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Non-Powered Damper Gas Storage Water Heater Lab Testing

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5. Executive Summary

In residential and commercial buildings, water heating is one of the largest uses of natural gas in the United States, responsible for 85 Mt of CO_2 equivalent emissions annually (US Department of Energy (DOE) 2020). In residential applications, this market has been dominated by low efficiency, unpowered storage water heaters, many of which have rated Uniform Energy Factor (UEF) of 0.64 or lower for older and grandfathered models. According to the most recent Residential Building Stock Assessment of the Pacific Northwest, of the homes with gas-fired water heating, only 15% have condensing efficiency equipment and 5% are "mid"-efficiency ($0.64 \leq$ UEF ≤ 0.77) (NEEA 2019). The low market penetration of higher efficiency water heaters can in large part be explained by high incremental equipment cost ($350+) as well as a requirement for a nearby outlet, which can add another $200 to the installation cost. Coupled with historically low natural gas prices, the simple paybacks of these energy efficiency upgrades can exceed the useful life of the products.

In response to the need for easy retrofits of low efficiency water heaters, A. O. Smith has developed a new line of products that utilize flue dampers without the need for electricity. Two models are now available to consumers, G12-CADT4040NV and G12-CADT5040NV (40 and 50 gal capacities, respectively), which have a rated UEF of 0.68, further referred to as Non-powered Damper (NPD-40 and NPD-50) water heaters. Both water heaters are ENERGY STAR certified.

The purpose of this investigation was to verify the rated performance of these new products by conducting rating tests according to the US DOE "Uniform Test Method for Measuring the Energy Consumption of Water Heaters". Additional tests were performed while operating the water heaters under adverse operating conditions to asses any potential challenges with the new damper mechanism. Finally, a competitive assessment was performed with alternative high-efficiency water heater options to estimate the potential of the new products to save energy and costs. It should be noted that these water heaters are certified under ANSI Z21.10.1, which exceeded that requirement.

The major findings from the performance verifications tests were:

- When strictly following the US DOE procedures, the measured UEF of the NPD products closely matched the values certified by the American Heating and Refrigeration Institute (AHRI), summarized in Table E1.
- Both water heaters had high altitude gas orifices installed for the UEF test. This was done to certify the products for altitudes up to 10,000 ft, and is a common practice among other brands as well. When tested in this configuration, the firing rate of both NPD products was ~17.5% lower than the nameplate rating. The measured UEF in this condition was 3 points lower than the AHRI rating.

Table E1 – Summary of performance verification tests performed at GTI

Water Heater	UEF Measured	UEF Rated	First Hour Rating Measured (gal)	First Hour Rating Rated (gal)	Recovery Efficiency Reported (%)	Recovery Efficiency Measured (%)	Standby Heat Loss Coefficient Measured (Btu/°F)
NPD-40	0.68	0.68	77	82	75	77	6.9
NPD-50	0.69	0.68	74	75	75	80	6.6

For the competitive assessment, the 50-gallon NPD-50 water heater was compared to a non-ENERGY STAR GCR-50 (0.64 UEF, the current federal minimum for the product category), a powered damper ENERGY STAR GCF-50, a power vent ENERGY STAR GPVL-50, and a legacy 0.59 EF water heater (not A. O. Smith). The major findings from this analysis were:

- The NPD-50 energy and operating cost savings relative to the non-ENERGY STAR GCR-50 were comparable to the other ENERGY STAR options (GPVL-50 and GCF-50), ranging from 10-12% and $15-20 per year in the Pacific Northwest, respectively. This comparison is plotted for different usage cases and locations in Figure E1 and Figure E2.
- When compared to the legacy EF 0.59 water heater, the energy and operating cost savings of NPD-50 increased to over 20% and $40 per year, respectively.
- With an incremental cost over the baseline GCR-50 of only $38 at the time this report was written, the simple payback period for NPD-50 would be less than 3 years when compared to GCR-50, and less than 9 years when compared to the cheapest A. O. Smith water heater in the same product category.
- Both powered ENERGY STAR alternatives had simple payback periods in excess of their useful lifetime due to high incremental equipment costs.

Figure E1 – Predicted average annual gas savings for different storage water heaters options, using a non-ENERGY STAR 0.64 UEF water heater as a baseline of comparison

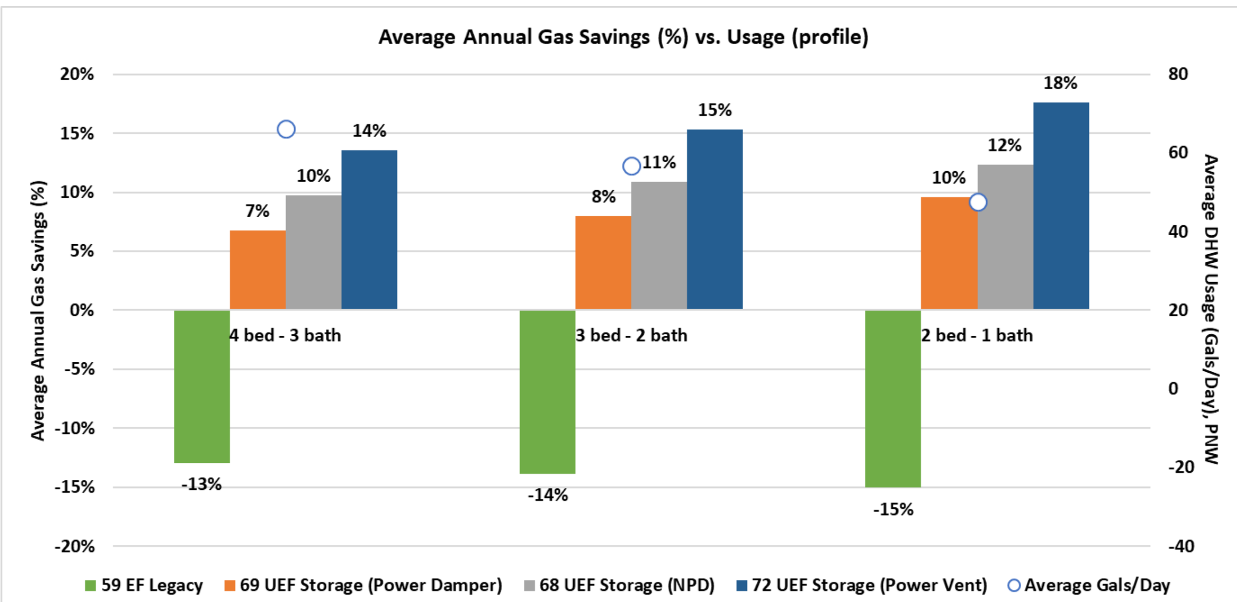
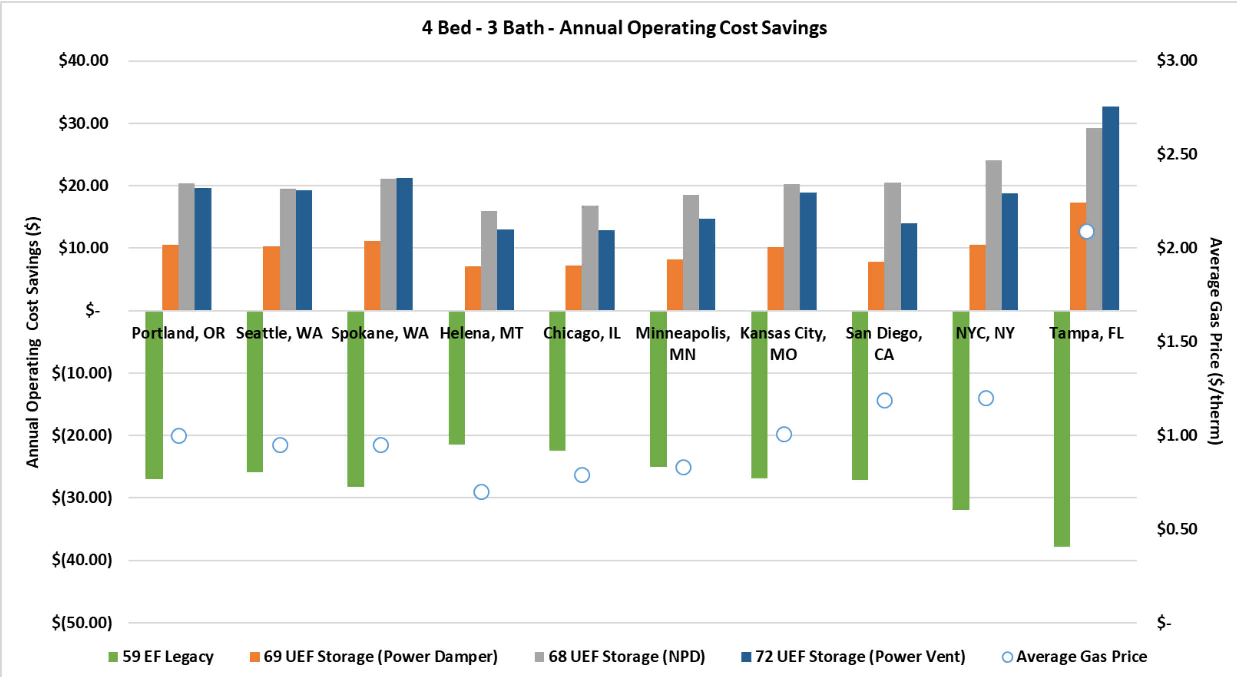


Figure E2. Predicted annual operating cost savings for different water heaters and locations



6. Introduction

Figure 1. A. O. Smith NPD-50 tested at GTI

In buildings, water heating is one of the largest uses of natural gas in the United States, responsible for 85 Mt of CO_2 equivalent emissions annually (US DOE SCOUT, Baseline Energy Calculator 2020). In residential applications, this market has been dominated by low efficiency storage, atmospherically vented, unpowered water heaters, many of which have rated Uniform Energy Factor (UEF) of 0.64 (current federal minimum for 50-gallon gas water heaters - 10 CFR § 430.32) or lower for older and grandfathered models. According to the most recent Residential Building Stock Assessment of the Pacific Northwest, of the homes with gas-fired water heating, only 15% have condensing efficiency equipment and 5% are "mid"-efficiency ($0.64 < \text{UEF} \leq 0.77$) (NEEA 2019).

A recent Energy Trust of Oregon report (Manclark and Gilman 2016) identified that replacing all low efficiency water heaters with higher efficiency ($\text{UEF} \geq 0.67$) models could save up to 910,000 therms of gas per year in Oregon and SW Washington. The same report identified that one of the largest barriers for installing higher efficiency models in retrofits are requirements for a nearby 110 V electrical outlet.

The first step in achieving higher efficiencies with gas water heaters is to minimize standby losses from the tank. Electrically powered dampers are a simple way to boost efficiency by several points. These devices seal off the flue during the off-cycle, reducing the heat losses. Power vent models minimize flue heat losses while also boosting heat transfer during the on-cycle. Tankless water heaters can almost eliminate standby losses by removing the tank entirely and providing hot water on demand, allowing them to achieve a UEF of greater than 0.8. Each of these approaches requires a nearby electrical outlet. This requirement can increase the installation cost by ~$200 if an outlet is not available. It will also result in a lack of available hot water during power outages. Coupled with higher equipment cost of high-efficiency water heaters and historically low gas prices, the simple payback periods for these upgrades can be in excess of the useful life of the product (Fridlyand and Liszka 2019).

In response to a need for easy retrofits of low efficiency water heaters, A. O. Smith has developed a new line of products that utilize flue dampers without the need for electricity. Two models are now available to consumers, G12-CADT4040NV and G12-CADT5040NV (40 and 50 gal capacities, respectively), which have a rated UEF of 0.68, further referred to as Non-powered Damper (NPD-40 and NPD-50) water heaters. Both water heaters are ENERGY STAR certified. An NPD-50 water heater is pictured in Figure 1.

The purpose of this investigation was to verify the rated performance of these new products by conducting rating tests according to the US Department of Energy (DOE) "Uniform Test Method for Measuring the Energy Consumption of Water Heaters". Additionally, a competitive assessment was performed with alternative high-efficiency water heater options to estimate the potential of the new products to save energy and costs.

7. Methodology

The project was broken down into two primary tasks. As part of Task 1, a laboratory evaluation was conducted of the new NPD products from A. O. Smith. The objectives of the first task were to:

- Verify their rated performance of NPD water heaters, as measured by the Uniform Energy Factor

A detailed description of the experimental apparatus and procedures is provided in Appendix A. Two NPD water heaters, provided by A. O. Smith, were tested as part of the first task and two additional water heaters, purchased for this project, were tested as part of Task 2 to provide performance data to use in the competitive assessment. A description of the water heaters tested is provided in Table 1.

Table 1. All water heaters tested as part of Task 1 and Task 2

Model	Rated UEF	Rated FHR [gal]	Volume [gal]	Type
NPD-50[a]	0.68	75	48	ENERGY STAR, NPD
NPD-40[a]	0.68	82	38	ENERGY STAR, NPD
GCR-50[b]	0.64[c]	81	48	Non- ENERGY STAR
GCF-50[b]	0.69	84	48	ENERGY STAR, Powered Damper

[a]Water heaters provided by A. O. Smith
[b]Water heaters purchased for the project
[c]According to the American Heating and Refrigeration Institute (AHRI) certificate. Reported as UEF 0.62 by A. O. Smith and retailers

The purchased water heaters were similarly found to be under-firing and their orifices were drilled out to the correct size (#31 vs #34 as received). The water heaters were likely shipped with smaller orifices to certify the products for altitudes up to 10,000 ft. While implicit in the Department of Energy test procedures, the 2020 AHRI Operations Manual for the Residential Water Heater Certification Program explicitly states that the water heater should be "re-orificed" to match the nameplate firing rate when adjusting the manifold pressure is not possible. However, because these water heaters would under-fire as-shipped and replacing orifices is not a common installation procedure, an additional UEF rating test was performed on NPD-50 with the original gas orifice to estimate the potential difference in efficiency between the official rating and what may be expected in the field.

Each condition was simulated in the lab on the NPD-50 water heater and its performance assessed, looking for signs of improper operation. Emissions of CO were monitored as an indicator of misfiring, where measurements of >400 ppmv were a clear sign of improper operation.

In Task 2, the performance data for each tested water heater was coupled with detailed 8760-hour energy simulations using BEopt 2.8 (Christensen et al. 2006) to estimate the potential savings for energy consumption, green-house gas emissions, and costs. The performance data collected was used to create a custom water heater option in BEopt with a 125°F setpoint temperature. Each water heater option was simulated at four different locations in the Pacific Northwest (Portland, Seattle, Spokane, and Helena) as well as six other locations around the US for comparison. Three different usage cases were considered (high, medium, and low), as well as installation inside the conditioned space and inside a semi-conditioned space (the garage). Section 8.3 summarizes the analytical findings from Task 2. Appendix B summarizes economic assumptions used in this analysis.

8. Findings

8.1 Performance Verification

Table 2 summarizes the results of all efficiency tests performed under Task 1 and Task 2. Tests 1 and 2 were to verify the rated performance of NPD-40 and NPD-50, using the replacement orifices provided by A. O. Smith. Test 3 was an additional test with NPD-50 to determine its "as-shipped" performance, i.e., while under-firing. Test 4 with NPD-50 was done while simulating the damper "fail open" scenario, discussed later in this section. Tests 5 and 6 with GCF-50 and GCR-50 were done to collect additional performance data to use in the competitive assessment, discussed further in Section 8.3. Because AHRI only certifies the UEF and First Hour Ratings (FHR), it was important to measure the recovery efficiency and the standby heat loss coefficient to use in simulations.

Table 2. Summary of UEF test results for Tasks 1 and 2

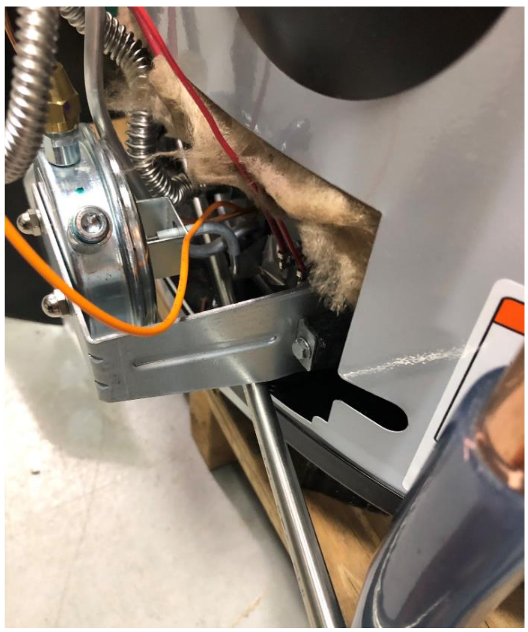
Test		Water Heater	UEF Measured	UEF Rated	FHR Measured (gal)	FHR Rated (gal)	Recovery Efficiency Reported (%)	Recovery Efficiency Measured (%)	Standby Heat Loss Coefficient Measured (Btu/°F)
1	Performance Verification	NPD-40	0.68	0.68	77	82	75	77	6.9
2	Performance Verification	NPD-50	0.69	0.68	74	75	75	80	6.6
3	Performance, under-firing	NPD-50	0.66	NA	59	NA	NA	77	6.8
4	Performance, damper fail open	NPD-50	0.66	NA	NA	NA	NA	78	9.8
5	Competitive Assessment	GCF-50	0.67	0.69	NA	NA	80	78	5.4
6	Competitive Assessment	GCR-50	0.63	0.64	NA	NA	80	80	10.3

The results of Test 1 and 2 verified the rated UEFs of both NPD-40 and 50, demonstrating ENERGY STAR compliance without the need for electricity. The measured FHR for NPD-40 is slightly lower than the rated value. However, this is likely an artifact of the UEF test rather than a significant deviation. The UEF test penalizes water drawn after the 1-hour expires if a recovery has not finished. Depending on how the test is run, the recovery could have finished right before the end of the hour, in which case the water drawn after the end would not be panelized and the FHR would have been at least 79 gallons. In either case, the water heater qualified for the "High" draw test profile per the UEF procedure. The emissions of CO and NOx, corrected to 3% O_2, were under 10 ppmv and 60 ppmv, respectively. While not part of the UEF rating method, emissions of CO and NOx were periodically checked for different water heaters to assess whether the water heater was operating properly.

Test 3 results indicate what the performance of the water heater would be if it was installed as shipped. The measured UEF was 3 points lower than the rated value, and the measured FHR would have qualified the product for the "Medium" draw profile instead (High draw profile was used for the test). A speculative explanation for the lower UEF is that using a smaller orifice will change primary air-fuel ratio in the burner, which could negatively impact heat transfer to the walls. Additionally, the lower firing rate will lead to longer recoveries, reducing the first-hour rating. As mentioned earlier, the smaller gas orifices were likely used to de-rate the burners for high-altitude operation (both water heaters are rated up to 10,000 ft operation). Use of smaller orifices has been seen with other brands of water heaters as well in prior research by GTI. This may in part explain lower than rated performance of water heaters observed in the field (Hoeschele and Weitzel 2013).

To simulate the damper "fail open" scenario, a metal rod was used to actuate the linkage and keep the damper open for another 24-hour test (Test 4), pictured in Figure 2. The FHR test was not repeated because it was expected to not be impacted by the damper staying open. The resultant UEF was 3 points lower than the rating. This is likely due to the increased heat loss coefficient (10.3 vs 6.6 Btu/°F), a direct result of the damper staying open. No operational issues were observed during this test, and emissions of CO were low. The takeaway from this test is that if the damper mechanism fails and stays open, it will only impact the efficiency of the water heater.

Figure 2. Damper actuator on NPD-50 during the "fail open" test. The damper was forced open by a steel rod jammed against the actuator



8.3 Energy and Cost Savings Potential

Section 7 described the methods used for the energy and cost savings analysis. The analysis is similar to the analysis performed for tankless water heaters under a prior NEEA funded study (Fridlyand and Liszka 2019). Two additional water heaters were tested to gather performance data for this analysis, GCR-50 and GCF-50, pictured in

Figure 3**Error! Reference source not found.**. Both are comparable water heaters to NPD-50, but the former is a non-ENERGY STAR water heater (used as the baseline of comparison), while the latter is an ENERGY STAR water heater that uses a powered damper. The measured performance data is summarized in Table 2.

Figure 3. GCR-50 and GCF-50 being tested at GTI

The collected data was augmented with performance characteristics for a legacy EF 0.59 water heater (non-A. O. Smith) and a power vent A. O. Smith water heater GPVL-50 (0.72 UEF), using a combination of older test data from GTI for power consumption and AHRI certificate information. Figure 4 plots the annual gas consumption of each evaluated water heater. Figure 5 compares the annual gas efficiencies for all water heaters considered.

Figure 4. Comparison of annual gas consumption for the high usage scenario in different locations.

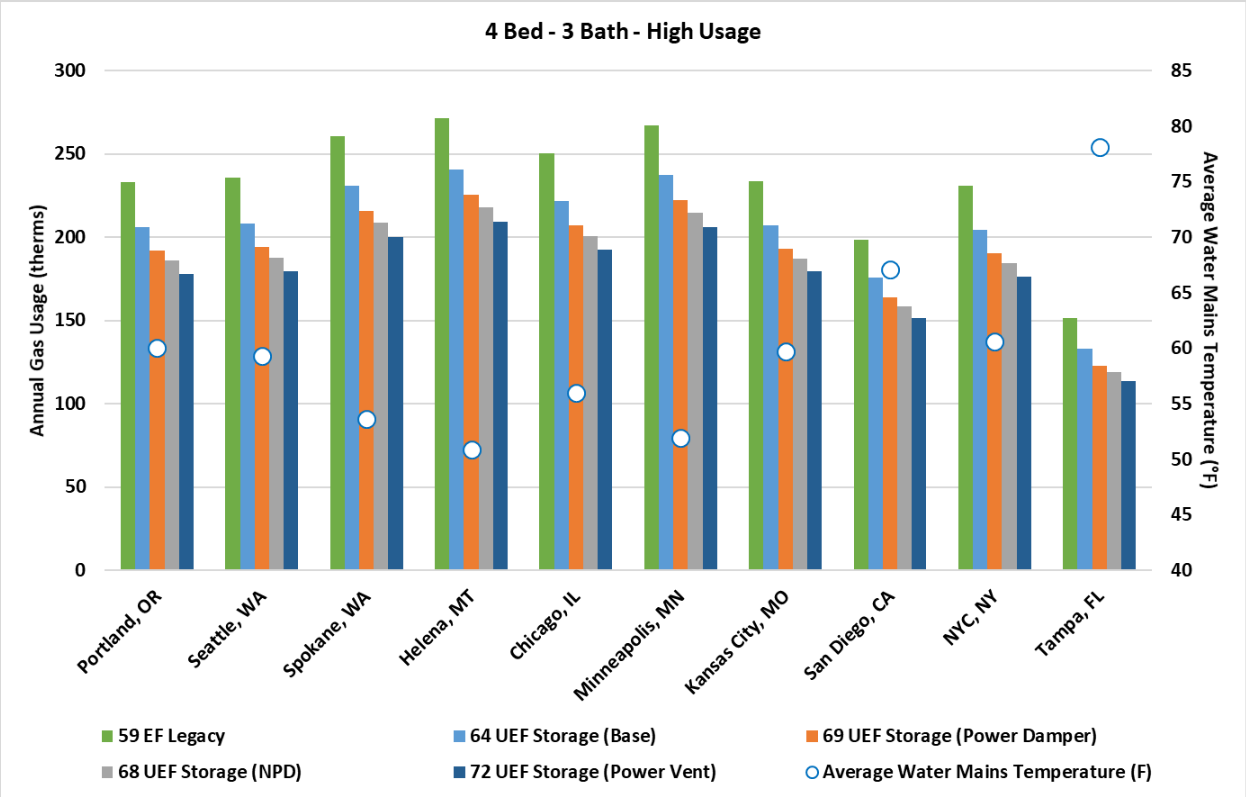
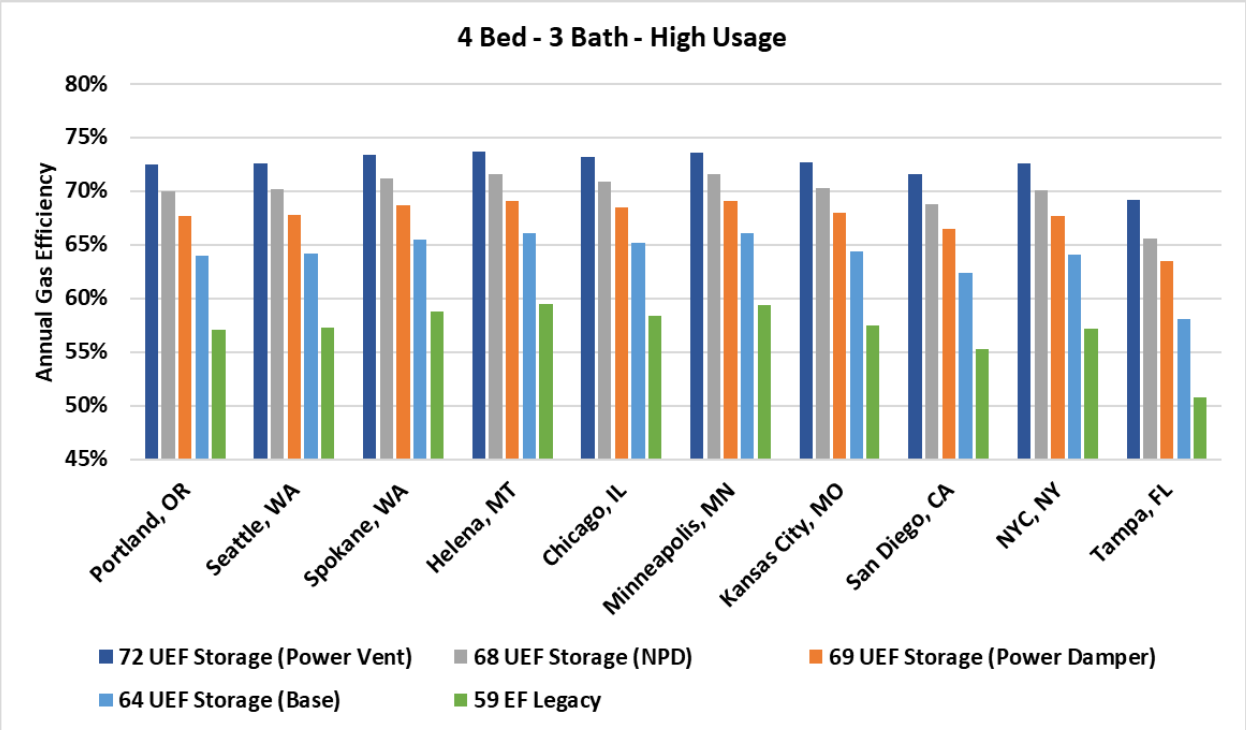


Figure 5. Annual gas efficiency of all storage water heaters considered for the high usage scenario in different locations



The results in Figure 4 and Figure 5 are for a water heater installation inside the garage, where temperature more impacted by outdoor conditions. The only differences between simulations in different locations is the ambient temperature inside the garage and the mains water temperature. In warmer climates, gas usage and efficiencies are lowest because standby losses are a larger relative fraction. In contrast, in colder climates such as Helena, more hot water is delivered due to colder mains temperatures, reducing the relative impact of standby losses, and achieving higher annual efficiencies. If installed inside the conditioned space, the storage water heaters are estimated to be 2-4 efficiency points higher in the four Pacific Northwest locations. The usage pattern also effects the water heater performance. Figure 6 compares the average annual savings relative to the 0.64 UEF baseline for the three usage cases considered. On average, higher relative savings can be expected for lower usage cases.

Figure 6. Estimated annual average gas savings for different usage scenarios relative to the 0.64 UEF baseline

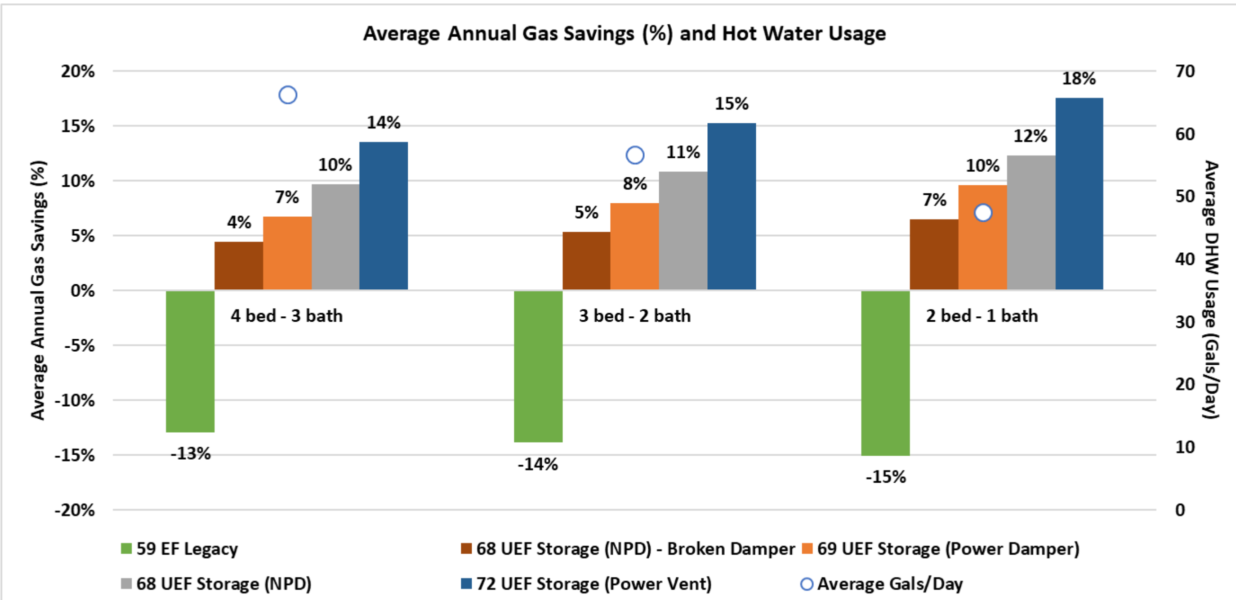


Figure 6 indicates that the non-powered damper provides comparable savings to the other two ENERGY STAR storage water heaters (0.69 UEF and 0.72 UEF), with a slight lead over the powered damper alternative, providing 10-12% in savings compared to the 0.64 UEF baseline. Figure 6 also provides a comparison with a legacy 0.59 EF water heater, which is predicted to use 13-15% more than the 0.64 UEF baseline. This water heater's rating is based on the Energy Factor, which preceded the Uniform Energy Factor until 2015. When tested according to the new rating procedure, its UEF was 0.56. When this legacy water heater is compared to the NPD option, the potential gas savings are over 20%. Figure 6 also provides a comparison with an NPD water heater that had a damper stuck open. The relative savings in this scenario were reduced to 4-7%.

Figure 7 and Figure 8 plot the predicted annual savings of CO_2-equivalent emissions and operating costs, respectively. These predictions are based on the economic assumptions summarized in Appendix B. In terms of greenhouse gas emission reductions, the NPD product edges out the 0.72 UEF power vent product. This can be attributed to the 0.72 UEF water heater using more electricity (50 W when it's on, and 5 W in standby). In states with higher electric grid emission factors, this results in an overall worse emissions performance compared to the NPD product.

Figure 7. Estimated CO_2-equivalent emissions savings of the storage water heaters compared to the 0.64 UEF baseline (including electricity and gas)

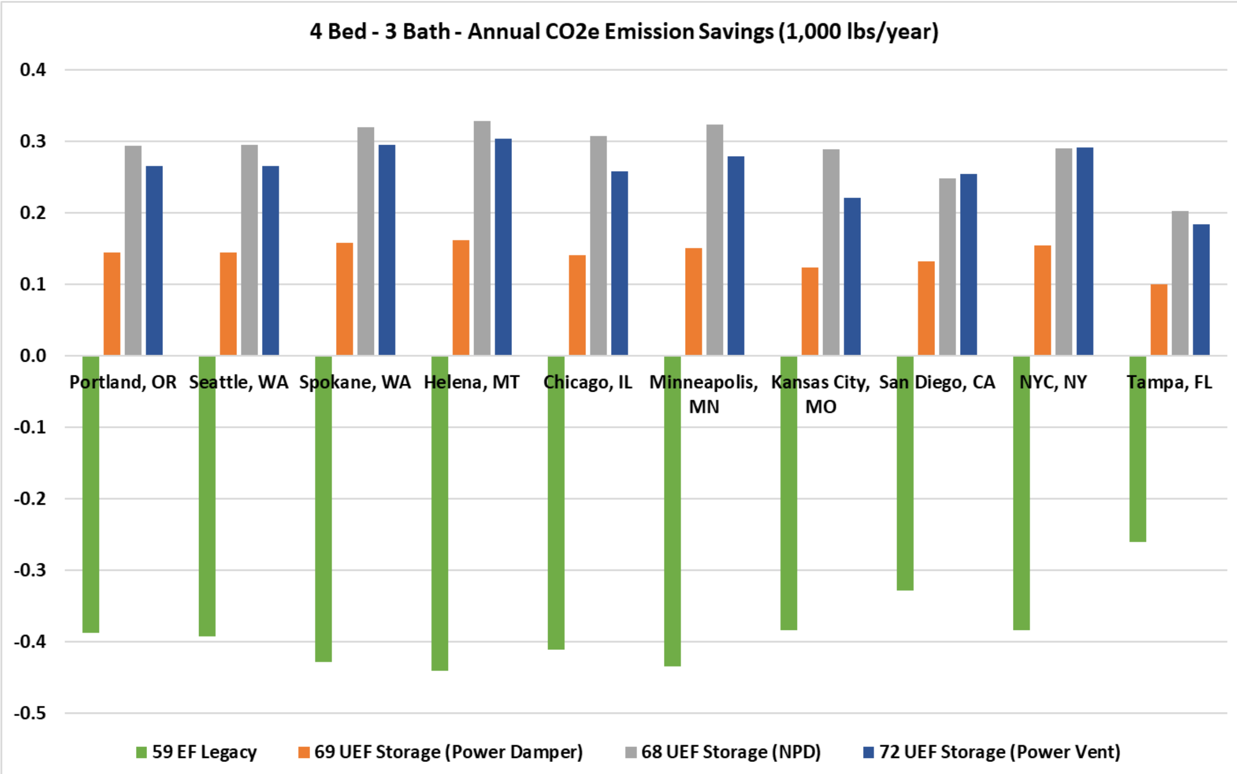
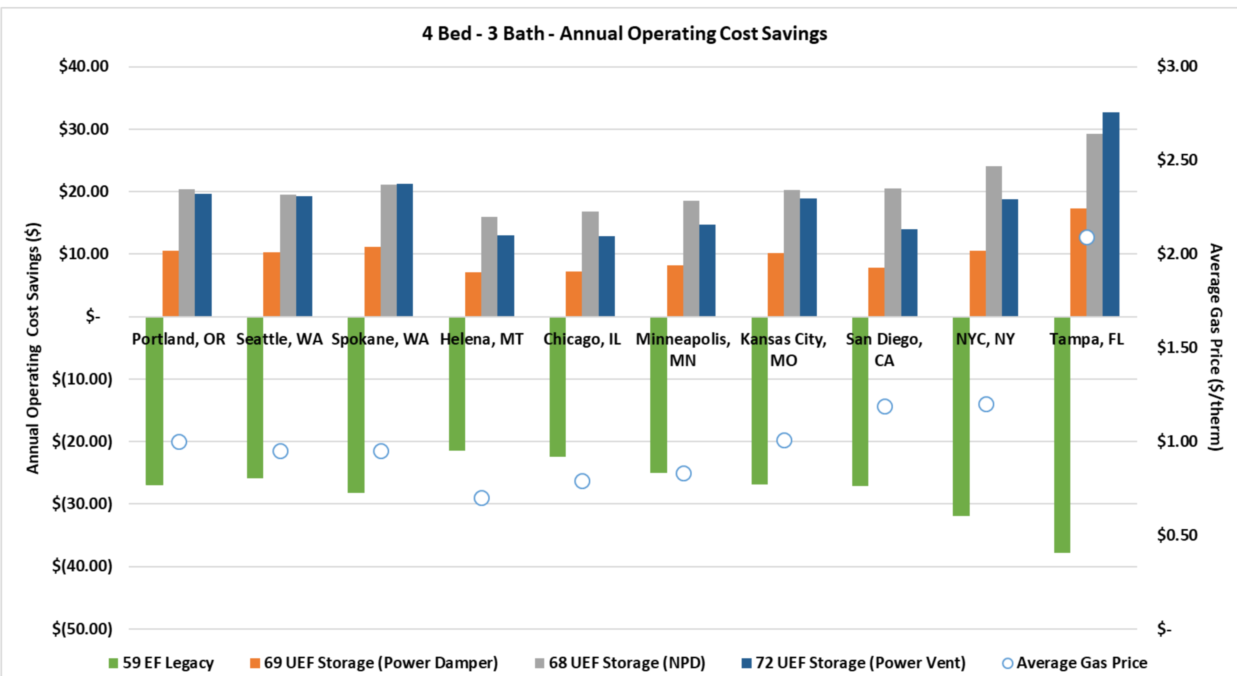


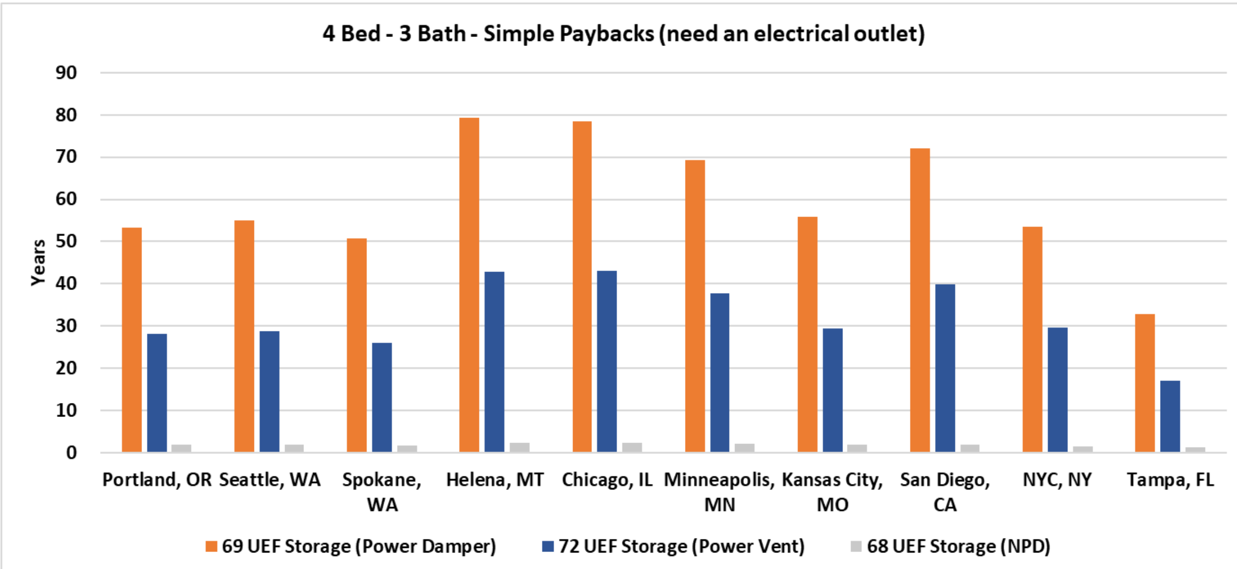
Figure 8. Estimated annual operating cost savings of the storage water heaters compared to the 0.64 UEF baseline (including electricity and gas)

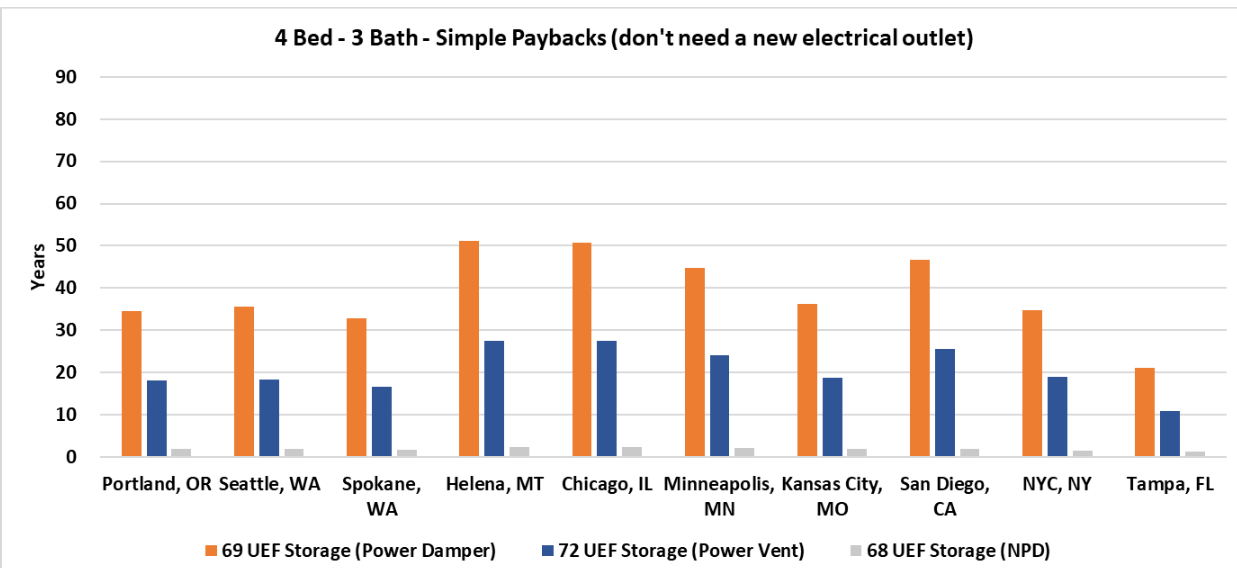


In terms of operating cost savings, the NPD water heaters can potentially save $15-20/year in the Pacific Northwest relative to the 0.64 UEF baseline, and $35-40/year compared to the legacy 0.59 EF water heater. At the time of the writing of this report (August 2020), the retail prices of GCR-50, GCF-50, and

GPVL-50 were $634, $999, and $989, respectively. The NPD products were also available from Lowes, retailing for $672 for NPD-50 and $593 for NPD-40, sold under retailer specific model numbers (G12-CADT4040NV and G12-CADT5040NV). With only a $38 premium for NPD-50 compared to GCR-50 (0.64 UEF baseline), the simple payback would be less than 3 years in all cases simulated. In contrast, the powered ENERGY STAR products have an equipment premium of over $350. They may also require a new electrical outlet, adding ~$200 to the incremental cost. The simple payback for the powered ENERGY STAR water heaters would be in excess of their useful lifetime. Figure 9 plots the estimated payback periods for all ENERGY STAR water heaters, assuming the only incremental costs are the equipment price difference and the need for an electrical outlet.

Figure 9. Estimated simple payback periods for the ENERGY STAR water heaters relative of the 0.64 UEF baseline, including the cost of a new electrical outlet (T) and without (B)





It should be noted that GCR-50 was not the cheapest 50-gallon, high usage A. O. Smith water heater that could be purchased. At the time of the writing, a model G6-T5040NVR (0.62 UEF) water heater could be purchased for $463 from Lowes. If this was the baseline of comparison, the simple payback of the NPD product would be 8-9 years, still within the useful life of the product.

9. Conclusions and Recommendations

In this study, new non-powered damper ENERGY STAR water heaters from A. O. Smith were evaluated experimentally to verify their rated performance. Additionally, an economic and energy savings competitive assessment was conducted, comparing the new NPD products to alternative low efficiency and powered ENERGY STAR products.

For the competitive assessment, the 50-gallon NPD-50 water heater was compared to a non-ENERGY STAR GCR-50, a powered damper ENERGY STAR GCF-50, a power vent ENERGY STAR GPVL-50, and a legacy 0.59 EF water heater (not A. O. Smith). The major conclusions were:

- The NPD-50 energy and operating savings were comparable to the other ENERGY STAR options, ranging from 10-12% and $15-20 per year, respectively, when compared to GCR-50.
- When compared to the legacy EF 0.59 water heater, the energy and operating cost savings increased to over 20% and $40 per year, respectively.
- With an incremental cost of only $38 at the time this report was written, the simple payback period would be less than 3 years when compared to GCR-50, and less than 9 years compared to the cheapest A. O. Smith water heater in the same product category.
- The powered ENERGY STAR alternatives all had simple payback periods in excess of their useful lifetime due to high incremental equipment cost.

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12. Appendices

Appendix A – Test Apparatus Description

The test apparatus used is schematically illustrated in Figure 10. Table 3 through Table 5 summarize the instrumentation and key components that were used in the testing. Data from the test skid was recorded at a of 5-second resolution intervals using custom data acquisition software and National Instruments hardware.

Table 3. Process Components and Critical Instrumentation in the Testing Apparatus. (A) – accuracy, (P) - precision

Measurement / Component	Instrument / Model Used	(UEF) Required Accuracy	Published Accuracy
Water Measurements			
[P1] **Water Pressure**	Ashcroft G2 (0-100 psig)	± 1.0 psi (A) ± 0.5 psi (P)	± 1% of scale (limit: -4 to 185°F)
[MF1] **Water Flowmeter / Water Flowrate**	Dwyer MFS2-2	± 1.0% (A)	± 1% of reading (0.26 to 5.3 gpm) (limit: 14 to 140°F)
[T3] **Water Inlet Temperature**	Omega (4-wire) P-M-1/10-1/8-6-0-P-3	± 0.2°F (A) ± 0.1°F (P)	less than ± 0.15°F at 140°F, less than ± 0.08°F at 50°F
[T4] **Water Outlet Temperature**	Omega (4-wire) P-M-1/10-1/8-6-0-P-3	± 0.2°F (A) ± 0.1°F (P)	less than ± 0.15°F at 140°F, less than ± 0.08°F at 50°F
Storage Tank Water Temperatures x6ᵻ	Omega T-type exposed-bead thermocouples (special limits of error)	± 0.5°F (A) ± 0.25°F (P)	± 0.8°F (Tolerance Class 1)
Energy Measurements			
[P2] **Natural Gas Pressure**	Dwyer ISDP-008	± 0.1 inHg (A) ± 0.05 inHg (P)	± 0.5% (0.25 to 100 in w.c.) (or 0.02 inHg to 7.35 inHg)
[T6] **Natural Gas Temperature**	Omega (3-wire) PRTF-10-2-100-1/8-6-E	± 1.0% (A) – to calculate Heating Value	± 0.5°F at 32°F (-58 to 500*F) (Accuracy IEF Class B)
Natural Gas Flowmeter / Fuel Flowrate	Elster DTM-200A Gas Meter	± 1.0% (A)	± 1% of reading (precision: 500 pulses per cf)
Electricity Consumption	CCS WattNode Pulse WNB-3Y-208 and CTS-0750-005	± 0.5% (A)	± 0.5% nominal (± 20% of VAC) ± 0.75% (1 to 120% of current)
Operating Conditions			
Air Dry Bulb Temperature	Omega (3-wire) PRTF-10-2-100-1/8-6-E	± 0.2°F (A) ± 0.1°F (P)	± 0.5°F at 32°F (-58 to 500°F) (Accuracy IEF Class B)
Atmospheric Pressure	Hourly pressure history obtained from weatherunderground.com		
ᵻValues are out of spec with DOE UEF test requirements			

Figure 10: Test stand that will be used for testing in Task 1 and Task 2.

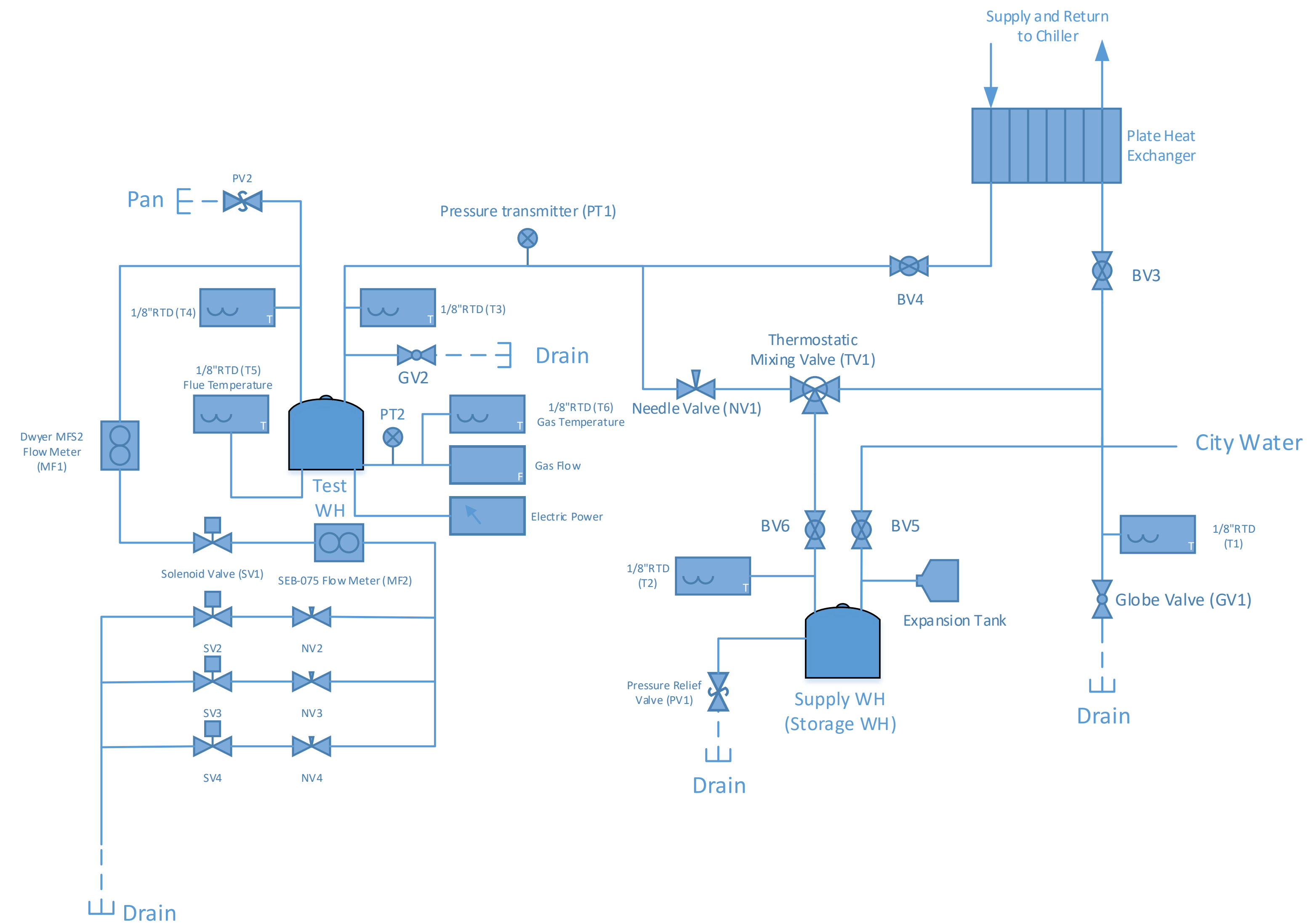

Table 4. Flue gas composition analysis equipment

Measurement	Analyzer	Calibration Range
O_2	Rosemount Analytical X-Stream	8% O_2
CO/CO_2	Rosemount Analytical X-Stream	0-400 ppm CO 18% CO_2
NOx (NO and NO_2)	Ecophysics CLD 700EL	80 ppm NO

Table 5. Data Acquisition Hardware in Test Skid

Module	Position in Test Skid	Model Number	Connector Block
Data Acquisition Chassis	N/A	NI cFP-2000	N/A
Analog Input	1	NI cFP-AI-110	NI cFP-CB-1
Counter	2	NI cFP-CTR-502	NI cFP-CB-1
RTD Acquisition	3	NI cFP-RTD-122	NI cFP-CB-1
Relay Output	4	NI cFP-RLY-421	NI cFP-CB-1
RTD Acquisition	5	NI cFP-RTD-124	NI cFP-CB-1

The UEF tests were conducted according to the appropriate operating patterns summarized in Table 6. 10 CFR Appendix E to Subpart B of 430 outlines specific procedures to be followed for testing. Only a high-level summary is provided here. Though GTI made its best effort to follow the UEF test procedures as closely as possible, it should be noted that GTI is not a certification laboratory.

Table 6. Expected 24-Hour Draw Pattern Tests to Determine UEF Rating

24-Hour Draw Pattern To Use	FHR>=	FHR<	Max GPM >=	Max GPM<
Very-Small Usage	0	18	0	1.7
Low Usage	18	51	1.7	2.8
Medium Usage	51	75	2.8	4
High Usage	75	Over	4	Over
All FHR in units [gallons]. All Max GPM in units [gallons per minute].				

The 24-hour UEF tests was conducted according to the following procedure:

1. In preparation for tests, each storage water heater had thermocouples mounted through the anode rod port to capture the minimum 6-required temperature measurements to determine average tank water temperature. The water heater was primed with a tank full of supply water temperature and set to operate at the most energy-intensive mode. The tank temperature was adjusted to the target 125°F setting.
2. Once the water heater dial setting was determined, the storage water heater was left alone for the required 12-hour "soak-in" period, prior to running more tests.
3. Following the "soak-in" period, each water heater underwent the First-Hour Rating test with a 3 gpm draw, to confirm the required 24-hour draw test pattern per Table 6
4. Prior to starting a 24-hour test, a recovery was forced and allowed to complete. The 24-hour simulated used test was started an hour after the recovery completed.
5. The 24-test was fully automated using custom developed software according to the draw patterns outlined in Section 5.5 "Draw Patterns" of the UEF test. Fuel, temperature dial, and power settings were not adjusted during that time.
6. UEF calculations were performed in accordance with 10 CFR Appendix E to Subpart B of 430, Section 6 through Section 6.3.6.

Analyses in addition to the UEF calculation were performed around each test:

1. A house gas analysis will be performed to obtain an updated gas heating value. The heating value was corrected to metered conditions for use in the UEF calculation.
2. The flue gas composition was periodically monitored to assess whether the water heaters were operating normally using analyzer equipment summarized in Table 4. This is not a requirement of the UEF test.

Appendix B – Economic Assumptions

Table 7 summarizes the energy price and emission factor assumptions used to estimate greenhouse gas emission and operating cost savings. The information was obtained the GTI Source and Emission Analysis Tool (http://seeatcalc.gastechnology.org/ResidentialBuildings.aspx - Accessed August 2020).

Table 7. Summary of economic factors used

	Portland, OR	Seattle, WA	Spokane, WA	Helena, MT	Chicago, IL	Minneapolis, MN	Kansas City, MO	San Diego, CA	NYC, NY	Tampa, FL
Average Electricity Price cents/kWh	11.0	9.8	9.8	11.0	12.8	13.1	11.3	18.8	18.5	11.5
Average Gas Price ($/therm)	1.00	0.95	0.95	0.70	0.79	0.83	1.01	1.19	1.20	2.09
Gas CO2e emissions (lb/MMBtu)	144	144	144	144	144	144	144	144	144	144
Electric grid CO2e emissions lb/MMBtu - Non-Baseload	533	533	533	533	603	590	655	345	409	400