



**Welcome to the
Heating Sector
Transformation
Workshop**

April 7, 2020

Slide deck is available on
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Rhode Island Heating Sector Transformation

PUBLIC WORKSHOP #3:
ANALYTIC FINDINGS AND
POLICY PROPOSALS

PRESENTED TO
RI Heating Sector Stakeholders

PRESENTED BY
Dean Murphy
Jurgen Weiss

April 7, 2020

THE **Brattle** GROUP



Agenda

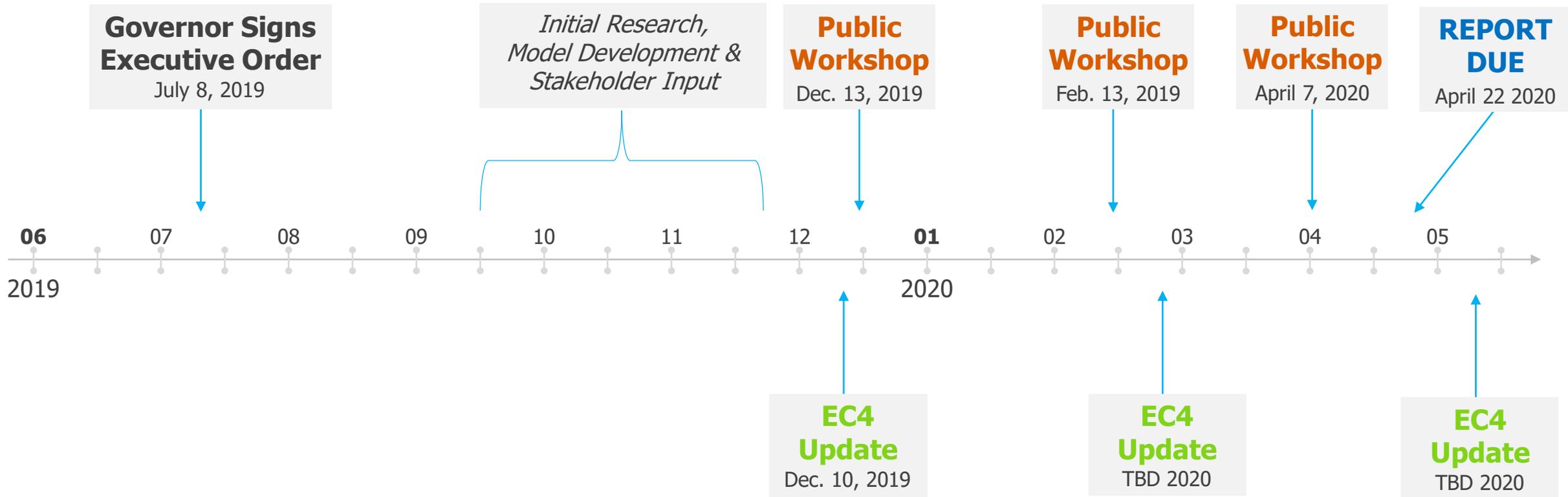
- 1. Introduction**
- 2. Analytic Findings and Conclusions**
 - Updated
 - Policy Principles
- 3. Policy Framework for the Next 10 Years**
- 4. Policy Discussion**

Webinar Logistics

- This webinar is being recorded.
- By default, everybody will be muted.
- If you have a substantive question, ask through the Q&A button at the bottom of your webinar screen.
 - You can see all the questions that have been asked – give a thumbs up if you want to ask a similar question.
- For technical questions about webinar logistics, send a chat to Becca Trietch (co-host).
 - Any logistical question you can't figure out through the webinar: email energy.resources@energy.ri.gov
- We'll have two times when we unmute everybody for additional opportunities to ask questions: at the end of the analytical findings and conclusions section, and at the end of the policy discussion
- If dialed in by phone
 - *9 to raise your hand

Project Timeline

Report due by April 22, 2020



Please note that all 2020 dates are subject to change.

Heating Sector Transformation

STATE PROJECT TEAM

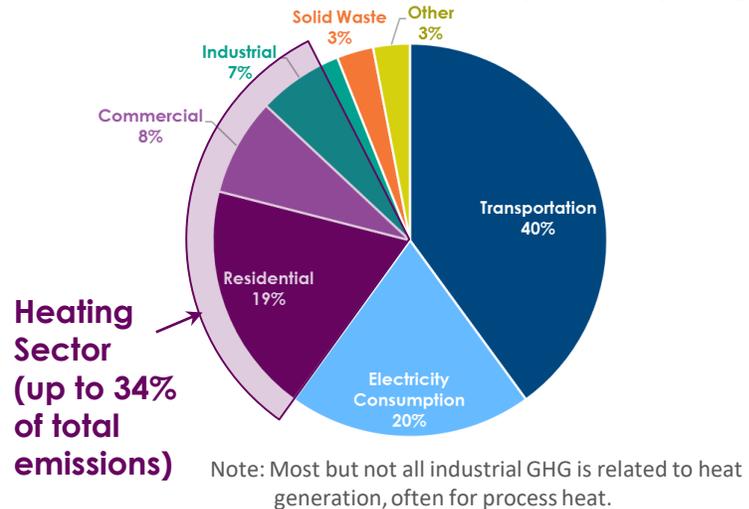
- RI Office of Energy Resources
- RI Division of Public Utilities and Carriers
- RI Governor's Office

CONSULTING TEAM

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Rhode Island GHG Emissions by Sector (2015)



“80x50” likely means (near) full decarbonization of residential and commercial heat – since full decarbonization of specialized industrial and transport sectors may be more difficult

The primary solutions for decarbonized heat

Space and water heat <i>Several primary solutions are feasible across many applications/buildings</i>	Decarbonized Fuel <i>Supply may be limited from less-costly sources</i>	Renewable gas/power-to-gas (P2G) for gas customers <ul style="list-style-type: none">– Landfill gas, anaerobic digesters, gasification, synthetic gas
		Biofuel or power-to-liquids (P2L) for most other customers <ul style="list-style-type: none">– Biodiesel, ethanol, synthetic fuels
	Heat Pumps	Air source heat pump (ASHP)
		Ground source heat pump (GSHP) <ul style="list-style-type: none">– Including GeoMicroDistrict
Industrial heat	<ul style="list-style-type: none">– May be more specialized (e.g., high-temp)– May require (decarbonized) fuel, including hydrogen	

2. Analytic Findings & Conclusions

- Energy Efficiency's Role
- Electrification via Heat Pumps
- Decarbonized Fuels
- Economics: Residential Single Family Home
- Heat in Larger Buildings, and Other Heat Needs
- Conclusions and Policy Principles

Cost-effective energy efficiency (EE) lowers customer bills and reduces decarbonization challenge

- EE is very cost-effective in new construction, but more challenging (and highly idiosyncratic) in existing buildings
 - RI consists mostly of existing buildings – and most will last beyond 2050
- Some EE in existing buildings is cost-effective and relatively “cheap”
 - Air sealing, weather stripping, attic insulation: ~\$4,000 yield 10–15% energy savings (based on EnergyWise total program costs including audits etc.)
- But “deep energy retrofits” (walls, windows) are typically costly
 - \$50–\$100K+ for 30–75% savings: Costly, disruptive, maybe not cost-effective

Energy efficiency alone cannot fully decarbonize

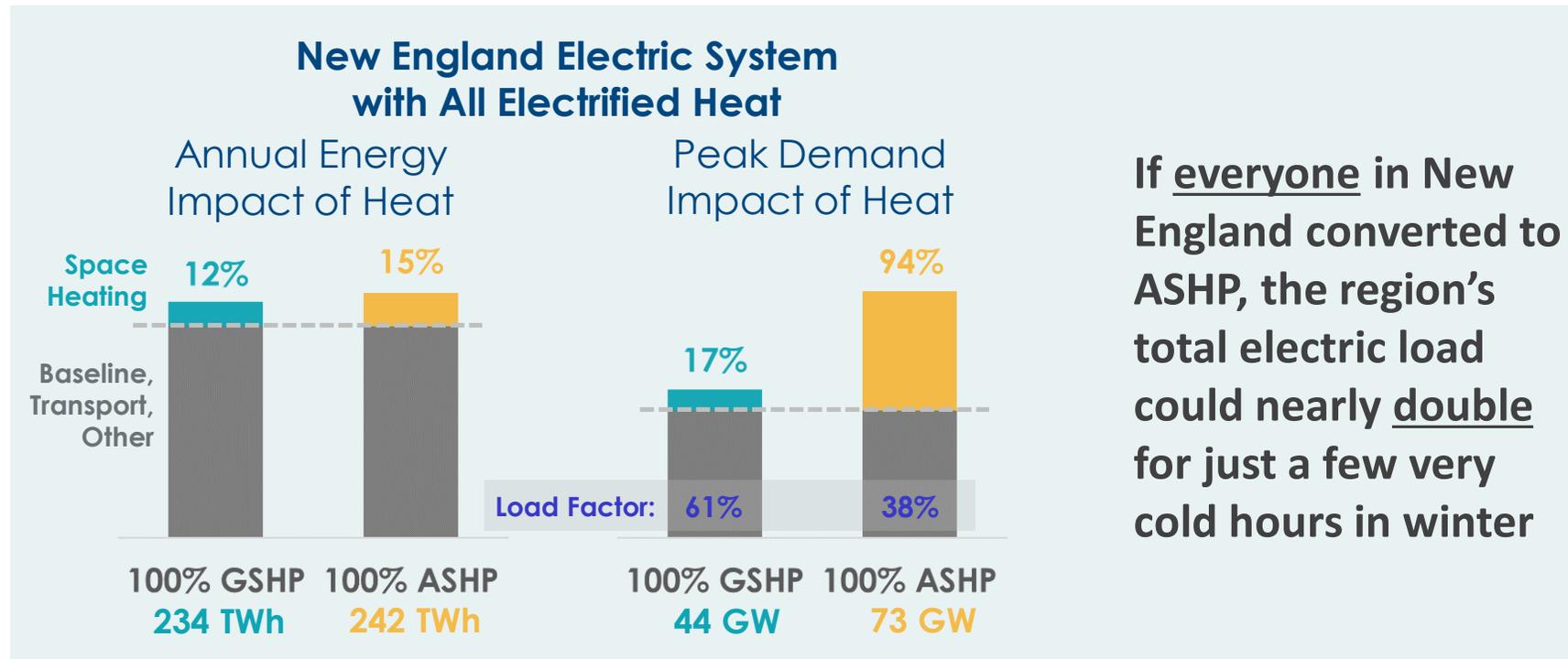
– Decarbonized heat is still needed –

But cost-effective EE saves customers money

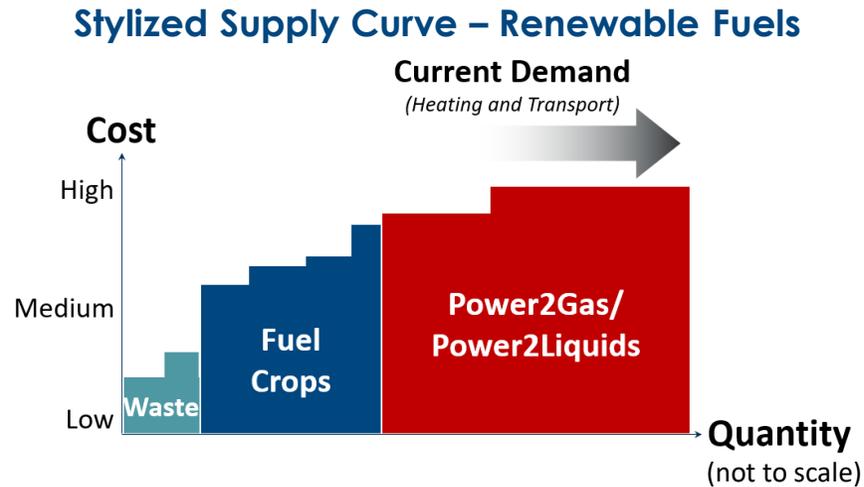
It is an essential component of decarbonization strategy

Decarbonized Electrification via ASHP and/or GSHP has several benefits and challenges

- Both have higher up-front costs than furnaces and boilers
 - Especially GSHP due to ground loop (GeoMicroDistrict approach may help)
- ASHPs could create extreme electric peak, if implemented widely
- Must also decarbonize electricity to be effective

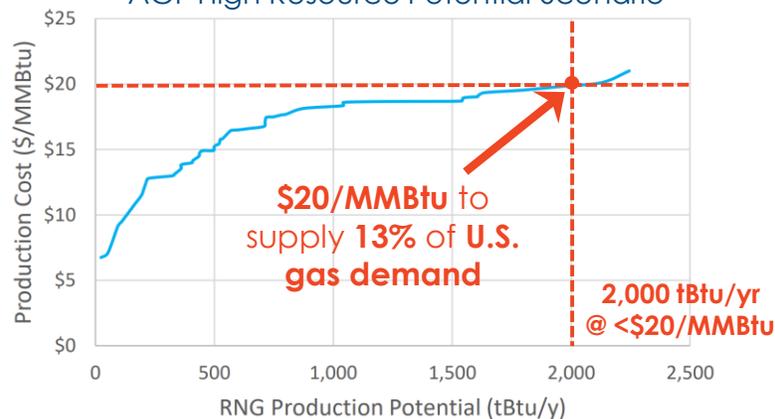


Decarbonized Gas or Oil require little change in infrastructure, but low-cost supplies are likely limited



Combined RNG Supply-Cost Curve, 2040

AGF High Resource Potential Scenario



Source: American Gas Foundation, Renewable Sources of Natural Gas, December 2019.

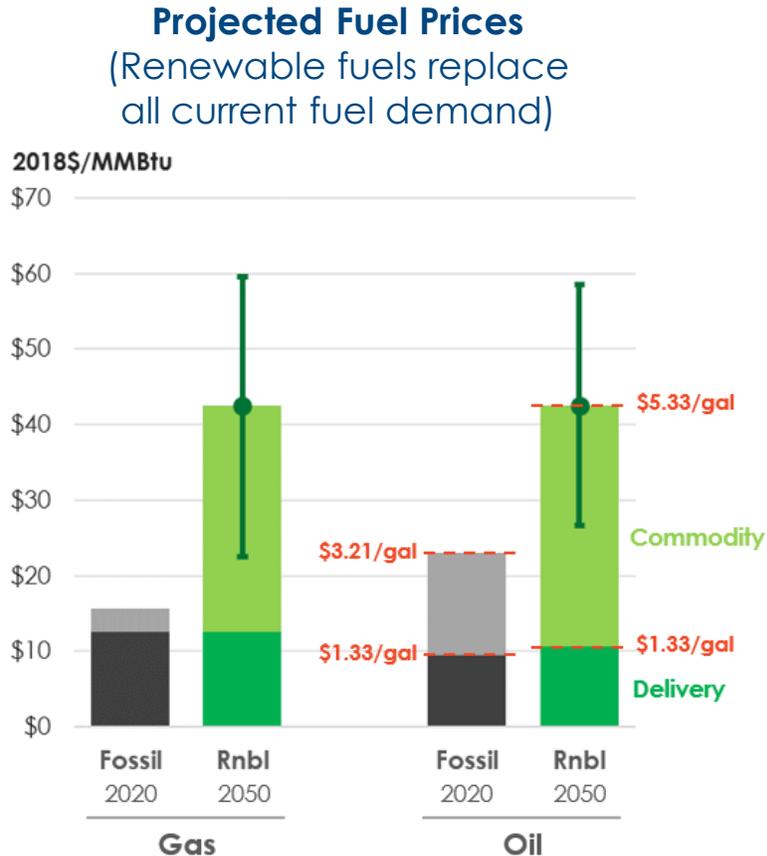
Current (national) demand for oil and gas far exceeds low cost supplies for renewable oil/gas

- American Gas Foundation study estimates “low cost” renewable gas could supply up to 13% of current gas demand
- “Low cost” is below \$20/MMBtu, about 8 times current natural gas price

For renewable oil/gas to have low price, future fuel demand must be well below current demand

- Unlikely given high-value demand from other sectors with few alternatives (e.g., jet fuel)

If price of renewable fuels is set by “Power2Fuels” technology, prices are likely to increase significantly



Note: Assumes 10% less energy per volume for renewable oil, relative to fossil heating oil

Power2Fuel production costs for renewable oil and gas are roughly comparable

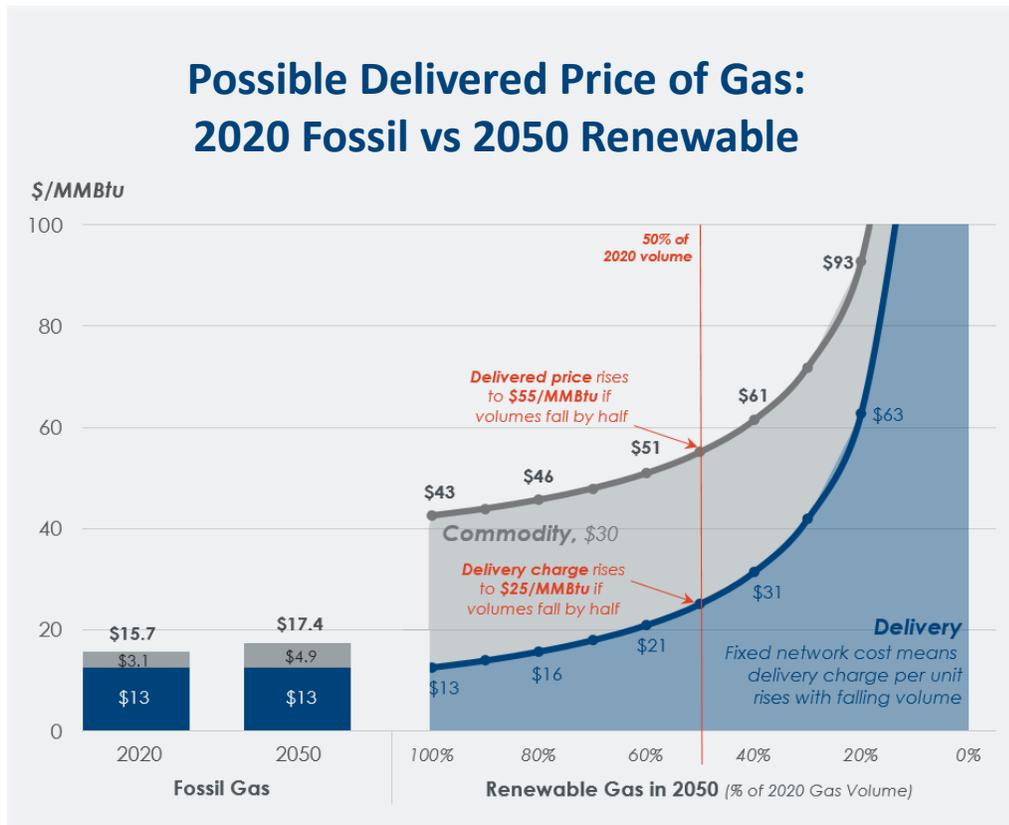
- But currently natural gas is much cheaper than oil (per MMBtu of energy content)
- Implies larger relative increase in gas price, vs current fuel price

Future (renewable) gas price could increase further if gas volumes decline, given largely fixed cost of gas infrastructure (next slide)

- At present, delivery cost of gas is already higher than delivery component of oil price (offsetting some of gas' commodity price advantage)

Gas may face additional challenges: safety, indoor air quality, leaks and volume loss

- Just like NG, renewable gas has potential safety and indoor air quality issues
- Even if gas itself is renewable, leaks still cause GHG emissions
- Volume loss could increase delivered cost:



Gas distribution costs are mostly fixed

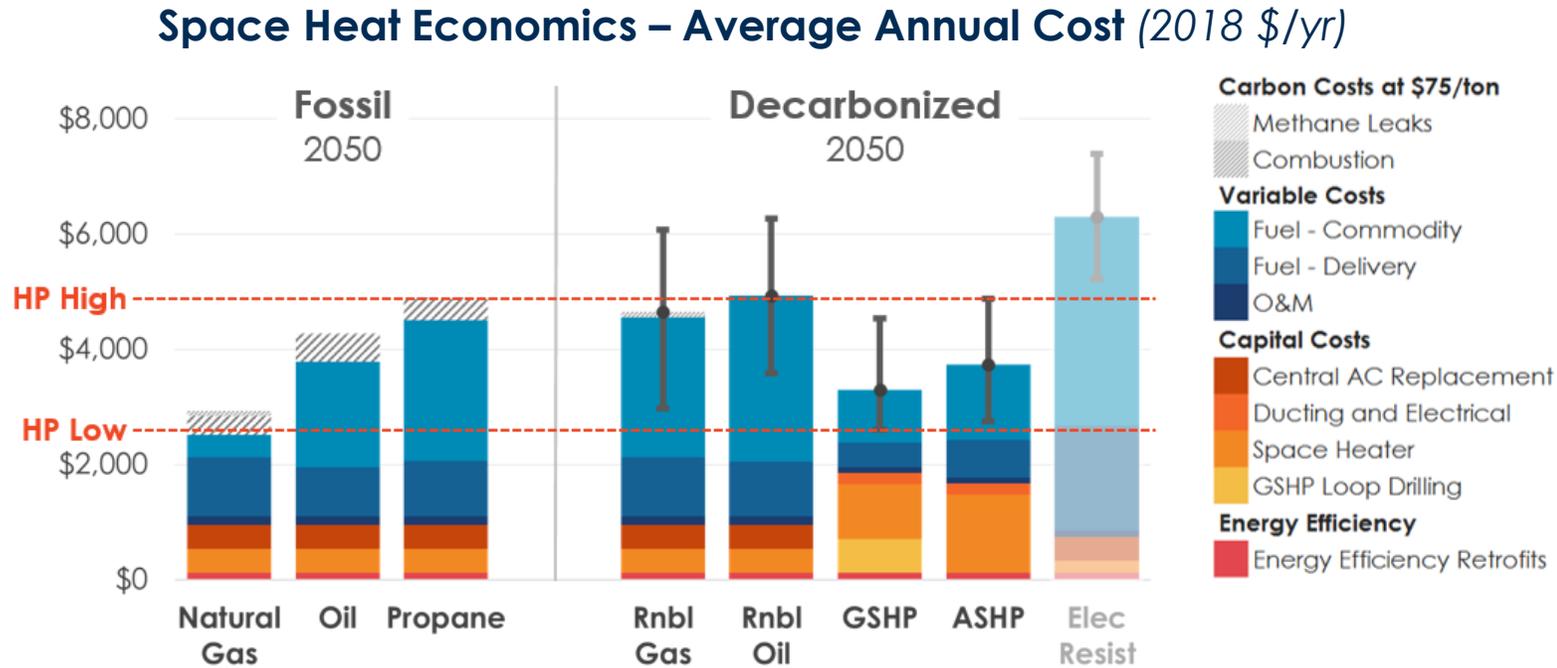
- System is largely built
 - Cost is mostly independent of throughput
- Unless fixed cost can be lowered, reduced volume raises unit rate – and could result in more defections
 - Maintaining high volume almost certainly implies using P2Fuels for supply, which means higher commodity cost
- How far can volumes fall and the system remain viable?
 - If necessary, how to “unwind” part or all of the system, without hurting vulnerable customers?
 - Spreading costs across both gas and electric customers may help
 - In RI, same utility provides both

Economics of an existing Single Family Home

Heating Transformation Strategy relies on an economic comparison of decarbonized heat

- **“Typical” Existing Single Family Residential as “base case”**
 - Represents the single largest share of heating demand and related GHG emissions
 - Size of home (heat load) does not affect relative costs significantly
 - Must recognize that individual buildings are idiosyncratic – comparison looks at rough averages
 - Customization, ductwork, electrical upgrades, etc. may vary considerably
- **Annualized cost – capital cost is spread over equipment life**
 - Annualized cost represents societal view of long-run economics of technologies
 - This assumes initial cost is not a barrier!
 - Not a good predictor of consumer behavior
- **Based on projected 2050 equipment, installation, fuel costs**
 - Use ranges to characterize uncertainty
 - E.g., Heat pump costs assumed to decline by 0.5-2%/yr (15-45% by 2050)

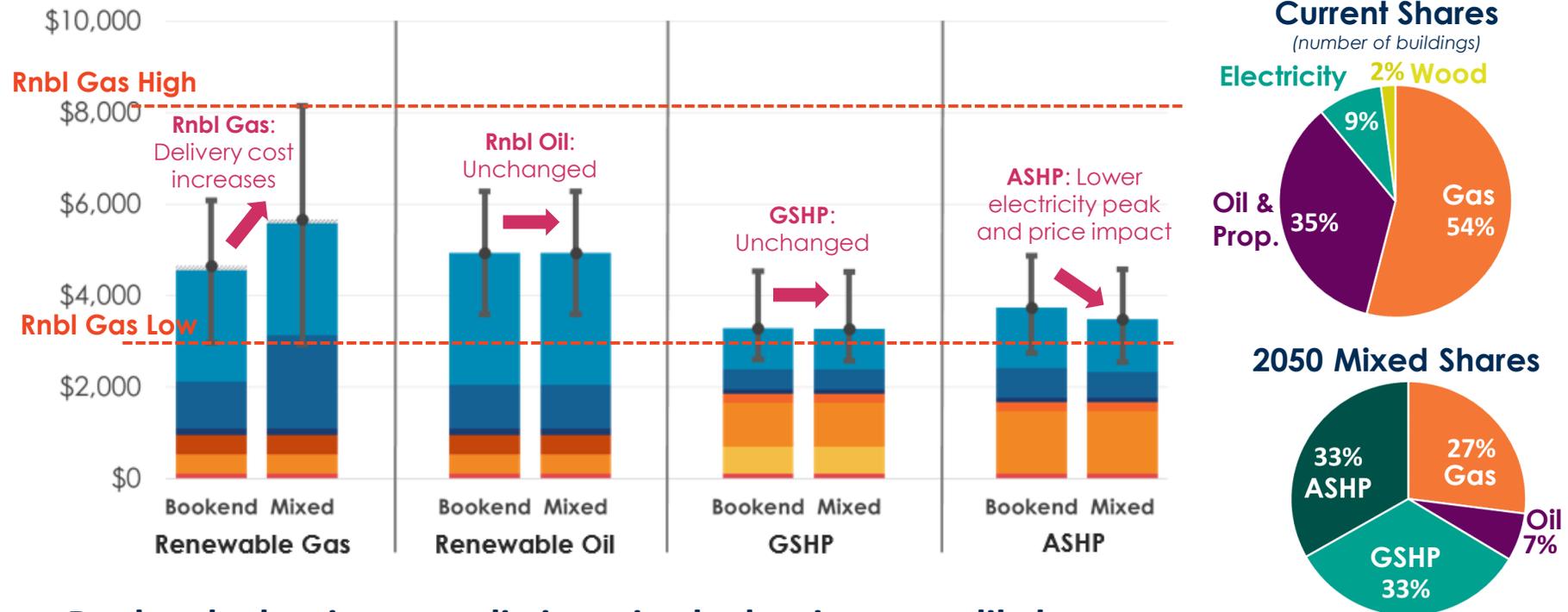
Economics for representative single family home with bookend scenario show no one “best solution”



- Bookend scenario assumes current fossil shares are retained (Rnbl Gas, Rnbl Oil), or that all heat is provided by GSHPs or ASHPs
 - ASHP bookend has higher electric peak and prices, natural gas volume unchanged
- **Broadly similar costs when recognizing large uncertainty ranges**
 - “Central” projections are quite uncertain; ranges likely more reliable
 - Annualized costs of decarbonized heating comparable to oil or propane, more than gas

One possible example of more realistic mixed adoption highlights potential price risk to gas (and benefit to ASHPs)

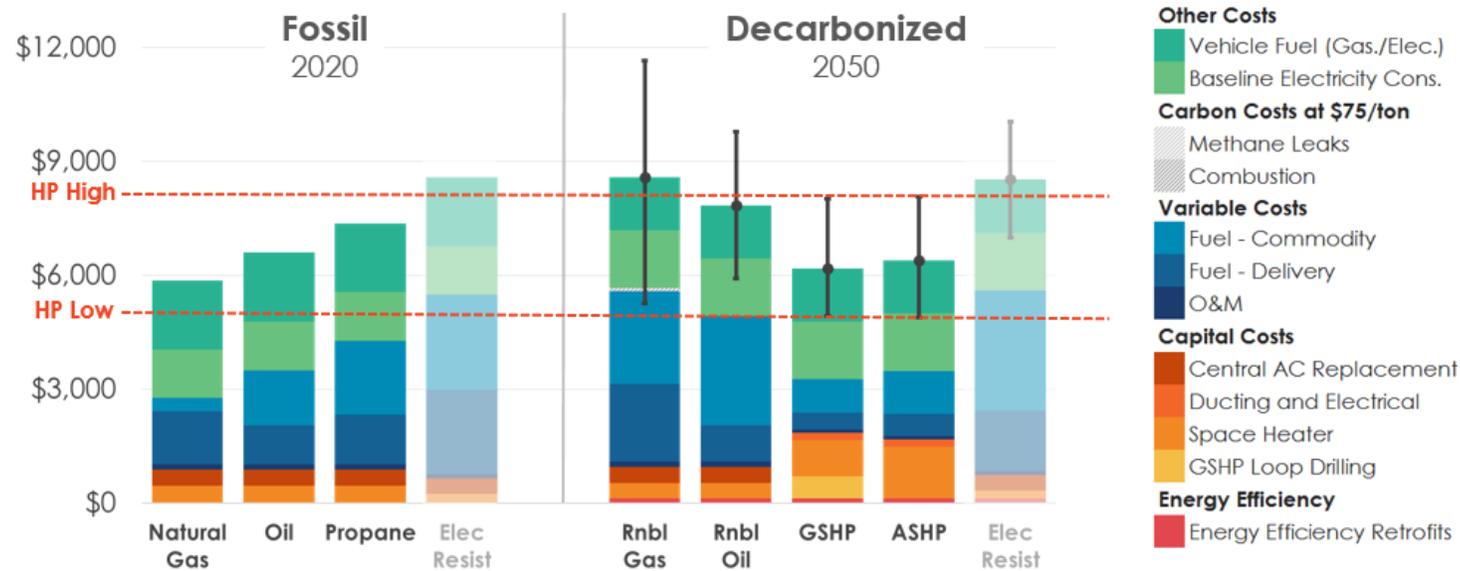
Space Heat Economics – Average Annual Heating Cost in 2050 (2018 \$/yr)



- **Bookend adoption unrealistic - mixed adoption more likely**
 - One possible mixed example: GSHP and ASHP each provide 1/3 of heat, with fuel use falling due to efficiency and electrification (Gas down 50%; oil down 80%)
- **Volume loss of delivered gas results in higher gas delivery cost**
 - For ASHPs, electricity price increase is smaller than in bookend case
- **Would lead to renewable gas cost range mostly above heat pumps**

Typical energy spending will likely be comparable to today (except perhaps for current gas customers)

Average Annual Total Energy Cost(2018 \$/yr)
 Current (2020) Fossil vs Projected 2050 Decarbonized (Mixed Scenario Example)

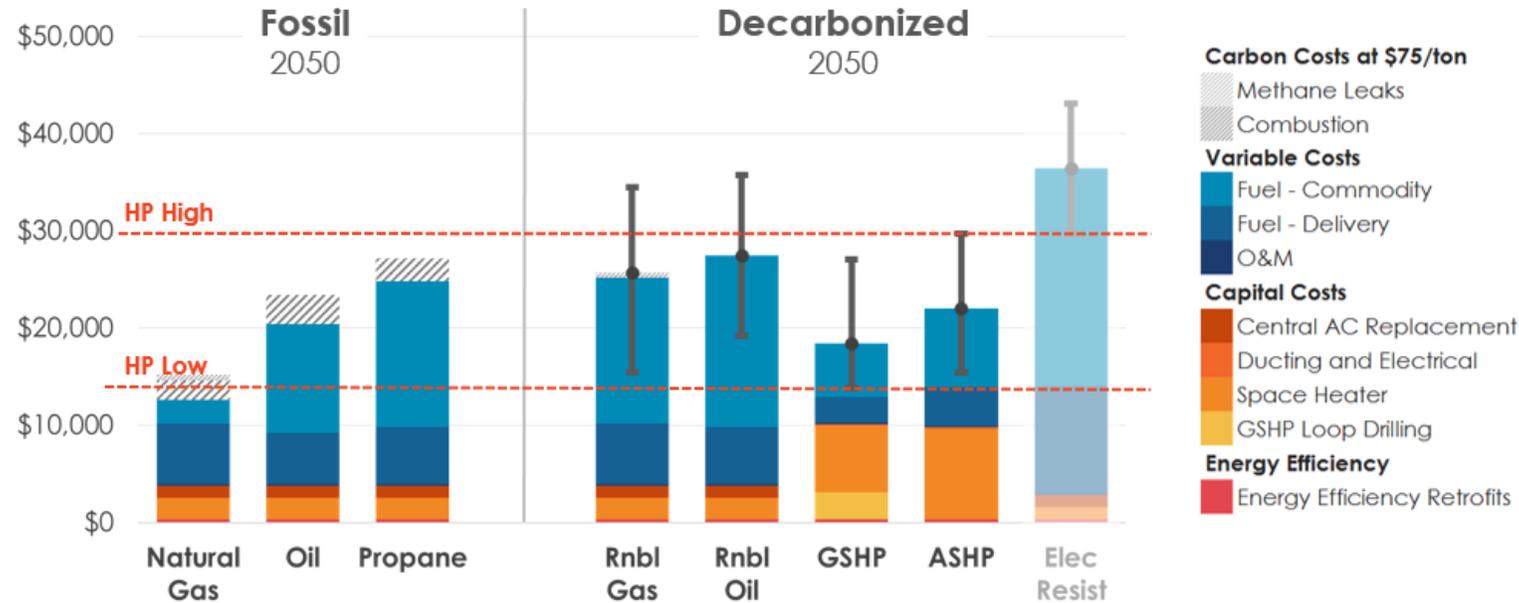


Total energy wallet likely comparable to today for typical consumer (within uncertainty range)

- May be slightly higher for customers now using fossil gas heat (which is at historic lows)
- **EV charging is likely cheaper** than current motor fuel, offsetting other energy costs
- Not everyone is “typical” – **must recognize and mitigate impacts on disadvantaged consumers**

Results are similar for larger (commercial) buildings even though also more idiosyncratic

Space Heat Economics – Average Annual Heating Cost (2018 \$/yr)



Large buildings are more idiosyncratic

- Gas/oil boilers; electric/absorption chillers; varied internal distribution systems
- **Relatively less heat needed**; cooling necessary even in heating season
- But same basic decarbonization approaches: electrification or decarbonized fuels
- **“Typical” economics are like Residential, and same conclusion – no clear winner**

Other heat needs: Water, Industrial, etc.

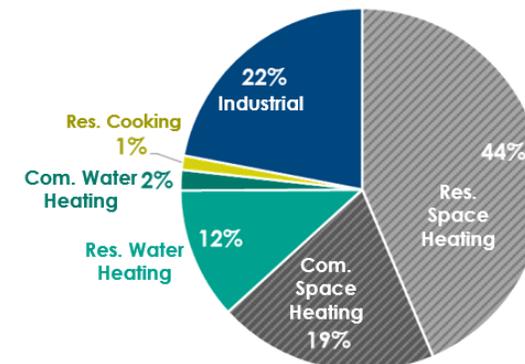
— Other, smaller heat needs (water, cooking, etc.) may electrify, especially if space heat is electrified

- Can avoid second delivery system and costs, for low volumes
 - Though legacy gas (or oil) system may be kept for space heat backup, and secondary uses
 - Consumers reluctant to give up gas for cooking?

— Industrial needs may be specialized – e.g., requiring high temperatures

- Electrification may not be workable or cost-effective for all applications
- Decarbonized solutions likely increase costs for industrial users as well – and industry can move...

Estimated Heat Energy Consumption in RI by Heating End Use



Source: BuroHappold.

Notes: Due to data limitations, the “Industrial” category includes all the energy consumption of the sector, not only heating. Space and water heating for industrial buildings is also included within this category.

Analysis of different decarbonization approaches shows no clear winner (from society's perspective)

- **Economics depend on several critical but highly uncertain factors**
 - Cost of “drop-in” replacement fuels for gas and oil
 - Installed cost of heat pumps and ground source loops
 - Retail price of (almost-all-renewable) electricity
 - Likely building-specific factors
- **The “preferred” (most cost-effective) approach is sensitive to the choice of assumptions, within reasonable ranges**
- Some “themes” provide guidance:
 - **Heat pump systems** are more **capital intensive** – especially GSHP – with lower operating cost; may be relatively more **economic for larger** (heat and cool) **loads**
 - **ASHP** (if adopted for most heating needs) could cause an **extreme electric peak**
 - It may be possible to partially mitigate this
 - **Renewable fuels have potentially high cost**, and also high cost uncertainty
 - **RNG is susceptible to GHGs from leaks**, even if RNG itself is CO₂-free; also safety, indoor air quality, and volume loss risks

Also need to consider that individuals' decisions may not align with preferred societal solutions

Decarbonized solutions are not necessarily lower cost for customers

(especially current gas customers)

- May also be disruptive, inconvenient; consumers unsure of performance
- Also, regardless of long-run economics, high initial cost may impede adoption
 - Consumers often require payback periods of just a few years

Misalignment between policy goals and individual decision making

- Customers may tend to remain with fuel-based heating (or choose ASHP over GSHP), even if it is not lowest long run cost
- Implies policy intervention is likely necessary to transform heating sector
 - To promote policy goals where they may not be lowest direct cost for customers
 - E.g., due to externalities
 - To induce or enable customers to choose solutions that are lower (long-run) cost, despite higher initial costs

Qualitative factors are also very relevant for understanding attractiveness of solutions

- **Feasibility in 30 years** – Weatherization/heat pump installations pose significant implementation challenges, given >400,000 residential/commercial buildings
- **Work force** requirements, especially for widespread heat pump deployment
 - Also workforce transition issue in fuel industries
- **Customer preferences**
 - Reluctance to give up gas for cooking, to endure disruption, etc.
- **Existing codes, standards, zoning rules etc.** may inhibit some technologies
- **Long life of heating infrastructure** creates challenges for altering it
- **High up-front cost and cost uncertainties** of heat pumps
 - The need for financing creates a barrier to adoption
- **Geology** may limit GSHP implementation
- To decarbonize heating, heat pumps **require decarbonized electricity**
- **Air quality** impacts of fuel burning (indoor from gas cooking; outdoor from gas and especially oil)
- **Safety concerns** of any gaseous fuel

Summary of analytic conclusions

- **Efficiency is essential, but cannot achieve full decarbonization** on its own
 - Still need heat (esp. in existing buildings), and it must be decarbonized
- **Two primary pathways to decarbonized heat**, each with pros and cons
 - **Decarbonize fuel**
 - Quantities of lower-cost fuels are likely to be limited
 - Prices high if used at volumes approaching current fuel use
 - Lower gas volumes could challenge LDC viability – even if intending to maintain it
 - Rnbl Gas causes GHGs via leaks, which limit its GHG reduction potential
 - **Electrify via heat pump**
 - Heat pump solutions are capital-intensive, but have lower operating costs – makes it less likely that consumers will choose those unless there is policy support
 - ASHP can cause extreme electric peak, if widely implemented
 - GSHP may be more cost-effective than ASHP, even considering ground loop cost, but big cost uncertainty re ground loop, likely cannot be universally deployed
- **There is no clear winner, economically** – depend on several highly uncertain factors
 - **Heating cost may increase modestly with decarbonization**, though efficiency helps, and lower EV charging cost may also help offset costs

Principles to guide policy can be derived from the analytic insights

Policy Principle	Based on Analytic Insight(s)
Ensure progress independent of technology solution	Uncertainty, No technology is a clear winner on economics
Make progress early	Long infrastructure lives, and much infrastructure (many buildings) to be transformed
Learn and share information	Uncertainty, lack of knowledge/awareness
Stress cost-effective EE to reduce customer costs	Decarbonized solutions may be more costly (particularly for current NG customers)
Take advantage of natural investment opportunities	Long infrastructure lives
Consider policy interventions that reduce upfront cost burden	High upfront costs, and consumer preference to avoid them
Implement no-regrets actions – and go beyond	Uncertainty, No technology is a clear winner on economics
Keep options open	Uncertainty, No technology is a clear winner on economics
Extend planning horizon, and future-proof	Long infrastructure lives, uncertainty about best technology
Plan for contingencies	Uncertainty, long infrastructure lives

Questions?

(We'll unmute everybody)

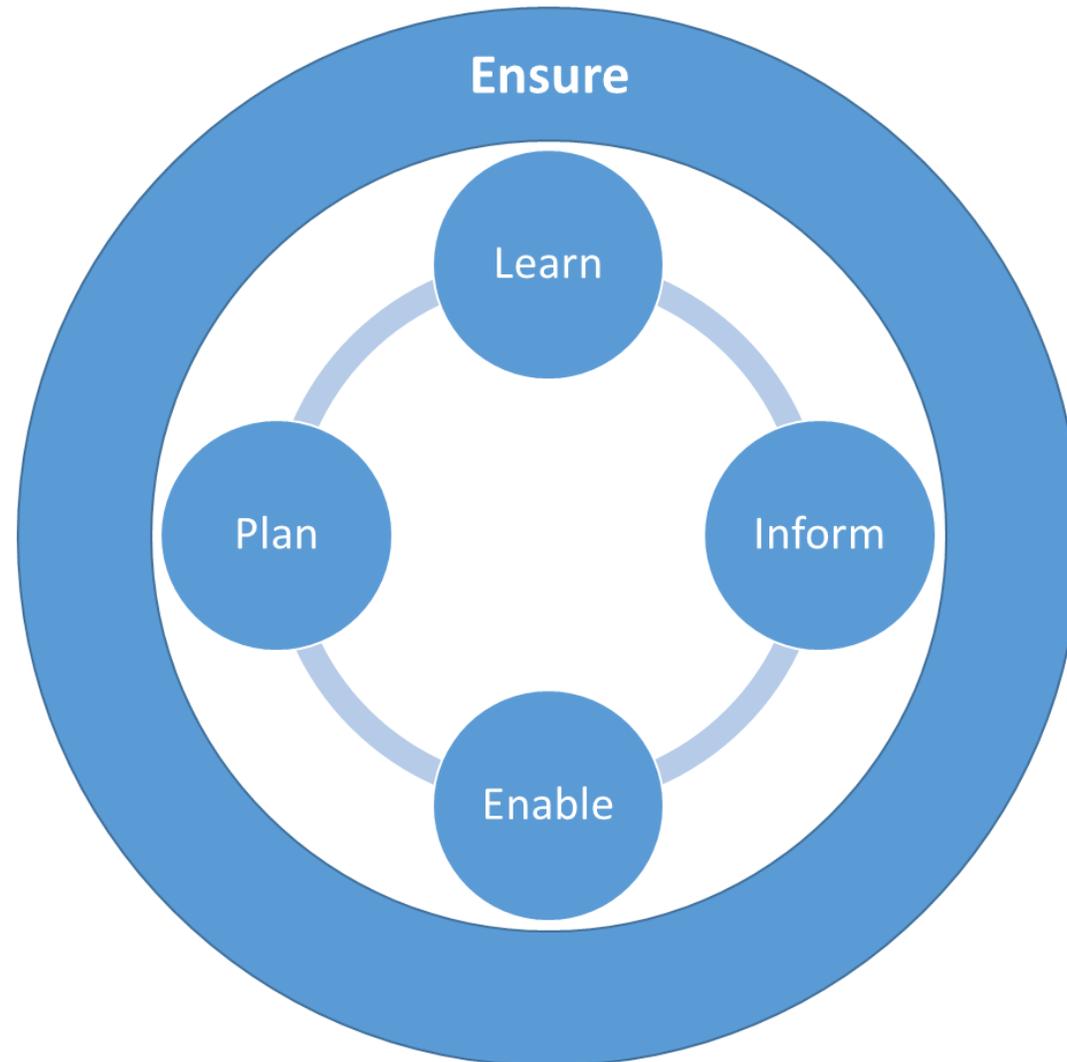
“Raise hand” if you have a
question (*9 on phone)

Followed by

10 minute break

Policy Implications

These policy principles can be mapped into a policy framework for the next 10 years



Policy framework

Ensure	Increase efficiency and reduce carbon content of all fuels to zero over time – ensures progress no matter which technologies are used
Learn	Data collection, R&D, pilot projects to understand technologies, infrastructure, and customers
Inform	Educate stakeholders – customers, installers, policy-makers – about pros and cons of options, system interactions, etc.
Enable	Facilitate deployment with incentives; target natural investment opportunities; align regulation, rules, codes; expand workforce
Plan	Expand planning horizon; develop long-term, high-level contingency plans now (don't commit yet) and use to guide near-term policy

The next slides go into some detail for each of these, with some potential policy examples (rather than prescriptive policy proposals)

Possible policy approaches to **ENSURE** decarbonization regardless of technology

Policy Area	Possible Approach
Address all sources of heat	<ul style="list-style-type: none">• Develop policies that guarantee gradual decarbonization of all heating “fuels”• Use a form of “backstop” policy that makes sure decarbonization occurs
Expand cost-effective energy efficiency improvements for existing buildings	<ul style="list-style-type: none">• Ensure cost-effective EE measures are implemented by improving/expanding efforts and leveraging natural investment moments for deeper retrofits
Improve new building efficiency	<ul style="list-style-type: none">• Tighten new building codes to ensure consumption is reduced as number of new buildings increases
Offer voluntary green tariffs	<ul style="list-style-type: none">• Allows consumers to push decarbonization ahead of policy mandates, at their discretion

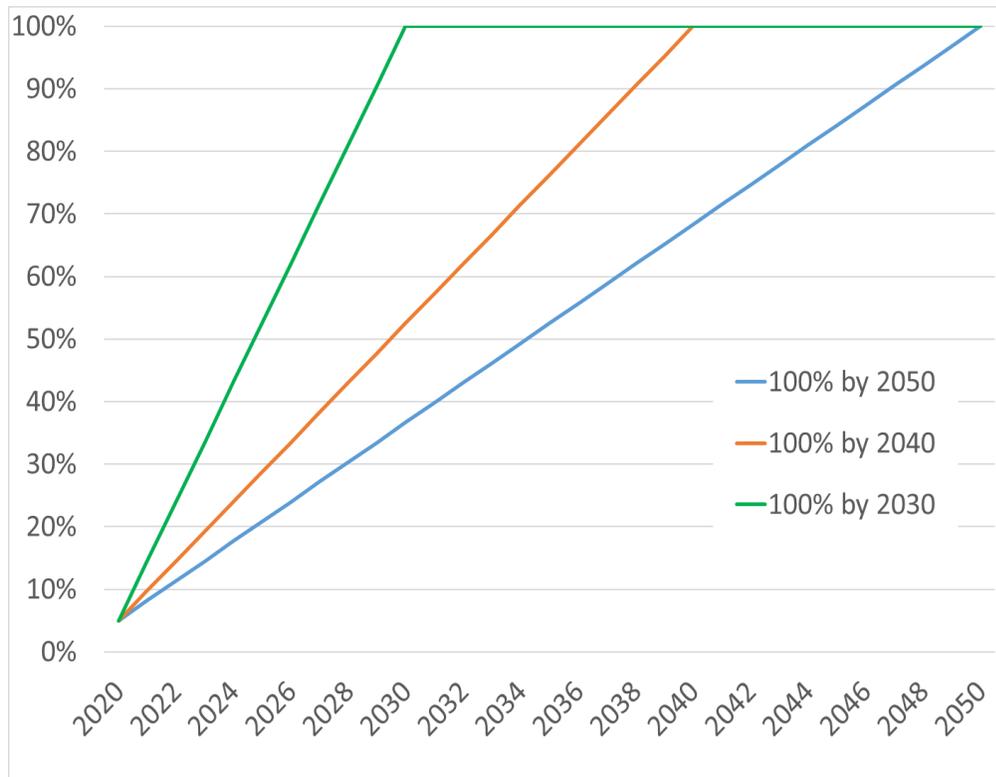
Several alternative backstop policies to ensure technology-neutral decarbonization could work

Potential Policy Approaches	Specific Examples for Exploration
Economy-wide or sector-specific carbon pricing or cap-and-trade	Expand RGGI, create heating sector specific cap-and-trade (regional or RI), create economy-wide or sector specific carbon price (RI or regional)
Expand Renewable Portfolio Standard/Clean Energy Standard or create heating sector-specific CES/thermal RPS	Add heating fuels to existing CES (so that renewable fuels can get credit) Expand CES coverage to include heating Create a separate tier of CES focusing on heating sector
Create low carbon fuel standard for heating fuels and separate 100% renewable electricity target	Create heating fuel specific low carbon fuel standard – likely for gas and liquids (but consider interactions with electric sector) Fuel specific or all fuels – e.g. increasing blend requirement causes gas to become more renewable, heating oil to become B100 over time

Each approach has pros and cons – developing a preferred approach for RI will require significant additional analysis

Example of fuel specific decarbonization approach

**Illustrative Biodiesel Blend Mandates:
Decarbonization by 2030, 2040 or 2050**



- Could develop similar **renewable gas blending requirement for natural gas**
- Could also develop a **renewable blending requirement for all heating fuels**
- Could choose **2030, 2040 or 2050 as full decarbonization target**
 - 2030 matches electricity decarbonization target

Some thoughts on pros/cons of various approaches

- All else equal, **leveraging existing programs and regional solutions is likely more efficient** than new state level programs
 - Rhode Island is small
 - Fuel markets (both fossil and decarbonized) are regional/national
 - Administrative burden for some approaches can be significant
- **Cross-fuel programs may be more economically efficient (in theory), but fuel-specific program may be more straightforward**
 - Electricity is complex itself with ISO-NE rules and 100% by 2030 executive order and other states' RPS interactions
 - Adding fuel markets to this may be particularly complex
 - All approaches require essentially full decarbonization across sectors, so potential efficiency gains may be limited
 - Fuel-specific requirements may be more straightforward
 - RI should leverage experience with these approaches elsewhere

Possible policy approaches to **LEARN**

Policy Area	Possible Approach
Gather information	<ul style="list-style-type: none">• Status of <u>current</u> customer heating equipment – type, remaining life, etc.• Cost, performance and applicability of new technologies (ASHP, GSHP)• Collect data via existing programs• Reevaluate periodically
Research	<ul style="list-style-type: none">• Understand how the gas distribution system responds to volume loss• Understand industrial heat needs• Research Renewable Fuel supply limits• Understand opportunities and limitations on GSHPs
Use pilot and demonstration projects	<ul style="list-style-type: none">• To characterize peak impact of ASHP, and options to mitigate (storage, etc.)• To understand technical issues with blending renewable fuels into fossil fuel streams

Possible policy approaches to **INFORM**

Policy Area	Possible Approach
Public information campaigns	<ul style="list-style-type: none">• Create familiarity and share knowledge via utility bill inserts, billboards, online, TV and radio ads
Demonstration projects	<ul style="list-style-type: none">• Publicize projects such as public buildings with decarbonized heat – Town Hall, library, retail, Airbnb, ...• Induction cooking in restaurants
Training and certification programs	<ul style="list-style-type: none">• Improve understanding and willingness of professional installers• May prevent underperforming installations that hurt word-of-mouth reputation
Provide information about qualified installers	<ul style="list-style-type: none">• Database of trained and certified installers

Possible policy approaches to **ENABLE**

Policy Area	Possible Approach
Provide buyer incentives for “all” to encourage all promising solutions	<ul style="list-style-type: none">• Utility rate-basing or financing• Internalize carbon costs• Address adoption barriers (payback per.)
Improve regulatory structures	<ul style="list-style-type: none">• Improve rate design• Don’t incentivize gas growth• Enable a regulatory planning process• Explore a combined energy utility• Decouple incentives; tighten EE standards
Take advantage of “natural” investment opportunities	<ul style="list-style-type: none">• Combine decarbonizing with other work on building envelope or heat system• Opportunities are scarce; don’t waste!
Identify and remove barriers	<ul style="list-style-type: none">• Existing rules and codes; workforce, ...• Build supply capacity
Ensure that uses with few alternatives retain access to needed fuels	<ul style="list-style-type: none">• Consider need for maintaining gas infrastructure to certain industrial sites
Mitigate adverse effects	<ul style="list-style-type: none">• Vulnerable consumers; exposed industries
Keep options open	<ul style="list-style-type: none">• Don’t foreclose them early; may be useful

Possible policy approaches to **PLAN**ning

Policy Area	Possible Approach
Develop a heating transformation implementation plan	<ul style="list-style-type: none">• Use this report as a basis to create a policy roadmap, and specific policy proposals
Expand planning horizons	<ul style="list-style-type: none">• Add 2050 planning horizon for all state-level heating related planning
Use longer-term planning for the electric distribution grid	<ul style="list-style-type: none">• Include 2050 in distribution grid planning; understand cost of future proofing in case more ASHP adoption
Develop a gas system transition plan	<ul style="list-style-type: none">• Include 2050 in planning horizon; develop contingency plans to efficiently unwind (parts of) the gas system if necessary; also plans to bolster system for key zones (e.g., industrial)
Plan a centralized heat pump conversion effort	<ul style="list-style-type: none">• Particularly GSHP deployment could benefit significantly from more coordinated roll out – especially for MicroGeoDistricts
Develop policy solutions for customer groups affected by decarbonization costs	<ul style="list-style-type: none">• Understand and mitigate impacts on energy-intensive industries• Identify negative impacts on certain customer groups; develop mitigation policies

Questions/Discussion

- What are your ideas and your policy priorities?
- Which policy approaches should be pursued?
- What policies should **not** be considered?
- Are there additional policy alternatives that have not been identified?
- **Use the Q&A button if on the webinar link, or *9 if only connected via phone**

Glossary and Acronyms

- **GHG**: Greenhouse gas
- **ASHP**: Air source heat pump
- **GSHP**: Ground source heat pump
- **Renewable Gas**: Methane made from renewable sources, e.g., landfill gas, anaerobic digesters, gasified biomass, Power2Gas
- **Renewable Oil**: Oil made from renewable sources, e.g., waste cooking oil, oil crops, Power2Liquids
- **P2Fuel** (also P2Gas, P2Liquid): Power-to-fuel processes for synthesizing gas or liquid fuels using renewable electricity
- **TWh**: Terawatt-hour = one million MWh = one billion kWh, a unit of electric energy
- **MW**: Megawatt, a unit of electric capacity (rate of delivering electric energy)
- **MMBtu**: Million Btu, a unit of heat energy

THE POWER OF **ECONOMICS**

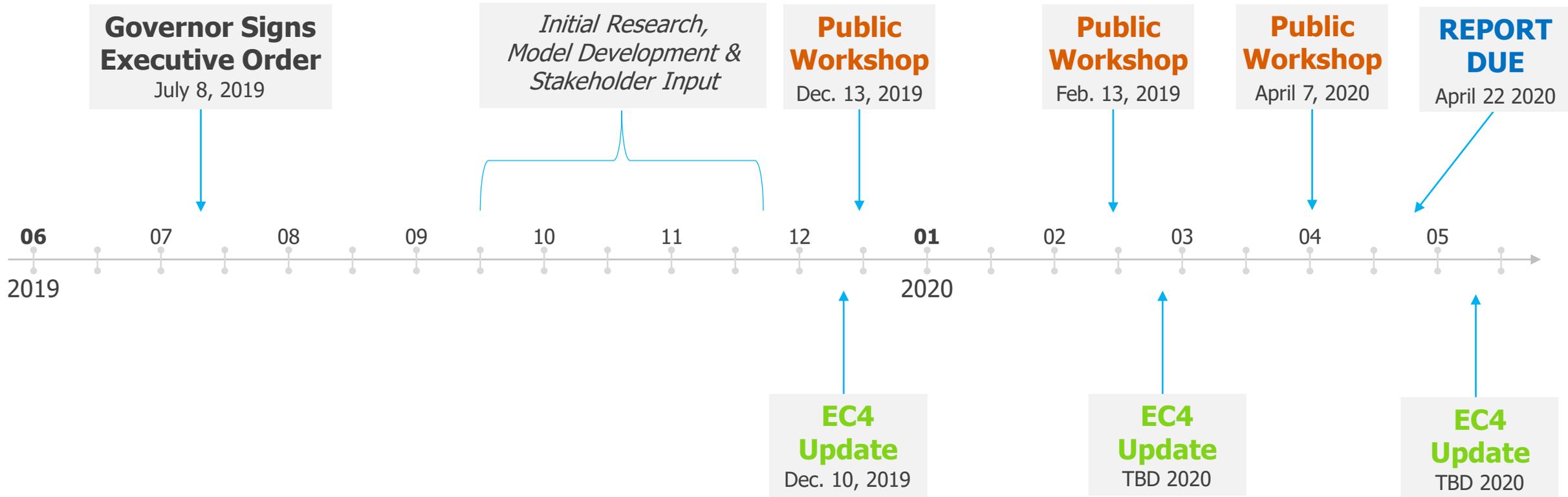
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Project Timeline

Report due by April 22, 2020



Please note that all 2020 dates are subject to change.



Save the Date

HST Final Report

April 22, 2020

Report will be available here:
www.energy.ri.gov/HST



HST Webpage

www.energy.ri.gov/HST/

Workshop materials and final report
will be posted on this webpage.

Thank You

✉ Energy.Resources@energy.ri.gov

*Please note new email address for
public comment.*

We invite you to attend, contribute,
and help shape pathways to a
clean, reliable and affordable
heating future!

