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GEOTHERMAL NETWORK ECONOMICS

Frameworks, Pilot Learnings, and the Path Forward

Eric Juma, Mark Kleinginna, Don Lessard

LeGUp Annual Meeting, November 5, 2026

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Today's topics

1. Framework & pilot costs

External benefits

Framework fundamentals

Framingham costs and bills

2. The road to thermal parity

The parity gap today

Scaling, capacity and learning

Value streams

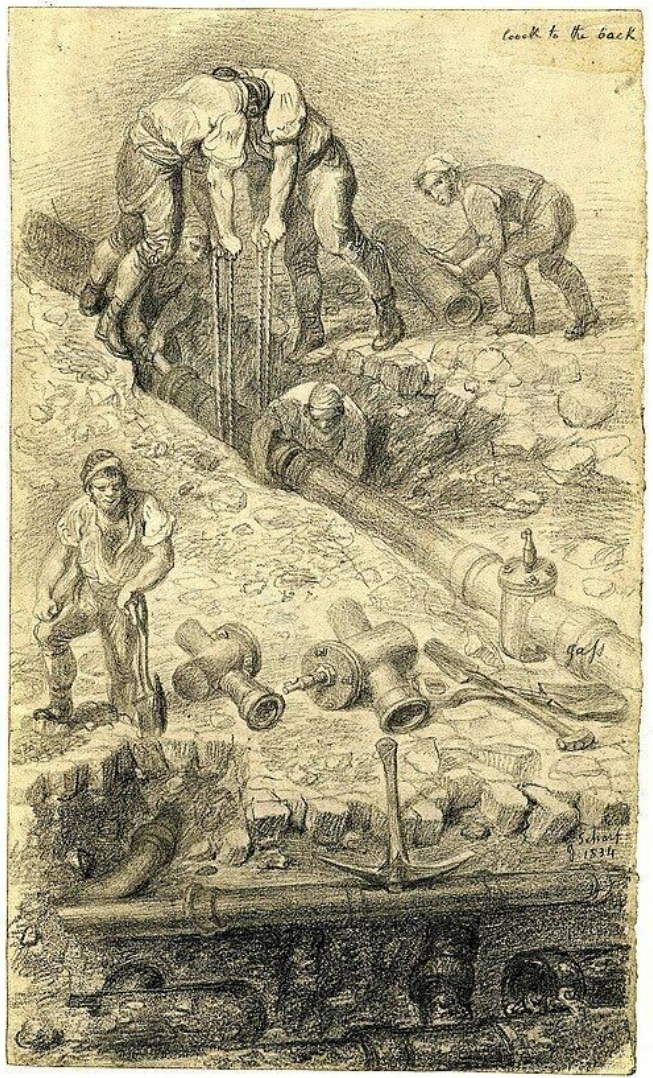
3. Capital recovery

Functionalizing financing

Time pattern of recovery

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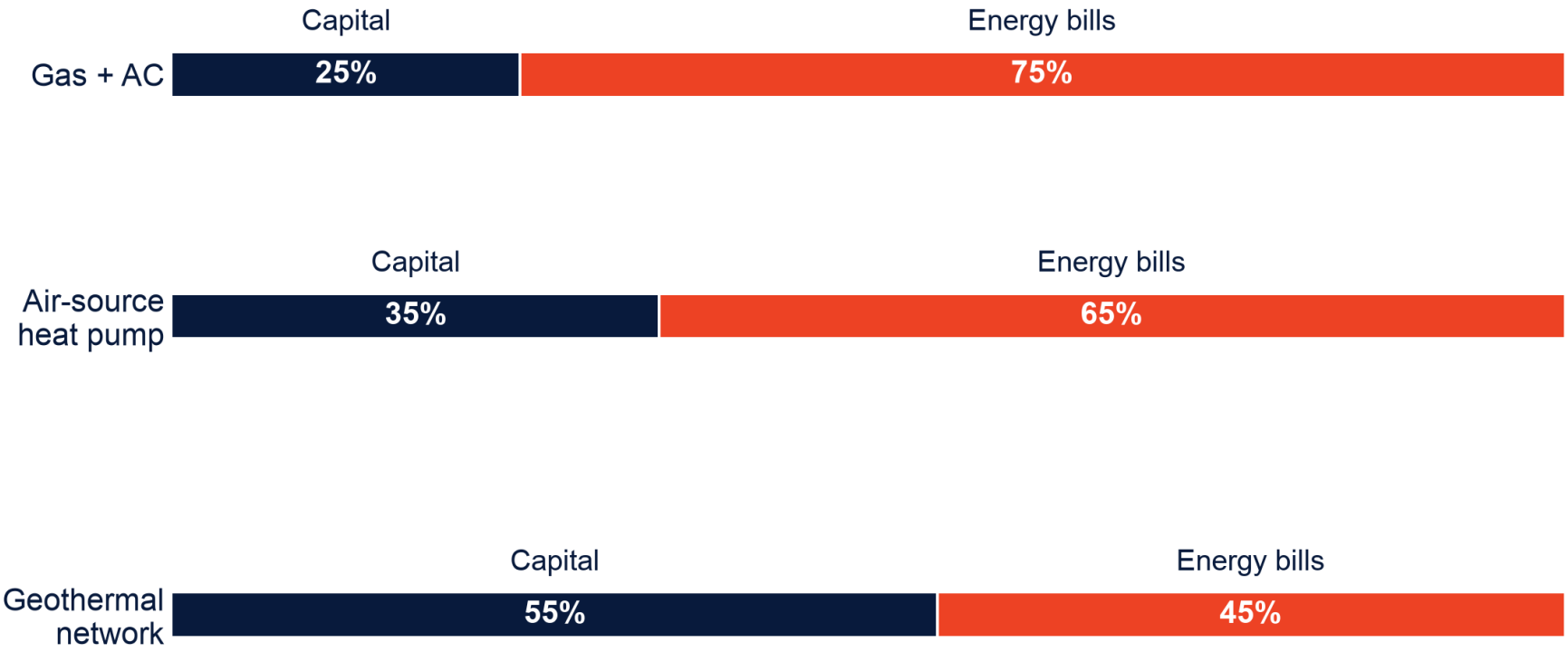
Historical context of delivered energy



Laying a gas main: drawing by George Scharf, 1834 (British Museum)

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Exposure to variable and future costs



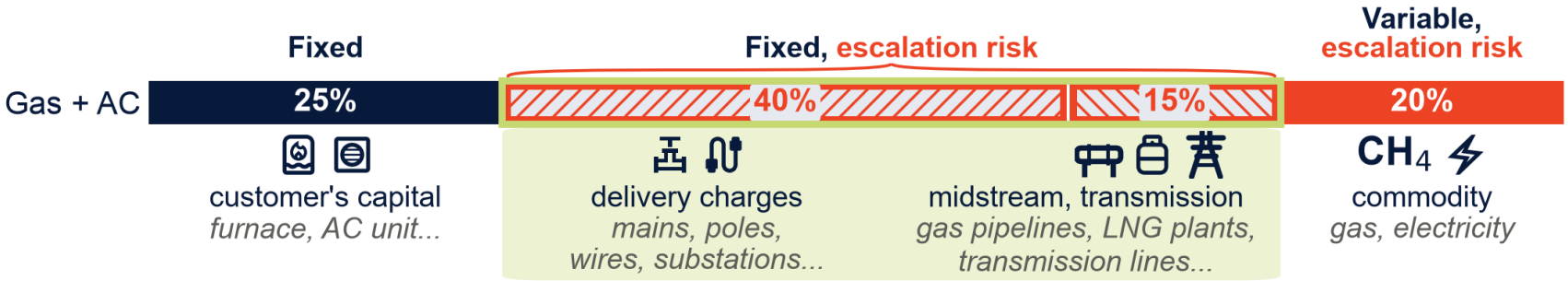
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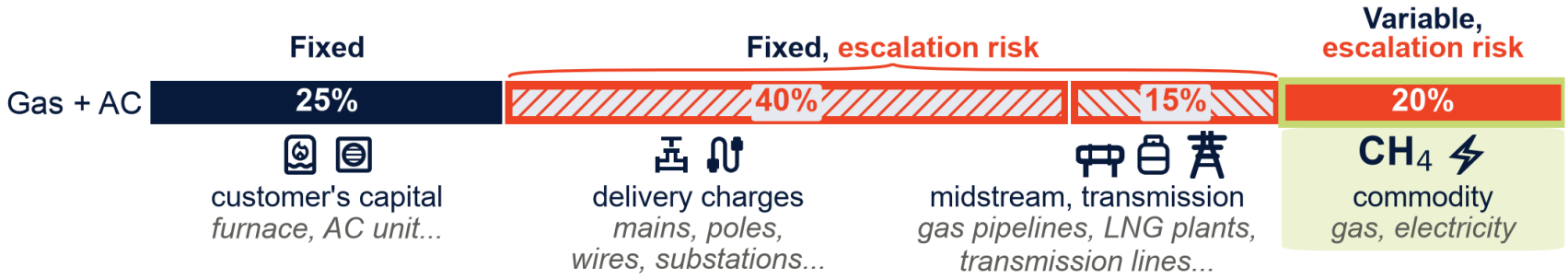
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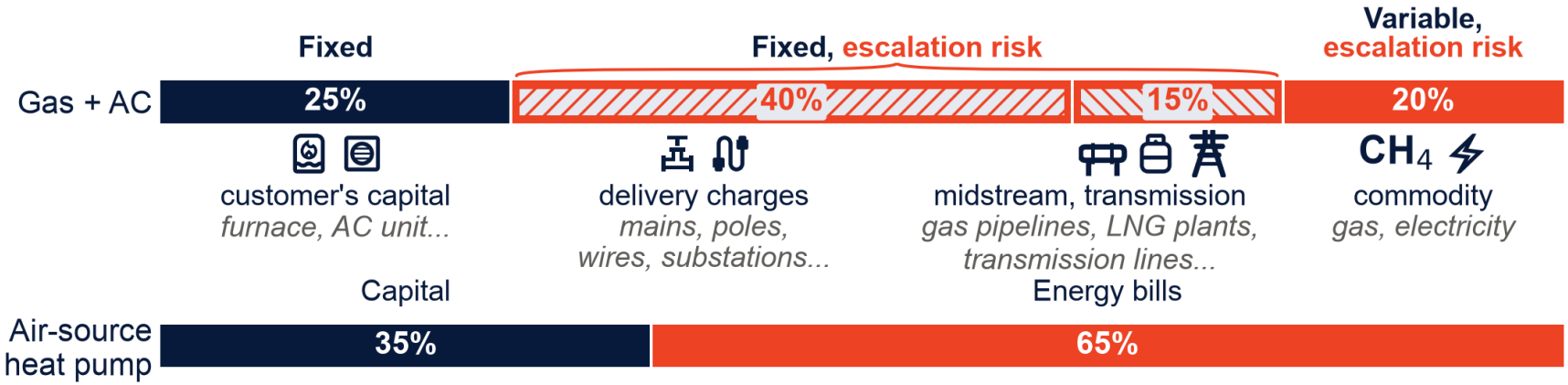
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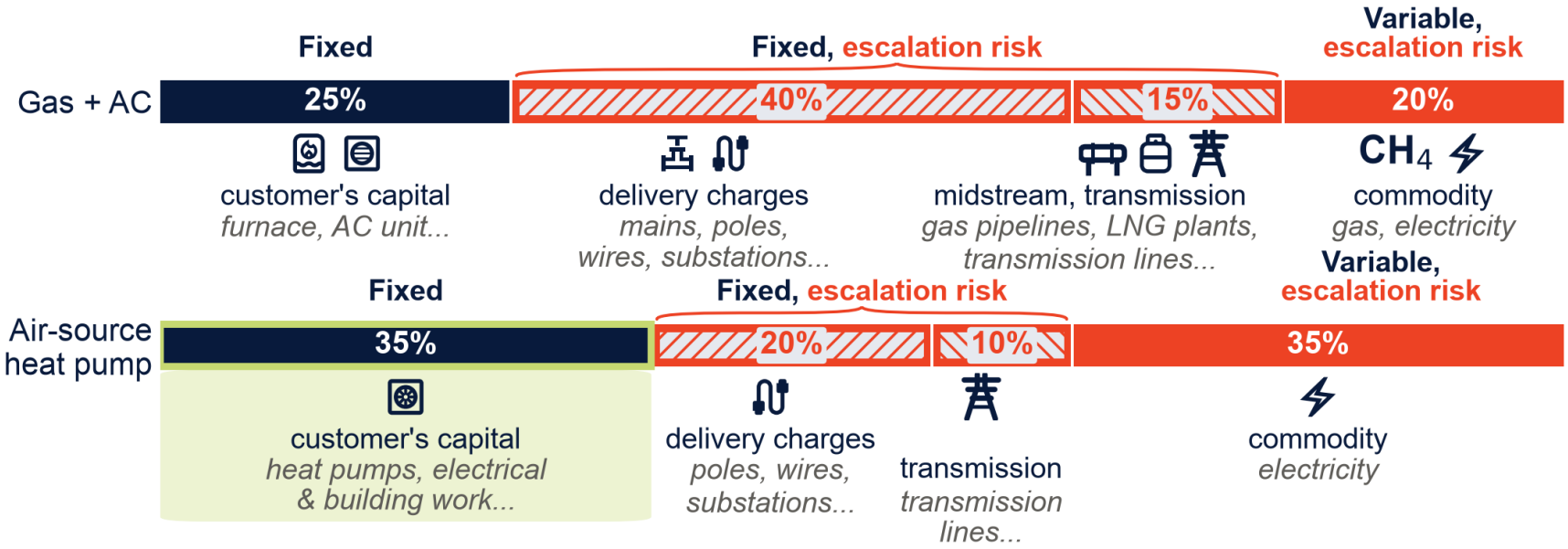
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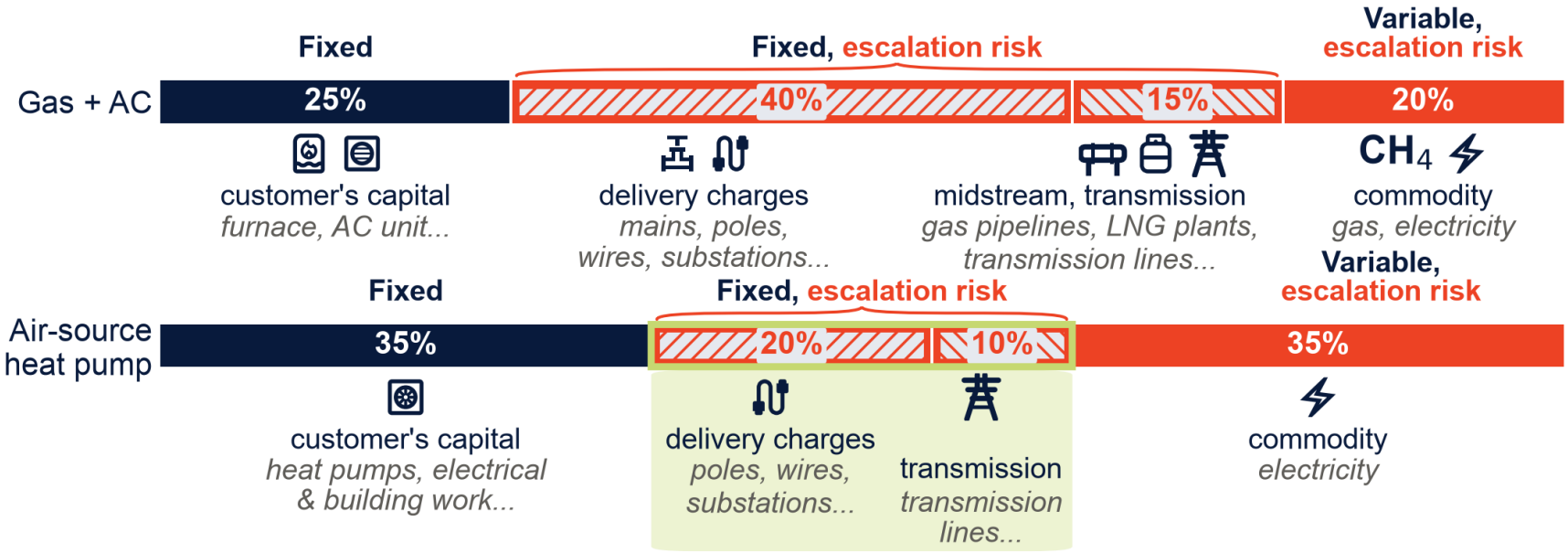
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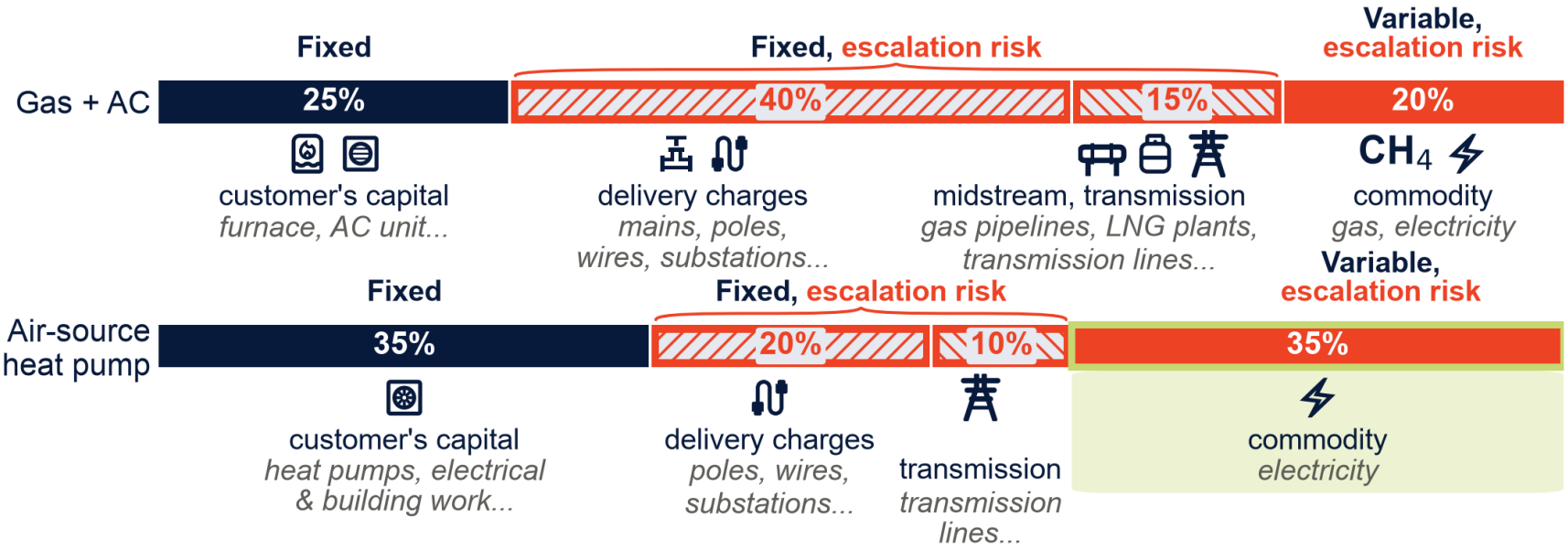
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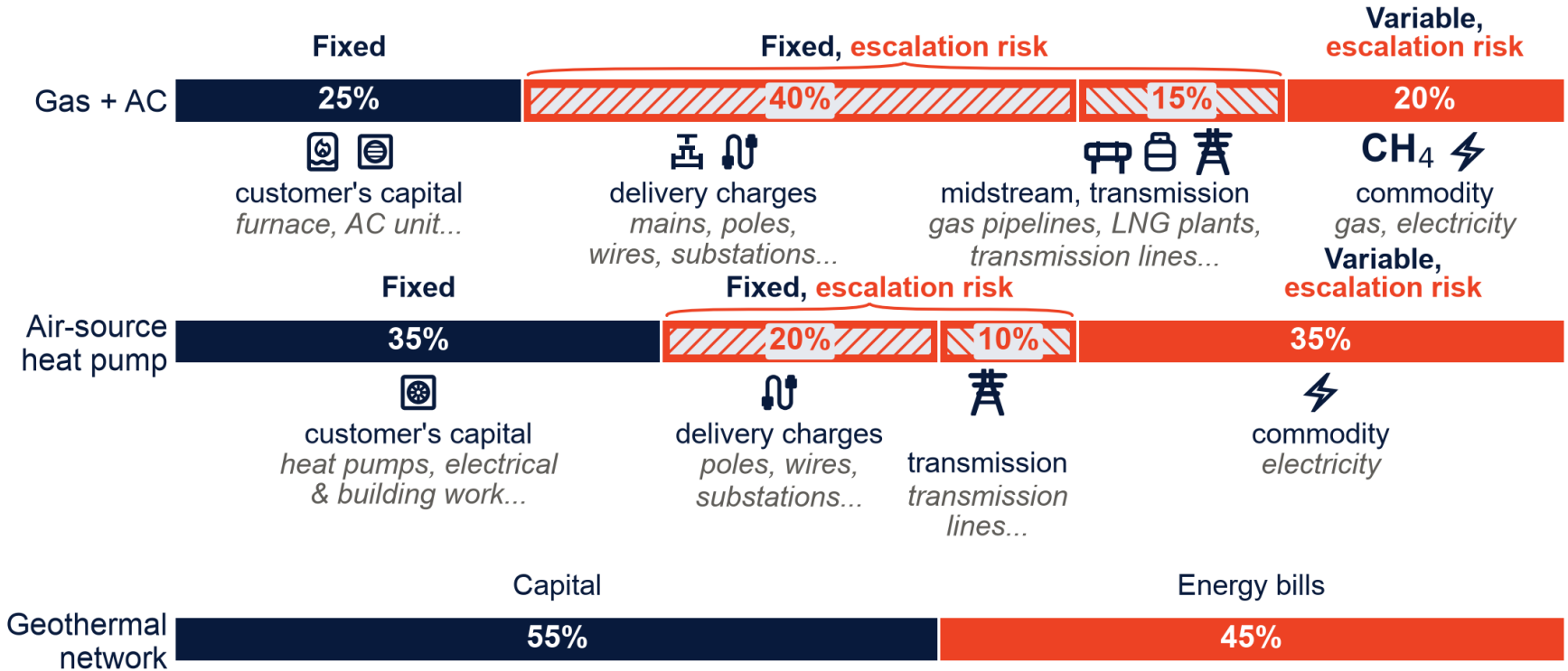
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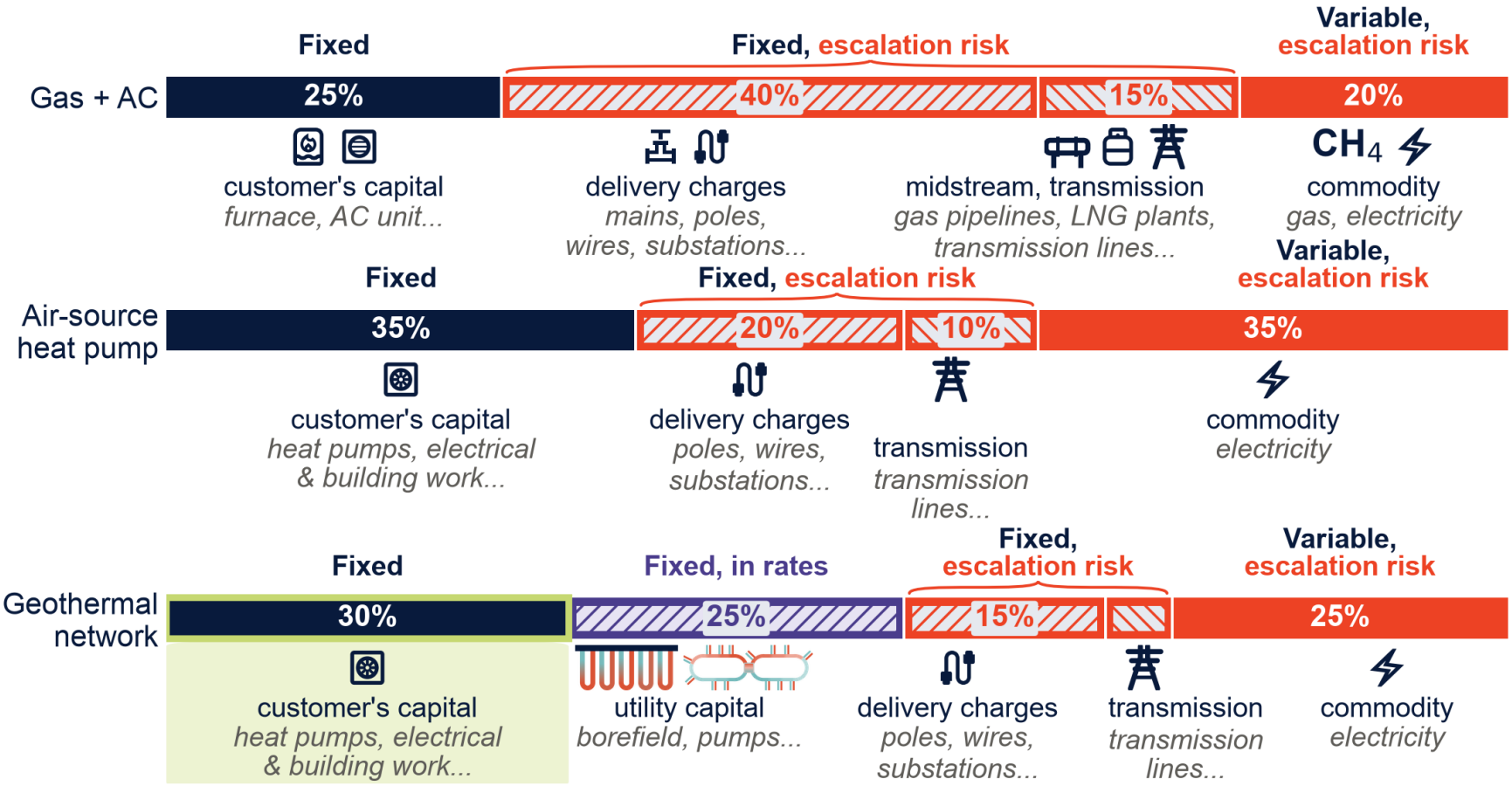
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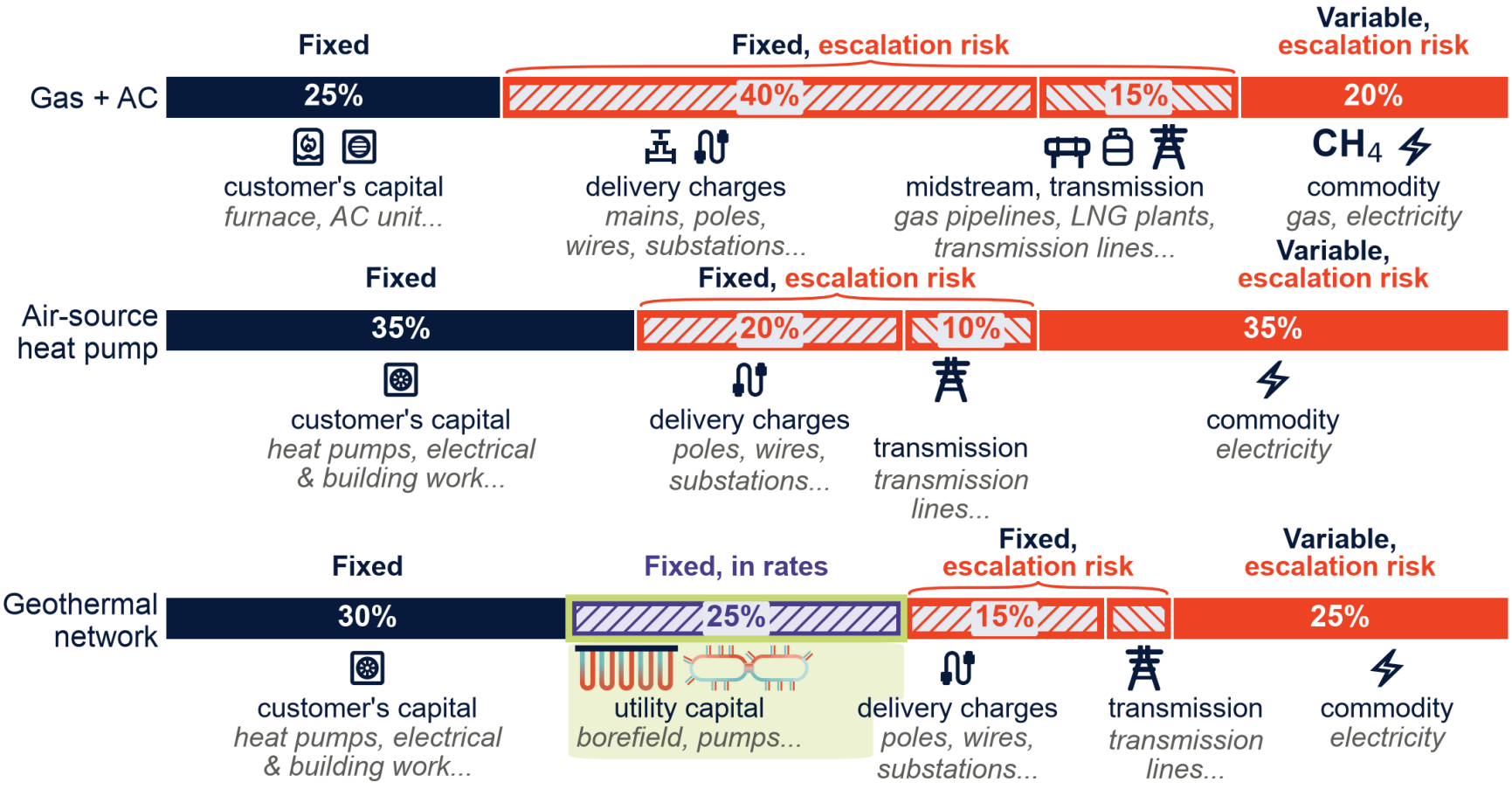
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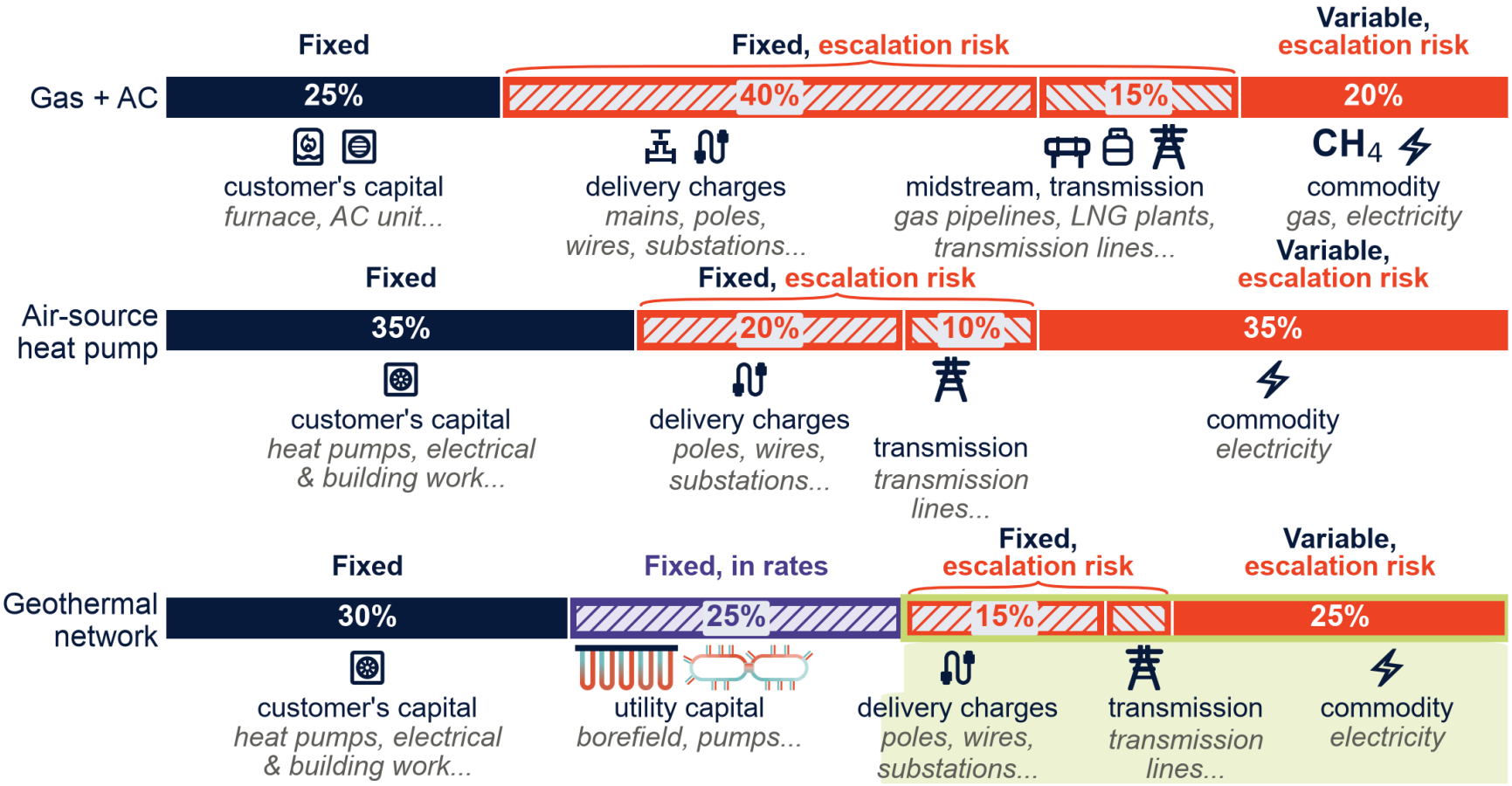
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Exposure to variable and future costs



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Exposure to variable and future costs



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Examples of Broader Benefits for MA

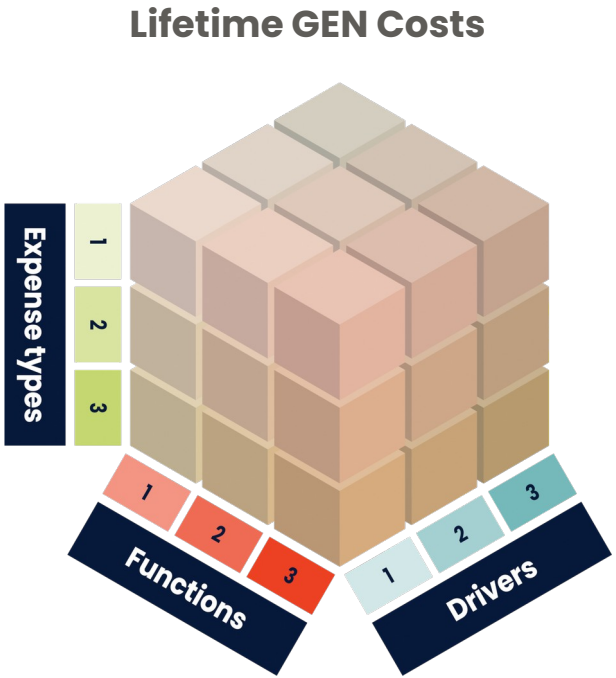
Safety	$1.9B	Merrimack Valley, 2018, one event
Public health	749	early deaths a year, building fuels
Avoided gas infrastructure & stranded assets	~$17B	3,000+ miles of replacements planned
Grid impacts	50-70%	winter peak 50-70% below ASHPs
Workforce	14,850	direct jobs, statewide buildout
Climate	~19 million metric tons	CO_2e a year from MA building fuel

Sources: Safety, NTSB PAR-19/02 (2019), PHMSA incident data (2026). Public health, RMI (2021), 2017 data, after Buonocore et al. (2021). Grid impacts, Jouler for LeGUp (2026). Avoided gas infrastructure, Attorney General's Office witnesses, Exh. AG-DL-DM-1 in D.P.U. 25-GSEP-01 to -06 (2026). Workforce, Cornell ILR Climate Jobs Institute, A Climate Jobs Roadmap for Massachusetts (2024), as quoted by the MA Commission on the Fossil Fuel Workforce (2025). Climate, MassDEP greenhouse gas inventory, 2023, residential and commercial fuel combustion (EEA Clean Energy and Climate Metrics).

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Breaking down GEN costs



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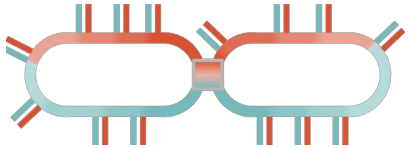
Breaking down GEN costs

Functions

1 Thermal resources
Boreholes and other heat sources/sinks



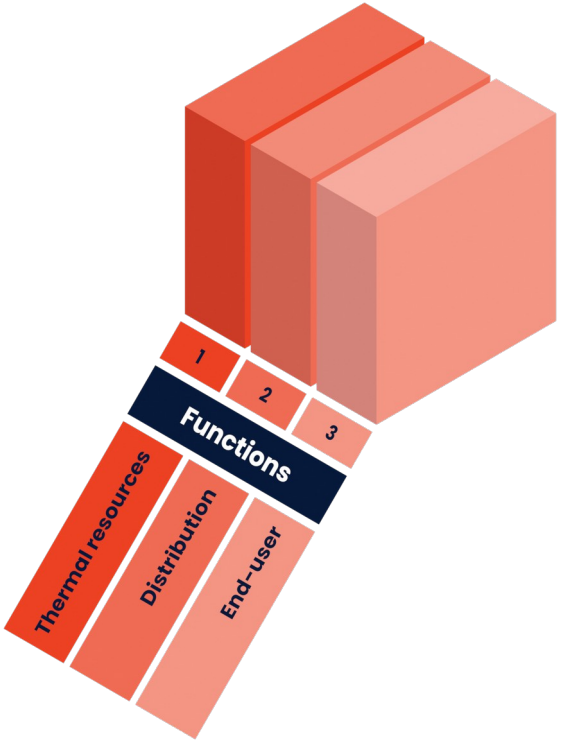
2 Distribution
The loop, pumps, vaults and controls



3 End-user
Heat pumps and building upgrades



Lifetime GEN costs



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Breaking down GEN costs

Drivers

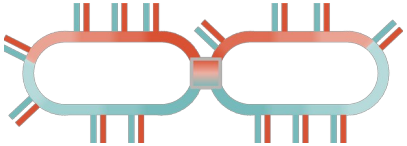
1 Demand
Costs that scale with peak load



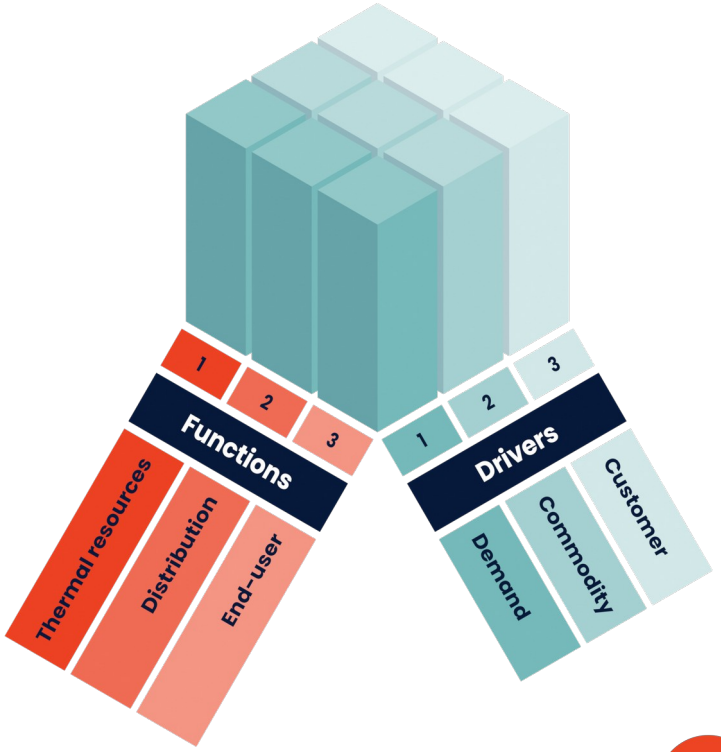
2 Commodity
Costs that scale with cumulative load



3 Customer
Costs that scale with buildings & density^{-1}



Lifetime GEN costs



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Breaking down GEN costs

Drivers

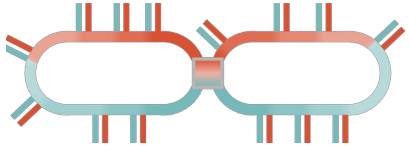
1 Demand
Costs that scale with peak load

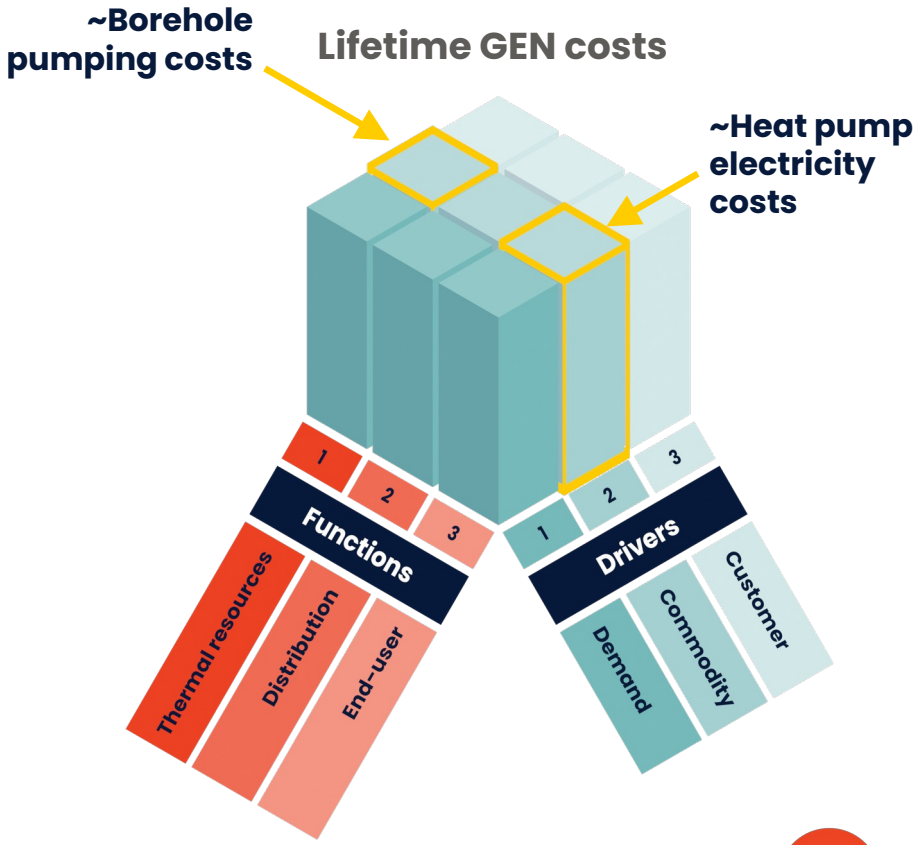


2 Commodity
Costs that scale with cumulative load



3 Customer
Costs that scale with buildings & density^{-1}





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Breaking down GEN costs

Expense types

1 Capital
Infrastructure and major replacements



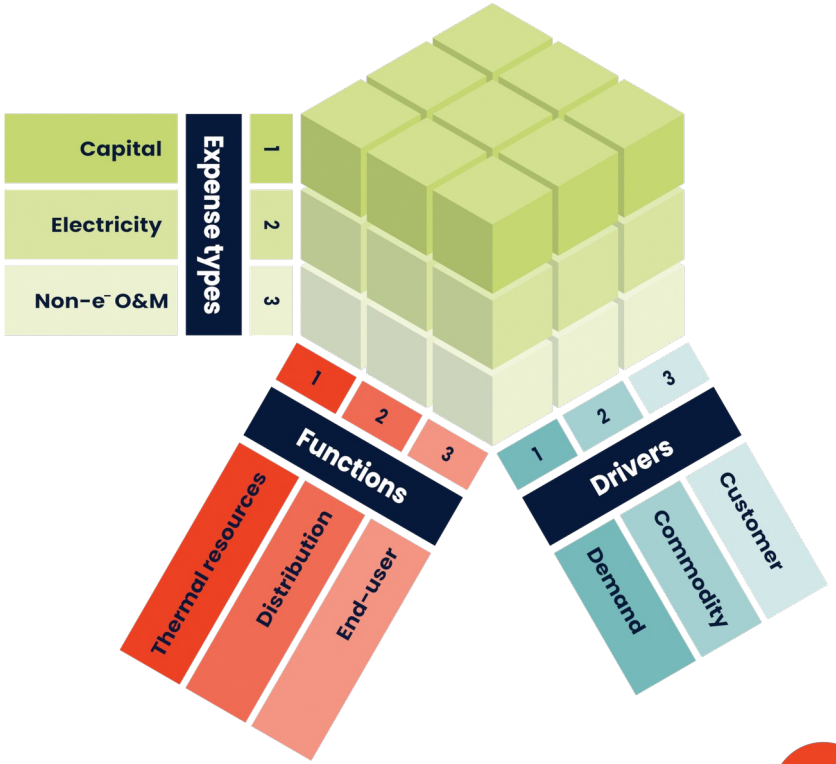
2 Electricity
Power for pumps, heat pumps, etc.



3 Non-electric O&M
Operating labor, parts and repairs



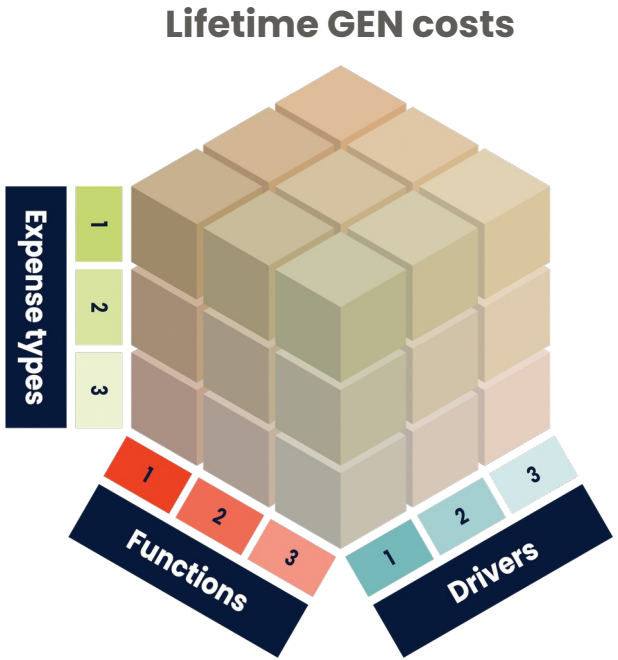
Lifetime GEN costs



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Breaking down GEN costs

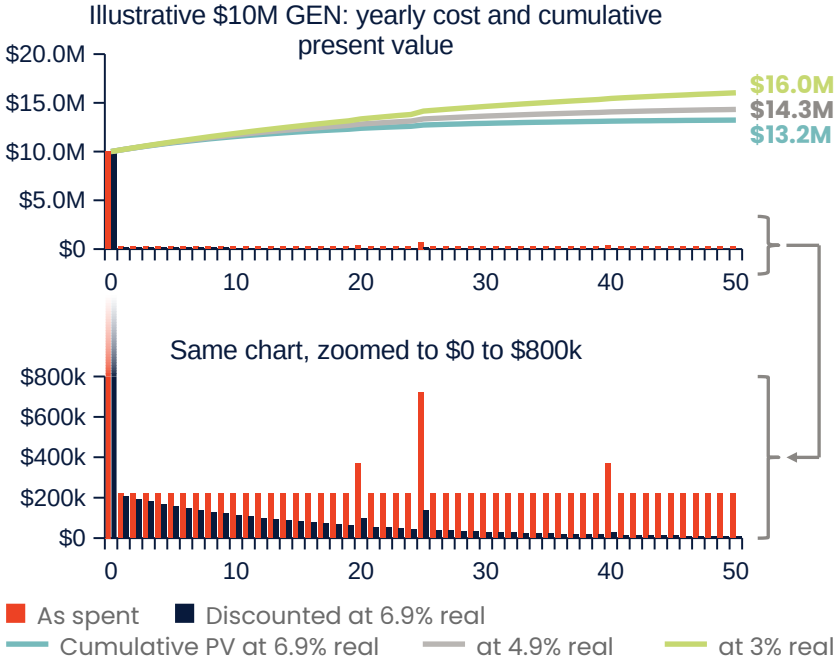
Functions	Drivers	Expense types
1 **Thermal resources** Boreholes and other heat sources/sinks	1 **Demand** Costs that scale with peak load	1 **Capital** Infrastructure and major replacements
2 **Distribution** The loop, pumps, vaults and controls	2 **Commodity** Costs that scale with cumulative load	2 **Electricity** Power for pumps, heat pumps, etc.
3 **End-user** Heat pumps and building upgrades	3 **Customer** Costs that scale with buildings & density^{-1}	3 **Non-electric O&M** Operating labor, parts and repairs



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Enabling GEN lifetime cost comparisons

Present value of lifetime costs



$$\frac{\$}{kW_{thermal}}$$

present value of lifetime costs

peak load served (Building Peak Loads H+C)

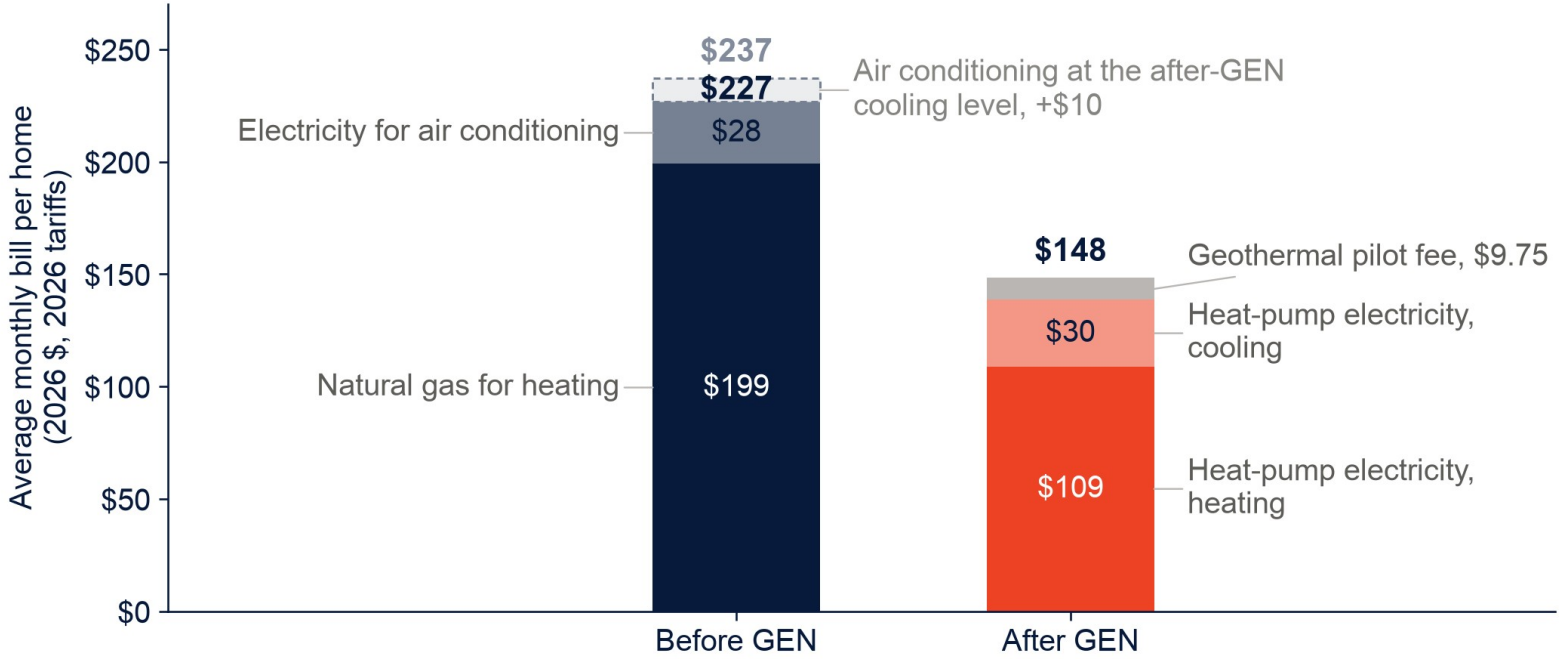
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$ per $kW_{thermal}$

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Energy Use Based Estimates for Customer Bills

Framingham Loop 1 Residential



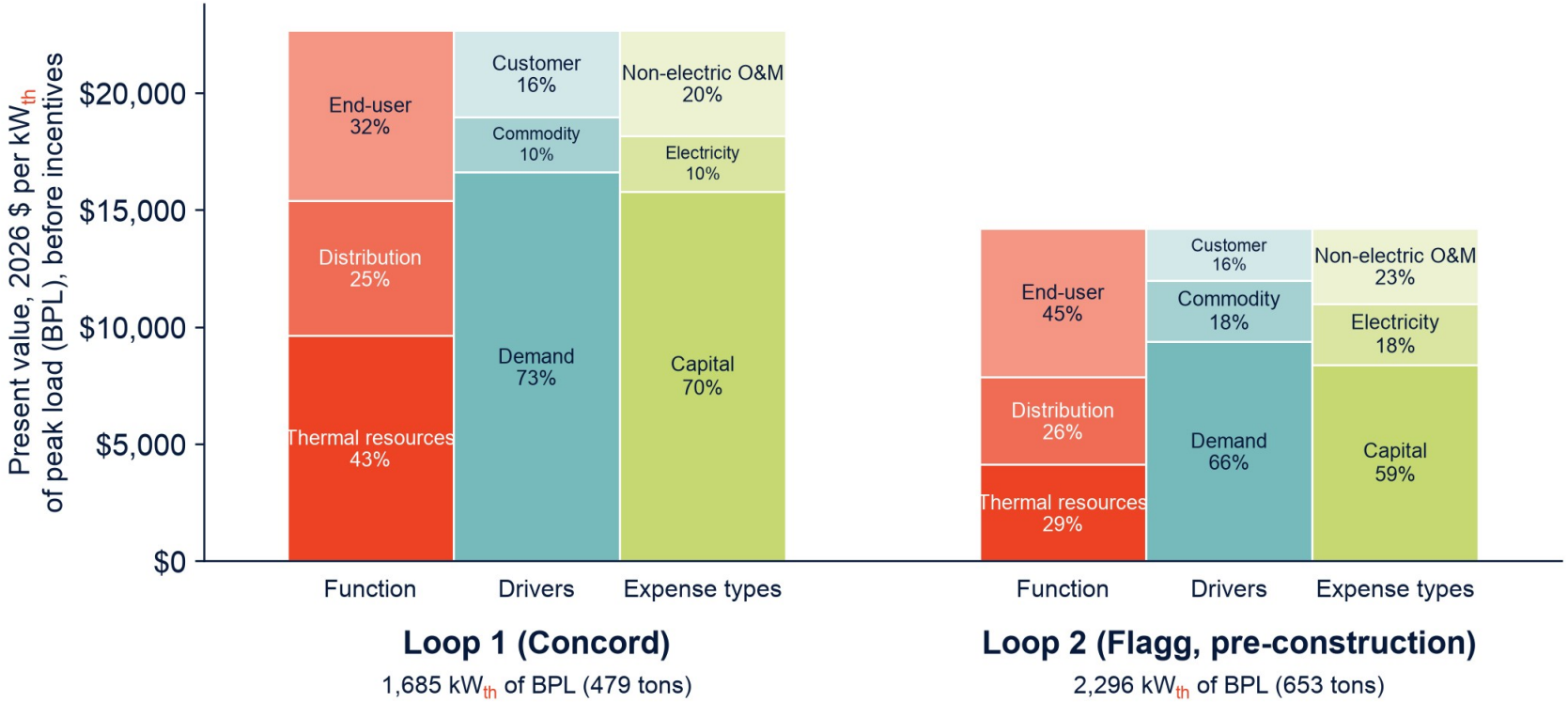
Estimated monthly heating and cooling energy costs, 18 Loop 1 homes, at 2026 tariffs.

Source: Anonymized Eversource LeGUp Research Data

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Framingham Loops 1 and 2 budgets

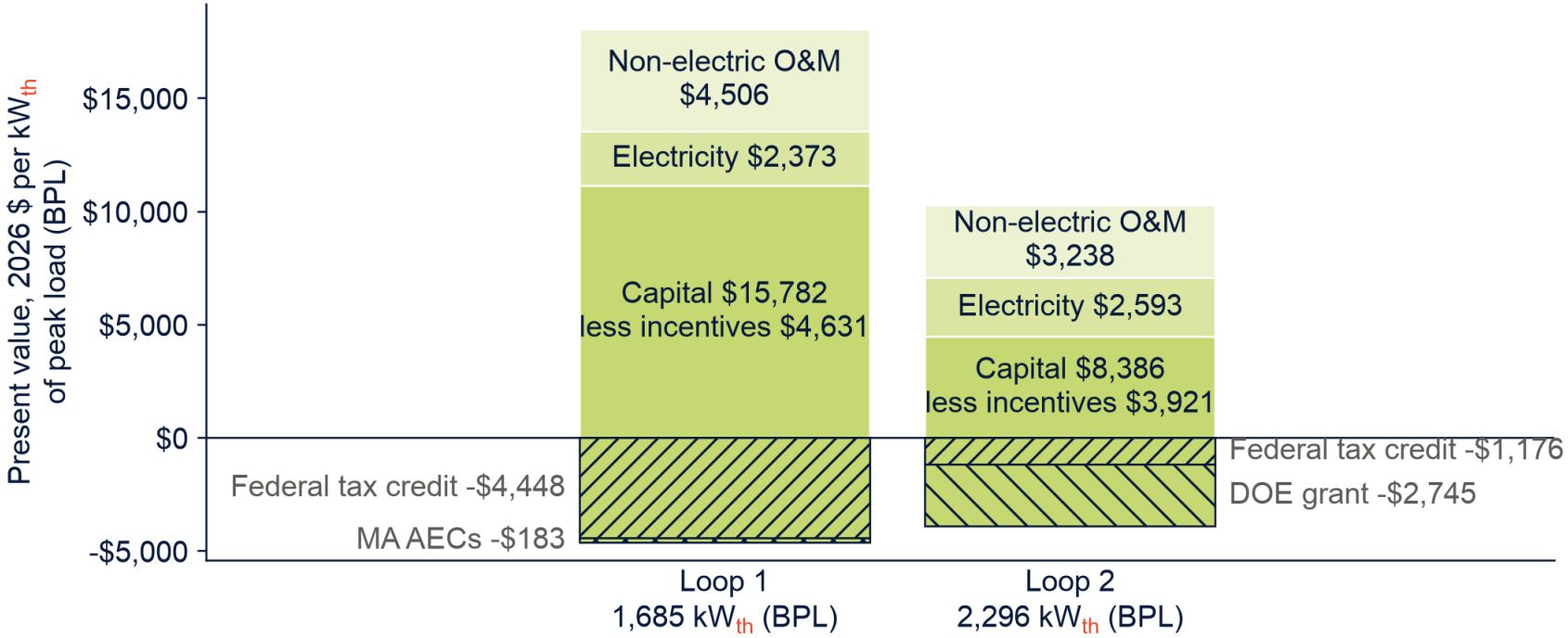
by function, classification and cost type



Lifetime cost per kW_{th} of buildings peak load (BPL), present value, 50 years at 3% real, 2026 dollars, before incentives.

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Loop 1 to Loop 2



Lifetime cost per kW_{th} of buildings peak load (BPL), present value, 50 years at 3% real, 2026 dollars.

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How costs fall as loops are built

Lower cost per unit of plant

Learning
From continuous building

Scale
Economies of scale

Less plant per unit of load

Shared assets
Plant, design and controls serve more loops

Scaling and interconnection benefits
Connected loops stabilize and share energy

Reuse of spare thermal resource capacity
Through adding buildings and connected loops

Right-sizing
Thermal resources sized closer to demand

Funding beyond thermal prices

Used on the pilots

Federal tax credit

Alternative energy certificates

Available, not yet used

Building incentives

Summer grid value

Avoided pipe replacement

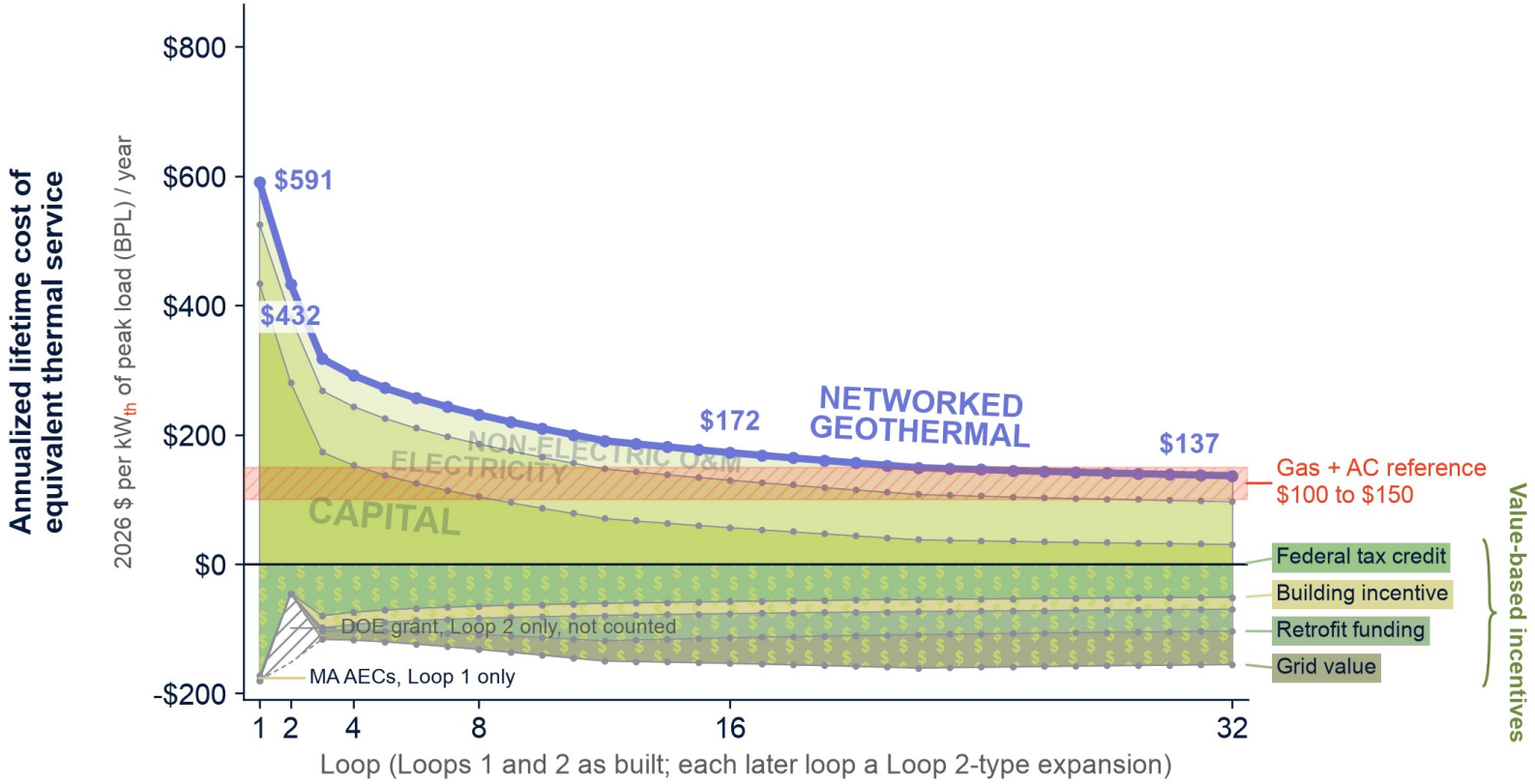
Unavailable today

Winter grid value

Climate impact funding/offsets

Estimated cost changes if expansions continue

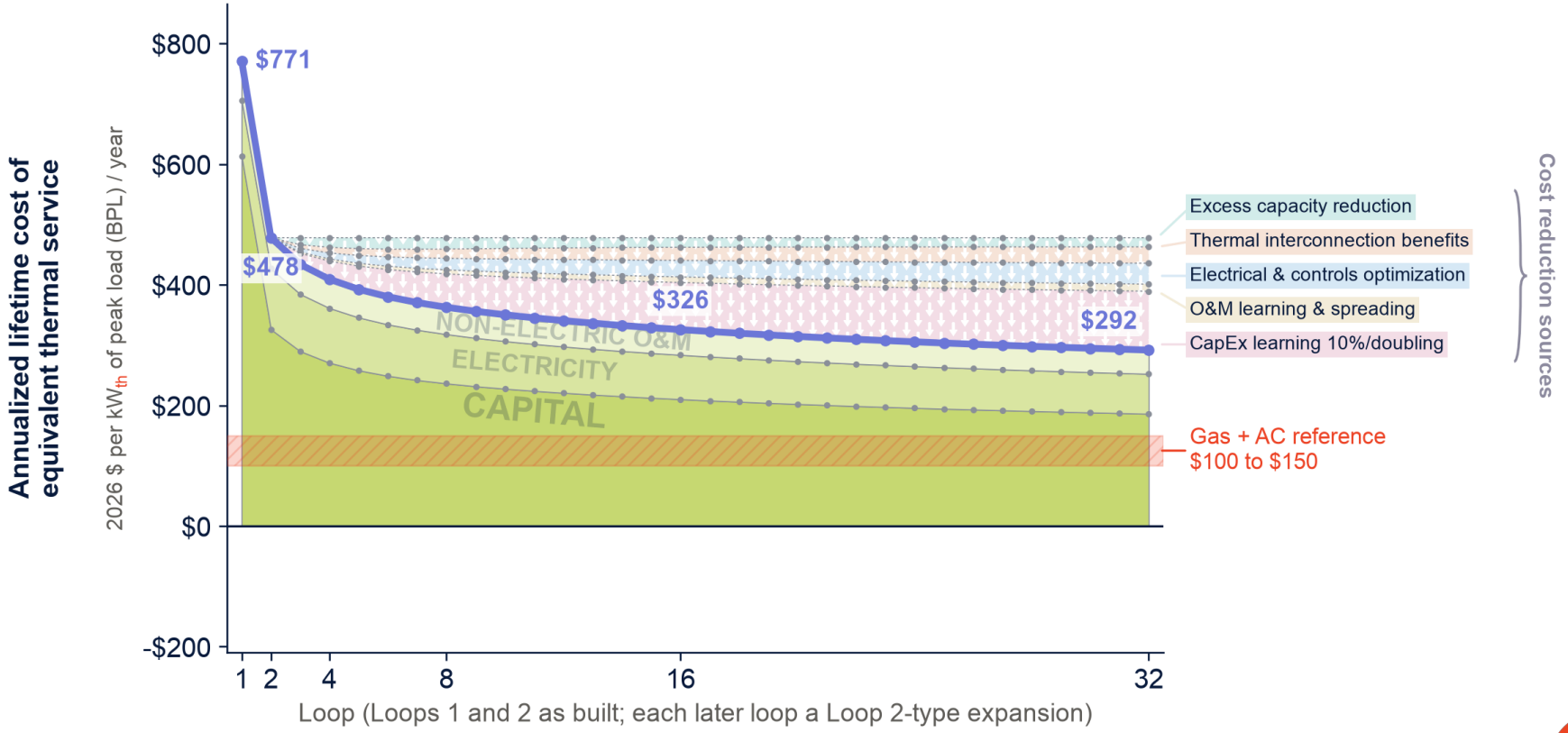
With incentives and credits



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Estimated cost changes if expansions continue

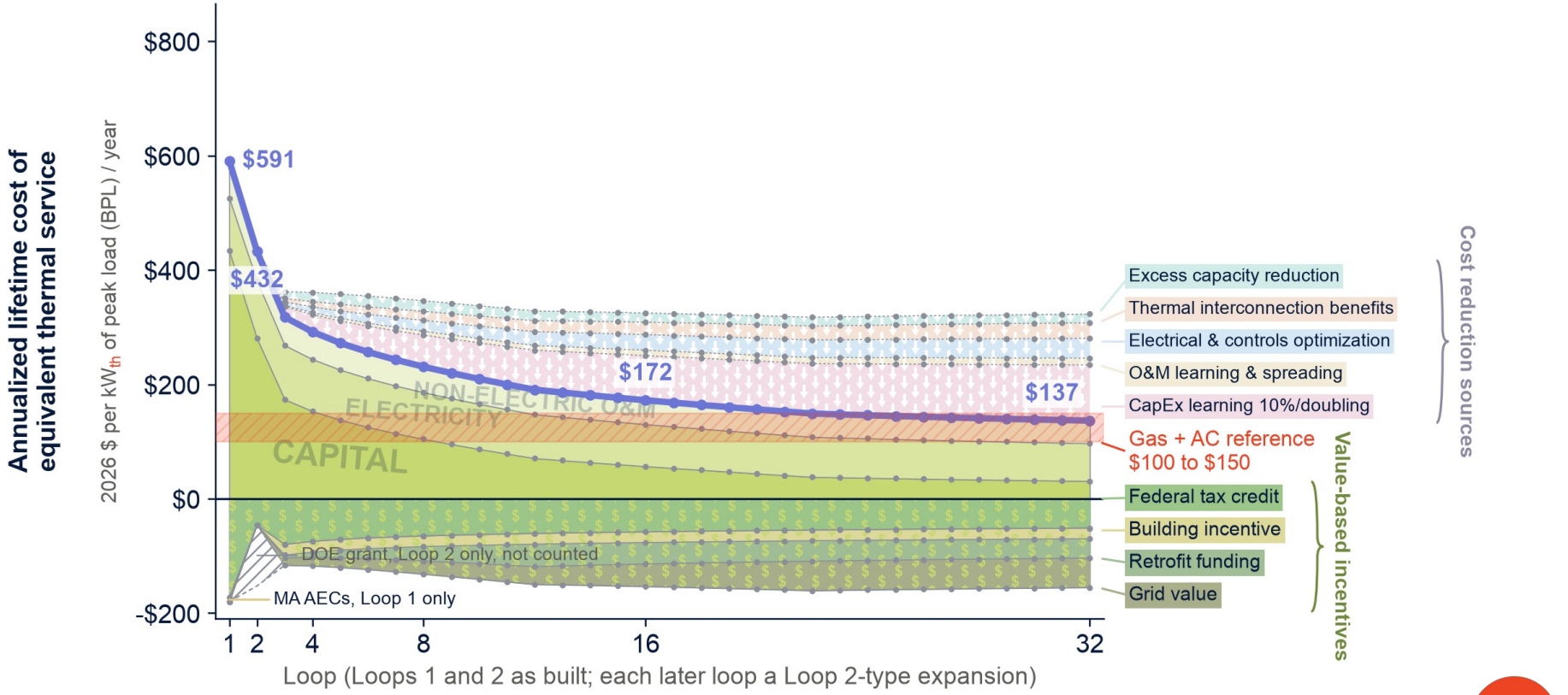
Not including any subsidy, incentives, or value-based funding



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Estimated cost changes if expansions continue

Including ITC, building incentive, retrofit funding, and grid-value funding



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Phases of the buildout



Demonstration
Initial learning

Pilot loops built and running

Highest financial support

Development
Learnings applied

Drive down the cost curve

Convert external benefits to funding streams through policy

Iterate to scalable rate design & financing, per function

Deployment
Mass buildout

Rates fully recover the cost of the networks

Recovery shaped for long-lived infrastructure

GENs deployed wherever net beneficial

Steady state
Buildout complete

Infrastructure of every age, as the gas system has today

Cost at or below the incumbent

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Translating costs into customer rates

With **utility ownership**, customer rates are determined by:

1. Revenue requirement
2. Billing determinants

Revenue requirement in each period =

Pass-through costs (purchased power, gas, O&M) + Capital recovery + Taxes

Alternate ownership models and financing methods can be applied per function:

Thermal resources and distribution
e.g. project finance, municipal ownership, cooperative, state facility

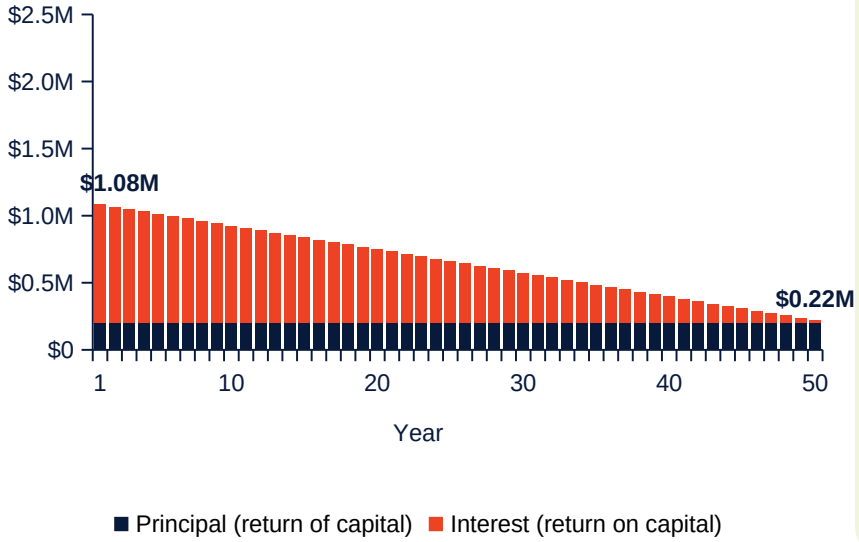
Building side
e.g. on-bill financing, leasing, other mechanisms

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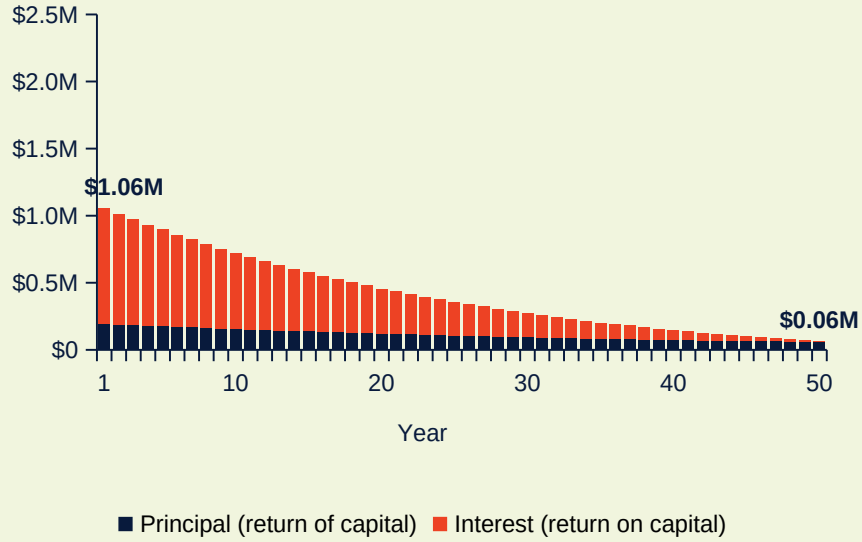
Standard utility capital recovery

Return on rate base plus straight-line depreciation

As billed: nominal $ per year



Same amount, adjusted for inflation (2026$)



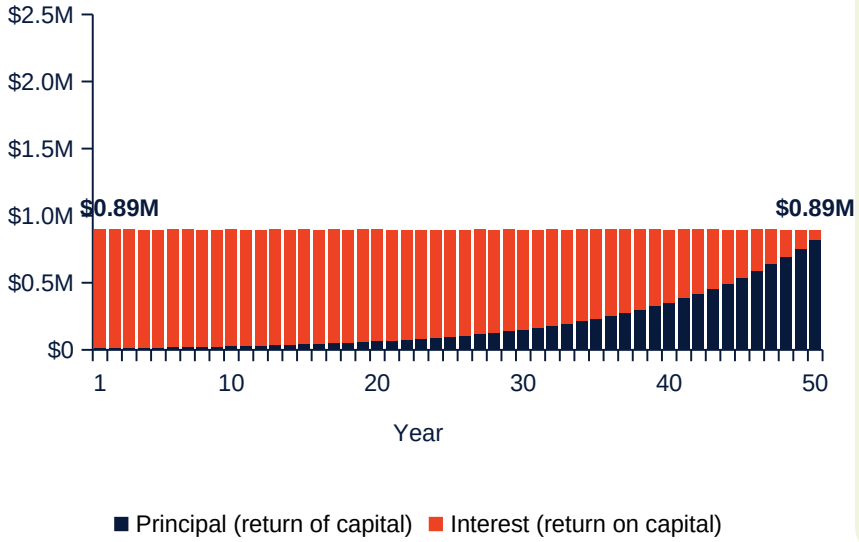
Illustrative system, $10M CapEx, 6.164% real rate of return

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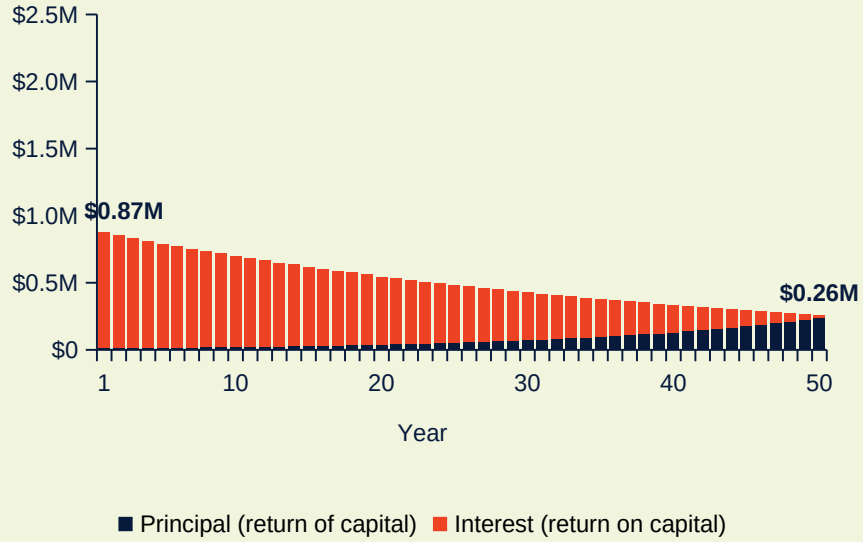
Levelized capital recovery: level nominal

A fixed payment, like a fixed-rate mortgage

As billed: nominal $ per year



Same amount, adjusted for inflation (2026$)

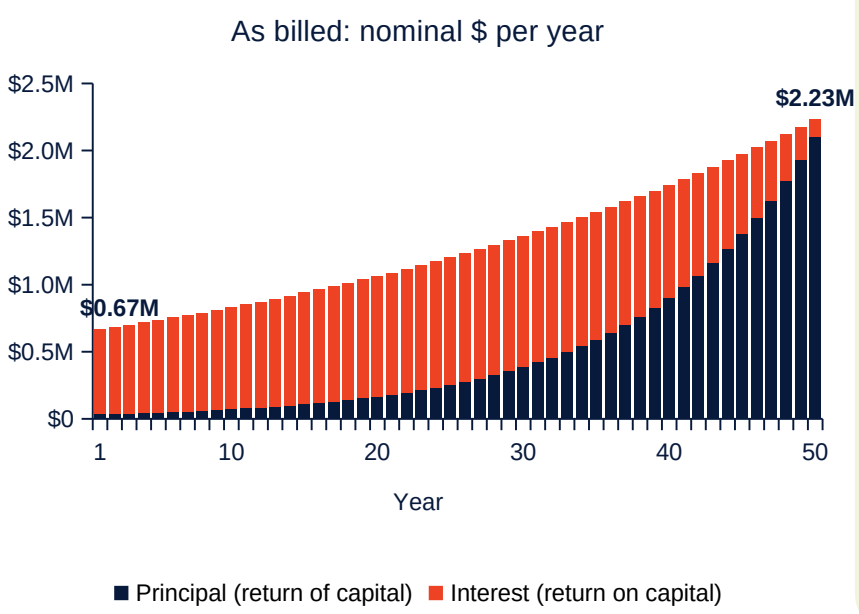


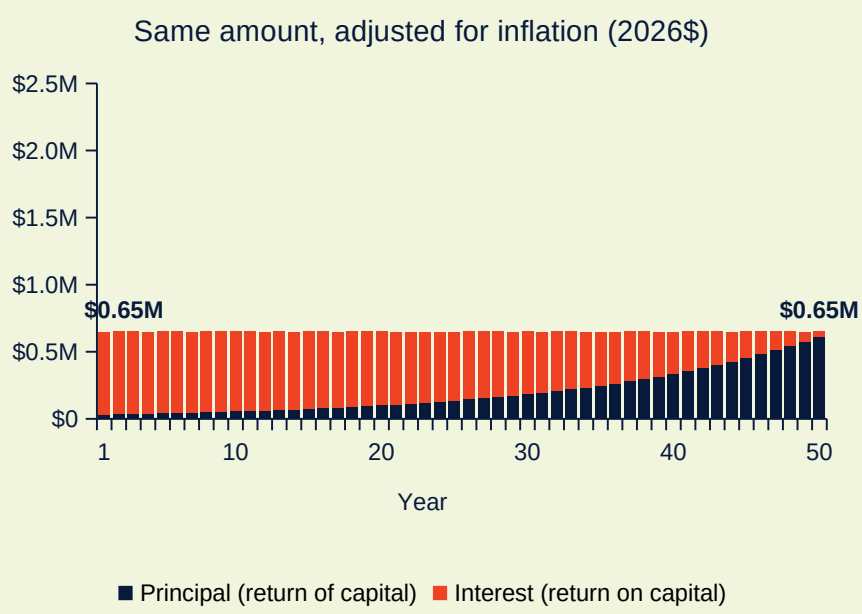
Illustrative system, $10M CapEx, 6.164% real rate of return

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Levelized capital recovery: level real

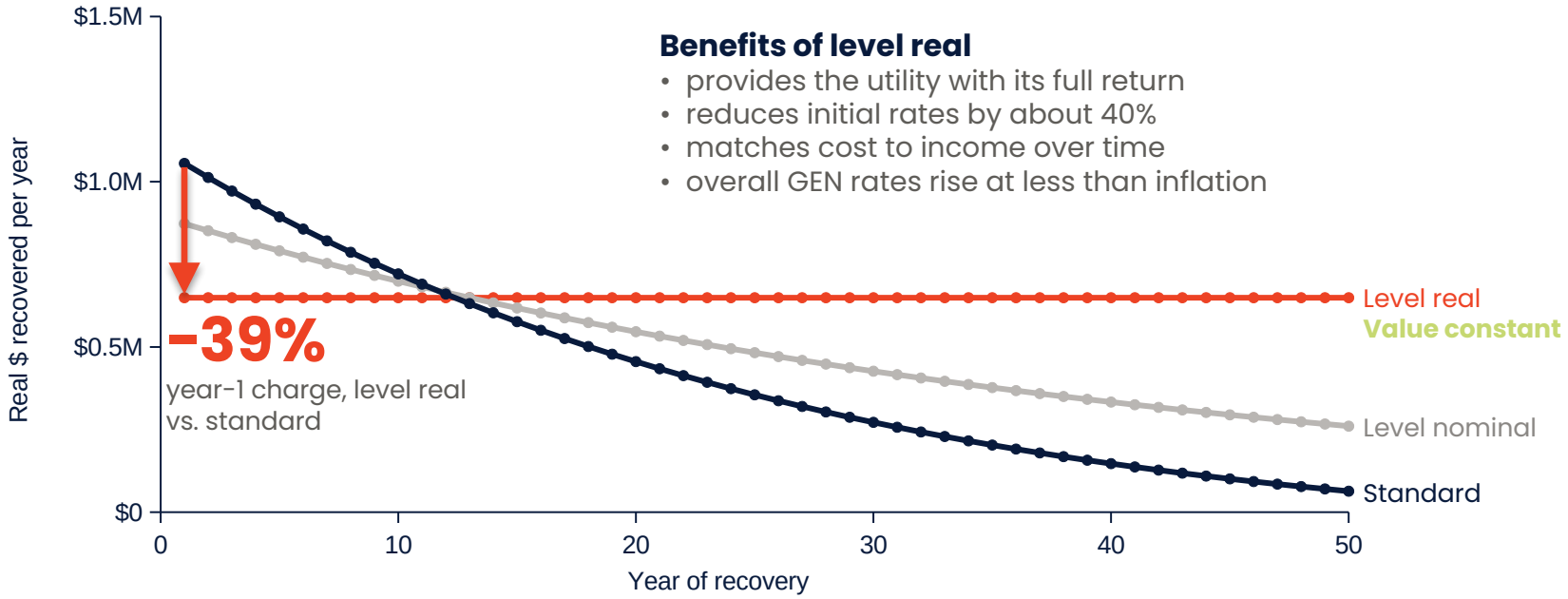
A payment that keeps its purchasing power, like an indexed annuity





Illustrative system, $10M CapEx, 6.164% real rate of return

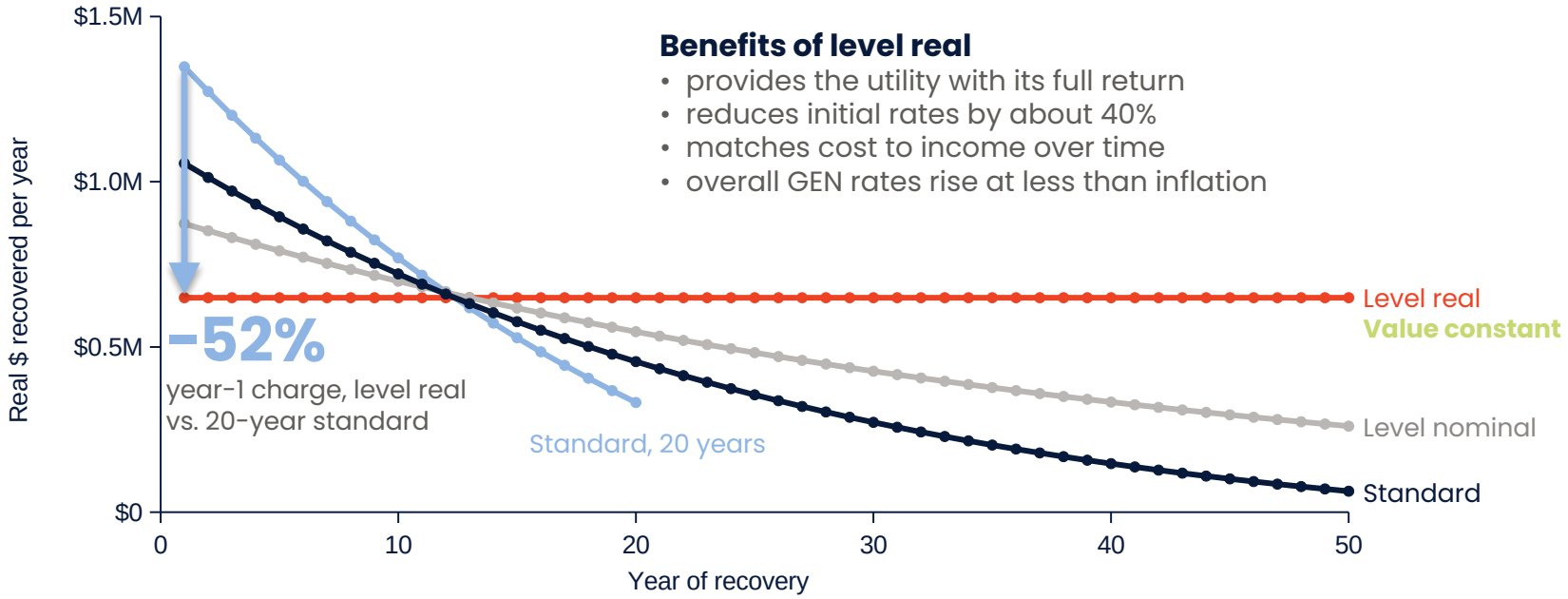
Same capital, same present value, three recovery paths



Illustrative $10M system, 50 years, 6.164% real.

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Compressed lifetime increases near-term rates



Illustrative $10M system, 50 years, 6.164% real.

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An open-source model for buildout scenarios

1. Costs

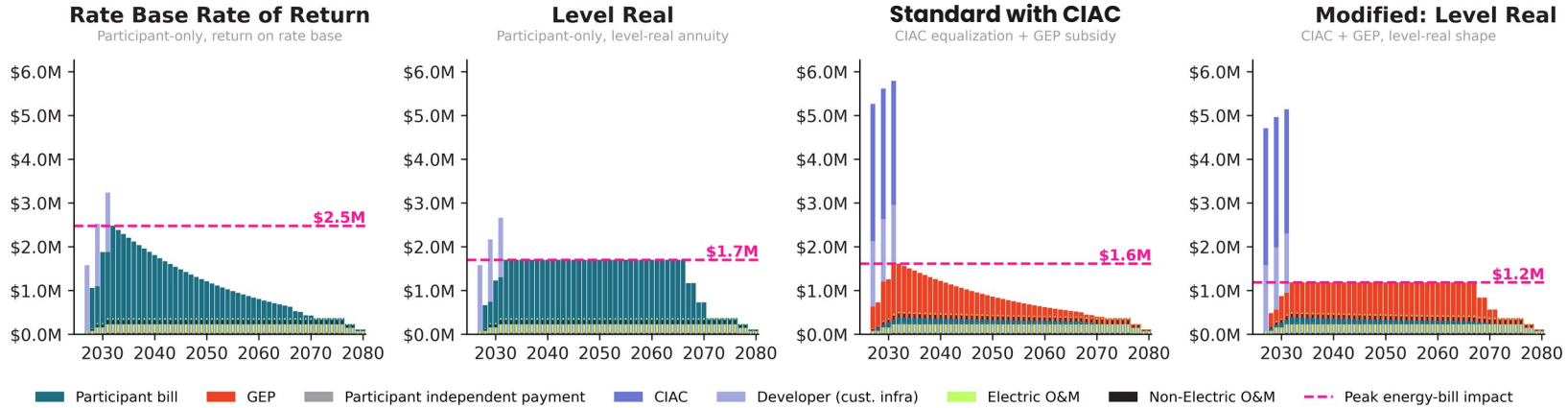
What a portfolio of networks costs year by year, capital, maintenance and electricity, as it is built and learns

2. Recovery

How those costs come back under each ratemaking design: rate base, level real, with CIAC, and variants

3. Who pays

What lands on participants' bills, including electricity, on other gas customers, and on developers, and when



* Income tax only; all other taxes (property tax, deferred tax) excluded.