Session: Gas alternatives to electrification - Affordably reducing emissions

Roland Berger

A Better Pathway:

The Role of Improved Gas Direct-Use Efficiency in Decarbonization Plans for Gas Distribution Utilities

Summary for Presentation May 27, 2022

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1. Overview and Background

This paper summarizes the results of various studies conducted by Roland Berger since 2019 on decarbonization pathways for gas LDCs[1)]

- Two studies for the American Gas Association and its educational foundation, on the costs and benefits in the U.S. residential and commercial building sectors from widespread adoption of emerging technologies for direct use of gaseous fuels[2)]
  - Pathways Phase 1 focused on GHG reduction potential at the customer level
  - Pathways Phase 2 focused on the aggregate GHG reduction potential across the US, across a range of policy scenarios
- Several projects for US gas distribution companies (LDCs) on the feasibility, costs and timing of their available pathways to net neutral GHG emissions across Scopes 1, 2 and 3
- Our objective is to provide useful technical and economic information for gas utilities to incorporate in their medium- and long-term planning, together with "no regrets" actions that can be taken in the 2020s to demonstrate commitment and meaningful progress toward net carbon neutrality goals
- Illustrative results in GHG abatement and cost for a generic large US gas utility are also provided.

1) LDC = local distribution company, which in the US includes distribution services with a default option for bundled supply
2) Natural gas, biogas, green hydrogen, synthetic e-methane

2. Approach

Phase 1 objective: Identify innovative gas end use technologies and translate their impact into customer value & environmental benefits

Emerging residential and commercial gas end-use technologies[1)]

1 Innovation area

1	Condensing Technology
2	Hot water heating / boilers
3	Kitchen
4	On-Site Generation
5	Burners
6	Heat Pumps
7	Changes to laundry processing
8	Solar Thermal / Heat Recovery
9	Improved Energy Management
10	Transportation
11	Building Envelope
12	Miscellaneous

2 Technologies

1. Condensing Technology	Integrated contact condensing water heater
	In-situ flue burner – applying premix burners to storage GWH
	Transport Membrane Humidifier (TMH)
	High efficiency condensing condo packs
	Residential condensing water heater
	Condensing wall furnace
	Rooftop units – heating and cooling
	Condensing economizer
2. Boilers	Tankless water heater
	Solar-assisted heating
	Thermal compression gas heat pump
	Combined space and water heating systems
nen	Combination steam and heat oven
	Boilerless steamer

3 End-use pathways

4 Customer value

Affordability

Sustainability

Resilience

Comfort

12 Innovation areas

~100 Technologies

7 End use-pathways

26 Prioritized technologies

Note: Some technologies have multiple end uses and can be used in the residential and commercial sectors. These technologies are represented in all applicable sections

1) See Appendix of full paper for list of gas end-use technologies considered

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Combining emerging end-use technologies in the residential sector creates multiple pathways for customers to reduce GHG

Building Efficiency, 10-45%

- > IoT based thermostat
- > Building Envelope

Space Cooling, up to 45%
Space Heating, up to 40%

- > Gas heat pump

Water heating, up to 55%

- > Absorption heat pump

Cooking, minimal change

- > Gas stove
- > Gas oven

Laundry, 55%

- > Gas dryer
- > Ozone washing

Generally similar potential for small commercial customers

Notes: GHG reduction potential is estimated based on efficiency improvements over stock average gas equipment efficiency in base year

Phase 2 objective: Assess the national-level costs, speed and GHG impacts of faster penetration of more efficient residential direct use gas technologies

Technologies selected for detailed modeling

End-Use	Scenario 1 (commercially available by 2022)	Scenario 2, 3 (commercially available before 2030)
Space heating	Natural gas furnace (AFUE 97%)	Natural gas furnace (AFUE 97%) Gas absorption heat pump (AFUE 1.4)
Water heating	Gas heat pump water heater (1.3 UEF)	Gas heat pump water heater (1.3 UEF)
Cooking [1)]	Gas standard cooking range	Gas standard cooking range
Clothes drying	Standard Energy Star certified dryer (CEF 3.49)	Standard Energy Star certified dryer (CEF 3.49)
Micro CHP [1)]	Gas internal combustion engine micro CHP (electric efficiency 28%-30%)	Solid oxide fuel cell micro CHP (electric efficiency 40%)

Source: Roland Berger, GTI

1) Modeled, but not included in the final results

Established data sources and methodologies were used to build technology usage and market penetration rates in Phase 2

Analysis flow chart: Space heating example.

Base Case Inputs

- Housing units by census region, and type of fuel used for space heating
- FORECAST Equipment stock & efficiency by fuel type
- FORECAST Fuel use for space heating by type
- FORECAST Generation mix by region
- Emission intensity by fuel type

Equipment usage module

- HDD by state
- Number of households by state
- FORECAST Electricity & natural gas price
- Historical electricity & natural gas price by region
- BASE CASE and ALT. SCENARIO Technical parameters & equipment cost for space heating by state

Key Modeling Outputs

- FORECAST Base Case and Alt. Scenario space heating equipment, fuel use and emissions by region
- FORECAST Net emissions and cost per ton of reduction by region and by customer/household

Penetration Module, net emissions and cost per ton of reduction

- Equipment lifespan and useful remaining life
- Saturation ratio
- Payback period sensitivity
- FORECAST Installed & operating cost subsidies by state
- FORECAST Technology cost improvement curve

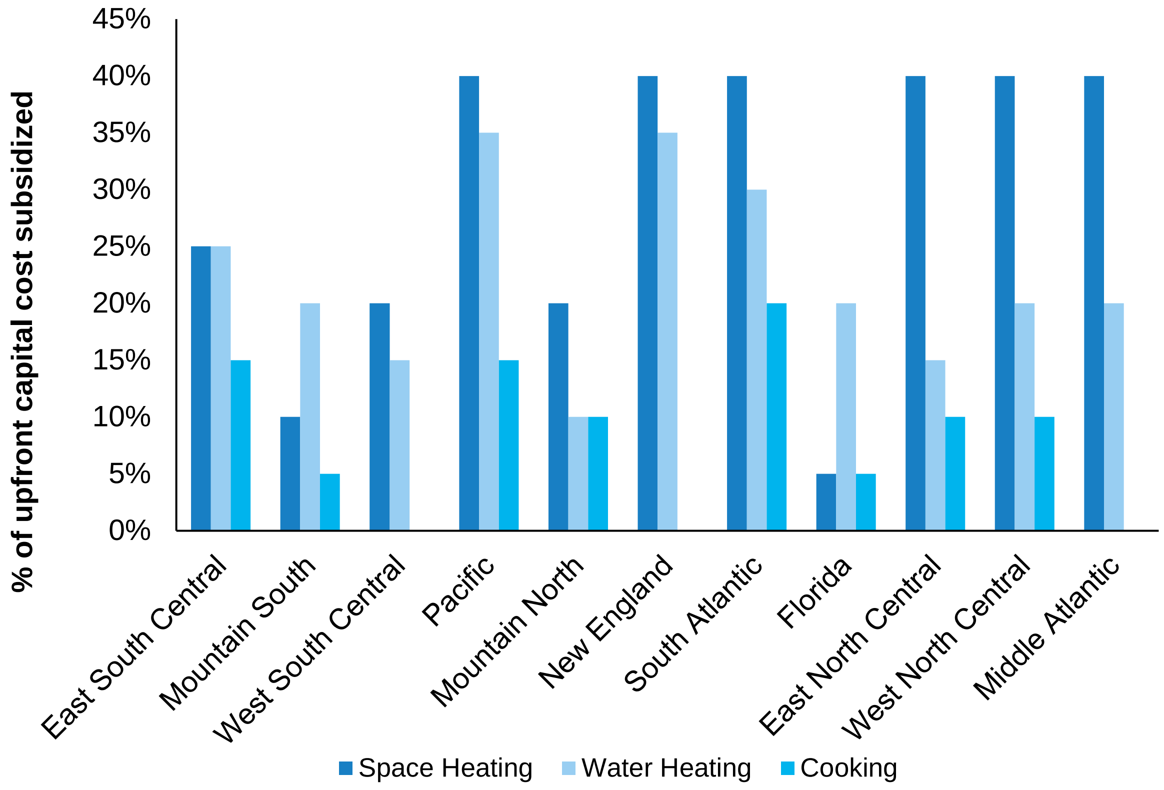
GTI | EPA | Assumptions/ modeling parameters | Calculations | Census data and EIA | EIA (AEO 2019, Residential Energy Survey)

Adoption of new technologies was assumed to follow the well-established S-curve of consumer behavior

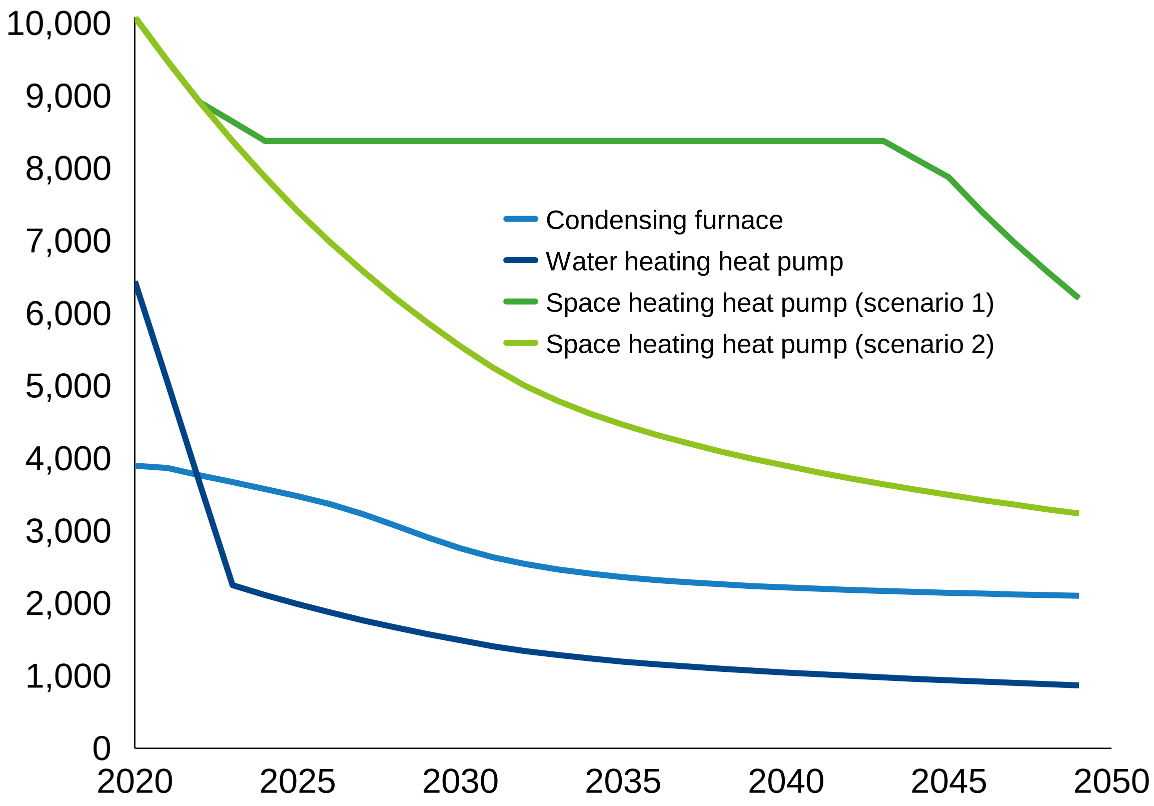
Note: Penetration module methodology derived from NREL

We modeled the size of temporary first cost subsidies that would be needed to achieve full benefits of increased scale and cumulative experience

Level of capital cost[1)] subsidy assumed (by use case and region)



Resulting decline curves for installed cost[2)] (2020 USD/unit)



1) The cost decline curve is composed of appliance cost which declines with experience and scale and installation cost which also declines with experience but at much lower rate;
2) The cost decline curves are adjusted to nominal values for the analysis

Source: Roland Berger analysis; Incorporating Experience Curves in Appliance Standards Analysis, LBNL; GTI

3. Gas End-Use Innovation Results

Smart, temporary subsidies[1)] for high efficiency technologies can drive substantial cost-effective reduction in GHG emissions

Regional emission reductions by 2050 and range of subsidies applied for *gas heat pumps for space heating*

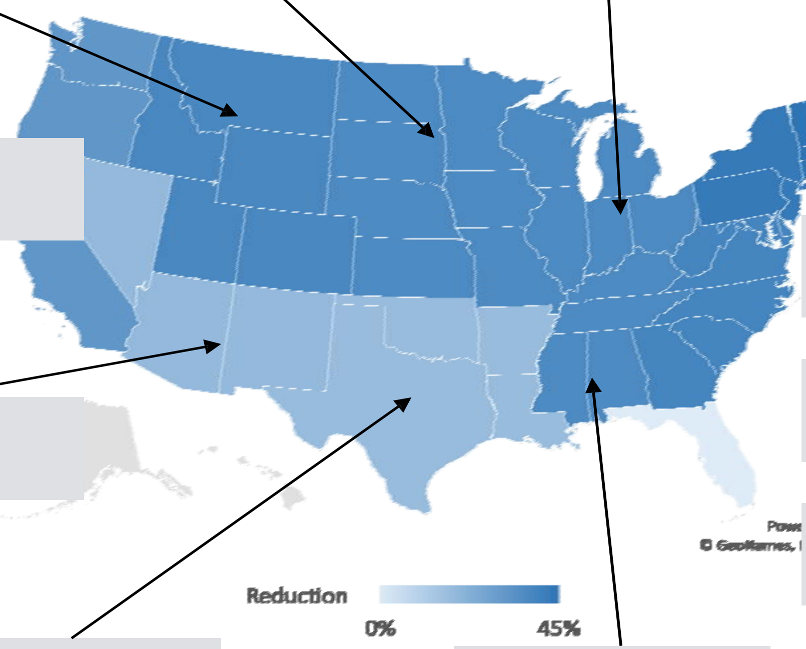
Mountain North
% reduced: 38%
Subsidy: $800-1,800

West North Central
% reduced: 37%
Subsidy: $1,080-2,500

East North Central
% reduced: 37%
Subsidy: $970-2,300

New England
% reduced: 45%
Subsidy: $1,400-3,200

Pacific
% reduced: 32%
Subsidy: $800-1,900



Middle Atlantic
% reduced: 43%
Subsidy: $1,090-2,500

South Atlantic
% reduced: 39%
Subsidy: $560-830

Florida
% reduced: -
Subsidy: none

Mountain South
% reduced: 19%
Subsidy: none

West South Central
% reduced: 18%
Subsidy: $440-1,020

East South Central
% reduced: 37%
Subsidy: $630-$1,440

National Level Results

Emission Reduction
46%

Abatement Cost
$90/ton

Consumer Impact
Savings of $220/year

Technology Penetration
85%

1) Subsidy levels were modeled as a percentage of commodity cost savings and removed after adequate scale is achieved (typically no later than 2035)

Source: Roland Berger analysis

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Smart, temporary subsidies[1)] for high efficiency technologies can drive substantial cost-effective reduction in GHG emissions

Regional emission reductions by 2050 and range of subsidies applied for *gas heat pump water heaters*

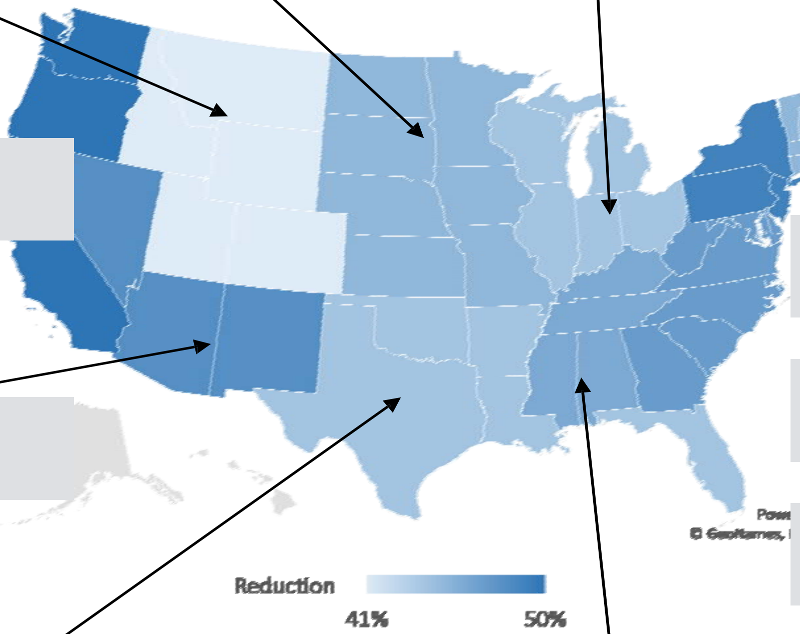
Mountain North
% reduced: 41%
Subsidy: $500-600

West North Central
% reduced: 45%
Subsidy: $600-700

East North Central
% reduced: 44%
Subsidy: $600-700

New England
% reduced: 45%
Subsidy: $800-1,000

Pacific
% reduced: 50%
Subsidy: $850-1,000



Middle Atlantic
% reduced: 49%
Subsidy: $800-900

South Atlantic
% reduced: 47%
Subsidy: $800-900

Mountain South
% reduced: 48%
Subsidy: 600-800

Florida
% reduced: 44%
Subsidy: 600-800

West South Central
% reduced: 44%
Subsidy: $600-800

East South Central
% reduced: 46%
Subsidy: $600-800

National Level Results

Emission Reduction
36%

Abatement Cost
$39/ton

Consumer Impact
Savings of $143/year

Technology Penetration
96%

1) Subsidy levels were modeled as a percentage of commodity cost savings and removed after adequate scale is achieved (typically no later than 2035)

Source: Roland Berger analysis

Overall CO_2 reductions are most sensitive to the amount of subsidies

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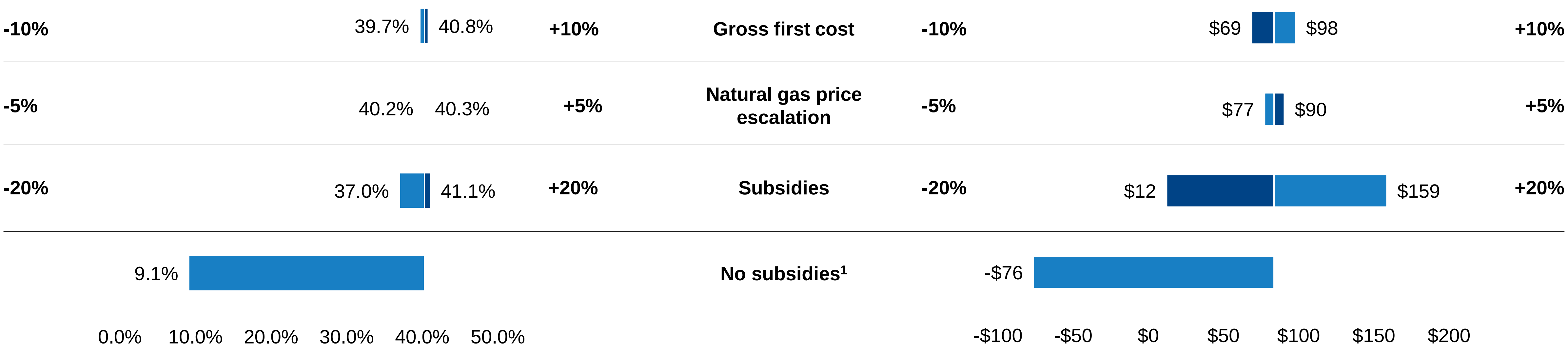
Sensitivity of CO_2 abatement volume and cost to major assumptions

Sensitivity analysis for emission reductions [%]

40% Scenario 2

Sensitivity analysis for cost per ton of emission reductions [$/ton]

$84/ton Scenario 2



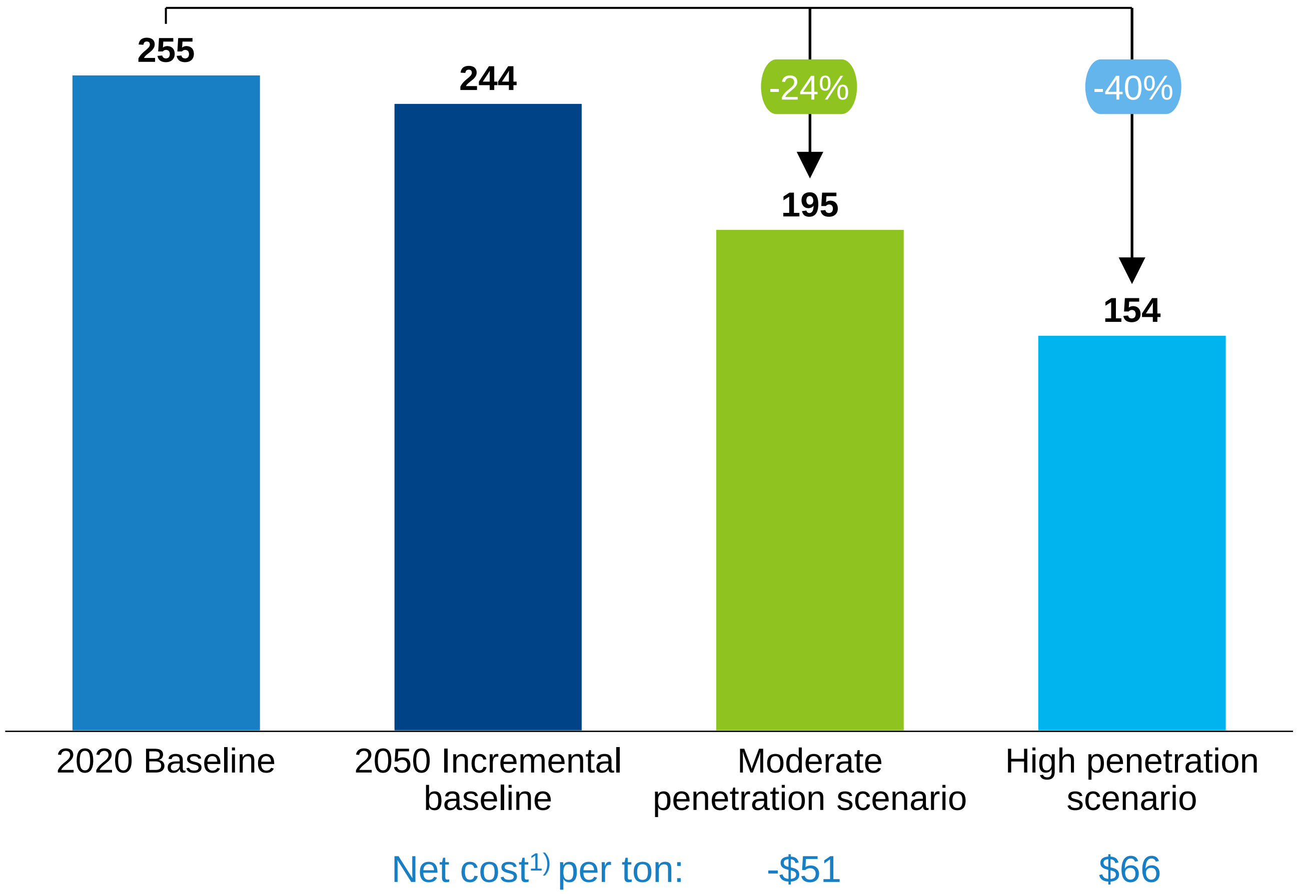
Minus sensitivities | Plus sensitivities

1) "No subsidies" sensitivity recalculated the cost decline curve to reflect lower penetration

Note: Only 3 major end-uses are included in the sensitivity analysis

High efficiency technologies could dramatically reduce CO_2 emissions by 2040 relative to the baseline (before considering green gas blending)

CO_2 emissions from residential direct use of natural gas (million tons of CO_2, per year by 2040)



1) Vs. baseline. Includes all relevant costs – equipment purchase, installation, fuel, O&M, and subsidy

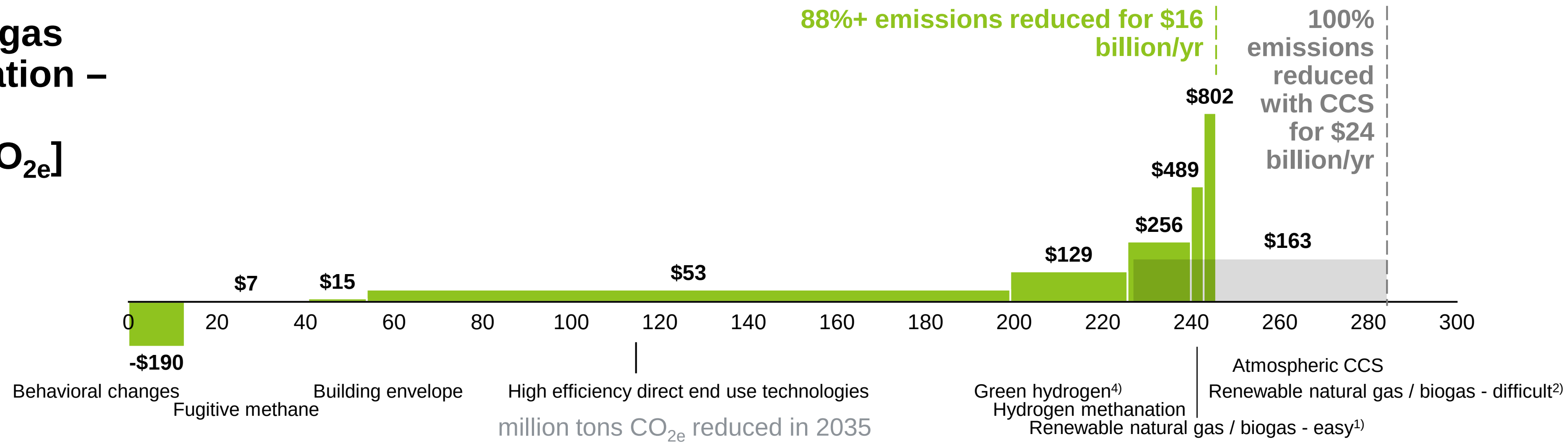
Source: Enovation Partners analysis, Roland Berger

1)

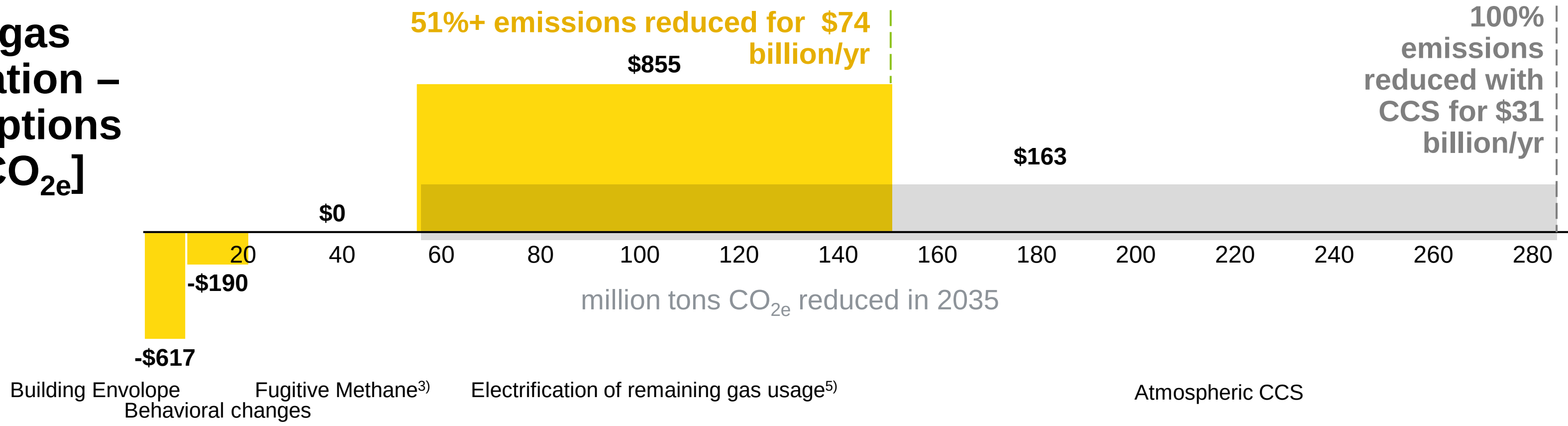
- Under either scenario, the CO_2 reductions are significant on a national scale, and costs per ton are low relative to other potential options for reducing emissions such as heating electrification at ~$300-600 per MT (full system costs) and direct capture and sequestration of CO_2 at ~$100-220 per MT
- These levels of CO_2 emission reductions are achieved despite the overall increase in number of equipment units in each end-use analyzed. For example, in space heating the total number of equipment units increases by 36 percent from 2020 to 2050, in water heating by 35 percent, and in clothes drying by 53 percent.

Abating GHG emissions from current gas end uses is much less costly for gas pathways than electrification, when full energy system costs are considered.

Residential gas decarbonization – gas options USD / ton CO_{2e}]



Residential gas decarbonization – electricity options [USD / ton CO_{2e}]



Insights

- Building & end-use efficiency and methane leak reduction are always the lowest hanging fruit – robust across other national energy markets
- Fully costed heating electrification in cold winter climates is quite expensive; may be higher than direct air capture

1) Relating to feedstock that is easily accessible for the generation of renewable natural gas / biogas; 2) Relating to feedstock that is not easily accessible for the generation of renewable natural gas / biogas; 3) Fugitive methane emissions under electrification pathway is zero cost because it is achieved by avoiding natural gas use; 4) Green hydrogen quantity is limited conservatively to 10% blending by volume to avoid infrastructure upgrades required for higher H2 blends; 5) Cost per ton for electrification of remaining gas usage sourced from ICF; includes costs of electric generation and T&D capacity; deflated by 2%/yr to consistently report all costs in 2019 $ terms

Source: EIA, ICF, AGF, NPGA, desktop research, Roland Berger

4. Updated Recent Results

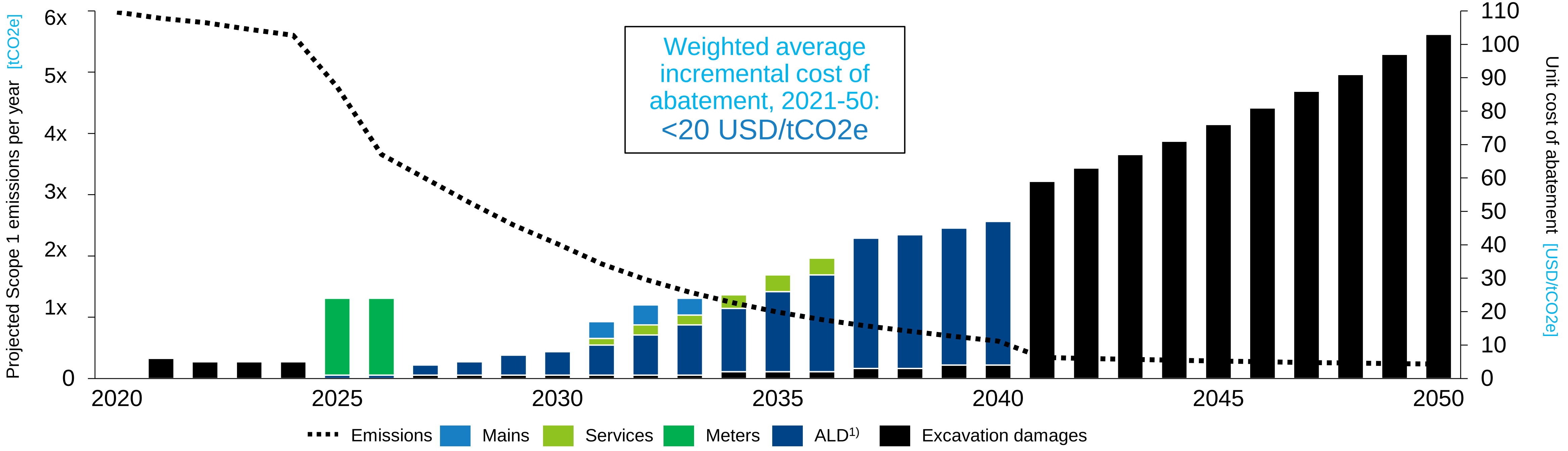
Illustrative Case Study

Gas LDCs have clear, affordable pathways to eliminate almost all scope 1 emissions (methane leakage), mostly by extending existing programs; offsets could cover small residual.

Projected emissions abated and incremental costs/ton.

Schedule and priority for specific measures will vary by utility.

Illustrative for large US gas utility



1) Advanced Leak Detection with mobile units; only includes above and below ground repair costs. Capital and O&M costs are included in existing corporate program budgets

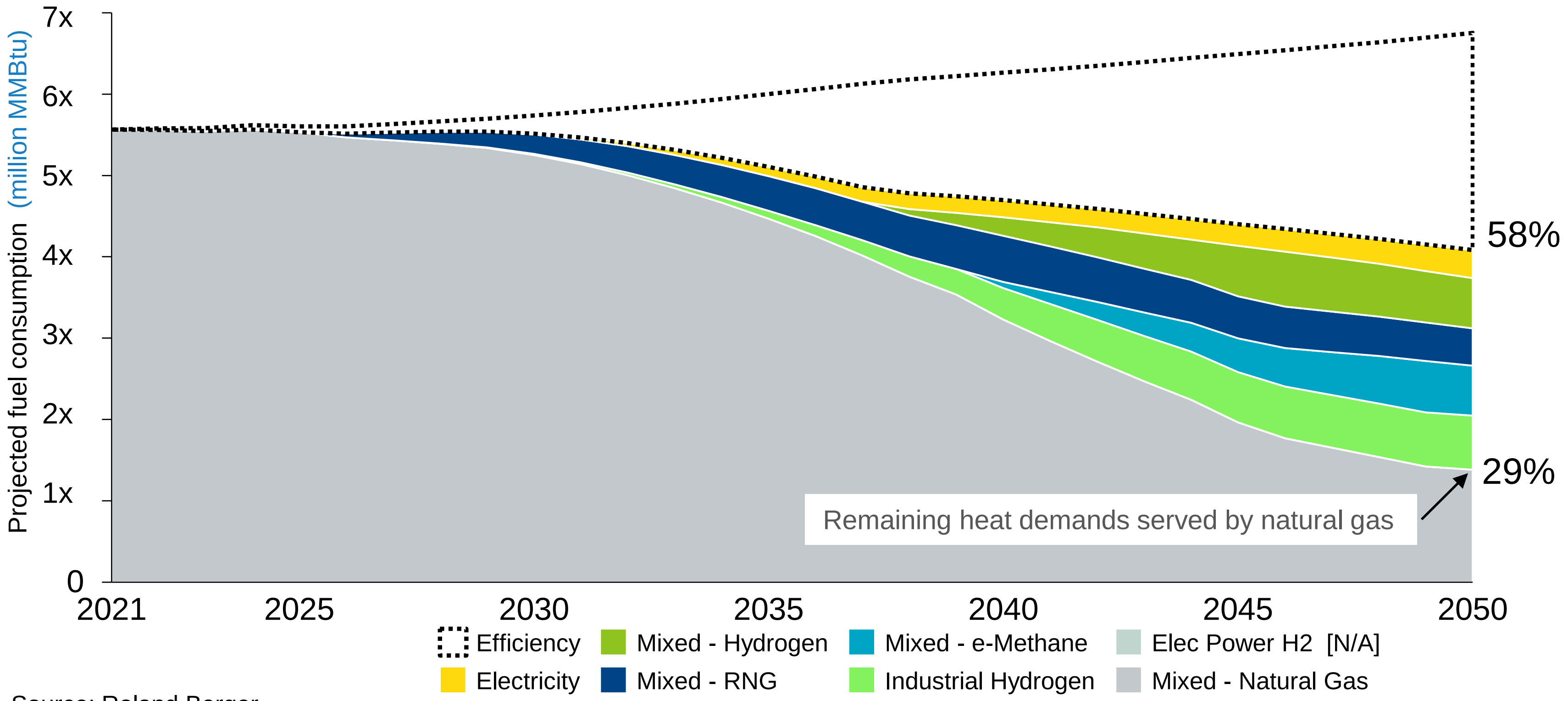
Source: Roland Berger

Gas grid gets much greener after 2040, as low carbon gas becomes cheaper than natural gas + carbon price

Scope 3 Fuel Consumption [million MMBtu] for Utility Service Territory

Illustrative for large US gas utility in cold winter zone

Aligned future state



Source: Roland Berger

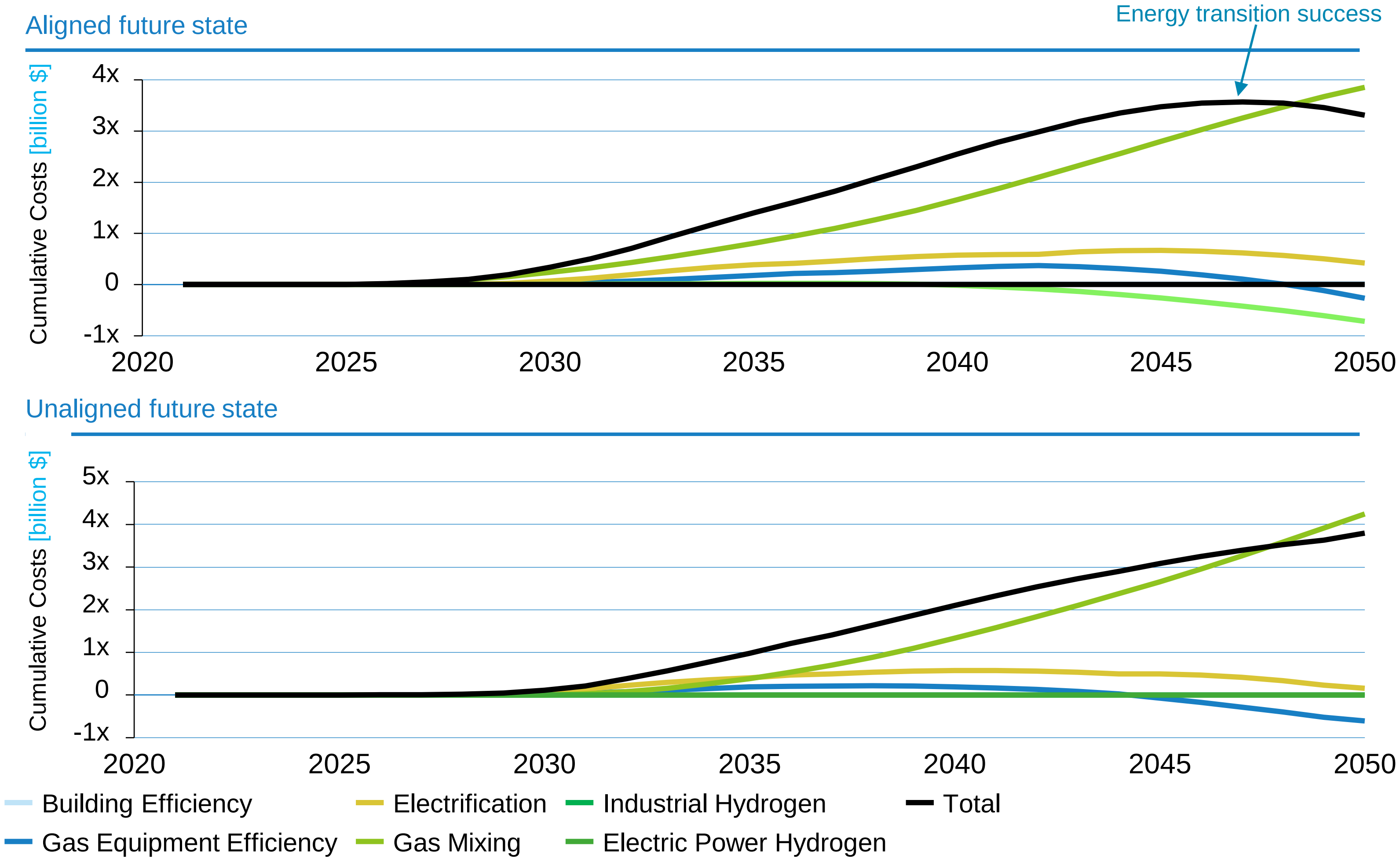
Key Points

- > Total energy efficiency (building, equipment) achieves ~40% reduction in fuel consumption by 2050 with significant impact across all future scenarios. Reflects long-term effects of technology innovation.
- > Mixing in of low-carbon gases for standard service and dedicated hydrogen service to industrials drive significant shifts in fuel consumption in base future state
- > E-methane and RNG could reduce emissions further

Decline in hydrogen price enables nearly double abatement at similar cumulative costs for customers in aligned future state

Cumulative total abatement cost to customers, million $[1)]

Illustrative for large US gas utility in cold winter zone



Key Points

- Cumulative abatement costs notably higher(>15%) and achieved abatement lower in future state without public/private sector alignment and coordination. Lower costs of RNG and hydrogen in aligned future state enable greater levels of low carbon gas mixing and emissions abatement.
- RNG/e-methane blending is more expensive than other gas abatement measures; serves as marginal abatement resource
- Decline in hydrogen prices results in negative incremental abatement costs (vs. baseline) by mid-2040s, bending cumulative curve down in aligned future state

	Base State	Unaligned State
Total abatement [MM tCO2e]	13.3	7.0
Cumulative average abatement cost [$ / tCO2e]	$50	$118

1) Incremental cost vs. EIA base case natural gas price plus moderate carbon price

Source: Roland Berger

5. Strategic Directions for Gas Utilities in the Energy Transition

GHG abatement by a gas utility should start with end-use efficiency, continue with methane leakage reduction, and address remaining gaseous fuel demands by migrating toward a greener gas mix as costs come down.

Residential natural gas innovations pathways. Staged approach to demonstrate commitment and optimize affordability.

1 Demand & natural gas technology innovation (efficient use)

- Improvement and adoption of high efficiency residential technologies, specifically in:
  - Space heating
  - Water heating
  - Drying
- Implementing behavioral changes towards energy efficiency
- Updating the residential building envelope with energy efficient materials & technology

35-45% reduction in CO_{2e} emissions

2 Delivery enhancement

- Reducing fugitive methane leaks during the following steps of the value chain:
  - Transportation/ distribution
  - Meters
  - Behind the meter at homes
- Implementing hydrogen ready infrastructure

5-10% reduction in CO_{2e} emissions

3 Supply innovation

- Maximizing cost-effective production of renewable natural gas (RNG or biogas)
- Scale adoption of power to gas, including:
  - Hydrogen displacement of natural gas
  - Hydrogen methanation
- Switching from carbon-intensive fuels (e.g., propane, heating oil, kerosene) to natural gas

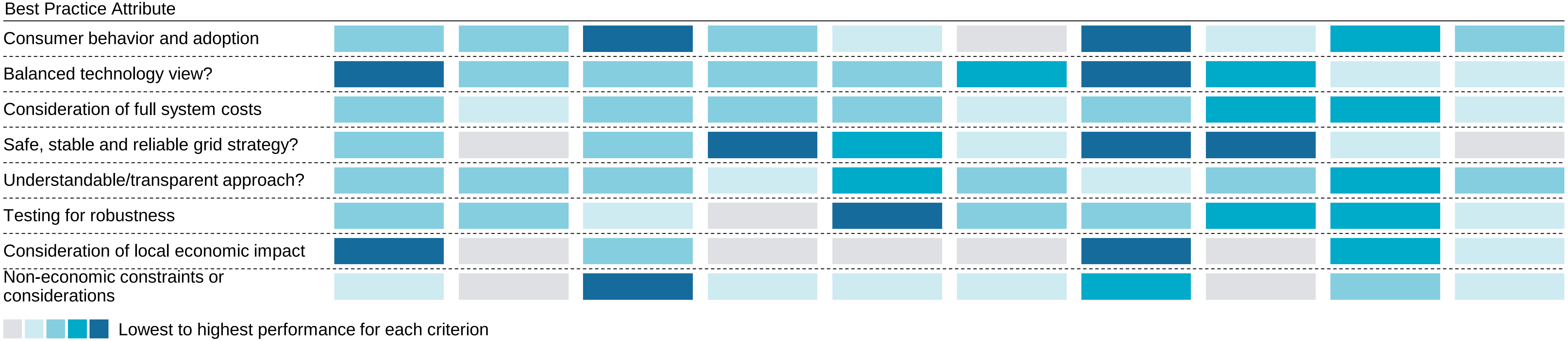
40-50% reduction in CO_{2e} emissions

Source: Enovation Partners analysis, Roland Berger

Gas LDCs are charting a myriad of different paths to decarbonization, but commonly emphasize affordability and practical limits to the pace of building new energy infrastructure

Comparison of decarbonization pathways studies; ten most relevant studies out of over 50 reviewed.

	Princeton	NREL	NYC; ConEd; National Grid	SCE	NW Natural	AltaGas	LADWP	PNM	Ameren	AEP
Target	Net Zero 2050	83% 2050 from 2005	Emissions-free 2050	Carbon neutral 2045	80% 2050 scopes 1-3	Carbon neutral 2050	100% renew-ables 2045	Emissions-free 2040	80% 2050 from 1990	Net Zero 2050
Scopes	U.S.	U.S.	NY state	California	OR-WA utility territory	D.C. utility territory	Utility territory	NM utility territory	MO utility territory	Utility territory
Sector	Economy-wide (incl. electric + gas)	Energy (incl. electric + gas)	Energy (incl. electric + gas)	Energy (electric focus)	Gas	Gas	Electric	Electric	Electric	Electric



Source: Desktop research, SME interviews

Achieving net neutral GHG emissions by 2050 is feasible at a reasonable total cost of abatement for most gas utilities

Key messages for stakeholders from Roland Berger GHG emissions abatement analysis

- Scope 1 emissions (primarily methane leakage) can be reduced to almost zero through existing programs and technologies, at a relatively low cost.
- Scope 3 abatement is the biggest challenge, but technically feasible and cost-effective pathways for meeting net neutral goals by 2050 have been defined and are broadly consistent across countries.
- The utility industry can reach common decarbonization goals much more effectively and at lower cost if the utilities and their stakeholders (customers, policy makers) work together in a coordinated fashion. Technology and market development need strong, consistent support.
- The gas-focused decarbonization pathway for the biggest current residential/commercial gas end uses (space and water heating) is cheaper, faster, and better for customers. It is generally lower cost compared to electrification alternatives, achieves quicker GHG emissions reductions, and delivers better comfort and resilience.

Source: Roland Berger

What strategic lessons are emerging as natural gas utilities navigate the energy transition?

Lessons from US experience – and elsewhere?

1 **Speed matters** – Certain activities benefit first movers (creating hydrogen hubs) and subsidy programs can change or be phased out with new political administrations.

2 **Pursue cluster-level change** – Developing regional ("hub") plans enables capture of economies of scope & scale in infrastructure, establishing long-term relationships with "baseload" customers, and solving coordination ("chicken & egg") challenges

3 **Capture perishable arbitrage opportunities** – Existing and new subsidies may create clear opportunities for arbitrage of different forms of methane that can be captured if executed before 2030 (e.g., RNG in North America)

4 **Offense is the best defense** – Opportunities are finite and fleeting - companies that expand into new geographies, grow across the value chain, and diversify into new asset classes most decisively will succeed.

Source: Roland Berger

Thank you

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