2	2	**2**	SF	5-200
Hayward	2	2	**1**	SF	5-100
Berkeley	2	2	1	SF, MF	≤5
Union City	2	2	-	SF, MF	10-400
Tracy	2	2	-	SF, Mobile Home	10-200
Livermore	1	1	1	SF	≤5
Fremont	1	1	-	SF, Non-res	10-20

Green sites went through PG&E engineering review.
No candidate sites were identified in Albany, Dublin, Emeryville, Newark, Piedmont, Pleasanton, or unincorporated Alameda County.

Source: Gridworks (2023)

International Best Practices – Removing Key Consumer Barriers

Consumer Barriers Identified in Desktop Research and Interviews



- From our research and interviews, we found that customers are primarily concerned with high upfront costs
- Our interviews also identified:
  - Customers are concerned with quality over health benefits
  - 100-amp panel upgrades are sometimes necessary
  - Installation cost and time are difficult barriers for low income consumers
  - Financing can be an issue for low income consumers
- Based on the above, Energeia has identified key strategies for addressing key barriers
  - Focus on upfront costs most important
  - Streamlining, turnkey service, and spares address inconvenience barrier
  - Education also key as addresses multitude of barriers

Source: Energeia Research

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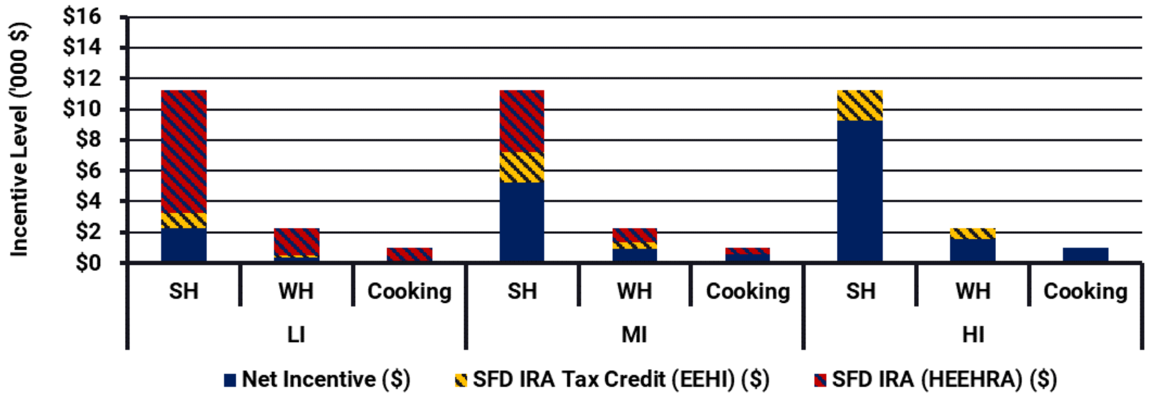
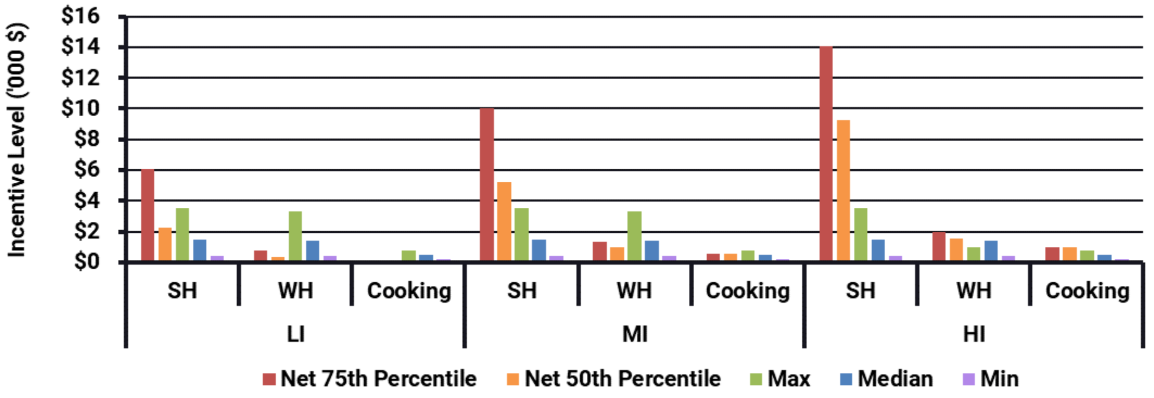
International Best Practices – Removing Upfront Barriers

Appliance Installation Premium, Net of IRA at 50th Percentile



Source: Energeia Research, The Switch is On

Ideally, Incentives Need to Vary with Premiums



Source: Energeia

- Upfront cost premiums are being offset by estimated IRA rebates and tax credits to identify a target net differential for customers by income level and end use
  - IRA tax credits assume one appliance is installed per household per year
  - IRA tax credits cover 30% of net install cost (after rebates), up to $2,000
  - Incentives make cooking and low-income and middle-income segments much more cost effective

- It is important to also consider the distribution of cost impacts, and how best to target the incentives, e.g.
  - By income
  - By actual project costs
  - By end use
  - All the above
- Our research has found that most programs (max, median and min) are below the level needed to offset the upfront cost
  - Low income incentives are the exception

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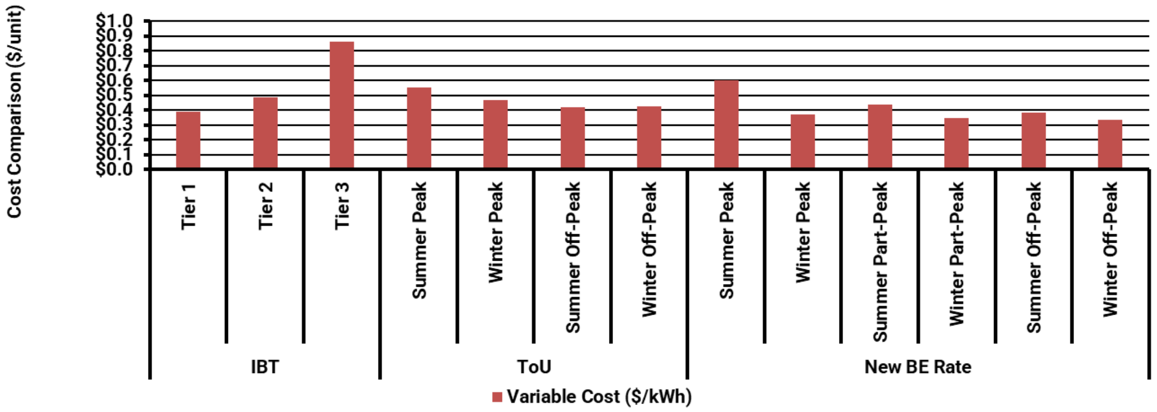
International Best Practices – Tariffs and Cost Allocation

Electricity Tariff Design – California Utility Example



Source: PG&E (2024)

Decommissioning Cost Allocation

Options for Ofgem	Action Defined
Government	Write-down and decommissioning costs are recouped from current and future consumers
Gas Network Investors	Ofgem highlights would this “create asset stranding risk” and “likely not be in the consumer interest”
Future Consumers	Ofgem notes that this will be a relatively small group of consumers, with many falling into ‘vulnerable’ categories
Current Consumers	Requiring an increase in network charges from 2026
Purchasers of the Networks for Repurposing	The network owners would probably claim any residual asset value to be theirs regardless of the Regulatory Asset Value (RAV) position

Source: Regen UK (2024)

- Recognizing that steep rises in electricity prices are increasingly making electrification more costly for consumers, the CPUC recently required IOUs to implement a lower variable cost tariff
- Lower variable costs are achieved by moving costs into the daily fixed charge
  - $15/month charge added to the Building Electrification (BE) rate
  - IBT and TOU rates include no fixed cost component
- It is worth noting that Australia’s fixed charges are already higher than these levels
- Lower left table shows the five options defined by the UK Office of Gas and Electricity Markets (Ofgem) to pay for the £3bn cost
- Similar discussions are being had in most other jurisdictions, but few appreciate the impact on decommissioning cost efficiency

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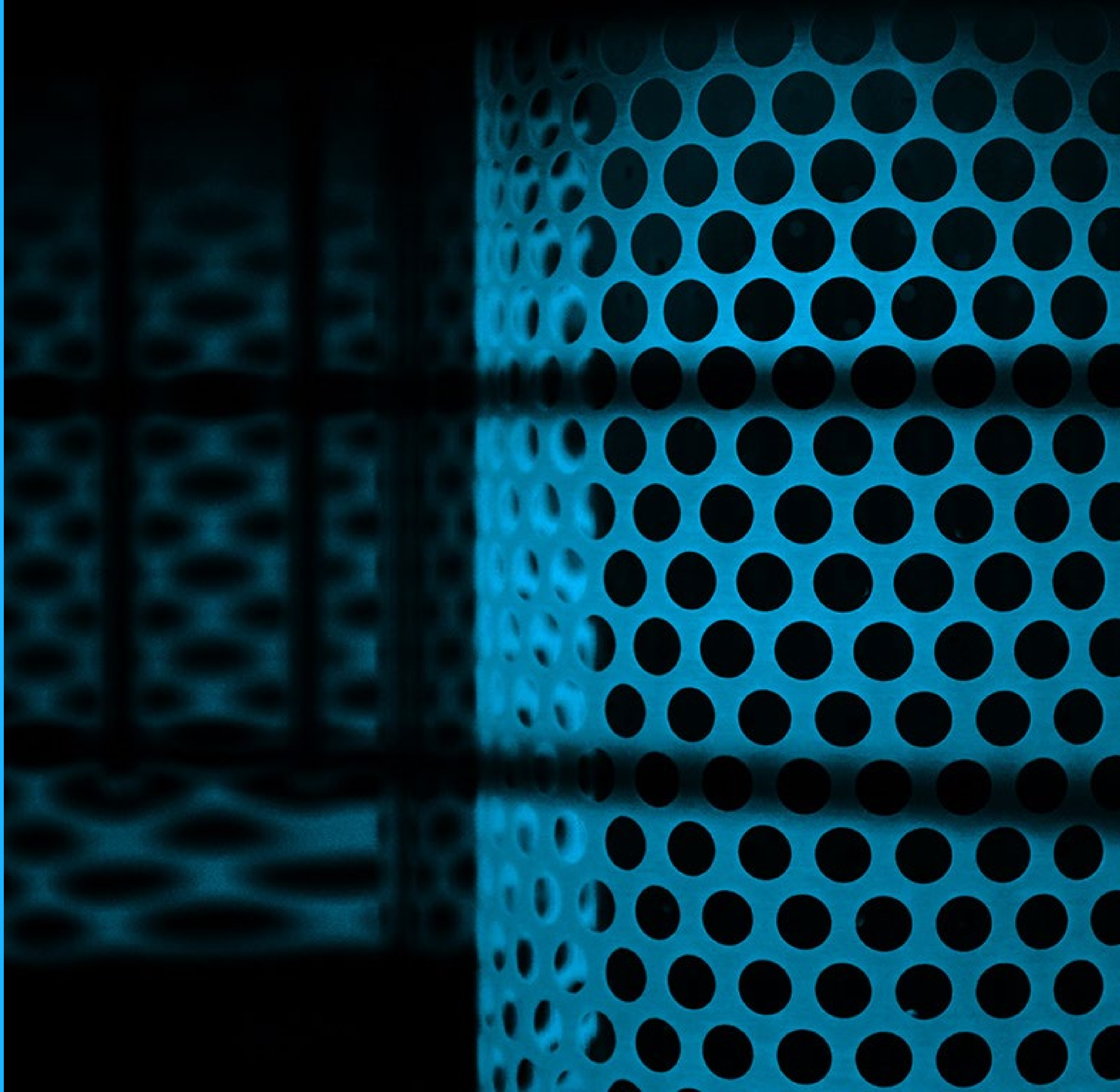
Optimizing Gas Sector Decarbonization

- Key Data Sources
- Targeting, Timing and Duration
- Costs and Cost Allocation
- Customer Behavior
- Cross-Sector Issues



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Key Decommissioning Optimization Data Sources

Key Gas Decommissioning Costs and Data Sources

Category	Sub-Category	Main Drivers	Cost or Benefit Compared to No Shutdown	Available
Electricity Network	Electricity Network Peak Demand Costs	Network Incremental Demand	Cost	1, 2
Gas Network	Gas Network Maintenance Costs	Gas Network Repex and Opex Costs	Benefit	1, 2
	Gas Network Shutdown Costs	Gas Network RAB Recovery and Decommissioning Costs	Cost	1, 2
Energy Retailers	Wholesale Electricity Costs	Electricity Consumption and Wholesale Price	Cost	1
	Wholesale Gas Costs	Gas Consumption and Wholesale Price	Benefit	1
Energy Consumers	Appliance Replacement Costs	Appliances Replaced Before End of Economic Life	Cost	1, 3
Government	Government Program Costs	Level of Electrification Incentive	Cost	3
Wider Community	CO2e Emissions Costs	Reduction in CO2e Emissions	Benefit	1

Note: 1 = Public Domain, 2 = Utility Held, and 3 = Neither

- Developing an optimal decommissioning strategy requires access to a range of data, ideally spatially integrated
- The table to the left identifies a range of key data needed to optimize gas sector decarbonization, and the expected source
  - While some key data is available in the public domain, such as the Regulatory Asset Base (RAB), it may not be broken out in sufficient detail to link to highly granular prioritization analysis
  - It is important to note that hydraulic modeling is a key factor in the efficient decommissioning of gas networks, and the inputs to this type of modeling are only held by gas utilities
- Not all gas utilities will keep granular data on their assets, but in general, the industry's asset management data is improving
- In Energeia's experience the most difficult data to collect is:
  - **Gas network decommissioning costs** – Decommissioning gas pipelines is highly variable in cost and there are currently many unknowns in the space of gas network decommissioning
  - **Gas network infrastructure data** – Only very general information (e.g. total pipeline length) is publicly available. GIS pipeline data is only obtainable through the system operator
  - **Hydraulic modelling data** – Needed to determine feasibility of decommissioning portions of the network, this data is only obtainable through the system operator and requires specialist engineering knowledge to use

Gas System Targeting, Timing and Duration

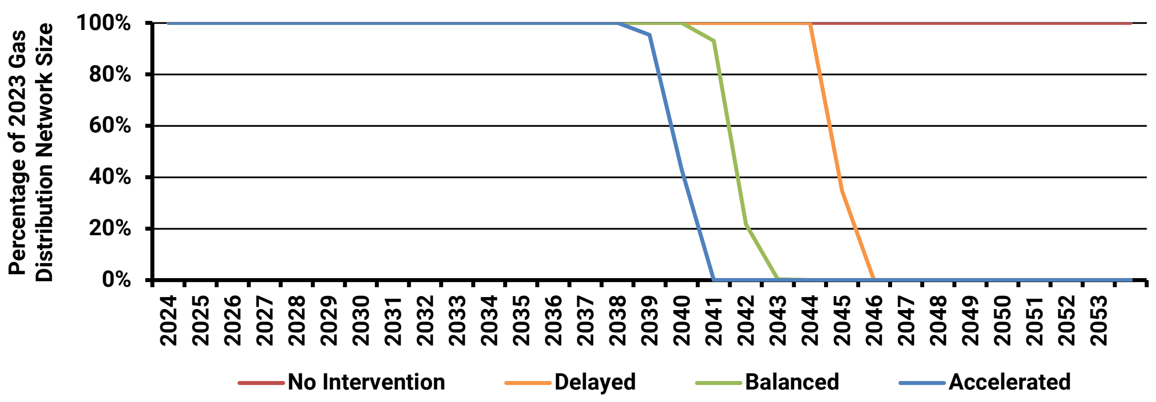
Key Shutdown Optimization Criteria

Criteria Category	Description
Hydraulic Feasibility	Initial screening and hydraulic modelling to confirm hydraulic feasibility
Benefit and Cost Criteria	Gas system avoided costs and electricity distribution system costs
Usage Criteria	Gas usage criteria, which drives the cost per therm, for a given section
Equity Criteria	Impact on disadvantaged communities (DAC)

Source: Energeia Research

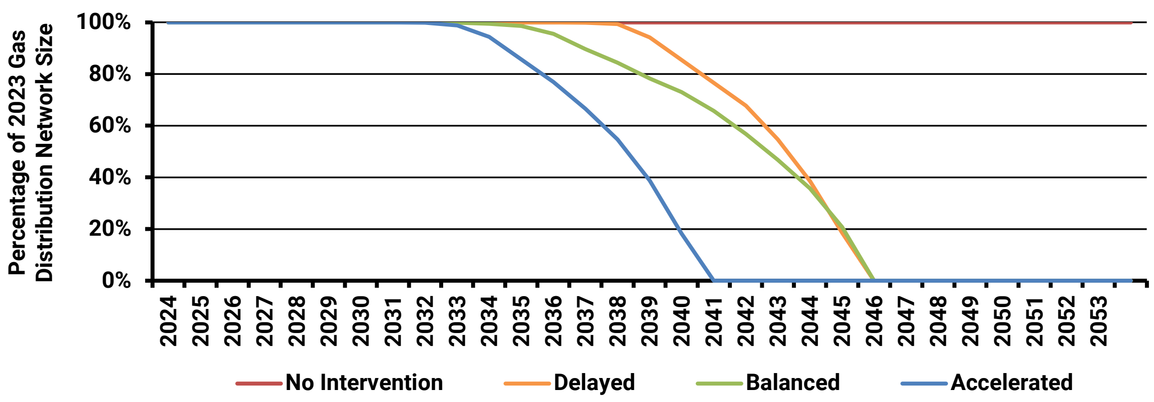
- Energeia has modeled shutdown at the suburb or state level due to data limitations
- Energeia has modelled two main shutdown methods:
  - **Phased approach** – Shutting down an equal number of suburbs by year starting from the suburbs with the least gas consumption
  - **Threshold approach** – Shutting down suburbs when they reached an assumed percentage (20% assumed here) of 2023 consumption
- Importantly, the threshold approach can lead to rapid shutdowns, in part due to consumer defection
  - The impact on deliverability and cost are important to know

Illustrative Threshold Shutdown



Source: Energeia Modelling

Illustrative Phased Shutdown



Source: Energeia Modelling

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Gas System Decommissioning and Write-down Costs

Normalized Decommissioning Costs

Source	Jurisdiction	Normalized Decommissioning Cost (AUD/km)
Frontier (2016): Future Regulation of the UK Gas Grid	United Kingdom	$79,178
ICF (2016): Decommissioning Methodology and Cost Evaluation	Virginia, United States	$99,163 - $264,436
EvoEnergy (2023)	Australian Capital Territory, Australia	$30,682

Source: Energeia Research

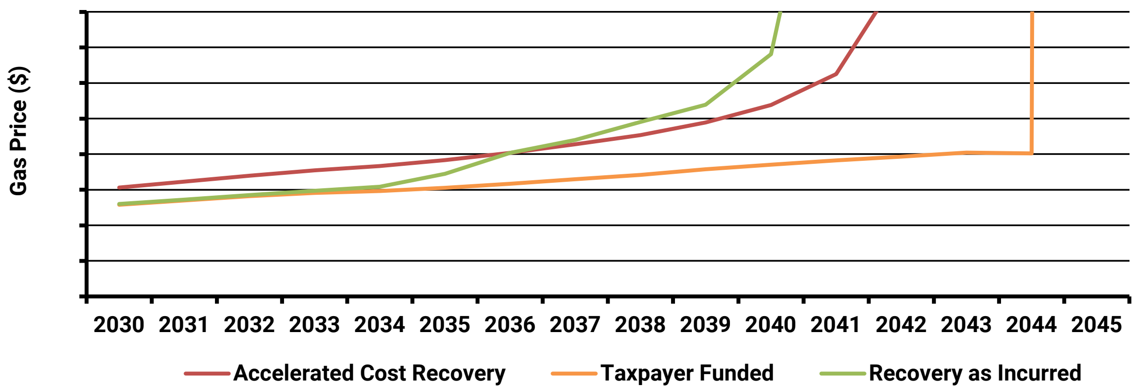
Summary of Cost Allocation Options

Cost Allocation Options	Definition	Why they're used	Stakeholders Most Impacted
Accelerated Cost Recovery	Current users pay a greater share of asset write-down and decommissioning costs	Spreads costs more equitably between current and future consumers, potentially more efficient	Current Gas Customers
Taxpayer Funded	Taxpayers fund the cost of the decommissioning and asset write-downs	Reduces price impacts to push out the death spiral, potentially resulting more efficient, equitable outcome	Taxpayers
Recovery as Incurred	Asset write-down and decommissioning costs are recovered when they are incurred	User pays, though it can potentially impact vulnerable consumers more and be less efficient	Remaining Gas Customers

Source: Energeia

- Decommissioning costs in the public domain vary widely, reflecting less experience but also differences in territories
- Illustrative outcomes from each of the key cost allocation methods is shown below
- These results show how taxpayer funded methods keep prices down, avoiding mass consumer defection as costs rise
- This can help minimize consumer gas appliance and industry gas asset write-down costs – at least until policy requires it

Illustrative Impact of Cost Allocation Options on Prices



Source: Energeia Modelling

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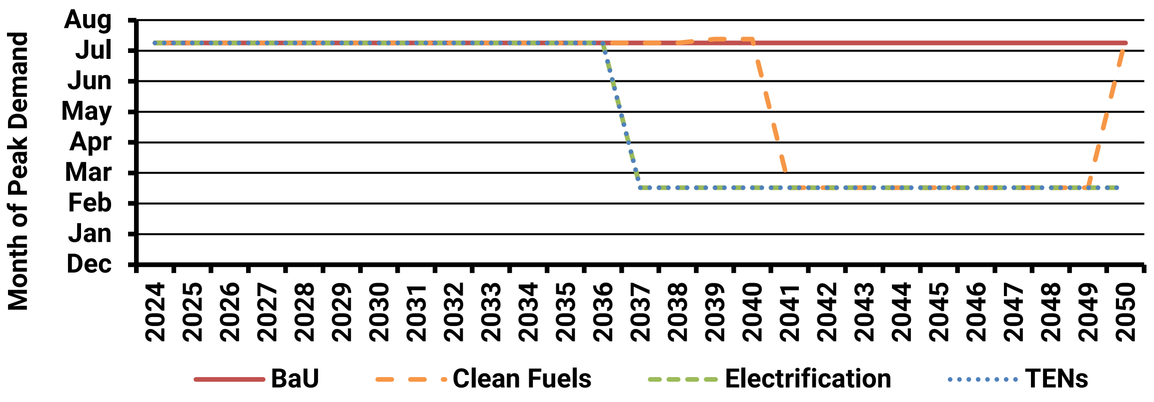
Electricity Sector Impacts

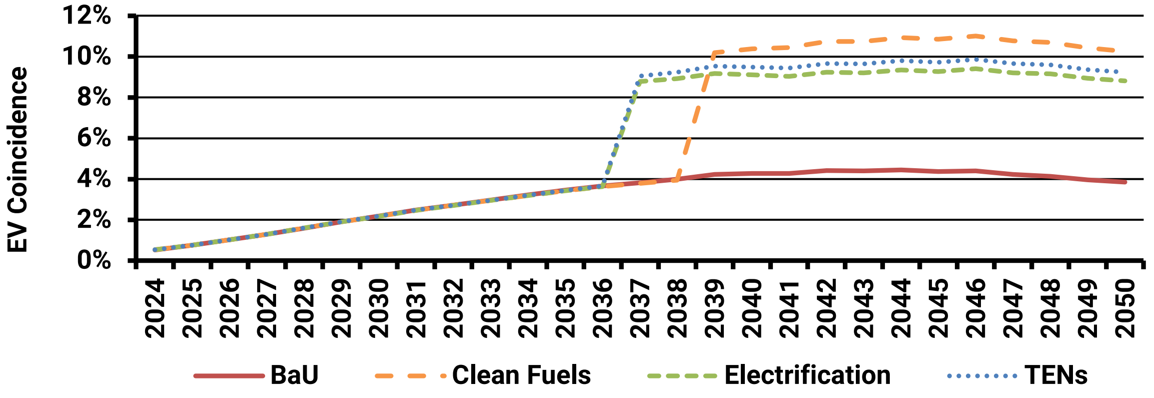
Impacts on Peak Demand Timing



Source: Energeia Modelling

- These graphs illustrate the potential impact by scenario over time on electricity peak demand timing
- Also shown is the potential impact of a change in peak demand timing on the contribution of transport electrification
  - This is due to shifting peak into when more charging occurs
- Below right shows a range of potential peak demand mitigation options, depending on the electricity system conditions

Impacts on Transport Coincidence



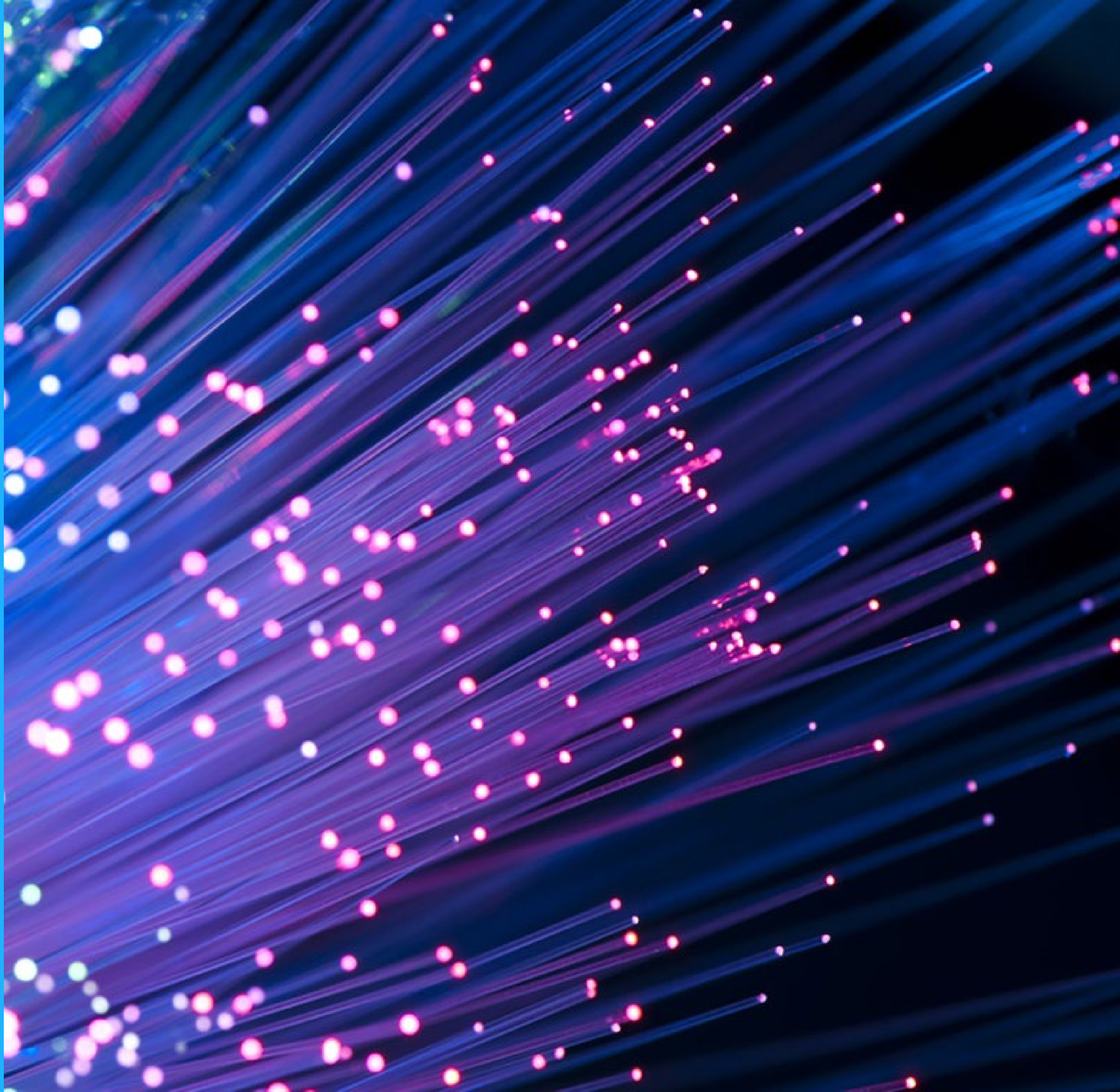
Source: Energeia Modelling

Options for Electricity System Impact Mitigation

Low Temp Heat Pump | *Water Heating Heat Pump* | *Schneider Wallbox Electric Vehicle Charger* | *Tesla PowerWall 2 Battery* | *LG Solar Panels*

Source: Energeia Research

Key Takeaways and Recommendations



Key Takeaways and Recommendations

- **Key Takeaways**
  - As the 2nd largest source of CO_2 emissions by fuel type, decarbonizing U.S. gas consumption is essential
  - Electrification is one option, but there are other options as well, including green hydrogen and other clean fuels, and TENs
  - A hybrid approach appears to be most common approach currently, enabling technology to develop
  - Electrification can deliver full decarbonization of the natural gas system, but comes at a cost, including gas asset write-downs, decommissioning costs
  - Optimizing these costs requires a whole of system (including electricity and gas) approach
  - Data availability is often limited, but needed to identify the optimal pathway
  - Key considerations include timing, duration, and segmentation of the gas system, as well as bans, incentives and cost allocation
  - Significant decommissioning and write-down costs, including customer appliances, may favor pushing out these costs
- **Key Recommendations**
  - Take a wide view of potential pathways to decarbonizing the natural gas system, including TENs and clean fuels
  - Investigate costs for emerging technologies like TENs and zero carbon fuels, and potentially invest in their R&D to bring costs down
  - More data is essential to making the best possible decisions
  - When optimizing the decarbonization pathway, it is essential to take a whole of system approach, including customer appliance costs
  - Cost allocation is a key policy decision to be made, due to the feedback loops involved and recovery of costs from fewer users and usage

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