Supply Side Resources Technical Working Group #3

2022 Integrated Resource Plan Technical Working Group (IRP-TWG#3)
March 28, 2022

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Forward Looking Statement

This and other presentations made by NW Natural from time to time, may contain forward-looking statements within the meaning of the U.S. Private Securities Litigation Reform Act of 1995. Forward-looking statements can be identified by words such as “anticipates,” “intends,” “plans,” “seeks,” “believes,” “estimates,” “expects” and similar references to future periods. Examples of forward-looking statements include, but are not limited to, statements regarding the following: including regional third-party projects, storage, pipeline and other infrastructure investments, commodity costs, competitive advantage, customer service, customer and business growth, conversion potential, multifamily development, business risk, efficiency of business operations, regulatory recovery, business development and new business initiatives, environmental remediation recoveries, gas storage markets and business opportunities, gas storage development, costs, timing or returns related thereto, financial positions and performance, economic and housing market trends and performance shareholder return and value, capital expenditures, liquidity, strategic goals, greenhouse gas emissions, carbon savings, renewable natural gas, hydrogen, gas reserves and investments and regulatory recoveries related thereto, hedge efficacy, cash flows and adequacy thereof, return on equity, capital structure, return on invested capital, revenues and earnings and timing thereof, margins, operations and maintenance expense, dividends, credit ratings and profile, the regulatory environment, effects of regulatory disallowance, timing or effects of future regulatory proceedings or future regulatory approvals, regulatory prudence reviews, effects of regulatory mechanisms, including, but not limited to, SRRM and the Company’s infrastructure investments, effects of legislation, including but not limited to bonus depreciation and PHMSA regulations, and other statements that are other than statements of historical facts.

Forward-looking statements are based on our current expectations and assumptions regarding our business, the economy and other future conditions. Because forward-looking statements relate to the future, they are subject to inherent uncertainties, risks and changes in circumstances that are difficult to predict. Our actual results may differ materially from those contemplated by the forward-looking statements, so we caution you against relying on any of these forward-looking statements. They are neither statements of historical fact nor guarantees or assurances of future performance. Important factors that could cause actual results to differ materially from those in the forward-looking statements are discussed by reference to the factors described in Part I, Item 1A “Risk Factors,” and Part II, Item 7 and Item 7A “Management’s Discussion and Analysis of Financial Condition and Results of Operations,” and “Quantitative and Qualitative Disclosure about Market Risk” in the Company’s most recent Annual Report on Form 10-K, and in Part I, Items 2 and 3 “Management’s Discussion and Analysis of Financial Condition and Results of Operations” and “Quantitative and Qualitative Disclosures About Market Risk”, and Part II, Item 1A, “Risk Factors”, in the Company’s quarterly reports filed thereafter.

All forward-looking statements made in this presentation and all subsequent forward-looking statements, whether written or oral and whether made by or on behalf of the Company, are expressly qualified by these cautionary statements. Any forward-looking statement speaks only as of the date on which such statement is made, and we undertake no obligation to publicly update any forward-looking statement, whether as a result of new information, future developments or otherwise, except as may be required by law.

Today’s Agenda

- Procedures and Introductions
- Recap from prior TWGs and IRP Process
- Supply Side Resources (Demand Side Resources will be discussed in a subsequent TWG)
  - Conventional Supplies
  - Portland LNG
  - Renewable Natural Gas
  - Hydrogen

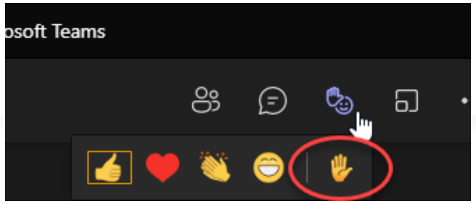
Procedures for Participation

- Please mute your microphones during the presentation, except when commenting and or asking a question
- All participants are muted upon entry into the meeting

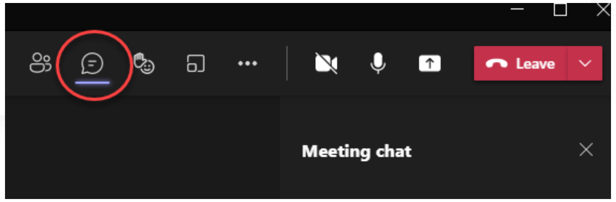
- Cameras are optional and up to each participant to use
- All participant cameras are set to off upon entry into the meeting

- Add a comment or question at any time using the “raised hand” or the chat box

Raised hand function is found in the reactions

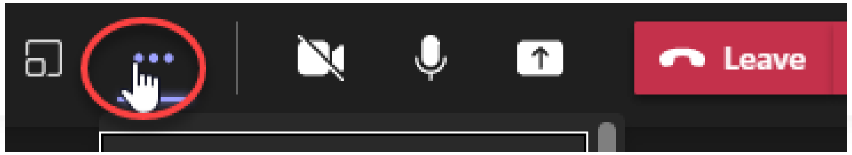


Chat box will open when you click on the conversation bubble



- Microsoft Teams has a live caption function for any participant to use

Click the ellipses, then chose “turn on live captions”



Take 2 Minutes for Safety:

Parking Safety Tips

- Drive slowly & use signals
- Park where there are the **fewest** hazards (examples- other vehicles, pedestrians, stationary objects)
- Make sure you are in a legal space & centered
- Pull as close to the curb as possible
- Look for pull-through spaces
- Check your surroundings before backing in or out of a space
- Fold in mirrors on narrow streets & in smaller spaces

Prepared for IRP Working Group- Not to be used for investment purposes. Adapted from NW Natural Safety Presentations.

2022 IRP Anticipated Timeline

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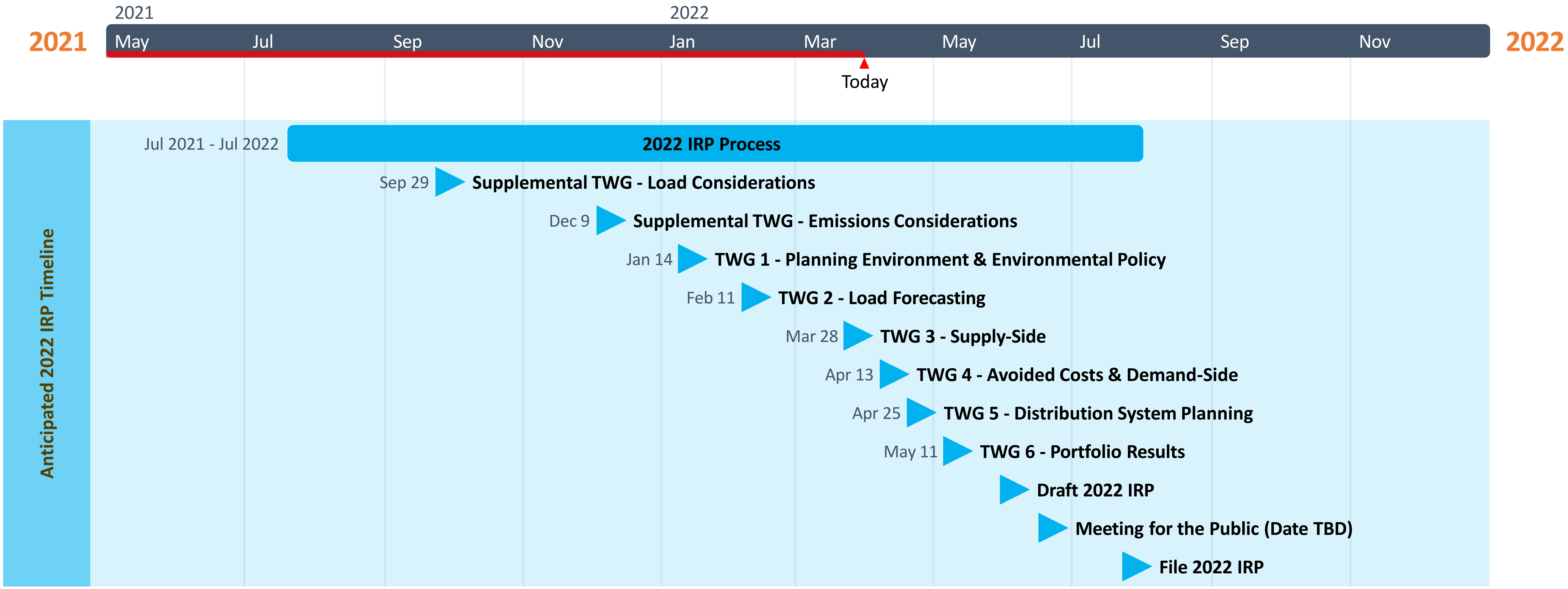

IRP on the NW Natural website

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Find information about NW Natural's IRP on our website

- Integrated Resource Plan page: https://www.nwnatural.com/about-us/rates-and-regulations/resource-planning

Integrated Resource Plan

- Resource planning process +
- IRP working groups & public meetings +
- Current and previous IRPs +
- 2018 IRP - letter from David H. Anderson, NW Natural President and CEO +

Click the tabs to expand each section

IRP working groups & public meetings –

Please feel free to get in touch with us with questions about the IRP, or to be added to a workshop or Technical Working Group (TWG) for our next plan.

All meetings listed below are tentative and subject to change.

Workshops
TBD

2022 IRP Technical Working Groups (TWG)	Date
TWG 1 - Planning Environment and Environmental Policy Presentation - TWG 1 (.pdf) Erratum Notice (.pdf)	January 14, 2022
TWG 2 - Load Forecasting Presentation - TWG 2 (.pdf) Erratum Notice (.pdf)	February 11, 2022
TWG 3 - Avoided Costs and Demand-Side Resources	April 13, 2022
TWG 4 - Supply-Side Resources	March 28, 2022
TWG 5 - Distribution System Planning	April 25, 2022
TWG 6 - Portfolio Results & Actions	May 9, 2022

IRP Process, Objectives, and Evolution

The IRP process is a public process and we welcome your feedback and participation!

- IRP participants come to the process with varying backgrounds and familiarity with IRP planning, and that is ok! Our IRP benefits from diverse perspectives
- We strive to strike the right balance in terms of the technical material presented, but are always evaluating the appropriate level of detail and might not always get it right

NW Natural's views on scope and role of the IRP:

- Rules and guidelines from the legislature and our regulatory commissions define the scope and purpose of IRPs and are grounded in a least cost-least risk approach to utility resource planning
- IRP rules and guidelines require robust planning that is highly complex and requires advanced modeling techniques and tools that are critical to serving our customers' needs as best we can
- IRPs assess the implications of the policy and market environment and how changes to that environment would impact meeting customer needs
- The IRP process is not a policy *making* process nor the best forum to discuss what policies should (or should not) be adopted

NW Natural acknowledges that IRPs are evolving and the active discussions about the role of IRPs and ways to make the process more inclusive and transparent as well as coordinate work across utilities

- We are proactively looking at ways to improve our IRP process and outreach and are excited to be able to lean on the experience and expertise of the Community and Equity Advisory Group NW Natural is forming moving forward

We value open and constructive discussion and IRP workshops are *LONG* meetings; we are bound to misspeak from time to time and we apologize in advance!

Overview of Previous TWGs

TWG #1- Planning Environment & Environmental Policy – Presentation Topics

NW Natural 101: Introduction to NW Natural's IRP

- The IRP team provided an overview of:
  - NW Natural as a Company, including gas purchases, customer types and rate schedules, emissions context, system capacity resources, and distribution system planning options
  - NW Natural's view on the scope and role of the IRP, regulatory basis for IRP process, IRP timelines, least cost-least risk considerations, and the interplay of parts within the Planning Environment which culminate in the Action Plan.
  - Updates on actions since the 2018 IRP and 2018 IRP Update, and new challenges for the 2022 IRP

Planning Environment & Scenario Discussion

- The IRP team reviewed changes in the policy landscape which impact the IRP in either or both OR & WA. Discussed the challenges associated with new policies and the compliance mechanisms associated with each.
- Discussion regarding the development of scenarios and analysis within each. Reviewed scenario analysis used in the 2018 IRP and presented draft scenarios for the 2022 IRP. Stakeholder feedback requested on scenarios by February 4, 2022.

Overview of Previous TWGs

TWG #2- Load Forecasting – Presentation Topics

Load Forecasting

- The IRP team discussed the goals, purpose, and framework within which load forecasts are developed, including the differences in the 2022 IRP compared to previous years.
- The TWG focused on understanding several concepts about load forecasting including:
  - When forecasting there is a trade-off between model parsimony and accuracy/precision
  - Historical trends establish our reference case, which is a key starting point for understanding how structural changes to customer growth and stock turnover of end-use equipment impact overall demand
  - The importance for peak planning in IRPs and the trade-off of between costs for reliable service and the risks of resource constraints during an extreme cold event
  - Load uncertainty and an overview of stakeholder feedback on draft scenarios as well as a preview of the draft load forecasts within such scenarios
- The IRP team reviewed the reference case for the expected weather load forecast and the design weather load forecast (inclusive of a cold event and peak day load forecast)
- Each part of load forecast modeling was reviewed with detailed discussion related to each section including the differences between the types of load forecasts.
  - Residential and commercial customer count and use per customer (UPC)
  - Industrial, large commercial, and compressed natural gas (CNG)
  - Accounting for impacts from energy efficiency
  - Total sales and transportation load

Scenario Analysis Feedback*

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	2022 IRP Proposed Scenarios- Summary Version	1 Base Case - Compliance with OR-CPP and SB 98 and WA-CCA	2 Carbon Neutral by 2050	3 New Direct Use Gas Customer Moratorium in 2025	4 Building Electrification	5 RNG and H2 Production Tax Credit	6 Limited RNG Availability	7 Supply-Focused Decarbonization	8 Deep Decarbonization Study-Based
Demand-Side	Customer Growth	Current Expectations		No New Customers After 2025		Current Expectations			
Demand-Side	Space and Water Heating Equipment	Moderate gas powered heat pump and hybrid heating adoption		High electrification of existing residential and small commercial load	Full electrification of existing residential and small commercial load by 2050	Moderate gas heat pump and hybrid heating adoption		No gas powered heat pumps and low levels of hybrid heating	Increasing gas heat pump and hybrid heating adoption
Demand-Side	Industrial Load Efficiency	Moderate increase	High increase	Moderate increase				Limited increase	Moderate w/ electrification
Demand-Side	Building Shell Improvement	Energy Trust projection	Energy Trust high sensitivity projection	Ajusted Energy Trust projection		Energy Trust projection			100% by 2030
Supply-Side	Renewable Natural Gas	Moderate availability and cost assumption	Moderately-high availability and moderate cost assumption	Moderate availability and cost		Moderate availability and low cost to customers	Low availability and moderately high cost	Moderate availability and cost assumption	Moderate availability and high (stale) cost assumption
Supply-Side	Hydrogen	Moderate blending and dedicated system deployment allowed; moderate cost assumption							Moderate blending allowed; high (stale) cost
OR- Community Climate Investements		Costs and limits defined in CPP rule							
WA- Allowances & Offsets		TBD- Pending Rule Development							

*Orange text indicates assumptions that received stakeholder feedback and adjustments are under consideration

Updated Scenario Matrix**

2022 IRP Proposed Scenarios- Summary Version		1 Balanced Approach to Serve Same Needs	2 Carbon Neutral by 2050	3 New Direct Use Gas Customer Moratorium in 2025	4 Building Electrification	5 RNG and H2 Production Tax Credit	6 Limited RNG Availability	7 Supply-Focused Decarbonization	8 Deep Decarbonization Study-Based
Demand-Side	Customer Growth	Current Expectations		No New Customers After 2025		Current Expectations			
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	Industrial Load Efficiency	Moderate increase	High increase	Moderate increase				Limited increase	Moderate w/ electrification
	Building Shell Improvement	Energy Trust projection	Energy Trust high sensitivity projection	Ajusted Energy Trust projection		Energy Trust projection			100% by 2030
Supply-Side	Renewable Natural Gas	Moderate availability and cost assumption	Moderately-high availability and moderate cost assumption	Moderate availability and cost		Moderate availability and low cost to customers	Low availability and moderately high cost	Moderate availability and cost assumption	Moderate availability and high (stale) cost assumption
	Hydrogen	Moderate blending and dedicated system deployment allowed; moderate cost assumption							Moderate blending allowed; high (stale) cost
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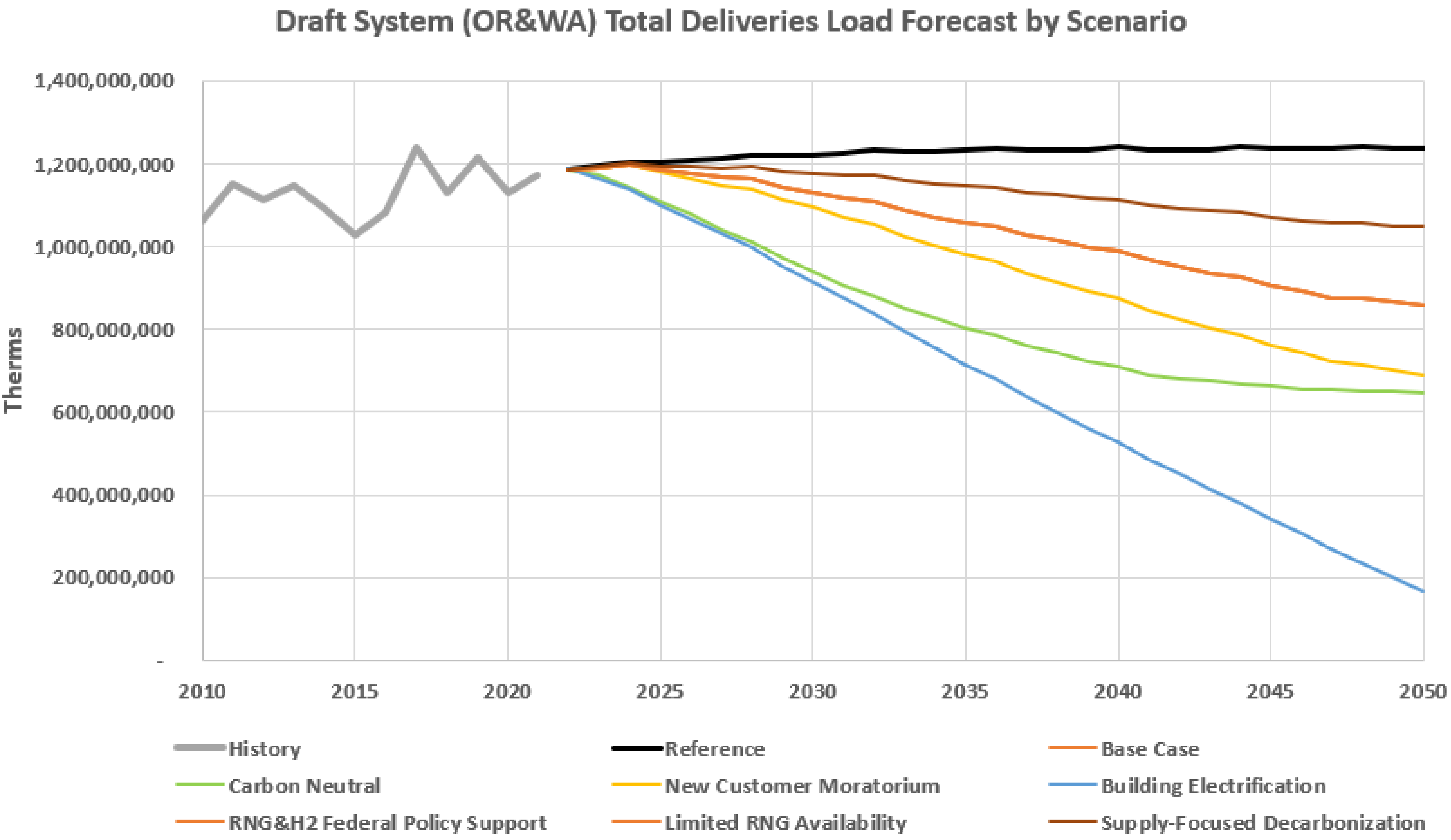
WA- Allowances & Offsets		TBD- Pending Rule Development							

*Orange text indicates assumptions that received stakeholder feedback and adjustments are under consideration

**All Scenarios will plan to meet obligations under OR CPP and WA CCA

Total Loads by Scenario



*Draft to indicate general range of loads to be considered. Final assumptions for load scenarios still being developed from stakeholder feedback

Stochastic Monte Carlo Load Simulation

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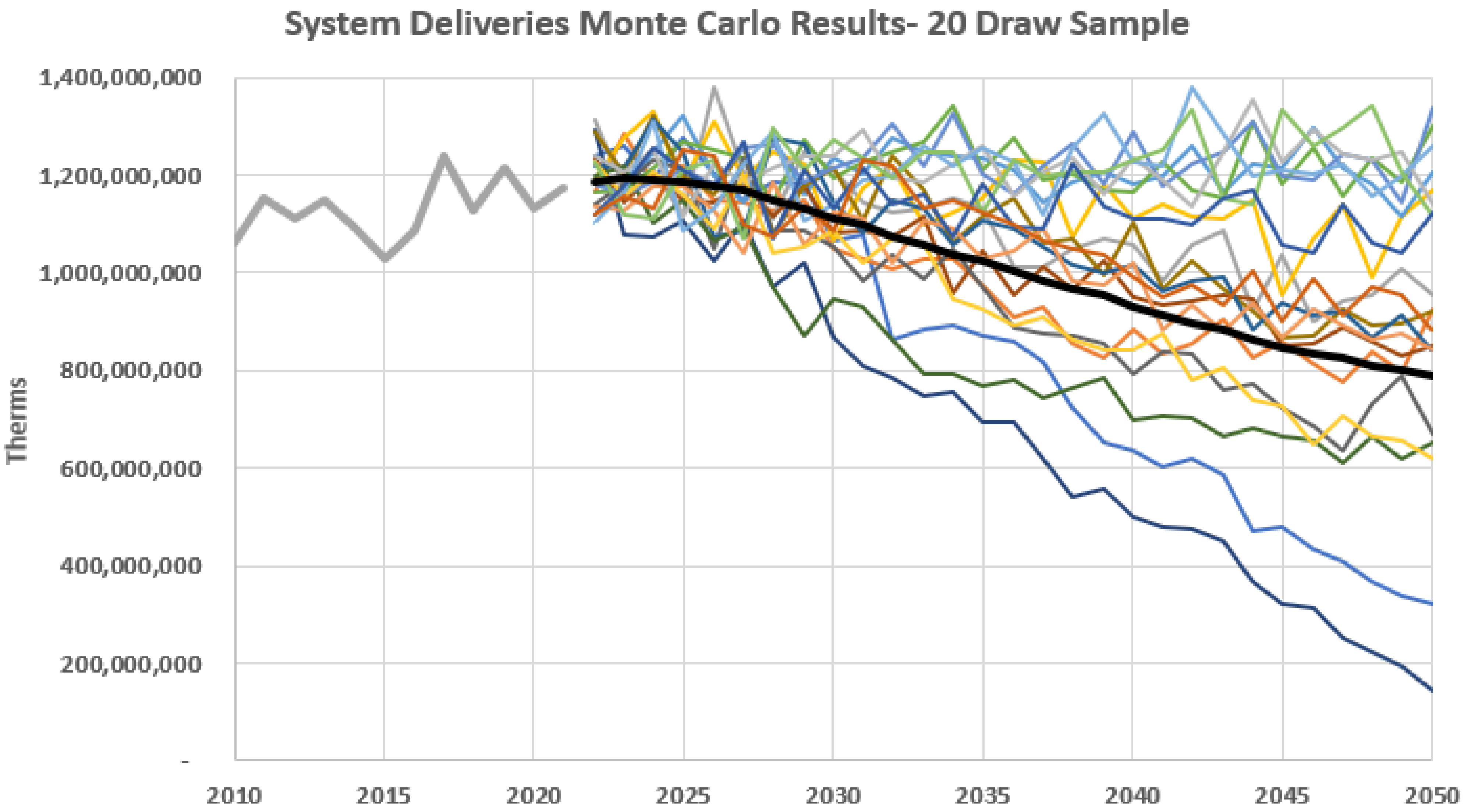
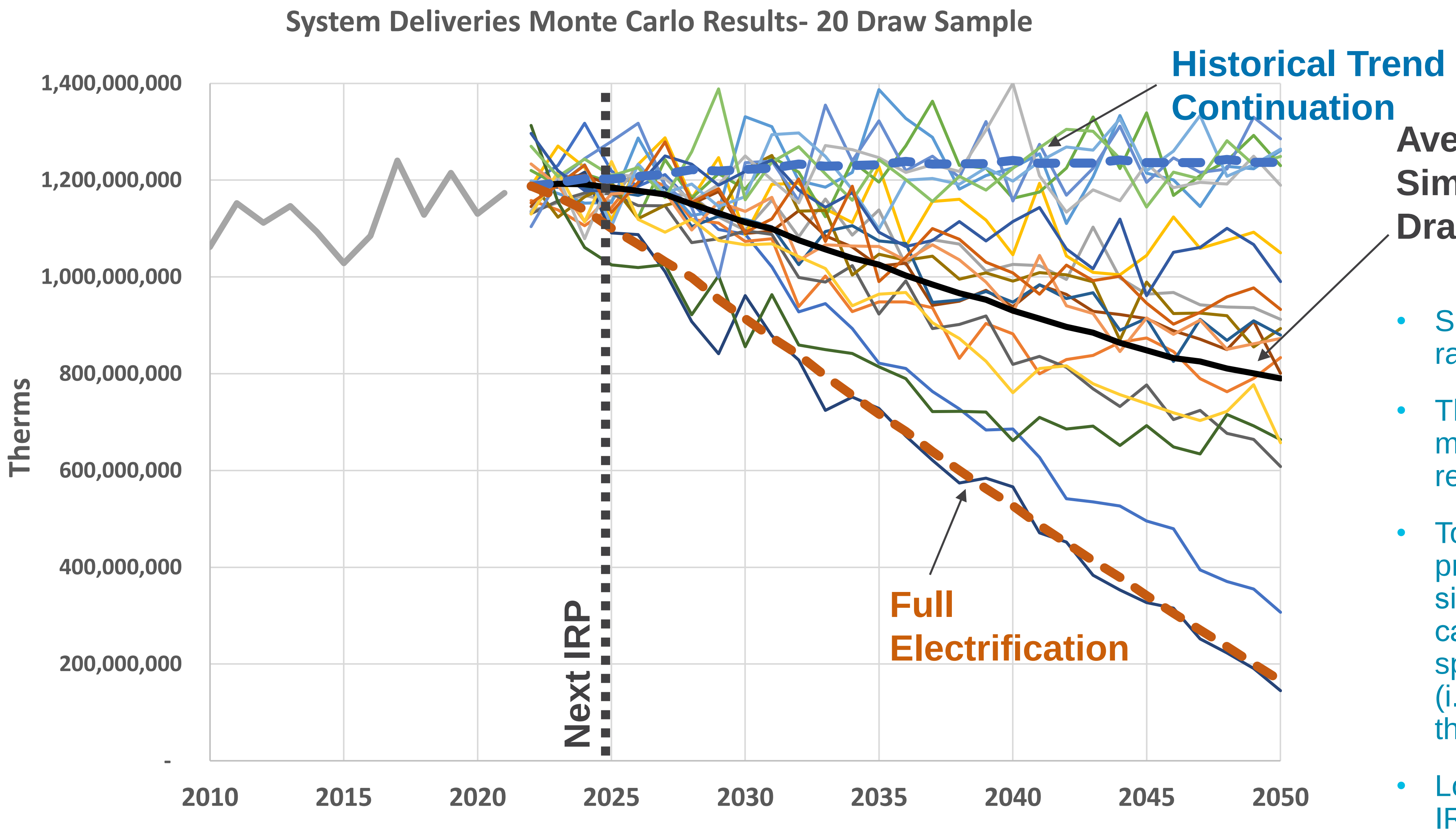
- Long-term variance in load determined by load scenarios
  - Current assumptions
    - Path deviation for a load scenario can start any year between 2022 and 2028
    - All scenarios equally likely
- Short-term variance in load determined by weather and economic uncertainties
  - Current assumptions
    - Standard deviation in annual heating degree days from weather modeling combined with economic deviation
    - Economic deviation from history of non-weather

Load Simulations for Optimization



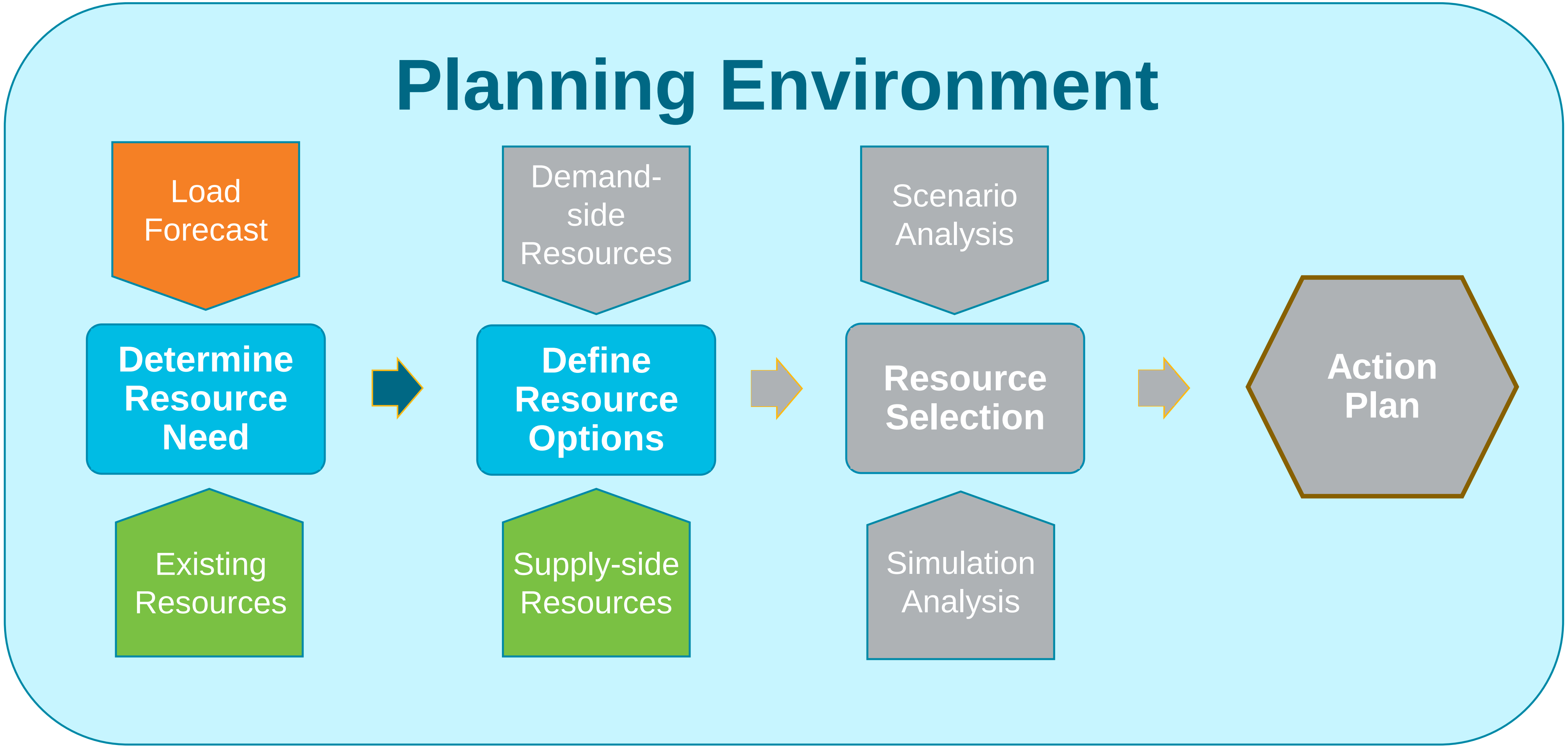
*Draft to indicate general range of loads to be considered and show how each forecast draw will deviate in the short-term around a long-term trend. Final assumptions for load scenarios still being developed from stakeholder feedback.

Accounting for Load Uncertainty



- Simulation draws cover the entire range of possible future loads
- The reason these loads might materialize is less important for resource planning
- To account for uncertainty we propose using the average of the simulation results as the "base case" rather than choosing a specific set of load assumptions (i.e. rather than choosing one of the scenarios)
- Loads will be re-evaluated in next IRP (2024 or 2025)

IRP Process



Green = Resources Orange = Tools

Resource Venn Diagram

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Demand-side Resources

Resources that reduce annual, seasonal or peak demand or annual compliance obligations

Supply-side Resources

Resources that provide annual, seasonal or peak natural gas deliveries or emission compliance credits to customers

Gas Supply Resources

Demand-side or supply-side resources required to provide energy services and emissions compliance for all NW Natural customers across the whole system

Today's TWG

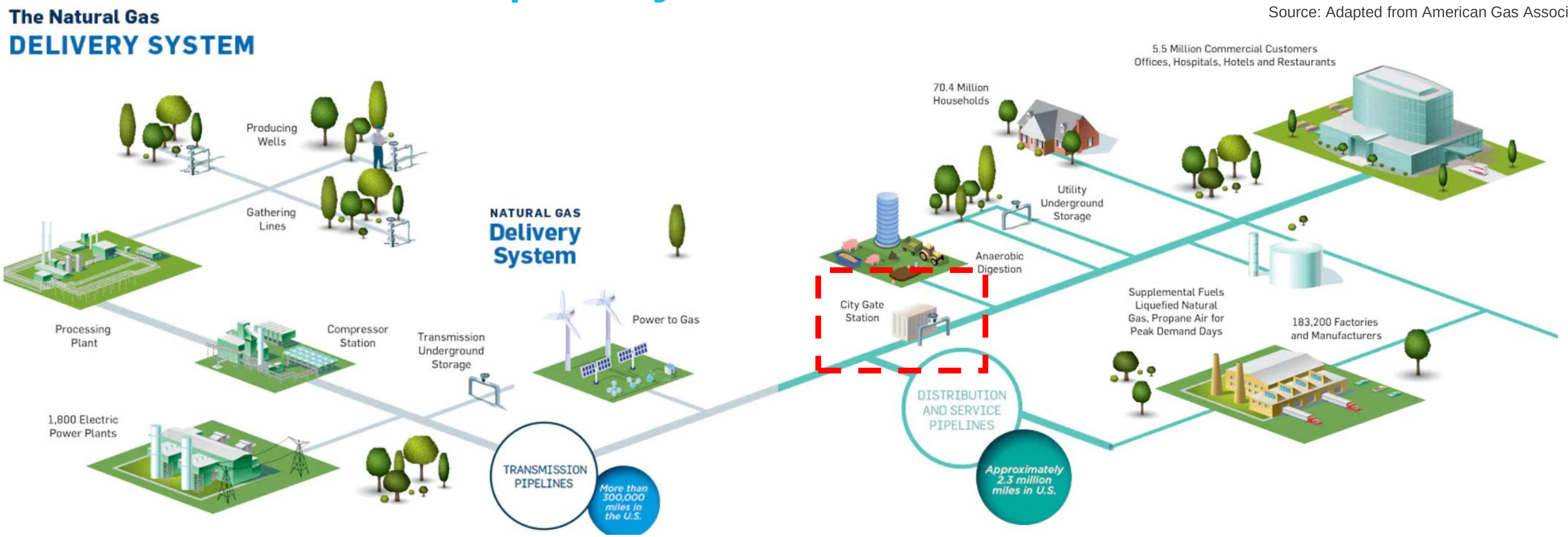
Gas Supply/Distribution System Resource Overlap

Distribution System Resources

Demand-side or supply-side distribution resources required to provide energy services to NW Natural customers in a specific area on NW Natural's distribution system

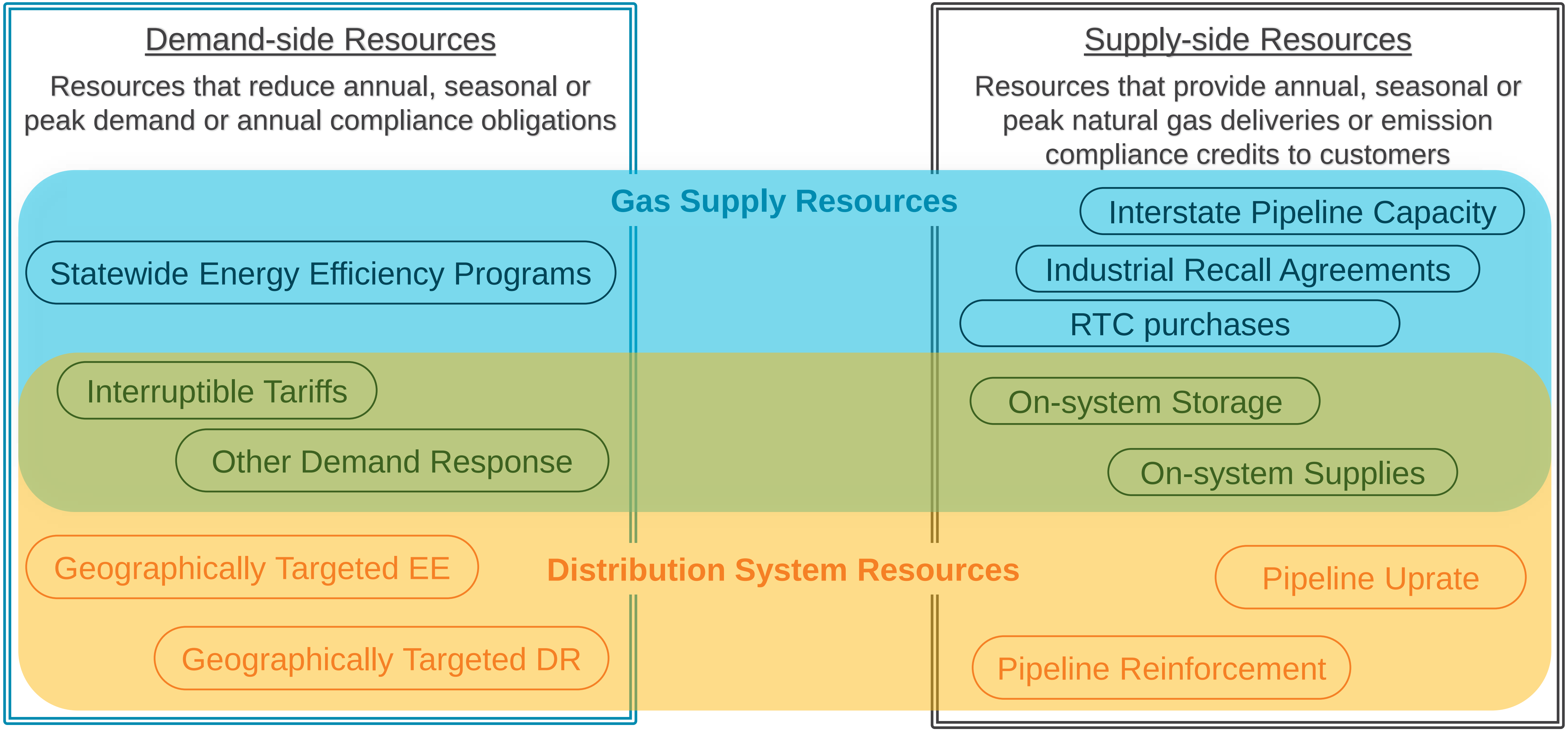
Supply Capacity Resources vs Distribution Capacity Resources

Source: Adapted from American Gas Association



On-system storage facilities or supply (e.g., on-system RNG) are considered both gas supply resources and distribution system resources as they provide pressure support on NW Naturals’ system; Resources upstream of the city gate station can only be a gas supply resource

Resource Venn Diagram



Not an Exhaustive List of Resources

Supply Resource Overview

Key Takeaways

- Currently have a small peak resource deficit based on updated load analysis
  - Alternatives being evaluated; however, expecting Mist Recall for at least a portion of the gap
- 50% of peak day supply comes from on-system storage facilities, all of which are aging and require periodic evaluation for refurbishment
- How long we continue to rely on Segmented Capacity - which is not a long-term firm resource - is a key determinant of our future resource needs
- Mist Recall has been the most cost-effective resource addition, but it is a finite resource
- All upstream pipelines are fully contracted, so any decisions to add future pipeline capacity will require an extended planning lead time of at least 5 years

Interstate Pipeline Infrastructure in the Pacific Northwest

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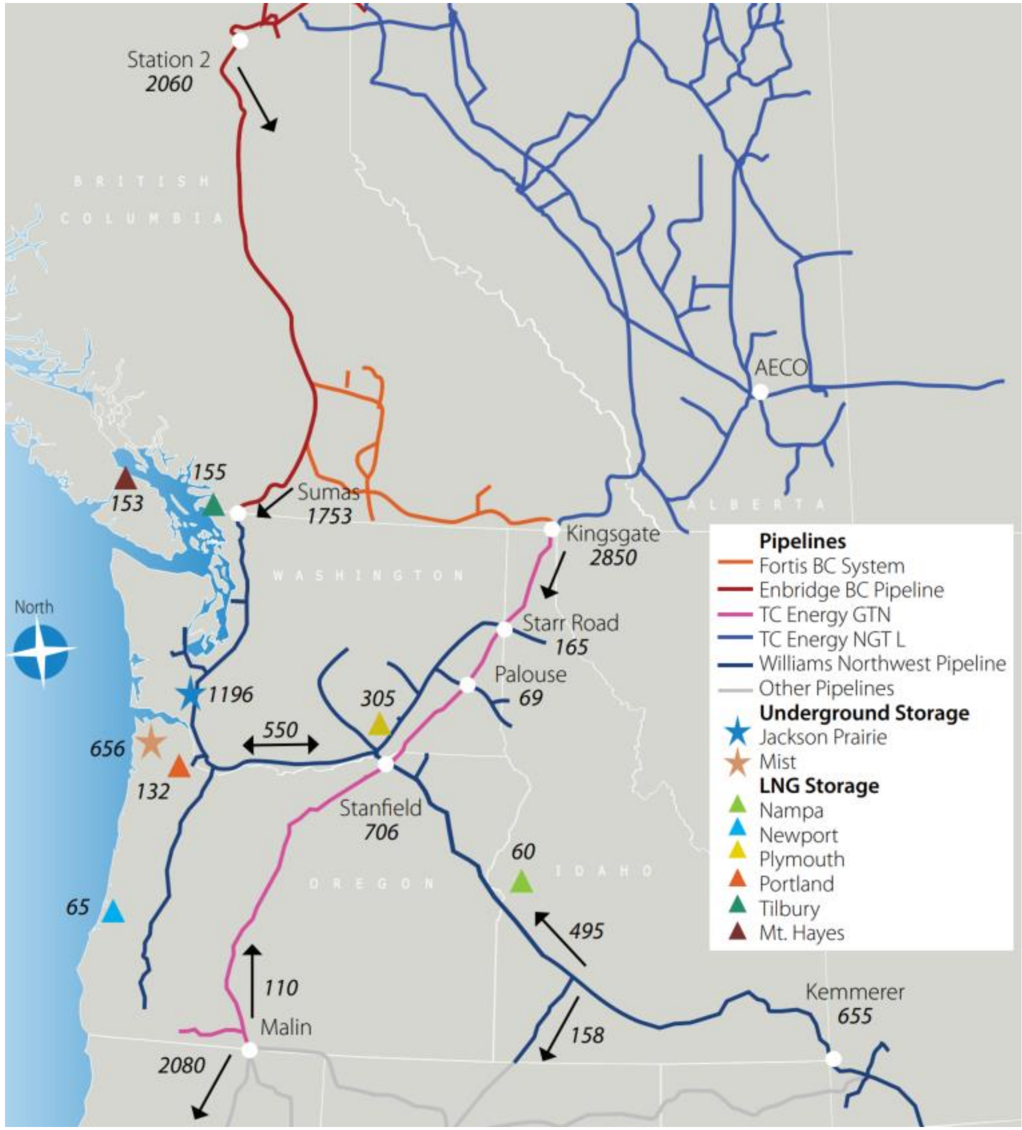
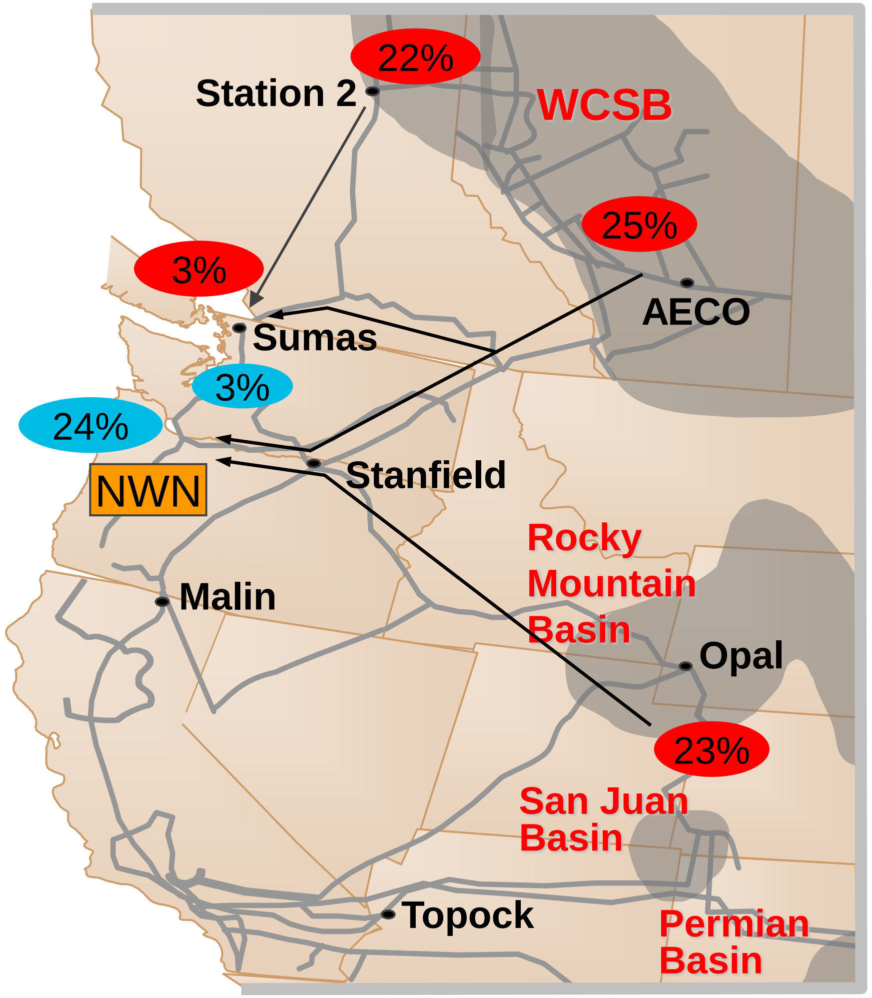
- NW Natural is one of many customers that holds capacity contracts on the interstate/interprovincial pipeline system
- These contracts reserve the right to ship gas from a receipt point (e.g., Station 2) to a delivery point (e.g., Molalla)
- Capacities numbers shown on the map are the total maximum capacity numbers for various segments of the interstate/ interprovincial pipeline system (thousand Dth per day)



Source: Northwest Gas Association, 2020 Gas Outlook

NW Natural Illustrative Winter Day Gas Supply Example



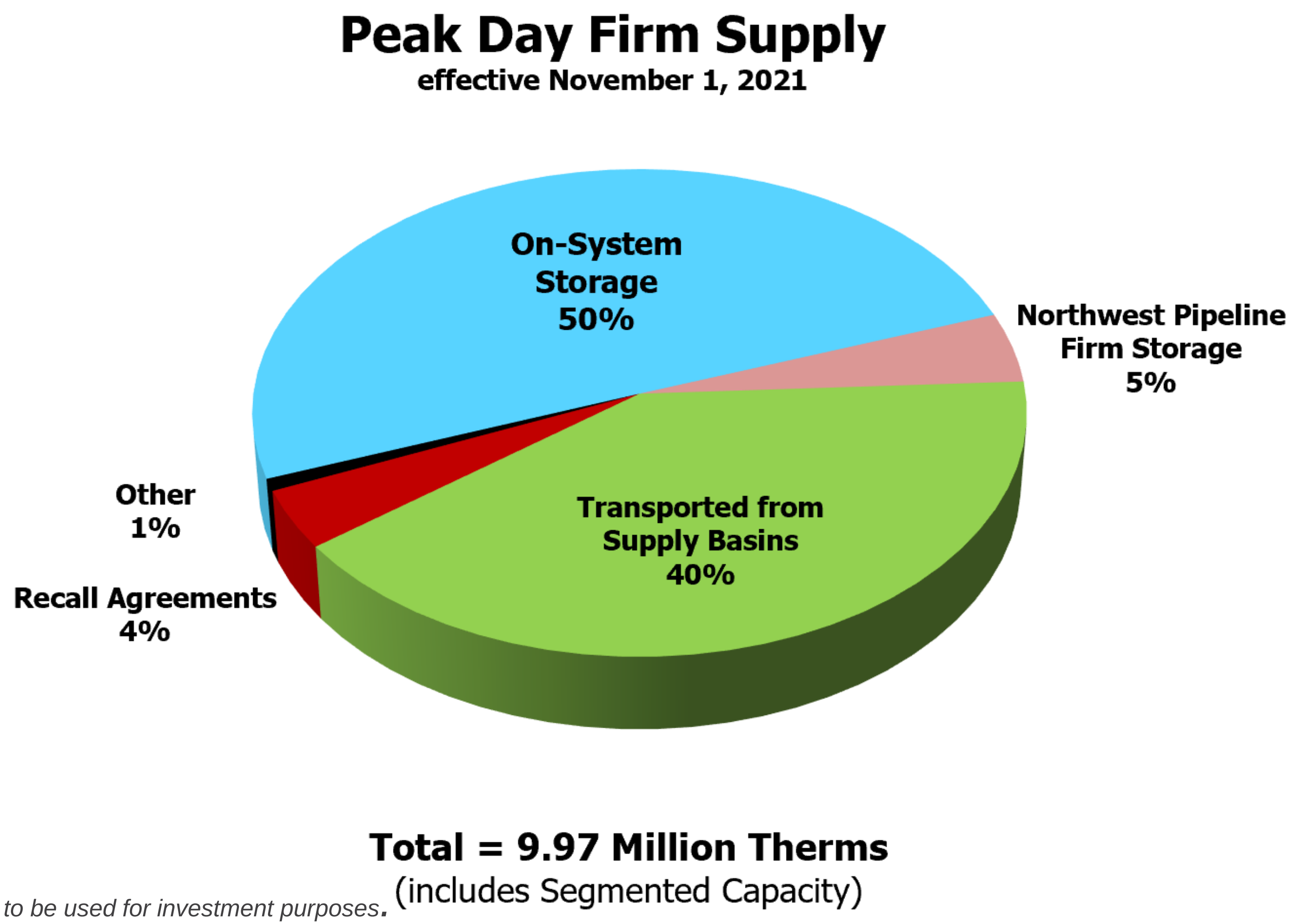
Flowing Supplies

Underground Storage

BC (Station 2)	88,000 Dth
BC (Sumas)	12,000
Alberta	100,000
Rockies	92,000
Jackson Prairie	12,000
Mist Storage	96,000
On-system Supplies	2,000
Portland LNG	0
Newport LNG	0
Total	403,000 Dth

Representation of a cold winter day; not a peak day

Existing Gas Supply Resource Capacity for Peak Day Demand



What is Segmented Capacity?

- Uses our Primary Firm Capacity from Stanfield to various points North, South and at Molalla
- Key Point - Molalla is authorized as both a Receipt and a Delivery Point
- Segments from Molalla South can be Used on a Secondary Basis anywhere in the NWP system

Mist Storage – A refresher

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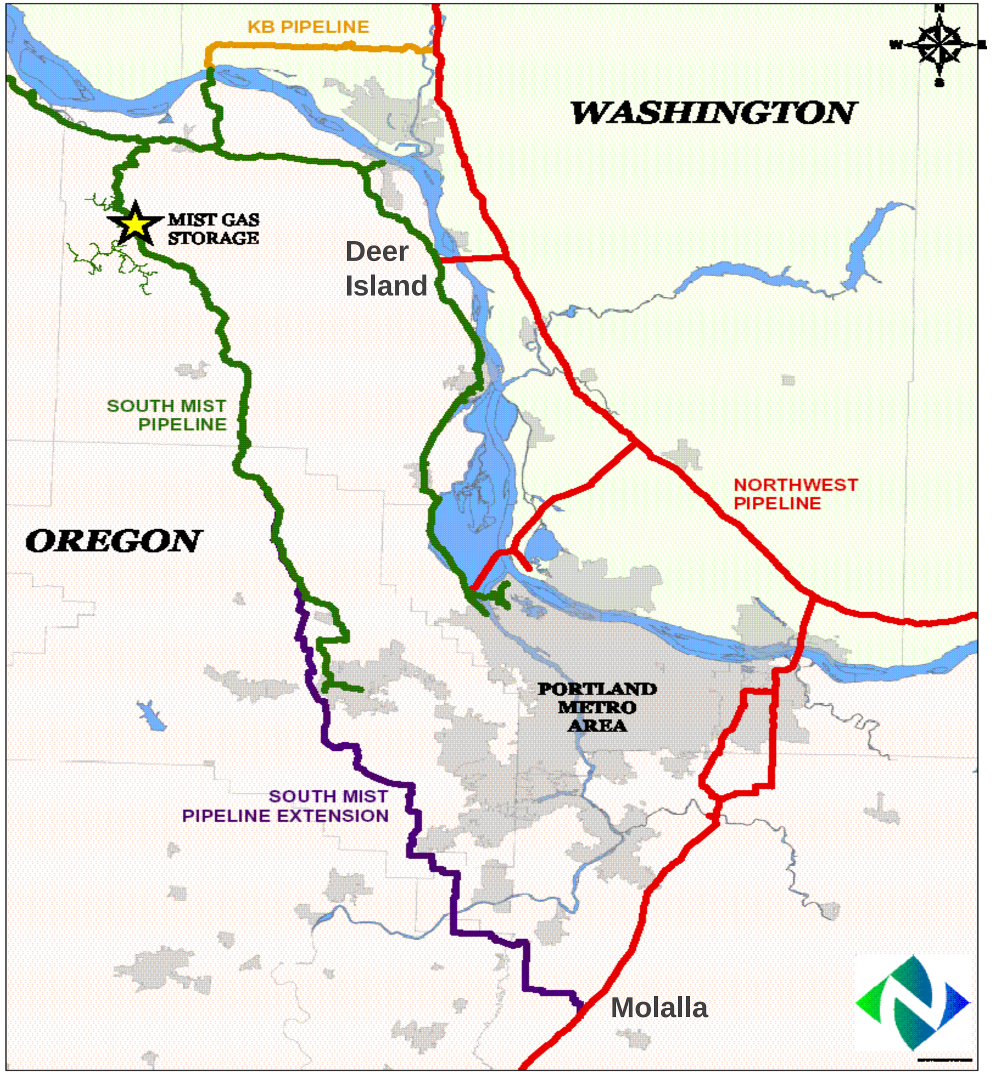

Pipeline takeaway

- North Mist Feeder (12”) to North Coast Feeder, Beaver lateral, and to Northwest Pipeline at Deer Island
- South Mist Pipeline (16” and 24”) and South Mist Pipeline Extension (24”) to west and south sides of Portland metro area and to Northwest Pipeline via Molalla gate

Mist Operation Center – Miller Station

Key Traditional Supply Side Capacity Resources for Evaluation

- Mist Recall – 200,000 Dth/day of the existing Mist resource remains for future recall
  - Incrementally in units of 5,000 Dth of deliverability, as needed
- On-system Supply – Could be RNG or hydrogen, relatively small volumes could potentially have a large impact on distribution planning
- Central Coast Feeder – Three sequential projects to increase take-away from Newport LNG
- Citygate Deliveries – availability, cost, and duration dependent on third party marketers
- Segmented Capacity (60,700 Dth/day) – retention in the firm portfolio depends on its reliability, which in turn depends on future load growth patterns in the I-5 corridor and spot liquidity in the Sumas market on a peak day
  - Impacts from Woodfibre LNG coming online in 2027 are also being evaluated
- Upstream Pipeline Capacity Additions – cost and timing is dependent on expansion projects
- Further Mist Expansion – reservoirs are available but cost to expand pipeline deliverability will be significant

Conventional Gas Market Fundamentals

Conventional Gas Market Outlook

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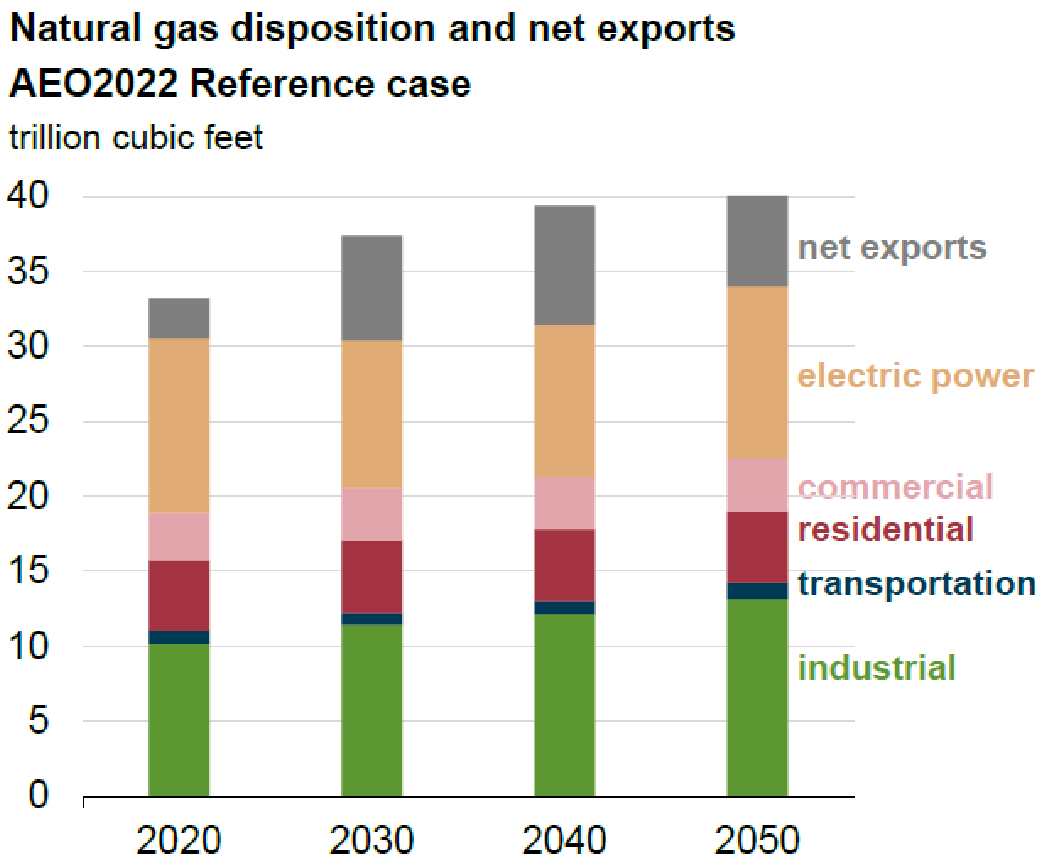
- Natural gas production is expected to increase over the next 20 years – driven by exports and industrial demand.
- Natural gas generation becomes the incremental electricity supply as the U.S. continues to transition away from coal and renewable generation grows.
- Price volatility is expected to continue due to impacts from the global market and swings in generation demand to cover retiring coal generation and firm up peak and base resource needs as renewable generation is added to the grid.

US Natural Gas Consumption

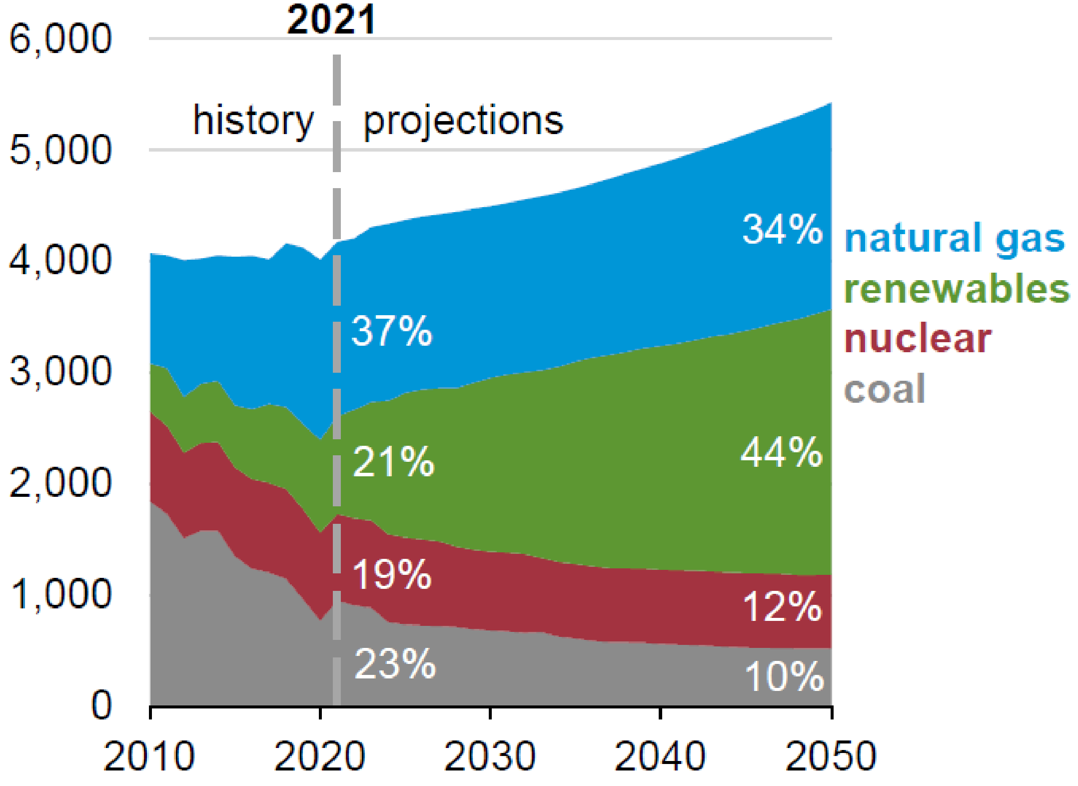
- Residential, commercial, and transportation demand remain stable.
- Industrial demand will continue to grow mainly in the Gulf Coast region.
- Electric power generation decreases by 2030 due to the addition of renewable generation, but then grows in the long range.
- LNG and pipeline exports continue to grow through 2040.



Source: EIA Annual Energy Outlook, March 2022

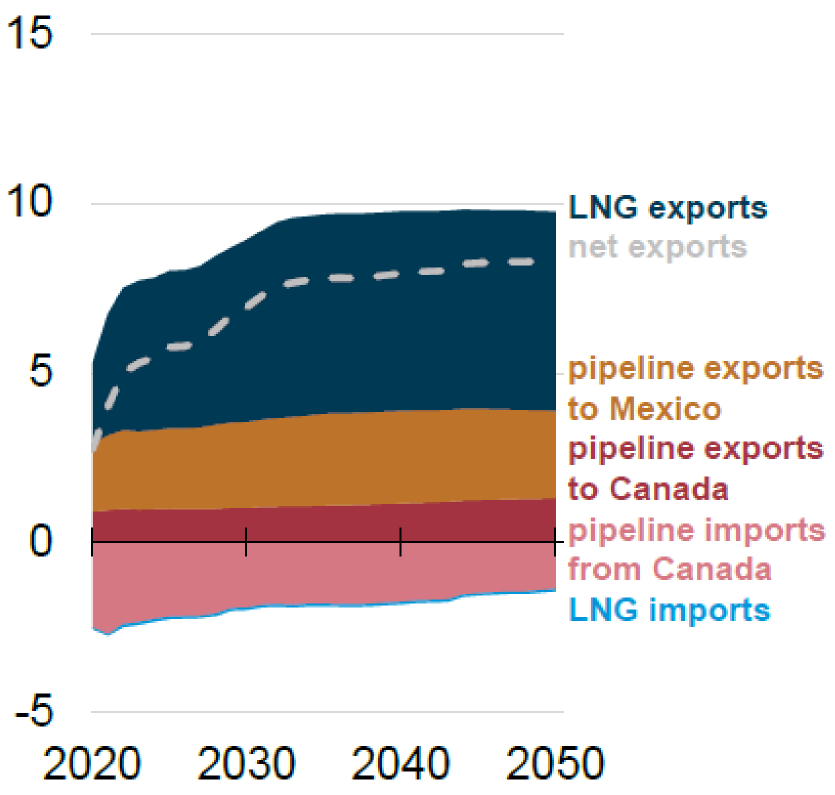
Demand Growth

U.S. electricity generation from selected fuels
AEO2022 Reference case
billion kilowatthours



Source: EIA Annual Energy Outlook, March 2022

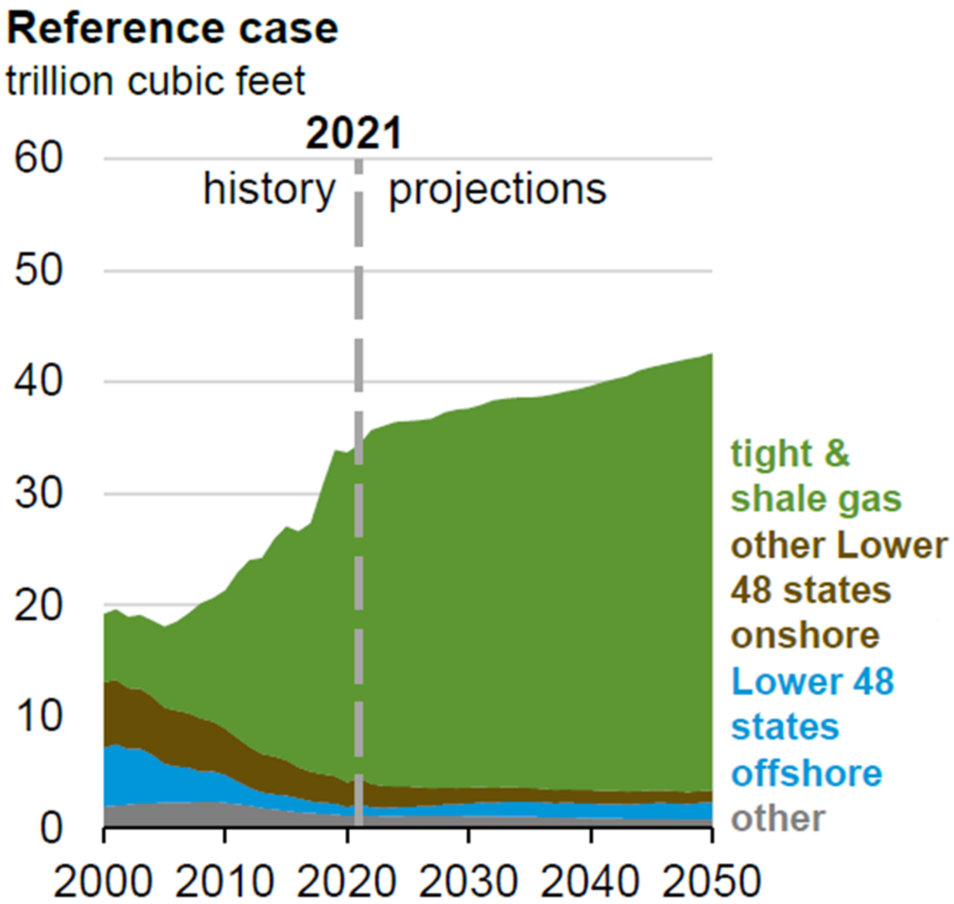
Natural Gas Trade
Reference case
trillion cubic feet



Source: EIA Annual Energy Outlook, March 2022

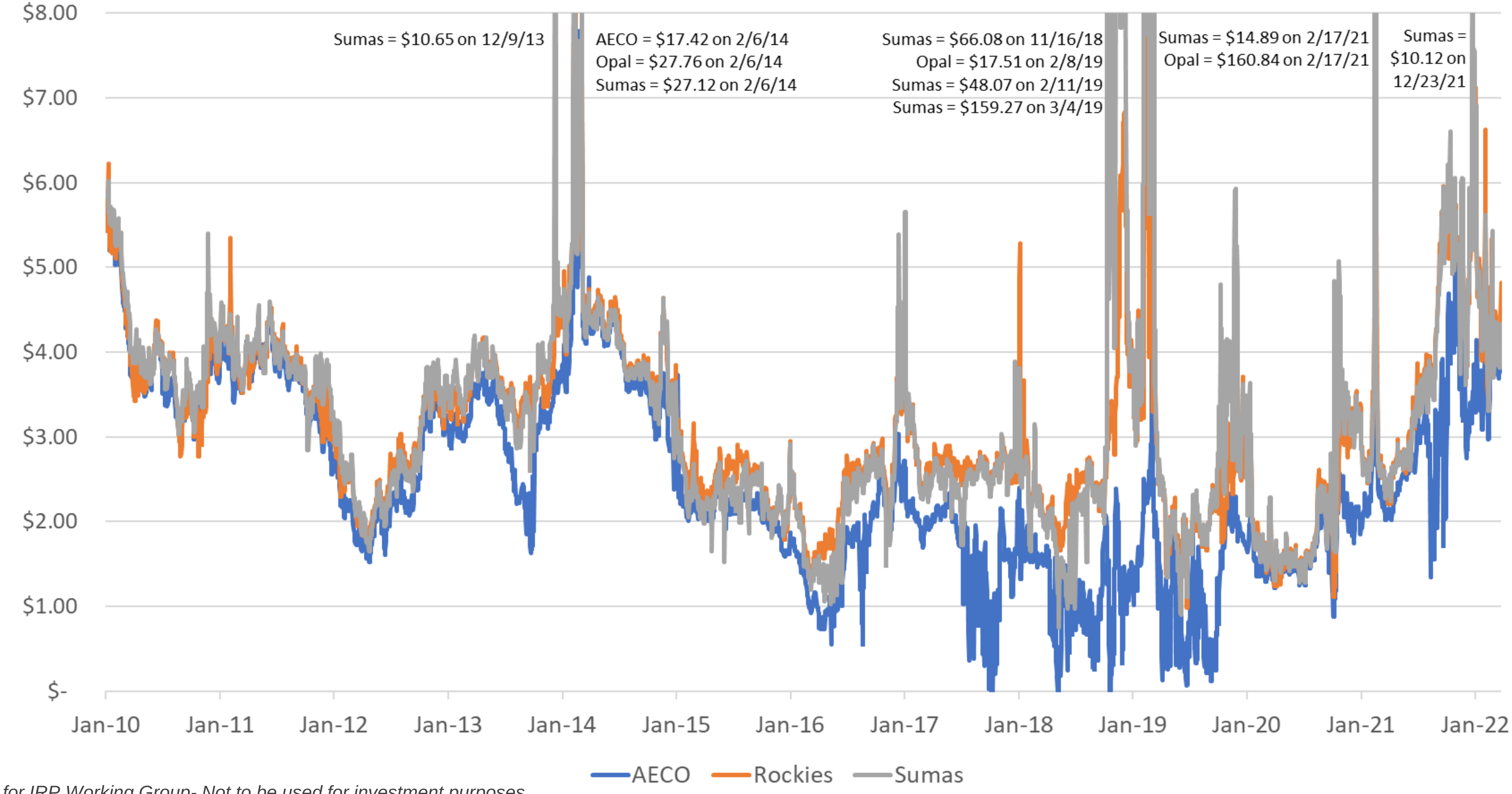
Natural Gas Production

- An increase in production is required to meet industrial and export demand.
  - The most growth is expected from associated gas production.
  - Haynesville and Appalachian dry gas production is expected to grow through 2030.
  - Canadian production is also expected to increase with most growth in the Montney.



Source: EIA Annual Energy Outlook, March 2022

Historical Natural Gas Prices



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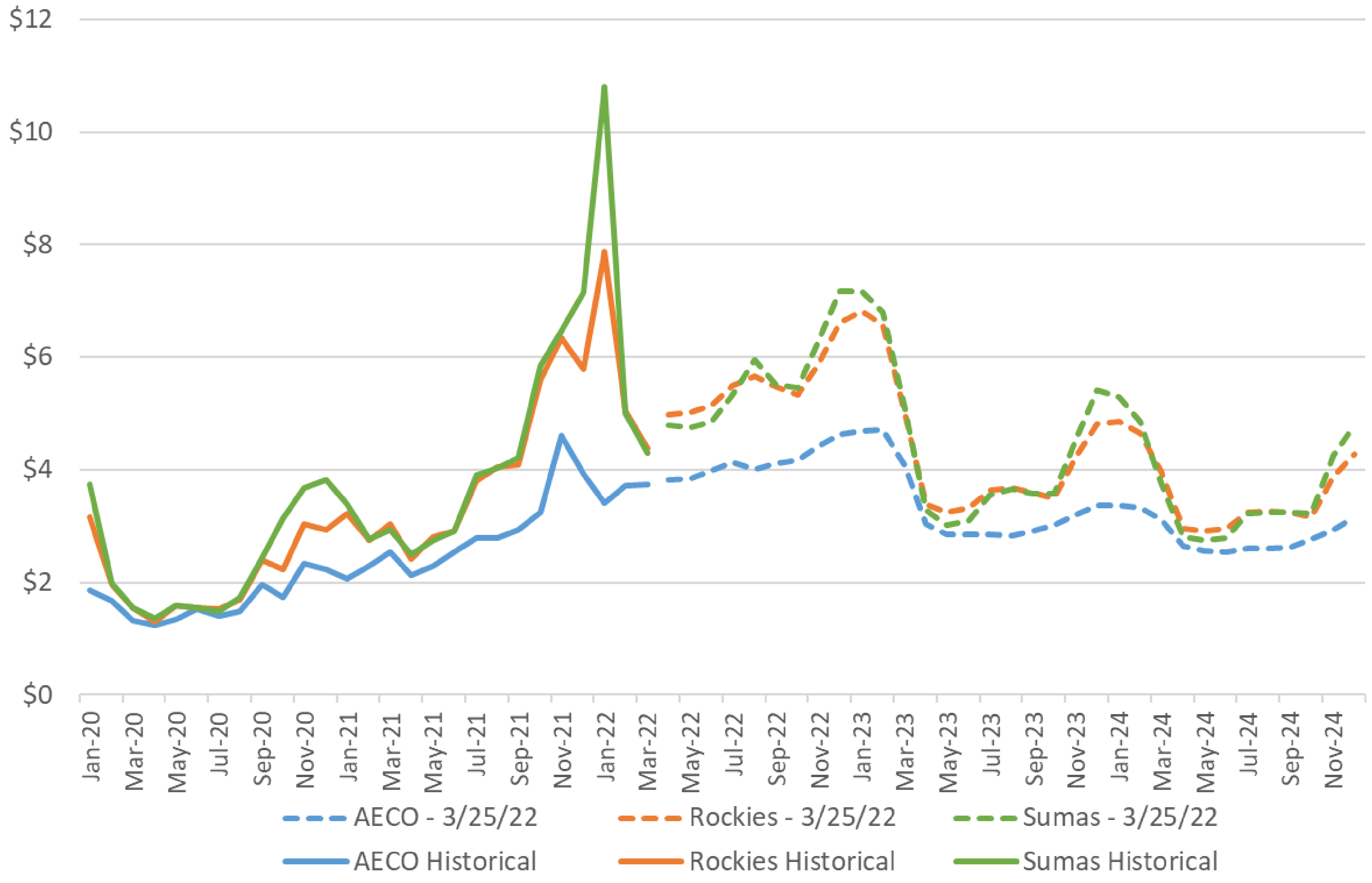
Conventional Forward Prices



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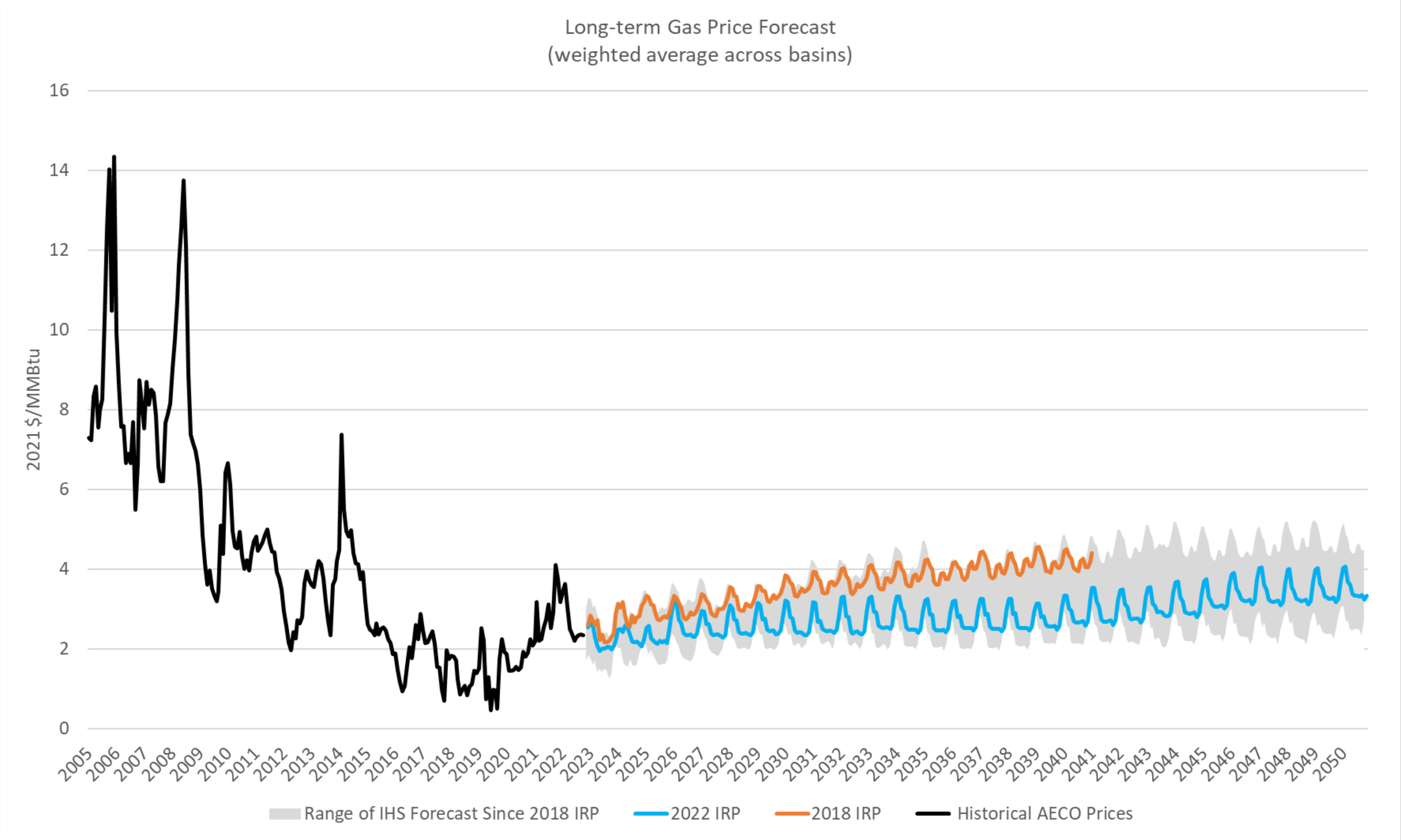
Long-term Gas Prices

- Our gas price forecast comes from a third-party vendor (IHS), who implements a complex supply and demand model for long term gas pricing across the U.S. and Canada
- We use the long-term forecast from IHS for each of our 4 purchasing gas hubs



Portland LNG

Portland LNG Facility Needs

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- Investments are needed to keep the Portland LNG facility as part of NW Natural's long-term resource portfolio
- Major investments in existing resources needed to keep them part of the resource portfolio undergo a complete alternatives analysis in IRPs
- Alternatives for evaluation include options to remove the resource from the portfolio and replace its capabilities with other resources

Newport LNG Cold Box Example from 2018 IRP Update #3

Portfolio PVRR (2021-2050)

	Fixed Storage Costs	Fixed Pipeline Costs	Supply Variable Costs	Other Variable Costs	Total Portfolio Costs
Cold Box Replacement	$63 M	$1,162 M	$10,548 M	$69 M	$11,841 M
Alternative Pipeline	≥$58 M	≥$1,312 M	$10,542 M	$70 M	≥$11,986 M
Delta	-$5 M	$150 M	-$2 M	$1 M	≥$145 M

Prepared for IRP Working Group- Not to be used for investment purposes.

- Today we will show the fixed cost portion of the alternatives to be used in resource optimization modeling
- Important note: **investment costs ≠ total portfolio costs**

PLNG History

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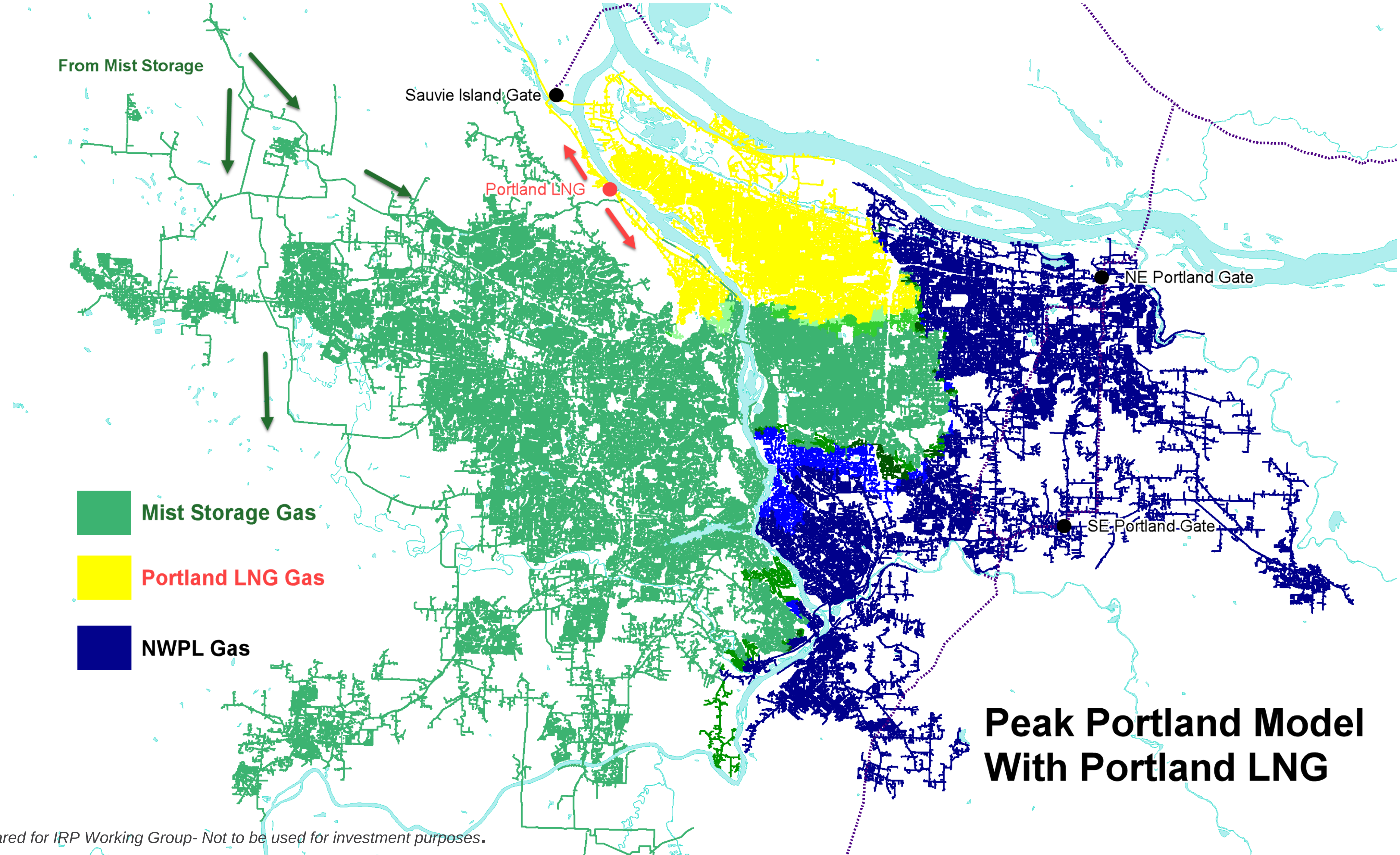
Portland LNG was constructed by Chicago Bridge & Iron (CB&I) and commissioned in 1968 as one of the first LNG utility facilities used for LNG liquefaction, storage, and LNG vaporization for supplemental winter supply. The Portland LNG facility's nominal capacity includes:

- LNG storage tank with a capacity of 175,000 barrels, (7,350,000 gallons) of LNG.
- Flow-by-expander liquefaction cycle (Turbo Expander) with a net LNG liquefaction capacity of 2.15 MMCFD (26,000 gpd).
- A net of 15.06 MMCFD tail gas is sent to the distribution system from pretreatment, LNG liquefaction, and vapor recovery operations during LNG liquefaction mode.
- Three submerged combustion vaporizers (SCVs) have a combined peak send-out capacity of 120,000 MCFD (130,800 Dth/day) at 400 psig.
- LNG truck loading bay using LNG tank static head gravity flow.

Peak Portland Model With Portland LNG



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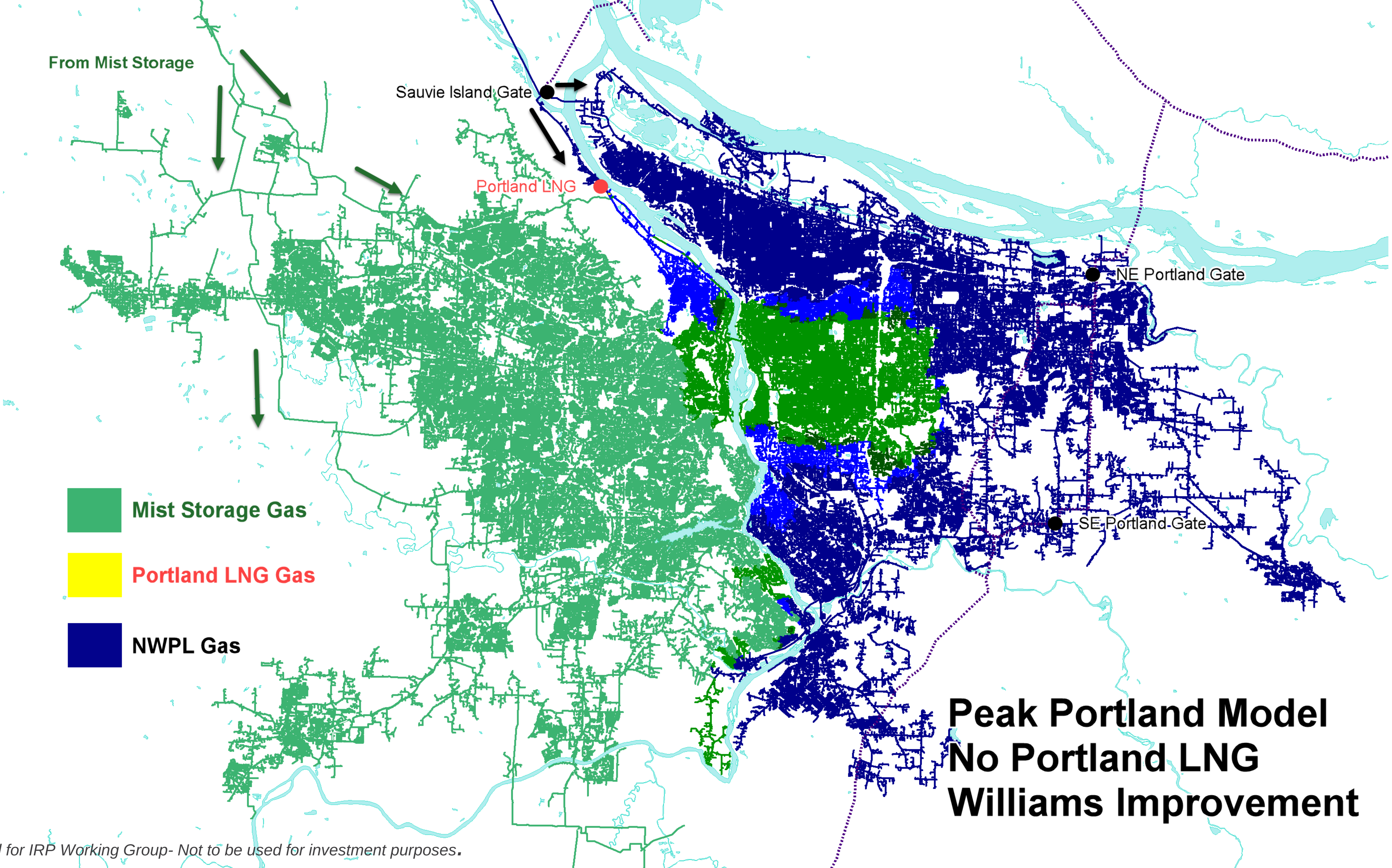
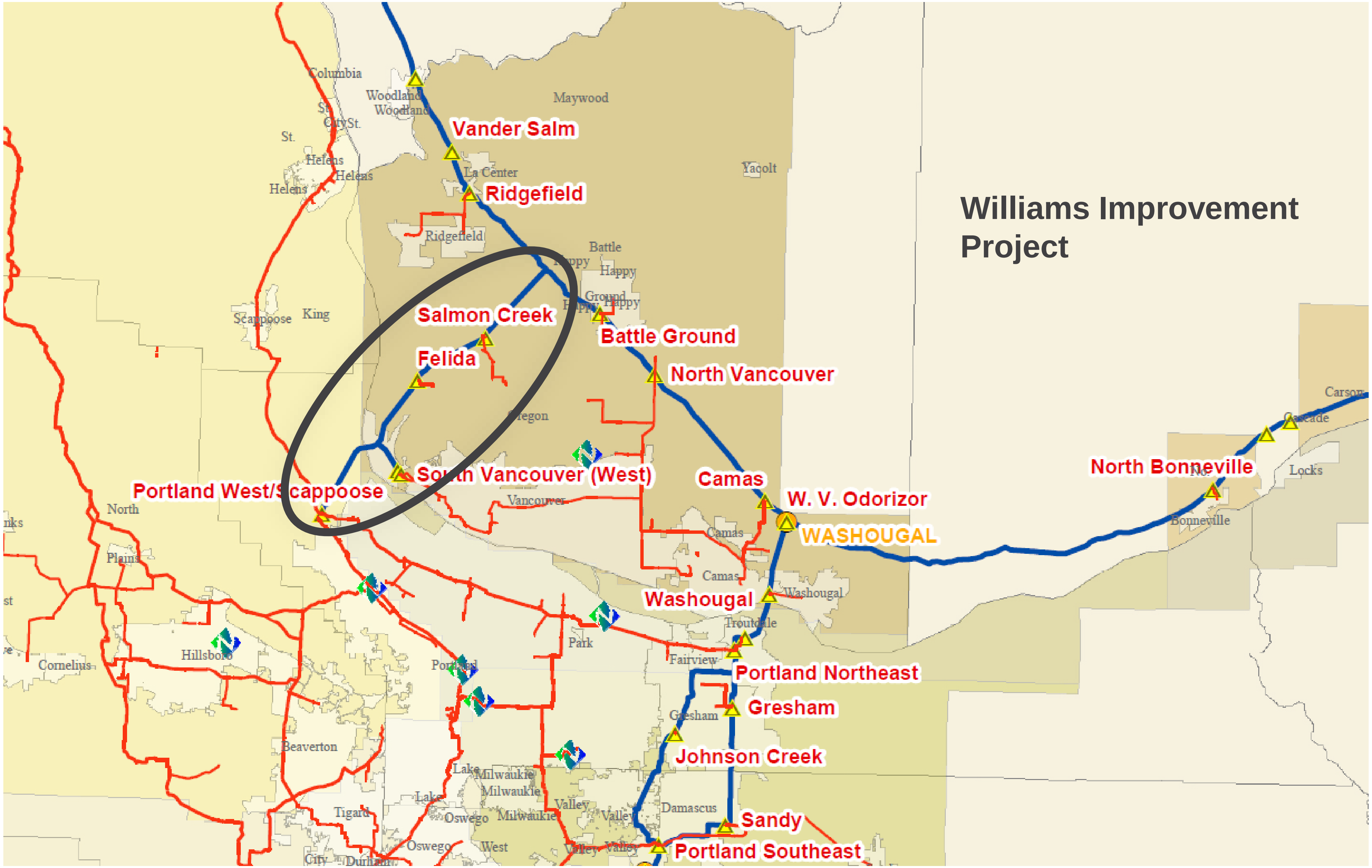


Peak Portland Model No Portland LNG Williams Improvement



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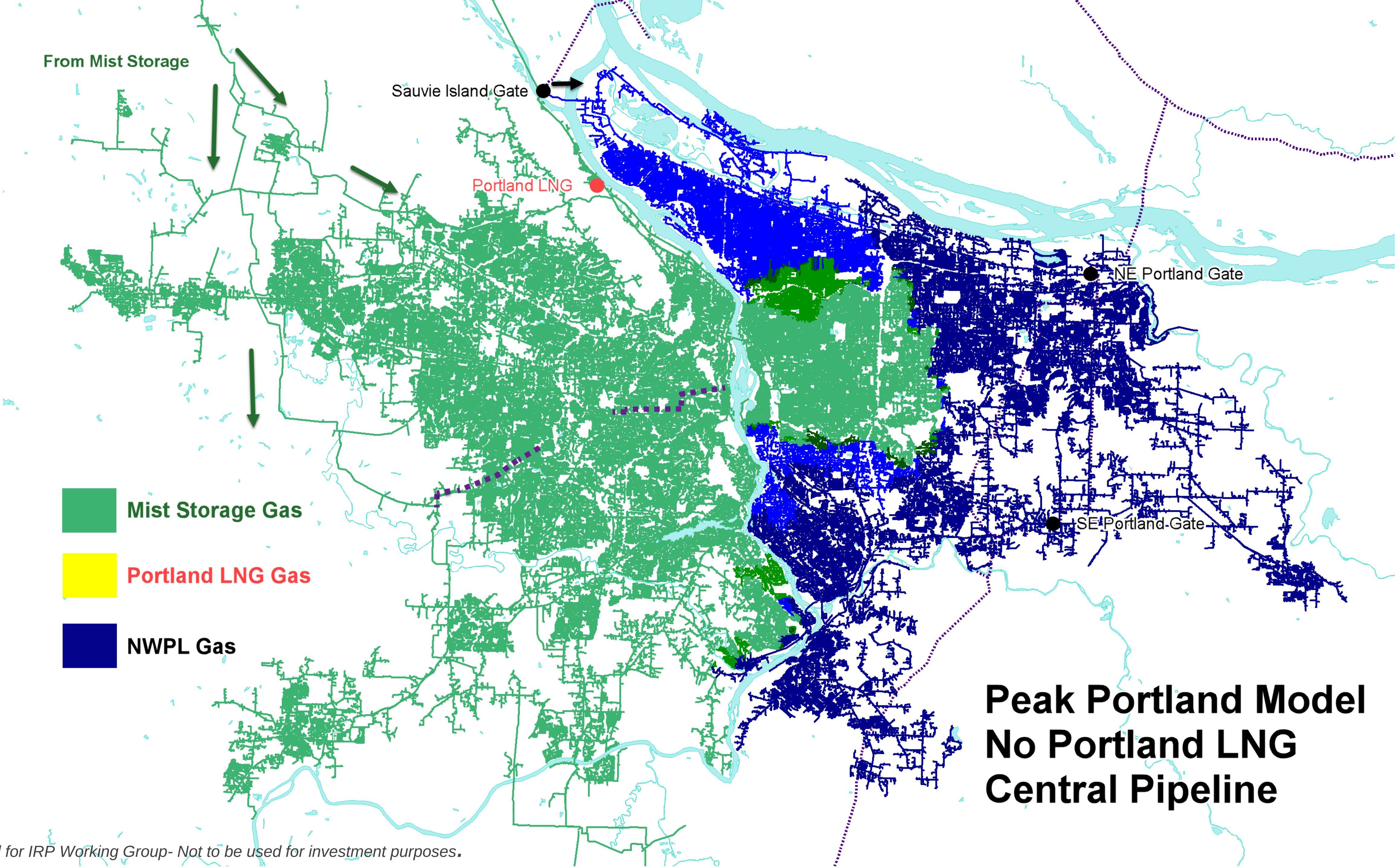
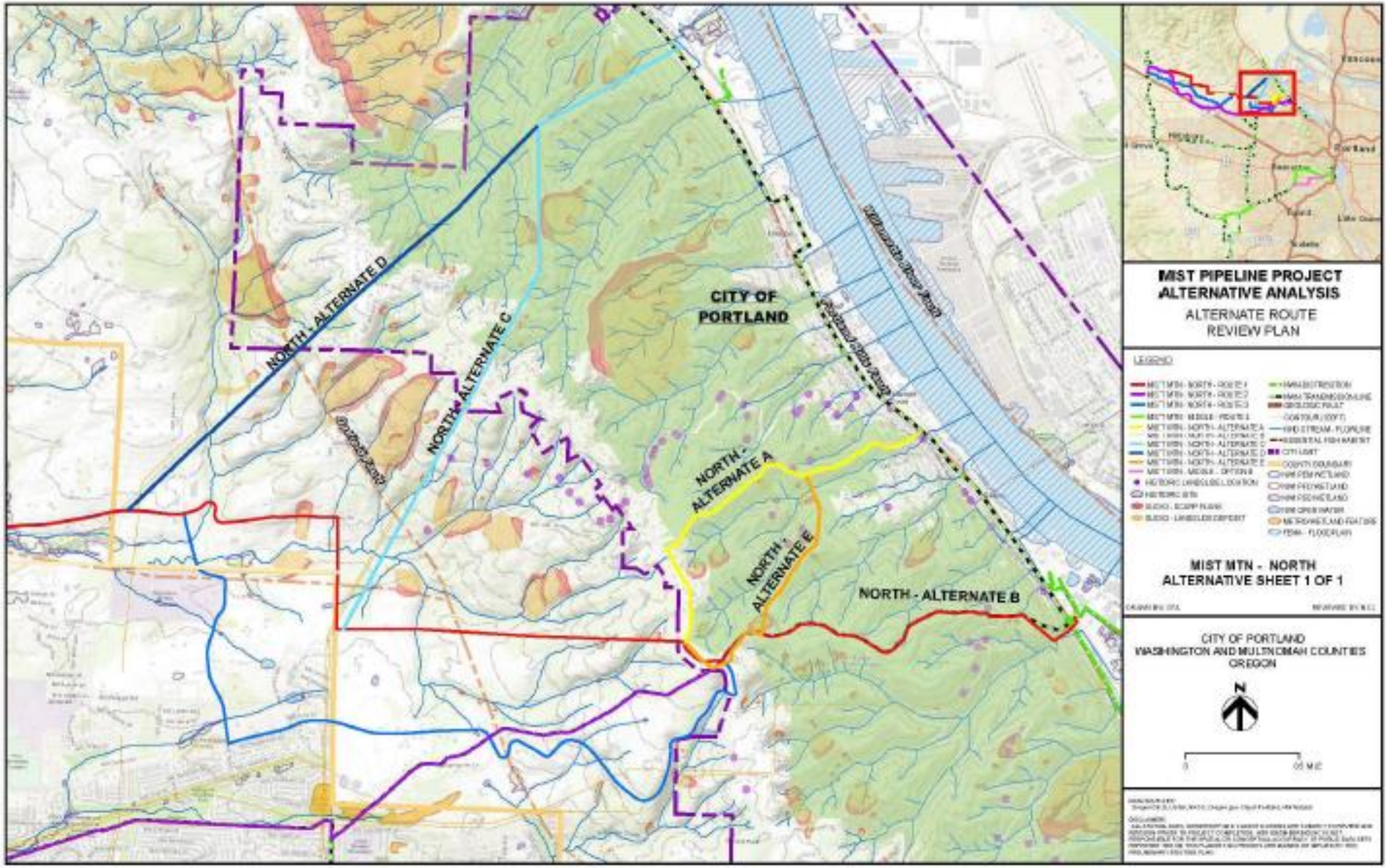


Peak Portland Model
No Portland LNG
Central Pipeline

Prepared for IRP Working Group- Not to be used for investment purposes.



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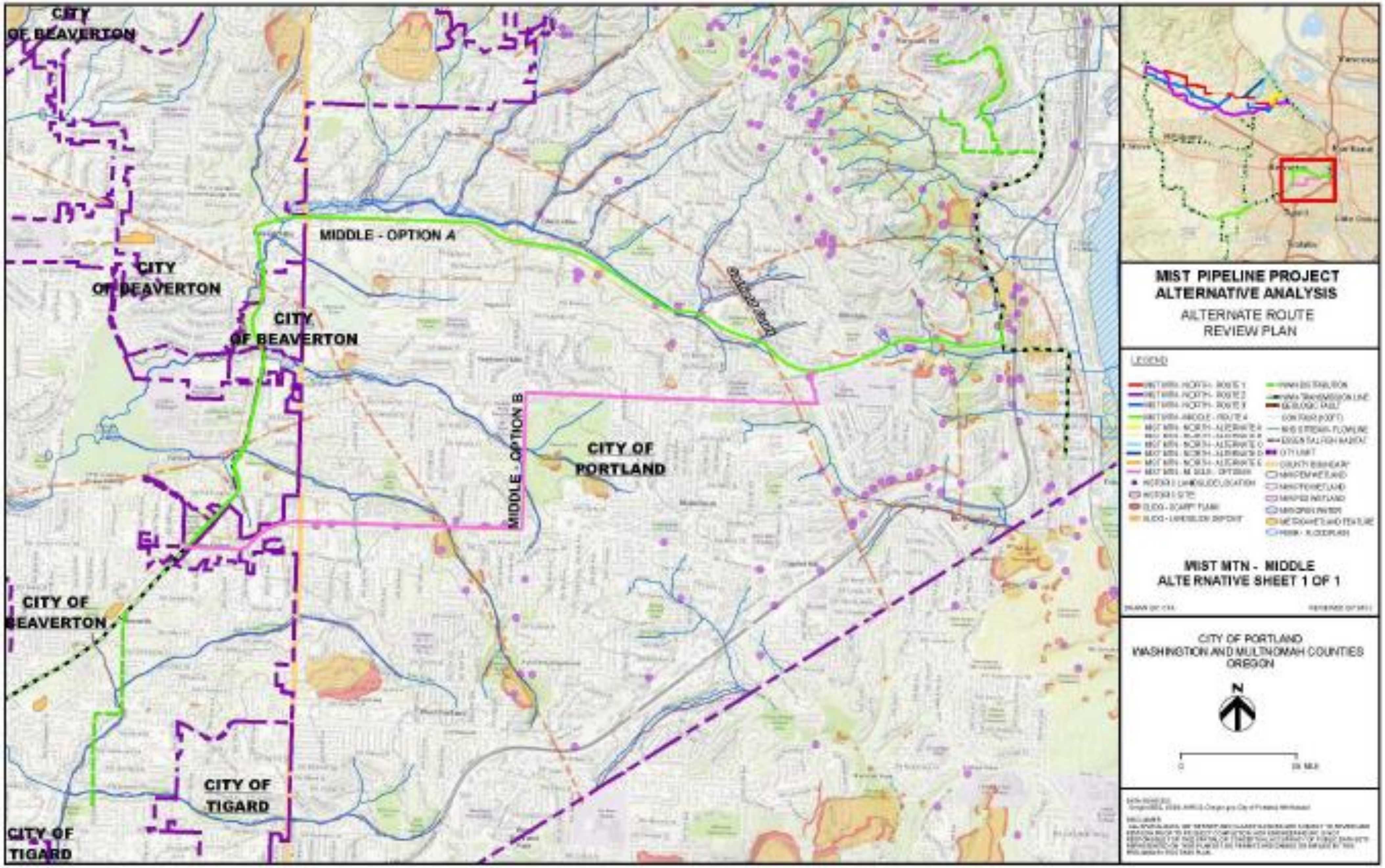


Prepared for IRP Working Group- Not to be used for investment purposes.

Why does the PLNG Cold Box Need Replacement?

- **Safety** – The cold box is an older design that's purged with natural gas. After 50+ years of service it leaks natural gas and has temporary repair clamps currently installed. A new cold box would be purged with nitrogen.
- **Heat Exchanger Fouling** – Sanborn & Head (SHA) performed modeling on the cold box that showed due to years of use and fouling the heat exchangers are no longer performing as designed.
- **Age** – The existing cold box design is outdated. Modern heat exchangers are less prone to failure. If one of the existing heat exchangers fails, it may be impossible to replace.
- **Temperature Rating** – The existing cold box is rated for 100°F which limits liquification operations. The new cold box will be rated for 150°F which will enable more efficient liquification runs.

Sanborn & Head FEED Study

NW Natural®

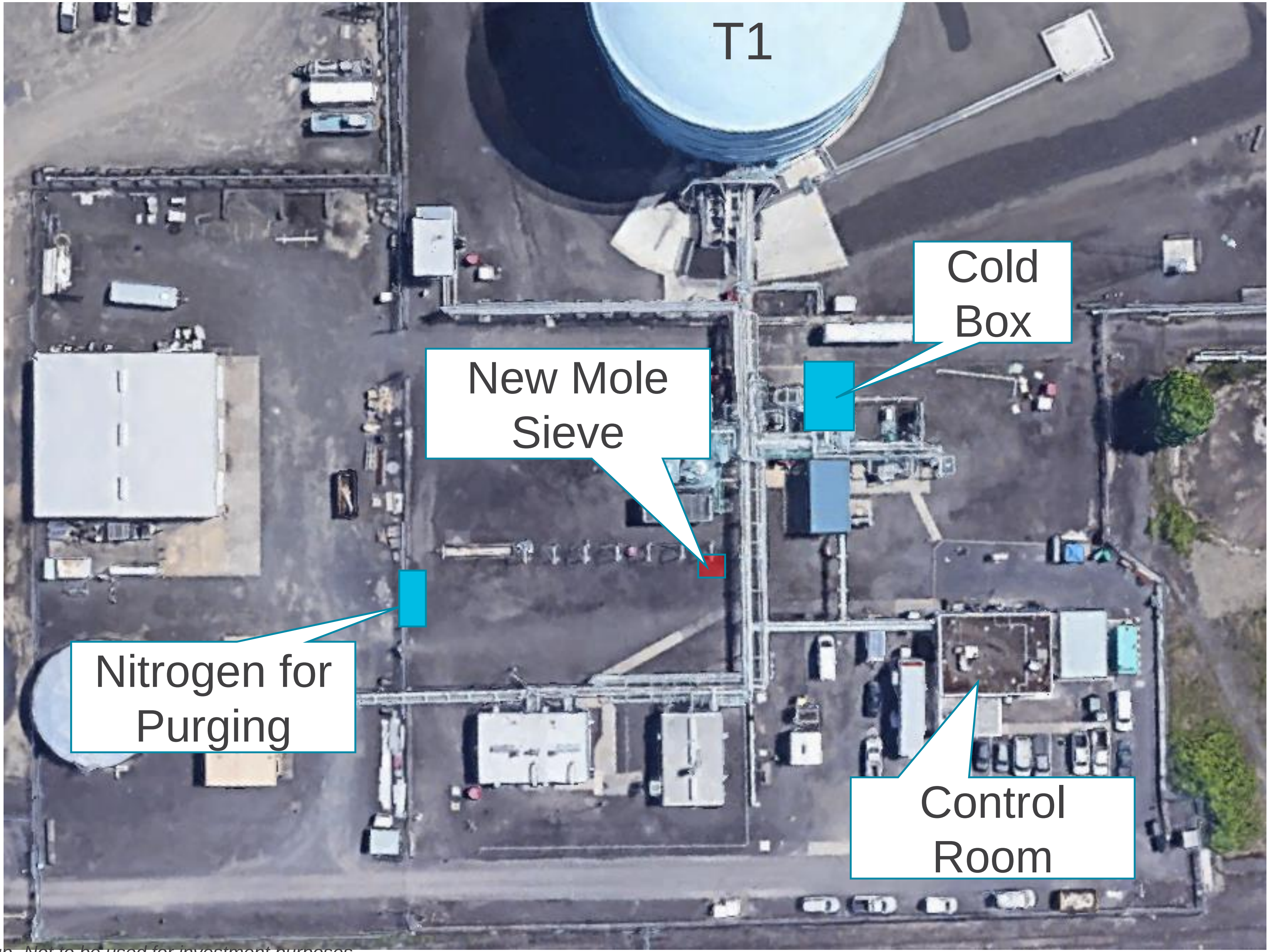
Sanborn & Head conducted a Front-End Engineering and Design (FEED) Study. Evaluations were executed to develop a Design Basis to support preliminary engineering and design of the Cold Box and its integration into the Facility's mechanical, electrical, and controls systems including:

- Geotechnical investigation
- Wind Study
- Nitrogen source and supply evaluation
- Hazard and Operability Study (HAZOP) based on existing conditions
- Pre-treatment evaluation

Sanborn & Head FEED Study

The FEED study was advanced with preliminary design tasks including the development of:

- Liquification Process Model
- Written Cold Box Specification
- Preliminary design documents:
  - Process Flow Diagram (PFD)
  - Process and Instrumentation Diagram (P&ID)
  - General arrangement drawings of the physical plant


T1
Cold Box
New Mole Sieve
Nitrogen for Purging
Control Room

Cold Box Cost Estimate

NW Natural®

Table OPCC-1: AACE Class IV Cost Estimate for NWN Cold Box Replacement			
Column	1	2	3
Line	Description and Breakdown	% of Total Project Cost	Estimated Installed Cost with Contingency
1	**Equipment**	**58%**	***$ 4,310,000***
2	2.15 MMSCFD Cold Box	48%	$ 3,560,000
3	Bulk Nitrogen Storage System & Integration	7%	$ 540,000
4	Mercury Guard Equipment & Integration	3%	$ 210,000
5	**Cold Box Systems Integration**	**18%**	***$ 1,330,000***
6	Cold Box Integration, Valves, Equipment, IC	18%	$ 1,330,000
7	**Civil/Structural**	**5%**	***$ 390,000***
8	Cold Box Foundation Incl. Demo of Mat with Piles	3%	$ 190,000
9	Nitrogen Storage System Foundation	2%	$ 140,000
10	Mercury Guard Foundation	1%	$ 60,000
11	**Engineering, Design & Construction Management**	**18%**	***$ 1,340,000***
12	Cold Box Integration Engineering	8%	$ 600,000
13	Cold Box CM	8%	$ 590,000
14	Nitrogen System Engineering	1%	$ 80,000
15	Nitrogen System CM	1%	$ 70,000
16	**Permitting**	**2%**	***$ 120,000***
17	Permitting	2%	$ 120,000
18	**Grand Total**		**$ 7,490,000**
19	**AACE Class IV Low Range (-30%)**		**$ 5,243,000**
20	**AACE Class IV High Range (+50%)**		**$ 11,235,000**

Construction estimated to take 2 years once project is started

Existing Cold Box

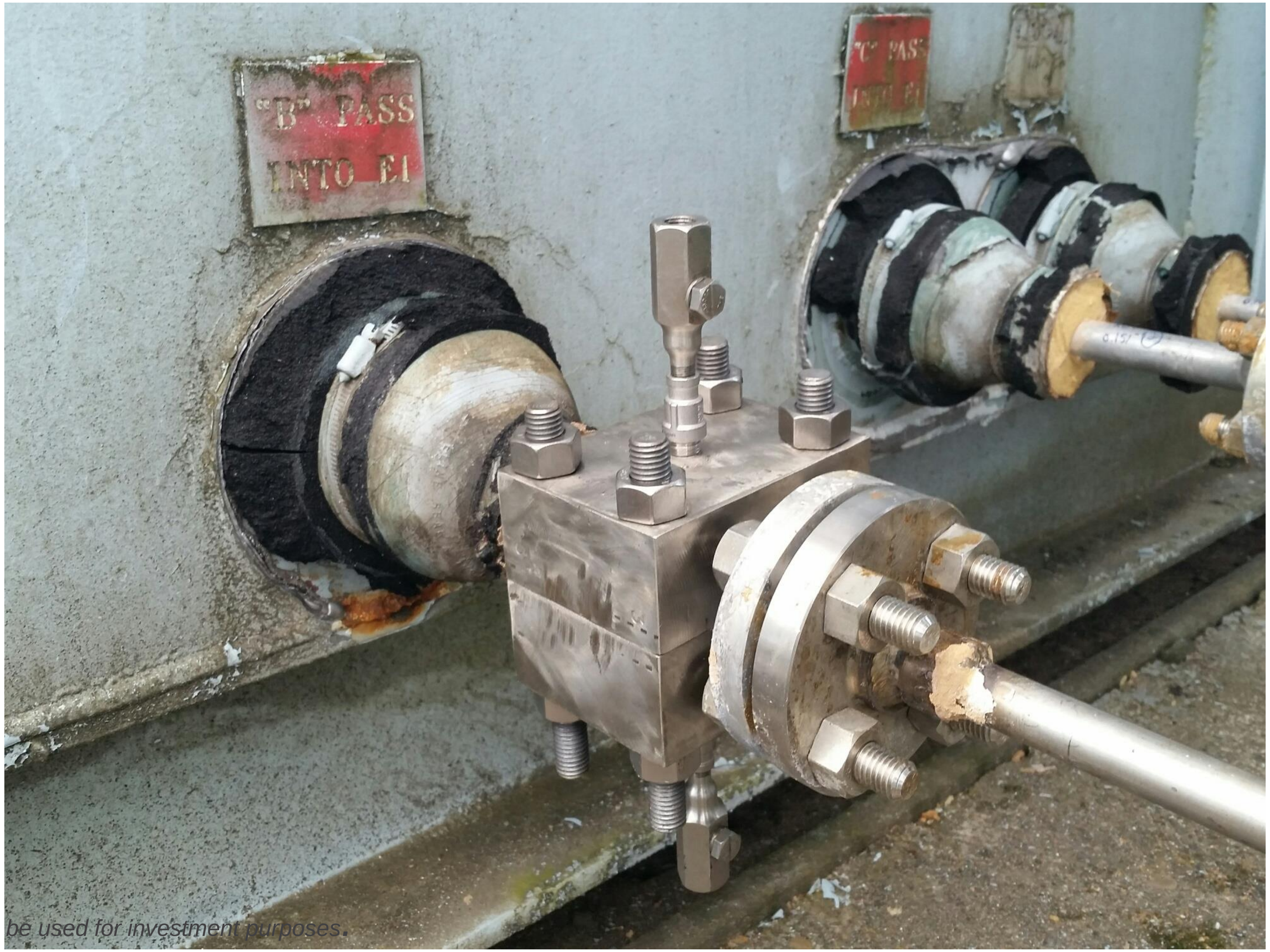
Existing Cold Box

Cold Box Penetrations

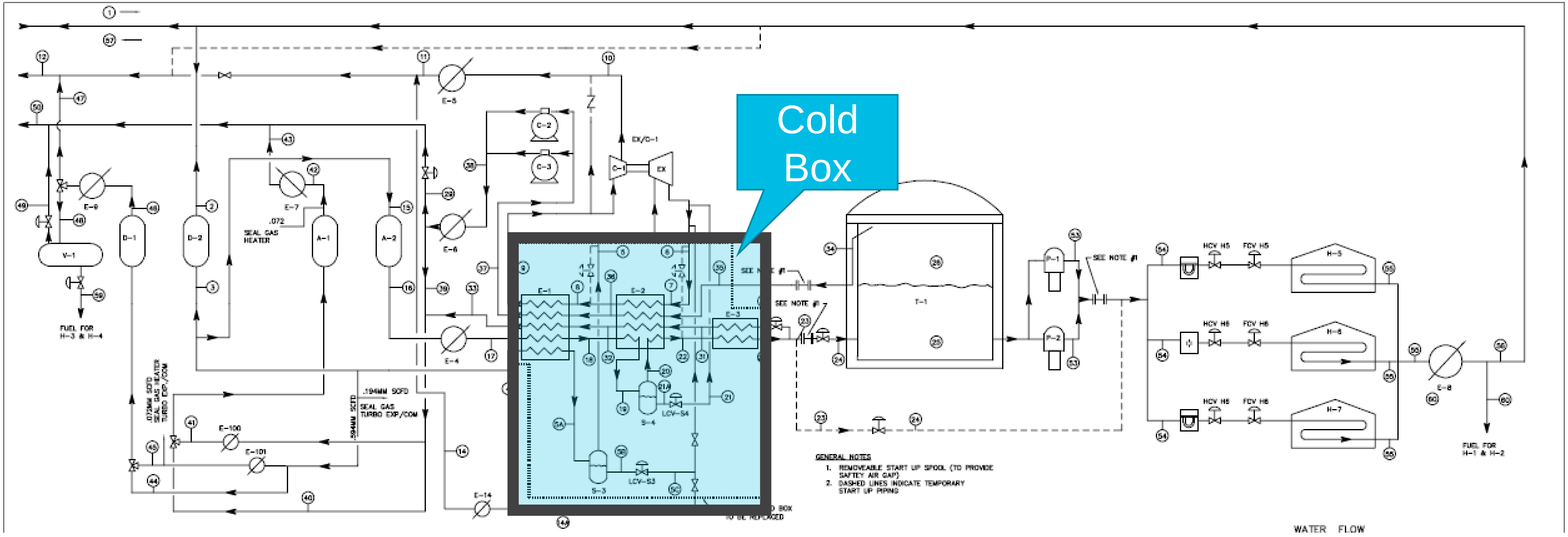
Aluminum Pitting

Aluminum Pitting

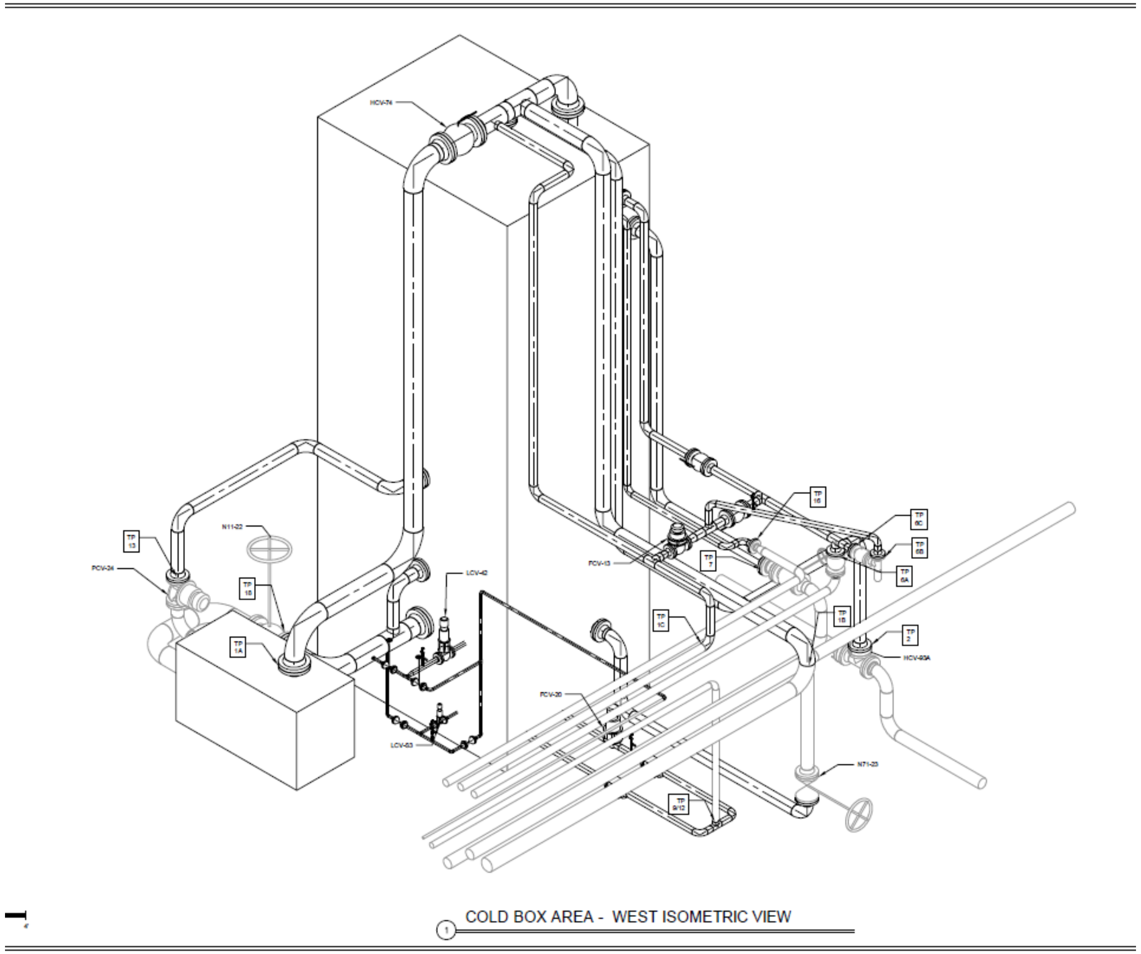
Pitting Correction



PLNG Process Flow Diagram



New Cold Box

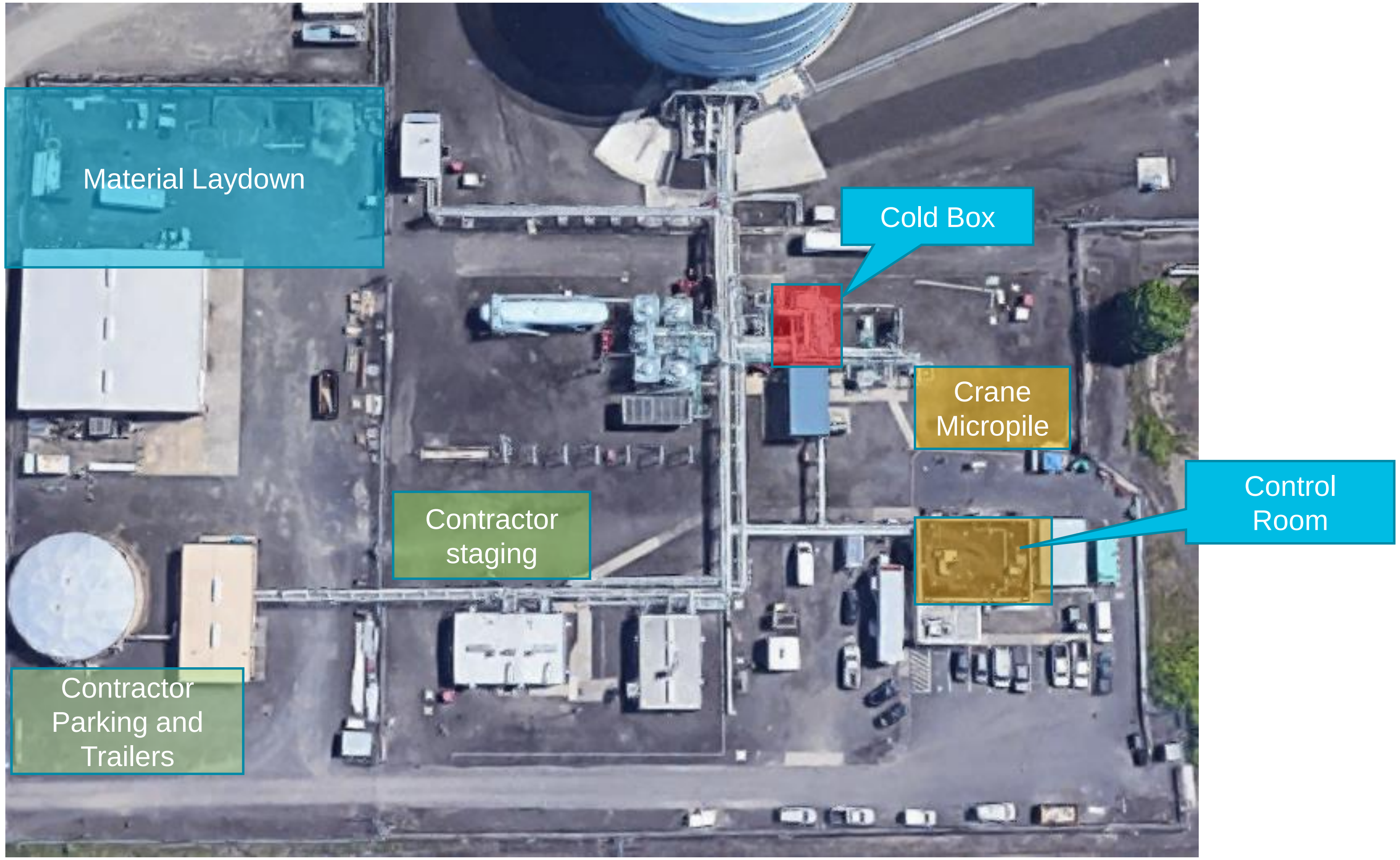


COLD BOX AREA - WEST ISOMETRIC VIEW

Construction Project Plan

- Construction Logistics
- Procurement of long lead equipment (including the cold box – 52 weeks)
- Contaminated soil removal and disposal at PLNG site
- Construction laydown area
- Crane and Crane setup
- Driving micropiles as foundational supports for the new cold box.
- New equipment installation and tie-in to the existing system
- Old equipment demo and removal
- Commissioning of the new equipment

Construction Activities



Portland LNG Project Alternatives Summary

NW Natural®

Installation Cost		Additional Resources Required
Cold Box Replacement	$11 Million	PLNG 10-Year Plan
“Central” NWN System Pipeline	$111 Million	Mist Recall
Interstate Pipeline Looping	$87 Million	Mist Recall

- Facility cost of service (COS) uses amortized payments to the investment
- Facility COS includes O&M and future expected investments
- Facility cost of service does **not** represent total cost to customers
- Total portfolio cost includes variable gas supply costs (i.e. gas costs)
- Total portfolio costs will be shown in future TWG where we show portfolio results

ICF Presentation Begins

AGA Net Zero Emissions Opportunities for Gas Utilities

Overview of RNG & Hydrogen Components

03/28/2022

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This information is from an American Gas Association (AGA) Study. The analysis was prepared for AGA by ICF. AGA and a steering committee of utilities defined the cases to be evaluated, vetted the overall methodology, and guided major study assumptions.

Disclaimer

- Overview of study's use of RNG & Hydrogen
- RNG supply details
- Hydrogen use cases

Agenda

Brief study RNG / H2 overview

Categories of Supply-Side Resources in the Study

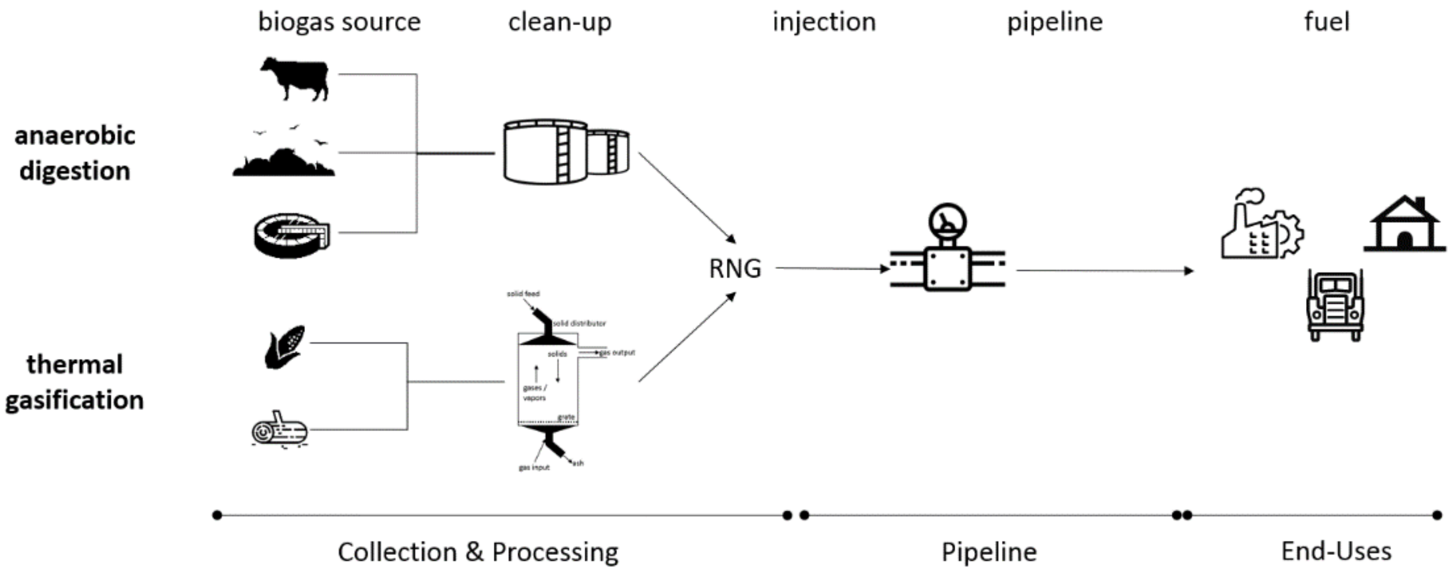
- Geological natural gas:
  - This portion of remaining gas demand which continues to be met by shale / conventional natural gas production
- Renewable natural gas (RNG)
  - This includes RNG produced by Anaerobic Digestion and Thermal Gasification from a variety of feedstocks
- Hydrogen blending into gas supply:
  - Hydrogen that is assumed to be mixed into existing gas infrastructure without requiring significant infrastructure upgrades
- Methanated hydrogen (RNG)
  - This supply represents RNG (or low carbon gas that can be blended without limit in existing gas infrastructure) that was produced from a clean hydrogen feedstock, through the addition of biogenic CO2 in a methanation process.
- Dedicated hydrogen infrastructure:
  - This represents the build out of new infrastructure to enable targeted customers/clusters to convert to higher levels of hydrogen use. These volumes include hydrogen used for industry (all scenarios) and hydrogen used in residential/commercial buildings (one scenario only), but do not include hydrogen used in the transportation sector for fuel cell vehicles.

RNG supply details

Renewable Natural Gas

- Renewable natural gas (RNG) is a pipeline-compatible gaseous fuel derived from biogenic or other renewable sources that has lower lifecycle carbon dioxide equivalent emissions than geological (conventional) natural gas.
- RNG is generally produced from waste-based feedstocks:
  - Includes landfill gas, wastewater, food waste, animal manure, agricultural and forestry residues, and energy crops.
  - Waste-to-energy pathways such as RNG displace fossil fuel consumption and avoid conventional waste management emissions.

RNG Production Process



RNG Supply – AGF 2019 Report

- In 2019 ICF completed a study of RNG supply potential for the AGF, looking out to 2040.
  - The AGF study looked at data on the resource availability for different RNG feedstock options and calculated a ‘Technical Potential’.
  - The AGF study included ‘High’ and ‘Low’ cases where different percentages of the technical potential would be realized.
  - The ‘High Case’ in the 2019 AGF study included 3,800 tBtu of RNG supply, about 27% of the ~14,000 tBtu technical potential.
- These supply cases were not developed or framed around specific policy objectives or GHG targets.
- Instead, purpose was to illustrate the diversity and volume of RNG potential with different, relatively conservative, constraints for each feedstock.

Figure 1. Estimated Annual RNG Production, Low Resource Potential Scenario, tBtu/y

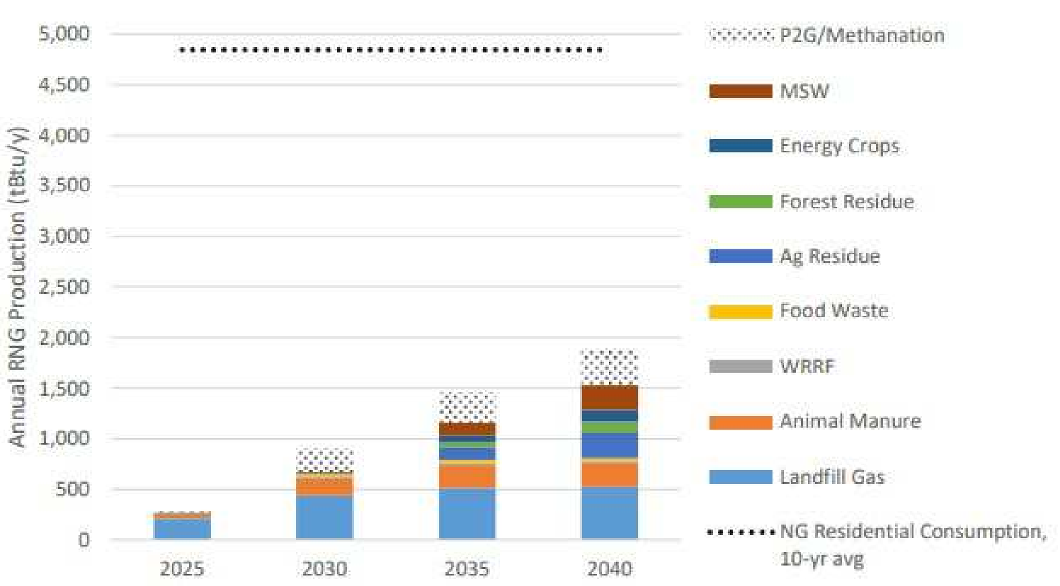
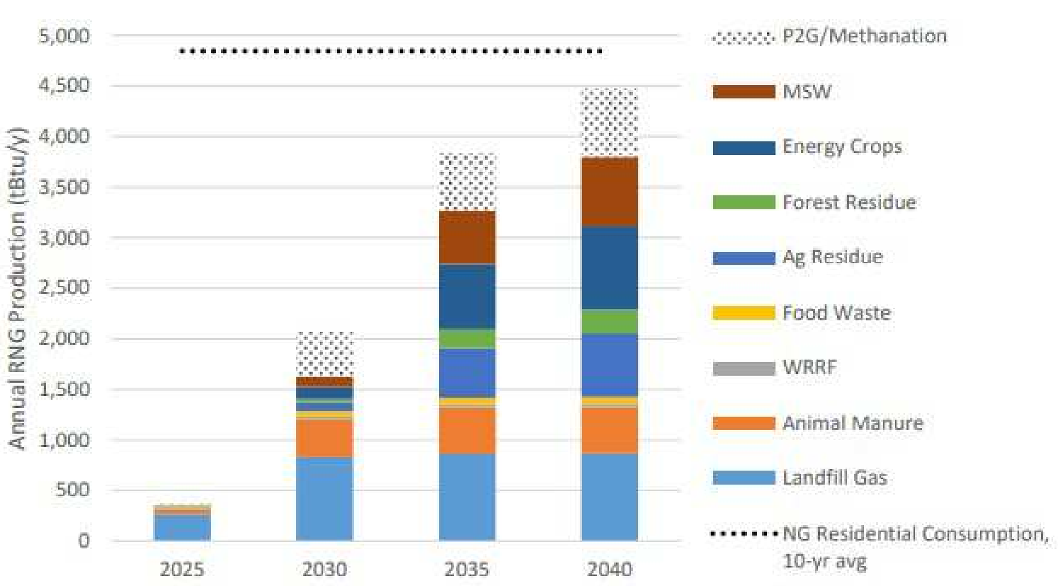


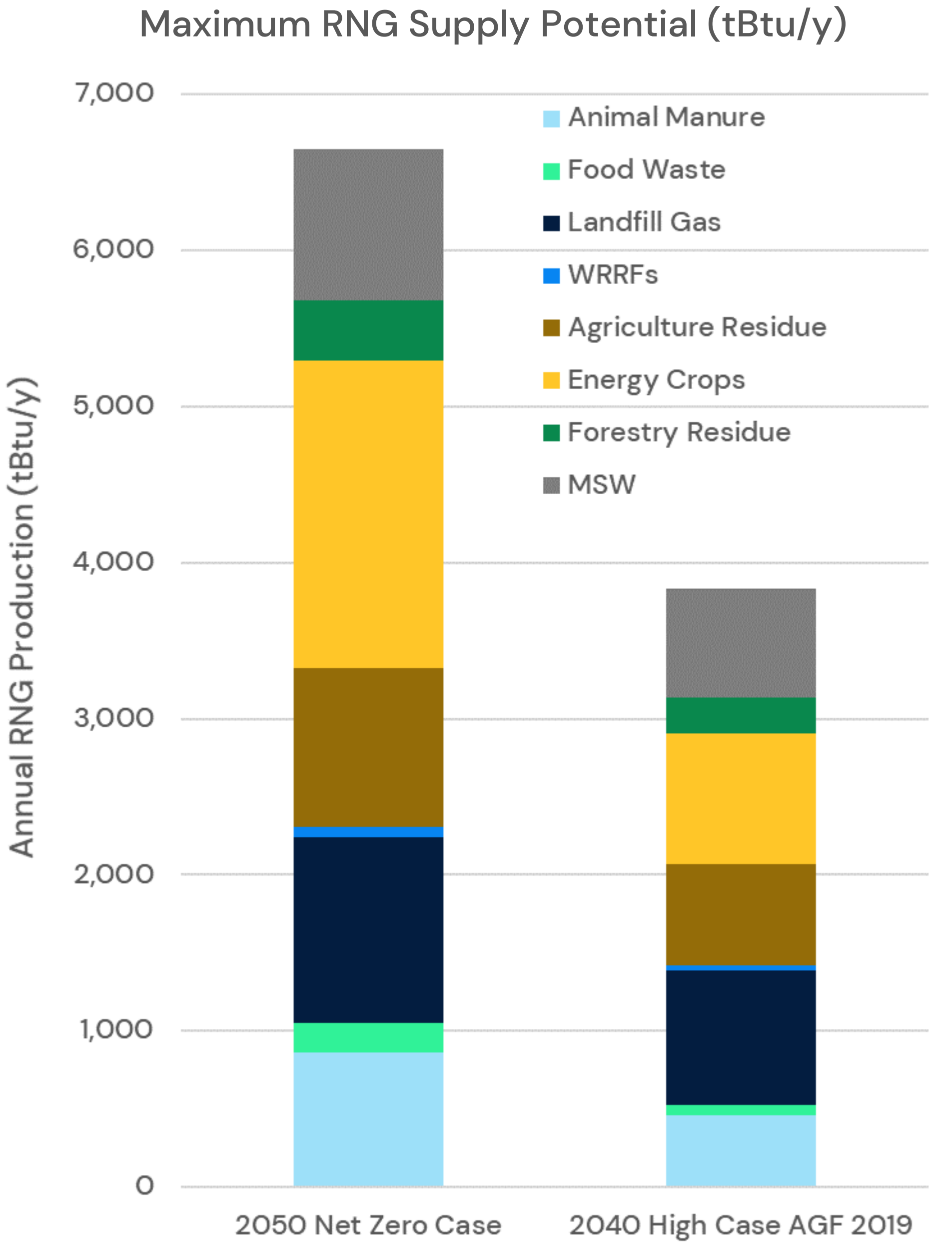
Figure 2. Estimated Annual RNG Production, High Resource Potential Scenario, tBtu/y



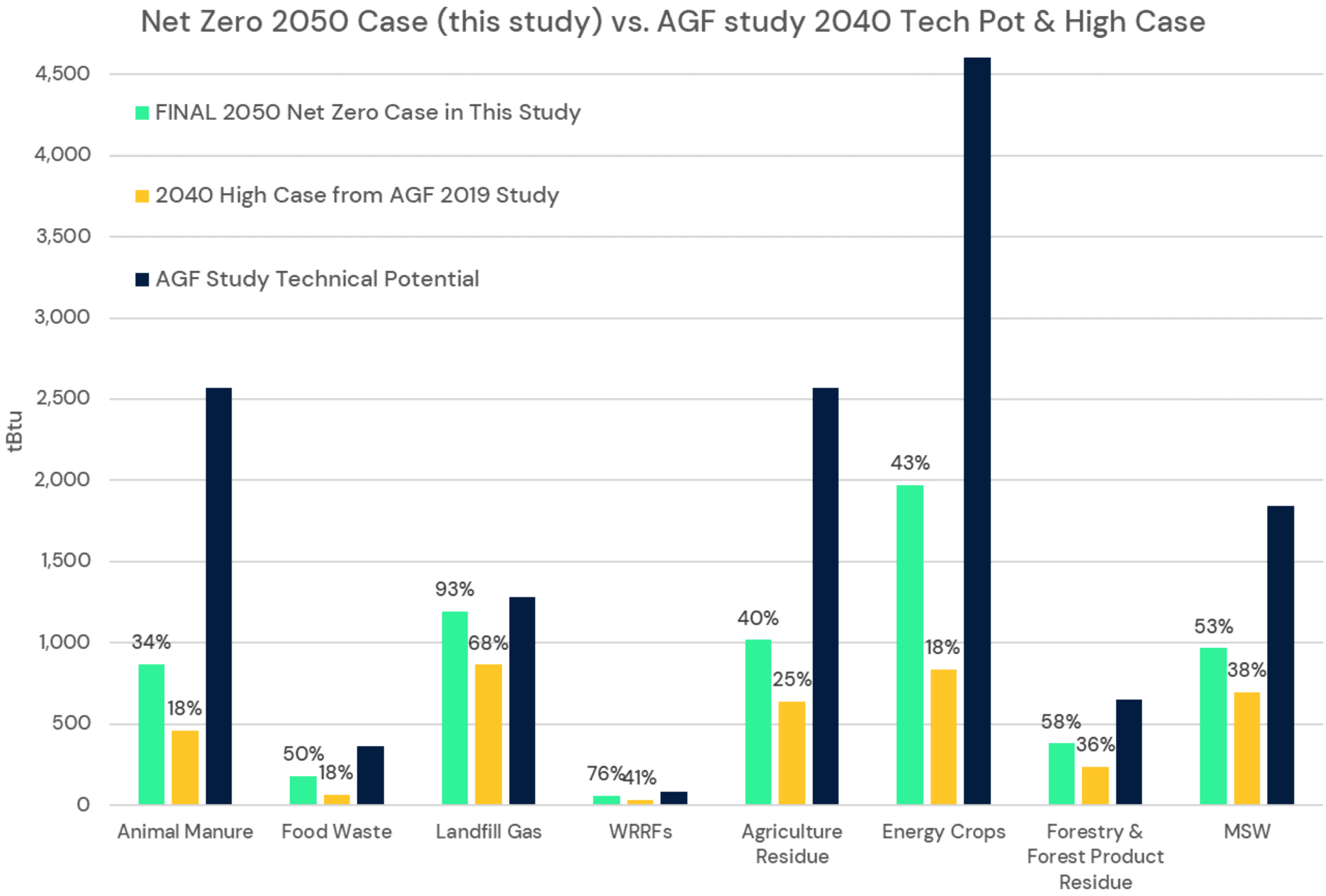
https://gasfoundation.org/2019/12/18/renewable-sources-of-natural-gas/

- Since the 2019 report, heightened focus on aggressive long-term GHG emission reductions, referred to as 'deep decarbonization'.
  - Deep decarbonization typically reflects emission reduction targets of between 80–100% by 2050 (e.g. Net-Zero).
- Deep decarbonization requires aggressive deployment of emission reduction measures across the economy:
  - GHG-free electricity grids, comprehensive transportation electrification, and deployment of low or zero carbon fuels.
  - Renewed focus on the role that bioenergy can play to reach these aggressive GHG emission reduction targets.
- RNG supply potential was re-evaluated for AGA's 2021 Net-Zero report in this context:
  - Focused on 2050 timeframe, consistent with aggressive GHG targets.
  - 2050 Net-Zero RNG supply case uses same feedstock data from 2019 report, but captures closer to 50% of technical potential in 2050.
  - Supply increased to reflect 'all hands on deck' approach to economy-wide deep decarbonization, while maintaining a conservative approach to feedstock constraints and limitations.

→ RNG Supply – 2021 Net-Zero Case



- AGF 2019 High Case captured 27% of all available feedstocks:
  - Ranging from 68% for landfill gas, to 18% for animal manure and energy crops.
- AGA 2021 Net-Zero case increased utilization, captured 48% of all available feedstocks:
  - Landfill gas is highly utilized.
  - Conservative constraints continue to limit supply of animal manure, agricultural residue and energy crops (34-43%).

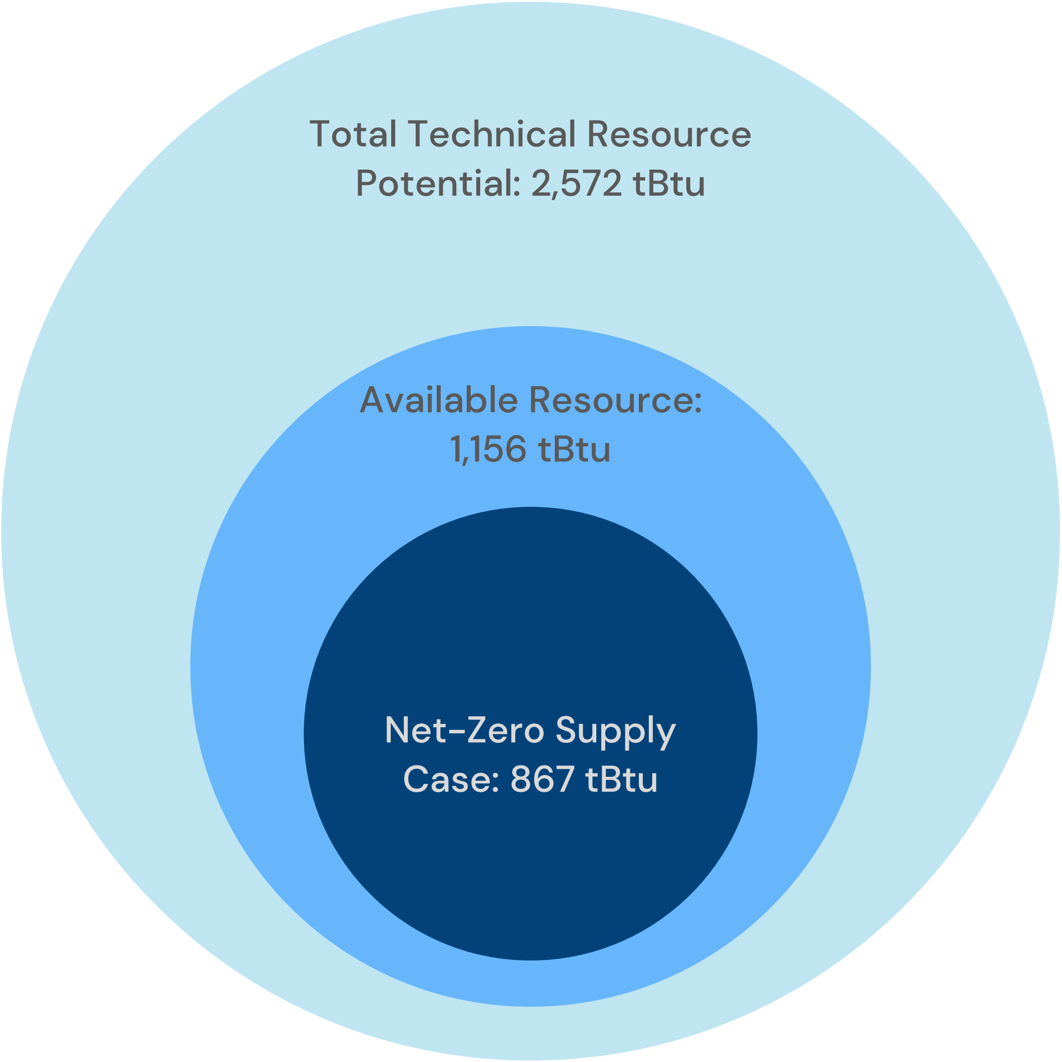


RNG Supply – Utilization Comparison

RNG Supply – Feedstock Utilization Example

- *Total Technical Resource Potential* reflects all animal manure produced from all animal populations:
  - Biomass estimate derived from daily manure production rates for beef cows, dairy cows, broiler chickens, layer chickens, turkeys and swine.
  - Total reflects collection of all manure.
- Technical Availability Factors (TAF) are then applied to estimate *Available Resource*:
  - From a practical perspective, not all manure can be collected and utilized for RNG production, e.g. dispersed in fields.
  - TAF varies by animal type, e.g. dairy and chickens have TAF of 50%; beef and swine 20%.
- Resource scenarios, such as the *Net-Zero Supply Case*, applies additional constraint on utilization of *Available Resource*, e.g.:
  - *Net-Zero Supply* case captures 75% of *Available Resource*.
  - AGA 2019 High Scenario captured 60% of *Available Resource*.

Animal Manure Feedstock



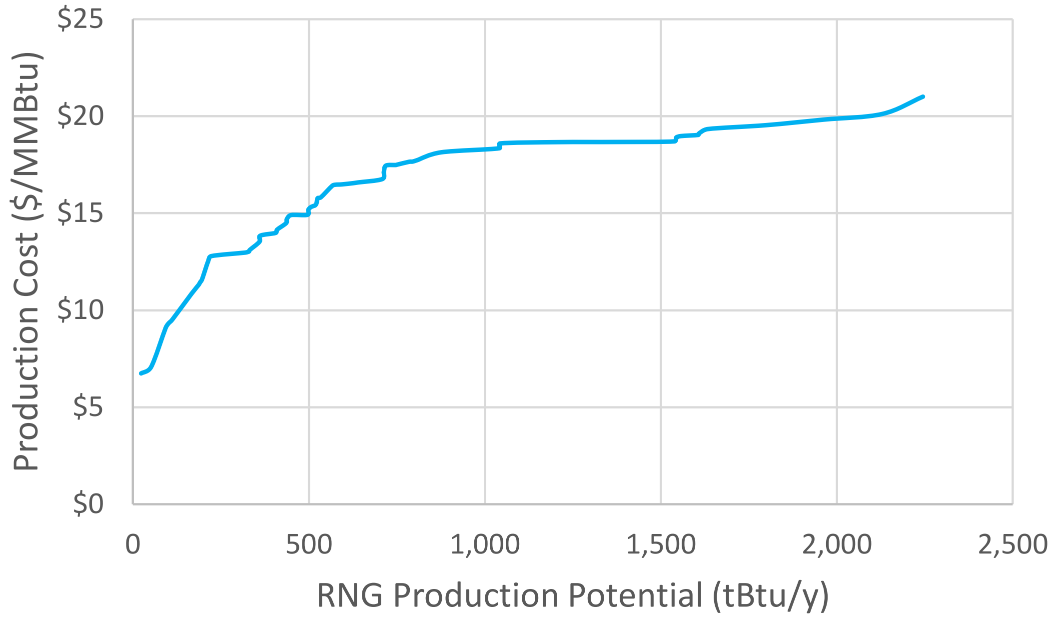
RNG Supply – AGA Net-Zero 2050

- AGA Net-Zero 2050 case framed around long-term and economy-wide deep decarbonization.
  - i.e. pushing hard on all emission reduction options across the economy, not just RNG.
- More optimistic assumptions on feedstock utilization.
- Case captures less than half of all available feedstocks.
  - 54% of anaerobic digestion feedstocks.
  - 45% of thermal gasification feedstocks.
- Over half of available biomass that could be used to produce RNG is not directed towards RNG production.
  - Allows for other sectors of the economy to capture and utilize the biomass, as needed (e.g. liquid biofuels).

Feedstock for RNG		Volume (tBtu)	Key Parameter
Anaerobic Digestion	Animal manure	867	75% of technically available
	Food waste	182	95% @ $100/ton
	LFG	1,195	95% eligible landfills
	WRRF	62	95% of facilities w/ >3.5MGD
	Subtotal & Utilization Percentage	**2,306**	**54%**
Thermal Gasification	Agricultural residue	1,019	80% @ $50/ton
	Energy crops	1,972	60% @ $50/ton
	Forestry & forest product residue	381	80% @ $50/ton
	MSW	968	80% @ $50/ton
	Subtotal & Utilization Percentage	**4,339**	**45%**
Total & Utilization Percentage		**6,645**	**48%**

- RNG production cost estimates reflect the all-in cost to collect, clean and deliver the RNG up to the point of injection into a common-carrier pipeline.
- Cost estimate do not reflect potential value of environmental attributes associated with RNG, such as when used in the transportation sector (Federal Renewable Fuel Standard).
- In the 2019 AGF Report, ICF estimated that the majority of the RNG produced in the High Resource Potential scenario would be available in the range of $7-$20/MMBtu.
- ICF also found that there was potential for cost reductions as the RNG for pipeline injection market matured, production volumes increased, and the underlying structure of the market evolved.

Combined RNG Supply-Cost Curve in 2040 (ICF AGF Report 2019)



RNG Cost Assessment – AGF 2019 Summary

Hydrogen discussion

- For RNG, the key limiting factors would be the total RNG feedstock potential (including competition from other sectors like Power), as well as RNG supply costs

- For Hydrogen, this study assumed the constraints are only limitations on customers' ability to acquire and use hydrogen (not H2 supply)
  - If hydrogen production is limited only by renewable and/or nuclear generation expansion, as well as SMR with CCS, the study working group was comfortable assuming that 'as much hydrogen as needed' can be made seems in line with the types of actions needed to hit net zero (for any pathway)
  - Methanated hydrogen was an exception to that – as it could be limited by the availability of CO2 for methanation of H2
  - Blending limits in gas distribution systems, limits from existing customer equipment, and safety considerations will all be key factors that could prevent customer adoption
  - Costs to convert to new hydrogen infrastructure and equipment, as well as H2 supply, also relevant

→ Limiting Factors for Hydrogen Use

Study included hydrogen use through the following five approaches

1 H2 Blended into NG Supply

2 H2 Methanated into Synthetic NG & Blended into NG Supply

3 H2 Clusters for Industry & Power Generation

4 New Customers in Targeted Regions Built for 100% H2

5 Targeted Conversion of Existing Customers to 100% H2

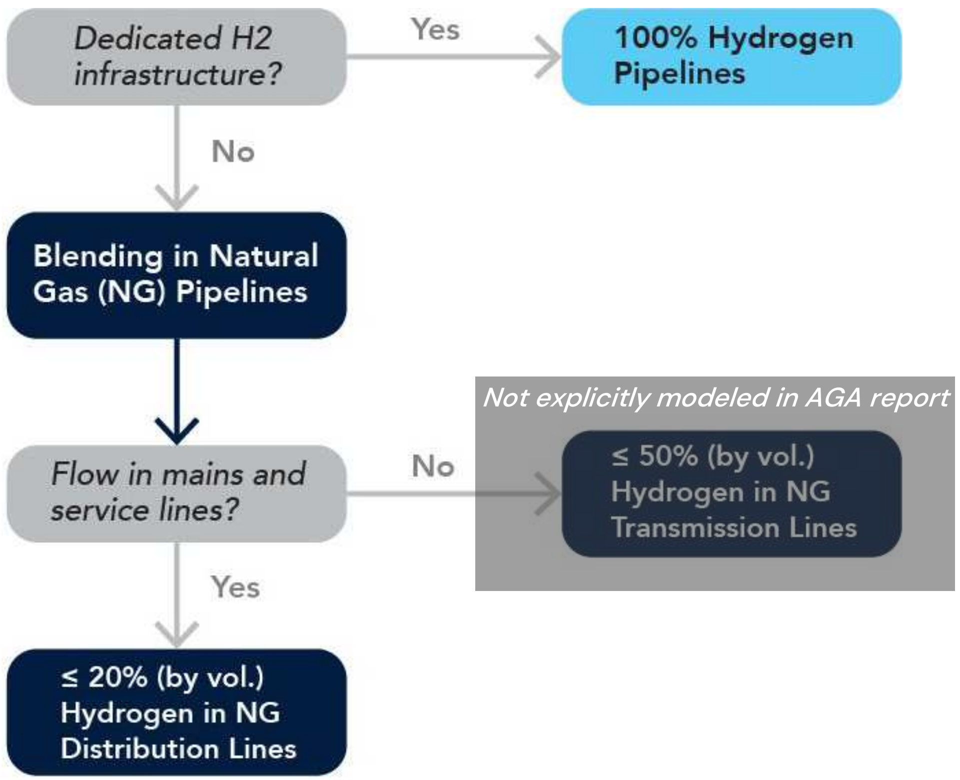
6 Other Approaches

E.g., H2 powering distributed fuel cells

Hydrogen Generation, Storage, Transportation

Hydrogen Blending into Natural Gas Supply

- Up to 7% on energy basis (20% by volume) by 2035
  - Hydrogen can blend in limited amounts into natural gas pipelines
  - Existing research suggests that blends up to 20% H2 by volume may be feasible in existing pipes, depending on pipeline material, without major infrastructure upgrades
  - Not all study scenarios went up to the 20% blend – as focus was demonstrating diversity of approaches



Methanated Hydrogen

- Carbon-neutral methane that can be blended without limit in existing infrastructure
- Produced by methanating clean hydrogen with biogenic CO2
- Functionally equivalent to renewable natural gas
  - Essentially adds to the aforementioned RNG supply from conventional anaerobic digestion and thermal gasification RNG processes (*but methanated hydrogen volumes are counted separately from the RNG supply / not included in the RNG section totals*)
- Limitation is the availability of 'carbon neutral CO2' for this process, to ensure the methanated hydrogen can be considered a renewable / low carbon fuel
  - This study indicates that a variety of biogenic CO2 options could be available – but for the potential here we quantified the Methanated Hydrogen potential based on an assumption that the RNG thermal gasification processes are paired with clean hydrogen, taking advantage of the biogenic CO2 emissions they produce and in effect doubling the RNG produced by thermal gasification
  - Thermal gasification RNG production creates enough biogenic CO2 to theoretically triple to quadruple RNG output through hydrogen addition – but it will also get harder / more expensive to utilize all available CO2
  - Some other studies includes CO2 from DAC – to increase available CO2 options beyond biogenic CO2

<u>Two key methanation reactions:</u>

$CO_2 + 4H_2 \rightarrow CH_4 + 2\,H_2O$

$CO + 3H_2 \leftrightarrow CH_4 + H_2O$ *(this is the Steam Methane Reforming reaction run backwards)*

Dedicated Hydrogen Infrastructure

- Customer's hydrogen needs could be met through newly built hydrogen pipelines, conversion of existing natural gas pipelines, or on-site hydrogen production

- All scenarios include a portion of industrial customers using 100% H2 (~10%), with higher levels in Scenario 4 (~17%)

- One scenario also includes some residential and commercial new construction customers using 100% H2 starting in 2040 and some existing residential and commercial gas buildings converted to use 100% H2 starting in 2045

Example commercially-available hydrogen combined heat and power (CHP) system

Hydrogen Production

- Focus in the report is on using 'clean hydrogen' with less emphasis on green vs. blue, but for the upstream emissions analysis assumptions on the supply mix were required
- Hydrogen supplies of interest to LDCs for net-zero targets were simplified to blue, green, and pink hydrogen
- Study assumed the initial adoption of hydrogen produced from conventional means (namely, steam methane reforming of natural gas) and from anticipated growing clean hydrogen supplies

	Gray Hydrogen	Blue Hydrogen	Green Hydrogen	Pink Hydrogen
Process	Steam methane reforming	Steam methane reforming with carbon capture and sequestration	Electrolysis	Electrolysis
Source	Methane	Methane	Renewably-generated electricity	Nuclear electricity generation

Assumed Supply Mix	2020	2025	2030	2040	2050
Green H2 (Renewable Electrolysis)	1%	20%	30%	52%	75%
Blue H2 (SMR with CC)	0%	5%	50%	48%	25%
Grey H2 (SMR)	99%	75%	20%	0%	0%

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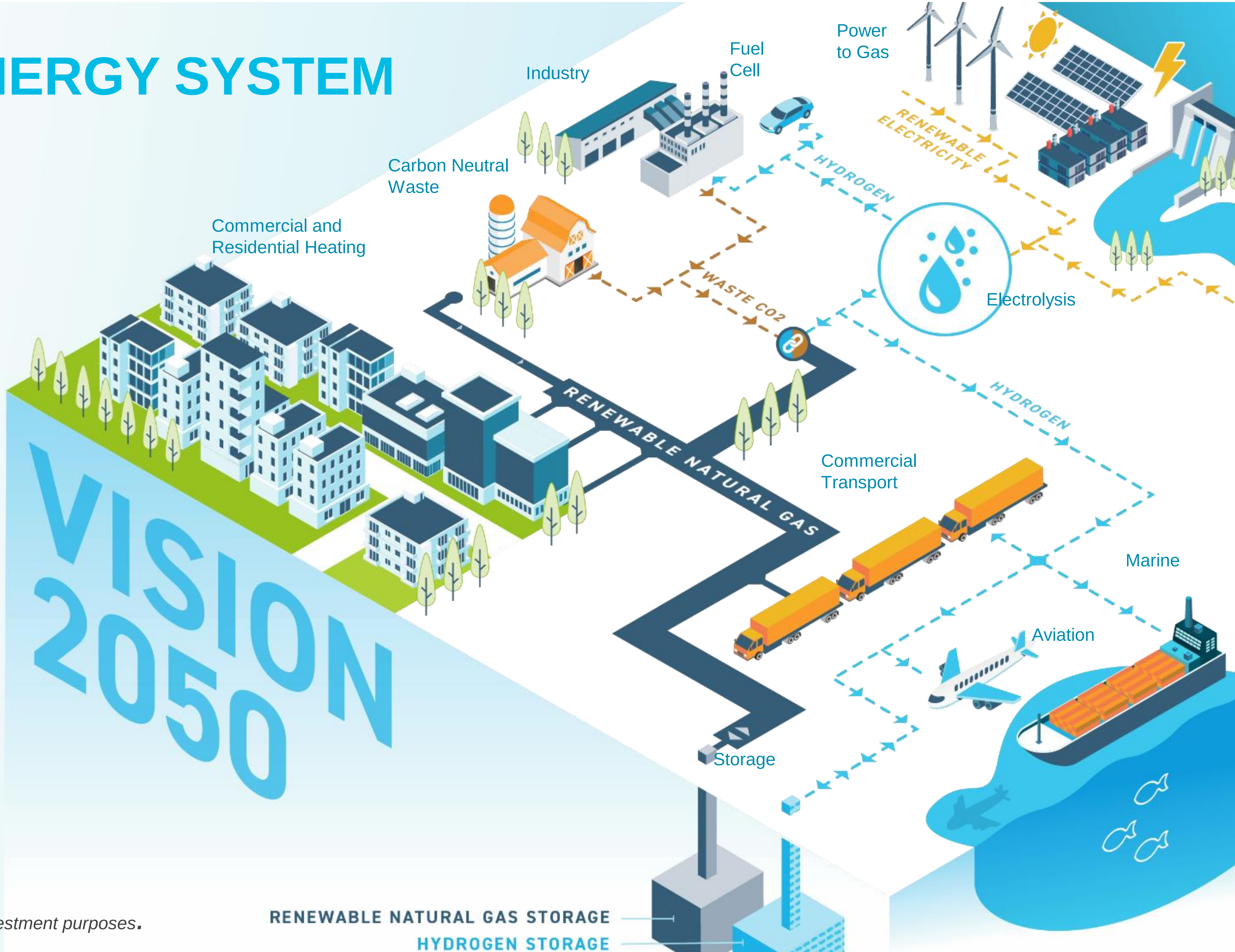
End of ICF Presentation

Renewable Natural Gas

THE FUTURE ENERGY SYSTEM

A decarbonized gas network:

- Deep energy efficiency
- Renewable natural gas
- Renewable hydrogen
- Blended and dedicated hydrogen systems



Renewable Natural Gas
Dedicated Hydrogen
Waste CO2
Renewable Electricity

Prepared for IRP Working Group- Not to be used for investment purposes.

What is Renewable Natural Gas?

NW Natural®

- **RNG is *pipeline-quality gas* derived by cleaning up the raw biogas emitted as organic material chemically breaks down.**
- **For RNG going directly onto NW Natural's system, RNG must be:**
  - **At least 97.3% methane**
  - **At least 985 BTUs/SCF**
- **RNG on our system is fully interchangeable with conventional natural gas**

Raw biogas can come from:

Wastewater Treatment Plants

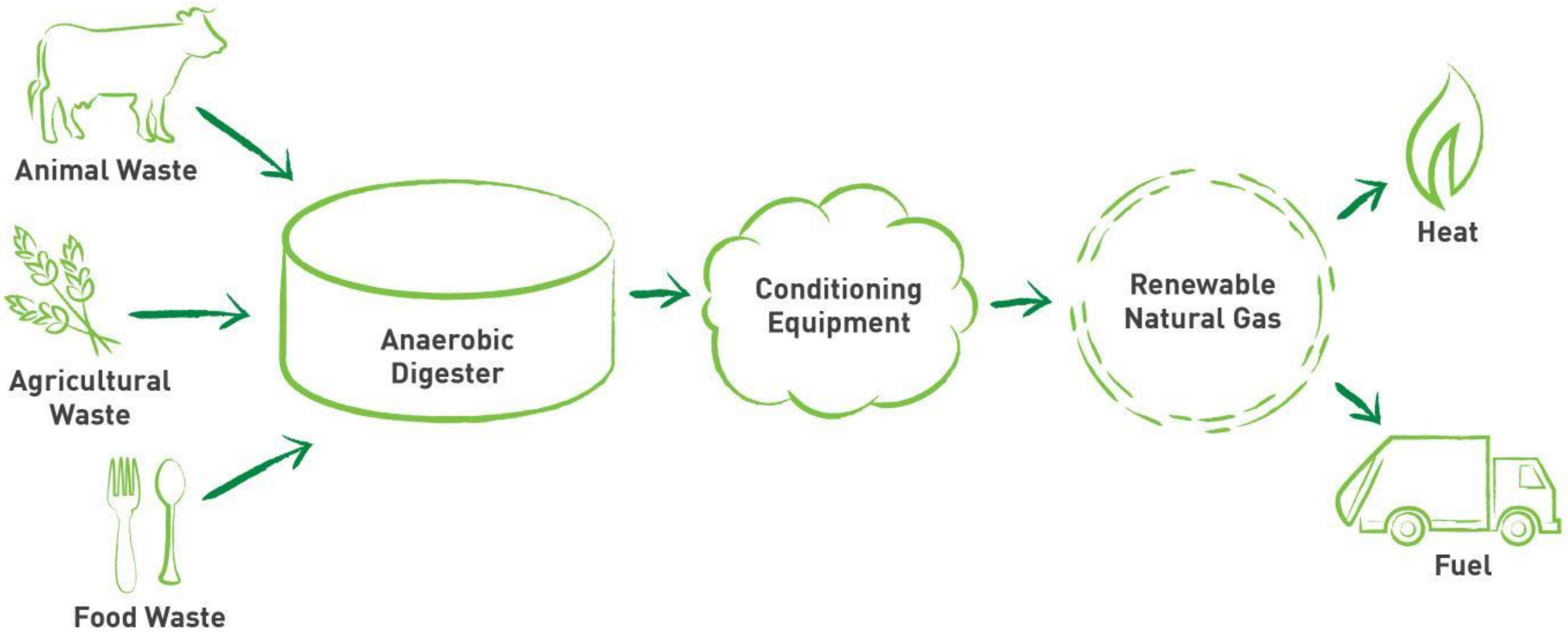
Municipal Solid Waste

Animal Manures

Landfills

Wood Waste/Residue

How is RNG made?



Policy Environment for Procuring RNG and Hydrogen

- Oregon Senate Bill 98
  - Volumetric targets for RNG procurement for Oregon sales customers
- Oregon Climate Protection Program (CPP)
  - Compliance will include RNG and hydrogen (above and beyond Senate Bill 98 volumes) when cost-effective to procure
- Washington House Bill 1257
  - Establishes both an option for delivery for RNG to all gas customers as well as a requirement to offer customers voluntary RNG tariff
- Washington Climate Commitment Act (CCA)
  - Sets emission cap that applies to gas utilities, which can use RNG and hydrogen as a compliance tool
- Voluntary offerings to customers
  - Building options for customers in Oregon and Washington to procure greater amounts of RNG and hydrogen

Oregon Senate Bill 98

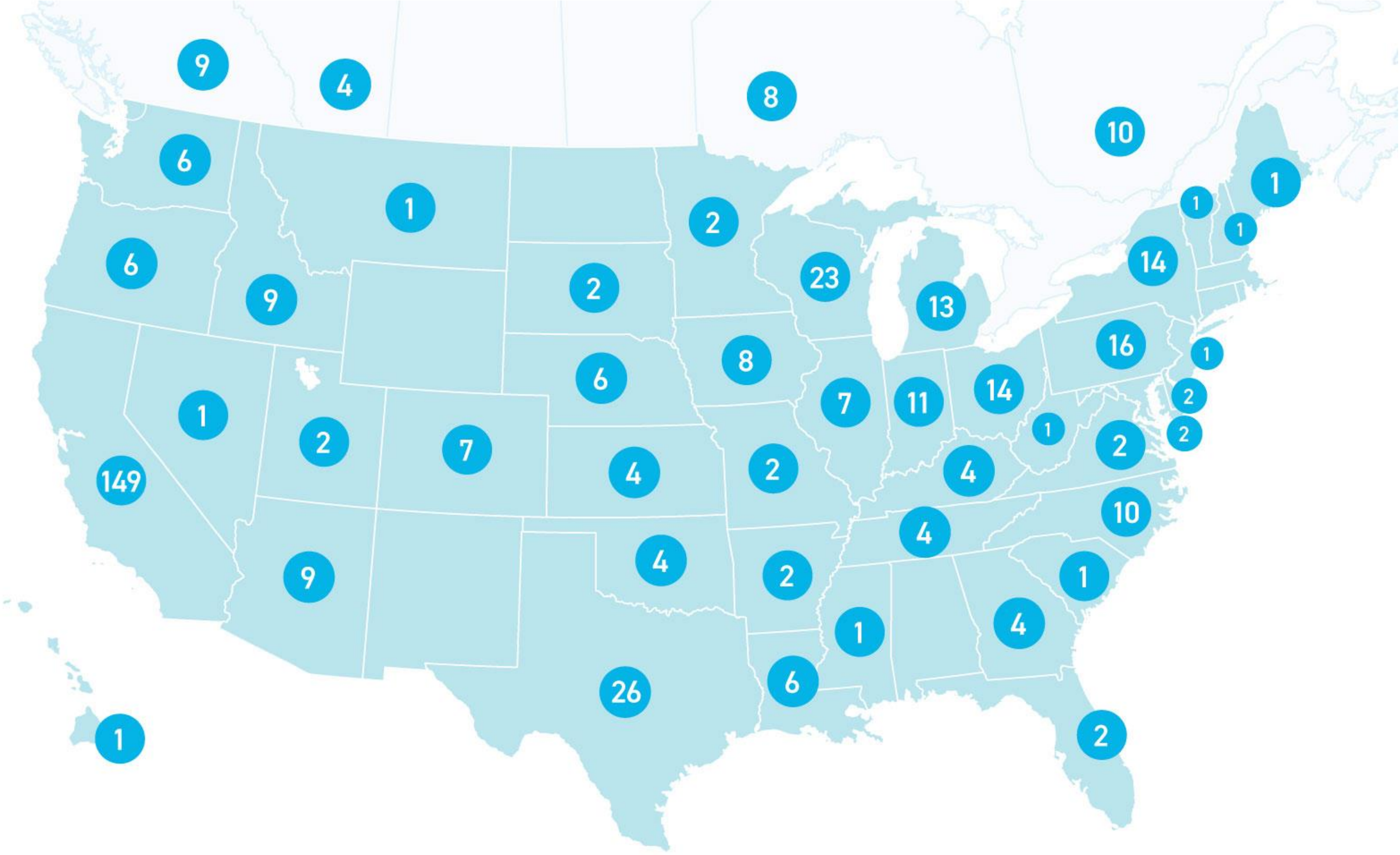
- Gas utilities can purchase RNG (including hydrogen) for all customers as part of our utility resource mix. This is a significant change, as prior to the passage of the bill, we could only buy the least-cost gas, which was not RNG.
- Gas utilities can invest in and own the equipment necessary to bring raw biogas and landfill gas up to pipeline quality, as well as the facilities to connect to the local gas distribution system.
- We must adhere to a spending limit to protect customers: we can spend up to 5% of our annual Revenue Requirement on the incremental cost of RNG.

Large Gas Utility Volumetric Targets

	% Target
2020 - 2024	5%
2025 - 2029	10%
2030 - 2034	15%
2035 - 2039	20%
2040 - 2044	25%
2045 - 2050	30%

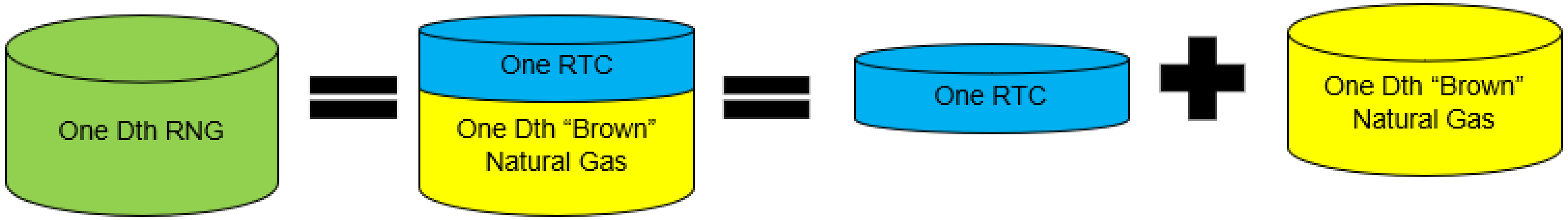
RNG Projects Across the Country

- 325 RNG facilities operating or under development today in North America
- We have connected 3 RNG projects in Oregon onto our pipeline system
- Under SB 98, we have been procuring RNG for our customers from projects around the country
- Over the last year we have announced our first RNG agreements totaling 3% of our Oregon annual sales volume



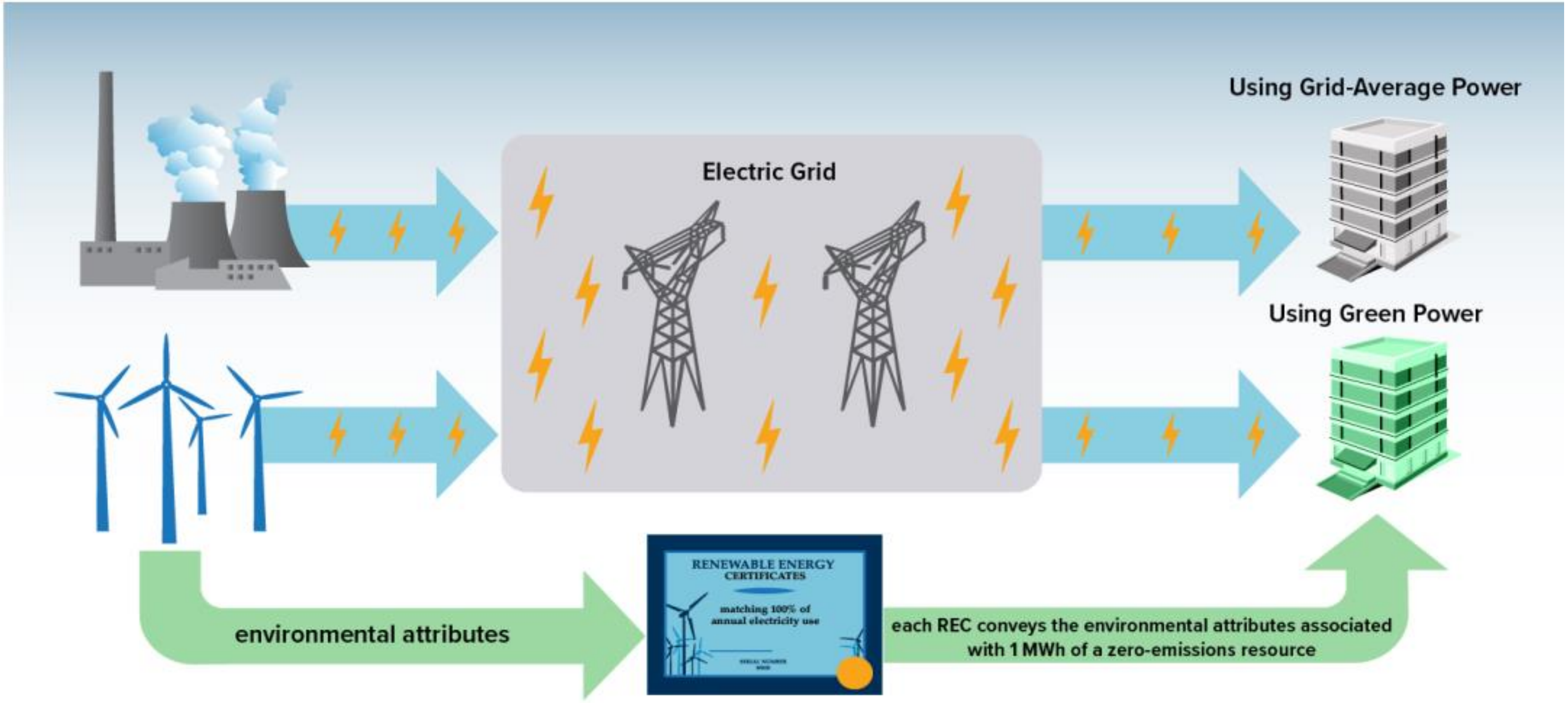
How is RNG Transacted?

- Renewable Thermal Certificates (RTCs) are instruments that represent the legal property rights to the 'renewable-ness' (i.e. environmental attributes) of RNG
  - One RTC is created for every Dth of RNG produced and injected into the "common carrier" network or an LDC's distribution system. RTCs can be unbundled from the underlying gas and sold separately.

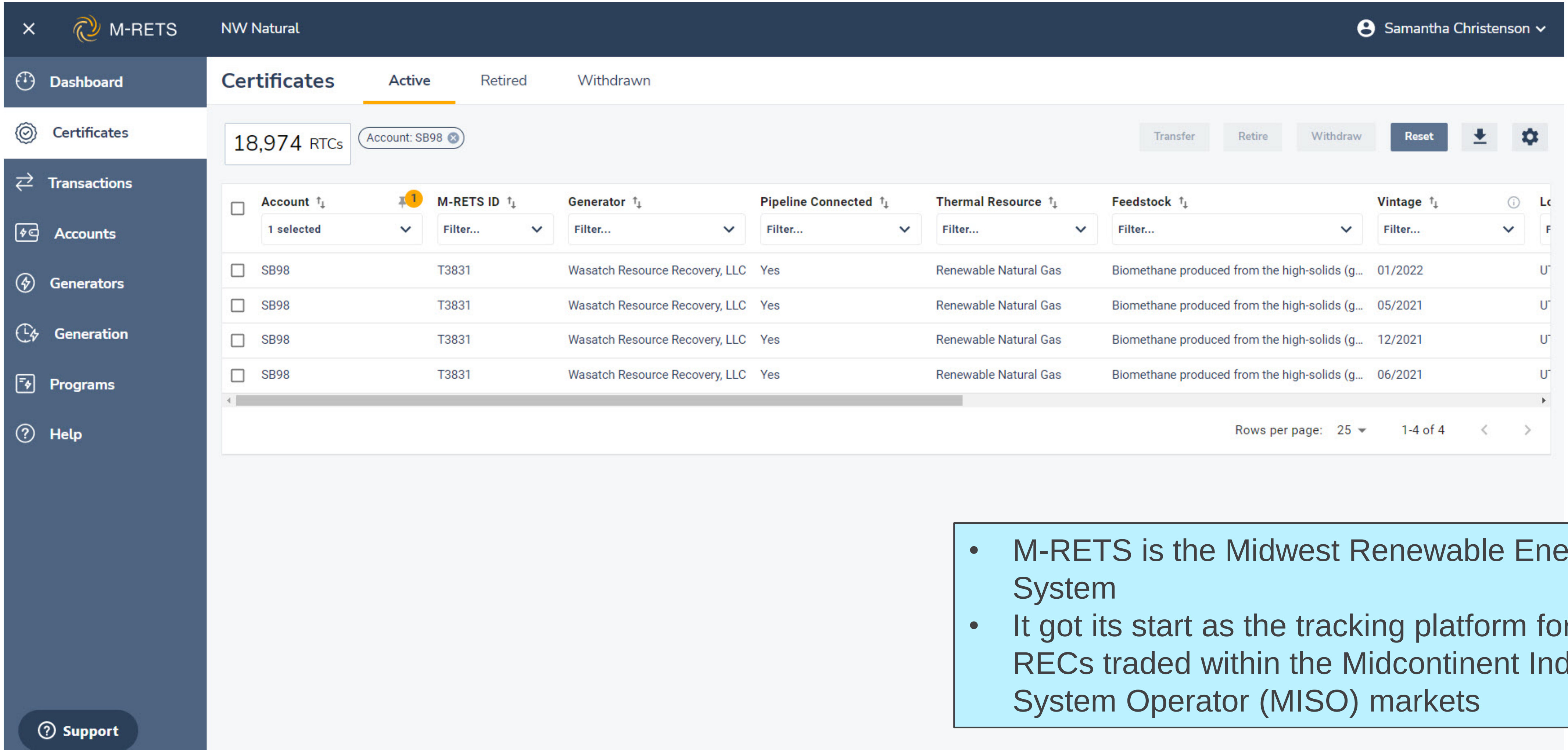


  - RTCs are issued, tracked, transferred, and retired through M-RETS, an online certificate system
  - To satisfy SB98 goals, we will need to show how many RTCs are retired each year

RTCs: Same Structure as Electric Renewable Energy Certificates (RECs)



Transacting RTCs: M-RETS

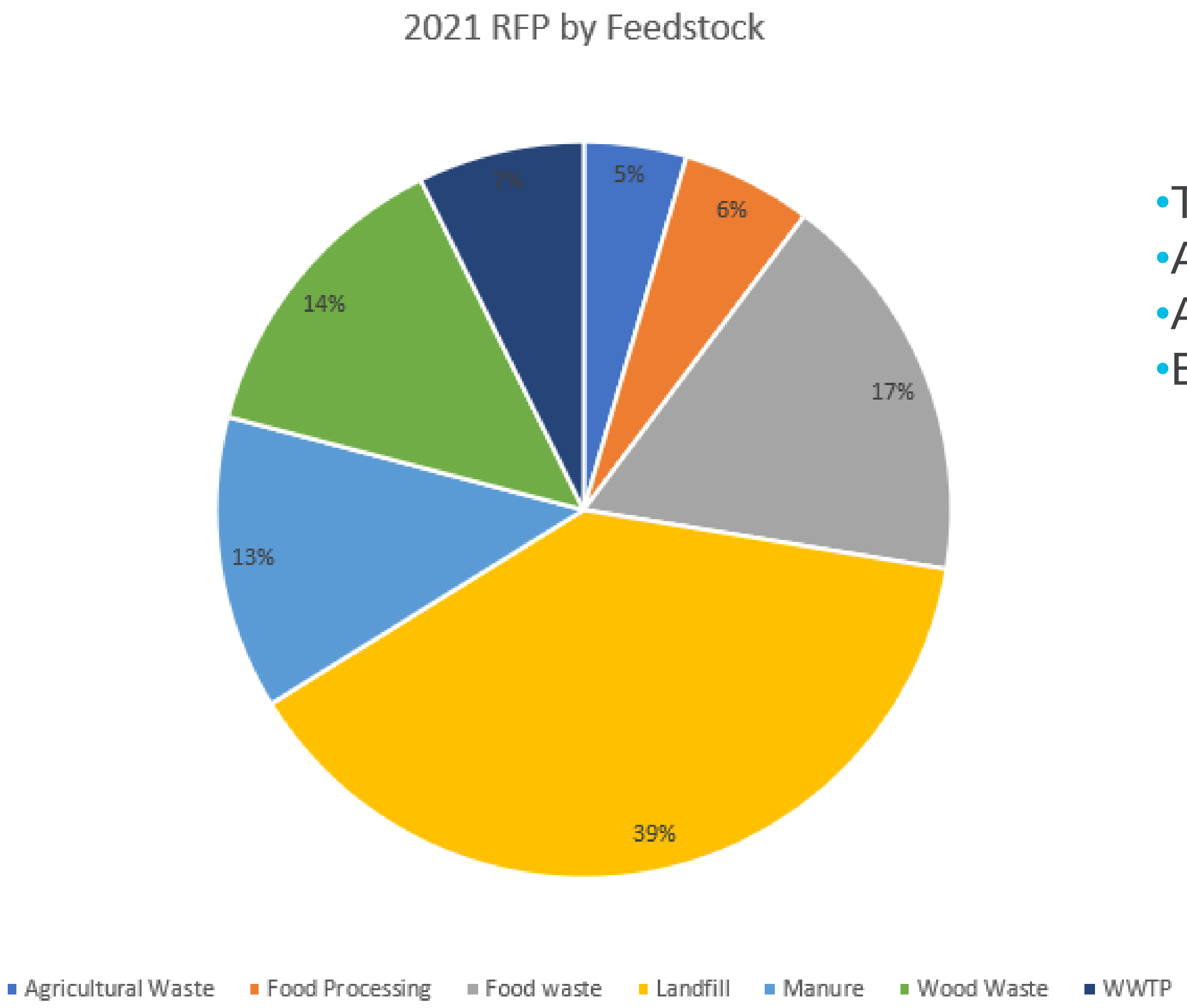


- M-RETS is the Midwest Renewable Energy Tracking System
- It got its start as the tracking platform for electricity RECs traded within the Midcontinent Independent System Operator (MISO) markets

RNG Procurement and Development Timeline Considerations

- 3rd Annual RFP for RNG Resources
  - Planned Release: April 14th
  - Short-listed respondents notified: mid-June
  - Diligence conducted on short-listed respondents: June-July
  - Final agreements negotiated throughout 3Q and 4Q 2022
- Rolling evaluation of other offtake resources in between RFP processes
- Rolling evaluation of RNG development opportunities
  - Non-disclosure agreement to collect initial data
  - Non-binding term sheet to explore economic agreements with feedstock owner, developer, etc.
  - Extensive diligence process to assess project economics and risks, including technical, legal, regulatory, financial, environmental, etc.
- Projects must be continually evaluated and acted on, which makes it hard to put specific resources into an IRP:
  - Typically must decide about whether to enter into definitive agreements within a set timeline (e.g., within 90-day exclusivity period, or in response to a formal bid process with a hard deadline)
  - All projects, regardless of timing or whether they are identified through the RFP process, are evaluated on the same metrics, which include incremental cost to customers, project risks, volume availability, etc.

2021 Request for Proposal Responses



- Total number of responses: 27
- Average term of contract: 14 years
- Average annual volume of resource: 597,806 mmbtu
- Bundled vs. unbundled: 52% / 48%

Example: Diligence on RNG Resources

Team	Diligence Findings	Outstanding
Accounting	No concerns	None
Tax	Tax outcomes are consistent with expectations	None
Financial Risk/Credit	Brown gas marketer may require further credit support	Review of brown gas offtake proposal
Legal	Risks are mitigated through investment agreements and contracts	Finalize and execute Interconnection Agreement
Strategic Planning	No concerns	None
Rates/Regulatory	Will need to file in WA prior to effective date	Finalize timing of WA filing
Investor Relations	No significant concerns	None
Financial Planning/Treasury	No concerns	None
Environmental/Environmental Policy	No concerns	None
Engineering	No significant concerns	None
Gas Supply	No significant concerns	Finalize offtake w/ 3rd party marketer
Risk/Land	No concerns	
Corp. Communications/Public Affairs	No concerns	Finalize communications plan

Current Contracted Offtakes

- NW Natural has entered into three offtake agreements to purchase RNG from operating RNG projects
- Current agreements total about 938,000 Dth in 2022 (over 1% of Oregon sales volume)
- Most will be delivered to Oregon customers via Oregon PGA, but some RNG will likely be used for other programs, such as those in Washington and future voluntary tariffs.
  - Offtake #1
    - Five-year term
    - About 200 Dth/day
    - Organic waste processing facility in Utah
    - Fixed price per RTC; only purchase what is delivered
  - Offtake #2
    - Two-year term, with option for one year extension
    - About 1,000 Dth/day
    - Wastewater treatment plant in New York + dairy-based agricultural waste in Wisconsin
    - Fixed price per RTC; only purchase what is delivered
  - Offtake #3
    - 21-year term
    - Production ranges from 500,000 – 1,000,000 Dth/year
    - Landfill facilities (multiple)
    - Fixed price per RTC; only purchase what is delivered; required minimums, damages for failure to deliver

Tyson Fresh Meats RNG Projects

NW Natural®

Tyson

Tyson Fresh Meats Facilities:

- Two of the largest beef processing plants in U.S.
- Beef processing and packaging; 7,000 employees across both facilities
- Lexington: newer plant (built in 1990); Dakota City: Tyson purchased in 2001 (built in 1966)
- Processes enough beef daily to feed 18 million people
- Both facilities recently received significant investment in new equipment, wastewater processing facilities, etc.
- Both facilities together expected to produce about 360,000 mmbtu/year of RNG (about 0.5% of Oregon annual sales)

Scope of RNG Projects:

- Utilize biogas off existing lagoons
- Implement biogas flow balancing control systems
- Address and correct leaks/sources of possible oxygen intrusion
- Invest in upgrading technology (membrane/pressure-swing absorption)
- Invest in interconnection to local gas pipelines
- Buy the RNG and sell “brown” gas locally
- Retire RTCs on behalf of NW Natural customers

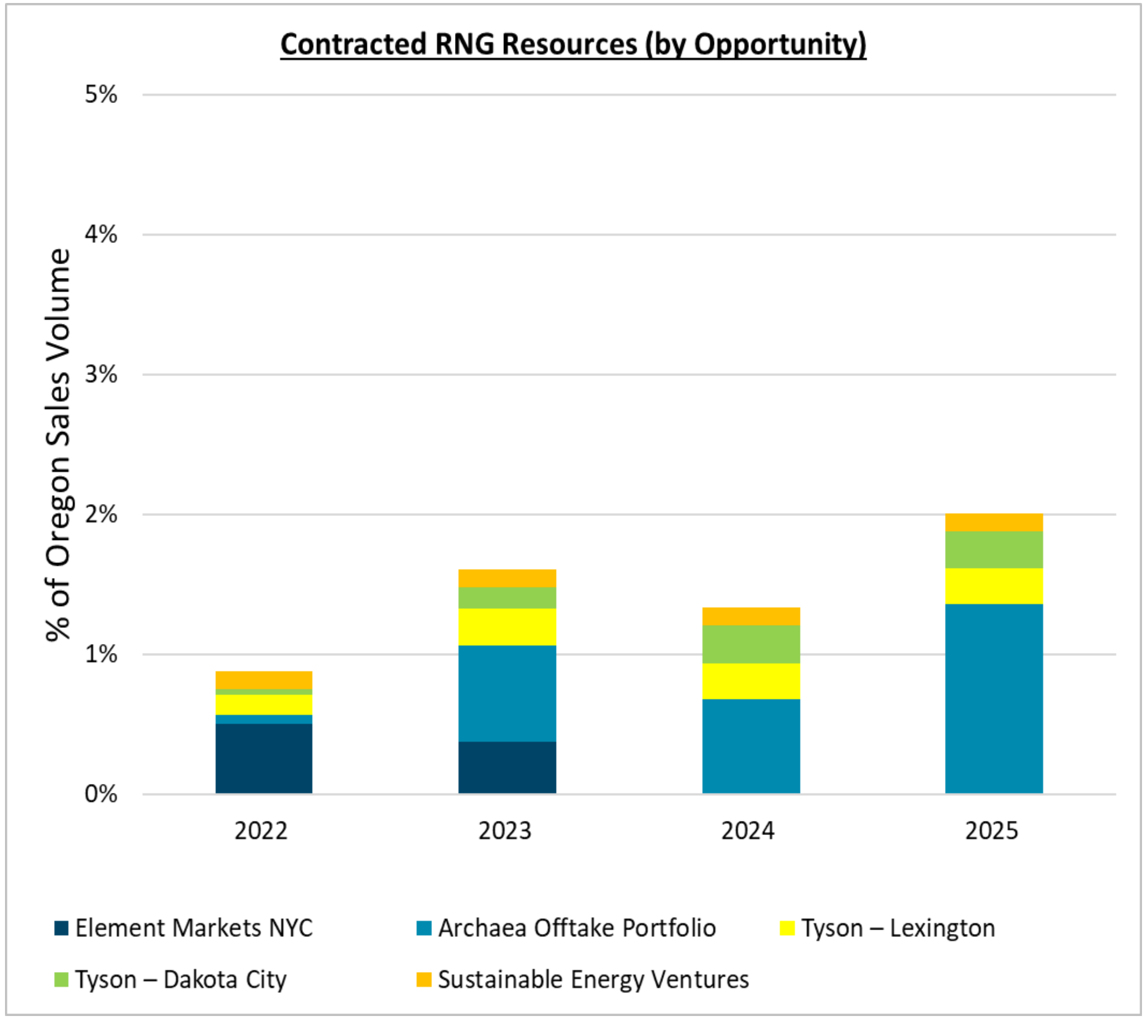
Tyson Lexington Project

Gas cleaning skid

Inside of skid
(membranes visible)

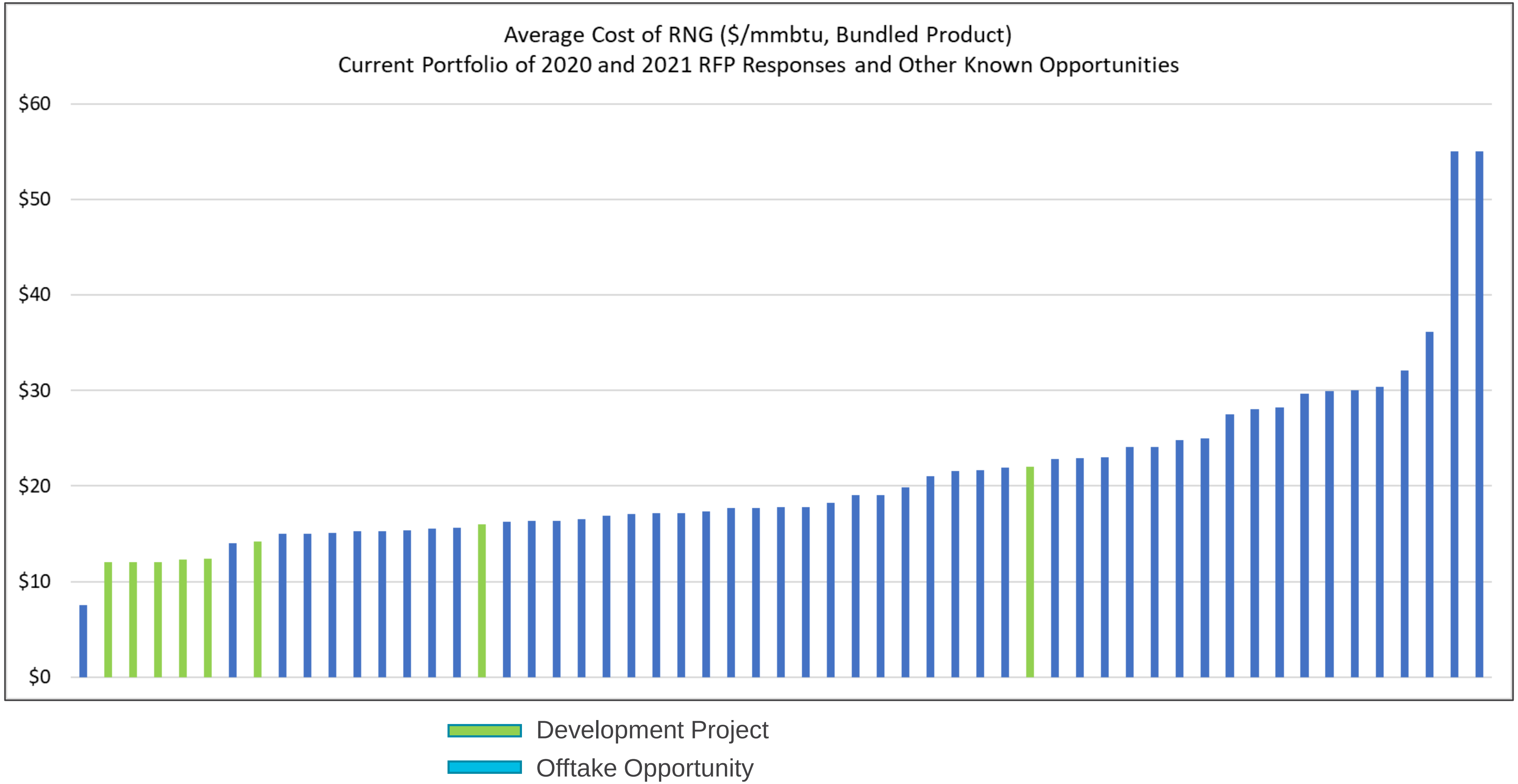
Interconnect to Black Hills

Summary: Current Committed RNG Portfolio



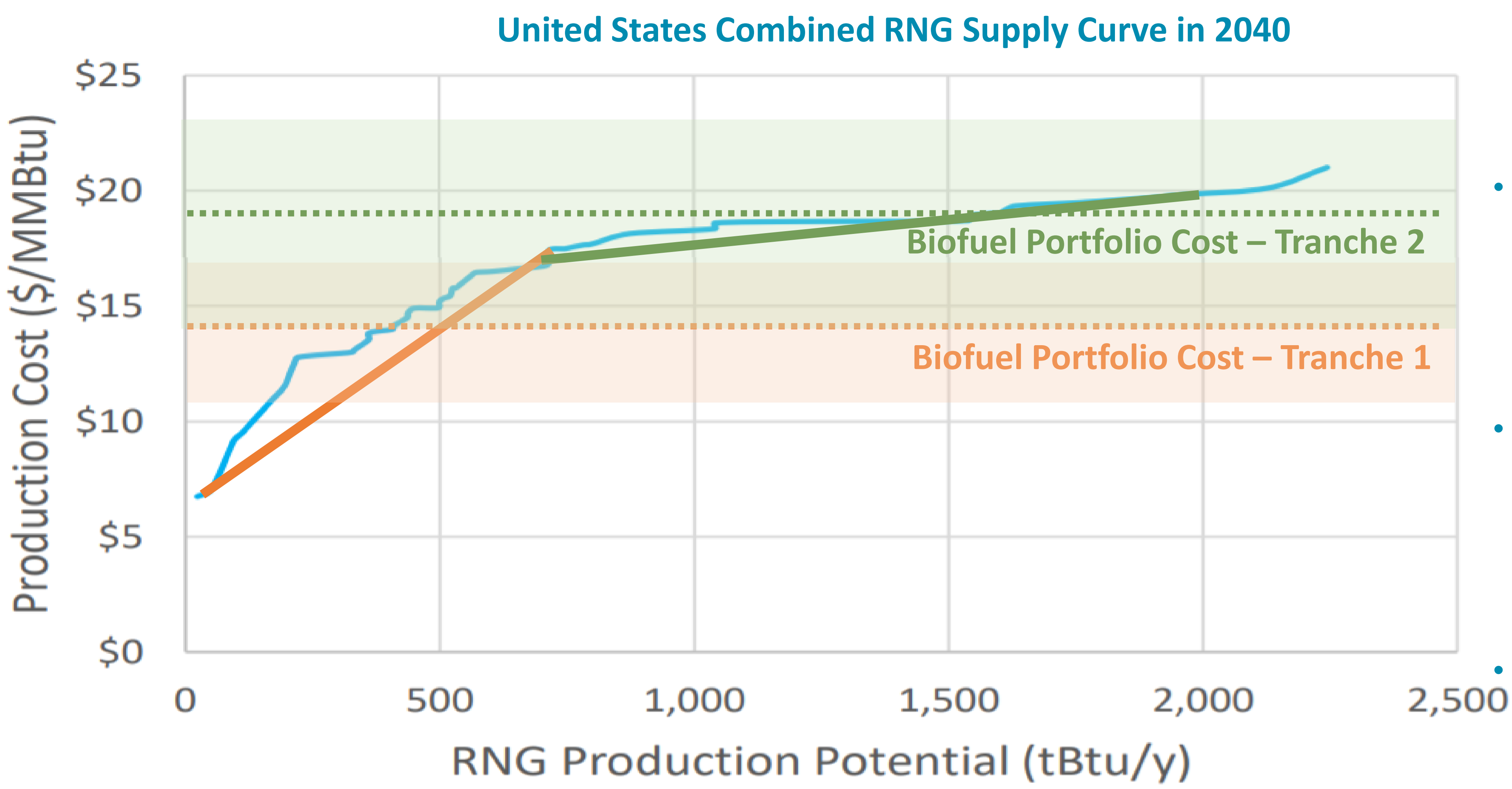
For these 5 resources, the weighted risk-adjusted incremental cost is projected to be $7.38/mmbtu

Building a Supply Curve for RNG



- Chart: 2020 and 2021 RFP responses, as well as the development projects NW Natural is currently evaluating
- Total production represented in chart: 35.3 million mmbtu/year (about 49% of all of NW Natural's annual sales in Oregon in 2021)
- New RFP to be issued next month
- Proposed supply tranches, +/- variability:
  - $14.00/mmbtu
  - $19.00/mmbtu

Biofuel RNG Assumptions



Key Assumptions:

- **Maximum available RNG to NW Natural is 75% of our customers' population weighted share of the national RNG supply potential**
- **Not all RNG Resources are available at all times, so using a traditional supply curve is inappropriate- we are looking to employ a tranched portfolio approach**
- **1/3 of resource available to NW Natural (~13 million MMBtu per year) can be acquired for a portfolio cost of $13.50/MMBtu +/- $3/MMBtu (Tranche 1)**
- **The remaining 2/3 of the resource can be acquired for a portfolio cost of $19/MMBtu +/- $5/MMBtu (Tranche 2)**

Supply Curve Source: "Renewable Source of Natural Gas." American Gas Foundation Study Prepared by ICF (2019). RNG supply potential adjusted for update in "Net Zero Emissions Opportunities for Gas Utilities." American Gas Association Prepared by ICF (2022).

Evaluating Specific Resources- Renewable Gas Evaluation Methodology

Renewable Resource Evaluation Methodology

- The IRP will use an uncertain tranched portfolio approach for modeling renewable resources representing a portfolio cost of RNG
- Specific resources do not align with IRP timing
- Specific resources are evaluated using NW Natural's renewable resource evaluation methodology
  - First proposed in last IRP (Included as Appendix H in 2018 IRP)
  - Methodology updated and approved by OPUC in UM 2030
  - OPUC RNG rules require methodology to be updated in each IRP
  - NW Natural is now using methodology to evaluate RNG resources
- Methodology will be covered in detail at a supplemental TWG

Renewable Natural Gas vs Conventional Natural Gas

- **All-in Cost = Commodity cost of gas + GHG Compliance costs + Supply Infrastructure Costs + Distribution System Capacity Costs**

- The first inclination in comparing the cost of RNG with the cost of conventional gas is to compare the commodity cost of the two types of natural gas
- This is not a complete comparison, as both energy *and capacity costs* should be considered
- Comparing the “all-in” cost of different natural gas supply resources is more appropriate
- “All-in” cost represents the total cost to deliver a unit of natural gas to customers (i.e. what customers pay for a unit of gas)
- Comparing the “all-in” cost of different gas resources complies with IRP Guidelines
- Incremental cost of RNG = All-in cost of RNG – All-in Cost of Conventional Gas

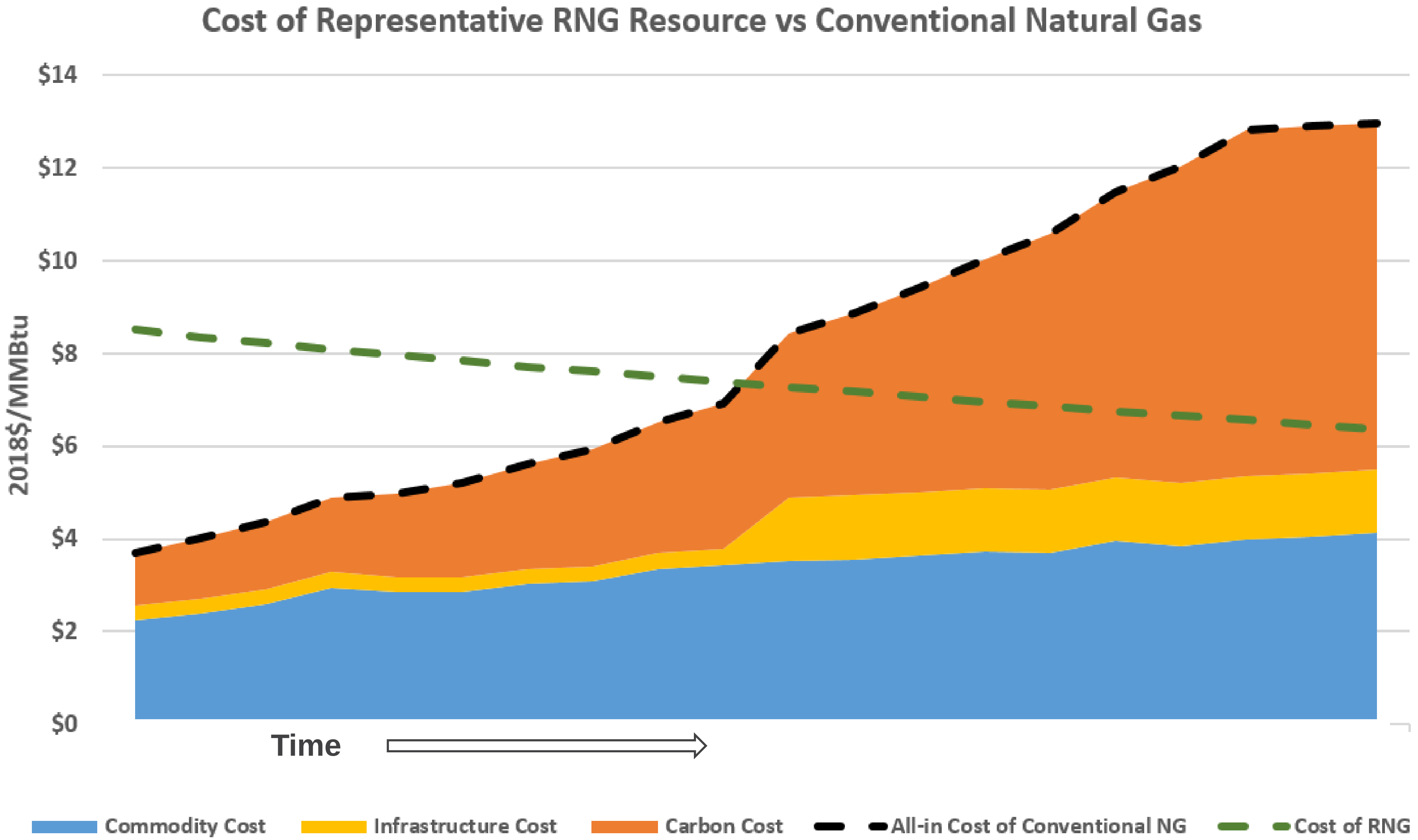
RNG vs. Conventional Gas

- Mathematically, the RNG project is a least-cost/least-risk resource to acquire if:

$$rPVRR(R) < rPVRR(C)$$

- In this case the all-in, risk-adjusted cost of the RNG project (R) is less than the comparable cost of a portfolio of resources without the RNG project (C)
- The above analysis examines cost and risk, consistent with the IRP mandate to evaluate all options for least-cost/least-risk portfolio to meet customer needs

Comparing RNG vs Conventional Gas Costs



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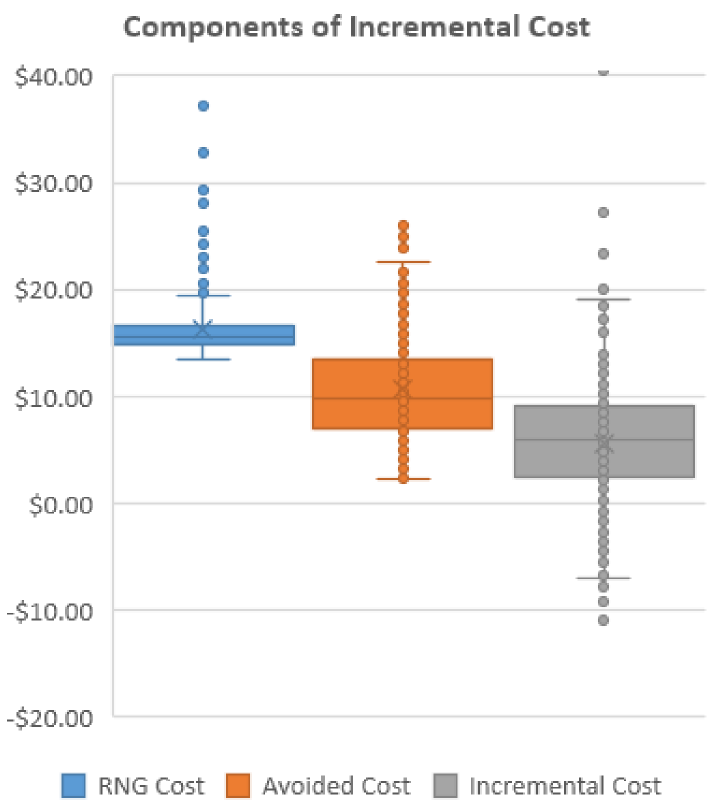
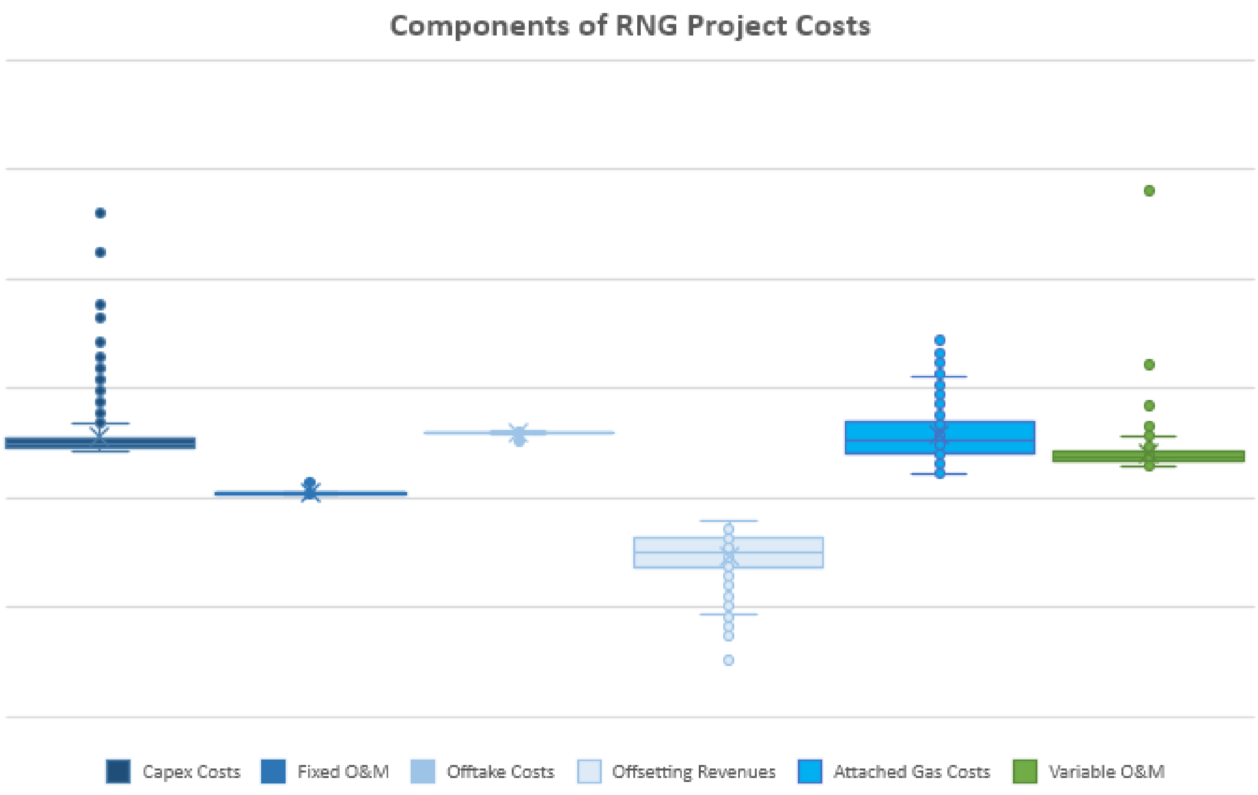
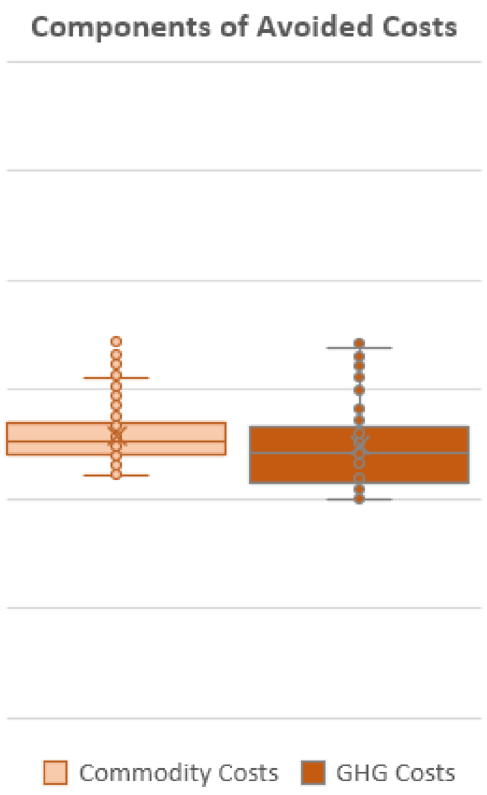
Accounting for Uncertainty

All components that are not contractually obligated are treated as uncertain







Prepared for IRP Working Group- Not to be used for investment purposes.

Variable Update Schedule

Input/Assumption/Forecasts	Frequency of Update	Additional Explanation
Resource Under Evaluation	Most Current Estimate	For example, if an RNG project requires any capital costs, the most current estimate of those costs will be run through the cost-of-service model and used for the evaluation.
Gas Prices (Deterministic and Stochastic)	Once a year	Our third party consultant provides long term gas price forecasts twice each year in August and February.
Peak Day & Annual Load Forecast	Once a year	These forecasts are updated spring/summer to include data from the most recent heating season.
GHG Compliance Cost Expectations (Deterministic and Stochastic)	Once a year	The GHG compliance cost assumptions will be updated each year after the legislation sessions in each state. are updated for each IRP.
Design, Normal, and Stochastic Weather	Each IRP	Resources are planned based on design weather, but are evaluated on cost using normal and stochastic weather.
Supply Resource Costs (Determinisitic and Stochastic)	Each IRP	For the 2018 IRP base case this included the cost of a pipeline uprate, a local pipeline expansion, and representative
Distribution Avoided Costs	Each IRP	NW Natural will calculate and present the avoided distribution avoided costs through the IRP process.

Hydrogen

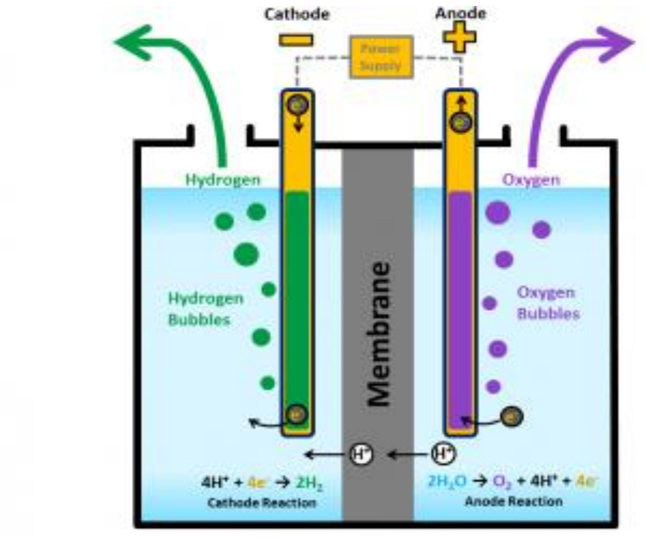
Why Hydrogen?

NW Natural®

- Needed molecules to deliver energy to customers
- Compatible with current gas operations: distribution, storage, appliances, etc.
- Diversity of supply
- Low-cost resource
- Critical for industrial process loads
- New markets
    - Trucking
    - Aviation
    - Marine
- Long-term renewable energy storage
- Backup generation for renewable intermittency

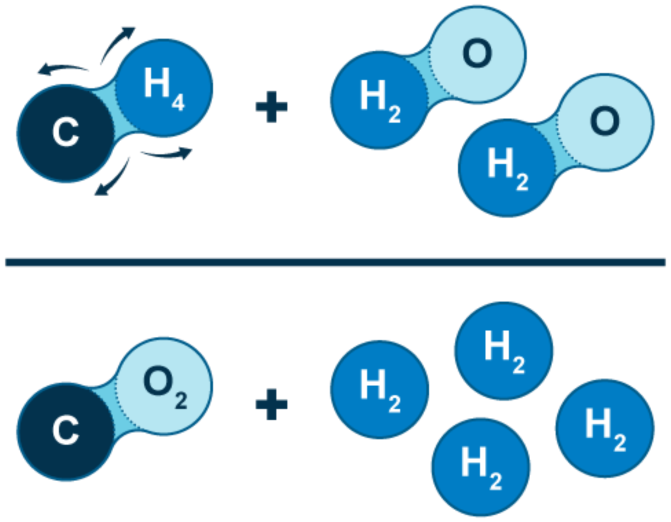
Hydrogen Sources

- Electrolytic hydrogen
  - Electric current passed through water to produce hydrogen and oxygen
  - Very energy intensive
  - Cost of electricity critical, followed by utilization factor (now)
  - Cost of electrolyzers critical in the future



Source: DOE

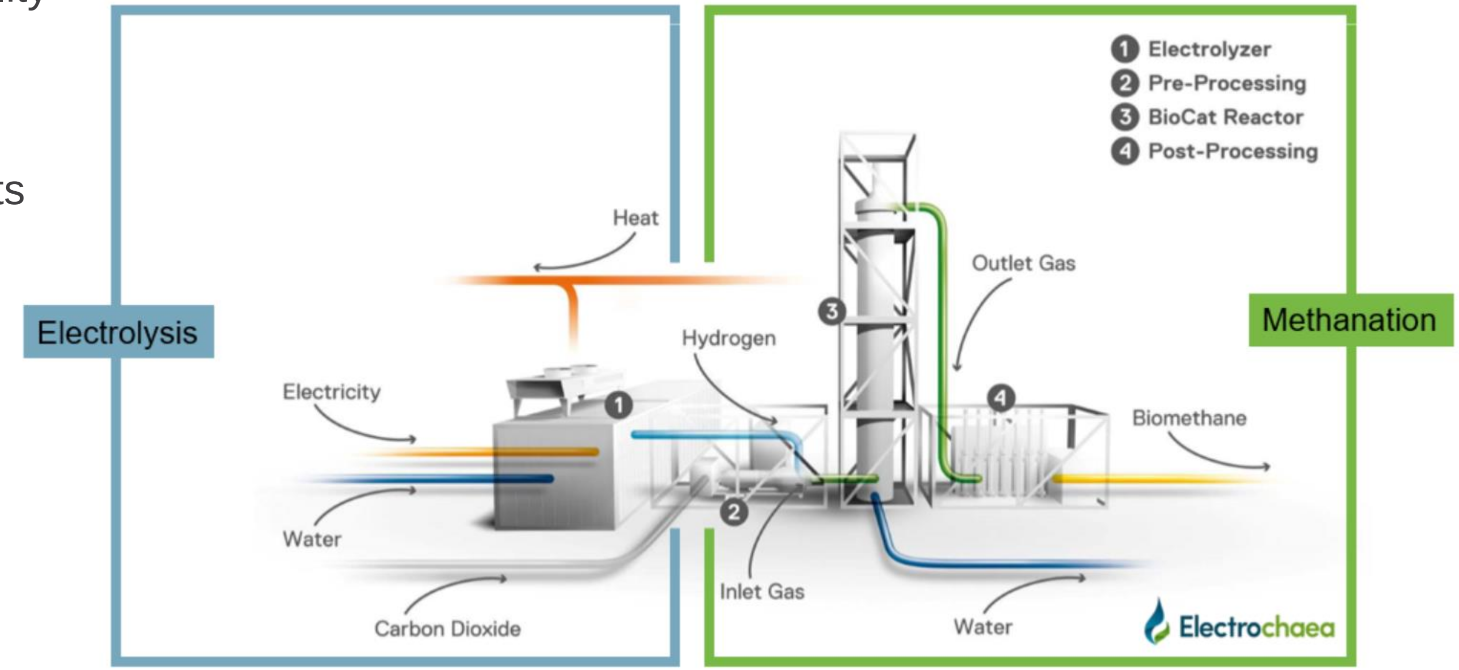
- Methane reforming
  - Convert CH_4 into H_2 and CO_2
  - Steam methane reforming – popular, less efficient for carbon capture
  - Auto-thermal (ATR) and partial oxidation (POx) reforming – much more efficient for carbon capture
  - Pyrolysis – converting CH_4 into H_2 and C
    - Catalytic, plasma, and thermal



Source: CGA

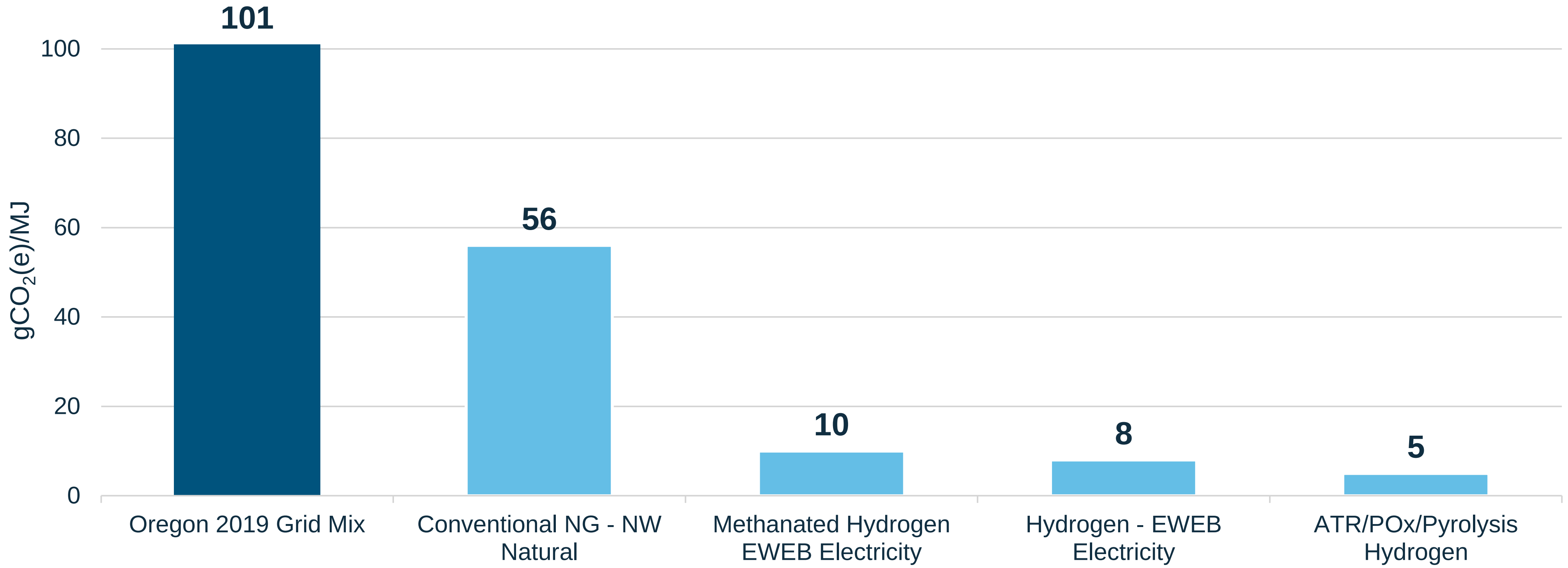
Methanation (Synthetic Natural Gas)

- Process combines waste CO_2 with hydrogen
- No system or downstream appliance compatibility issues
- No blending limits
- Can double the output of gas from RNG projects
- Biological methanation
  - Archaea converts CO_2 and H_2 into CH_4
  - Flexible operation
  - Robust – resistant to contaminants
  - No useable waste heat
- Chemical methanation
  - Mature technology
  - Uses catalyst
  - Steady-operation
  - Requires clean feedstock inputs
  - Useable waste heat



Prepared for IRP Working Group- Not to be used for investment purposes.

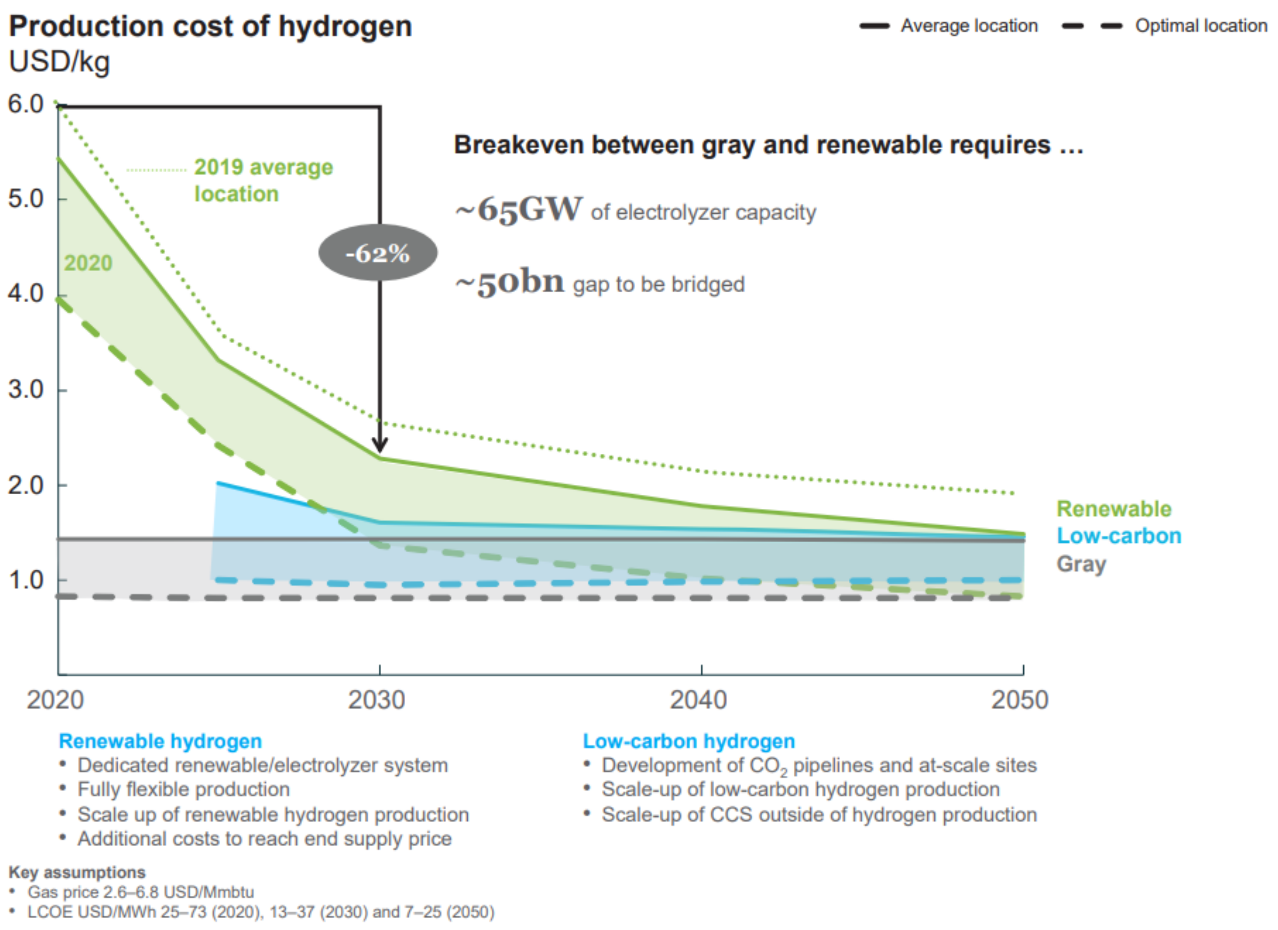
Carbon Intensities of Energy Sources



Estimates using power to gas efficiencies, Oregon DEQ, & California LCFS data

Cost of Hydrogen

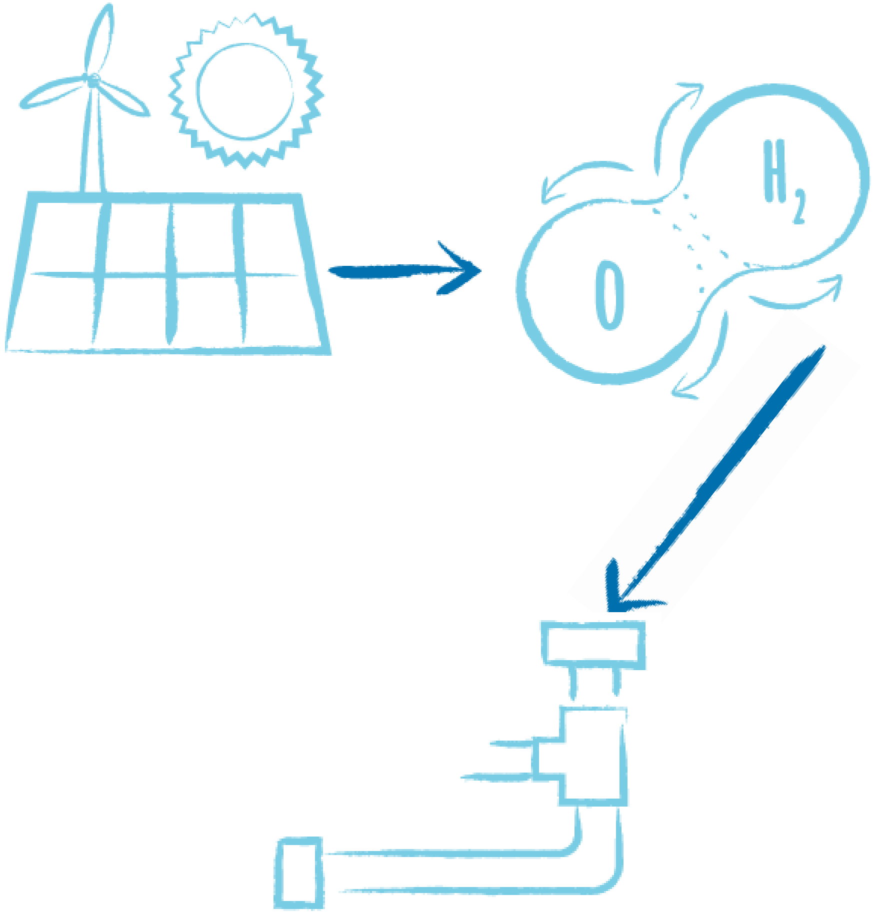
- Hydrogen sourced from natural gas with carbon capture is the lowest cost today
    - $7-$14/MMBtu
- Electrolytic hydrogen predicted to be on-par 2030 and onward
    - Highly dependent on cost of electricity
- Hydrogen production tax credit could reduce costs even more ($3/kg or $22/MMBtu)



Source: Hydrogen Insights Report 2021
Hydrogen Council, McKinsey & Company

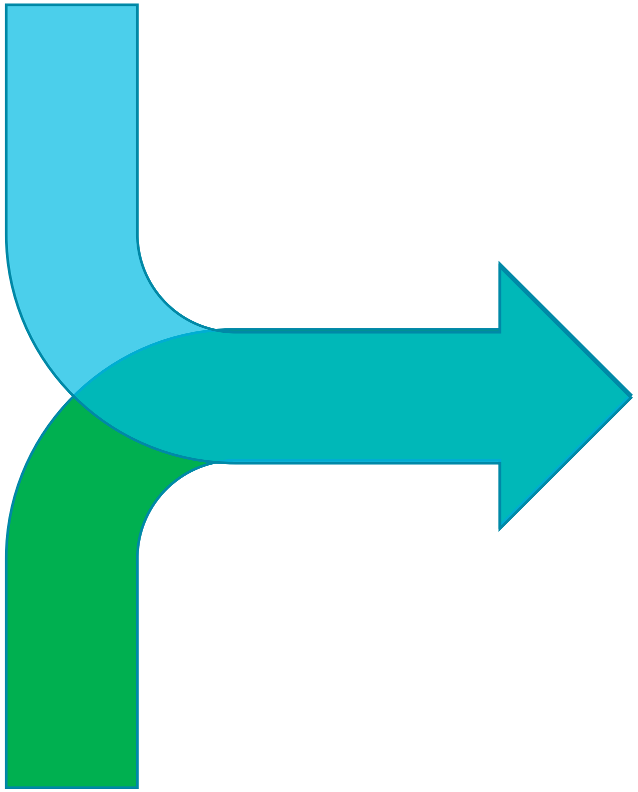
Off-System Resources

- Electrolytic hydrogen
  - Renewable electricity is much cheaper in other parts of the US (e.g., Texas)
  - Abundance of generation, electric transmission line congestion
  - Abundance of natural gas and CO_2 pipelines as well for methanation
  - Challenges:
    - Where to inject the hydrogen molecules?
    - CO_2 for methanation – competition with tax credits
    - Slightly higher in cost than RNG
    - Hydrogen production tax credit (PTC) coming?



On-System Resources

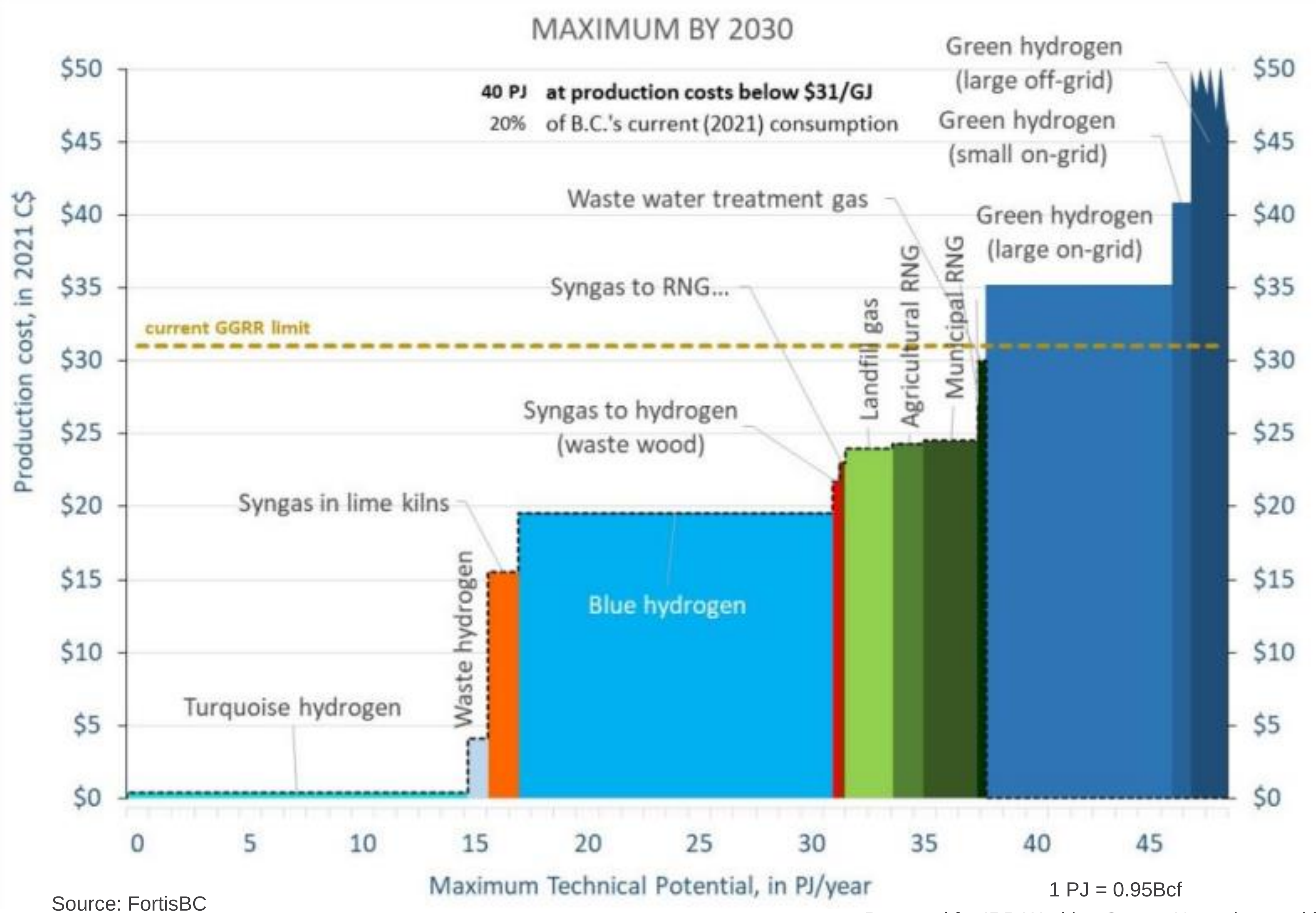
- Electrolytic hydrogen
  - Blending project under development for Eugene (SB 844 application)
  - Learnings will be applied system-wide
  - Enable opportunistic/distributed hydrogen production and blending
  - Enables third parties to inject hydrogen
  - Preparation for low-cost renewable future



On-System Resources

- Methane reforming with Carbon Capture (aka Blue Hydrogen)
    - Can provide an efficient and low-cost pathway towards decarbonization
    - Looking for suitable sequestration reservoir for carbon
        - Existing data show promising regions in the state
        - Third parties are looking at taking on the exploration risk
- Methane pyrolysis (Turquoise hydrogen) may be a more immediate opportunity

Cost and Supply of Turquoise Hydrogen

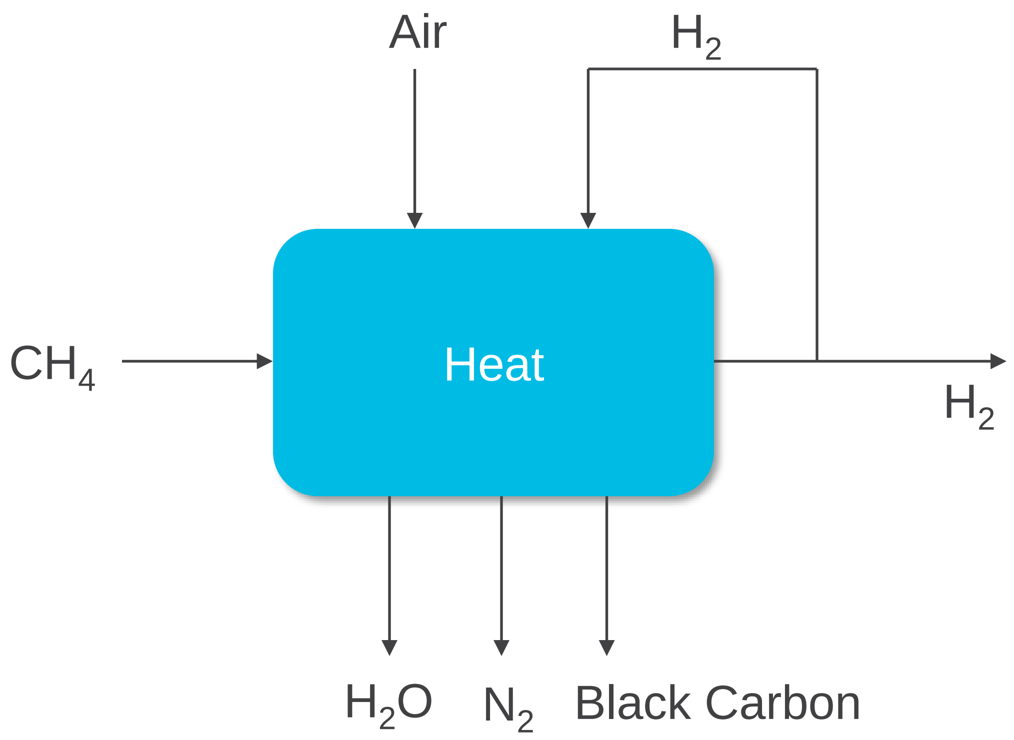


Source: FortisBC

1 PJ = 0.95Bcf

Turquoise Hydrogen Pilot

- Concurrent pyrolysis activities
  - Monolith - $1B DOE loan
  - Numerous collaborations in Canada (e.g., FortisBC/Hazer, ATCO/UBC)
  - LDCs provide critical use input
  - Secondary markets for the black carbon
- NW Natural proposing pyrolysis pilot for acknowledgment
  - Estimated pilot cost: $500,000
  - Estimated cost of energy: $1-1.50/kg ($7-11/MMBtu)
  - Technology Readiness level 6-7
  - NWN first in line for 50kg/day next generation equipment (7MMBtu/day)



Turquoise Hydrogen Pilot

NW Natural®

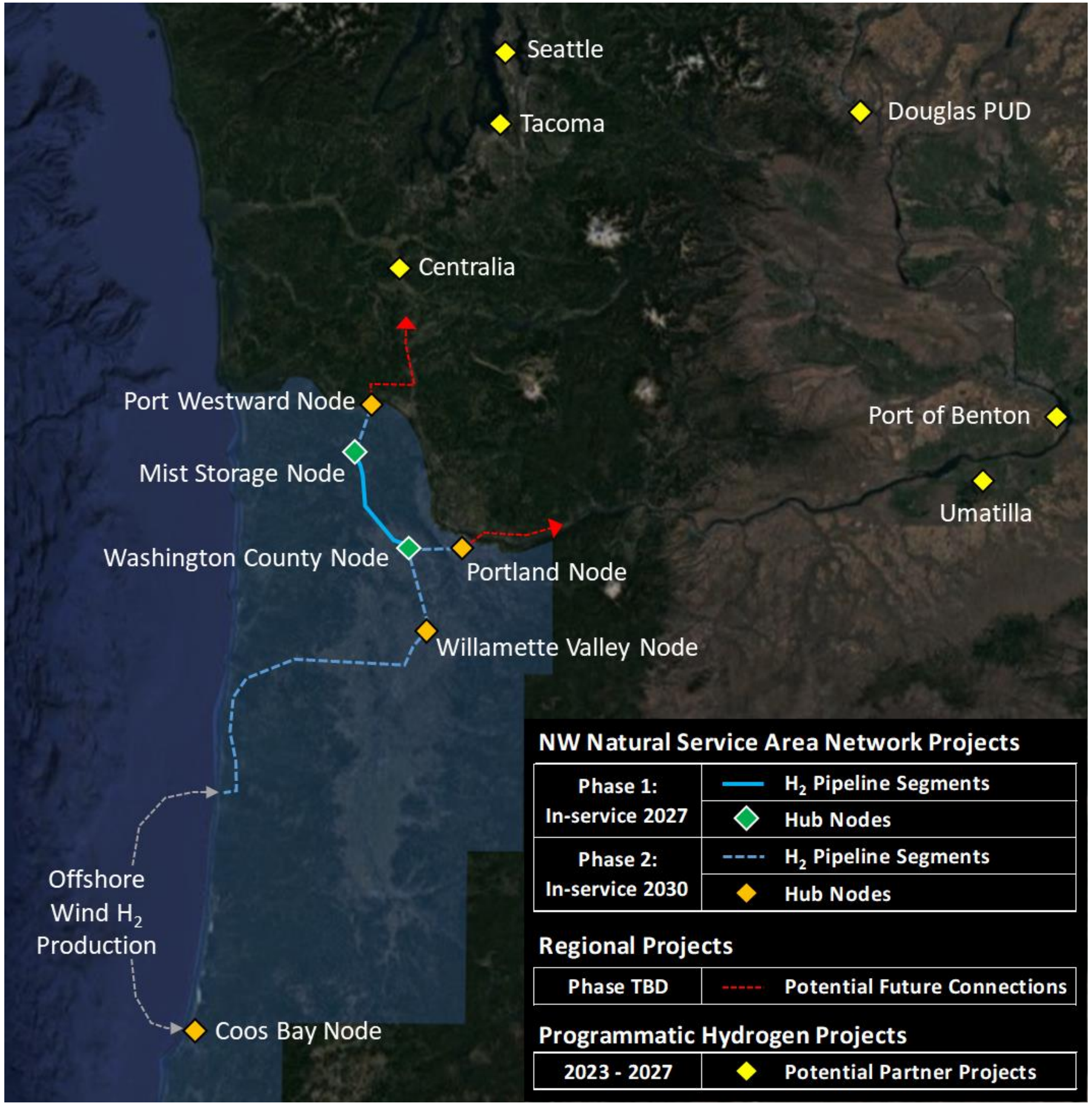
- Install a prototype unit for on-system gas blending
- Have identified 10+ in-territory industrial customers that would be a good fit for receiving the gas
- Duration: 3 years. Modern Electron will offer turn-key installation and lease.
- Research questions
    - How reliable is the technology at this point?
    - Will it fit with existing operations?
    - How can the black carbon be used or disposed of?
    - Does it deliver on gas quality?
    - How close to zero are the carbon emissions?
    - Can it deliver on the cost potential?
- Leverage learnings from Eugene blending pilot
    - Changes to standard operating procedures
    - Mitigation for any identified risks
- Delivery of prototype unit in Q4 2022; Installation targeted for Q1 2023
- Estimated production: 5kg (0.7MMBtu) of hydrogen per day

MODERN ELECTRON

Research scope will answer: Should more resources be put into pyrolysis development, and when?

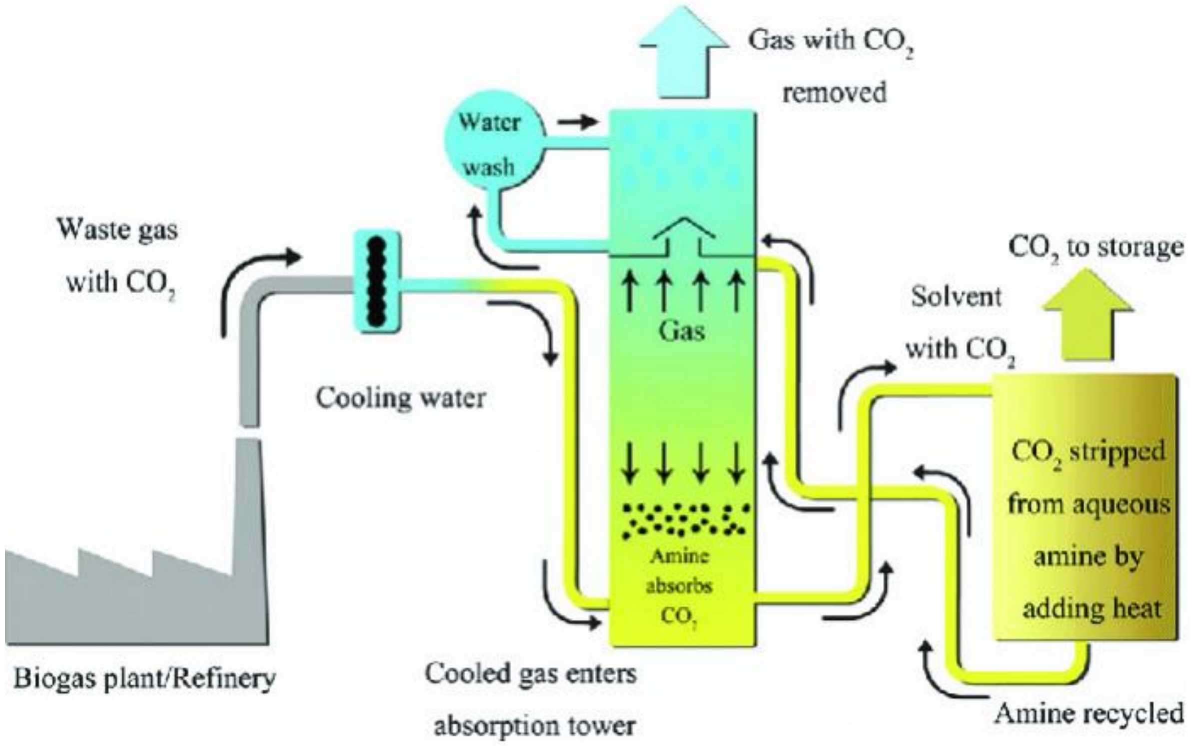
Hydrogen Hub

- $8B for hubs in 2021 infrastructure bill
- Minimum of four
- Opportunity for PNW hub?
- Multiple hydrogen sources (+ Port)
- Storage
- Transportation
- Offtake
  - Power generation
  - Process heat (e.g., pulp & paper)
  - Fertilizer
  - Microchip manufacturing
  - Natural gas system blending



Carbon Capture

- Pre-combustion
  - Methane reforming – CO_2
  - Methane pyrolysis – Carbon
- Post-combustion
  - Amine wash
  - Enzymes
  - Potassium hydroxide
- Direct air capture (DAC)
- <$20/t to over $120/t
- Varies in scale
  - Small appliances
  - Electricity generation plants
- Currently looking at opportunities with customers who might be interested in reducing their carbon footprint

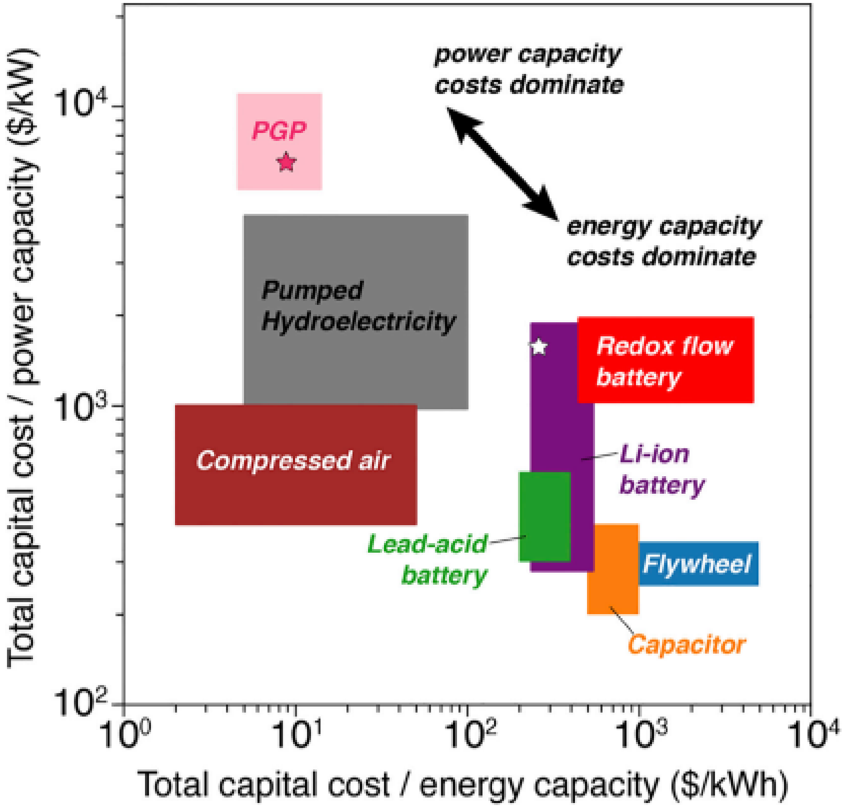


Source: TCM

Renewable Energy Storage

- NW Natural has ≈6 million MWh of energy storage
- Equivalent annual electric energy ≈600,000 average Oregon residential customers
- In terms of lithium-ion batteries: $2 trillion
- 50,000x larger than the largest battery project in Oregon
- Lowest capital cost storage available:
  - Lithium-Ion ≈ $375/kWh
  - Pumped hydro ≈ $165/kWh
  - Hydrogen (electrolyzer) < $1/kWh

- Building access to storage creates cost efficiencies

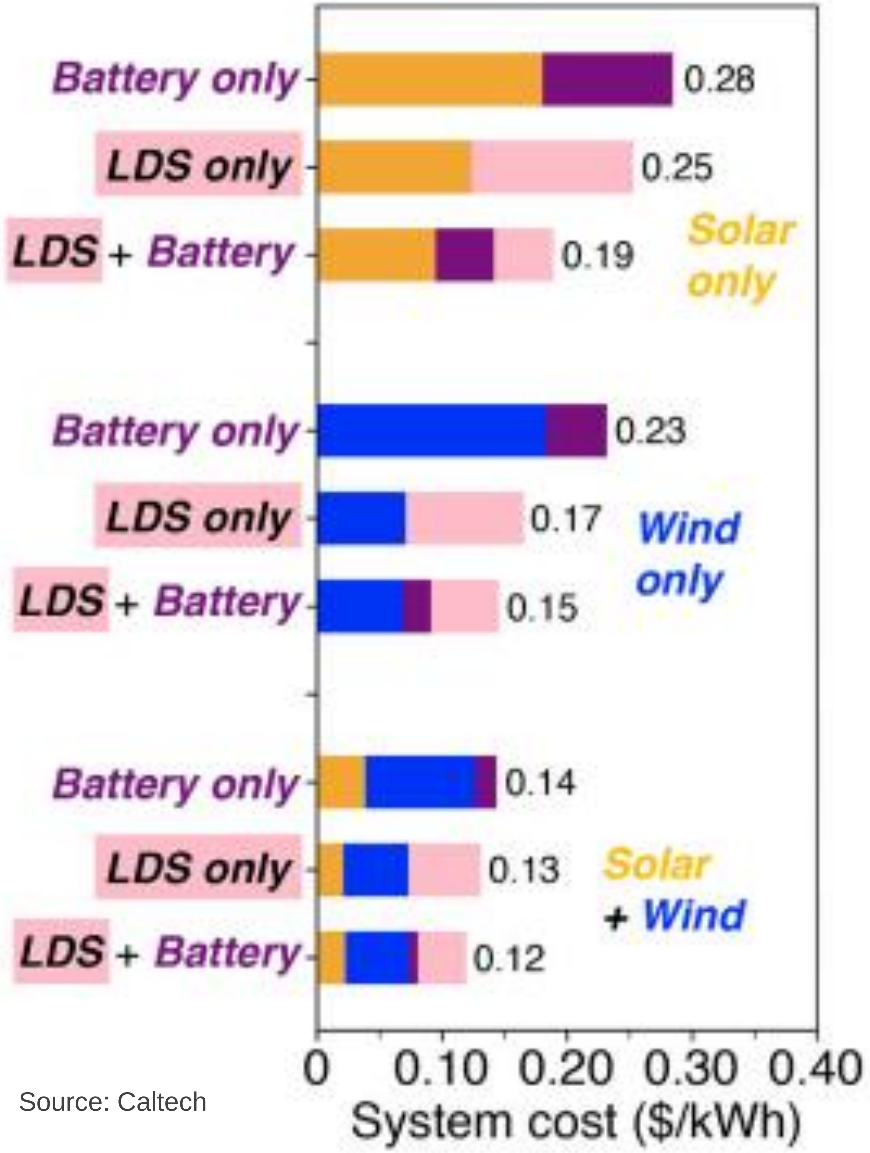


Source: Caltech

NREL (Li-Ion), PNNL (Pumped Hydro)

Gas System Storage Benefits

- Caltech study released in Joule
- Long-duration storage (LDS) (>10 h) reduces costs of wind-solar battery systems
- Dependence on long-duration storage increases with optimizations over more years
- Long-duration storage cost reductions lower system costs 2x more than batteries
- Power-gas-power (PGP) is currently lowest cost technology solution



Source: Caltech

Total Renewable Gas Supply Curve

NW Natural®

Resource	Cost			Volumes Available		
	10th Percentile	Base	90th Percentile	10th Percentile	Base	90th Percentile
Biofuels RNG Tranche 1	$10.50	$13.50	$16.50	-50%	13 Million Decatherms	+100%
Biofuels RNG Tranche 2	$14.00	$19.00	$24.00	-50%	27 Million Decatherms	+100%
Hydrogen				10% Combined	20% combined blending and dedicated systems	40% Combined
2022	-20%	$23.00	+40%			
2050	-50%	$6.00	+70%			
Synthetic Methane				Unlimited		
2022	-20%	$32.00	+40%			
2050	-50%	$9.00	+70%			

Questions/Feedback

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