Puget Sound Energy (PSE) GRC Settlement Study: Regional Context

Literature Review (Updated DRAFT)

June 2023

Energy+Environmental Economics

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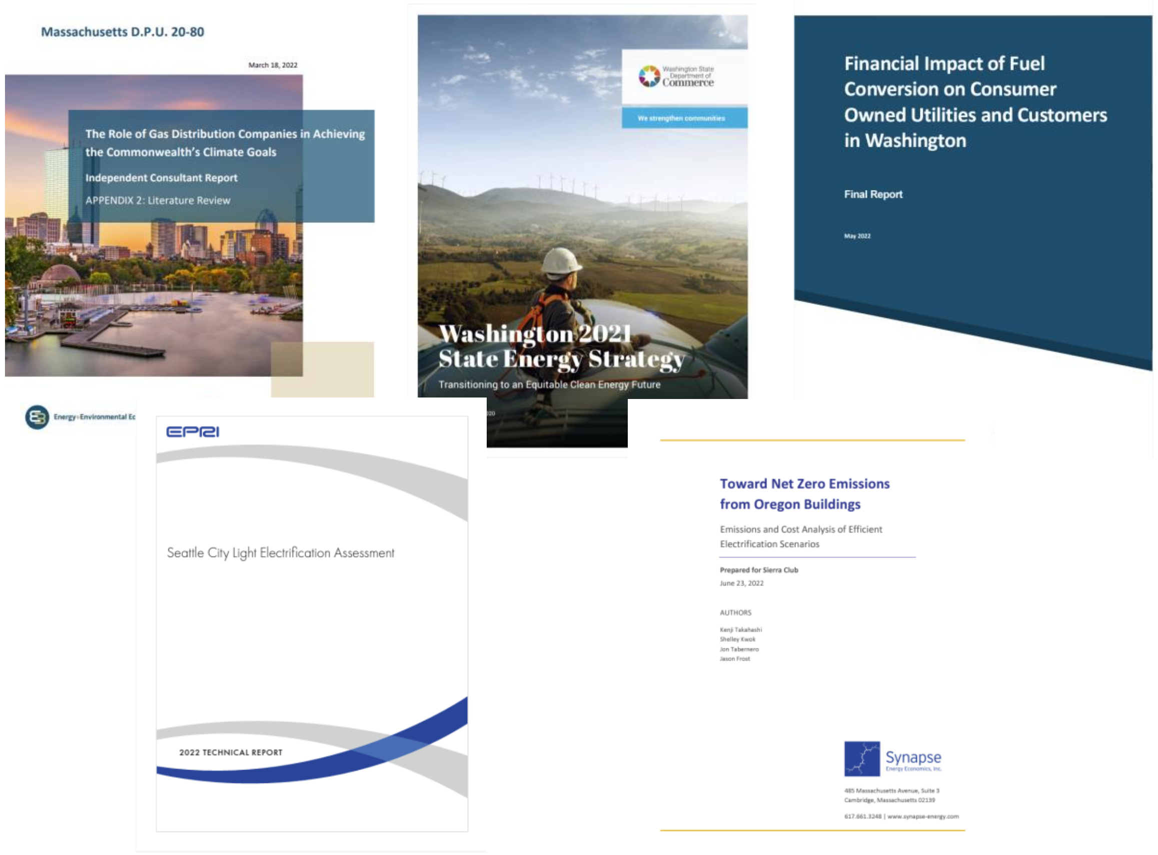
Literature Review Study Overview

- Objective: Draw findings on decarbonization technologies, economy-wide decarbonization scenarios, utility and customer impacts, and regulatory and policy proposals
- E3 conducted a literature review of decarbonization strategies studied and implemented in the U.S. and abroad with an emphasis on Pacific Northwest decarbonization findings and technical studies
- This review is built upon E3's previous work with a focus on the Pacific Northwest, complimented with several new studies in the region:
  - 2021 Washington State Energy Strategy
  - 2022 E3-Commerce study on Financial Impact of Fuel Conversion on Consumer Owned Utilities and Customers in Washington
  - 2022 Synapse-Sierra Club study on Toward Net Zero Emissions from Oregon Buildings
  - 2022 EPRI Seattle City Light Electrification Assessment

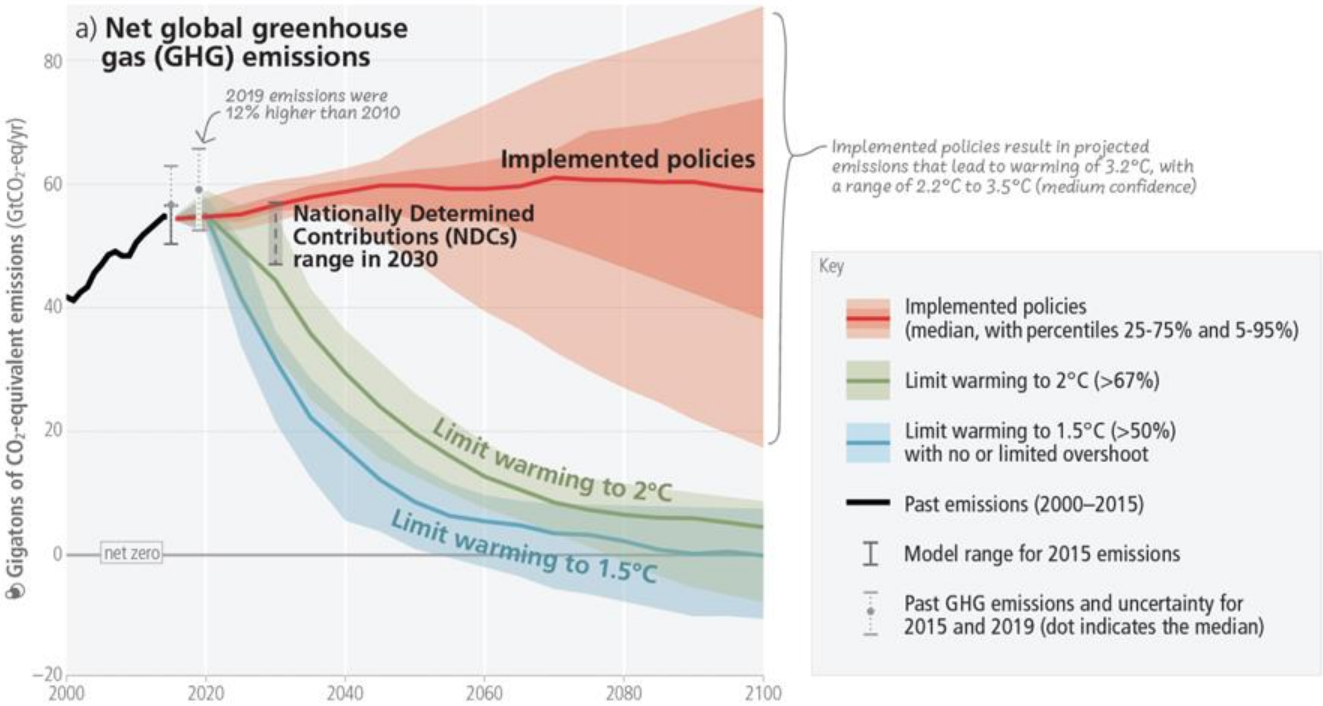


Key literature findings & takeaways for Pacific Northwest

The impetus for gas decarbonization is the global challenge of mitigating climate change

- **Parties to the Paris Agreement are committed to keeping global temperature rise "well below 2 degrees Celsius" and to "pursue efforts to limit the increase to 1.5 degrees Celsius"**
  - Practically, this means carbon neutrality must be achieved globally by mid-century, with sustained negative emissions beyond

- **Jurisdictions across the U.S. and abroad strive towards achieving the goals of the Paris Agreement.**
  - In response, several gas utilities in the US and abroad have been studying, planning, and implementing changes to their gas supply portfolios and business models to explore how to align with a net-zero future.



Source: IPCC Sixth Assessment Report (AR6), Synthesis Report, Summary for Policymakers

States in the Pacific Northwest act on the global challenge of mitigating climate change

Washington Climate and Clean Energy Targets

Climate Target (Climate Commitment Act, 2021)

- 95% below 1990 levels by 2050

Clean Electricity Targets (Clean Energy and Transformation Act, 2019)

- No Coal by 2025
- Carbon-neutral Electricity by 2030
- 100% Clean Electricity by 2045

Washington Clean Energy Transformation Act

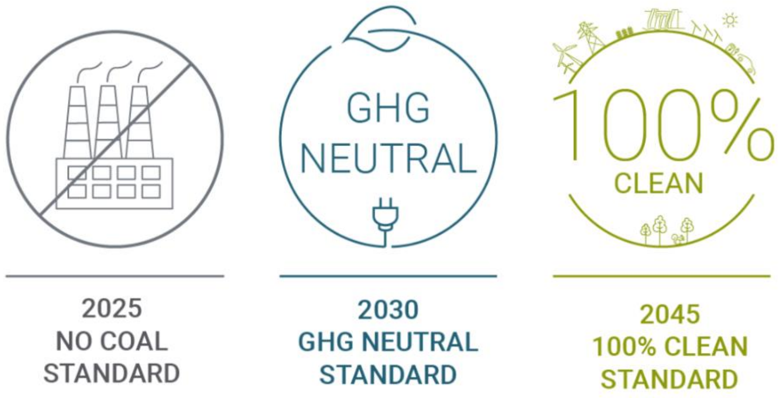


Image credit: Washington Department of Commerce

Oregon Climate and Clean Energy Targets

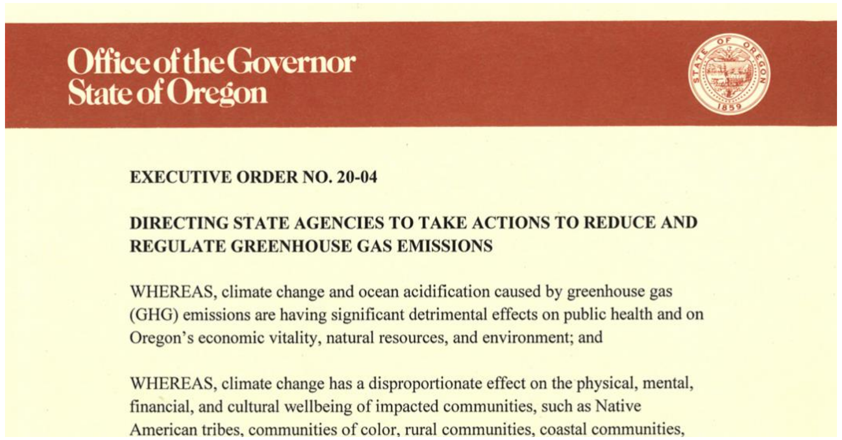
Climate Targets (E.O. 20-40 by Gov. Brown, 2020)

- 25% below 1990 levels by 2035
- 80% below 1990 levels by 2050

Clean Electricity Targets (Clean Energy Targets bill HB 2021)

- 80% below baseline emissions levels by 2030
- 100% carbon-free by 2045

Oregon Executive Order No. 20-40



Office of the Governor
State of Oregon

EXECUTIVE ORDER NO. 20-04

DIRECTING STATE AGENCIES TO TAKE ACTIONS TO REDUCE AND REGULATE GREENHOUSE GAS EMISSIONS

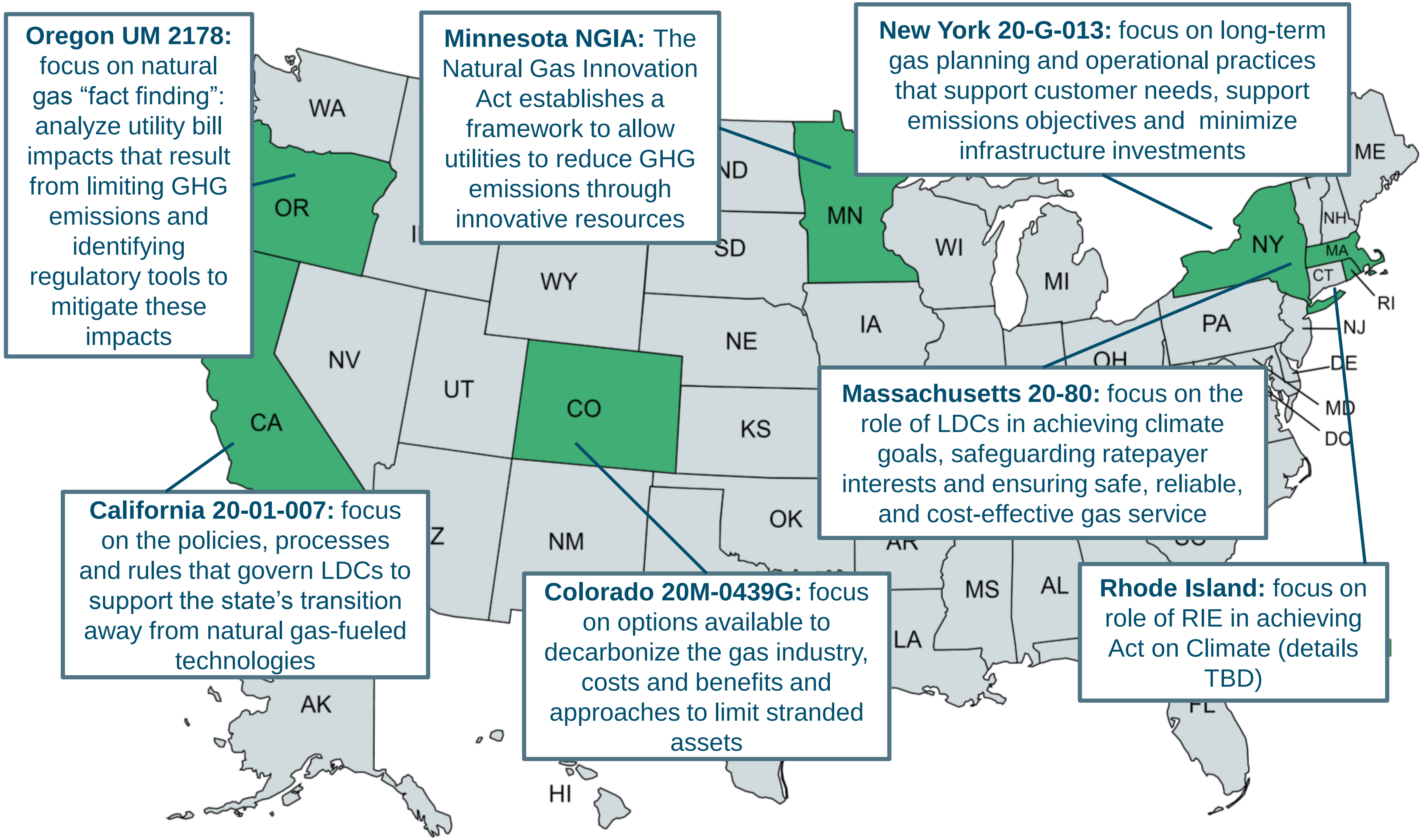
WHEREAS, climate change and ocean acidification caused by greenhouse gas (GHG) emissions are having significant detrimental effects on public health and on Oregon's economic vitality, natural resources, and environment; and

WHEREAS, climate change has a disproportionate effect on the physical, mental, financial, and cultural wellbeing of impacted communities, such as Native American tribes, communities of color, rural communities, coastal communities,

Image credit: Oregon Department of Environmental Quality

Several states have started investigating the effects of climate change mitigation on the natural gas industry

- **Several states have begun to explore the role of gas utilities in meeting climate objectives**
- **Proceedings explore solutions to mitigate bill impacts and balance competing objectives**
  - (i.e., safety, reliability and stranded costs vs rapid transition to state climate targets)
- **In the Pacific Northwest, utilities in Oregon are evaluating the utility bill impacts from reducing GHG emissions from the gas system**



Studies investigating how to decarbonize natural gas end-uses show several key commonalities

Commonalities found throughout literature:

Energy efficiency is a central component of decarbonization strategies. All existing decarbonization scenarios studied, both in the U.S. and abroad, result in flat to declining gas sales through a combination of high energy efficiency and fuel switching.

Gas can be an important component of a decarbonized energy system, particularly in supporting electric reliability and delivering heat during cold-snaps. Studies from the U.S. and abroad have identified hybrid systems as a potential solution, few studies have evaluated customer, business/regulatory implications of these choices.

Biomethane costs are significantly more expensive than natural gas and may be more expensive than low-carbon electricity as a fuel, after factoring in building equipment efficiency. Pacific Northwest has limited access to local bio-RNG feedstocks and would likely need to import these fuels from outside the region.

Alternative strategies, such as *hydrogen* and *networked geothermal*, are increasingly studied across the U.S. International studies show various outcomes on the role of hydrogen in buildings. Some find that hydrogen could have a significant role, while others emphasize cost and limited commercialization as key barriers.

Most studies find that *electrification* can efficiently convert electricity to low-temperature heat while making strides toward climate goals when electricity is decarbonized. However, studies also note how electrification requires high building retrofit costs and can result in significant electric grid impacts, particularly during cold weather.

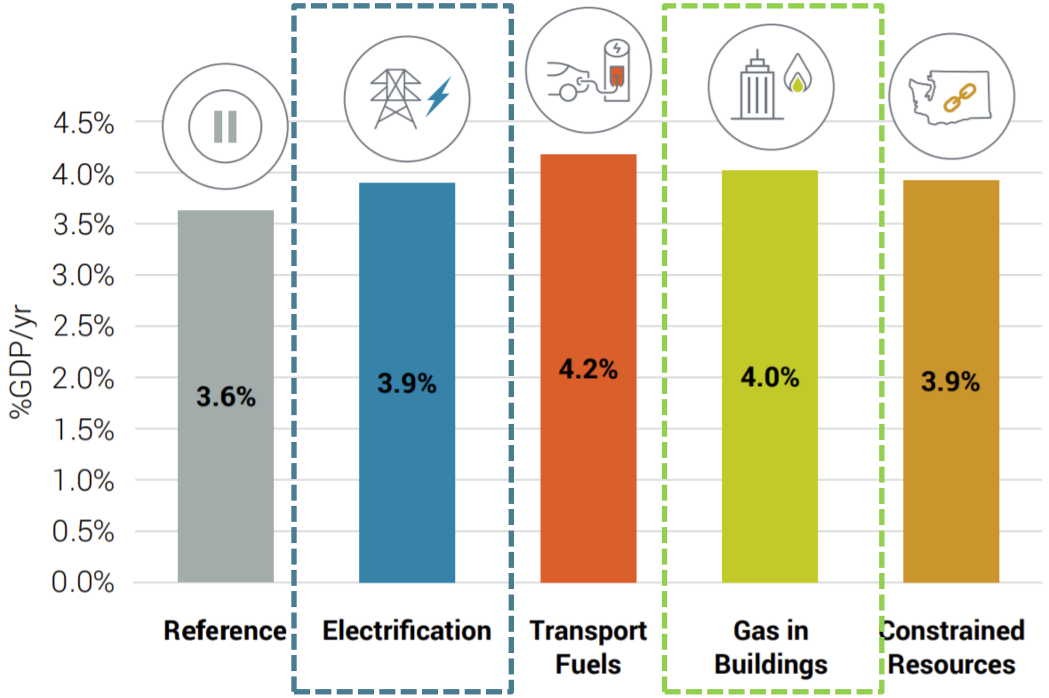
Decarbonization literature emphasize a combination of four pathways to decarbonizing natural gas end-uses

	Potential advantages	Potential drawbacks
Renewable Gas	Repurposes existing infrastructure with minimal consumer disruption, fuel diversity/reliability	High fuel costs, high feedstock needs, land-use constraints, not commercial at scale, potential methane leaks, criteria pollutants
Hybrid electrification	Commercially available, utilizes existing infrastructure, reduces demand for expensive gas, reduces grid impacts	Requires substantial regulatory adjustments, reduces gas system utilization while maintaining capacity needs and system costs
Networked Geothermal	Higher efficiency due to sharing of heating and cooling loads across buildings, reduces electric grid impacts	Relatively new low-carbon strategy in the U.S., high infrastructure investment costs, not suitable for all locations
Electrification	Commercially available, complementary to decarbonized electricity, improves indoor & outdoor air quality	Requires retrofits and high upfront capital costs, potential electric peak load impacts, may result in equity issues/stranded costs

Washington 2021 State Energy Strategy found that building electrification is a lower-cost solution for decarbonizing Washington's buildings

+ **The Washington 2021 State Energy Strategy identified building electrification as a lower-cost solution to achieving the state's greenhouse gas emission targets compared to other strategies**
  - Electrification leverages a clean electricity supply to decarbonize the building sector
  - Electrification vs. Gas in Buildings scenarios show that electrification of buildings lowers costs over retaining gas uses
  - Gas in Buildings is different from a scenario considering dual-fuel heat pumps as it assumes existing buildings that use only gas for heating will continue to do so through 2050
+ **The State Energy Strategy did not evaluate in detail peak load impact and consumer cost impact from electrification**
  - Both building electrification and transportation electrification will contribute to higher peak electric demand

Washington 2021 State Energy Strategy
Average Annual Energy Expenditure by Scenario



Source: Washington 2021 State Energy Strategy Report (p. 39)

Pacific Northwest has unique opportunities and challenges for gas decarbonization

Key opportunities for Pacific Northwest

- **Relatively mild climate on the west of the Cascades:** heat pumps work very efficiently in mild climates such as the Pacific Northwest leading to moderate load growth from electrification and less challenging peak impacts to manage
- **Additional demand for air conditioning as summer gets hotter:** many homes in the Pacific Northwest do not have air conditioning currently. As the summers become warmer, the need for AC may drive up the adoption of heat pumps given their ability to provide both cooling and heating
- **Peak impact mitigation from energy efficiency:** Electric heating is already prevalent in Pacific Northwest. It presents the opportunities to mitigate the peak impact from electrification by replacing current resistance heating with heat pumps

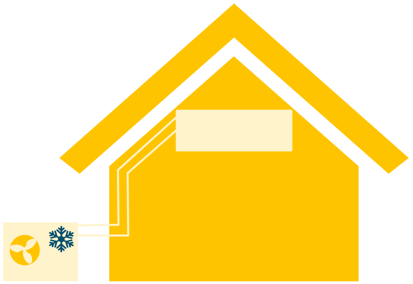
Key challenges for Pacific Northwest

- **Increasing electric demand :** peak heat need will increase due to electrification, a near-term challenge given the region's winter-peaking and capacity challenged electric system
- **Constraints on the distribution system:** the increasing electric demand from building electrification, as well as EV charging demand, may add stress to areas where distribution capacity is already constrained
- **Availability and storage of zero-carbon fuels:** Pacific Northwest has lower availability of biomass resources and geology that is not conducive to hydrogen storage; renewable gases are likely to be produced outside the region and delivered via pipeline
- **Long-term gas planning:** Gas decarbonization may lead to a spiral gas rate effect; a managed transition helps mitigate rate impacts

Deep-dive on gas decarbonization strategies

Energy+Environmental Economics

Heat pump technologies are the primary tool utilized in building electrification

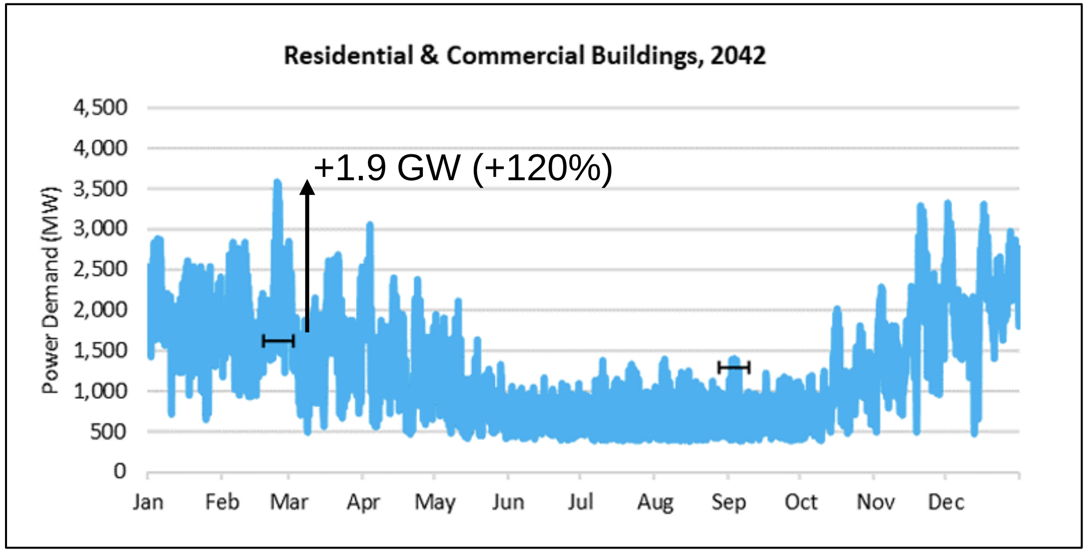
Air Source HP	Cold Climate ASHP	Hybrid HP	Ground Source HP
			
Uses outdoor air as an energy source/sink with electric resistance backup			Uses ground as energy source/sink
Electric resistance backup		Natural gas/propane backup	Backup may not be required
Greatest peak impact	Peak impact	Minimal peak impact	
Low upfront costs	High upfront costs	Lowest upfront cost	High upfront costs

Note: this list is not exhaustive but captures the main types of space heat electrification cited in literature. Electric stoves (induction & resistance), electric clothes dryers (resistance & heat pumps) and water heaters (resistance & heat pumps) are other building electrification technologies.

In Pacific Northwest, building electrification may drive significant increases in winter peak demand

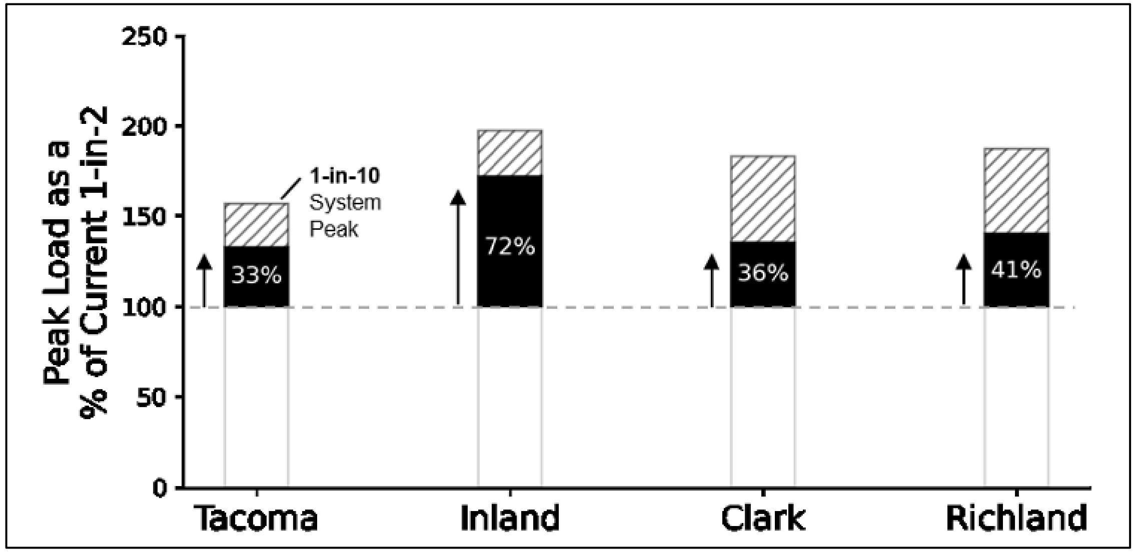
+ **Studies estimate that peak electric demand may double by 2050 under building electrification scenarios without energy efficiency and peak reduction measures**
+ **Majority of demand growth would occur in winter, driving up the peak electric demand of the already winter-peaking systems in the Pacific Northwest**

Building Electrification Load Impact in 2042, Seattle City Light



Source: Figure 3-10 from Seattle City Light Electrification Assessment, 2022 showing a scenario consistent with the goals and policies outlined in the Seattle Climate Action Plan reaching ~90% electrification of residential heating and ~80% of commercial heating without energy efficiency and peak reduction measures

Building Electrification Peak Impact in 2050, Selected Consumer-Owned Utilities



Source: *Figure 3-7 from E3's 2022 report on Financial Impact of Fuel Conversion on Consumer Owned Utilities and Customers in Washington showing peak impact from adopting standard air-source heat pumps under the trajectory envisioned in the Electrification Scenario of the 2021 Washington State Energy Strategy*

However, there are discrepancies among studies in the electric system peak impacts from building electrification

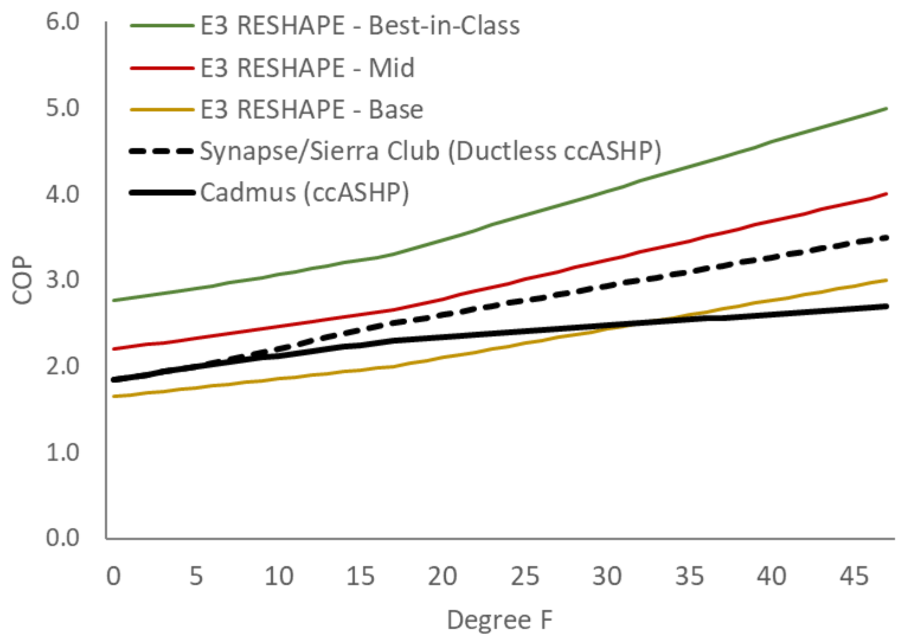
- **PNW studies all project moderate annual load growth under high levels of building electrification due to the high efficiency of heat pump in providing space heating in the relatively moderate climate**
- **Estimate of peak demand impact from building electrification vary among studies**
  - *Peak demand estimate from the SCL Electrification Assessment study* is on the higher end, but its methodology is *unclear* based on the report
  - *Synapse's 2022 Towards Net Zero Oregon study* is on the lower end, but we think it may have *underestimated* the peak impact
    - It likely overestimated the efficiency gain from replacing electric resistance with heat pumps by applying an average space heating demand per household regardless of heating fuel types, where in practice smaller homes tend to use electric resistance heating and larger homes tend to use gas for heating
    - It makes an optimistic assumption about heat pump performance by assuming no electric resistance backup is used even at the lowest temperature of ~0°F

Comparison of Building Electrification Impacts in the PNW Studies

	2021 Washington State Energy Strategy (SES)	E3-Commerce Study on Consumer-Owned Utilities in Washington	Seattle City Light Electrification Assessment	Towards Net Zero Oregon
End year of the study	2050	2050	2042	2050
Heat pump penetration by the end year (scenario name)	~90% (Electrification Scenario)	~90% (Modified SES Electrification Scenario assuming heat pumps instead of electric boilers for commercial buildings)	100% (Scenario 3: Full Adoption of Electrification Technologies)	100% (Both 2025 and 2030 Sales Target Scenarios)
Load Growth vs. 2019/2020	+37%	+7-13% (varies by utility)	+33%	+13%
Peak Growth vs. 2019/2020	N/A	+33-72% (varies by utility)	+144%	+11%

Cold climate heat pumps can operate at high efficiencies during cold winters, reducing peak impacts

Measured ccASHP Coefficients of Performance Used in Pacific Northwest Studies



Both black COP curves are based on measurements by Cadmus, Cold climate heat pumps can operate at low temperature ranges at efficiencies higher than conventional heat pumps and electric resistance.

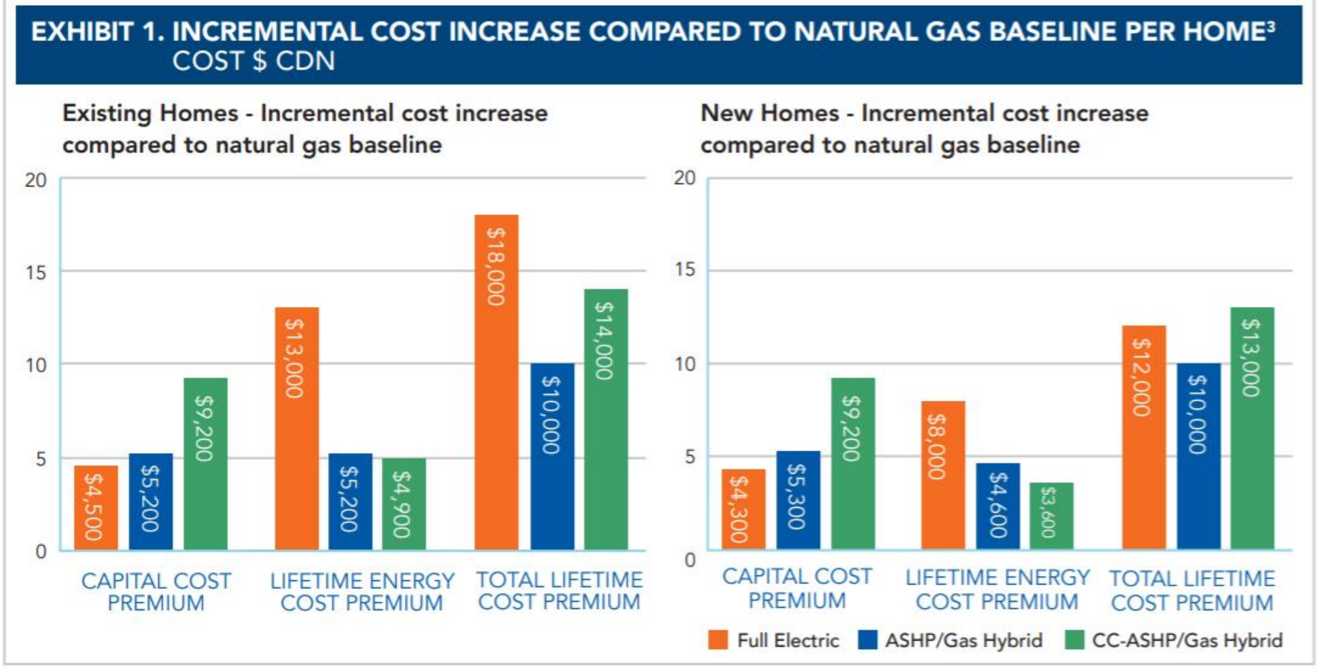
- **In 2021, the US Department of Energy (DOE) launched a technology challenge to accelerate performance of cold climate heat pump (ccHP) technologies**
  - The Challenge sets stretch goals for ccHPs to achieving COP greater than 2.1 at 5°F and optimized for -15°F operation
  - In 2022, DOE announced that one prototype that achieved the Technology Challenge's standards by delivering 100% heating at 5°F, and 70% to 80% heating at -5°F and -10°F.

Sources: Cadmus Group (2022) Residential ccASHP Building Electrification Study; Cadmus Group (2016) Ductless Mini-Split Heat Pump Impact Evaluation; E3 using NEEP specification list for cold-climate ASHPs

Several studies and programs begin to address the potential of hybrid strategies in North America as well

MaRS Cleantech Future of Home Heating Study for Ontario, Canada (2018)

✓ Lifetime energy costs for a hybrid scenario in *existing homes* in Ontario, Canada, are significantly lower than for a full-electric system while providing flexibility



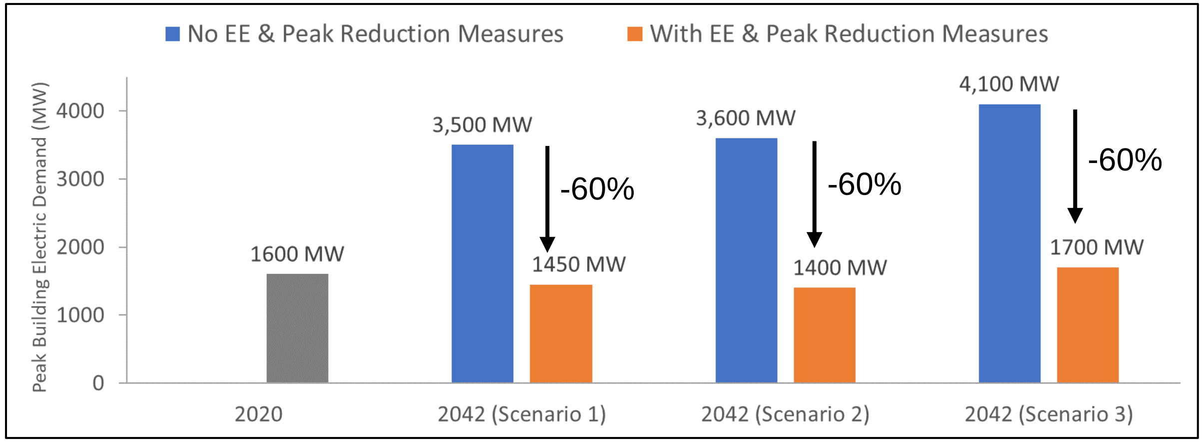
Several recent studies and programs emphasize the benefits of a hybrid strategy in cold climates regions:

- Climate Action Tracker (2022) found that hybrid systems as replacement for existing boiler/furnaces could achieve **rapid transition** to low carbon heating.
- EPRI Seattle City Light Electrification Assessment (2022) found that with dual-fuel space heating options (which employ fossil-fueled auxiliary heat at lower temperatures and do not affect peak hours) **helps limit impacts on system peak.**
- ACEEE Analysis of Electric and Gas Decarbonization Options for Homes & Apts. (2022) found that electric heat pump paired with alternative fuel backup for below 5°F **minimize the average lifecycle equipment costs** in relatively cold climates
- Non-profit CLASP (2022) found that a hybrid heating strategy focused on **air conditioning replacement** could cut national heating costs by $13.6 billion annually.
- The Massachusetts Clean Energy and Climate Plan (2022) offers a **plan that is based on a portfolio** of hybrid heating technologies alongside all-electric solutions.
- HydroQuebec and Energir in Canada (2021) engaged in a **dual energy partnership** to limit the impact of electric heating on peak periods.

Pacific Northwest has opportunities to manage large electric peak loads from electrification

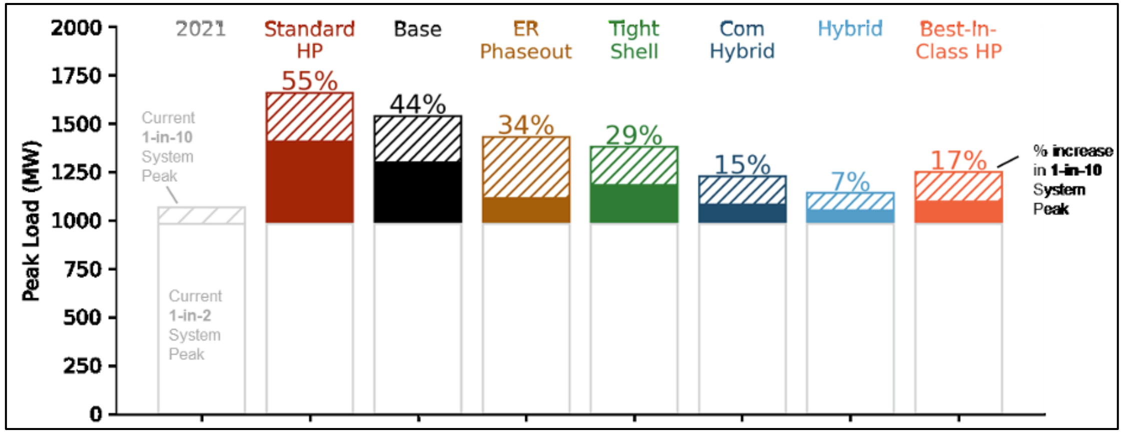
- **Pacific Northwest already has relatively high penetration of electric heating compared to other regions with similar climate, an opportunities for managing peak impact from heating electrification**
  - Electric heating makes up ~40% of existing residential heating in Washington and ~50% in Oregon
- **Replacing existing electric resistance heating with more efficient air-source heat pumps could significantly alleviate peak impact from heating electrification**
- **Other peak reduction measures such as adopting dual-fuel heat pumps, more efficient cold-climate heat pumps and improving building shells can also be effective peak mitigation measures**

Building Electrification Peak Impact with EE & Peak Reduction Measures in 2042, Seattle City Light



Source: Data based on Figures 3-7, 3-10, 3-13 and 3-15 from Seattle City Light Electrification Assessment, 2022. Scenario 1: Moderate Market Advancement, Scenario 2: Rapid Market Advancement, Scenario 3: Full Electrification by 2030

Building Electrification Peak Impact with Peak Reduction Measures in 2050, Tacoma Power



Source: *Figure 5-3 from E3's 2022 report on Financial Impact of Fuel Conversion on Consumer Owned Utilities and Customers in Washington*

Networked geothermal may provide benefits in regions with near-term pipeline replacement need; but carries many uncertainties

+ **Networked Geothermal Systems are closed vertical GSHP systems that connect several homes to a central infrastructure.**
+ **They provide an alternative business model for gas utilities with aging gas infrastructure that needs replacement in the near term, such as the Northeast**
  - However, there may not be as many opportunities in the **Pacific Northwest**, where gas infrastructure is relatively new.
+ **Advantages include minimization of the weather dependency of electric heating and the potential for load sharing between buildings.**
+ **Key uncertainties however exist with regard to cost and feasibility of networked geothermal systems**
  - Networked geothermal systems do not exist at scale and current evidence suggests that systems are expensive to install and highly dependent on geological conditions.
  - In addition, significant challenges exist with regard to system planning and customer choice as installations would need to happen at block or neighborhood scales.

Networked Geothermal utility pilots
Several gas utilities in the U.S. are exploring the concept of networked geothermal systems:
- Eversource in Massachusetts plans to pilot a networked geothermal demonstration project in several types of neighborhoods (total of 140 units with estimated installation costs of $10 million).
- National Grid in Massachusetts submitted a Geothermal Program Implementation Plan in May 2022, proposing up to four shared loop geothermal networks across its service territory at cost of $15.6 million.
- In Long Island (NY), National Grid launched a geothermal system connecting 10 homes to a shared system, gathering data on cost, effectiveness and customer satisfaction.

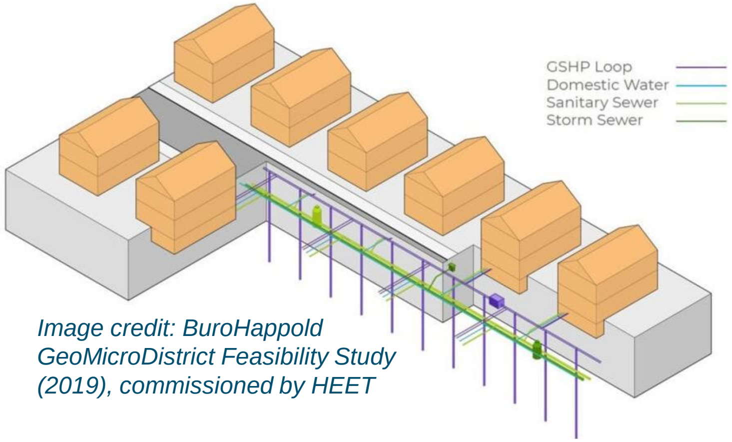
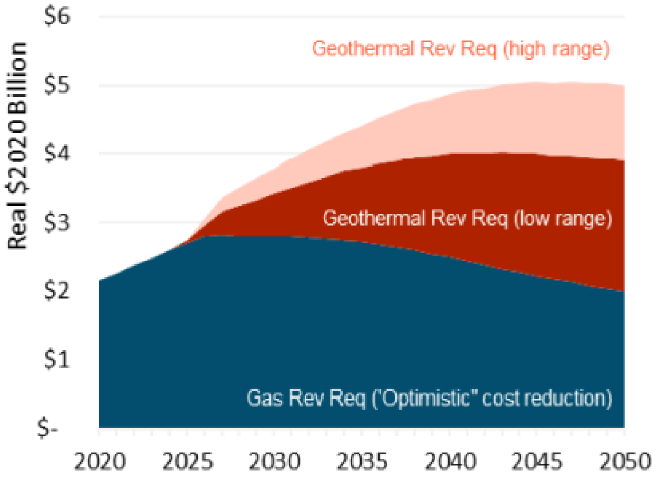


Image credit: BuroHappold GeoMicroDistrict Feasibility Study (2019), commissioned by HEET



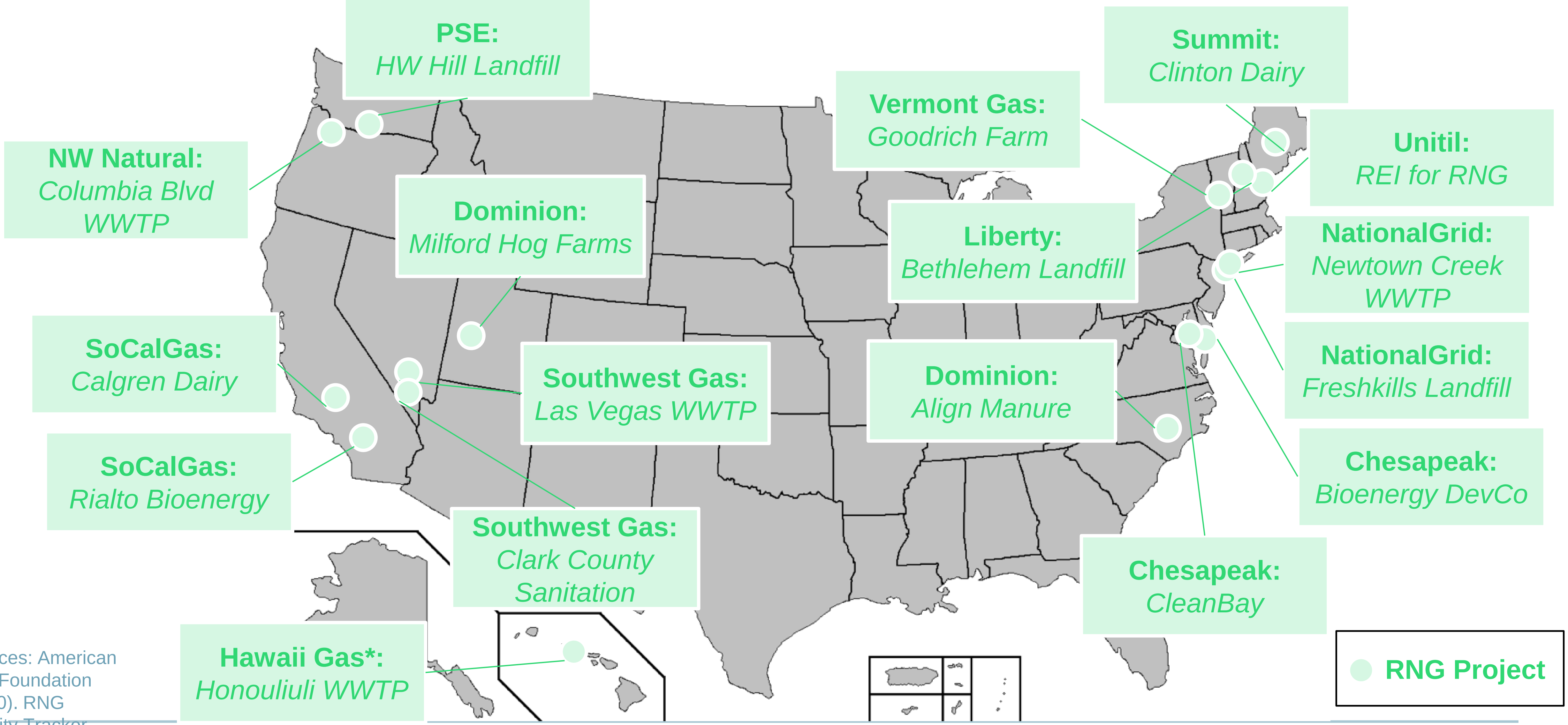
Source: E3 & ScottMadden (2022). 20-80 Decarbonization Pathways Report. Total LDC revenue requirement in Massachusetts with approximately 40% of customers converted to networked geothermal in 2050.

Several sources of decarbonized gas are considered throughout literature

Biomethane based		Hydrogen based	
Waste biogas	**Gasification of biomass**	**Hydrogen**	**Synthetic Natural Gas (SNG)**
Sources: Municipal waste, manure, landfill gas	**Sources:** Agriculture and forest residues, and purpose grown crops, e.g. switchgrass;	**Sources:** Electrolysis + zero-carbon electricity or Steam Methane Reforming of natural gas with Carbon Capture and Sequestration	**Sources:** Renewable hydrogen + CO_2 from biowaste (bi-product of biofuel production) and/or direct air capture (DAC)
Constraints: Very limited supply	**Constraints:** Limited supply and competing uses for biofuels	**Constraints:** Limited pipeline blends (7% by energy) without infrastructure upgrades, cost	**Constraints:** Limited commercialization, low round-trip efficiency, high cost

Note: The definitions of decarbonized gas sources vary across the literature. We use the definitions presented here throughout our study.

Utilities have started to acquire decarbonized gas, initially targeting municipal waste and biogas capture from agriculture



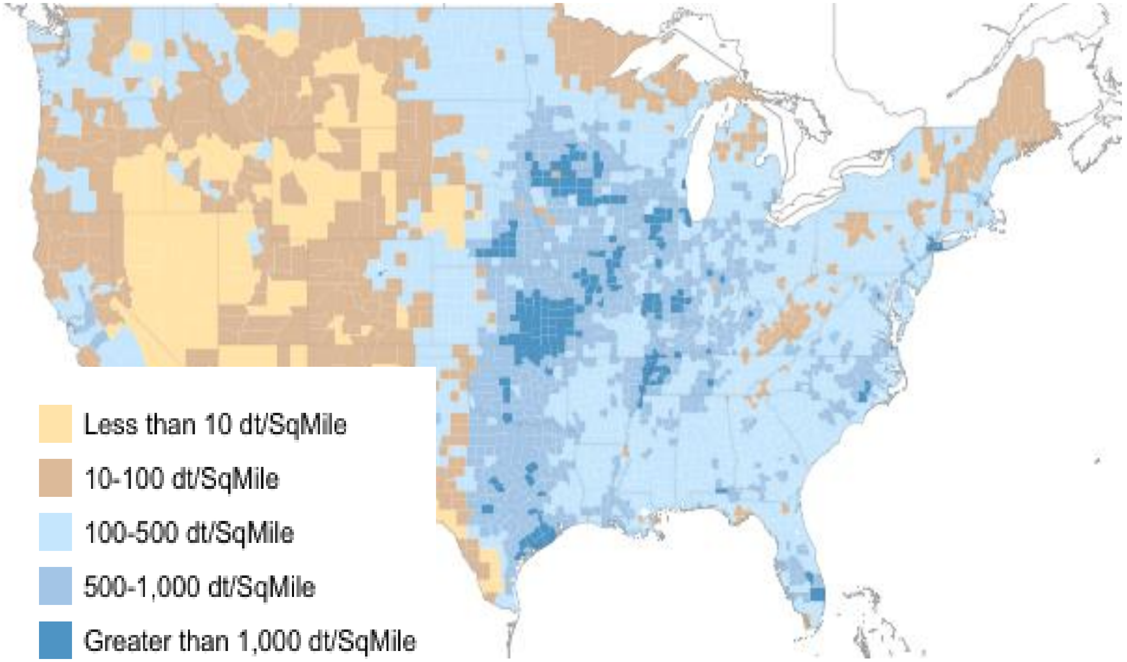
Sources: American Gas Foundation (2020). RNG Activity Tracker

* Hawai'i Gas has been blending up to 15% hydrogen into its gas mix since 1974.

Availability of local feedstock resources for production RNG is limited in the Pacific Northwest

+ **Estimates of decarbonized gas availability vary across the literature but overall show that *feasible availability would meet a relatively small fraction of demand***
+ **The Pacific Northwest is on the mid-to-low range of potential feedstock availability from forestry, wastes, and agricultural resources**
+ **Feedstocks for biomethane face competing demands from other sectors**
  - The California Low-Carbon Fuel Standard (LCFS) market offer credits to low-carbon fuel producers, which results in direct competition for same feedstocks that can be used for biomethane production
  - In a deep decarbonization future, demand for low-carbon liquid fuels such as biodiesel in transportation and industry sectors will also compete for feedstocks for biomethane

The Pacific Northwest is on the mid-to-low range of potential feedstock availability from forestry, wastes, and agricultural resources



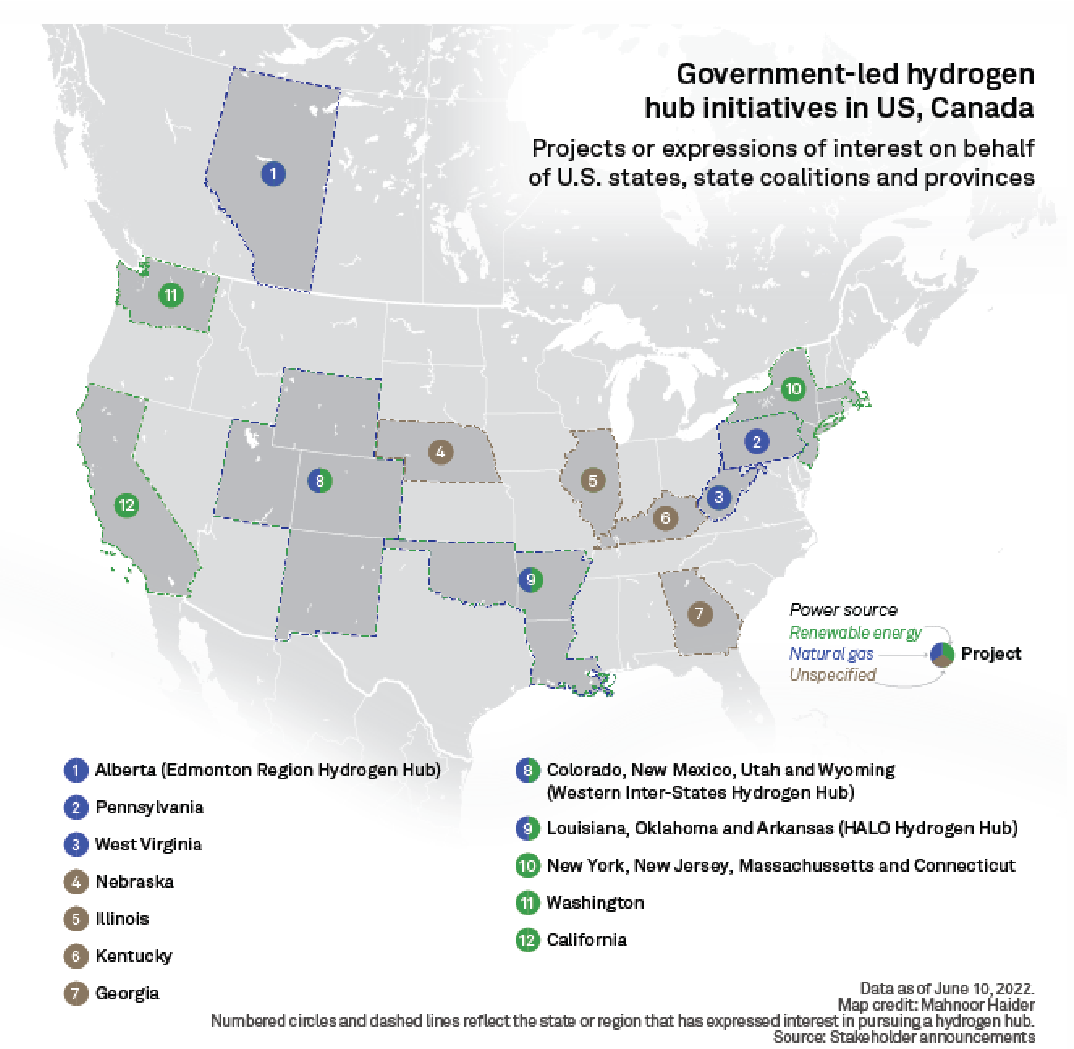
Sources: US Billion Ton Study (2016)

Federal initiatives may boost hydrogen industry in the next decade

+ **Hydrogen has gained renewed attention as an essential clean fuel for the energy transition, particularly for hard-to-electrify sectors**
  - Federal initiatives, including the funding of regional Hydrogen Hubs and the Production Tax Credit announced in the Inflation Reduction Act (IRA) give a strong boost to hydrogen in the next 10 years
  - DOE aims to bring down costs of hydrogen production to $1/kg by 2030, highly increasing the fuel's competitiveness. The IRA's $3/kg PTC may make hydrogen cheaper than natural gas in some areas

Hydrogen Initiatives relating to the Infrastructure & Jobs Act	Federal Funding
Regional Hydrogen Hub Program	$8 billion
Clean Hydrogen Manufacturing and Recycling Initiatives	$500 million
Clean Hydrogen Electrolysis Program	$1 billion

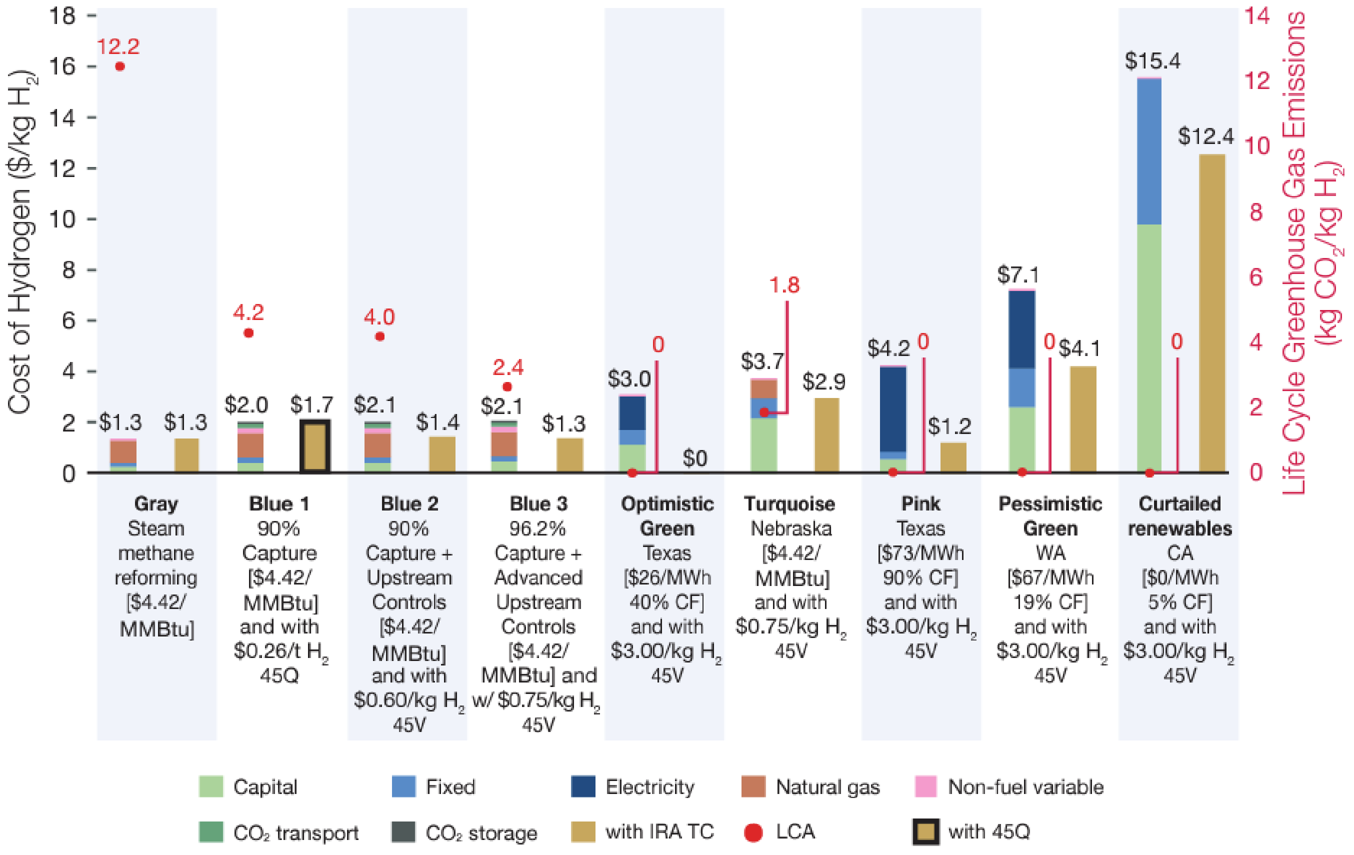
Hydrogen Initiatives relating to the Inflation Reduction Act	Federal Funding
Hydrogen Production Tax Credit	The Hydrogen PTC compensates producers of green hydrogen up to $3 per kilogram, depending on emissions levels



There are several ways to produce hydrogen; "green hydrogen" will likely be the lowest cost in some regions with IRA incentives

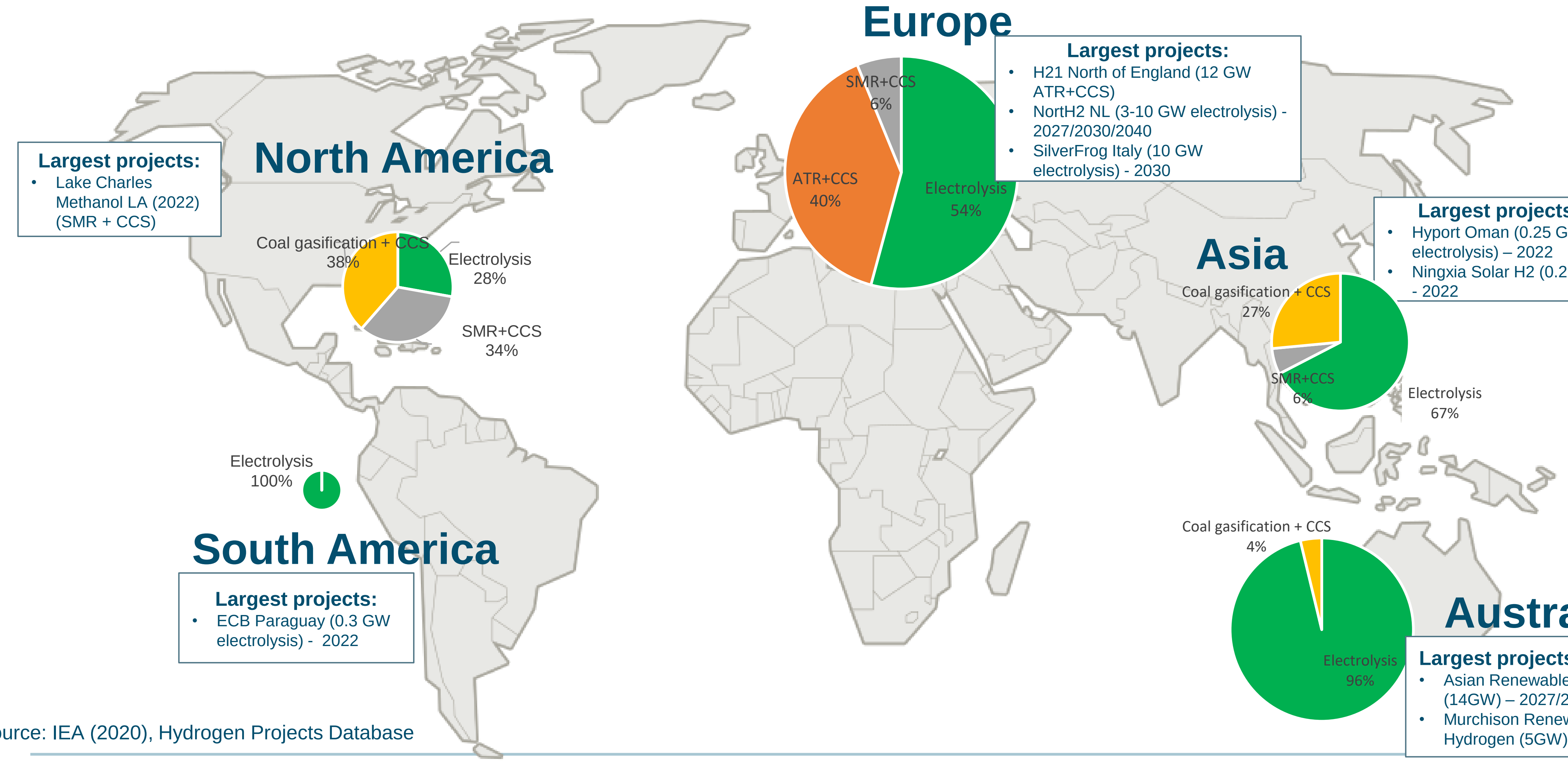
- **Most studies distinguish "blue hydrogen" produced through Steam Methane Reforming (SMR) with CCS (using natural gas) and "green hydrogen" produced through electrolysis with renewable electricity**
  - "Turquoise hydrogen" is produced through methane pyrolysis with inputs of natural gas and zero-emissions electricity
  - "Pink hydrogen" is produced through electrolysis with nuclear power
- **SMR with 90% CCS likely has the lowest production cost; but with IRA incentives, green hydrogen in some regions will likely be most cost competitive**
- **Cost of green hydrogen depend on electrolyzer power cost and capacity factor**
  - The bounds of each curve are traced out by optimistic and conservative alkaline electrolyzer capital cost trajectories

Cost Comparison of Major H2 Production Pathways and with IRA Incentives



Source: Energy Futures Initiative. "U.S. Hydrogen Demand Action Plan," February 2023.

Europe & Australia lead the way in global (planned) low-carbon hydrogen production



North America – Largest projects:
- Lake Charles Methanol LA (2022) (SMR + CCS)

South America – Largest projects:
- ECB Paraguay (0.3 GW electrolysis) - 2022

Europe – Largest projects:
- H21 North of England (12 GW ATR+CCS)
- NorthH2 NL (3-10 GW electrolysis) - 2027/2030/2040
- SilverFrog Italy (10 GW electrolysis) - 2030

Asia – Largest projects:
- Hyport Oman (0.25 GW electrolysis) – 2022
- Ningxia Solar H2 (0.2 GW) - 2022

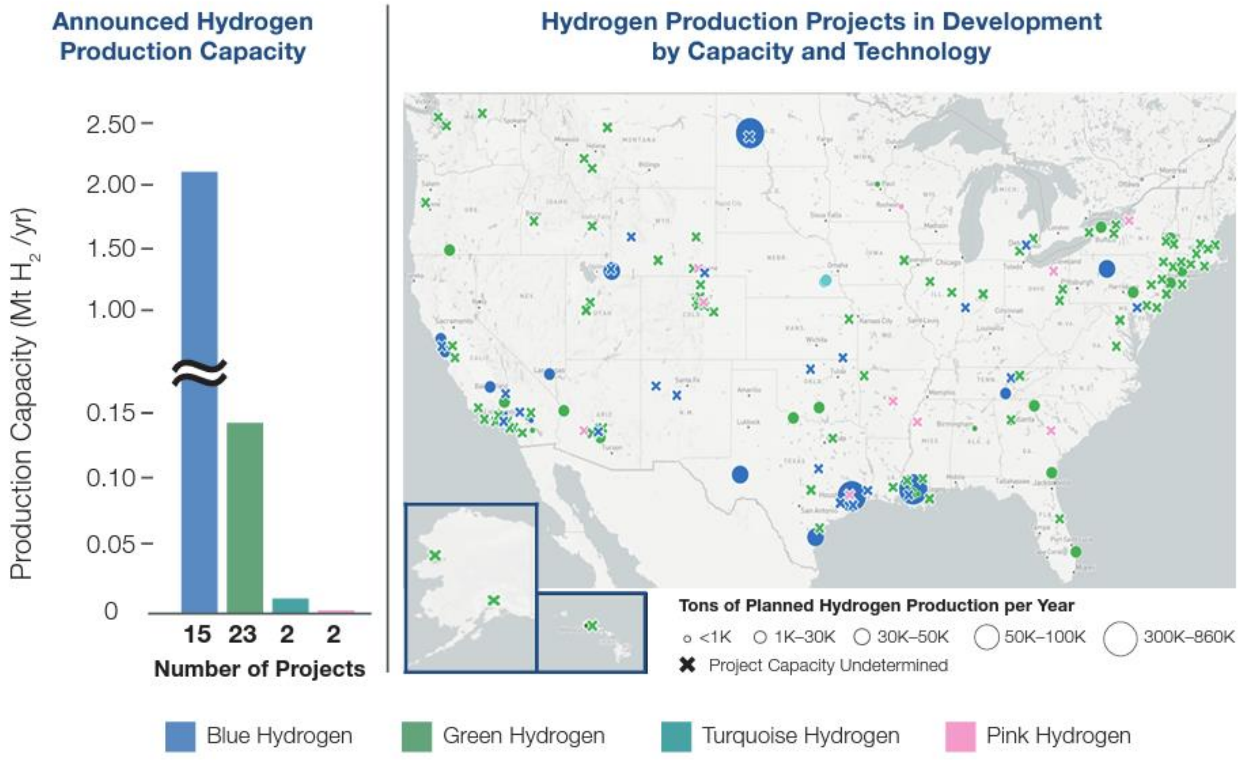
Australia – Largest projects:
- Asian Renewable Energy Hub (14GW) – 2027/2028
- Murchison Renewable Hydrogen (5GW) - 2028

Source: IEA (2020), Hydrogen Projects Database

Clean hydrogen "pilot" program developments are ramping up rapidly in the U.S. in recent years

+ **Hydrogen as a low-carbon alternative for the industrial, transportation, and building sectors**
  - Opportunity to blend hydrogen to decarbonize supply portfolio
    - High concentrations of hydrogen require modifications to existing end-use technologies
+ **More than 177 clean hydrogen production activities has been announced across the U.S.; 47 have declared total production capacity of over 2.2 Mt per year**
  - Enbridge Gas: pilot program with renewable hydrogen produced at a Power-to-Gas facility
  - Fortis B.C: plans to transition to hydrogen and other zero-carbon fuels to consist 10% (in volume) of supply mix in volume by 2030, and 30% (in volume) of supply mix by 2050

Announced Clean Hydrogen Project Activities

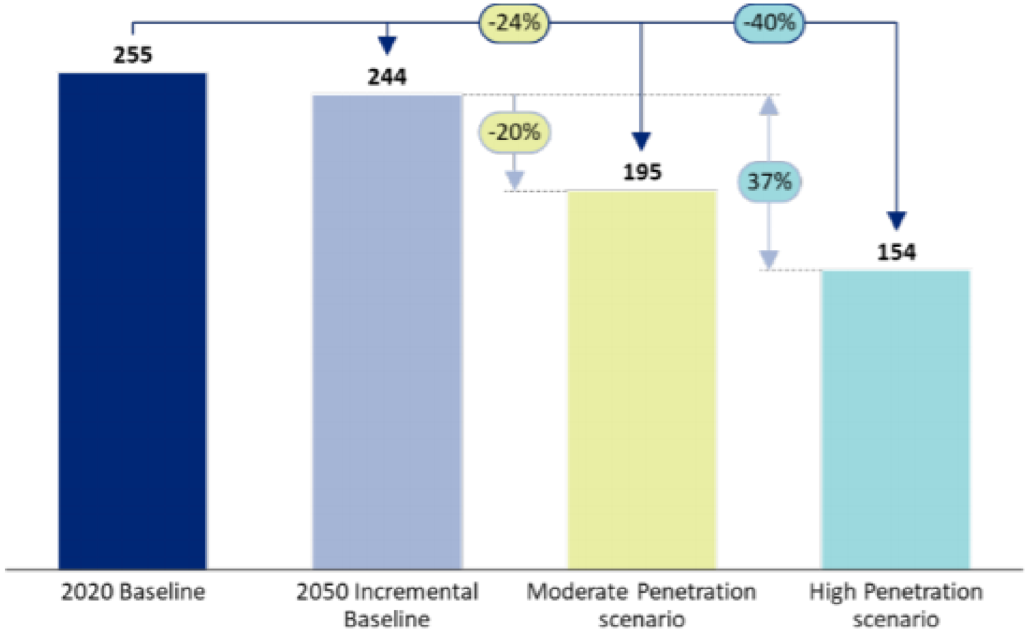


Sources: Energy Futures Initiative. "U.S. Hydrogen Demand Action Plan," February 2023.

Energy efficiency in gas end-uses is pivotal to minimize the cost and technology risks of decarbonized gases

+ **There are numerous high-efficiency gas technologies already on or coming onto the market, which, combined with decarbonized natural gas, can help meet 2050 goals**

A study by AGF found up to 40% CO_2 emissions reductions in the U.S. residential sector from the deployment of emerging natural gas direct use technologies (note: the study did not consider further reduction potential from decarbonized gas)



High Efficiency Direct Use Natural Gas Technologies

End-use	Technology	Commercial availability (year)	Efficiency (EF, AFUE, electric efficiency)
Space heating	**Condensing Gas Furnace**	**Now**	**97%**
	Gas Absorption Heat Pump	**2022**	**140%**
	Energy Star Condensing Gas Boiler	Now	95%
	Gas Absorption Heat Pump Boiler	2022	130%
	Thermal Compression Gas Heat Pump Boiler	2030	160%
Water heating	Gas Storage Condensing	Now	0.77
	Gas Tankless	Now	0.84
	Gas Tankless Condensing	Now	0.95
	Gas Hybrid	Now	0.96
	Solar Thermal with Gas Storage	Now	1.00
	Gas Heat Pump Water Heater	**2022**	**1.30**
	Self-Powered High Efficiency Tankless	2030	1.10
Dryer	**Energy Star Gas Dryer**	**Now**	**3.48**
	Next Gen Energy Star Gas Dryer	2030	4.00
MicroCHP	Gas IC-Engine Driven System 1.5 kW	2022	23%
	SOFC 2.0kW 2030	2030	40%
	SOFC 1.5kW 2030	2030	60%

Source: American Gas Foundation (2019)

A range of optimistic and conservative approaches to key assumptions strongly influence study outcomes

Optimistic perspective		Conservative perspective
The cost of heat pumps decreases with time as markets scale	**Heat pump costs**	Cold-climate heat pumps will continue with a cost-premium over other models
Consumer choices lead to high levels of electrification by mid-century	**Consumer acceptance**	Technology cost premiums lead to lack of consumer incentives to decarbonize
With energy efficiency and demand flexibility, peaks can be substantially reduced	**Electric peak demand impacts**	ASHPs require large amount of supplemental heat, particularly during design load conditions.
Market transformations lead to increased availability of RNG from gasification	**Availability of decarbonized gas**	RNG supply is limited by competing demands for biomass and sustainability concerns
Electrolytic fuels (H2, SNG) come down in cost as markets scale and challenges are overcome	**Availability of hydrogen**	Deployment of hydrogen may be limited by infrastructure or blending challenges
Deep retrofits can reduce space-heating demands with manageable costs	**Building shell improvements**	The costs of deep shell retrofits are high and exceed energy cost savings
Targeted electrification approach can bring down gas system costs significantly	**Gas system cost savings**	There are limited opportunities to save gas system costs due to choice & technical barriers

Utilities will need to balance a combination of GHG reduction strategies while managing key uncertainty

Utility decarbonization plans may include a combination of strategies

E3 Note: Most studies include **building electrification** as a strategy for gas demand reduction

Source: AGA (2022) Net-Zero Emissions Opportunities for Gas Utilities

Key uncertainties and considerations need to be taken into account

+ Availability of renewable gases (e.g., biomethane, synthetic natural gas) and hydrogen production levels
+ Reliance on alternative fuels by other hard-to-decarbonize sectors
+ Emergence of new technologies and cost trajectories of existing technologies
+ Changing energy system reliability and resilience needs
+ Opportunities for electric and gas system collaboration
+ Consumer impacts and influence over customer decisions
+ Equity, stakeholder acceptance and community engagement

Equity, affordability, and community engagement will be key to a successful implementation strategy

Gas utility decarbonization implicates equity and affordability, but the consumer perspective is often not a central focus in utility gas decarbonization studies

+ Most studies focus on societal cost metrics or technology-specific roadmaps
+ Some studies have begun to examine capital cost barriers to low-income building electrification and consumer implications for rising gas prices as customers exit the natural gas system

Decarbonization studies suggest the following practices to ensure consumers, especially those historically excluded from clean energy policy and decision-making, are at the center of future decisions:

+ Address root causes of past inequities in resource distribution or program participation
+ Shift funding to provide increased decarbonization support in impacted communities
+ Ensure information **transparency**, build transparent decision-making and **accountability** processes
+ Directly tie program success to equity
+ Invest in interdepartmental and cross-agency collaboration
+ Build out equitable stakeholder engagement (see below)

Stakeholder engagement should center the communities most impacted by climate change and upcoming policy decisions, but these communities have been underrepresented in the past

+ Decarbonization studies suggest the following to improve community engagement:
  - Hire facilitators
  - Work with community-based organizations and environmental justice groups
  - Compensate contributors for their time and expertise
  - Build community engagement into budget
  - Develop clear and transparent decision-making and accountability processes

Sources: David and Hausman (2021) Who will pay for legacy utility costs?; USDN (2021). Equity and Buildings: A Practical Framework for Local Government Decisionmakers

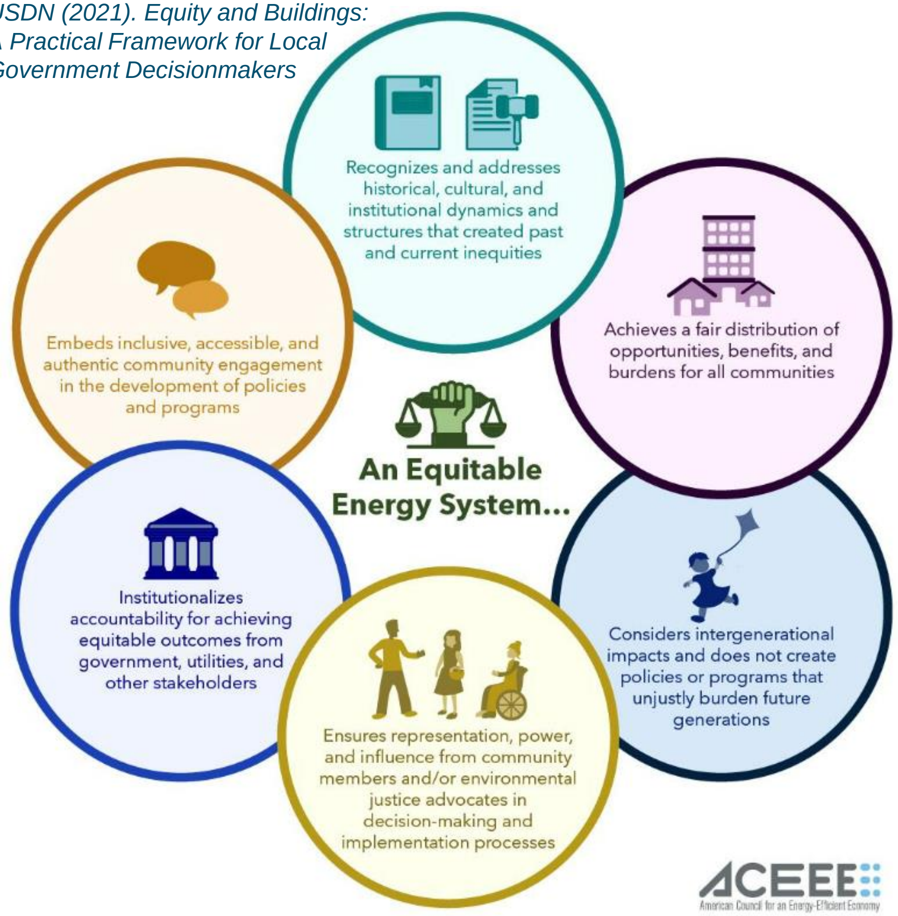


Image credit: ACEEE. Energy Equity Webpage.

Washington needs to access a larger share of the US air-source heat pump market and prepare labor force for the potential market transformation from building electrification envisioned in the State Energy Strategy

- **Across the US, air-Source Heat Pump market has seen rapid growth in the past decade at 10% per year, reaching 4.3 million shipments in 2022.**
  - In the Northwest, ASHP sales and market growth have lagged behind the US average
- **If Washington state achieves the level of building electrification envisioned in the Electrification scenario from the 2021 State Energy Strategy, ASHP sales need to ramp up rapidly to half a million in 2030 and 1.8 million in 2050.**
  - Such pace of electrification would require the state to access a larger share of the US ASHP market while it continues to grow and manufacturers continue to expand productions
  - It is also important to make sure skilled labor force keeps up with and support the potential market growth

Air-Source Heat Pump (ASHP) Market Transformation