Distribution System Planning for the 2022 IRP- Technical Working Group

Distribution System Planning (IRP- TWG#5)
April 25, 2022

NW Natural®

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

NW Natural®

- Introductions, Safety Moment, and Review
- Distribution System Planning
  - Overview
  - Peak Hour Load Forecasting
  - System Modeling
  - Supply-Side Option Evaluation
  - Incremental Demand-Side Option Evaluation
  - Forest Grove Uprate Project
- Lunch Break (~12pm-1pm)

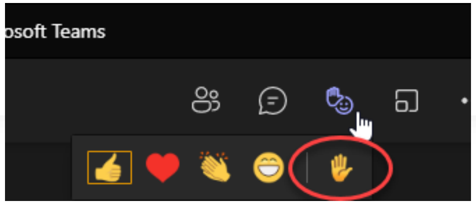
Procedures for Participation

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

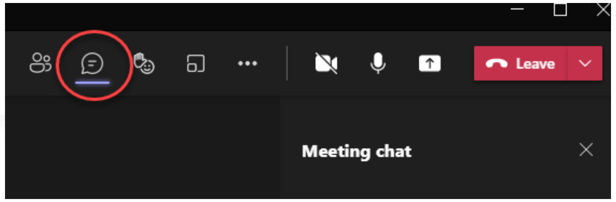
- Cameras are optional and up to each participant to use
- All participant cameras are set to off upon entry into the meeting

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

Raised hand function is found in the reactions

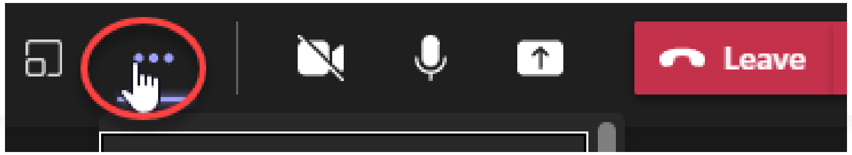


Chat box will open when you click on the conversation bubble



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

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



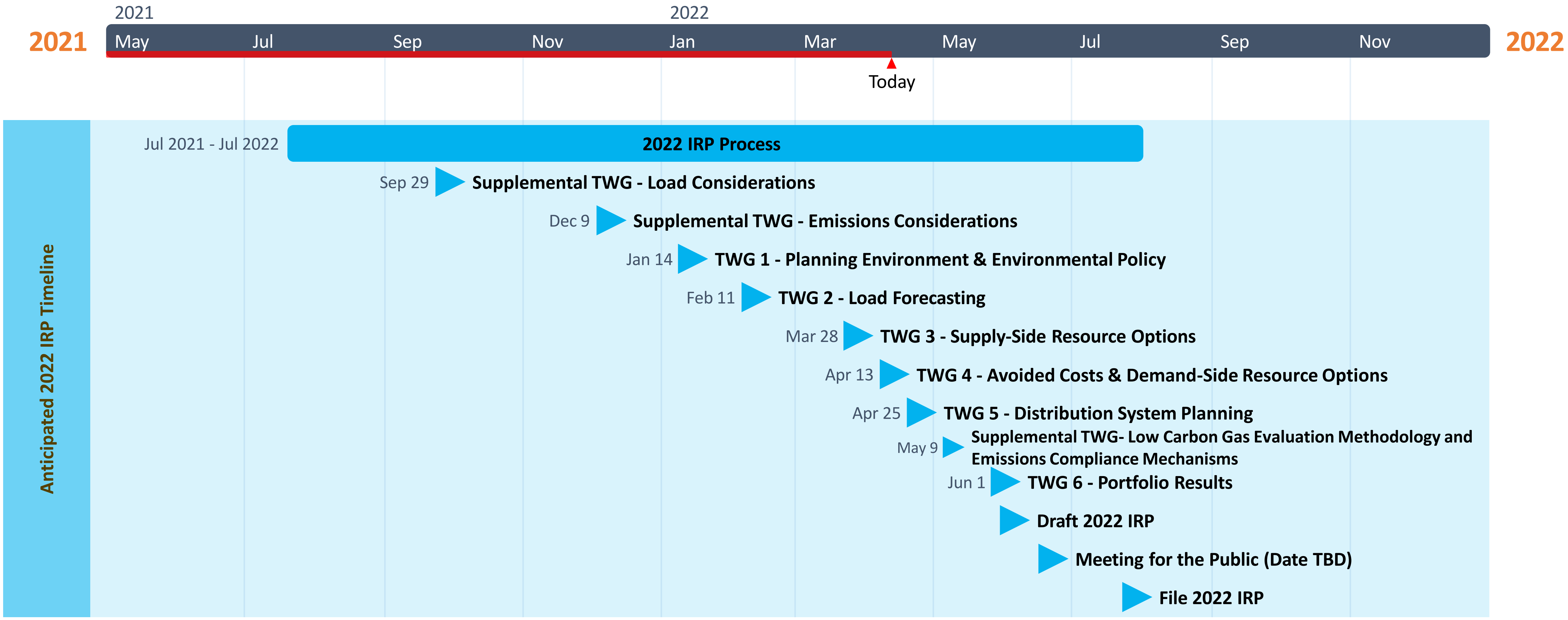
Prepared for IRP Working Group- Not to be used for investment purposes.

2 Minutes for Safety:

IT Security- Device Management Best Practices

- Be aware of your belongings. Do not leave devices unattended (even if “locked”)
- Use strong, unique passwords and change them frequently
  - Do not give out passwords to others
  - Use multi-factor authentication when available
- Keep software up to date to prevent attackers from taking advantage of known vulnerabilities
- Disable remote connectivity when not in use, preventing access to your device from another location (e.g., Bluetooth, Wi-Fi)
- Backup your files in the event your device is lost or stolen
- Be cautious of public networks such as in a hotel or coffee shop or on an airplane
  - Confirm the name of the network before joining to ensure network is legitimate
  - Do not conduct sensitive personal or business activities using public wireless networks
    - *Only use sites that begin with “https://” when online shopping or banking. Using your mobile network connection is generally more secure than using a public wireless network*
- Always Remember: Don’t click the link, if you don’t trust it

2022 IRP Anticipated Timeline



IRP on the NW Natural website

NW Natural®

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

Overview of Previous TWGs

TWG #3- Supply Side Resources – Presentation Topics

Scenario Feedback

- The IRP team reviewed, at a high level, feedback received from stakeholders on the 2022 IRP scenarios and NW Natural's proposal to utilize the average of simulation draws as the base case to account for uncertainty in load scenarios.

Focus on Supply-side Resources

- Differences and overlap between gas supply capacity and distribution capacity resources
- Existing supply-side resources and an overview of conventional market fundamentals
- Portland LNG contribution to serving current load
  - Overview of the required cold box to continue operations at Portland LNG
  - Overview of alternatives to the cold box to maintain reliable service for current peak day operations
- ICF reviewed and discussed the availability of Renewable Natural Gas (RNG) and hydrogen resources at a national level
- Policy environment and markets for RNG and Hydrogen, as well as current NW Natural projects
- A brief overview of NW Natural's methodology for evaluating the incremental cost of RNG resources

Overview of Previous TWGs

TWG #4- Avoided Costs and Demand-Side Resources – Presentation Topics

Avoided Costs

- The first portion of the TWG focused on understanding several concepts about Avoided Costs including:
  - What are avoided costs?
  - Principles of and standard industry approaches to avoided costs
  - Applications of avoided costs in cost-effectiveness evaluations, as well as the components of avoided costs and their associated resource option application
  - Energy and environmental related avoided costs including CPP and CCA compliance costs and calculating GHG price components
  - Risk Reduction Value and commodity price risk reduction costs
  - Infrastructure and capacity avoided costs including their relation to peak load and peak savings
- The IRP team shared avoided cost results by end-use for both OR and WA

OR And WA Conservation Potential Assessment (CPA)

- Energy Trust of Oregon (ETO) presented a section on OR CPA for Sales Customers, including forecast results
- Applied Economic Group (AEG) presented a section on WA CPA for Transport Customers, including draft conservation potential results
- The IRP team reviewed the WA CPA for sales load completed by AEG in 2021 and presented results for CPA for WA Transport Customers also conducted by AEG in 2021

Emerging Technology

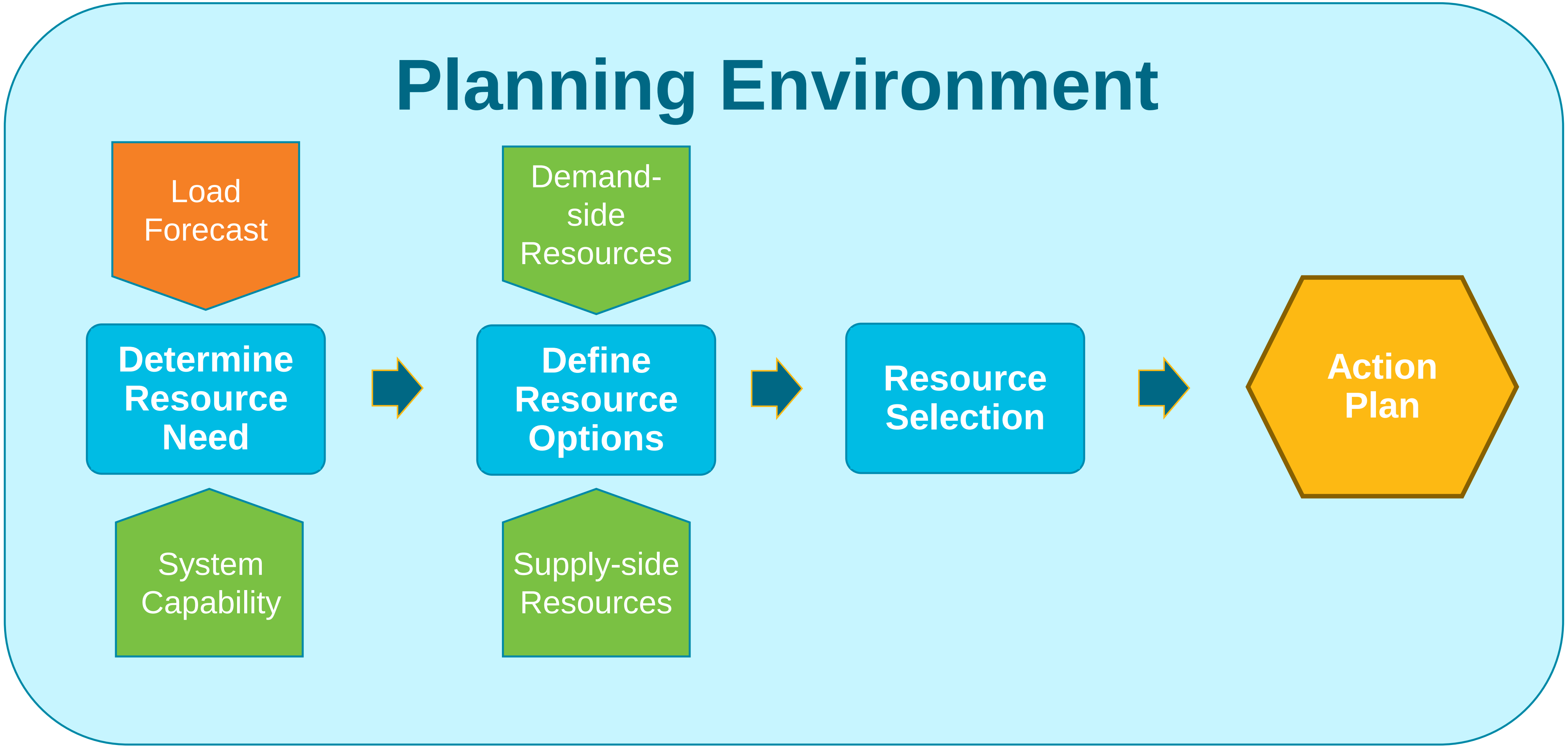
- GTI gave a presentation on thermal (gas) heat pumps and the status of new technologies coming to the market for residential and/or commercial customers
- NEEA spoke to market transformation and the partnerships between various organization which can accelerate the adoption of emerging technology

Distribution System Planning – Overview

Key Takeaways

- 10-year used planning horizon for distribution system planning
- Pipeline pressure modeling software is utilized to identify or validate system issues
- NW Natural designs it’s system to peak hour customer demand
- Standard criteria are applied to identify system issues and to initiate reinforcement project need
- Alternatives analyses are performed
- Currently deploy “pipeline” and “non-pipeline” solutions to maintain a reliable distribution system
- NW Natural currently transitioning from a “just-in-time” distribution system planning process based upon measured criteria violations to a forward-looking distribution system planning process to incorporate more non-pipeline options as viable resource planning options
- Outage considerations more extreme for gas distribution networks than electric ones and need to be considered when assessing risks of planning standards and resource options

IRP Process – Distribution System Planning Application



Green = Resources Orange = Tools

Forward-Looking Distribution System Planning

1. Supply: Model distribution system based on actual pipe placement and specifications

2. Demand: Forecast peak hour usage for the area in question **net of expected energy efficiency savings and demand response resources**

3. Simulate system under peak conditions and/or use field measurements during cold periods

4. Apply system planning criteria to identify areas of concern before planning criteria are violated
   - Ongoing field monitoring of pressures and customer growth informs which areas to investigate

5. Develop alternatives to address issue

6. Determine the lowest-cost/risk alternative to meet customer needs

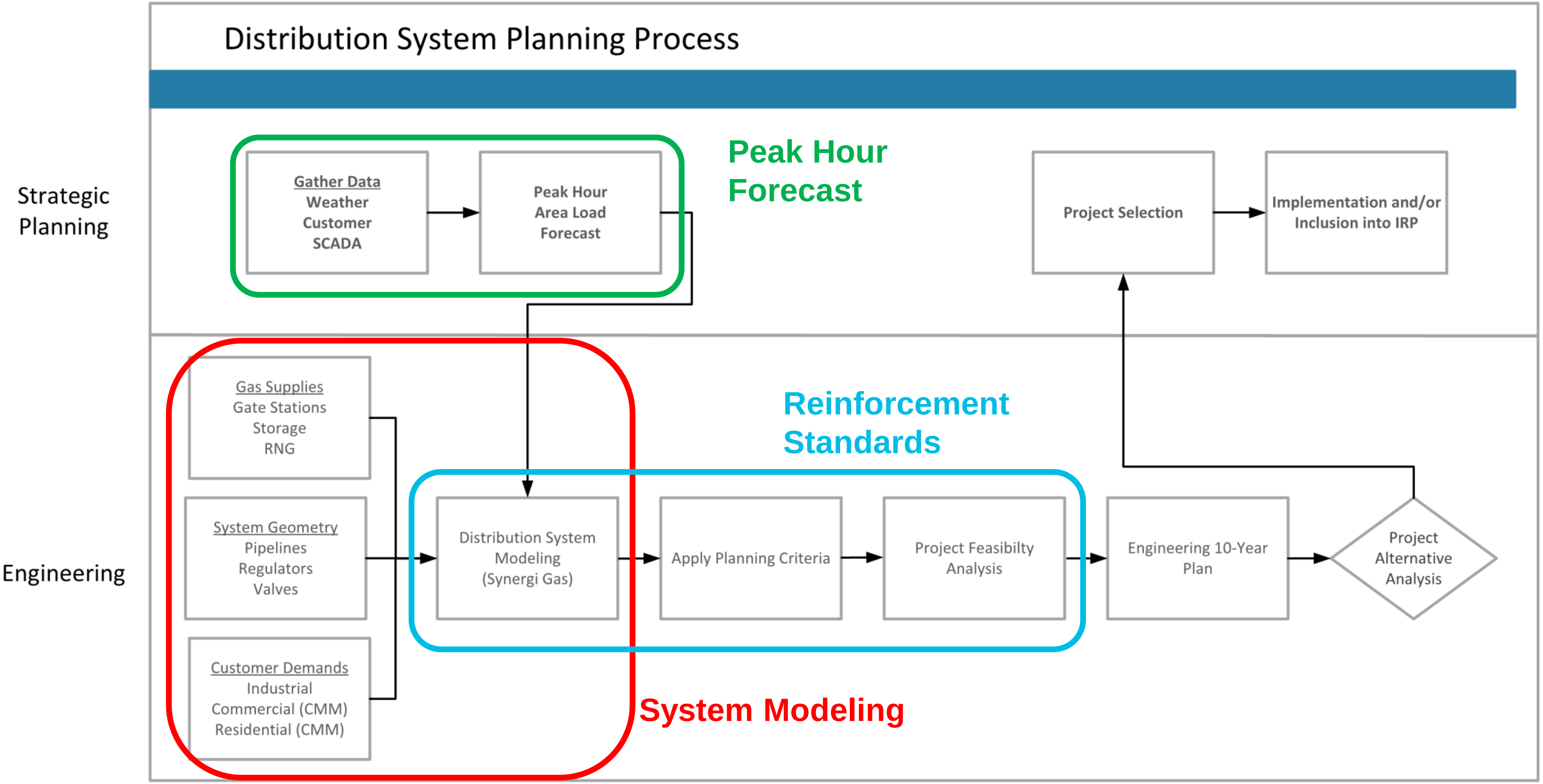
Distribution System Planning Resource Options

NW Natural®

Distribution System Planning Alternatives (not all options are possible or applicable in all situations)				Option Currently Considered for Cost-Effectiveness Evaluation
Supply-Side Alternatives	Pipeline Related Capacity Options		Loop existing pipeline	✓
			Replace existing pipeline	✓
			Install pipeline from different source location into area	✓
			Uprate existing pipeline infrastructure	✓
			Add or upgrade regulator to serve area of weakness	✓
			Gate station upgrades	✓
			Add compression to increase capacity of existing pipelines	✓
	Non-Pipeline Solutions	Distributed Energy Resources (DER)	Mobile/fixed geographically targeted CNG storage	✓
			Mobile/fixed geographically targeted LNG storage	✓
			On-system gas supply (e.g. renewable natural gas, H2)	✓
			Geographically targeted underground storage	✓
Demand-Side Alternatives		Demand Response	Interruptible schedules (DR by rate design)	✓
			Geographically targeted interruptibility agreements	✓
			Geographically targeted Res & Com demand response (GeoDR)	
		Energy Efficiency	Peak hour savings from normal statewide EE programs	✓
			Geographically targeted peak-focused energy efficiency (GeoTEE)	

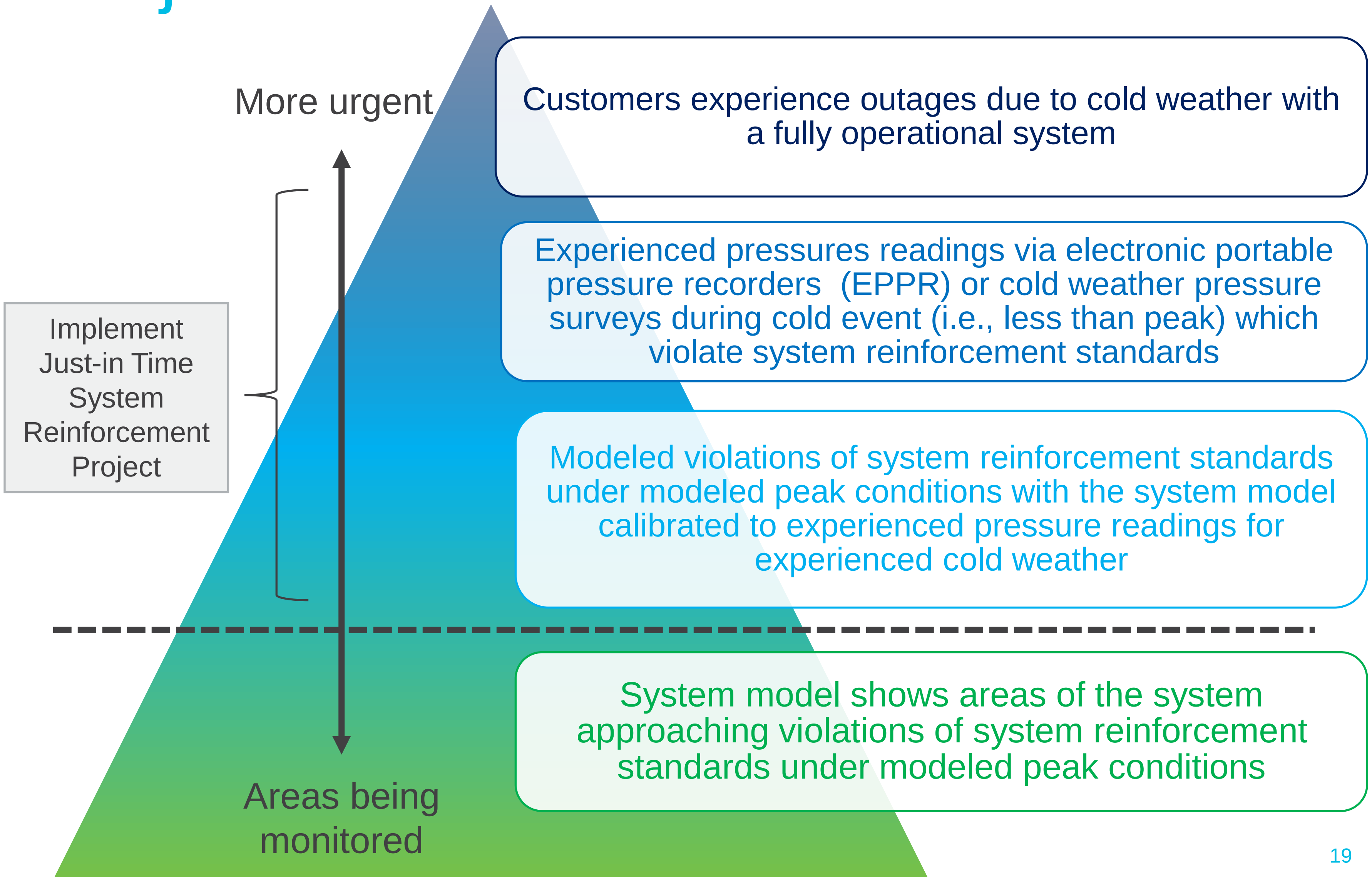
Feasibility, cost-effectiveness, and equity related policy issues of geographically-targeted residential and commercial demand-side alternatives currently being assessed as part of GeoTEE pilot

Supply-Side Distribution System Planning Process



Levels of Severity for System Reinforcement Projects

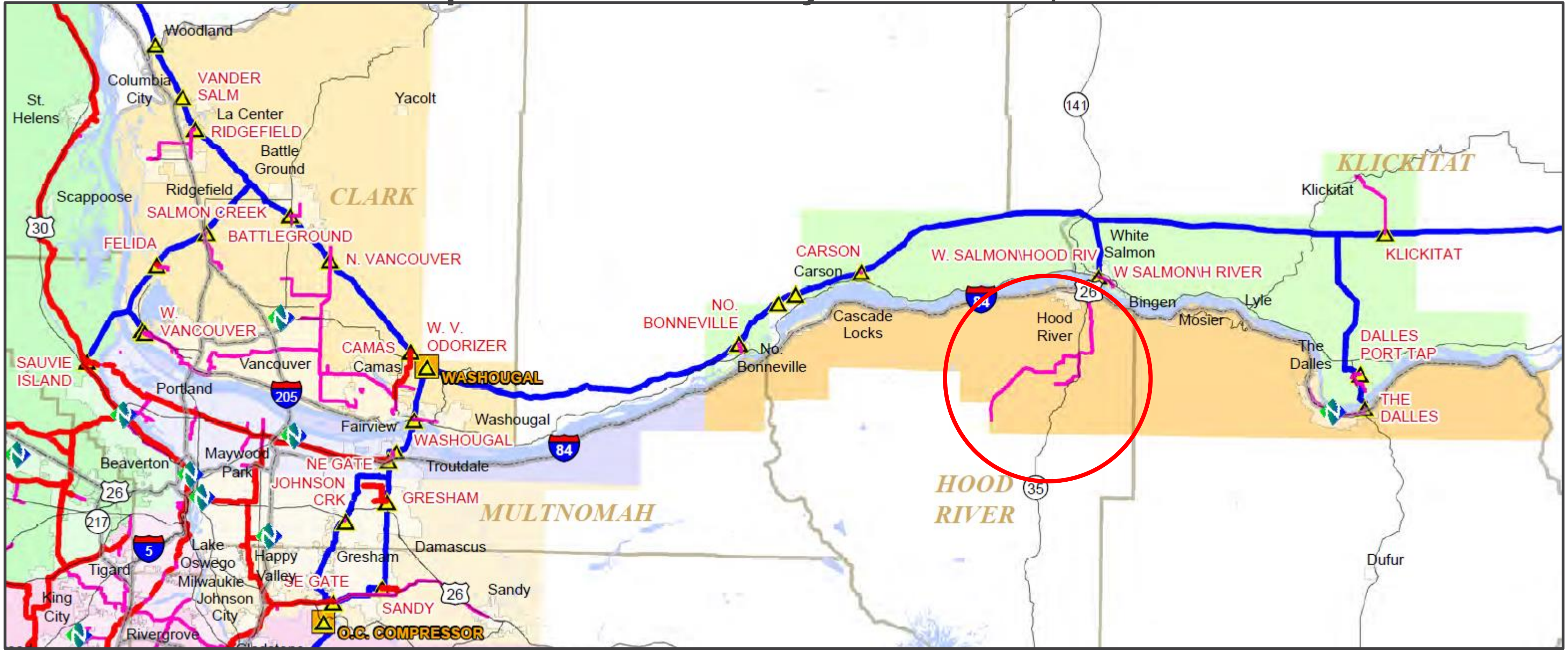
- The most likely time for customers to lose service due to pipeline constraints occurs during the most dangerous time for customers to lose service
- We rarely experience the design weather that we design our distribution system to be able to meet
- We must rely on system modeling to identify areas of concern (or vice versa) as the system changes through time



Peak Hour Load Forecast - Methodology

NW Natural®

Example: Area Served By Hood River, OR Gate



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

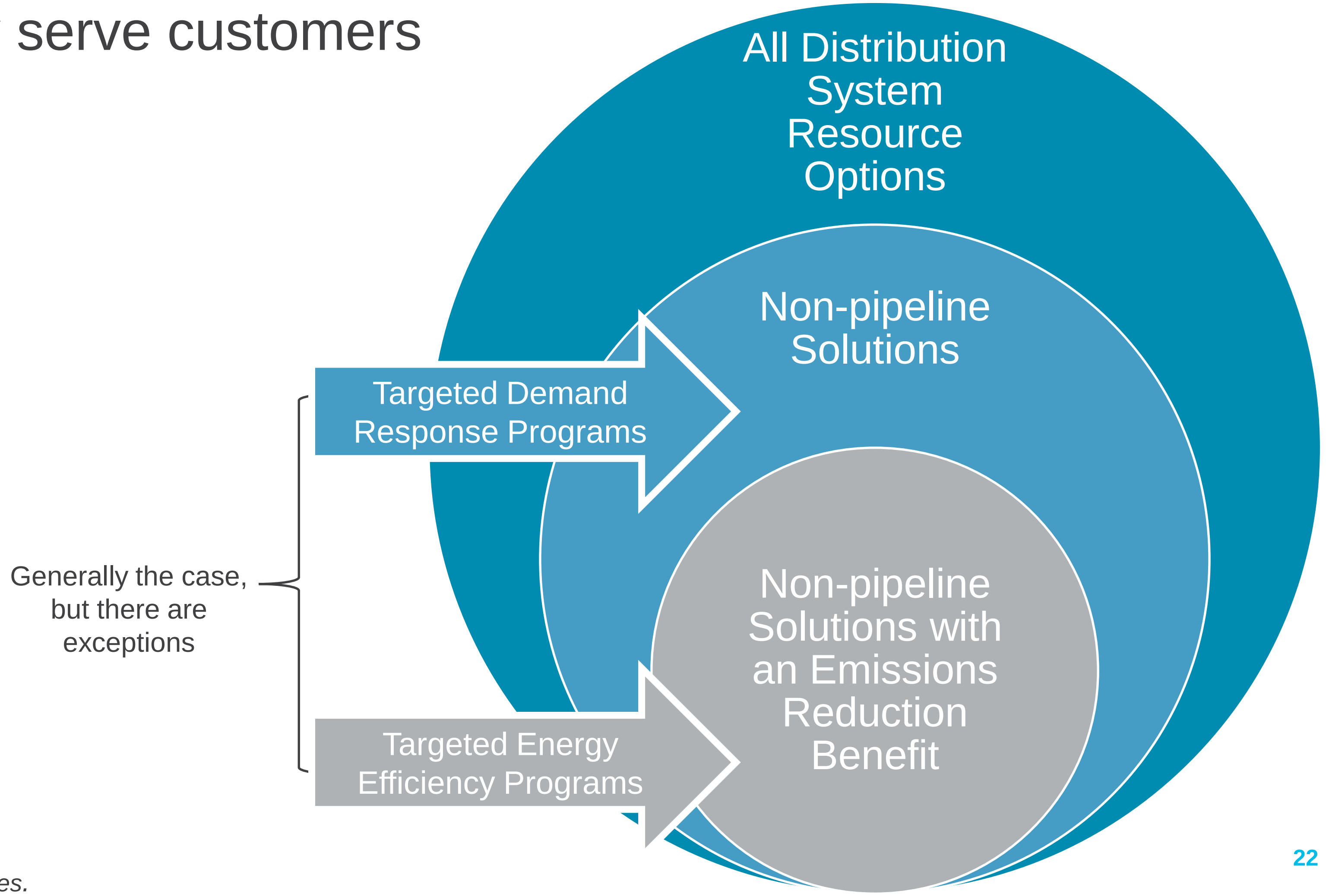
Distribution System Planning Considerations

- High frequency metering throughout our distribution system is limited
  - Peak hour load is forecasted from gate stations (Northwest Pipeline interconnection points) and large industrial customer flows as opposed to individual customer usages from each customer
- Metering capability for residential and commercial customers is also limited
  - Smallest increment meter in service today measures usage in 1 therm increments but average residential customers use far less than 1 therm per hour under normal conditions
- Forecasting changes in distribution system requirements is difficult and uncertain
  - Identifying specific locations where customer growth will occur is challenging
  - Uncertainty regarding peak hour load forecasting generally increases as the size of the area being forecast decreases
- Demand-side capacity options for natural gas distribution systems are not well studied
  - Costs and risks not fully developed

Purpose of Non-pipeline Solutions

Non-pipeline solutions are alternative distribution system resources to reliably serve customers

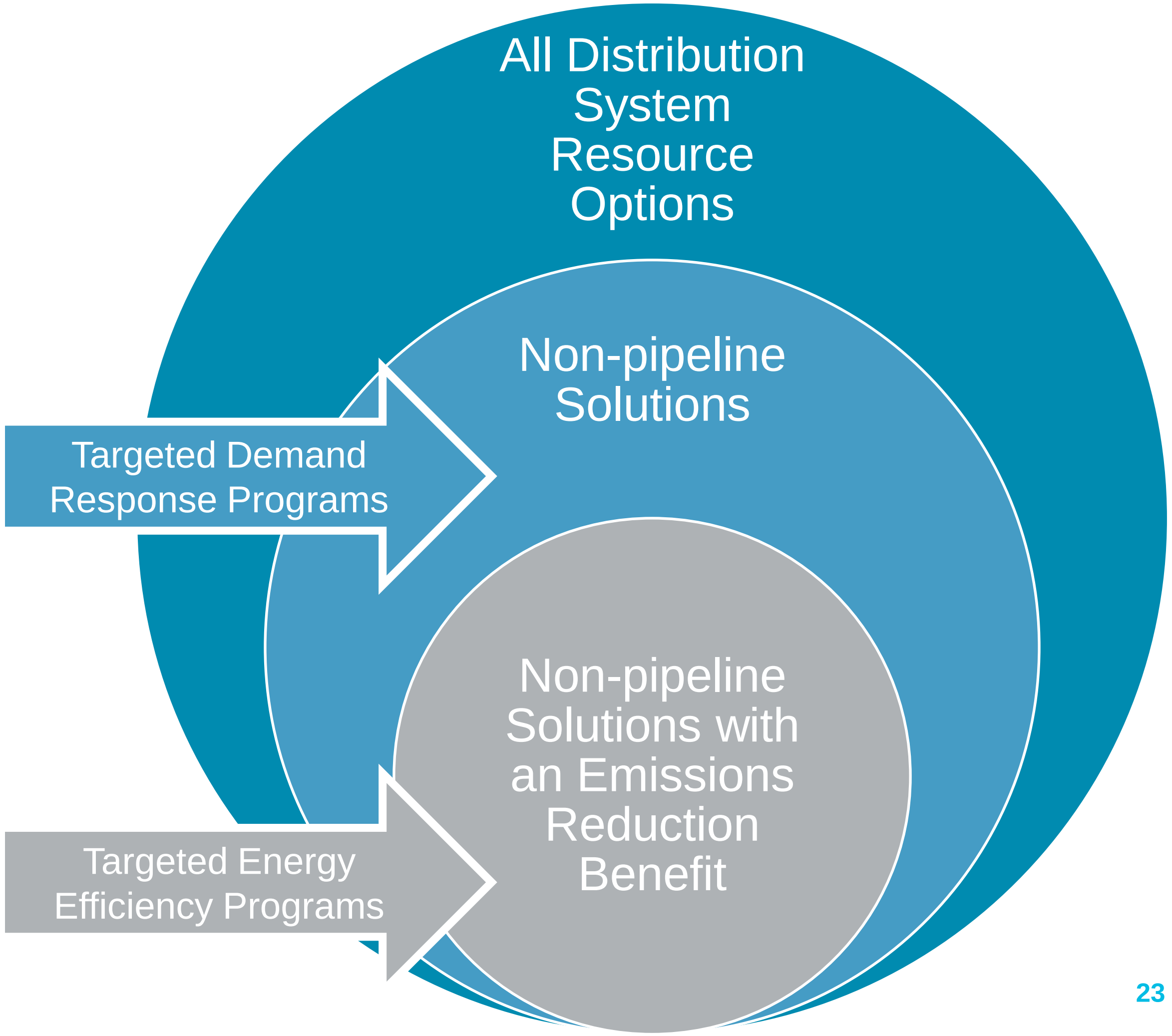
- Must help serve or reduce load during a peak event
- Evaluated for cost-effectiveness against other options
- Non-pipeline Solution ≠ Demand-side Resource
- Some non-pipeline solutions, such as demand response, may not reduce emissions, but rather shift the demand away from the system peak



Purpose of Non-pipeline Solutions

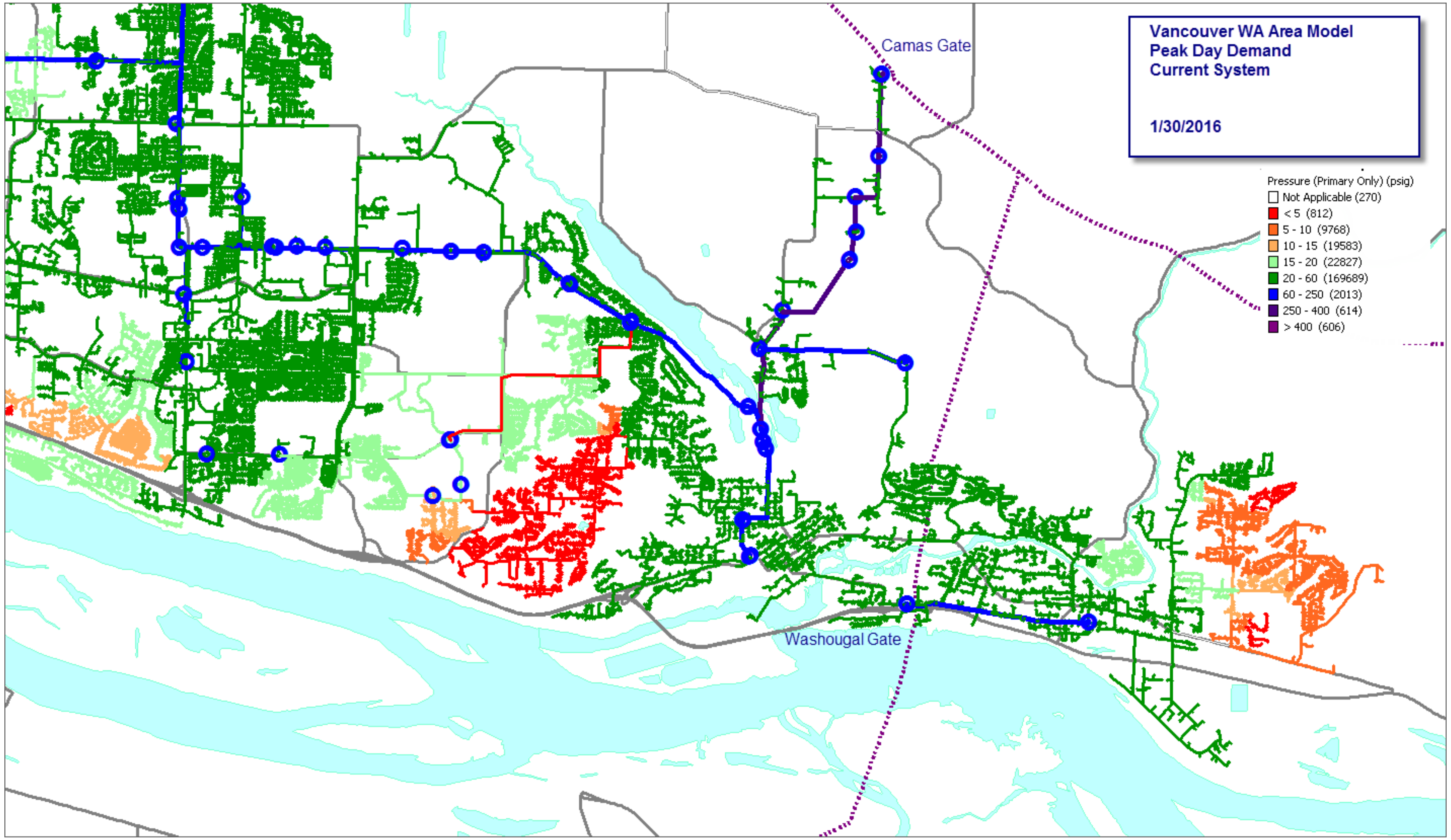
NW Natural is committed to decarbonization **AND** serving customers reliably

- These two objectives are essential and can both be achieved
- Attempting to achieve emission reduction options through peak planning can can be counter-productive and lead to unnecessary costs in some cases
- By definition, planning peak events happen far less than one time per year, such that emissions during these events are inconsequential to emissions levels over multiple years
- The emissions reductions benefit of non-pipeline solutions, such as GeoTEE, will be included in the cost-effectiveness evaluation of all distribution system resource options to address peak demand



Determining Area of Impact

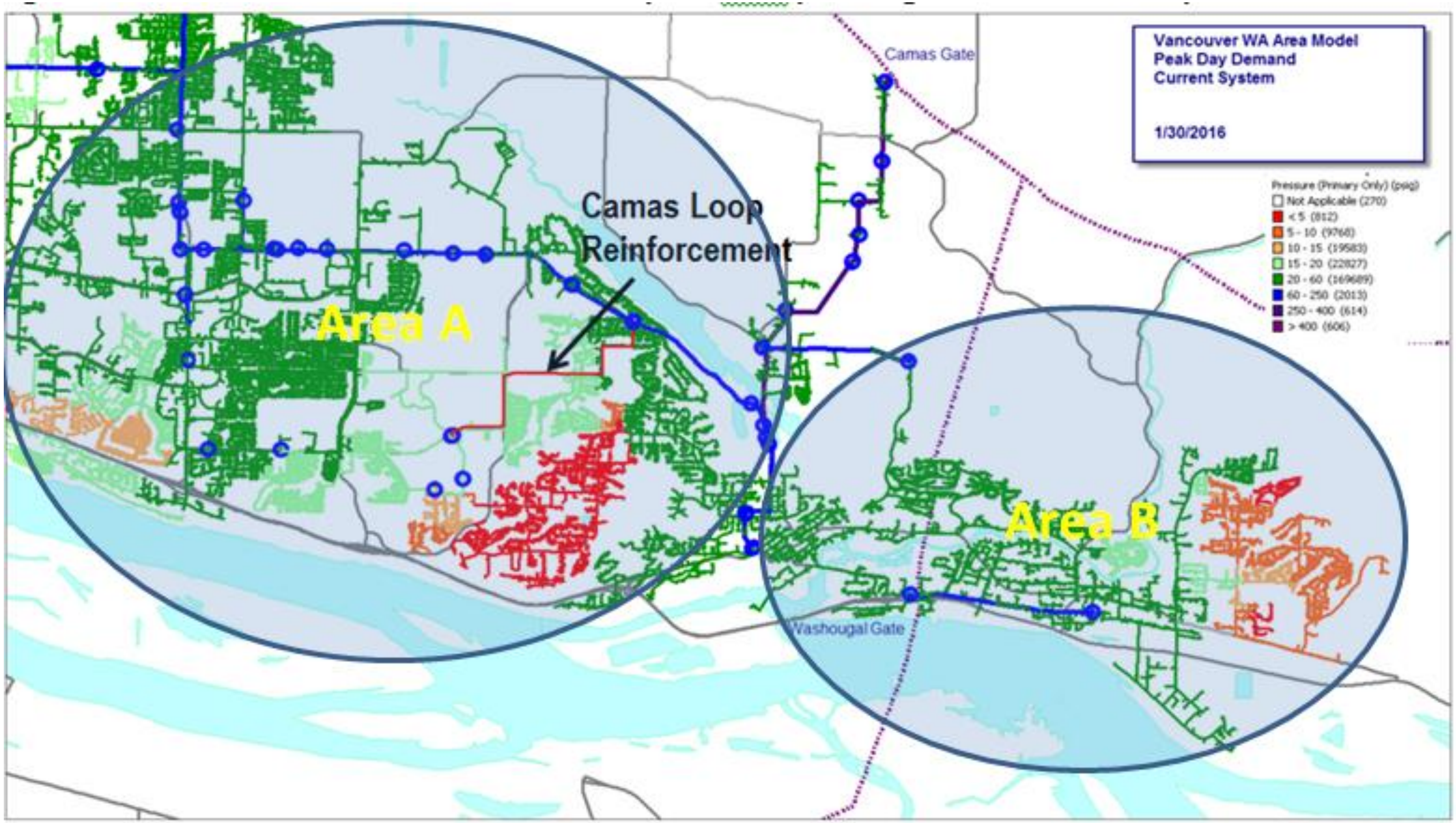
NW Natural®



Example from previous IRP: Weakness in distribution system system in

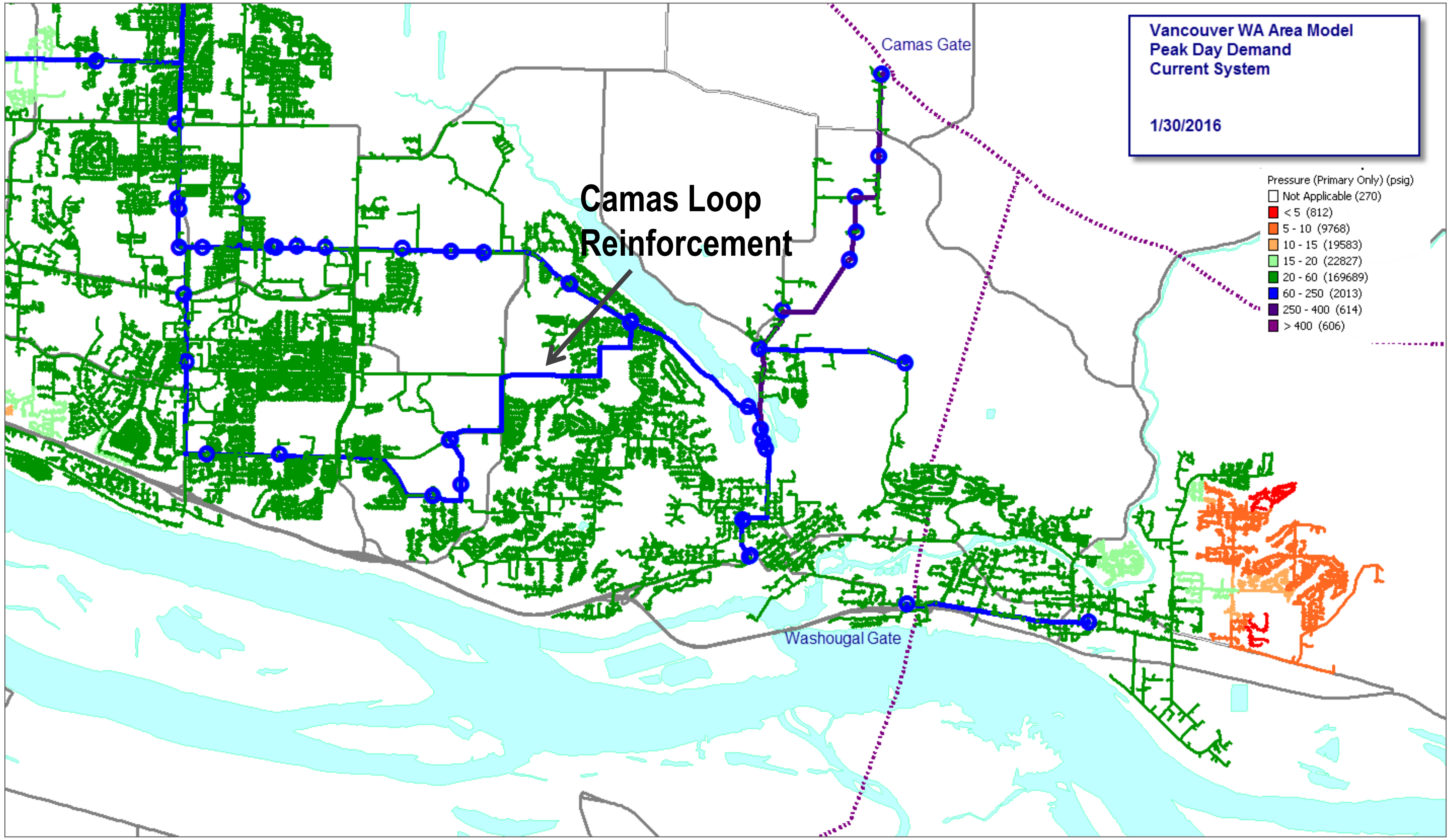
How is Area for Targeted Demand-Side Program Determined?

NW Natural®

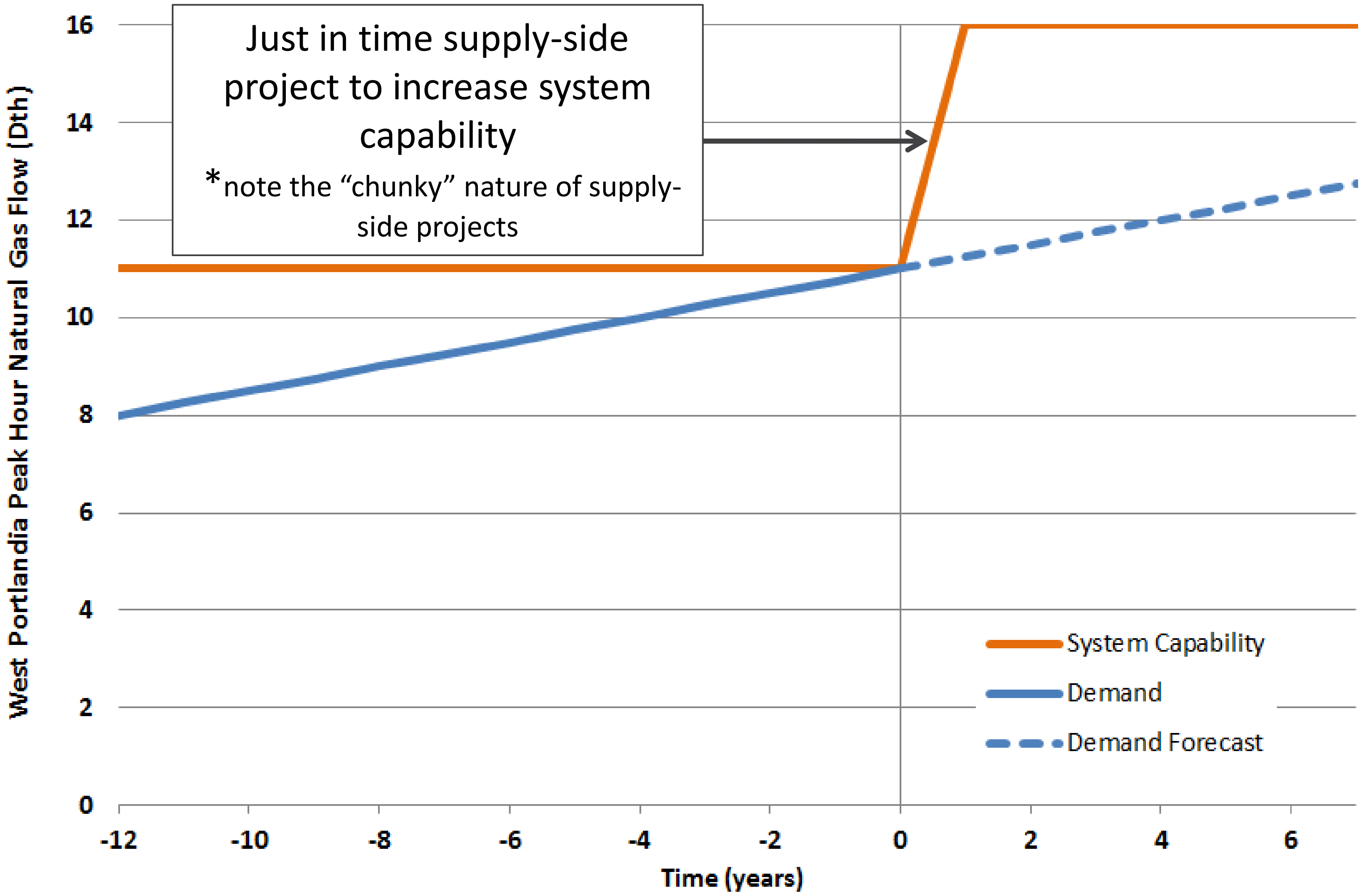


How is Area for Targeted Demand-Side Program Determined?

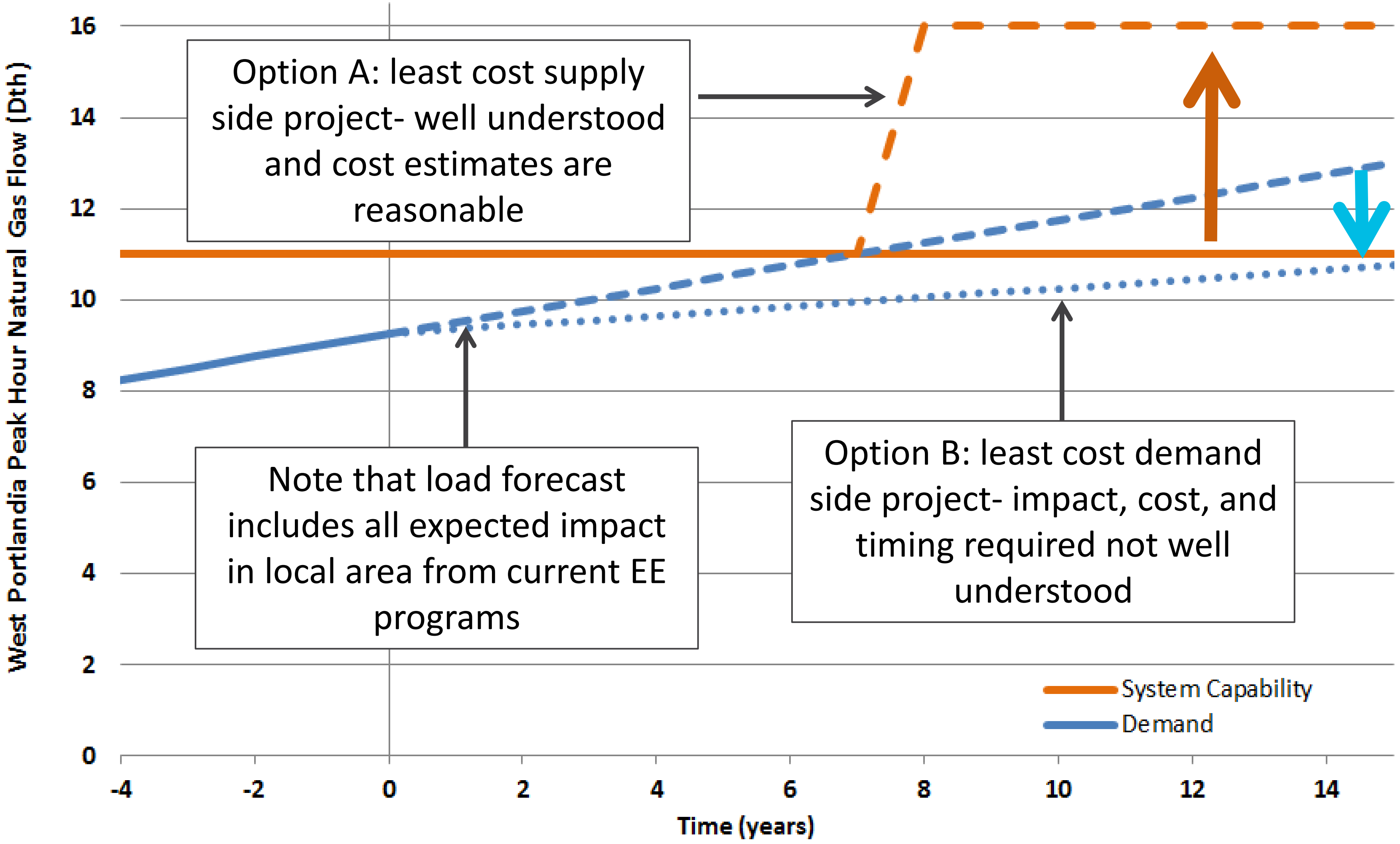
NW Natural®



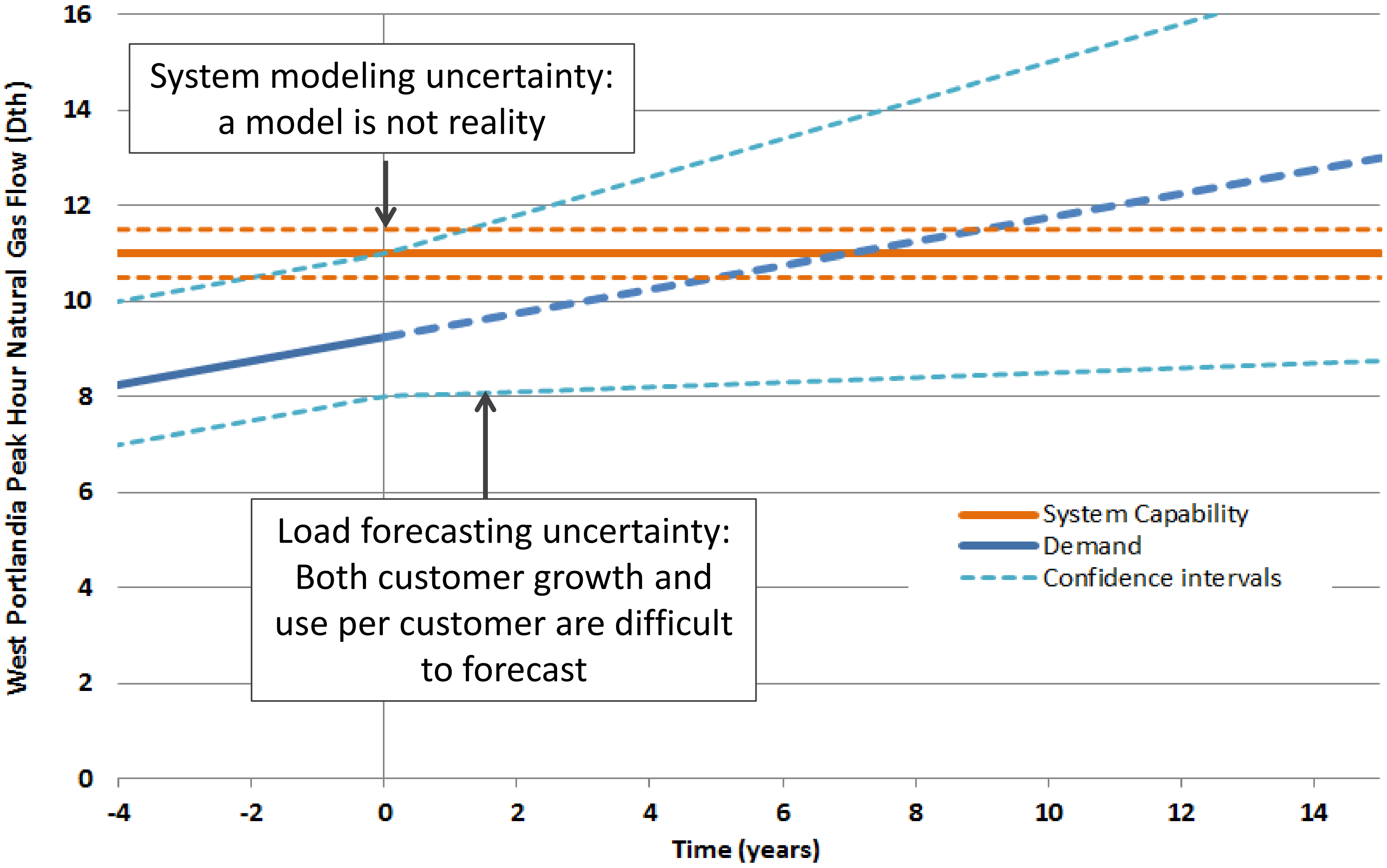
Current Distribution System Planning-Just-in-Time Solutions



Forward-Looking Distribution System Planning



Setting Realistic Expectations for EE as a Distribution System Capacity Resource



Distribution System Planning – Peak Hour Load Forecasting

Distribution System Peak Load Forecasting Key Concepts

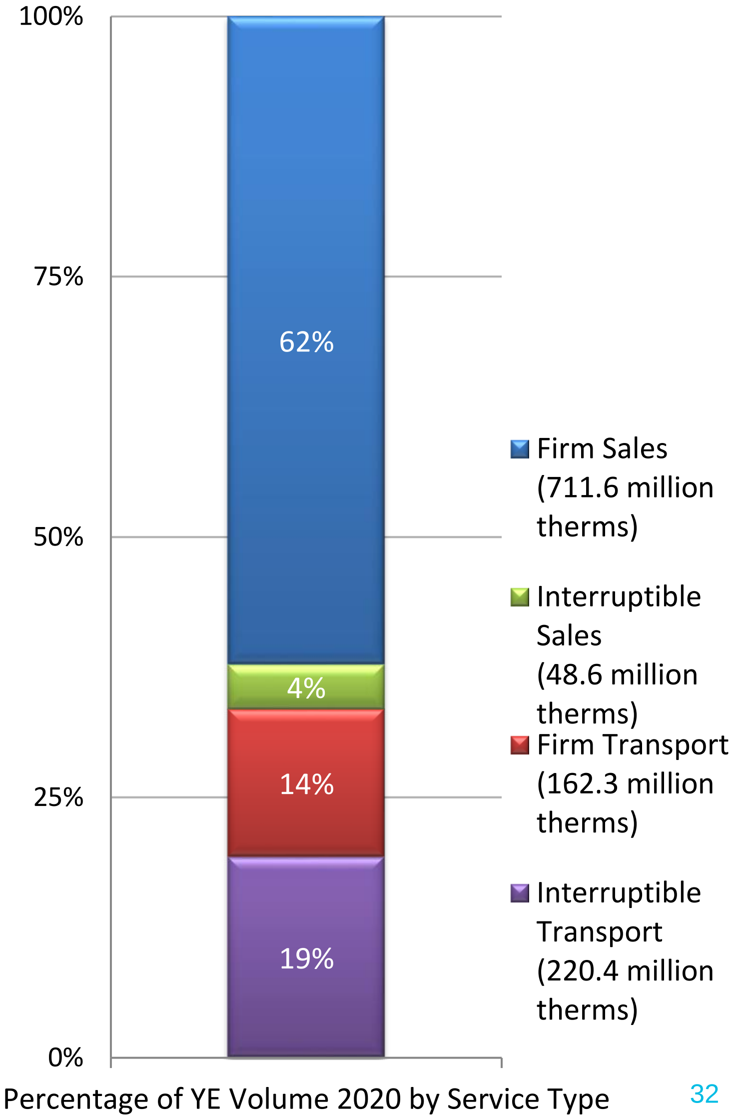
NW Natural®

- Deploys same general methodologies discussed in TWG #2
- Peak hour load driven primarily by space heating needs
- Combines top-down (system-wide) and bottom-up (customer-specific) information to forecast peak load
- Top-down methodology consistent with 2018 IRP, bottom-up estimates are undergoing process of improvement and peak estimates are now being made specifically for each customer
- Estimating peak demand for specific areas of the distribution system requires calibration of the system-wide top-down model with the bottom-up estimates
- Demand-response events are assumed to be in effect during peak events, so all interruptible customer loads are assumed to be zero in load forecast
- Includes transportation schedule loads that need to be delivered, even though NW Natural does not supply, but only delivers, gas to these customers

Customer Types and Resource Planning

NW Natural®

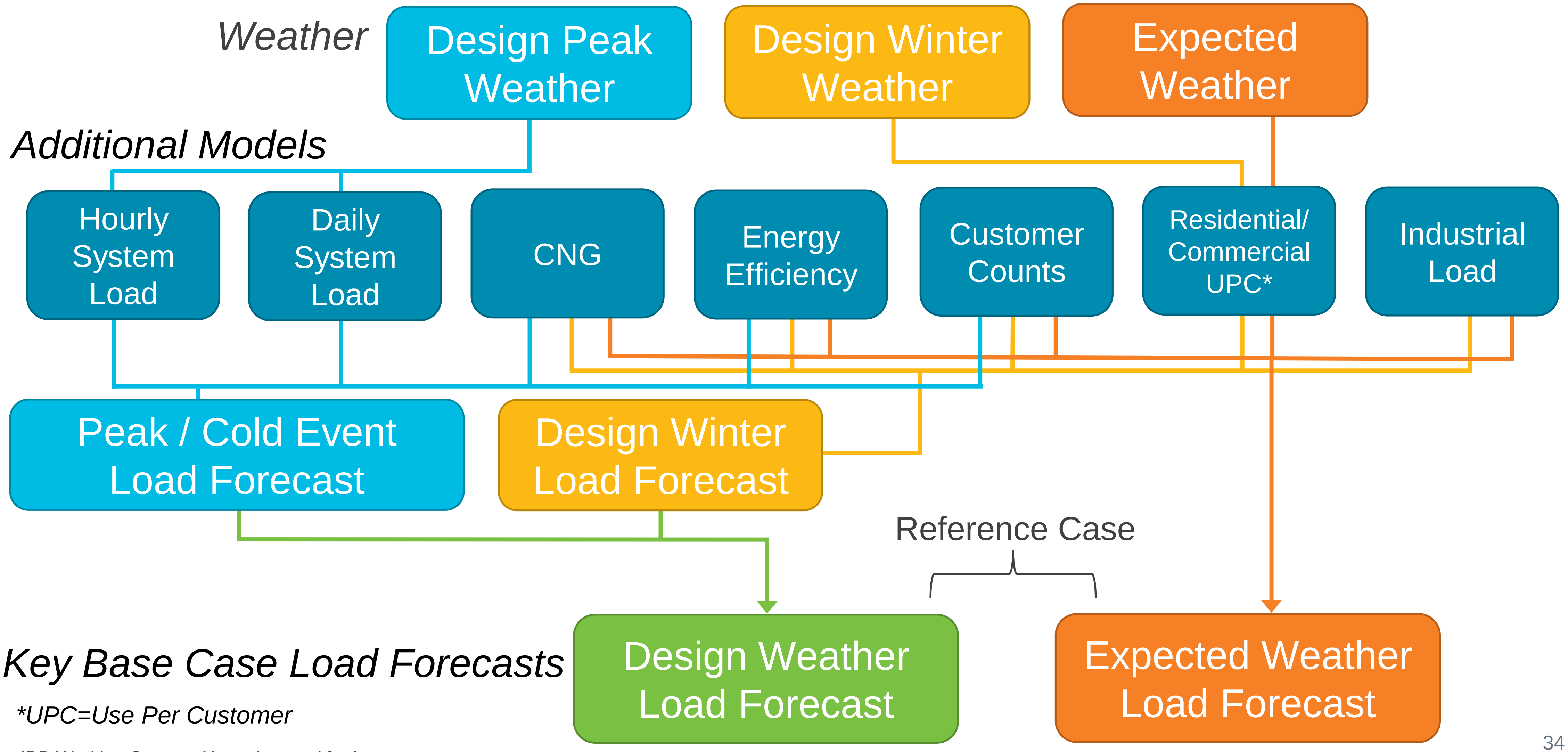
Customer Category	System Capacity Resource Planning: Design Winter Weather Energy Requirements	System Capacity Resource Planning: Peak Day Capacity Requirements	System Capacity Resource Planning: Emission Compliance	Distribution System Planning: Peak Hour Capacity Requirements
Firm Sales	✓	✓	✓	✓
Interruptible Sales	✓		✓	
Firm Transport			✓	✓
Interruptible Transport			✓	



Peak Hour Load Forecast - Methodology

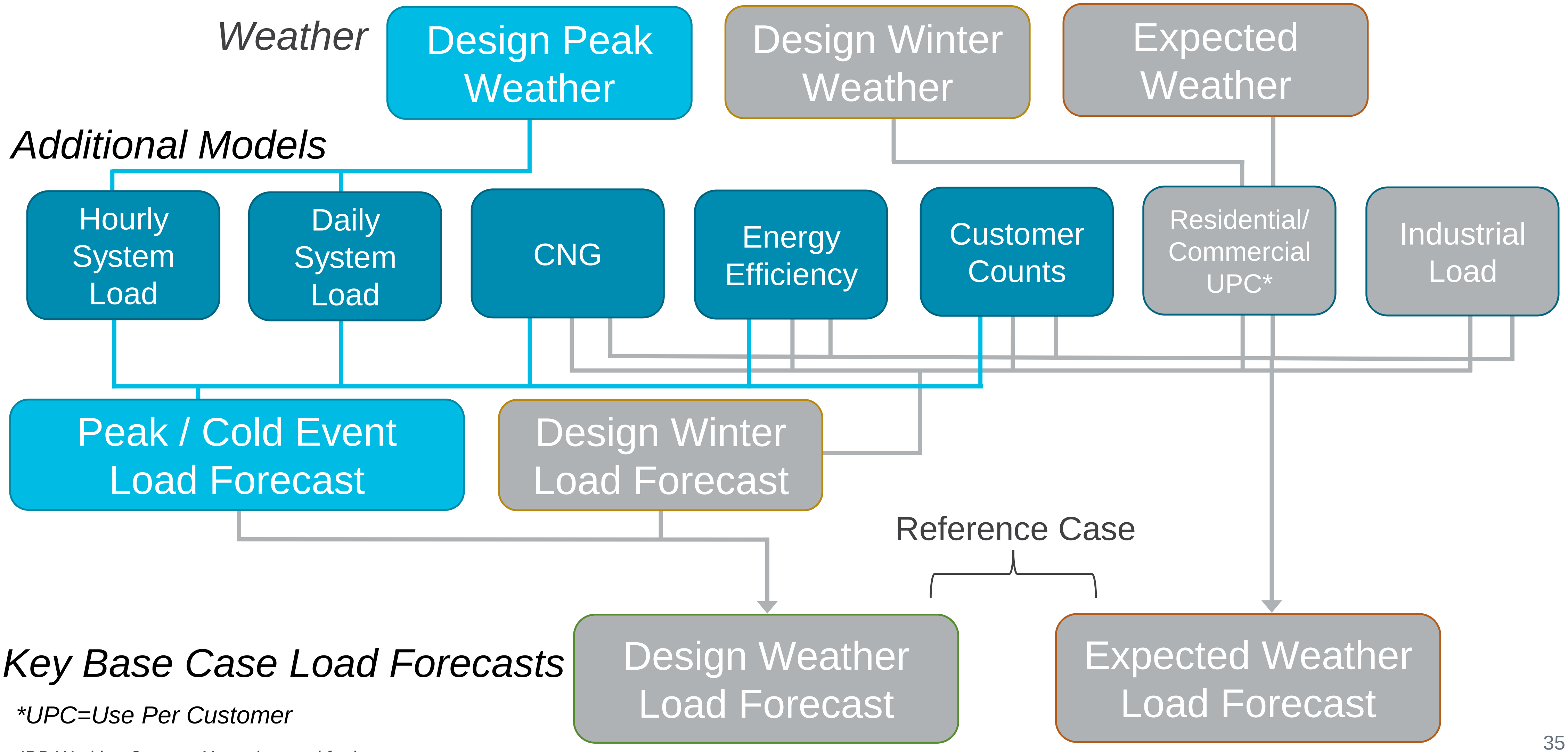
- Peak hour forecast methodology follows that of our peak day load forecast
- Using historical data and statistical analysis, we estimate the relationship between actual firm load (both sales and transport customers) and its drivers in a specific location
- These relationships, in conjunction with a planning standard, produce a prediction of load that would materialize in a specific area of the distribution system under peak conditions with current customers - and forecast of this prediction under peak conditions going into the future
  - Questions to answer:
    1. What load would be expected under peak planning weather conditions if those conditions were experienced today?
    2. What load would be expected for each year for 10 years under those same peak planning weather conditions?

Load Forecast Model Flow Chart



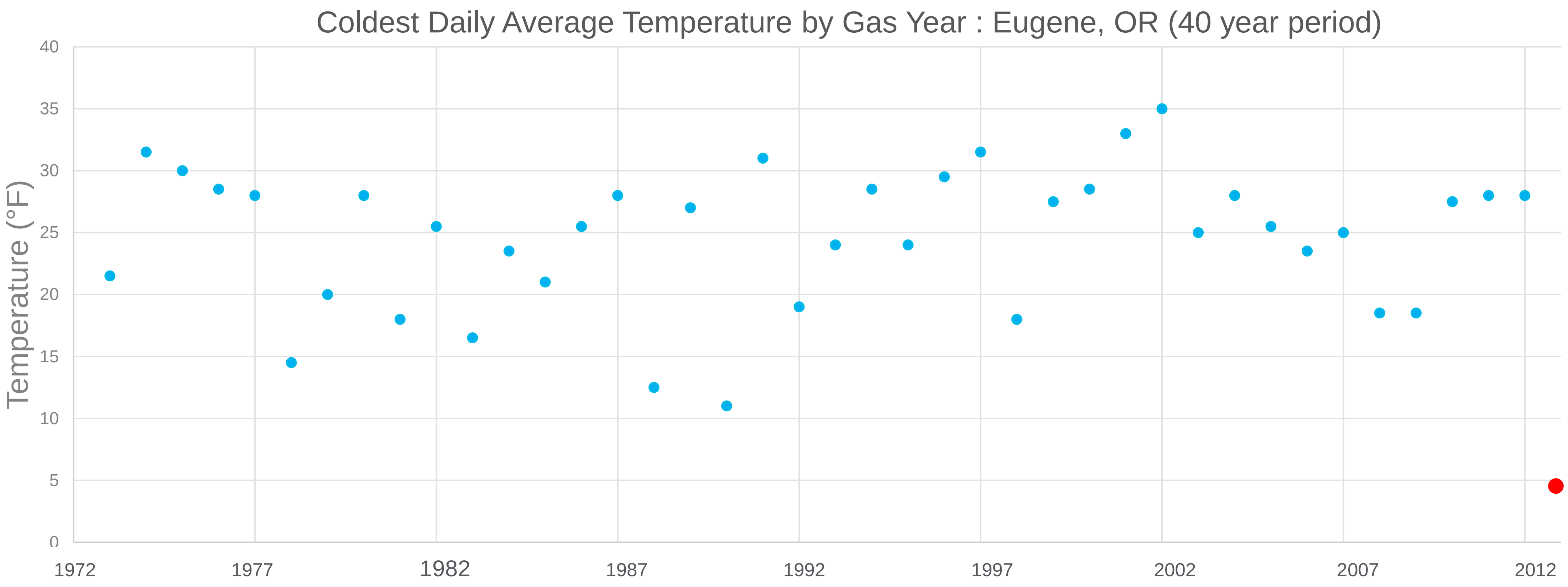
*UPC=Use Per Customer

Peak Forecast



**UPC=Use Per Customer*

Eugene weather



Peak Hour Load Forecasting Data

Bottom-Up Customer Specific Forecasts vs **Top-Down System Forecast**

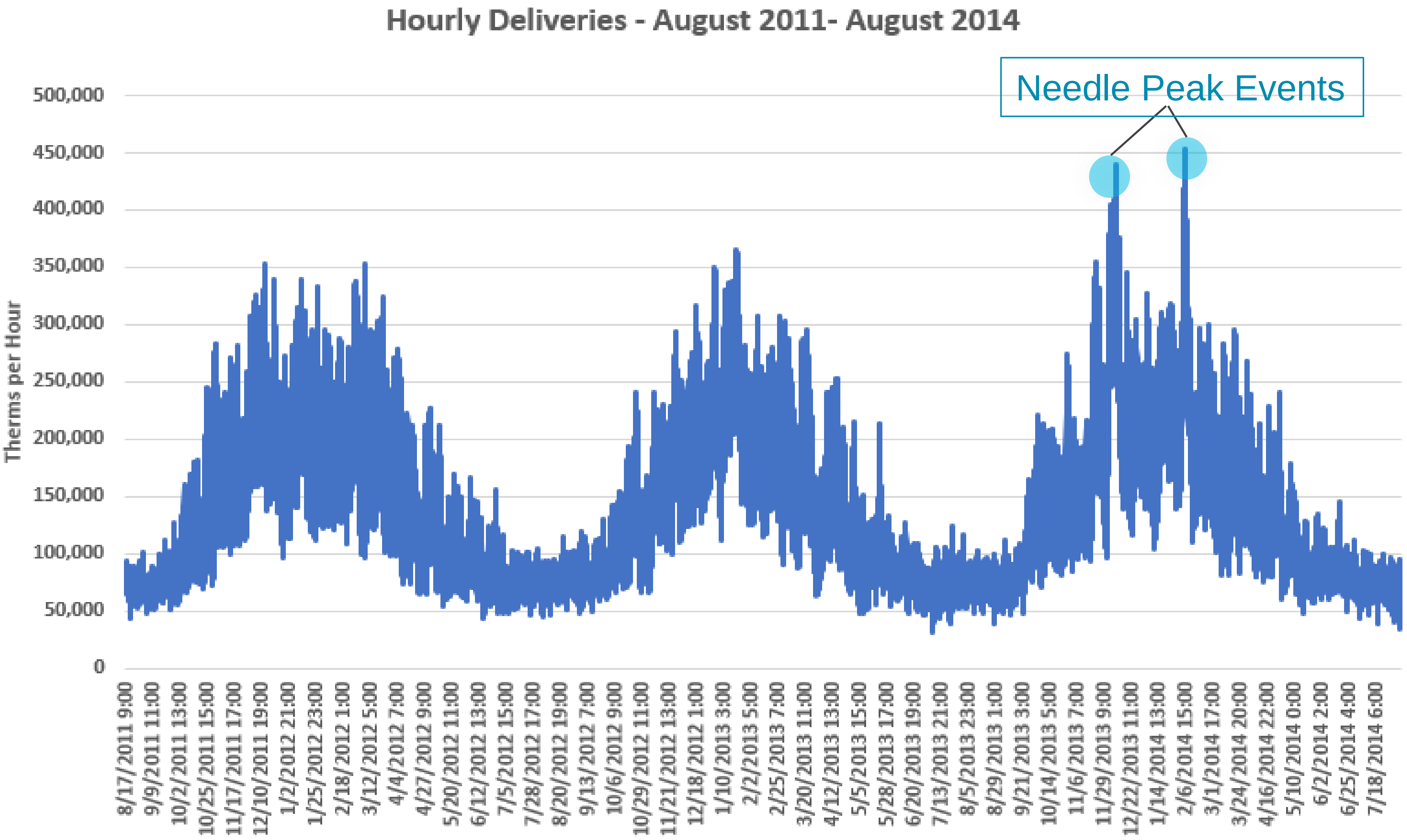
Billing Meters

- Records usage for every customer as they use gas
- Extremely accurate; batch sets of meters are tested regularly for accuracy
- Meters are read on billing cycles (roughly once a month) and time stamped for each read
- Provides monthly usage data for each customer
- Large transport and interruptible customers have more complex metering that records their usage hourly

Supervisory control and data acquisition (SCADA)

- Records gas flowing from the interstate pipeline onto NW Natural's System
- Also, records gas flowing in and out of storage
- Used by gas control to monitor our system on a day-to-day basis
- Generally, very accurate; but meters can record faulty data from time to time
- Used to view system or regional demand at a very granular time scale (e.g., hourly)

What is a "Needle Peak"?



- Extreme weather causes energy usage spikes that drive building heating or cooling needs
- These spikes, or peak events, result in much higher usage than all other times
- The more of a utility's load that is heating or cooling the "peakier" the load
- More than half of the energy NW Natural delivers is for space heating, so our load is very "peaky"
- Planning peak events occur far less frequently than each winter

Daily System Load Model

Linear Regression	Coef.	Robust Std. Err.	t	P>|t|
Temperature	17,530.49	6,743.85	2.6	0.009
Previous Day Temperature	-8,800.16	301.73	-29.17	0.000
Solar Radiation	-13.42	2.42	-5.55	0.000
Wind Speed	5,497.50	657.94	8.36	0.000
Snow Depth	-26,923.99	5,393.96	-4.99	0.000
Customer Count	2.80	0.47	5.97	0.000
Friday Indicator	-32,051.75	7,212.22	-4.44	0.000
Saturday Indicator	-46,305.20	7,239.25	-6.4	0.000
Sunday Indicator	-43,988.44	6,721.36	-6.54	0.000
Holiday Indicator	-26,013.29	3,629.11	-7.17	0.000
Time Trend	-17,466.71	4,458.50	-3.92	0.000
Bull Run River Temperature	-1,535.16	127.82	-12.01	0.000
Temperature * Previous Day Temperature	141.54	6.53	21.67	0.000
Temperature * Solar Radiation	0.16	0.05	3.04	0.002
Temperature * Wind Speed	-47.92	15.38	-3.12	0.002
Temperature * Snow Depth	697.40	177.77	3.92	0.000
Temperature * Customer Count	-0.05	0.01	-5.16	0.000
Temperature * Friday Indicator	499.65	158.31	3.16	0.002
Temperature * Saturday Indicator	579.50	163.26	3.55	0.000
Temperature * Sunday Indicator	674.01	151.08	4.46	0.000
Temperature * Time Trend	398.48	99.99	3.99	0.000
Constant	-590,018.30	299,682.00	-1.97	0.049

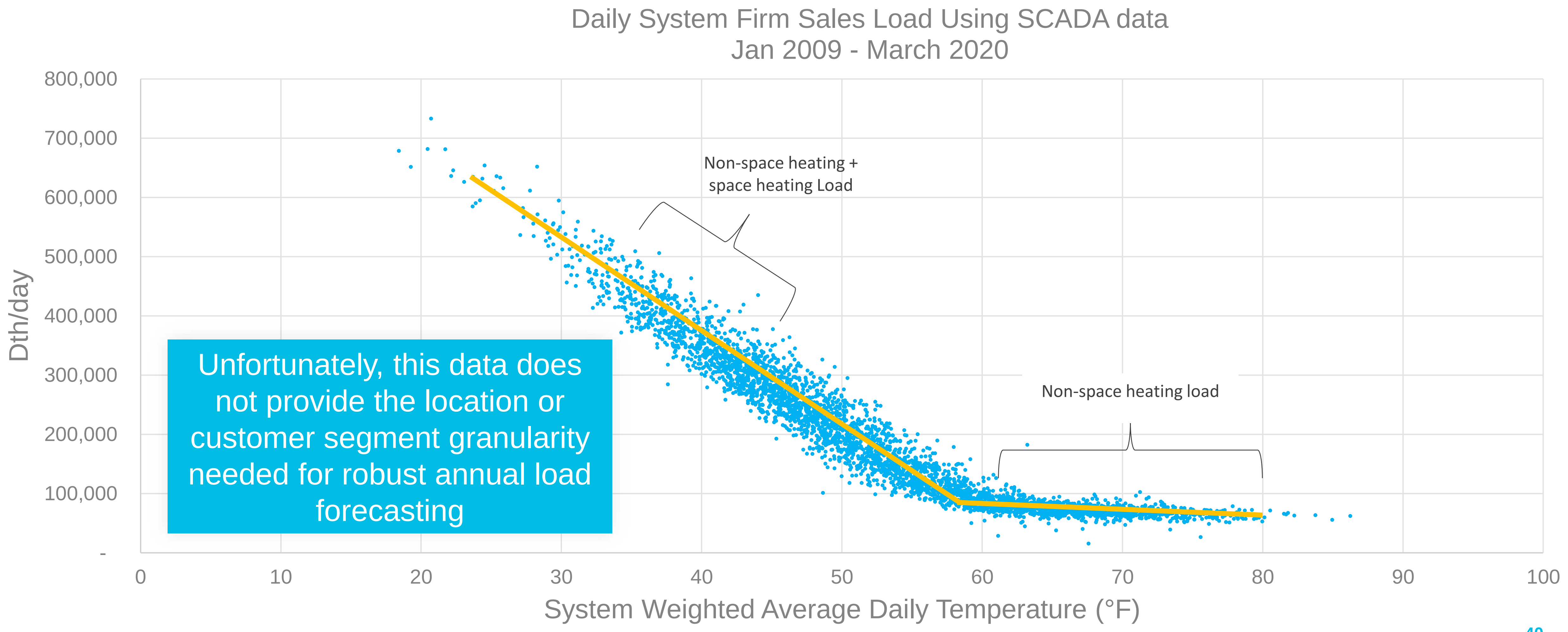
Note that coefficients cannot be interpreted individually.

Marginal Effect of Temperature For the Average January Weekday†	
Temperature	-13,964

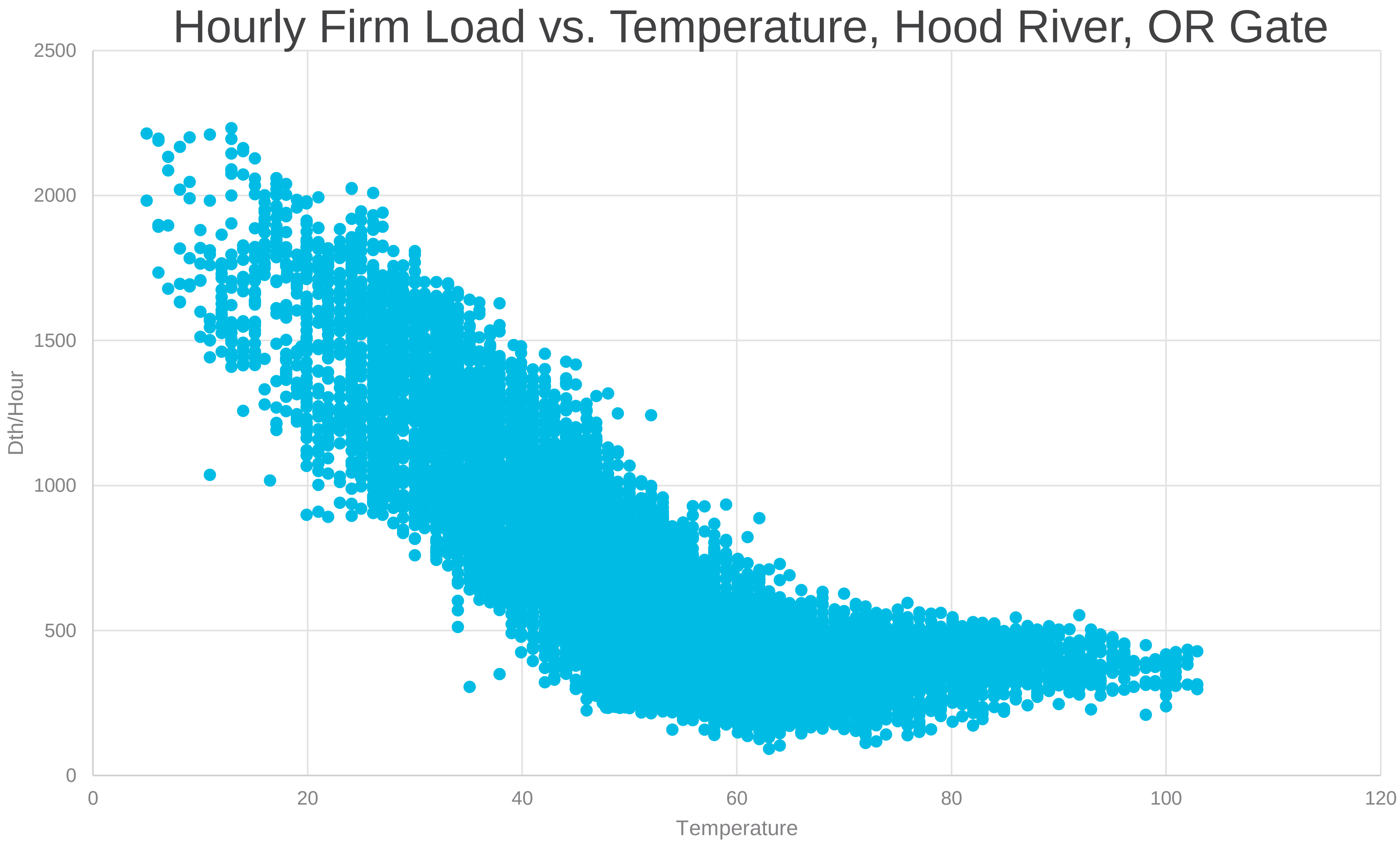
† Previous Day Temp = 41.3; Solar Radiation = 1,281; Wind Speed = 7.1; River Temp = 40.2; Time = 12; Cust (YE 2020 Com+Res) = 773,388

Marginal Effect	Evaluated at 25°F	Evaluated at 45°F
Previous-Day Temperature	-5,262	-2,431
Wind Speed	4,300	3,341
Solar Radiation	-9.5	-6.36
Customer Count	1.446	0.360
Saturday Indicator	-27,138	-20,228

What does NW Natural's System Load look like as a Function of Temperature?

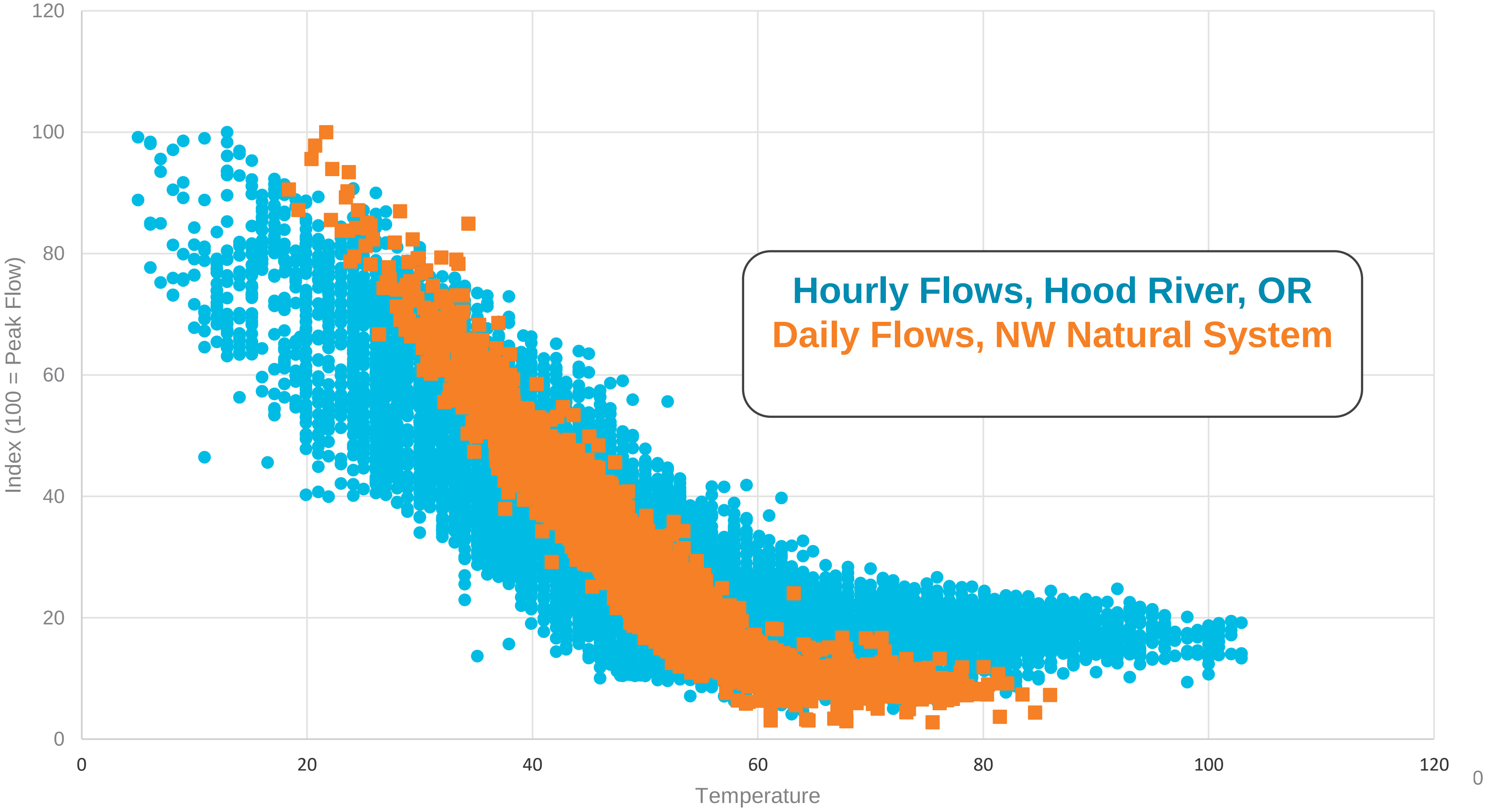


Hourly Level Disaggregation



Temperature Still Key

Load vs. Temperature, System Daily Flow and Hood River Hourly Flow



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

Hourly Load Forecasting Model

NW Natural®

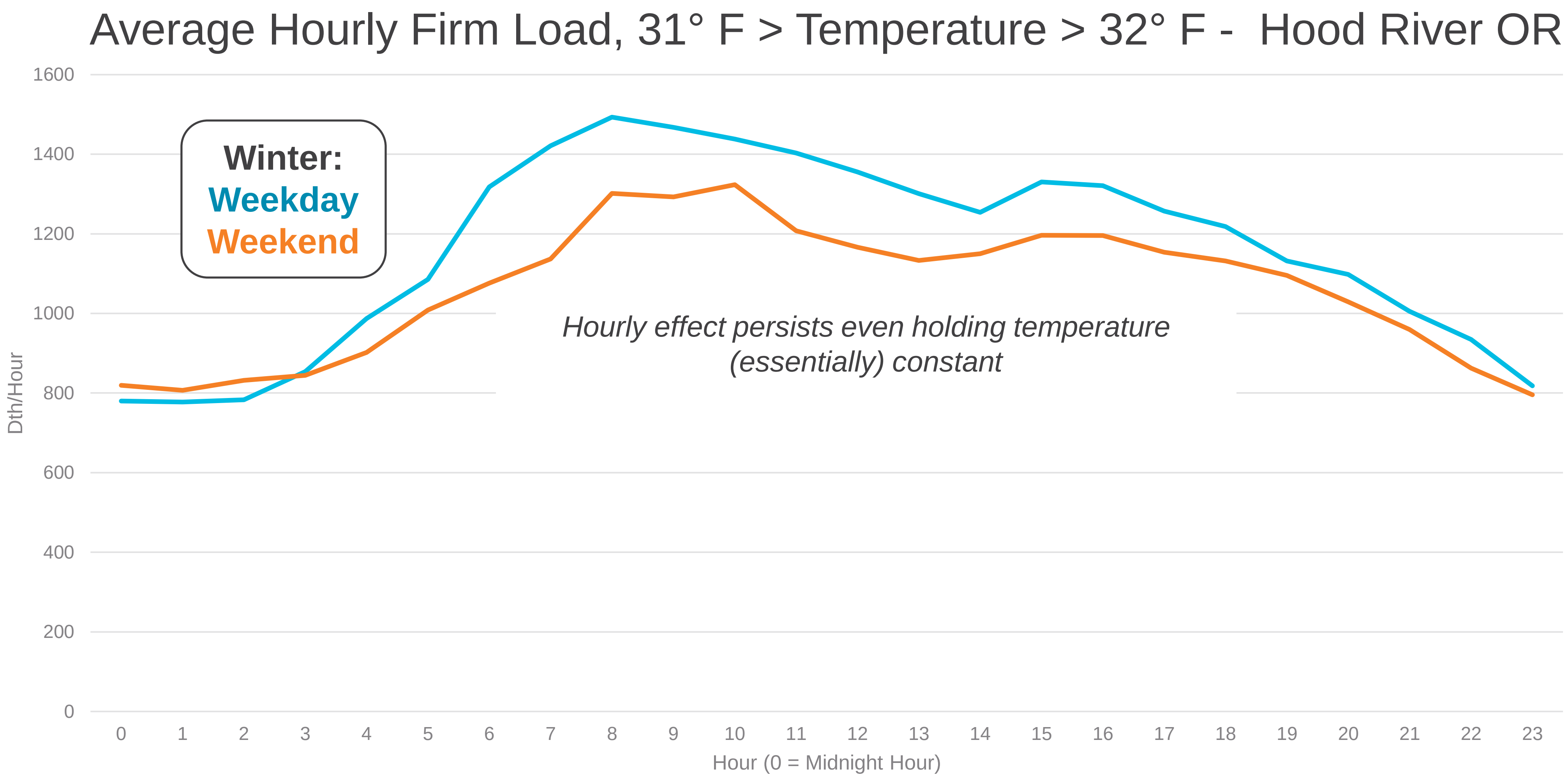
- Same drivers as peak **day** model, but incorporates how weather variables interact with **hours** of the day

Linear regression

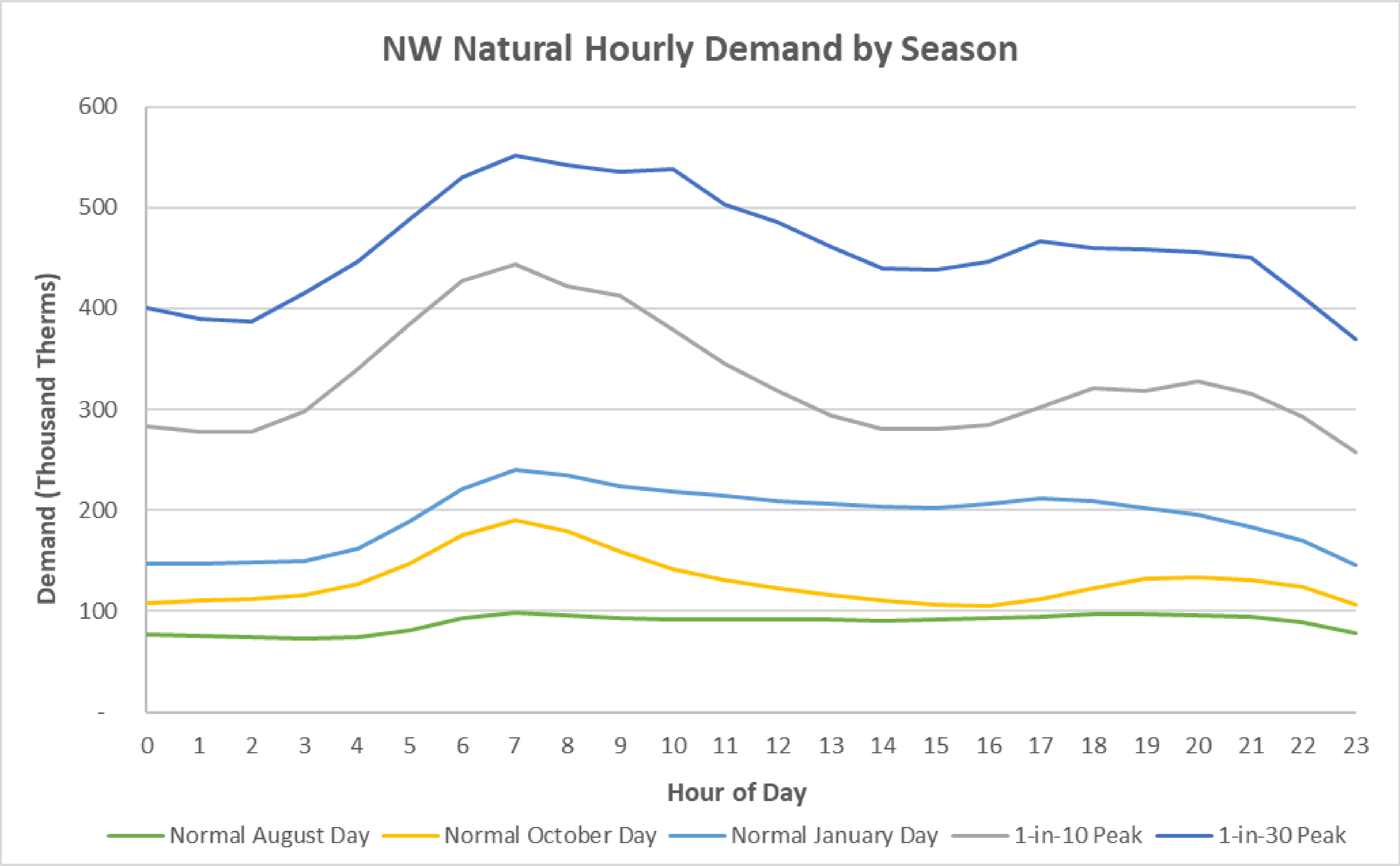
Number of obs	= 54395
F(90, 54304)	= 6216.29
Prob > F	= 0.0000
R-squared	= 0.9227
Root MSE	= 14569

Firm	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
COVIDDummy	-26382.95	1854.255	-14.23	0.000	-30017.3	-22748.59
COVIDTemp	459.0397	40.63215	11.30	0.000	379.4003	538.679
Customers	.3011844	.0137907	21.84	0.000	.2741545	.3282143
Temp	-576.5958	230.1086	-2.51	0.012	-1027.61	-125.5811
Wind	3865.531	104.2705	37.07	0.000	3661.16	4069.902
SolRad	-60.23418	1.280734	-47.03	0.000	-62.74443	-57.72393
TempLag1	-3487.78	69.4033	-50.25	0.000	-3623.811	-3351.749
TempWind	-47.58476	2.313356	-20.57	0.000	-52.11895	-43.05056
TempSol	1.061879	.0240879	44.08	0.000	1.014666	1.109091
TempCust	-.0013011	.0003045	-4.27	0.000	-.001898	-.0007042
WeekHour3	23022.6	3008.205	7.65	0.000	17126.49	28918.7
WeekHour4	53322.46	2942.19	18.12	0.000	47555.74	59089.17
WeekHour5	95276.02	3019.525	31.55	0.000	89357.72	101194.3
WeekHour6	138712.8	3197.028	43.39	0.000	132446.6	144979
WeekHour7	167798.6	3424.419	49.00	0.000	161086.7	174510.5
WeekHour8	173206.1	3637.032	47.62	0.000	166077.5	180334.8
WeekHour9	181680.4	3188.949	56.97	0.000	175430	187930.7
WeekHour10	187366	3297.154	56.83	0.000	180903.5	193828.4
WeekHour11	193015.8	3345.008	57.70	0.000	186459.6	199572.1
WeekHour12	194452.2	3517.542	55.28	0.000	187557.8	201346.6
WeekHour13	187529.9	3859.386	48.59	0.000	179965.5	195094.4
WeekHour14	180248.4	3745.213	48.13	0.000	172907.7	187589
WeekHour15	172530.2	3678.374	46.90	0.000	165320.5	179739.8
WeekHour16	167088.9	3403.553	49.09	0.000	160417.9	173759.8
WeekHour17	148014.5	3079.122	48.07	0.000	141979.4	154049.7
WeekHour18	113984.2	2939.172	38.78	0.000	108223.4	119745
WeekHour19	85484.72	2909.921	29.38	0.000	79781.25	91188.19
WeekHour20	74829.8	2851.378	26.24	0.000	69241.08	80418.53
WeekHour21	63073.27	2688.217	23.46	0.000	57804.34	68342.19
WeekHour22	34624.66	2606.112	13.29	0.000	29516.66	39732.66
WkndHour3	14549.9	4066.312	3.58	0.000	6579.893	22519.9
WkndHour4	32315.81	3903.833	8.28	0.000	24664.27	39967.35
WkndHour5	59280.64	3814.504	15.54	0.000	51804.18	66757.09
WkndHour6	90239.37	3988.111	22.63	0.000	82422.64	98056.1
WkndHour7	121271.5	4022.549	30.15	0.000	113387.3	129155.7
WkndHour8	144936.9	4590.048	31.58	0.000	135940.3	153933.4
WkndHour9	162225.1	4345.199	37.33	0.000	153708.5	170741.7
WkndHour10	173609.8	4498.276	38.59	0.000	164793.1	182426.4
WkndHour11	176163.1	4421.415	39.84	0.000	167497.1	184829.1
WkndHour12	172322.2	4632.914	37.20	0.000	163241.7	181402.8
WkndHour13	166653.3	5146.636	32.38	0.000	156565.8	176740.7
WkndHour14	156016	4846.401	32.19	0.000	146517	165514.9
WkndHour15	147782	4686.235	31.54	0.000	138596.9	156967
WkndHour16	137128.2	4647.257	29.51	0.000	128019.6	146236.9
WkndHour17	119109.3	4166.854	28.58	0.000	110942.2	127276.4
WkndHour18	85150.45	4045.033	21.05	0.000	77222.16	93078.75
WkndHour19	65830.77	4078.808	16.14	0.000	57836.27	73825.26
WkndHour20	58266.88	3919.387	14.87	0.000	50584.85	65948.91
WkndHour21	54069.34	3847.868	14.05	0.000	46527.49	61611.2
WkndHour22	31833.39	3917.116	8.13	0.000	24155.81	39510.97
TempWeek3	-527.6998	72.37603	-7.29	0.000	-669.5574	-385.8422
TempWeek4	-965.7835	71.22353	-13.56	0.000	-1105.382	-826.1848
TempWeek5	-1357.418	74.01414	-18.34	0.000	-1502.486	-1212.349
TempWeek6	-1575.778	78.53826	-20.06	0.000	-1729.713	-1421.842
TempWeek7	-1846.531	83.56659	-22.10	0.000	-2010.323	-1682.74
TempWeek8	-2190.646	87.18593	-25.13	0.000	-2361.532	-2019.761
TempWeek9	-2522.532	75.03303	-33.62	0.000	-2669.597	-2375.466
TempWeek10	-2650.732	74.21434	-35.72	0.000	-2796.193	-2505.271
TempWeek11	-2721.011	72.40816	-37.58	0.000	-2862.931	-2579.09
TempWeek12	-2689.374	73.49733	-36.59	0.000	-2833.429	-2545.319
TempWeek13	-2508.331	78.65955	-31.89	0.000	-2662.504	-2354.157
TempWeek13	-2508.331	78.65955	-31.89	0.000	-2662.504	-2354.157
TempWeek14	-2359.504	75.79967	-31.13	0.000	-2508.072	-2210.936
TempWeek15	-2176.138	74.44644	-29.23	0.000	-2322.054	-2030.223
TempWeek16	-1999.753	69.79275	-28.65	0.000	-2136.548	-1862.959
TempWeek17	-1587.842	64.49219	-24.62	0.000	-1714.247	-1461.437
TempWeek18	-978.2403	62.45017	-15.66	0.000	-1100.643	-855.8374
TempWeek19	-557.1887	62.82144	-8.87	0.000	-680.3192	-434.0582
TempWeek20	-532.7123	62.8573	-8.47	0.000	-655.9131	-409.5115
TempWeek21	-556.9927	60.24093	-9.25	0.000	-675.0654	-438.92
TempWeek22	-264.0771	59.41904	-4.44	0.000	-380.5389	-147.6154
TempWknd3	-432.872	97.5868	-4.44	0.000	-624.1429	-241.6011
TempWknd4	-730.7181	93.97658	-7.78	0.000	-914.9129	-546.5233
TempWknd5	-1050.134	92.88527	-11.31	0.000	-1232.19	-868.0786
TempWknd6	-1284.883	98.29802	-13.07	0.000	-1477.548	-1092.218
TempWknd7	-1542.682	99.77228	-15.46	0.000	-1738.237	-1347.128
TempWknd8	-1905.865	114.1743	-16.69	0.000	-2129.647	-1682.082
TempWknd9	-2164.473	102.9099	-21.03	0.000	-2366.177	-1962.769
TempWknd10	-2410.978	102.1171	-23.61	0.000	-2611.129	-2210.828
TempWknd11	-2467.166	96.33841	-25.61	0.000	-2655.99	-2278.342
TempWknd12	-2362.223	96.71954	-24.42	0.000	-2551.794	-2172.652
TempWknd13	-2243.219	104.6976	-21.43	0.000	-2448.427	-2038.011
TempWknd14	-2038.088	97.60935	-20.88	0.000	-2229.403	-1846.773
TempWknd15	-1870.572	94.06382	-19.89	0.000	-2054.938	-1686.206
TempWknd16	-1626.539	94.51179	-17.21	0.000	-1811.783	-1441.295
TempWknd17	-1255.413	87.2634	-14.39	0.000	-1426.449	-1084.376
TempWknd18	-641.4639	86.49539	-7.42	0.000	-810.9956	-471.9323
TempWknd19	-370.459	88.92544	-4.17	0.000	-544.7535	-196.1644
TempWknd20	-369.3073	87.90814	-4.20	0.000	-541.6079	-197.0066
TempWknd21	-514.4505	87.19178	-5.90	0.000	-685.347	-343.5539
TempWknd22	-318.0173	89.58839	-3.55	0.000	-493.6112	-142.4234
_cons	93707.76	9881.074	9.48	0.000	74340.78	113074.7

Time of Day and Day of Week Matters

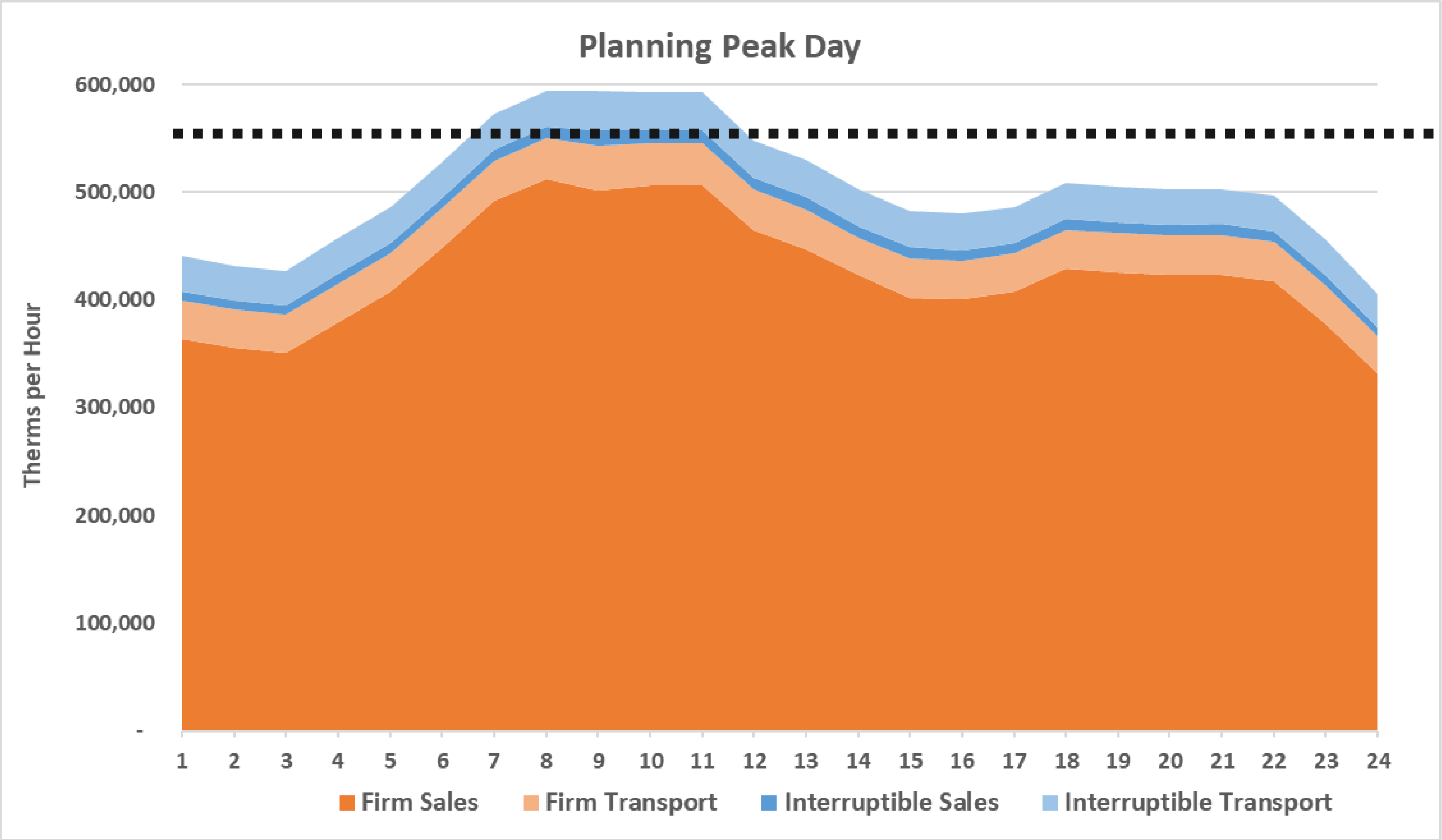


Weather Most Important Driver



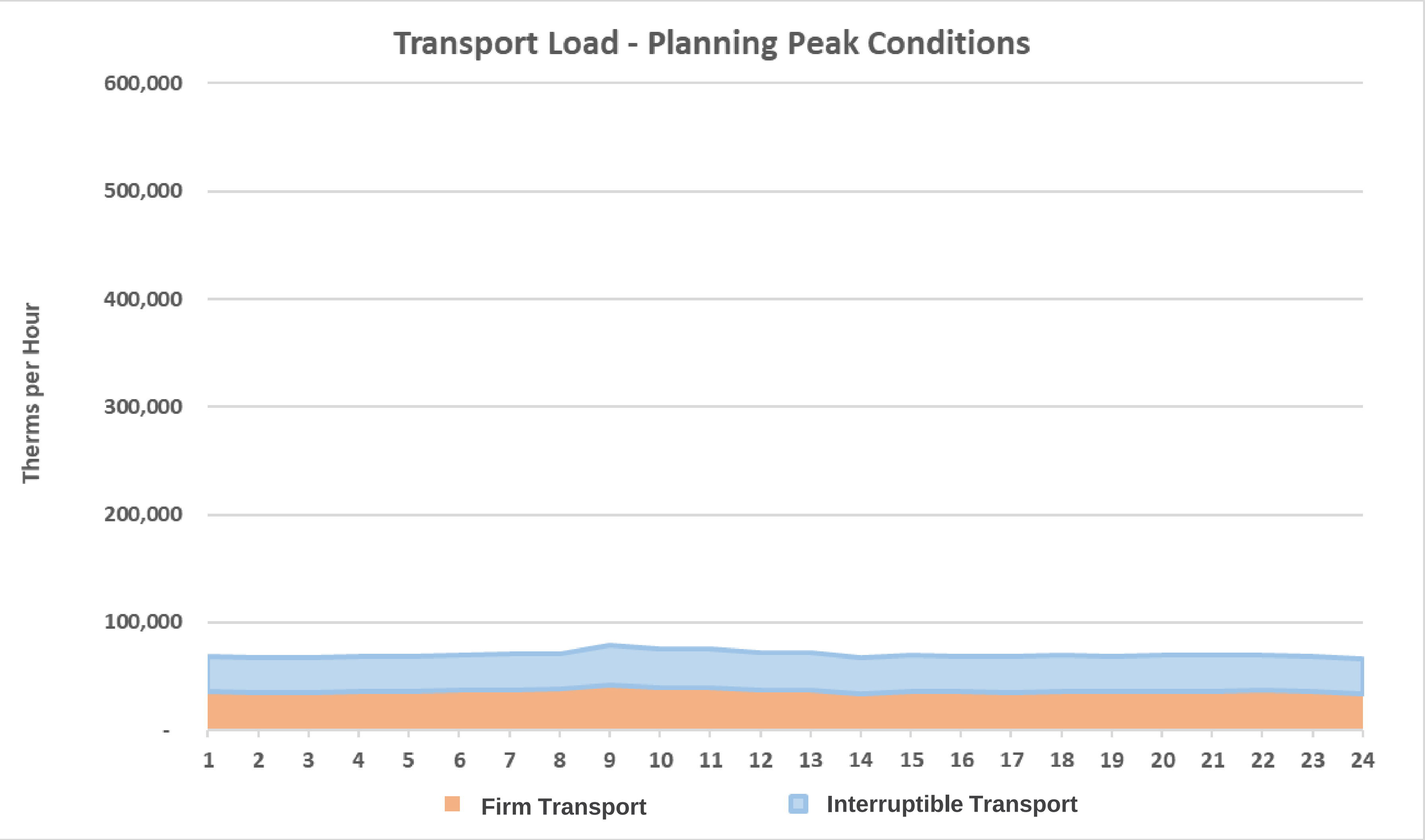
- NW Natural load is highest during the morning rush hour time frame, with the peak hour typically being the 7 a.m. hour
- Load is much greater in winter months than in summer
- Peak loads during cold events are far greater than even normal winter day loads
- Peak loads are driven by space heating needs
- Expected energy efficiency is accounted for in load forecasts

System-Wide Peak Deliveries



System designed to be able to meet load in the highest hour of the peak day

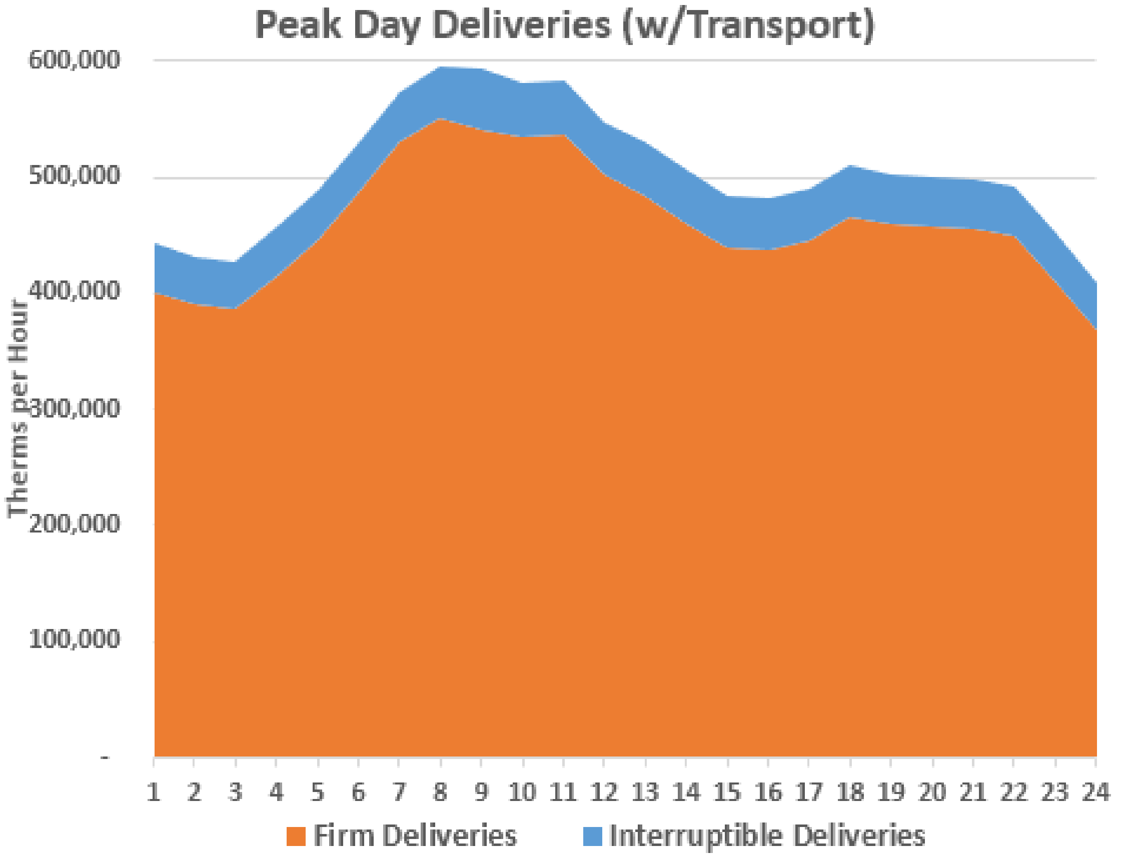
Transport Schedule Load and Distribution System Planning

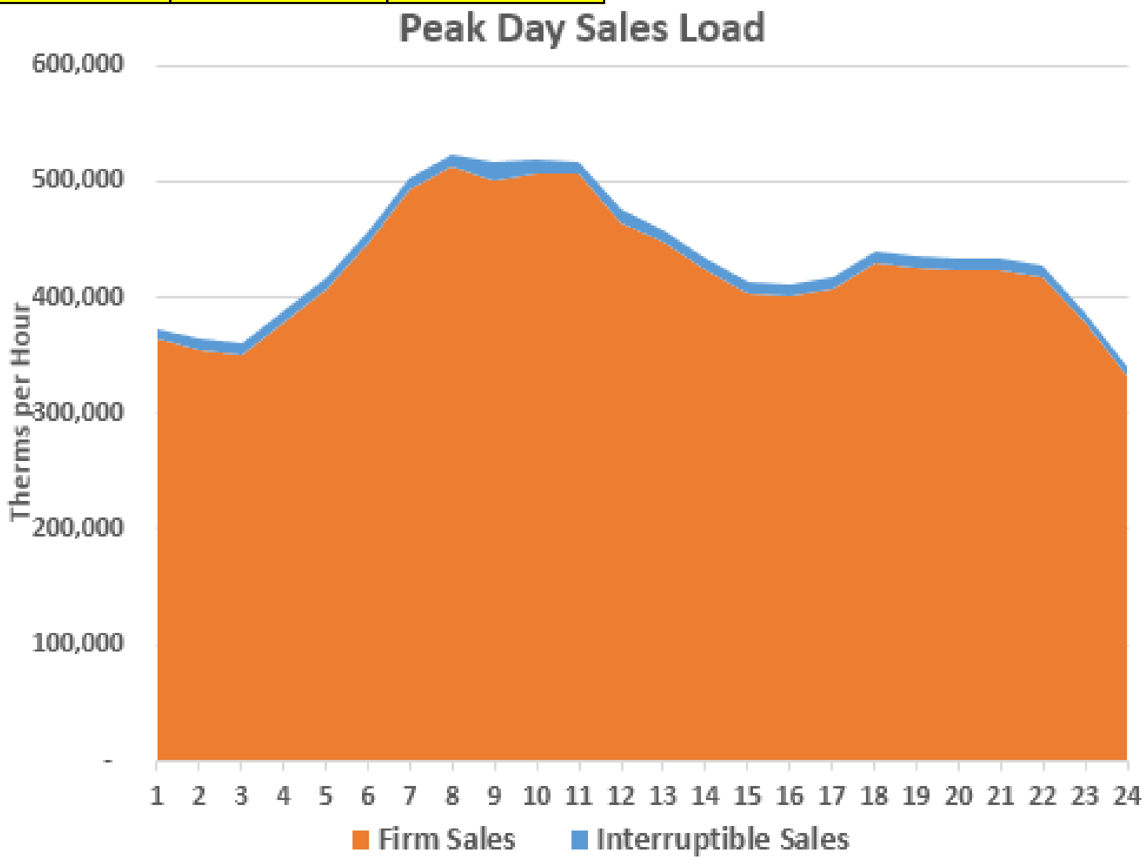


- Transportation schedule load represents roughly 1/3 of deliveries in a **year**
- The majority of transport load is interruptible
- Under **peak conditions** firm transport load represents less than 10% of load
- Roughly half of would-be peak transport load is part of existing demand response programs and would be interrupted during a peak even

Impact of Demand Response

Current NW Natural Demand Response via Interruptible Schedules				
		1-in-2 Peak	1-in-10 Peak	1-in-30 Peak
Interruptible Share of Throughput	Peak Hour	10.7%	9.9%	8.8%
	Peak Day	11.3%	10.4%	8.7%
Interruptible Share of Sales	Peak Hour	3.4%	3.4%	2.9%
	Peak Day	3.1%	2.9%	2.4%



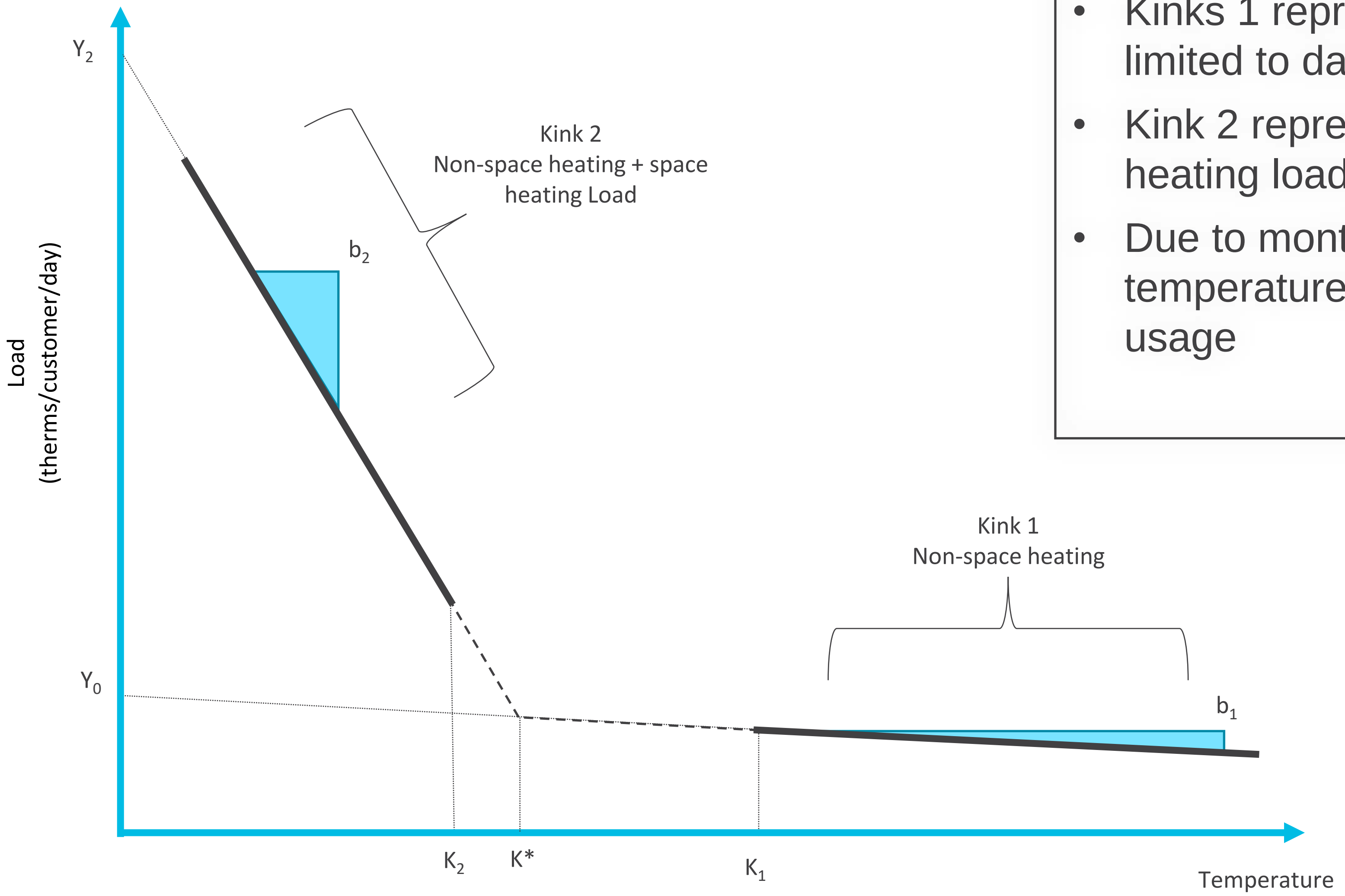


System Peak Hour Load Forecast

Hour	2022	2025	2030
0	391,391	410,317	444,465
1	382,366	401,134	434,957
2	379,906	398,639	432,386
3	408,303	427,658	462,637
4	437,995	457,968	494,179
5	478,443	499,238	537,098
6	520,956	542,632	582,250
7	543,943	566,084	606,632
8	541,257	563,219	603,417
9	537,270	559,258	599,504
10	538,398	560,407	600,690
11	510,791	532,162	571,201
12	491,748	512,671	550,835
13	465,735	486,055	523,040
14	442,758	462,582	498,587
15	437,712	457,426	493,215
16	441,297	461,098	497,059
17	452,346	472,450	508,987
18	445,701	465,735	502,106
19	443,844	463,824	500,089
20	442,033	462,002	498,237
21	439,120	459,061	495,223
22	404,479	423,735	458,519
23	365,812	384,245	417,400
Total	**10,943,605**	**11,429,600**	**12,312,714**

- Reminder: Peak hour load is growing much faster than annual loads, which are more or less flat in Oregon
- Bottom-up customer specific peak load forecasts used in system modeling are calibrated to align with system peak hour load forecasts (i.e. top down is the “truth” everything is calibrated to) and to develop peak loads in a given area on the distribution system

Customer Specific Peak Estimate from Billing Data



- Kinks 1 represents non-space heating load and is limited to data with temperatures above K_1
- Kink 2 represents space heating plus non-space heating load and is limited to temperatures below K_2
- Due to monthly averaging including bills with temperatures between K_1 and K_2 will over-estimate usage

Distribution System Planning – System Modeling

Our System

Quick Stats

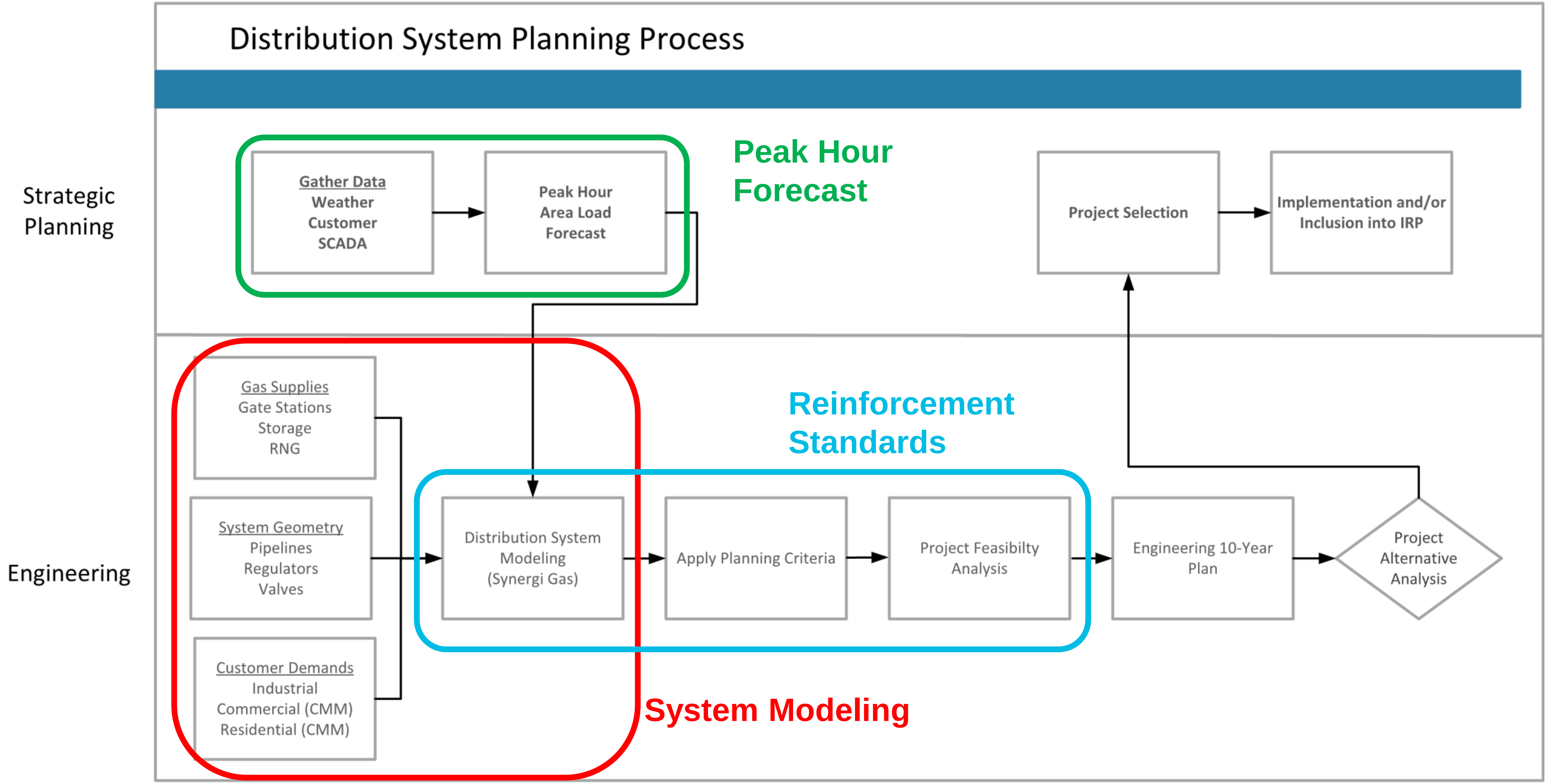
- Approximately 14,600 miles of transmission and distribution pipelines
- 54 gate stations and farm taps from NWPL
- 2 RNG injection sites
- 2 LNG facilities
- Mist Underground Storage
- Approximately 1,030 district regulators
- Approximately 780,000 customers in Oregon and Washington

Objectives of Distribution System Planning

NW Natural®

- ✓ Operate a distribution system capable of meeting firm service customer peak hour requirements
- ✓ Address distribution system needs related to localized customer demand or growth
- ✓ Minimize system reinforcement costs by selecting the most cost effective alternative and implementing at the best time

Distribution System Planning Process



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

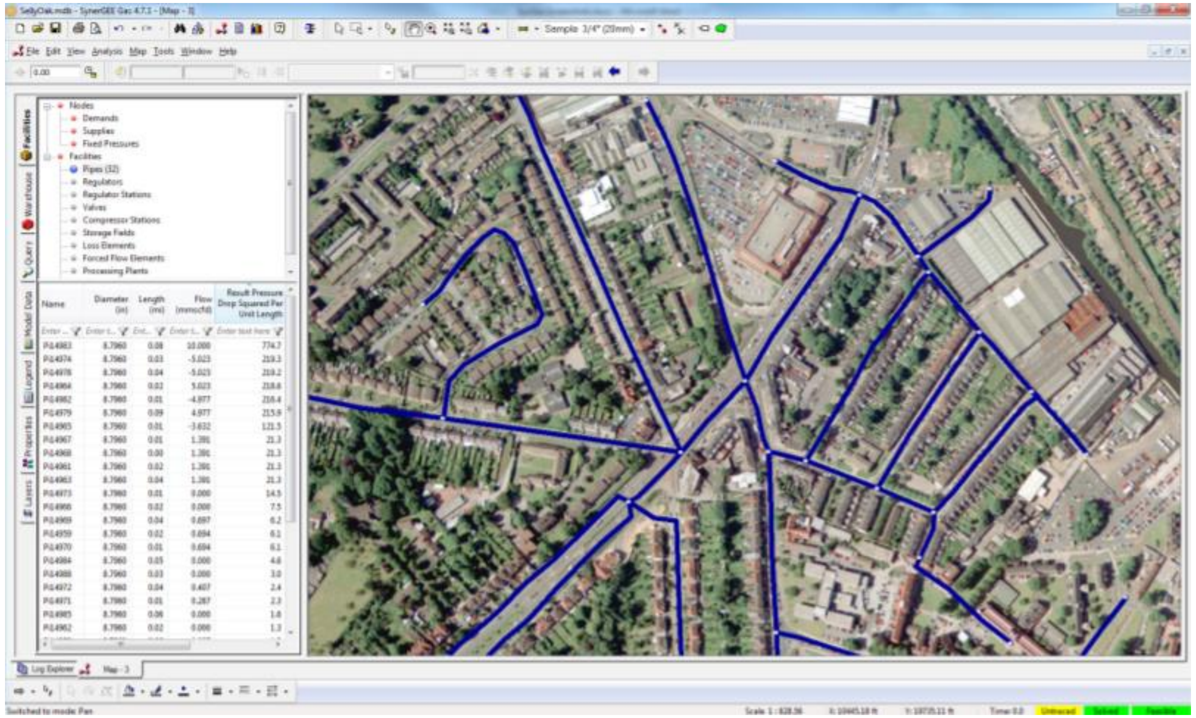
Distribution System Planning Tools

They all work together …

- System Modeling allows system planners to effectively visualize the system and identify system issues
- Distribution System Load Forecasts allow system planners to develop a model for a peak hour customer demand
- System Reinforcement Standards allow system planners to consistently apply criteria to identify a condition in the model or the real world as an issue that must be addressed

System Modeling

SYNERGI® GAS



Network Modeling and Analysis

- SYNERGI® GAS models and analyzes closed conduit networks of pipes, regulators, valves, compressors, storage fields and production wells.
- SYNERGI® GAS is in wide use across the gas distribution and transmission industry.
- SYNERGI® GAS is a product of DNV, formerly GL-Noble Denton, formerly Stoner Associates

System Modeling

Supply	Pipeline Network	Demand

Supply

- Gate Station Supplies (SCADA)
- Storage Facility Supplies (SCADA)
- Pressure Data (SCADA)

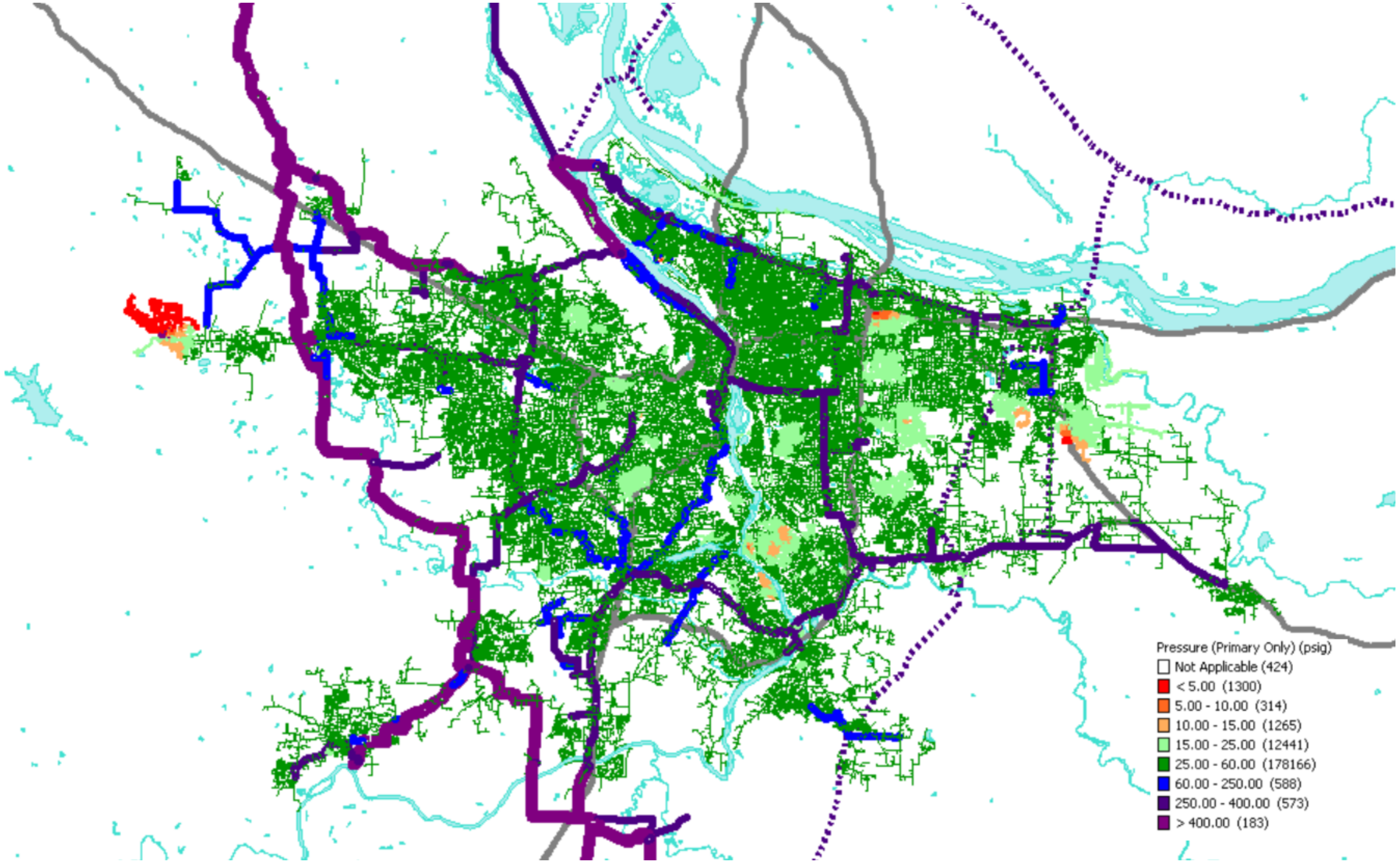
Pipeline Network

- Pipe Network Topology and Pipe Attributes (GIS)
- Customer Location (GIS)
- Field As-Built information
- Operating Parameters – Regulator Setpoints, Valve Status, etc.
- Cold Weather Pressure Survey
- **Electronic Portable Pressure Recorders (EPPR)**

Demand

- Largest Customer Demands (SCADA)
- Large Customer Demands (Industrial Billing)
- Residential and Commercial Demands (Billing Data)

System Modeling



- Gas Networks are very complex and computer tools are required to properly understand and model them

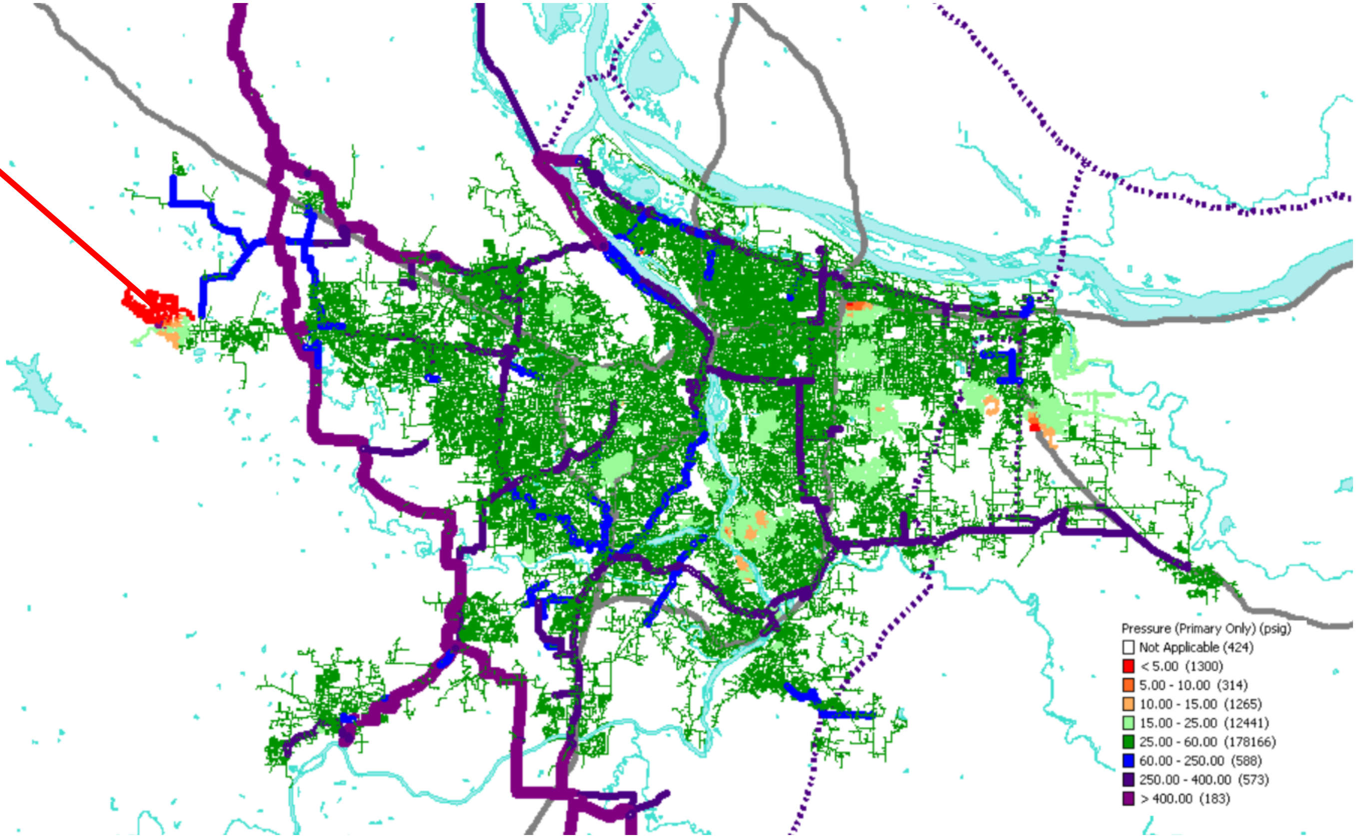
System Modeling

Interpreting system model results has two distinctly different methods:

1. Low Pressure Distribution Systems (less than 60 pounds per square inch gauge, or psig)–easy to interpret the health of the system via pressure colors
    - Green is good
    - Red is bad
2. High Pressure Distribution Systems (more than 60 psig)–the health of these systems depend on pressure drop criteria or their ability to serve the downstream system
    - More difficult to represent visually as a color gradient

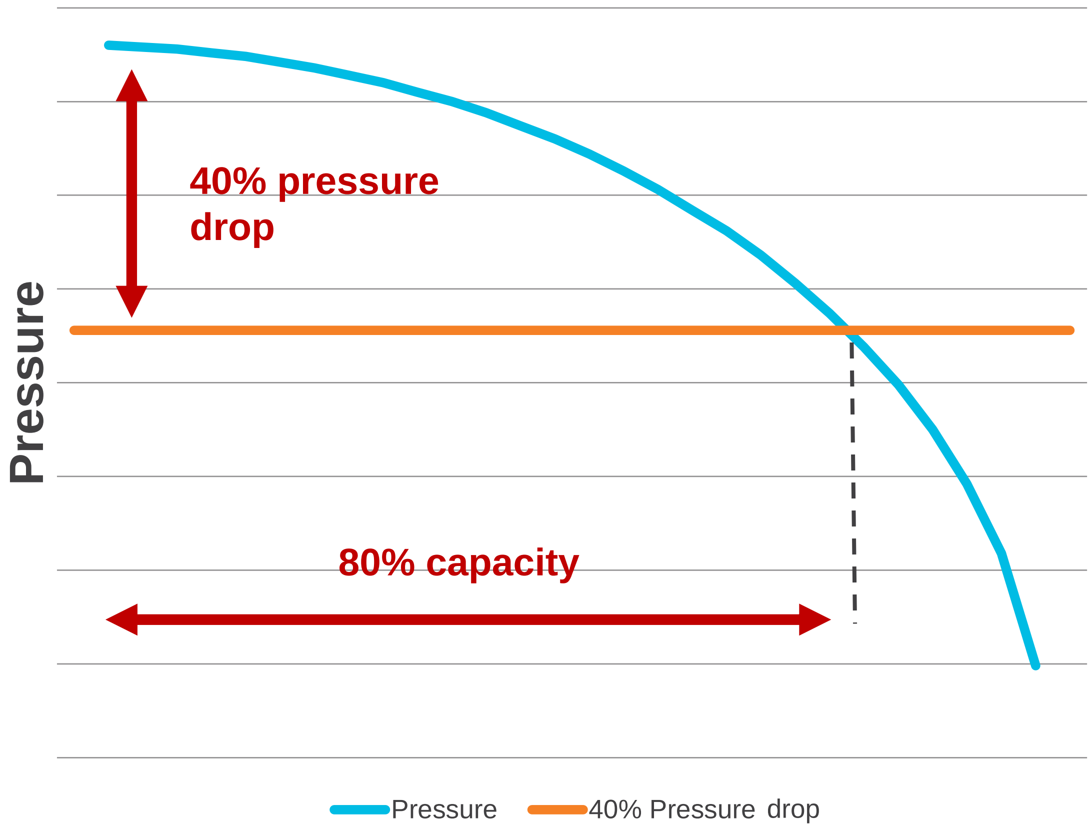
System Modeling

Low Pressures in Forest Grove



Areas of weakness in systems with less than 60 psig are easy to see:
Green is good … Red is bad

System Modeling



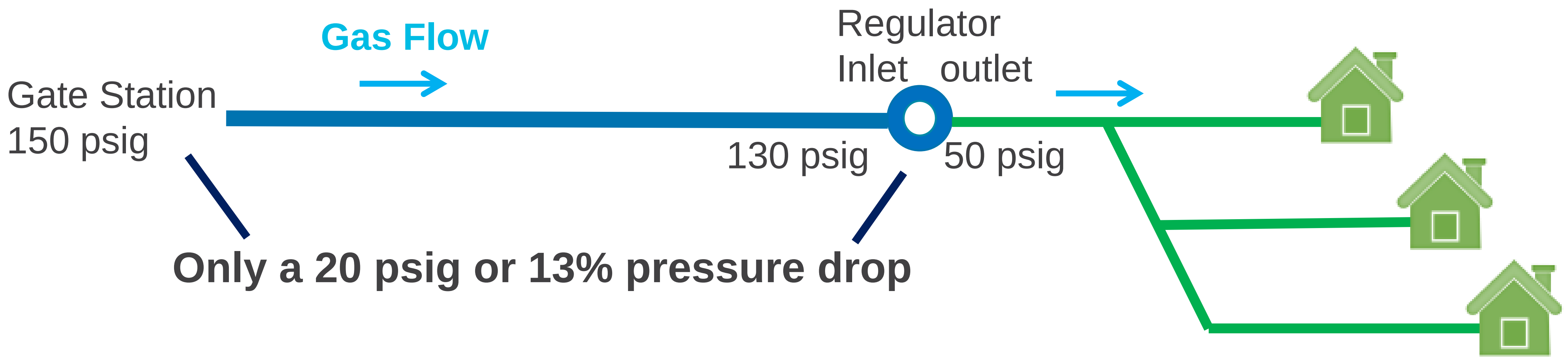
When a gas pipeline is experiencing a 40% pressure drop it is flowing at 80% of maximum capacity

The relationship between pressure and available capacity is non-linear

In other words, small increases in demand from weather or growth can cause outages when pipelines operate above 80% capacity and pipeline pressure falls rapidly

System Modeling

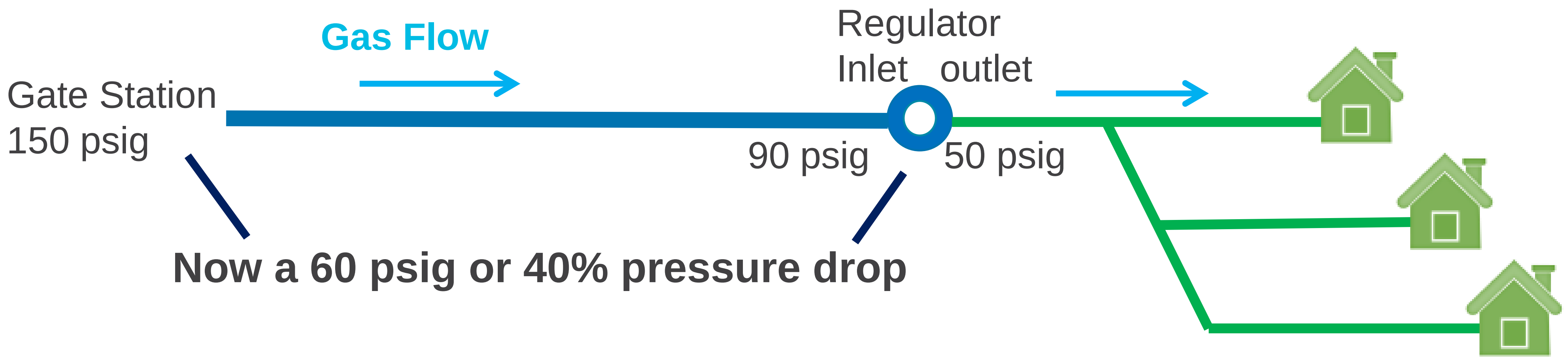
High Pressure Distribution Systems (more than 60 psig)-



Regulators require adequate inlet pressure to operate properly and deliver gas to downstream customers. This is typically 25 psig higher than the outlet pressure.

System Modeling

High Pressure Distribution Systems (more than 60 psig)

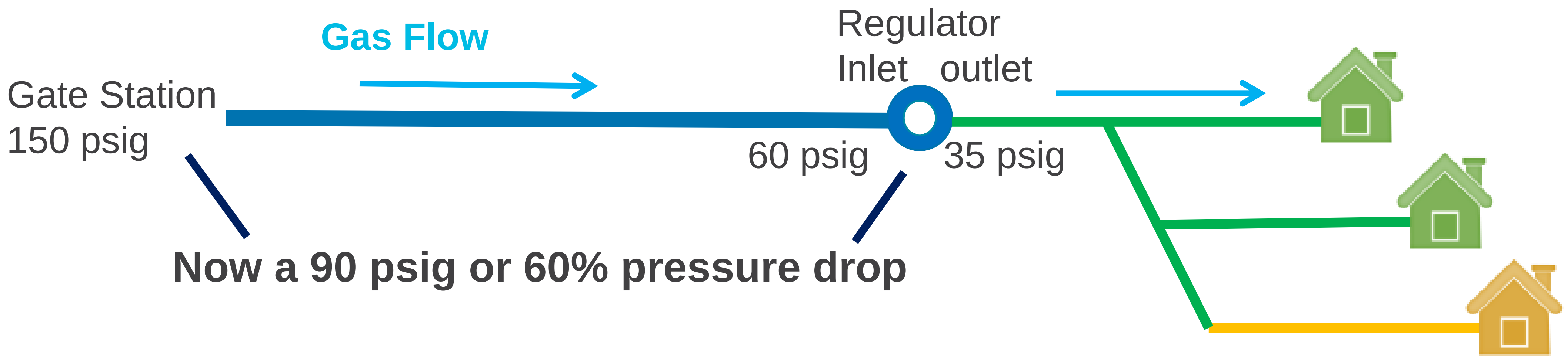


Demand increases about 35%

The regulator still functions adequately, as it has 90 psig inlet pressure versus 50 psig outlet. But the upstream pipeline is seeing a 40% pressure drop.

System Modeling

High Pressure Distribution Systems (more than 60 psig)

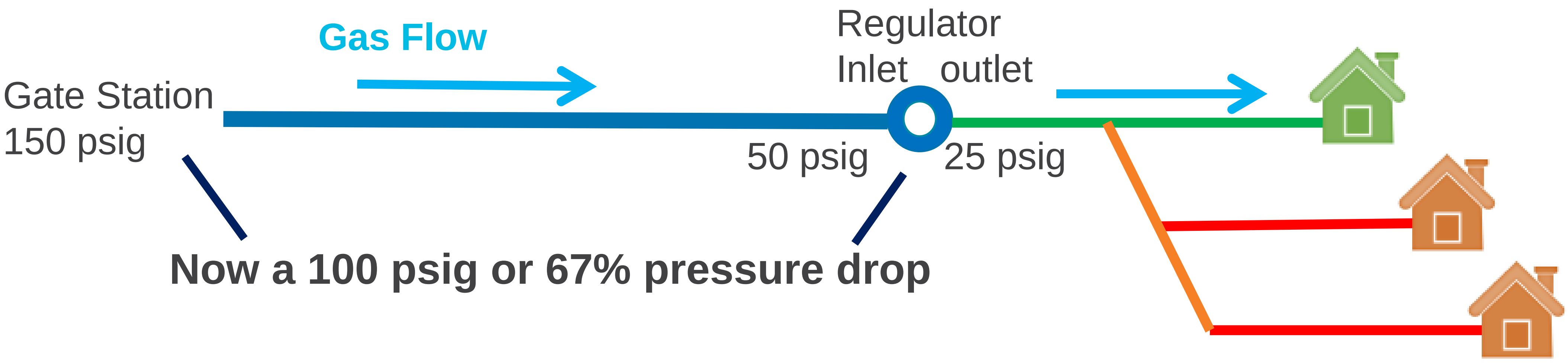


The regulator is being starved by low inlet pressure and is delivering lower pressure to customers.

Demand increases an additional 10%

System Modeling

High Pressure Distribution Systems (more than 60 psig)

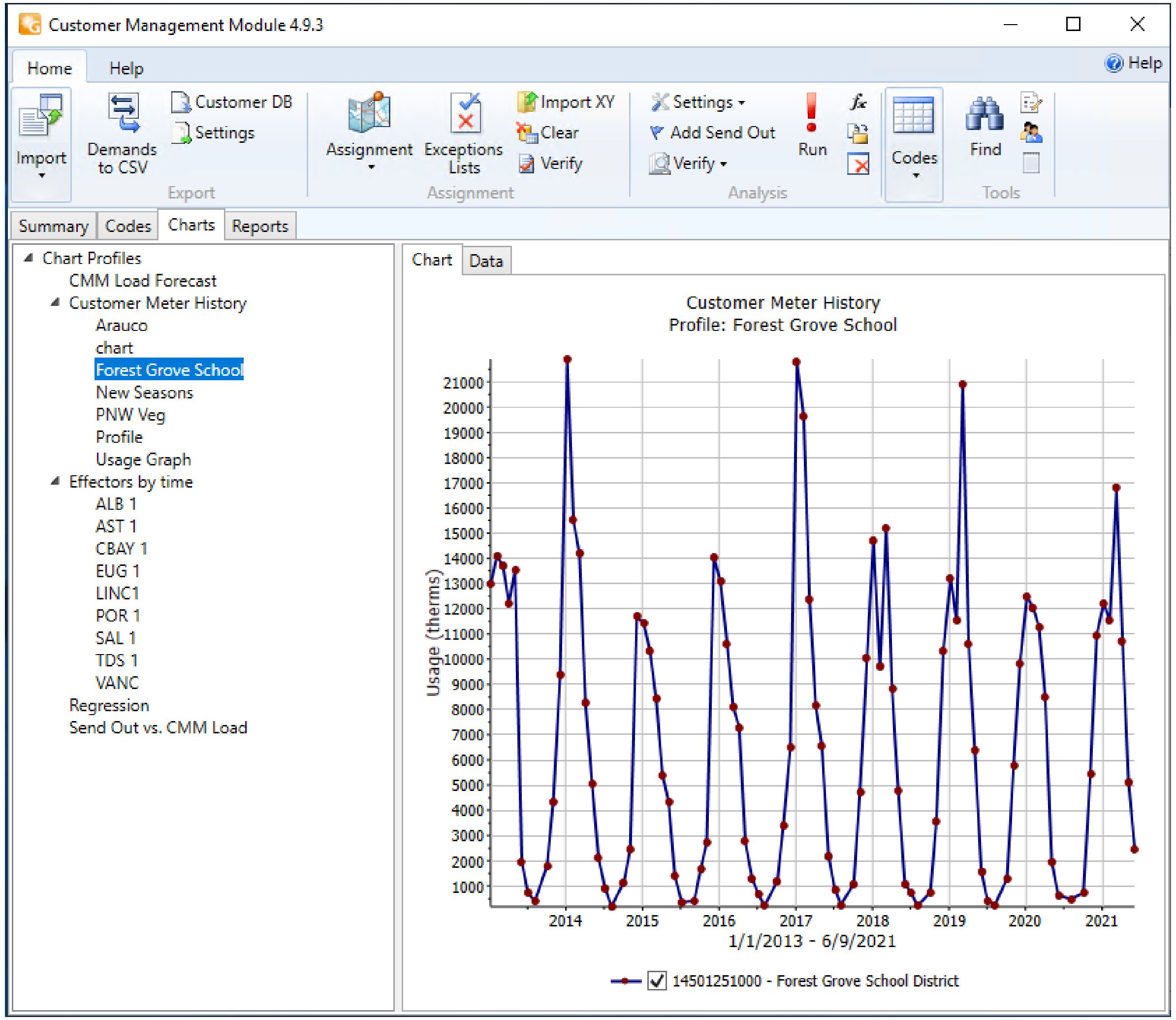


The regulator is being starved by low inlet pressure and is delivering lower pressure to customers. **Customer outages occur**.

Demand only increases an additional 4%

Improvements to the System Modeling

- Customer Management Module (CMM) Project Completed in 2021
- Software developed by DNV
  - Same company as Synergi modeling software
- Creates a connection between
  - CIS - customer usage
  - GIS - customer location
  - Synergi Gas Models



Improvements to the System Modeling

NW Natural®

Customer Management Module (CMM) - a new software module that links the Synergi system modeling software to our CIS and GIS systems

- Connection between GIS, CIS and Synergi Gas provides automation benefits
  - Customer information updates
    - Demand Changes, New Customers, Customer Disconnections, Rate Schedule Changes
  - Demands can be automatically geographically assigned to facilities on Synergi Models
    - Prior technique was a manual process
- CMM provides individual demands based on their own customer specific historical usage
  - Residential and Commercial customers are based on historical weather and billing data
    - Previous method used average residential and commercial estimates for a defined region

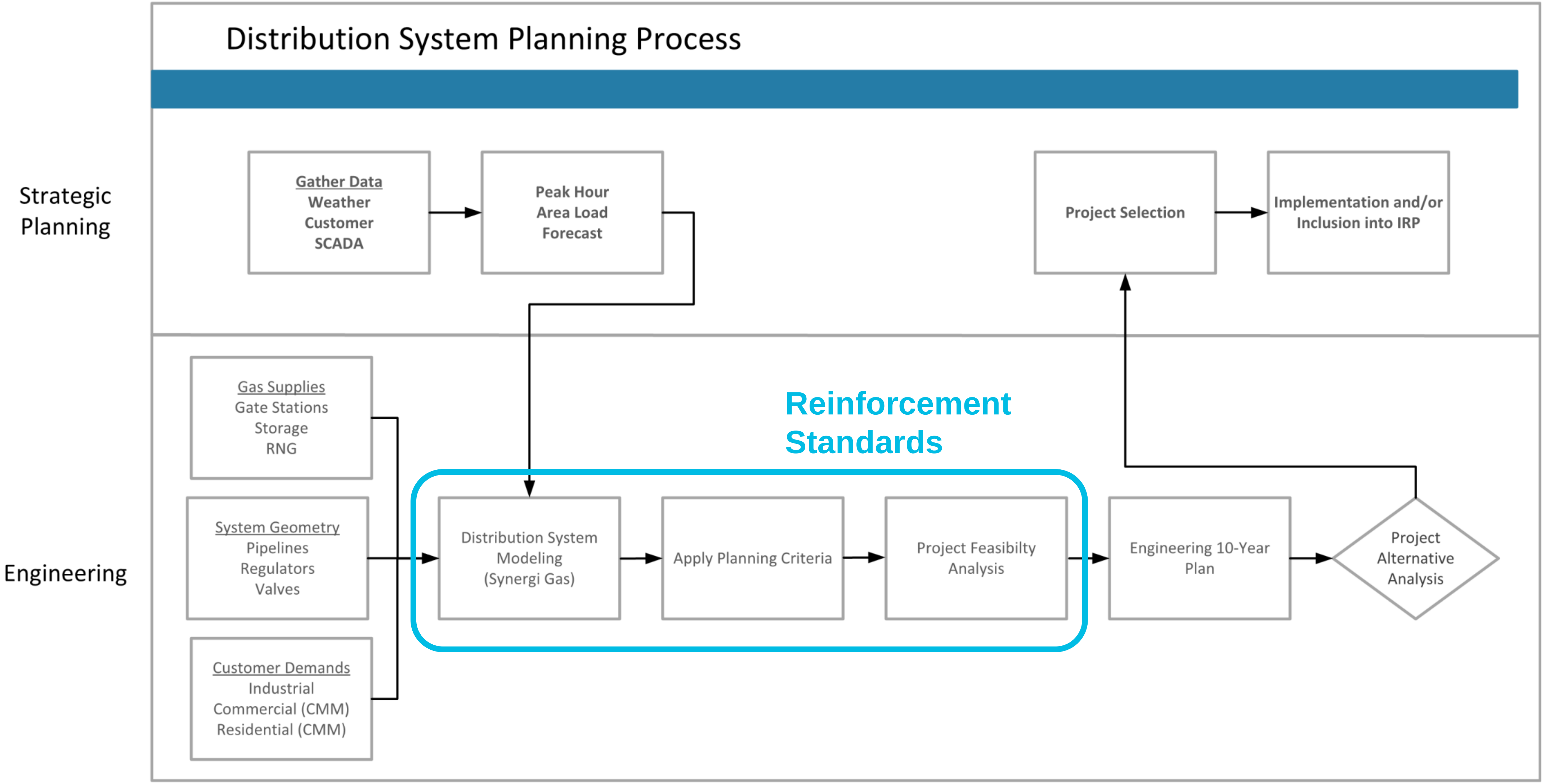
Improvements to the System Modeling

Customer Management Module (CMM) - a new software module that links the Synergi system modeling software to our CIS and GIS systems

- New Synergi Models are being created with CMM data integration
  - All models will be updated to CMM demands in 2023
    - Synergi Models with CMM data were prioritized based near-term need
  - We will continue to refine the process
- Implications of this improvement in system modeling
  - We may find some areas in our system that are of more concern than previously thought
  - Or vice versa, projects that were being considered in the near-term may show that they are not as urgent

Distribution System Planning – Reinforcement Standards

Distribution System Planning Process



System Reinforcement Standards

System Reinforcement Standards are criteria that indicate conditions representing trigger points which identify systems under stress and in need of attention to reliably serve firm customers.

1. Transmission and high-pressure distribution systems criteria
2. Standard pressure distribution systems criteria (Class B)

Typical conditions are:

- A pipeline nearing peak capacity
- Inadequate pressures to properly operate equipment including
  - Regulators–service to customers
  - Excess flow valves–safety
  - Customer equipment–service to customers

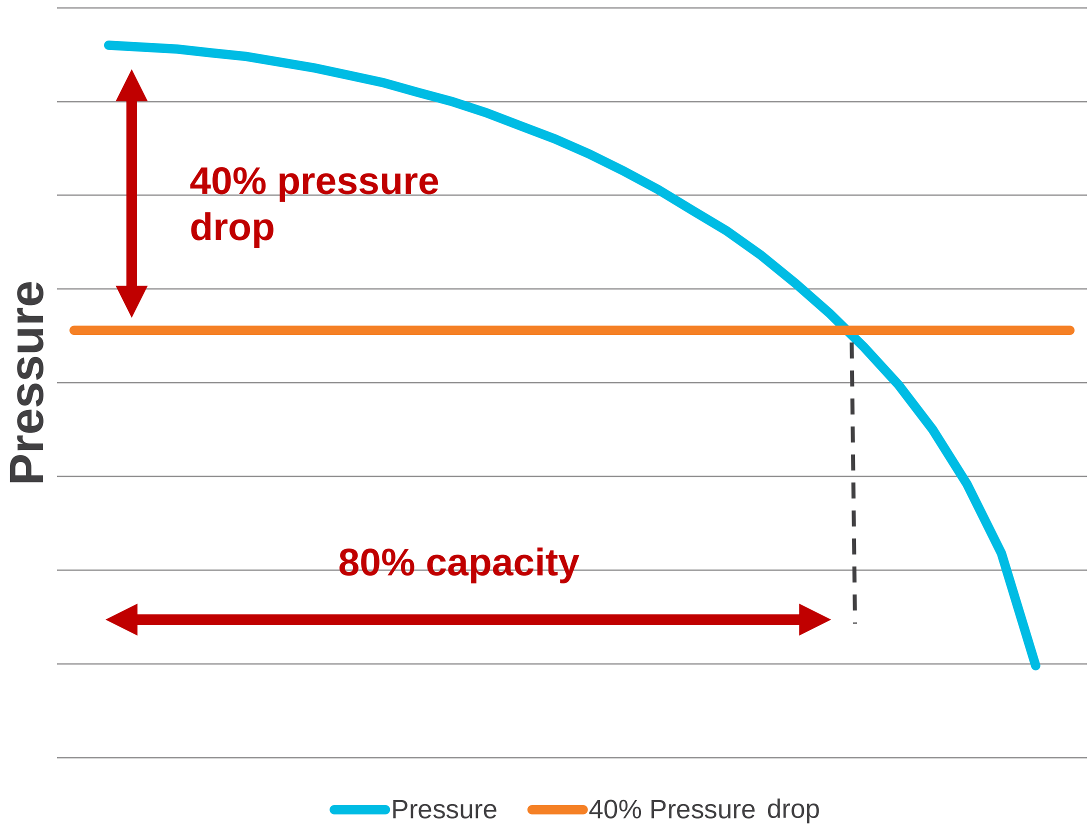
System Reinforcement Standards

NW Natural®

Transmission and high pressure distribution systems criteria with design parameters set to peak hour load requirements

- Experience at least a 30% pressure drop over the facility length indicates an investigation will be initiated
- Experience or model a 40% pressure drop indicates reinforcing the facility is critical (40% Pressure Drop = 80% pipeline capacity utilization)
- For pipelines that feed other high pressure systems, consider minimum inlet pressure requirements for proper regulator function in addition to total pressure drop
- Near term growth identified by one or more leading indicators (e.g. new road construction, subdivision or planned industrial development). This may require reinforcing a system that has satisfactory performance prior to the growth occurring
- Firm service customer delivery requirements (flow or pressure)
- Associated with supply requirements identified in the IRP

System Modeling



When a gas pipeline is experiencing a 40% pressure drop it is flowing at 80% of maximum capacity

The relationship between pressure and available capacity is non-linear

In other words, small increases in demand from weather or growth can cause outages when pipelines operate above 80% capacity and pipeline pressure falls rapidly

System Reinforcement Standards

Standard pressure distribution systems criteria with design parameters set to peak hour load requirements

- Experience a minimum distribution pressure of 15 pounds per square inch gauge (psig) indicates an investigation will be initiated
- Experience or model a minimum distribution pressure of 10 psig indicates that reinforcement is critical
- Near term growth identified by one or more leading indicators (e.g., new road construction, subdivision or planned industrial development). This may require reinforcing a system that has satisfactory performance prior to the growth occurring
- Firm service customer delivery requirements (flow or pressure)

System Reinforcement Standards

Why are System Reinforcement Standards important?

- System planners can identify and prioritize system issues with adequate time to implement solutions in a cost-effective manner
- Standards provide a consistent framework to evaluate and plan projects
- Customer service is improved by relying on planning and ***not failures*** to identify needed system improvements

Distribution System Planning – Alternatives Analysis

Distribution System Planning Resource Options

NW Natural®

Distribution System Planning Alternatives (not all options are possible or applicable in all situations)				Option Currently Considered for Cost-Effectiveness Evaluation
Supply-Side Alternatives		Pipeline Related Capacity Options	Loop existing pipeline	✓
			Replace existing pipeline	✓
			Install pipeline from different source location into area	✓
			Uprate existing pipeline infrastructure	✓
			Add or upgrade regulator to serve area of weakness	✓
			Gate station upgrades	✓
			Add compression to increase capacity of existing pipelines	✓
	Non-Pipeline Solutions	Distributed Energy Resources (DER)	Mobile/fixed geographically targeted CNG storage	✓
			Mobile/fixed geographically targeted LNG storage	✓
			On-system gas supply (e.g. renewable natural gas, H2)	✓
			Geographically targeted underground storage	✓
Demand-Side Alternatives		Demand Response	Interruptible schedules (DR by rate design)	✓
			Geographically targeted interruptibility agreements	✓
			Geographically targeted Res & Com demand response (GeoDR)	
		Energy Efficiency	Peak hour savings from normal statewide EE programs	✓
			Geographically targeted peak-focused energy efficiency (GeoTEE)	

Feasibility, cost-effectiveness, and equity related policy issues of geographically-targeted residential and commercial demand-side alternatives currently being assessed as part of GeoTEE pilot

Alternatives Analysis Process

1. Determine the amount of load that would need to saved or served on a peak hour to delay or avoid traditional system reinforcement project

2. Determine most cost-effective traditional system reinforcement option

3. Determine if there is sufficient peak hour load from large customers that could be interrupted to bring system back within system reinforcement design criteria
    - If yes, pursue contacting customers with cost-effective interruptible option, if no, consider in conjunction with options below

4. Determine feasible set of geographically-targeted demand-side and alternative supply-side options, including cost, impact, and timing
    - This is where there is currently a gap for some resource options as good cost, impact, and timing estimates are not possible to obtain
        - There are also outstanding policy considerations around equity and cost allocation

5. Choose least cost/risk resource to meet distribution system need based upon relative Present Value of Revenue Requirements (PVRR) for the entire resource portfolio

GeoTEE Pilot Objectives as Filed with Pilot Plan

NW Natural®

<u>Primary Objective</u>

1. Develop the data and ability needed to construct a peak hour energy efficiency supply curve for any given geographic area so that it can be compared for cost-effectiveness against other distribution system capacity options

<u>Secondary Objectives</u>

2. Determine whether GeoTEE represents a socially desirable tool to serve LDC customers if it shows the potential to be a cost-effective capacity resource

3. Explore and discuss with key stakeholders the appropriate funding mechanism for future GeoTEE projects should they show as a potentially cost-effective way to address distribution system weaknesses

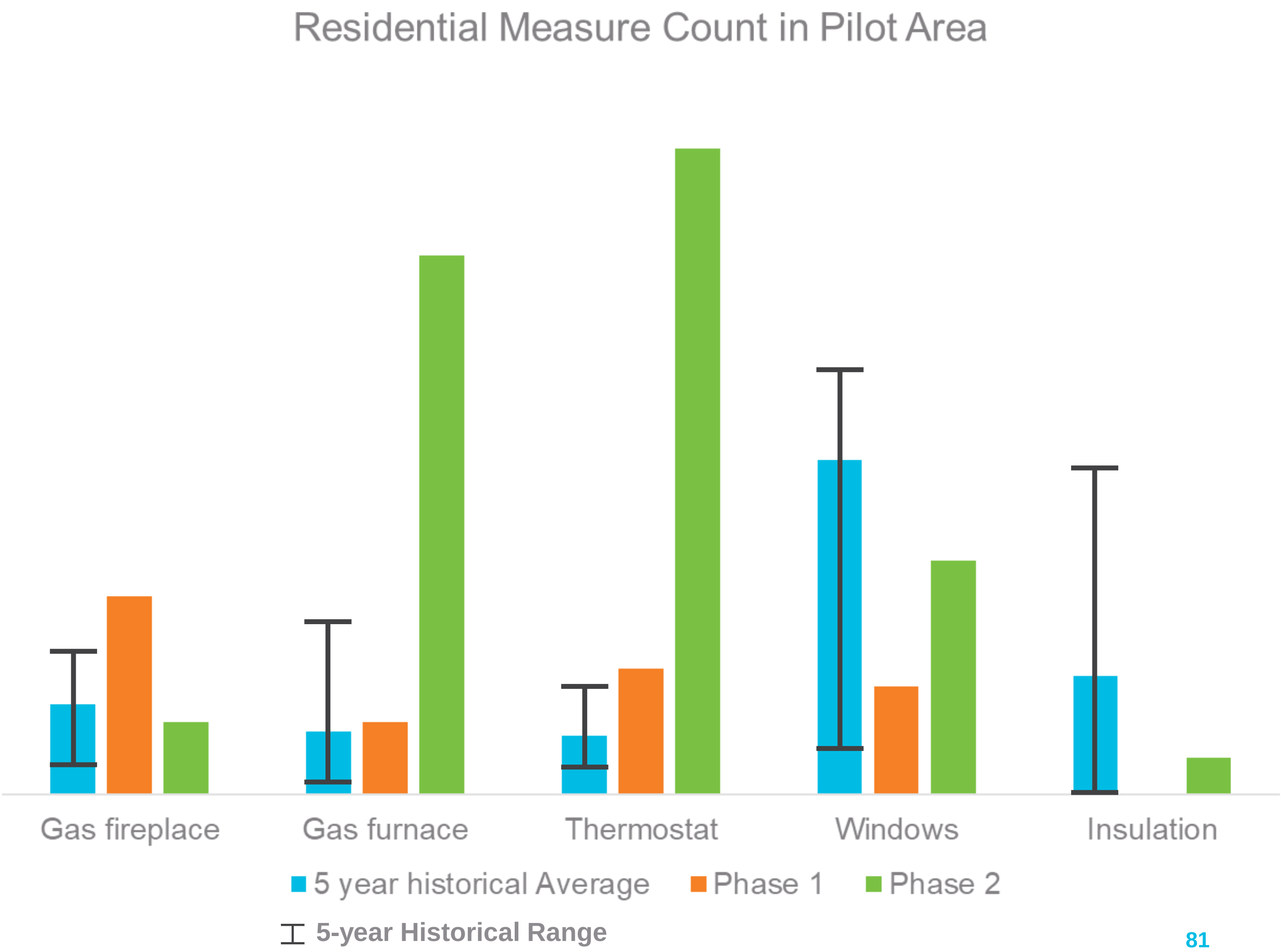
GeoTEE Pilot Timeline

- Here is the expected timeline for the pilot from when we filed the pilot plan
- We are currently in Phase 3 of the pilot which will be ending later this year
- We will be able to report on the measures installed for all 3 phases by the end of the year
- Evaluating peak hour savings will still require analyzing customer usage during cold weather
    - In other words, we won't have data for late phase 3 participants, until after next year's heating season

Update on GeoTEE Pilot

Residential

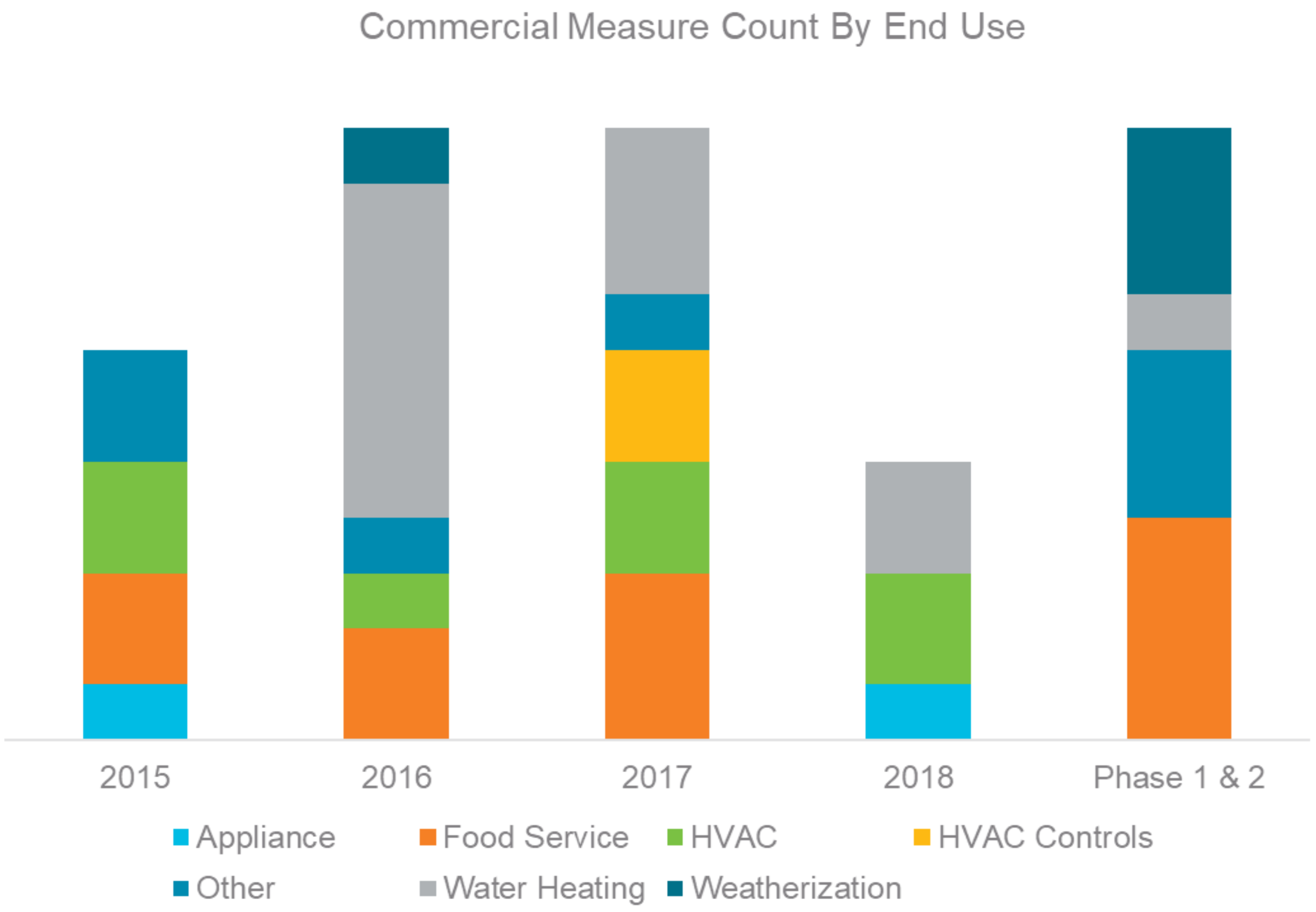
- There has been clear residential uptake of furnace and thermostat measures due to increased incentives
- Still unclear results for fireplaces, insulation, and windows



Update on GeoTEE Pilot

Commercial

- Commercial customers are more unique and projects are more lumpy year over year for any single type of measure, especially in a small pilot area
- The amount of peak therms saved is very dependent on the type of commercial customers in the area, but measure that impact space heating (i.e., HVAC and Weatherization) will have the biggest impact on peak

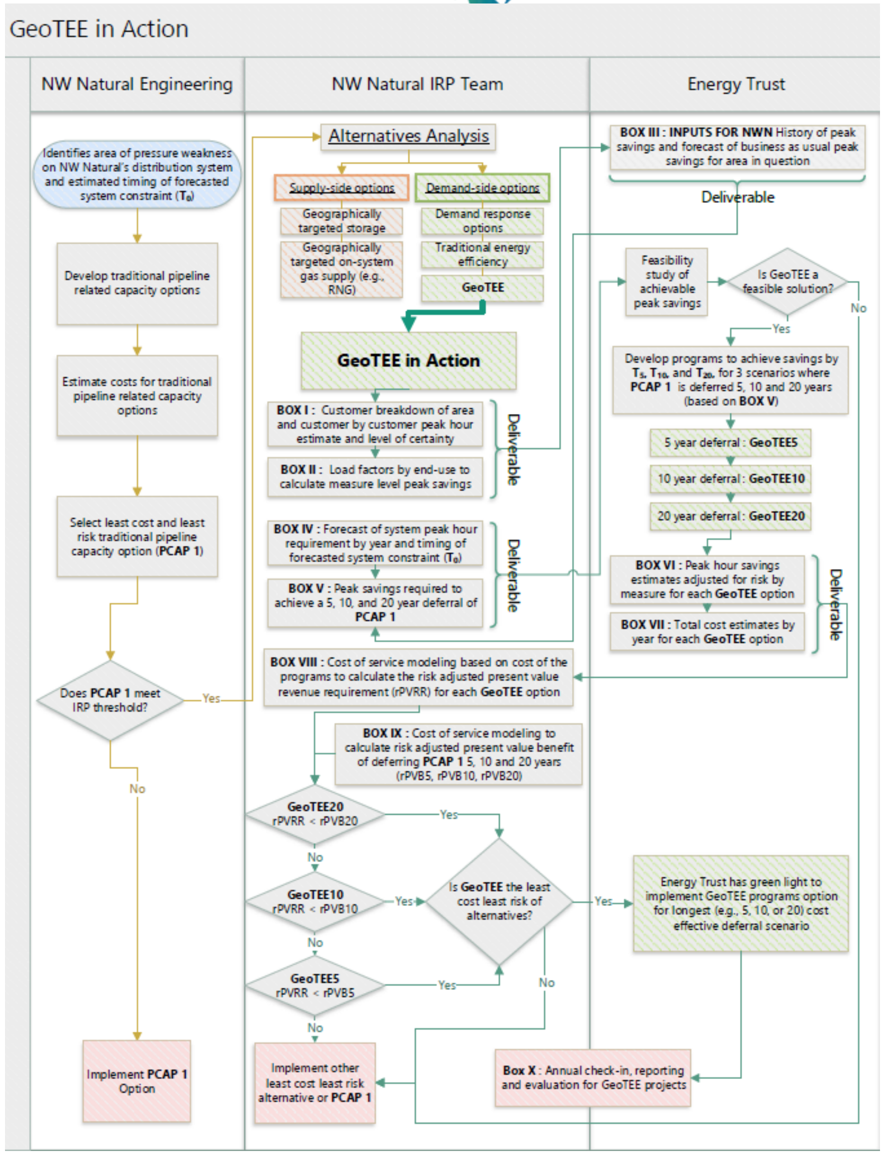


Note: Water heating counts in graph excludes aerator measure counts

Evaluating GeoTEE as a DSP Option

- In order to do a robust alternatives analysis comparing GeoTEE to other distribution system options, we need to have confidence in the costs, quantity and timing of achievable peak savings
- The results of the pilot will give us a good idea about the costs and quantity of measure uptake
- Evaluating the peak hour savings of customers in the pilot area will help establish the reliability of achievable peak saving for specific measures
- GeoTEE in Action will require high coordination between Energy Trust and NW Natural and will be implemented for significant distribution constraints and evaluated in future IRPs

NW Natural®



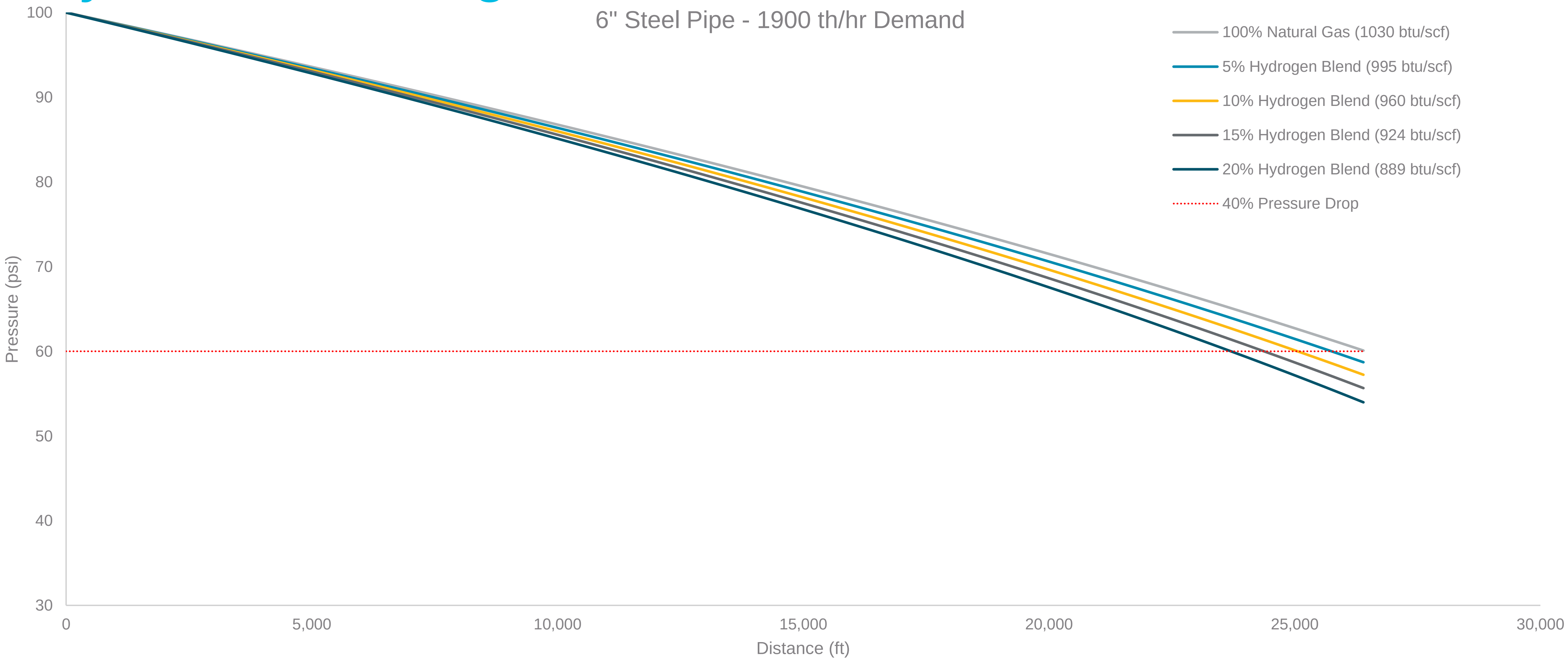
Draft Process Diagram of GeoTEE in Action

The Future of Hydrogen and Distribution System Planning

Hydrogen blending is a carbon reduction methodology and is not a feasible system reinforcement alternative

- The BTU value of Hydrogen is Lower than Natural Gas
  - Hydrogen: 325 btu/scf
  - Natural Gas: 985 btu/scf – 1155 btu/scf (OR Tariff)
- The blending of Hydrogen with Natural Gas is done on a volumetric basis (i.e. 5%, 10%, etc.)
- Therefore, blending Hydrogen with Natural Gas reduces the overall btu Value of the gas delivered to customers
  - Lower btu value gas requires higher volumes of gas to deliver the equivalent energy of non blended higher btu value gas
- Higher volumes of blended gas by customer demands results in lower pipeline pressures
- A strategically placed electrolyzer alone could not help by injecting hydrogen, due to blending concerns

The Future of Hydrogen and Distribution System Planning



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

Other options

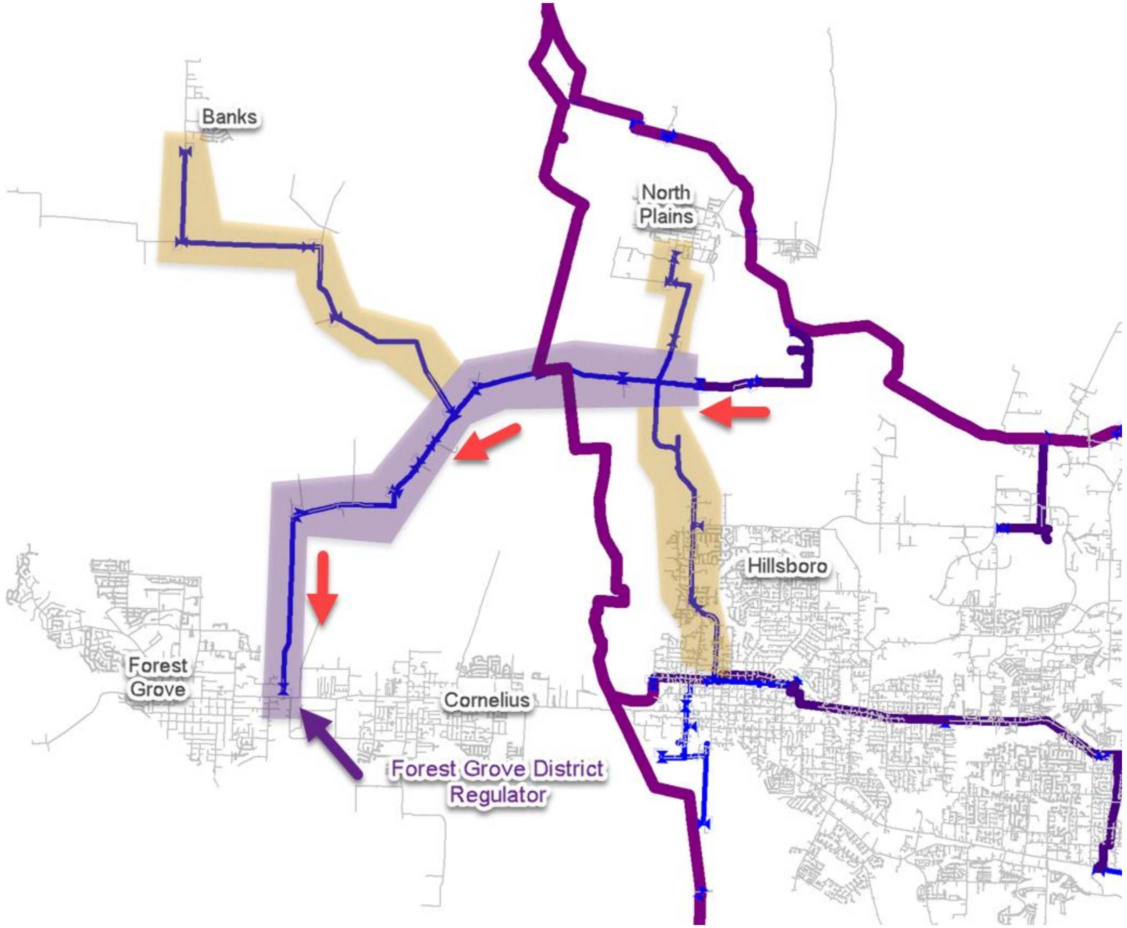
- Geographically-targeted RNG or Synthetic Methane
  - Given that these gas supply resources are 1-for-1 replacements with conventional gas, additional supply in an area that is expected to violate a system reinforcement criteria can be viable options for alleviating distribution system weaknesses
- Geographically-targeted Demand Response for Residential and Commercial Customers
  - Pending results of policy considerations in GeoTEE process GeoDR will be considered going forward
- Satellite CNG or LNG
  - We currently evaluate these options for every distribution system project evaluated in IRPs
  - They have not shown as near cost-effective in any evaluation so far, but we will continue to evaluate these options moving forward

Forest Grove Feeder

Overview of Project Development Process

- Model system based on forecasted demands, recorded pressures, and equipment settings
- Verify equipment settings and functionality
- Monitor pressures in system and record results
- Develop and model System Reinforcement solution
- Develop cost estimate for proposed Project
- Consider alternatives to System Reinforcement Project

Forest Grove Feeder



- 6.3 miles of 175 MAOP HP main.
- Two district regulators supply the Forest Grove Feeder.
- Serves customers in Forest Grove, Banks, Cornelius, North Plains and Hillsboro.

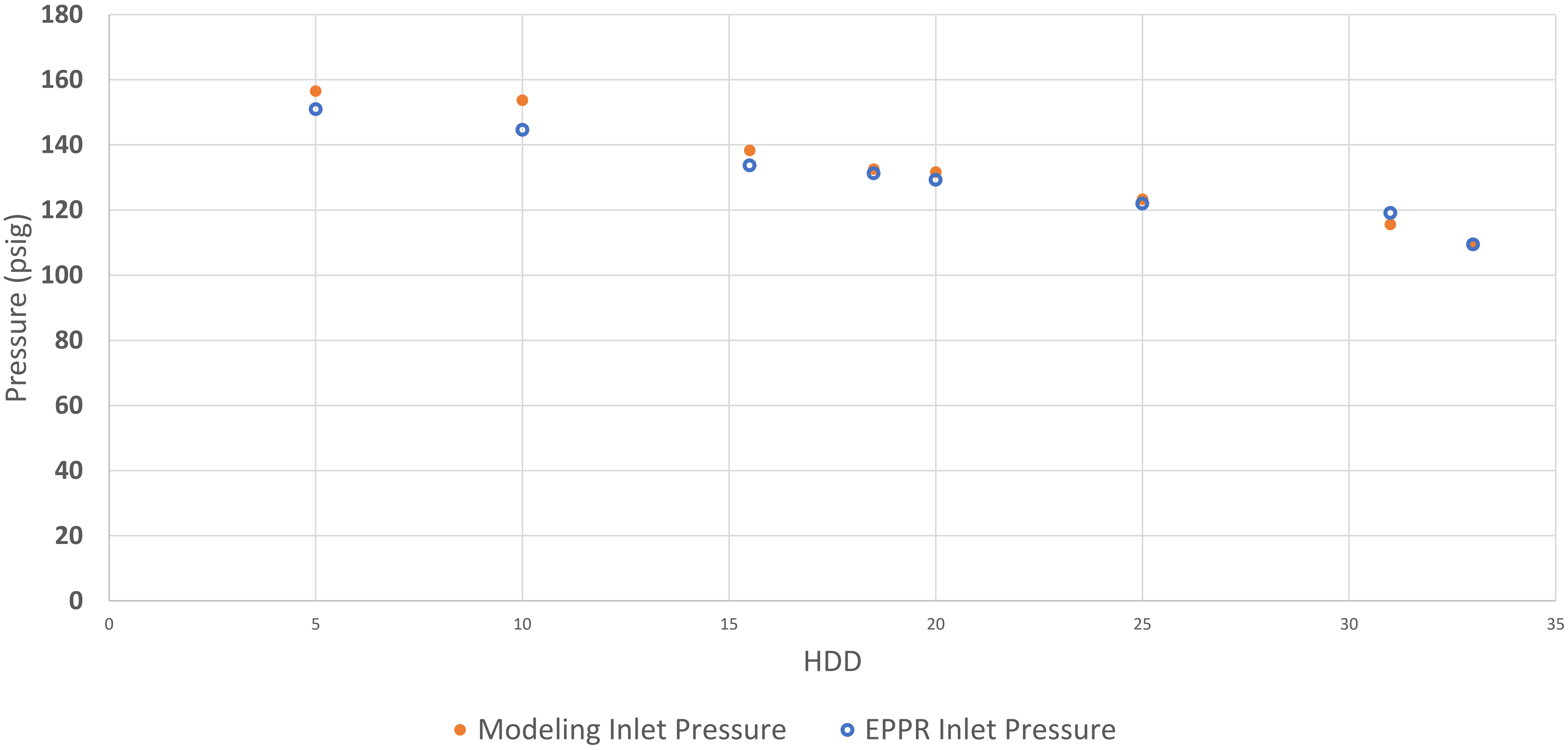
Forest Grove Feeder

- Growth has occurred in this area and modeling results indicate that this pipeline is operating beyond its design capacity in cold weather.
- Existing system operates at 175 MAOP.
- Fed from the 720 MAOP Rock Creek Feeder and South Mist Feeder
- The low pressures found in the hydraulic model triggered a request to site an EPPR (Electronic Portable Pressure Recorder) at the inlet of the Forest Grove district regulator to monitor pressures.
- Residential and commercial customer demands for Cornelius, Forest Grove, North Plains and Banks were estimated and incorporated using the new CMM software

Forest Grove Feeder

- Nine data points were used to validate demands in the system model
  - Compares EPPR pressure reads sited at the inlet of the Forest Grove District Regulator to modeled pressures.
  - Sample period is between 2020 and 2022.
  - Interruptible customers are enabled in model because curtailments were not issued during sample period.
  - Percent difference ranged between -2.98% and 3.67%.
  - Average percent difference for 9 samples equaled 1.83%.
- Chart provided on next slide

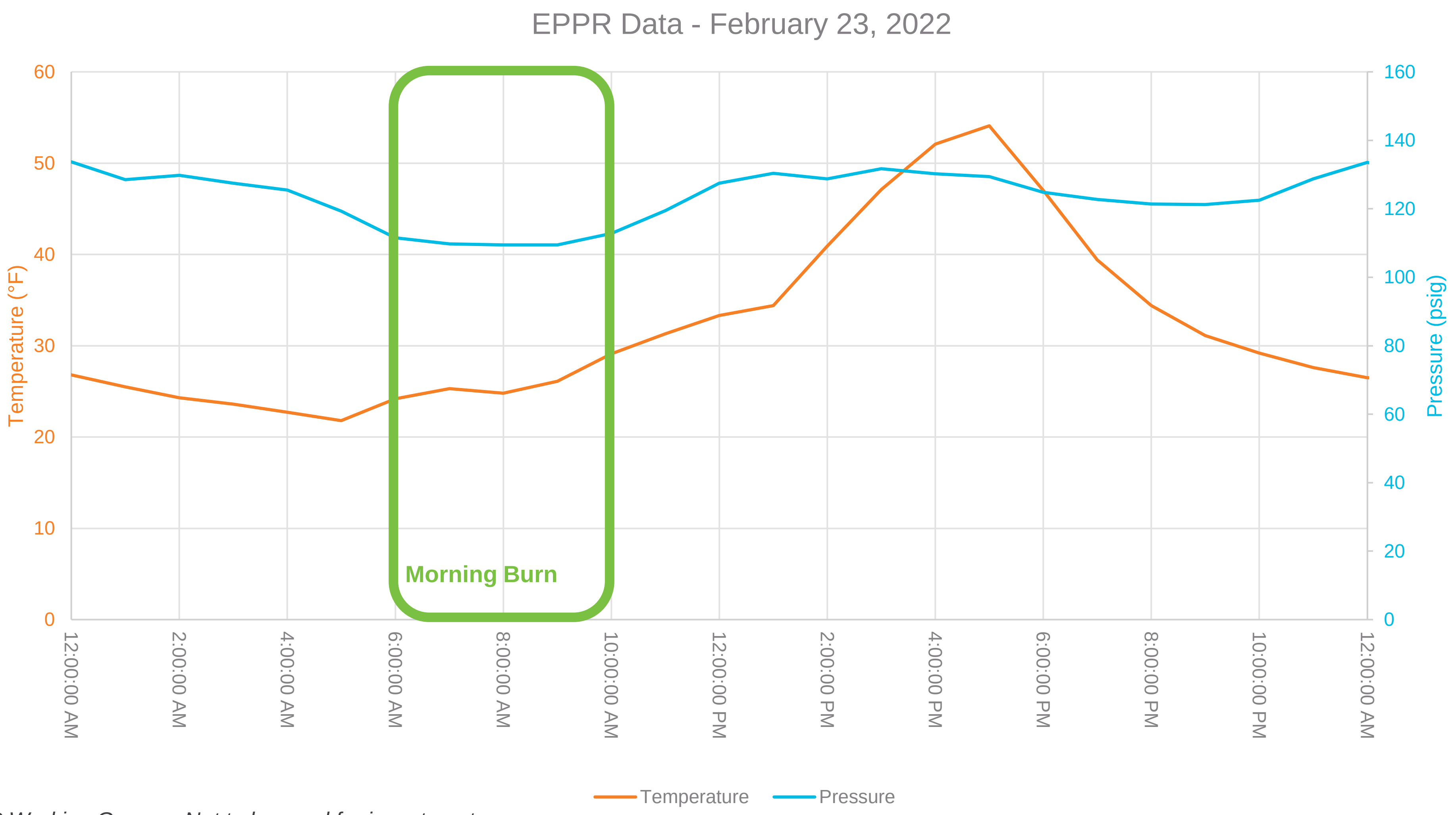
Forest Grove Feeder



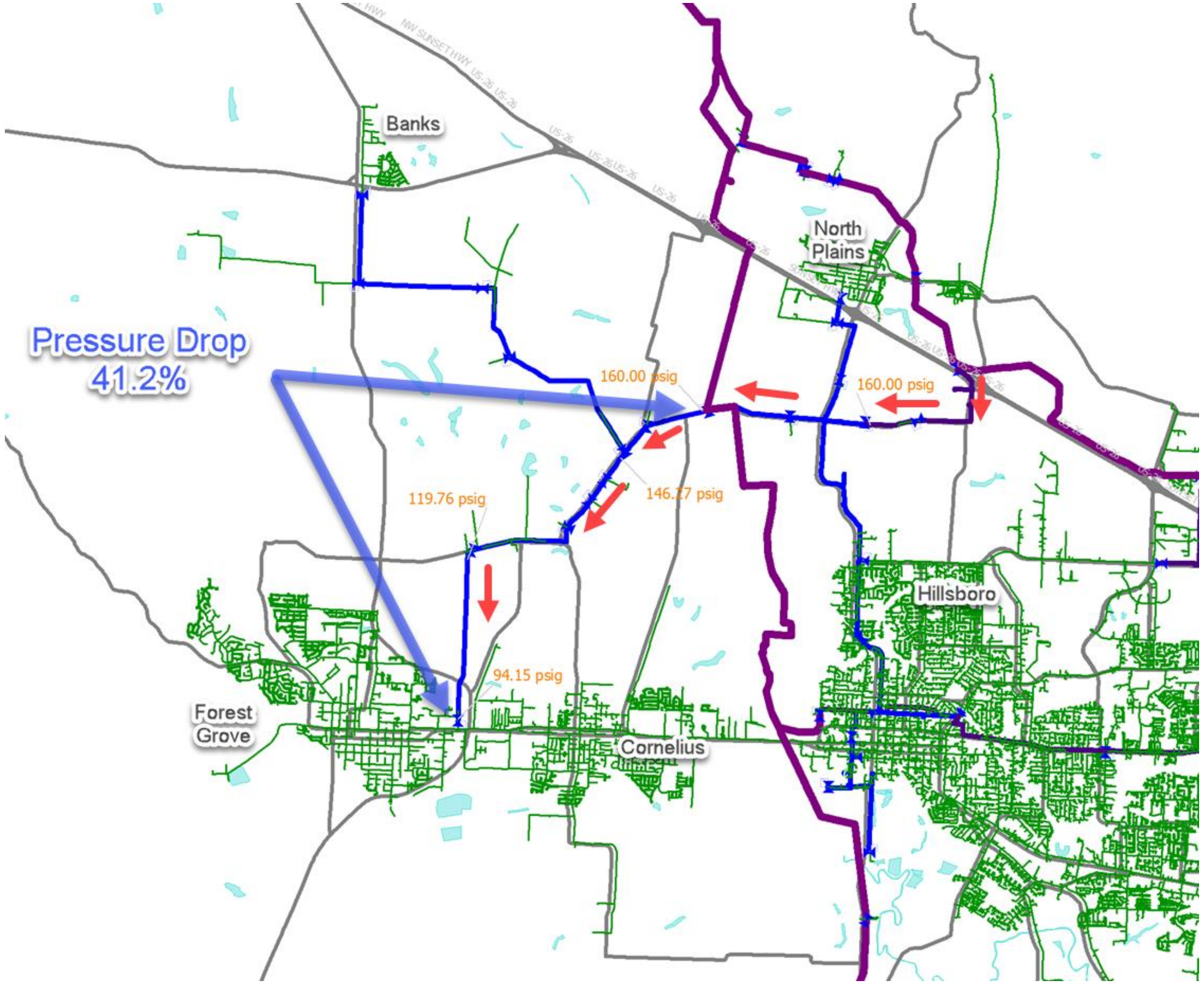
Forest Grove Feeder

- EPPR readings indicate that the lowest pressure drop in the last two years occurred on February 23, 2022
  - Forest Grove District inlet pressure dropped to 109 psig while the upstream district regulators were set at 160 psig.
  - Pressure drop for this event was 32%.
  - The EPPR case temperature during this event revealed that Forest Grove average temperature was 32°F.

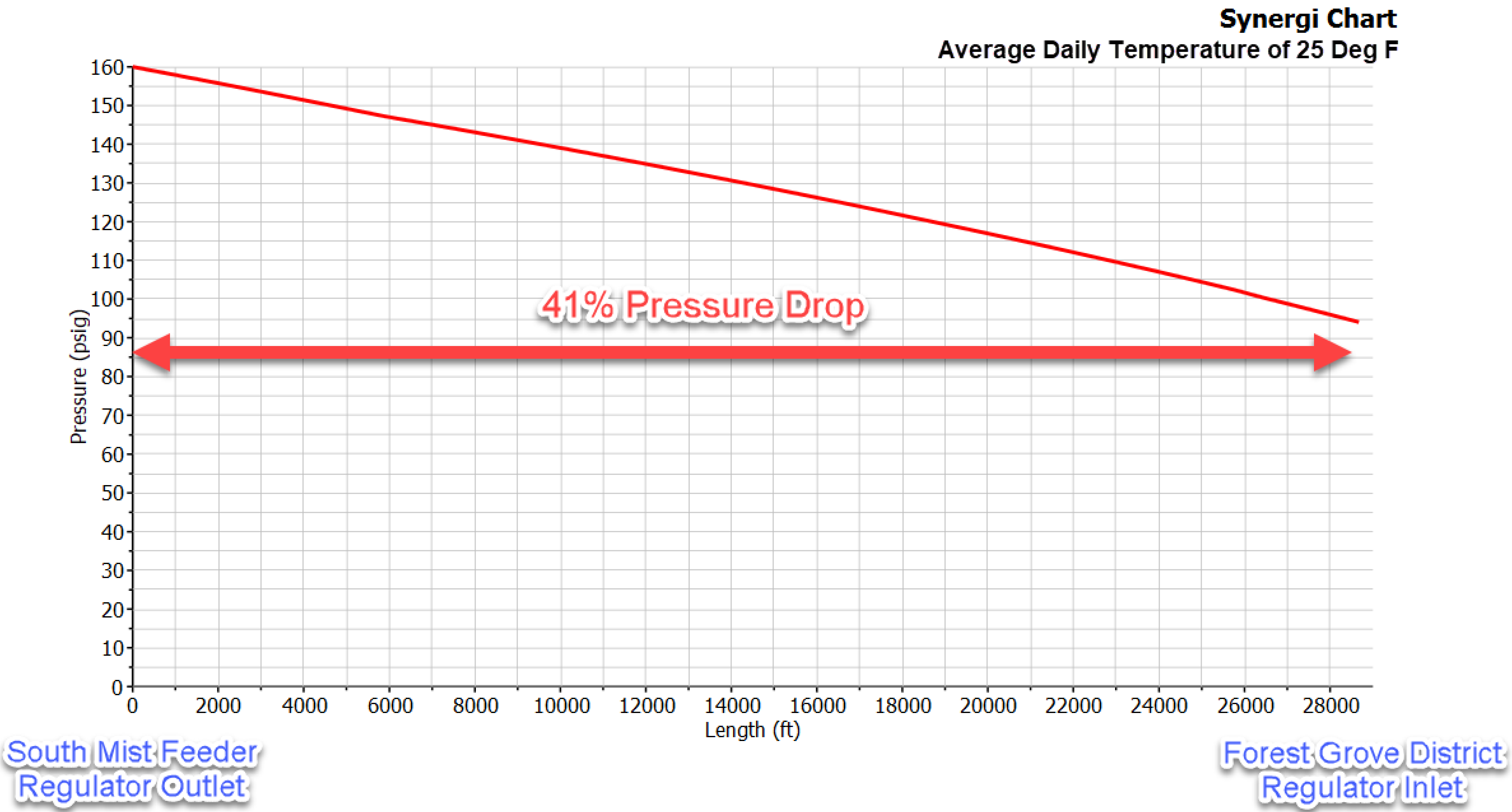
EPPR Data from Forecast Grove District Regulator



Forest Grove Feeder

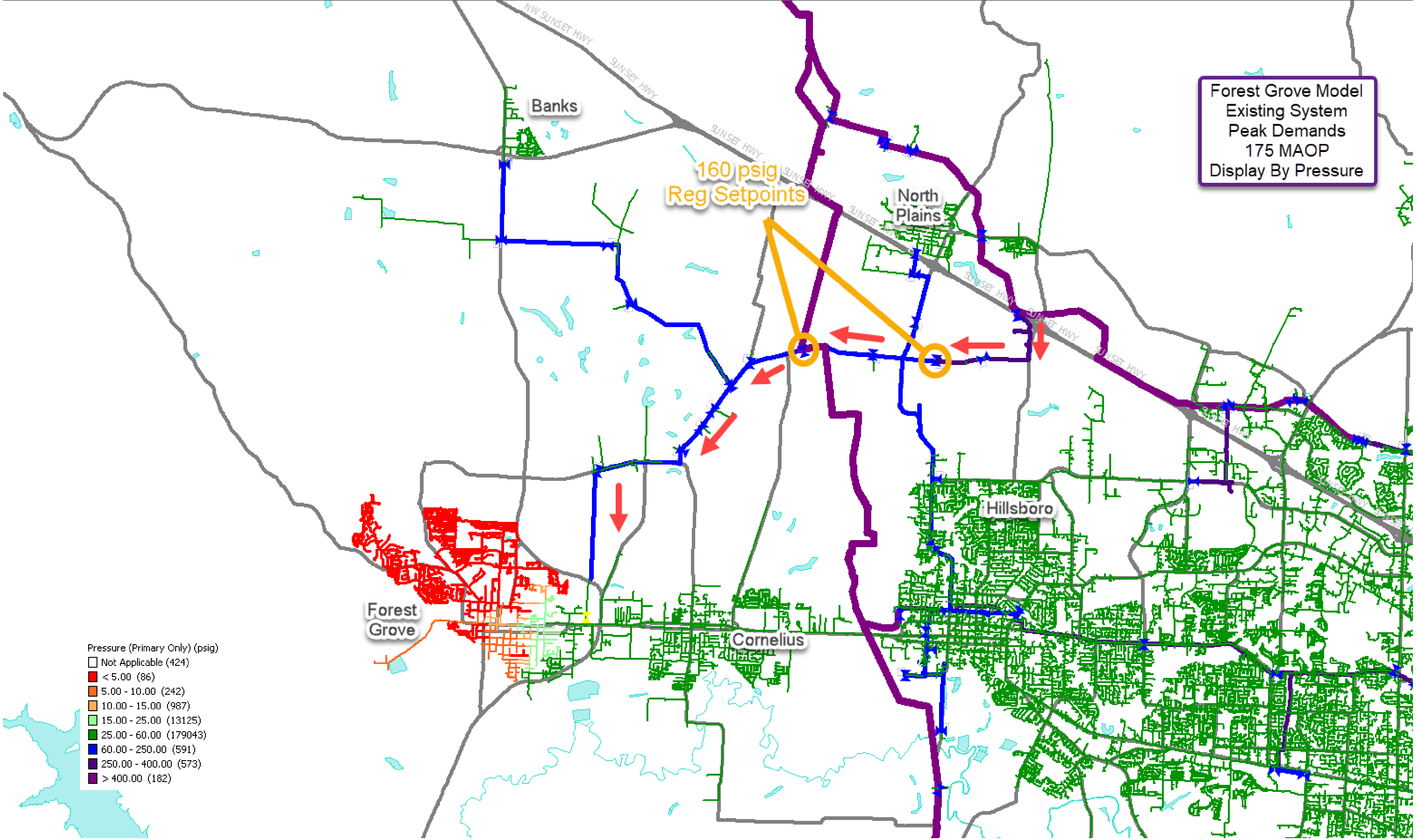


- Model results indicate that an average temperature of 25°F would cause the pressure on the Forest Grove Feeder to drop by over 40%
- This area experiences a cold event with an average temperature < 25°F about once every 3 years, with the last cold event occurring in January of 2017


Synergi Chart
Average Daily Temperature of 25 Deg F
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Pressure (psig)
41% Pressure Drop
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
Length (ft)
South Mist Feeder Regulator Outlet
Forest Grove District Regulator Inlet

Forest Grove Feeder

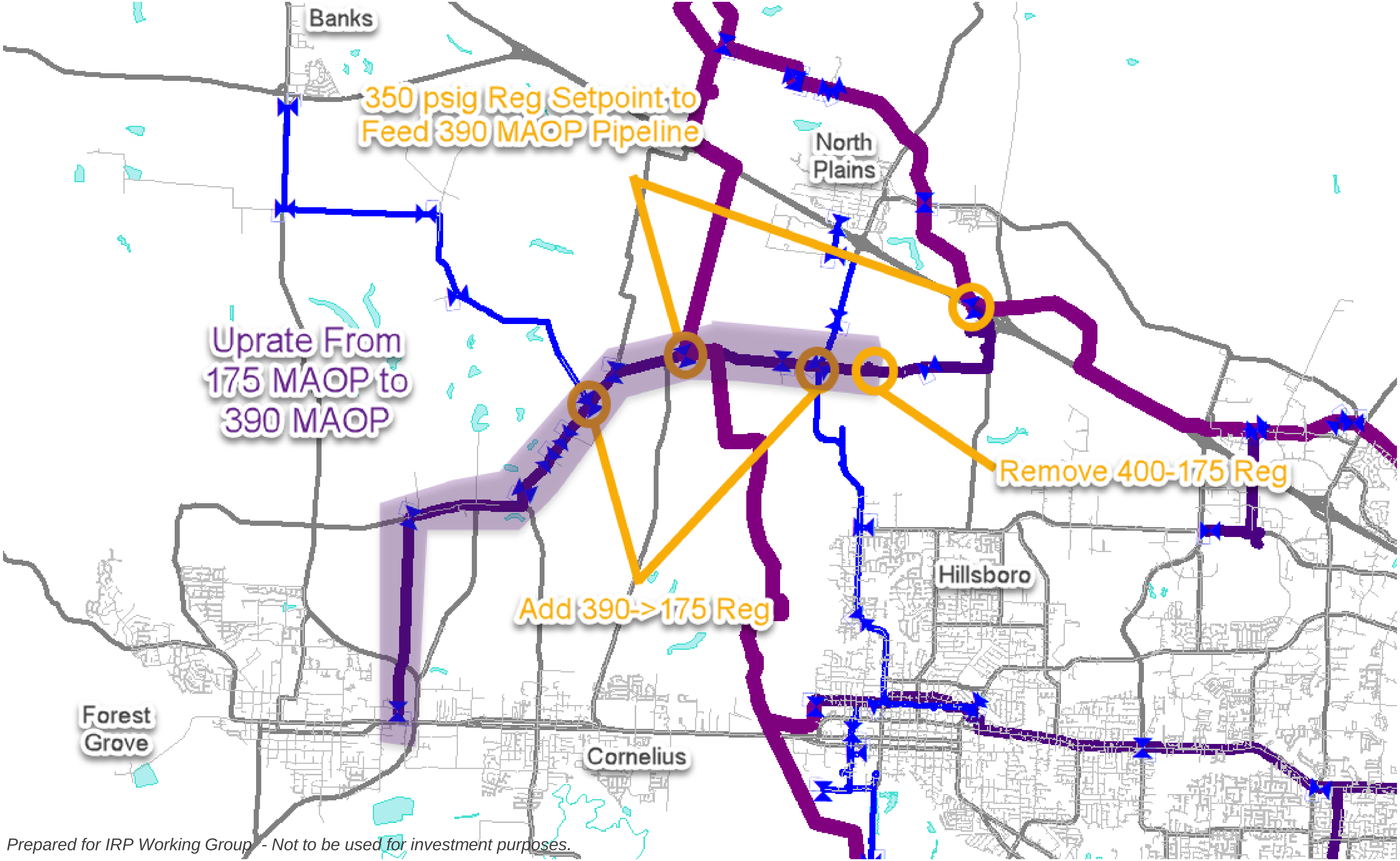
- Modeling results suggest that customers may experience outages during a cold event.
- The next slide illustrates peak model results:
  - Areas in red show potential customers that may experience service disruptions.
  - Interruptible customers were disable in the model.
  - Potential outages are a result of low inlet pressure at the Forest Grove district regulator



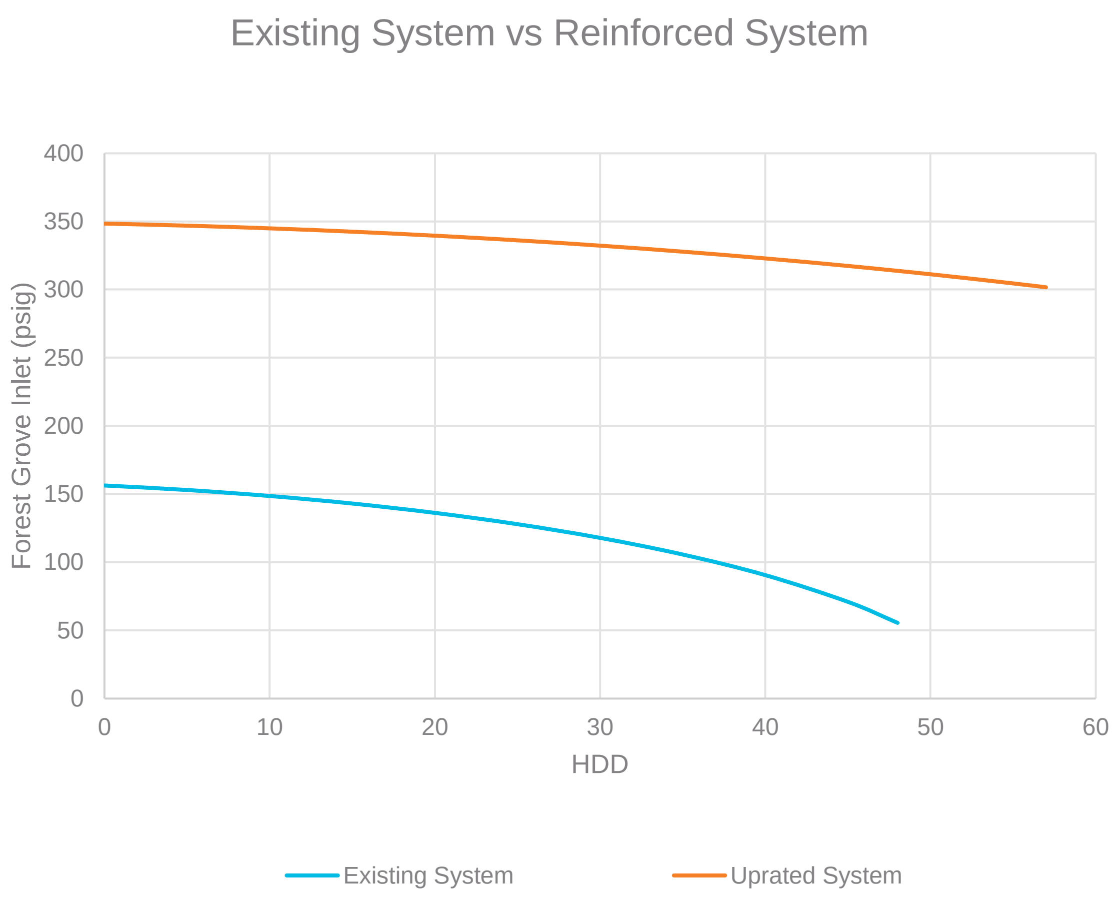
Forest Grove Model
Existing System
Peak Demands
175 MAOP
Display By Pressure
160 psig
Reg Setpoints
Banks
North
Plains
Hillsboro
Forest
Grove
Cornelius
NW SUNSET HWY
SUNSET HWY
Pressure (Primary Only) (psig)
Not Applicable (424)
< 5.00 (86)
5.00 - 10.00 (242)
10.00 - 15.00 (987)
15.00 - 25.00 (13125)
25.00 - 60.00 (179043)
60.00 - 250.00 (591)
250.00 - 400.00 (573)
> 400.00 (182)

Forest Grove Feeder

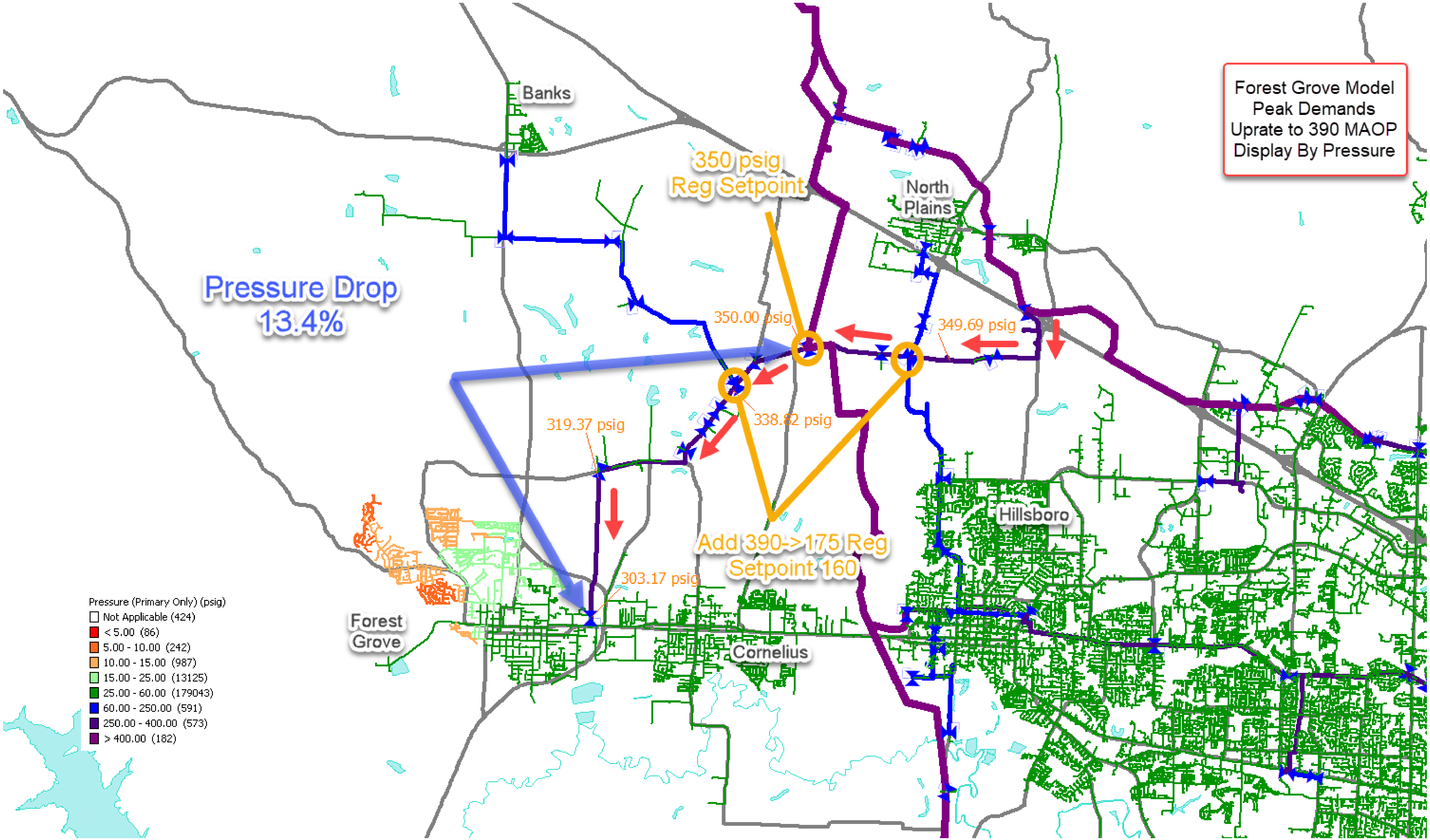
- Proposed System Reinforcement
  - Uprate approximately 6.3 miles of high pressure main from an MAOP of 175 to an MAOP of 390
  - Remove existing 400-175 District Regulator
  - Install two new 390-175 District Regulators
- The 175 MAOP laterals to Banks, North Plains, and Hillsboro would remain at their current 175 MAOP


Banks
350 psig Reg Setpoint to
Feed 390 MAOP Pipeline
North
Plains
Uprate From
175 MAOP to
390 MAOP
Remove 400-175 Reg
Hillsboro
Add 390->175 Reg
Forest
Grove
Cornelius

Forest Grove Feeder

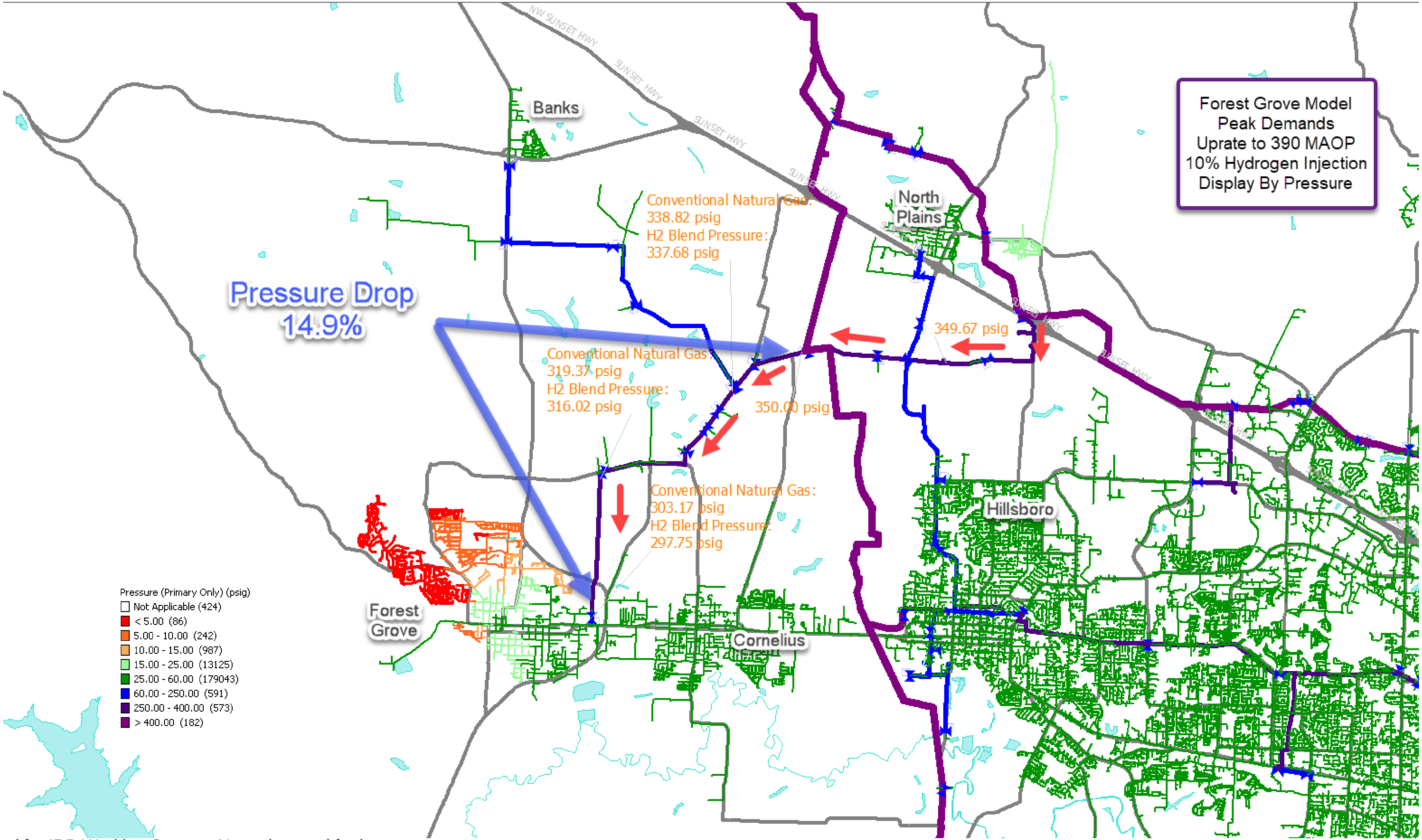


- Modeling results after uprate
  - Forest Grove district regulator inlet pressure modeled at 303 psig under peak hourly conditions.
  - Pressure drop = 13.4%.
  - Forest Grove distribution system pressures are above 5 psi.
- Chart compares pressures before and after system reinforcement.
- Next Slide displays Synergi Map View.


Forest Grove Model
Peak Demands
Uprate to 390 MAOP
Display By Pressure
Banks
North Plains
Hillsboro
Forest Grove
Cornelius
350 psig
Reg Setpoint
Pressure Drop
13.4%
350.00 psig
349.69 psig
338.82 psig
319.37 psig
303.17 psig
Add 390->175 Reg
Setpoint 160
Pressure (Primary Only) (psig)
Not Applicable (424)
< 5.00 (86)
5.00 - 10.00 (242)
10.00 - 15.00 (987)
15.00 - 25.00 (13125)
25.00 - 60.00 (179043)
60.00 - 250.00 (591)
250.00 - 400.00 (573)
> 400.00 (182)

Forest Grove Feeder

- Results of Hydrogen Blending with Natural Gas
  - Hydrogen blended with natural gas lowers the BTU values of the gas on a pipeline system.
  - Higher volume of gas required to serve the same demand results in increased pressure drop in the pipeline.
- Existing System H2 Blending Capability
  - Because of greater pressure drop, the system would not be able to receive a hydrogen blend without worsening the inlet pressure of the Forest Grove District Regulator.
  - 40% Pressure Drop and potential outages would occur at higher temperatures.
- Uprated System H2 Blending Capability
  - Proposed uprate of the system would satisfy requirements of blending hydrogen and serving peak demands.
  - 10% Hydrogen Blend = 14.9% pressure drop.
  - The next slide shows a 10% hydrogen blend on the uprated system.


Forest Grove Model
Peak Demands
Uprate to 390 MAOP
10% Hydrogen Injection
Display By Pressure
Pressure Drop
14.9%
Banks
North Plains
Hillsboro
Forest Grove
Cornelius
NW SUNSET HWY
SUNSET HWY
Conventional Natural Gas:
338.82 psig
H2 Blend Pressure:
337.68 psig
Conventional Natural Gas:
319.37 psig
H2 Blend Pressure:
316.02 psig
Conventional Natural Gas:
303.17 psig
H2 Blend Pressure:
297.75 psig
349.67 psig
350.00 psig
Pressure (Primary Only) (psig)
Not Applicable (424)
< 5.00 (86)
5.00 - 10.00 (242)
10.00 - 15.00 (987)
15.00 - 25.00 (13125)
25.00 - 60.00 (179043)
60.00 - 250.00 (591)
250.00 - 400.00 (573)
> 400.00 (182)

Forest Grove Feeder

- Summary of the scope of work and preliminary cost estimate for the Forest Grove Feeder Uprate project for inclusion in the 2022 IRP:
- Note: All piping and regulators with insufficient test documentation must be retested or replaced before pressure uprate can occur.
    - 12 service regulator inlet piping replacement or full replacement
    - 4 district regulator inlet piping replacement or full replacement
    - Install 2 new pressure regulating stations
    - Abandon 1 District Regulator
- The preliminary total project cost estimate for the above scope of work for the Forest Grove Feeder Uprate is between $2.1M and $4.2M without COH.

Alternative Analyses

- **Targeted Interruptible Schedule Agreements**
  - Estimated technically potential load savings from large firm industrial loads in the affected area switching to interruptible service
  - Insufficient technical potential available
  - With **all** firm industrial loads curtailed in the model, Synergi Gas results demonstrate that the 175 MAOP system will continue to experience a greater than 40% pressure drop during peak hourly conditions
- **Satellite LNG Facility**
  - Estimated cost to site LNG facility to serve affected area
  - Cost significantly higher than pipeline uprate (more than double uprate project)
- **Geographically-Targeted RNG/Synthetic Methane**
  - Site not conducive to cost-effective RNG interconnection project

Questions/Feedback

Strategic Planning | Integrated Resource Planning Team

irp@nwnatural.com