



Residential Dual-Fuel Heat Pump Water Heater

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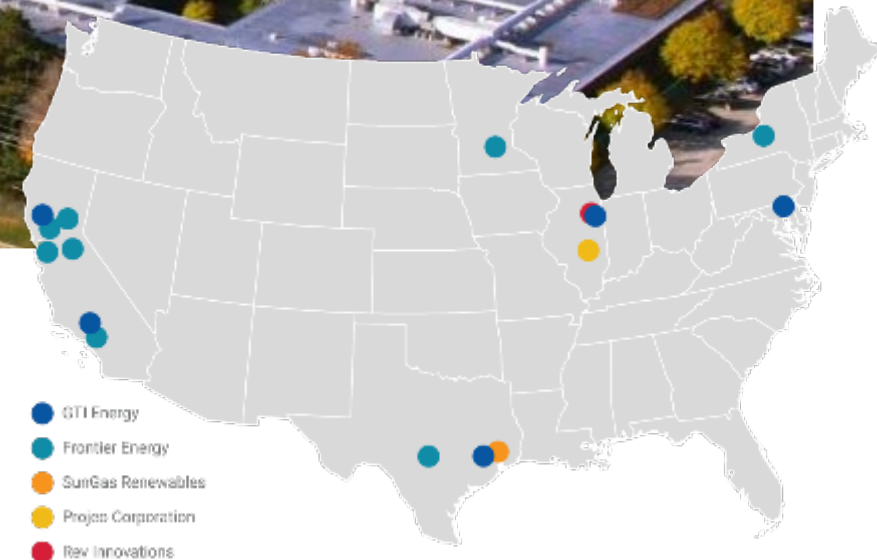
Project Sponsors:
Navien
ICF / SoCalGas
APGA Research Foundation
Northwest Energy Efficiency Alliance
Enbridge Gas
SEMCO



GTI Energy Overview: Developing solutions for resilient, low-cost energy systems



We work collaboratively to address critical energy challenges impacting gases, liquids, efficiency and infrastructure



GTI Energy Commercial Water Heating Test Rig



Indoor installation

Outdoor installation



Ability to simulate component configurations (buffer / swing tank, various recirc loop lengths, boiler integration, etc)

Growing Dual-Fuel Research and Deployment in Residential and Commercial Buildings



Lab Testing and Product Validation

- Testing emerging controllers from manufacturers like Navien, iFLOW, Napoleon, GreenBox
- Lab characterization of emerging dual-fuel heat pumps from major OEMS like Carrier, Mitsubishi

Energy Modeling

- Web-interactive tool for Hybrid Heating comparison
- Techno-Economic Assessment Tool covers 10 cities across North America

Field Demonstrations

- Large scale hybrid heating demo for Cascade Natural Gas in Bend, OR (climate zone 5B).
- Hybrid commercial water heating (Lync Aegis)
- Dual fuel rooftop units



The logo for the GTI Energy Emerging Technology Program (ETP), featuring a green circular icon with a circuit-like pattern and the text "GTI ENERGY EMERGING TECHNOLOGY PROGRAM (ETP)" in blue.

Hybrid (Dual-Fuel) Heating Emissions and Cost Comparison Tool

Download PDF

Inputs

Cities
Des Plaines, IL

Home Vintage
1980 Vintage

Hybrid Model
Furnace Baseline 80%

Equipment Models
80% AFUE Furnace, 90% AFUE Furnace, 95% AFUE Furnace, ASHP, ccASHP, Hybrid 3 (Furnace + ASHP), Hybrid 4 (Furnace + ccASHP)

Hybrid Control Strategy
Hybrid Cost Optimization, Hybrid Emission Optimization, Hybrid Switchover Temperature

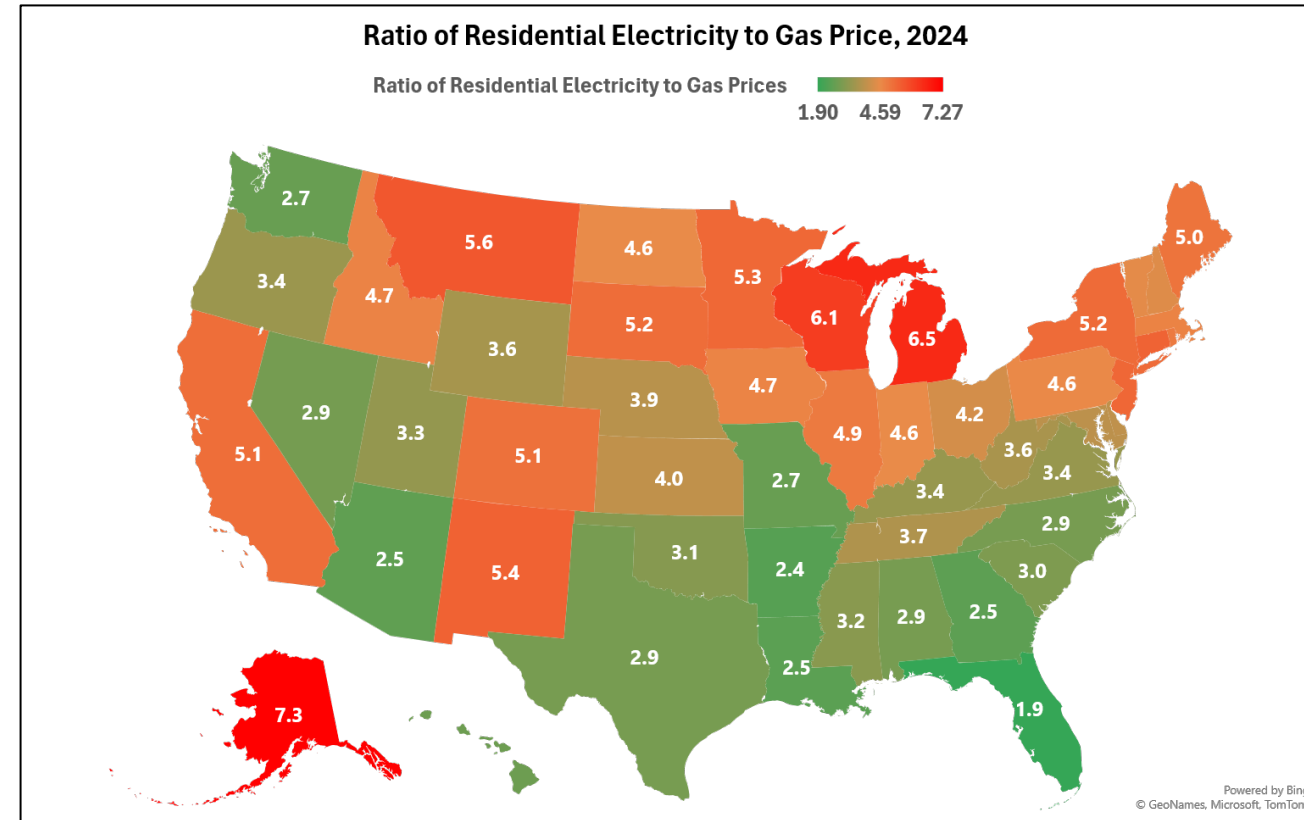
Hybrid 2 Switchover Temperature
20°, 30°, 40°

Result

Annual Space Heating Cost (\$/year)
City: Des Plaines, IL; Average Electricity Rate: \$0.13/kWh; Average Natural Gas Rate: \$0.64/therm; Electricity Grid: 1,204 lbCO2/MWh(Annual Average)

Product Evaluation Methodology

- GTI Energy engagement in residential and comm hybrid products:
 - Air source heat pumps with natural gas boiler
 - Air source heat pumps with gas furnace
 - Air to water heat pumps with gas tankless
- GTI Energy and Navien has had extended product collaboration over the past year
 - Detailed review of the components and controls
 - Two near-production prototypes evaluated with GTI Energy.
 - Testing began Q4 2025 on DFHP water heaters
 - Refinement of controls



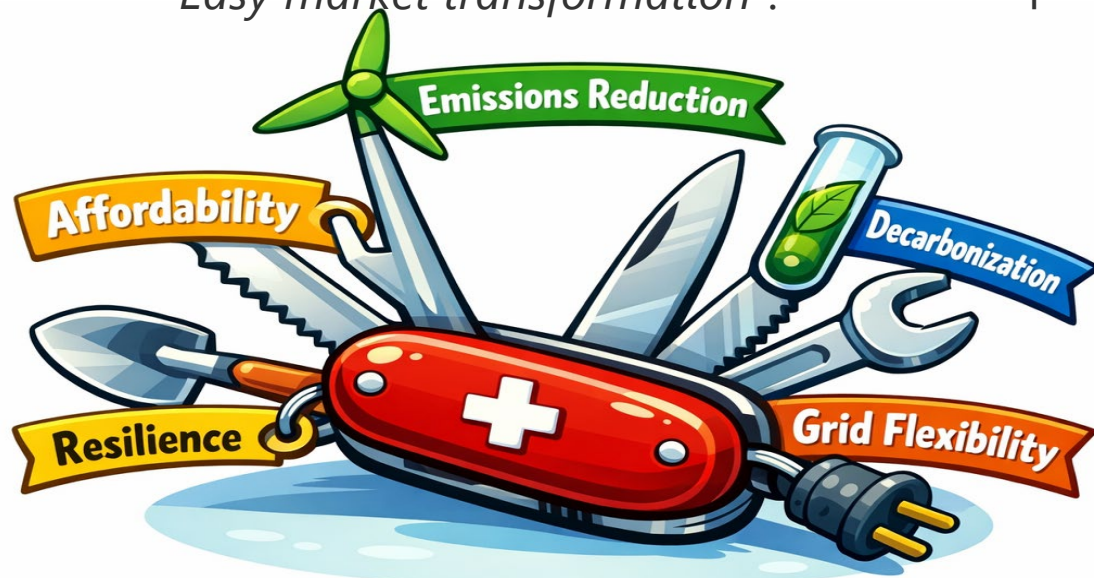
Why **dual-fuel** 120V water heaters?

- Dual-Fuel water heating potential benefits:

- Energy efficiency
- Affordability
- Emissions reduction
- Grid flexibility
- *Comfort (no run-outs)?*
- *Installation cost and barriers?*
- *Easy market transformation?*

Lab tests

Field pilots



Source: AI generated

Emerging Product Category



Navien dual-fuel hybrid WH

Source: GTI Energy



Rheem dual-fuel hybrid WH

Source: Rheem



Others coming?

Source: AI generated

Residential Dual-Fuel Heat Pump Water Heater



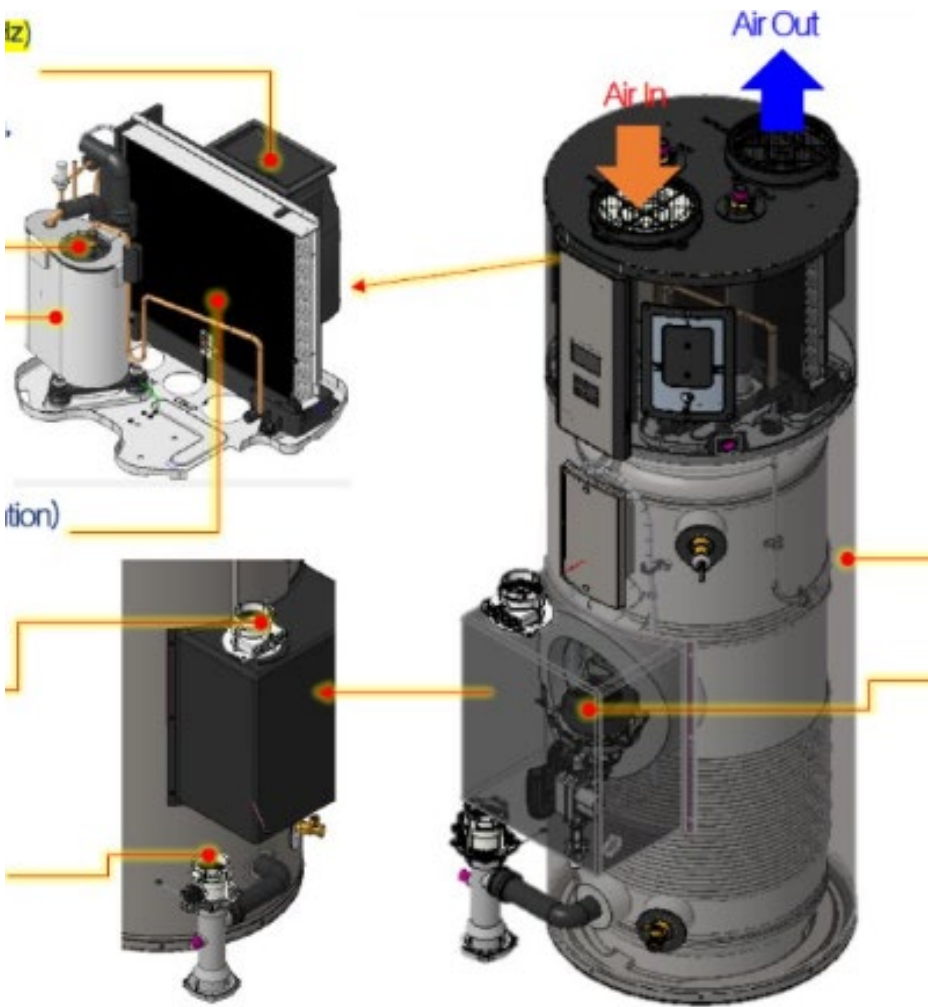
Residential Dual-Fuel Heat Pump Water Heater

Published Information - Navien NXW700	
Heating Capacity (Btu/h)	60,000
Nominal Capacity (gal)	50
Rated Storage Volume (gal)	47
Uniform Energy Factor (UEF)	3.80
First Hour Rating (FHR)	100
Recovery (90°F rise in gal/h)	80

Operating Modes	Description
E-Saver (default)	Hybrid mode prioritizing efficiency with HP primary; gas back-up for fast recovery.
Hi-Demand	Hybrid mode prioritizing fast hot water recovery for larger volume users.
Gas only	Fast recovery time with minimal electric usage <i>(for testing setup only)</i>
Heat Pump only	Maximum energy savings using only the heat pump. Results in longer recovery times.

Electric
400 W
compressor

Fuel-fired
60 MBH
condensing
burner unit

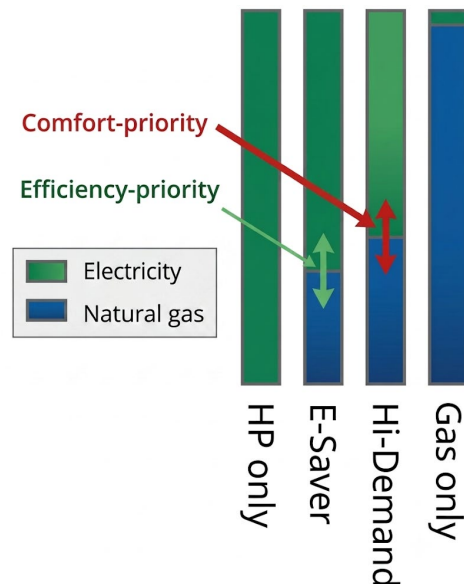


Dual-Fuel Heat Pump Water Heater

Control Modes and Experimental Setup

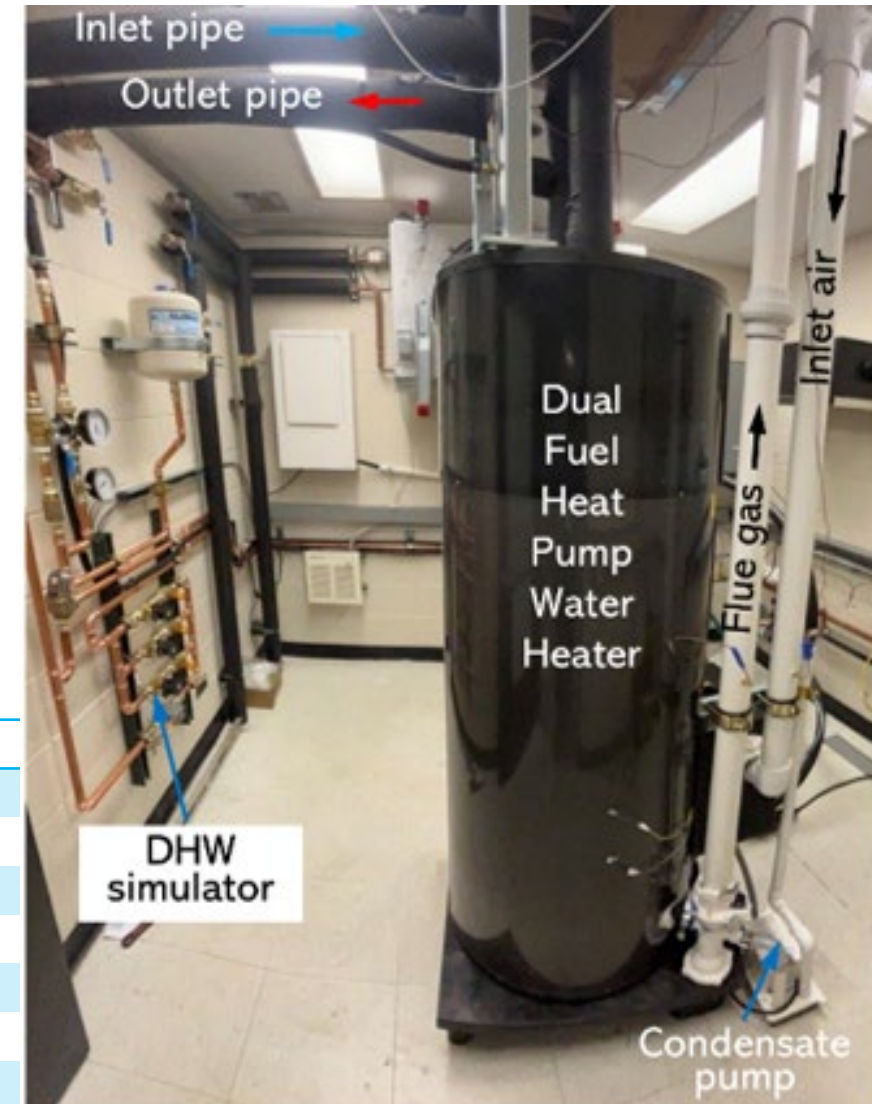
Operating Modes	120V Plug-in heat pump with condensing gas backup
E-Saver (default)	Hybrid mode prioritizing efficiency with heat pump primary heat source; gas back-up for fast recovery.
Hi-Demand	Hybrid mode prioritizing faster hot water recovery for larger volume users.
Gas only	Fast recovery time with minimal electric usage (<i>for testing only</i>)
Heat Pump only	Maximum energy savings using only the heat pump. Results in longer recovery times.

Generally representative energy inputs for each mode
Source: GTI Energy



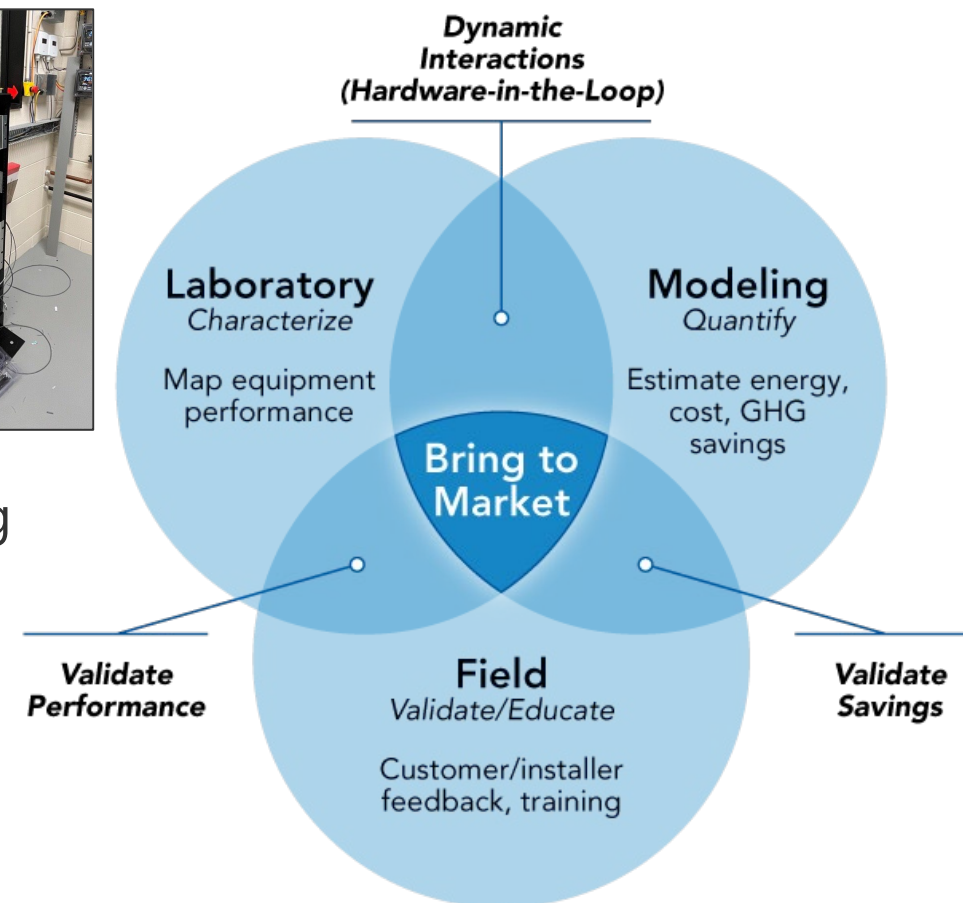
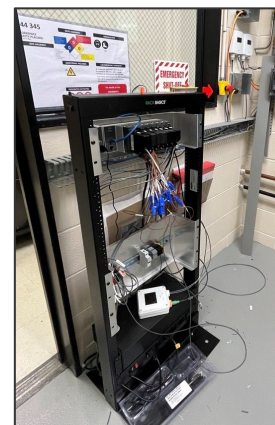
Lab assessed via:

- Gas meter
- Temperatures
- Ambient Temp and RH
- City water in
- Hot water out
- Water loops
- Electricity use

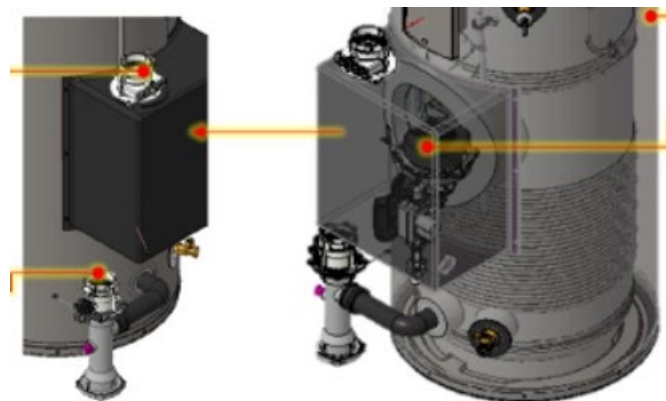


Test Methodology – Modeling Development

- Initial testing across operating conditions:
 - UEF and FHR
 - High and low flow rates
 - Some operating modes
- Selected manufacturer test data evaluated for modeling
- Testing provides inputs for performance modeling
- Evaluating energy and cost for 6 cities:
 - Los Angeles CA, Portland OR, Boise ID, Port Huron MI, Toronto ON, Atlanta GA
- Provides solid basis for performance evaluation and potential field demonstrations



Flexible sizes for combustion system

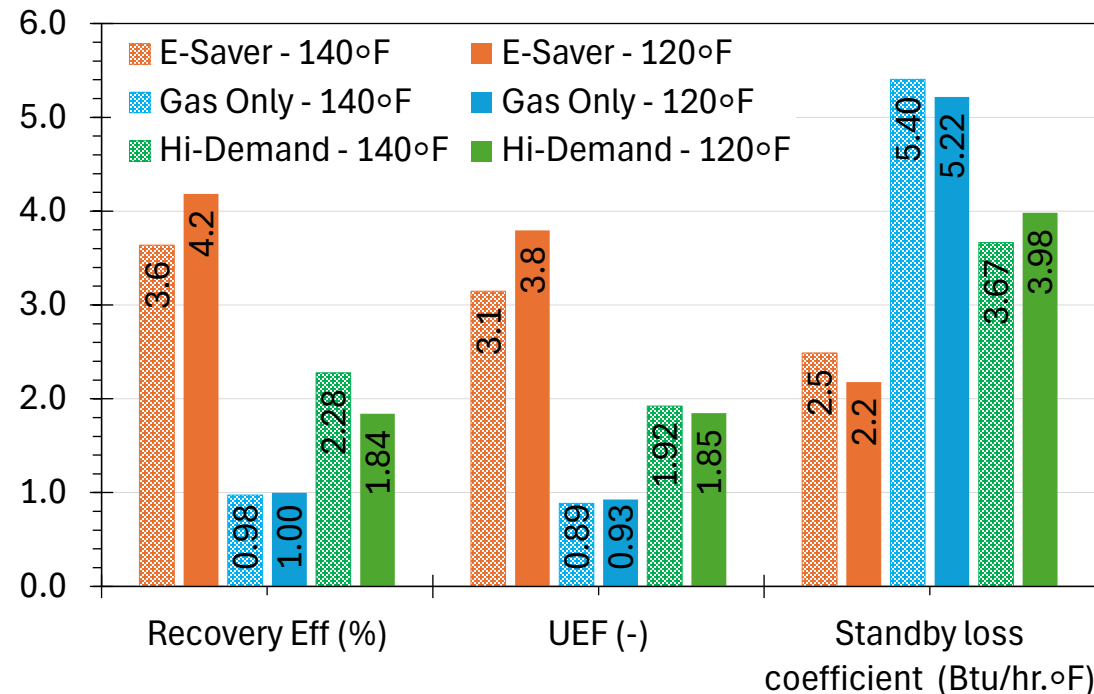


Parameter	40 MBH unit			60 MBH unit		
	E-Saver	Gas Only	Hi-Demand	E-Saver	Gas Only	Hi-Demand
FHR	81.67			98.18		
Recovery efficiency	4.27	0.89	0.95	4.18	0.998	1.84
UEF	3.86	0.88	1.22	3.79	0.93	1.85

Dual-Fuel Heat Pump Water Heater

Experimental Results

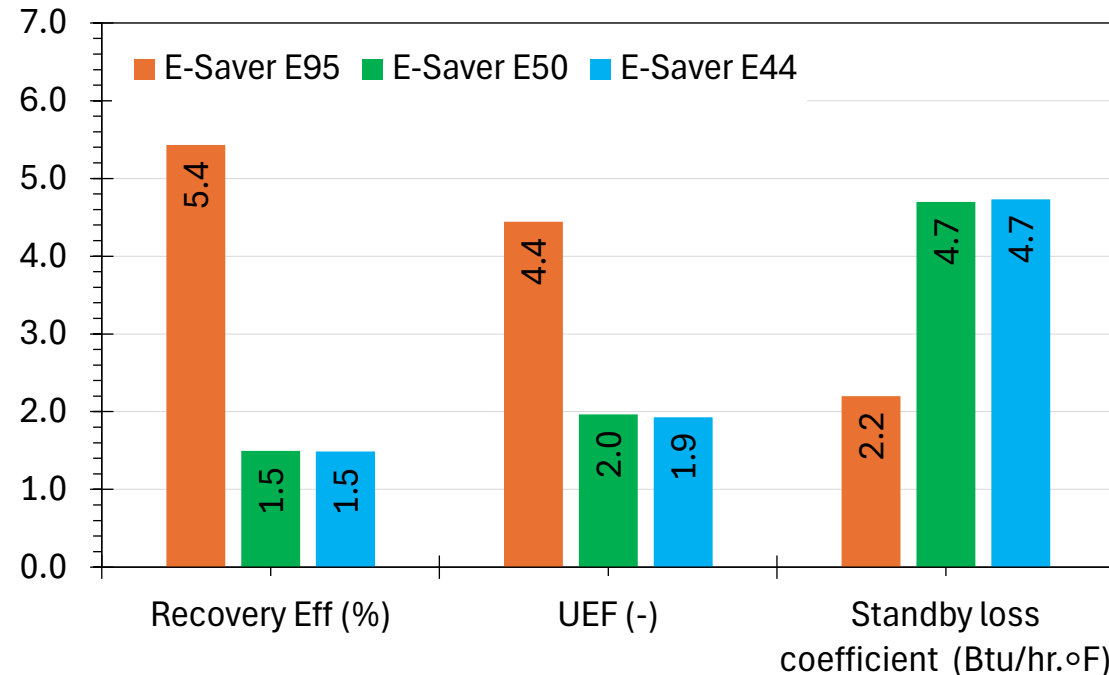
UEF Test



Recovery efficiency, UEF, and standby loss coefficient at 120 °F and 140 °F.

- Higher setpoint → higher standby losses

UEF Test – Optional tests



Recovery efficiency, UEF and standby loss coefficient of E-Saver mode during **the optional tests**.

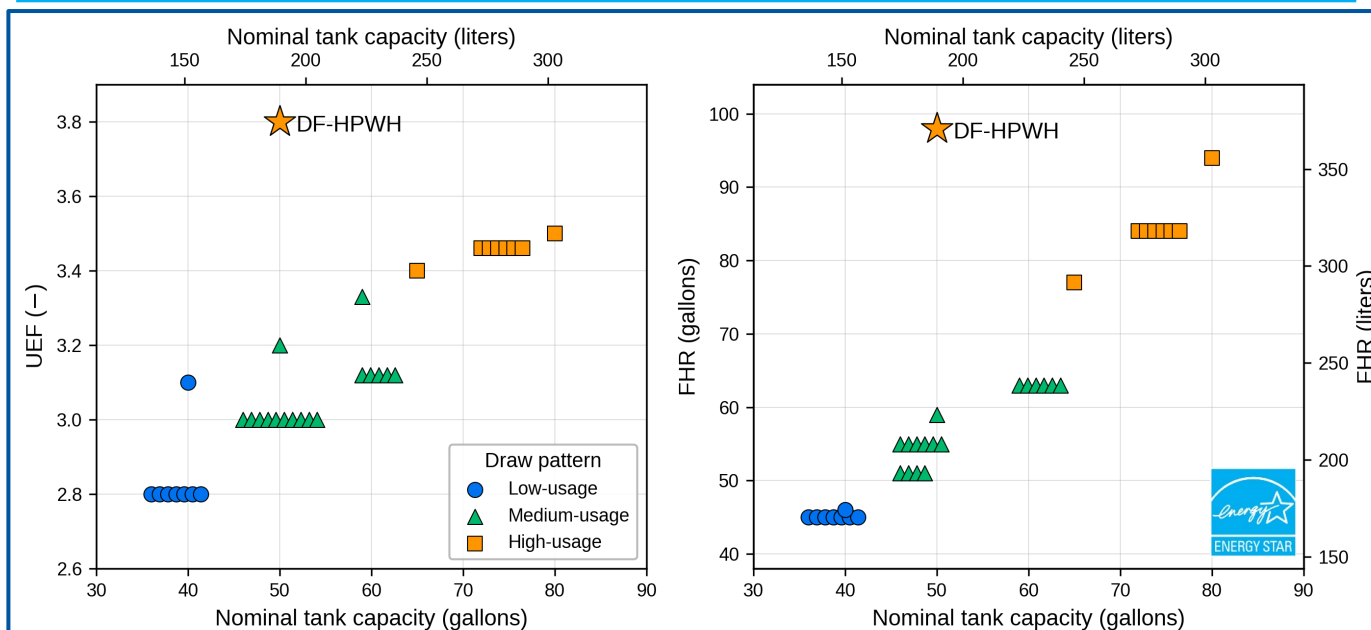
Test Name	E95	E50	E44
City water inlet temperature (°F)	67	50	50
Ambient temperature (°F)	95	50	44
Ambient relative humidity	40	58	58
Setpoint (°F)	120	120	120
Draw profile	High-usage		

Dual-Fuel Heat Pump Water Heater

Experimental Results – 60 MBH unit

Tests Summary

Parameter	E-Saver	Gas	High-Demand
Setpoint, °F	120	120	120
Avg delivered temp, °F	118.0	119.4	121.8
Avg inlet temp, °F	58.7	58.0	58.3
Recovery efficiency (%)	4.18	0.998	1.85
Standby loss coefficient, Btu/hr. °F	2.18	5.22	3.98
Energy delivered, kBtu	41.50	42.30	44.14
Electrical consumption, kwh	3.22	0.138	2.62
Gas consumption, kBtu	0	44.00	14.48
UEF	3.80	0.93	1.85



Across 120 V HPWHs...

Using the same tank size, DF-HPWH increased the **UEF by > 20%** (left), and **FHR by > 60%** (right)

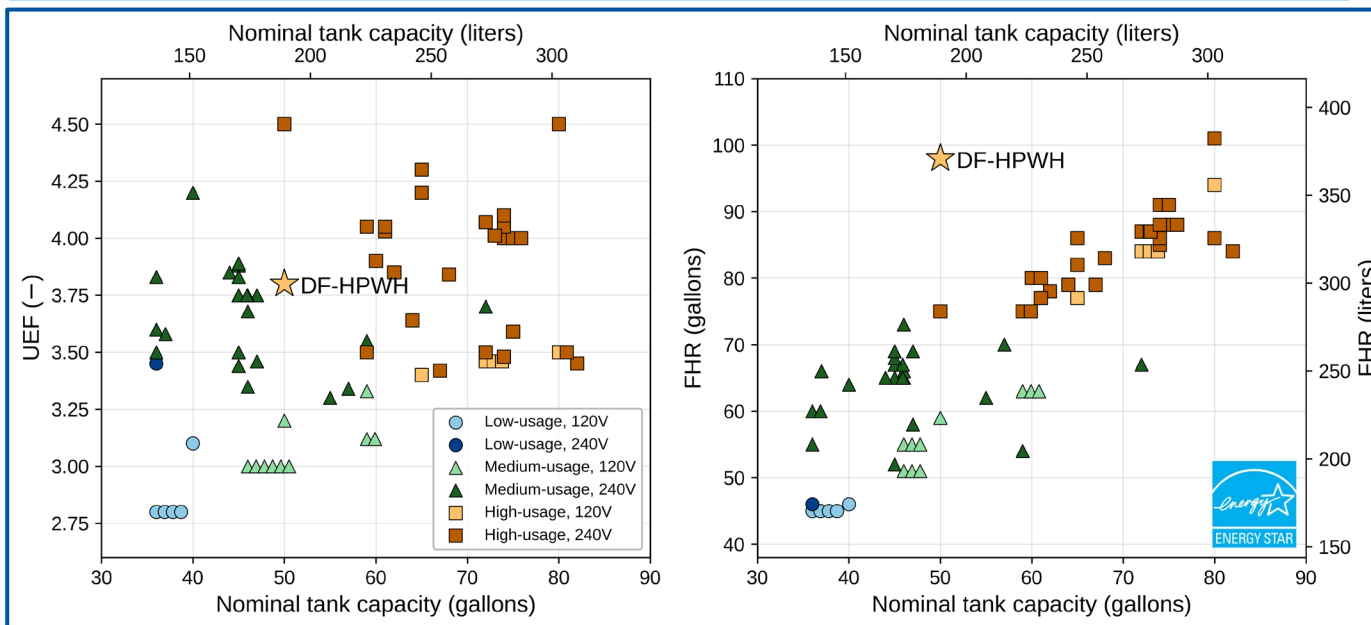
Source: ENERGY STAR
published rating information

Dual-Fuel Heat Pump Water Heater

Experimental Results – 60 MBH unit

Tests Summary

Parameter	E-Saver	Gas	High-Demand
Setpoint, °F	120	120	120
Avg delivered temp, °F	118.0	119.4	121.8
Avg inlet temp, °F	58.7	58.0	58.3
Recovery efficiency (%)	4.18	0.998	1.85
Standby loss coefficient, Btu/hr. °F	2.18	5.22	3.98
Energy delivered, kBtu	41.50	42.30	44.14
Electrical consumption, kwh	3.22	0.138	2.62
Gas consumption, kBtu	0	44.00	14.48
UEF	3.80	0.93	1.85



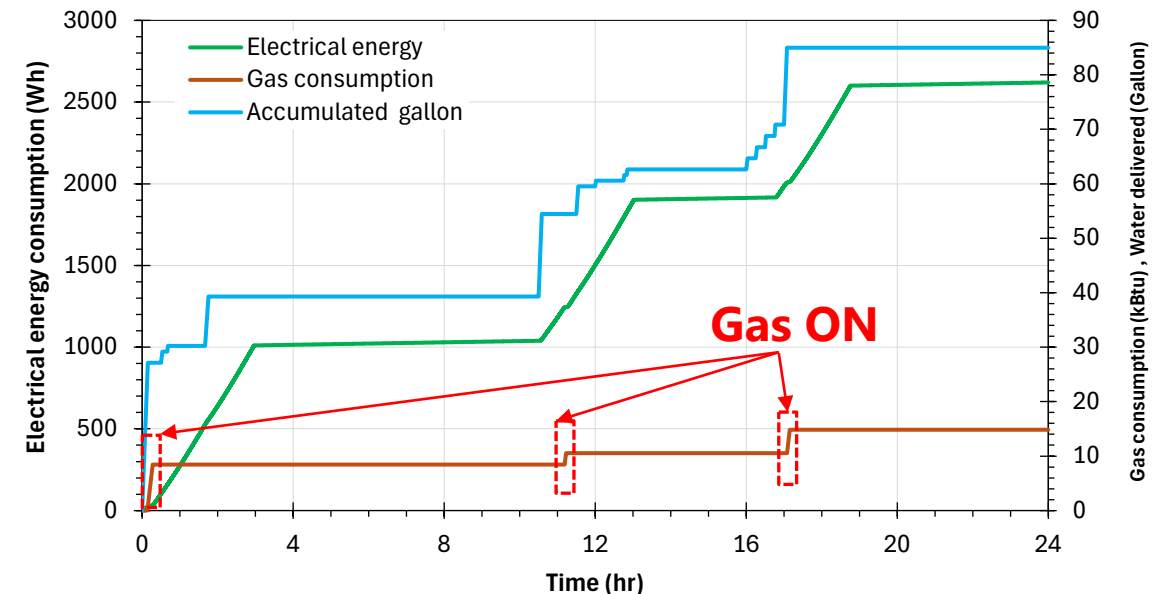
Across 120V & 240V HPWHs...
 UEF was middle of market range
 FHR is significantly faster

Source: ENERGY STAR
 published rating information

Dual-Fuel Heat Pump Water Heater

Dual-Fuel operation

- The figure reflects the dynamic interaction between the heat pump and gas backup.
- Gas runs for **a couple of minutes**. Capturing these rapid switching requires a **high-resolution model**.
- Specifically, the simulation time step must be **smaller than** the shortest draw event.
- Otherwise, the model may **not capture** burner cycling, heat pump operating, and **inaccurately** estimate system efficiency, energy use, and emissions.
- **NEED for a calibrated high-resolution MODEL.**

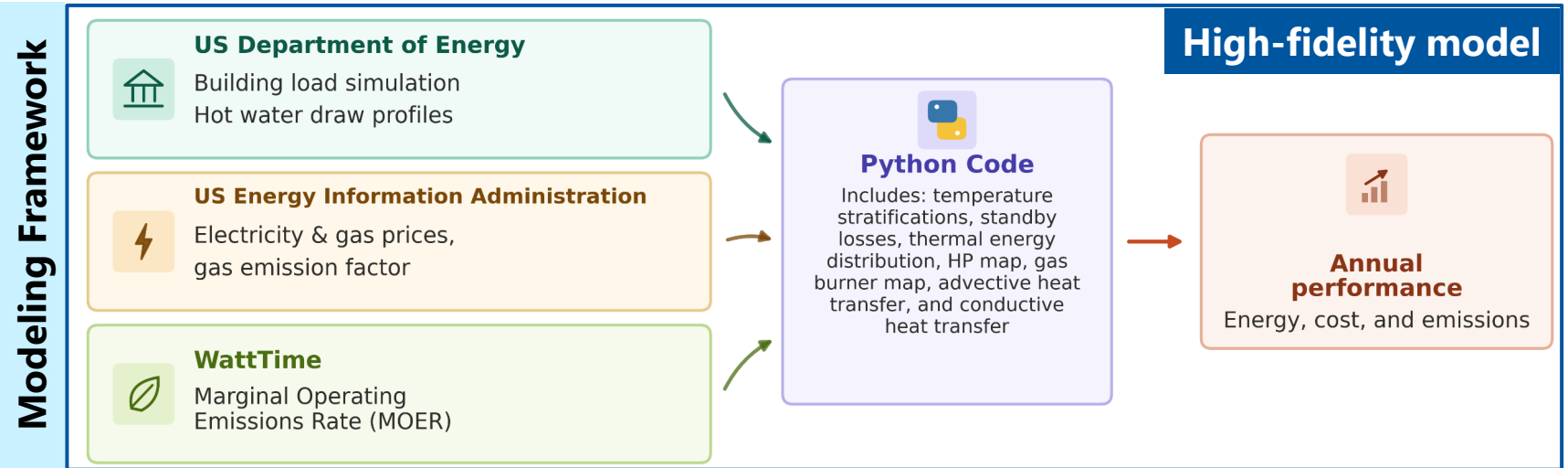


24-hr profile of energy consumption and draws for Hi-Demand mode.

Dual-Fuel Heat Pump Water Heater

Modeling

High-resolution,
physics-based model

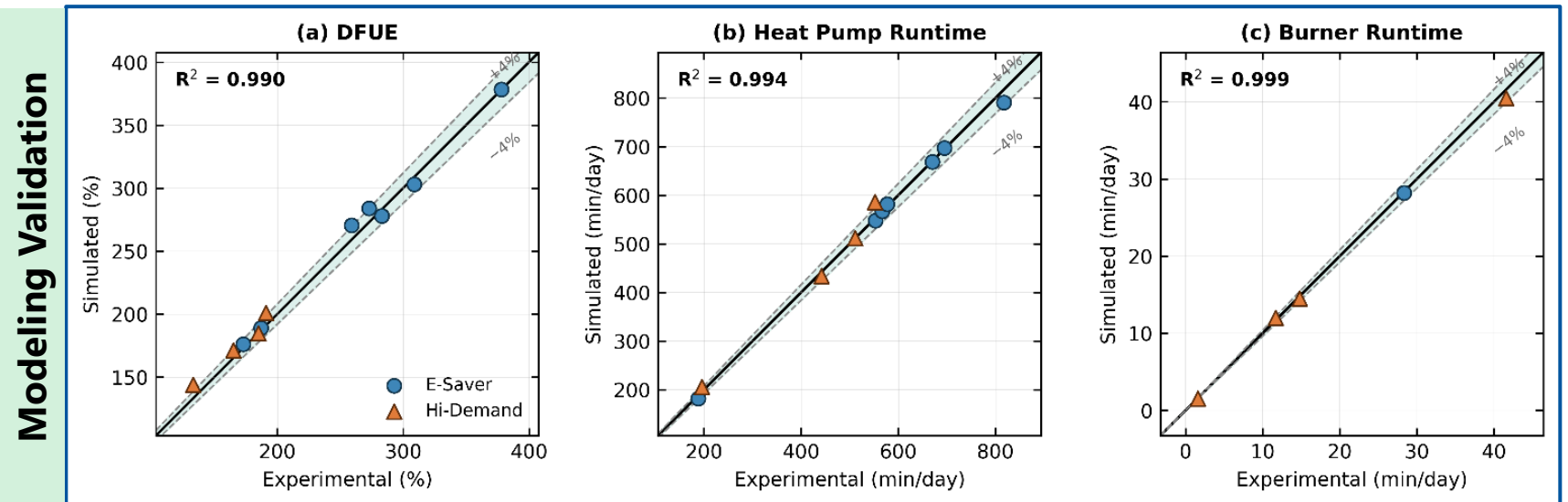


Exp. vs. model is < 4%

Simulate 14 locations
Indoor, basement and
garage installation.

5 bd, 3 bd, and TOU
400+ cases

120°F setpoint



Dual-Fuel Heat Pump Water Heater

Modeling Results

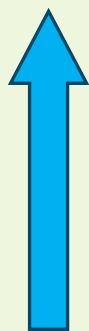
$$DFUE = \frac{\dot{Q}_{out}}{\dot{Q}_{in} + \dot{W}_{in}}$$

Heat Pump
E-Saver
Hi-Demand
Gas



$$CM = \frac{\text{Duration when } T_{DHW} > 105^{\circ}\text{F}}{\text{Total draw duration}}$$

Hi-Demand
Gas
E-Saver
Heat Pump



DFUE (%) by City and Mode — Split by Install Location
(each cell: top band = Indoor (ID), middle = Garage (GR), bottom = Basement (BM))

Toronto, ON	ID	91%	ID	197%	ID	232%	ID	372%
	BM	90%	BM	185%	BM	216%	BM	341%
	GR	84%	GR	116%	GR	128%	GR	180%
San Diego, CA	ID	88%	ID	206%	ID	279%	ID	399%
	BM	86%	BM	194%	BM	262%	BM	372%
	GR	86%	GR	194%	GR	263%	GR	371%
Portland, OR	ID	90%	ID	204%	ID	252%	ID	391%
	BM	87%	BM	187%	BM	231%	BM	351%
	GR	85%	GR	168%	GR	205%	GR	300%
Port Huron, MI	ID	91%	ID	199%	ID	236%	ID	375%
	BM	89%	BM	186%	BM	222%	BM	342%
	GR	85%	GR	133%	GR	152%	GR	216%
Palm Springs, CA	ID	85%	ID	157%	ID	264%	ID	350%
	BM	83%	BM	154%	BM	251%	BM	331%
	GR	85%	GR	155%	GR	249%	GR	333%
Orlando, FL	ID	86%	ID	195%	ID	296%	ID	391%
	BM	85%	BM	191%	BM	285%	BM	379%
	GR	86%	GR	194%	GR	289%	GR	385%
Oakland, CA	ID	89%	ID	206%	ID	261%	ID	399%
	BM	87%	BM	194%	BM	246%	BM	366%
	GR	86%	GR	183%	GR	232%	GR	342%
Los Angeles, CA	ID	88%	ID	207%	ID	276%	ID	401%
	BM	87%	BM	197%	BM	263%	BM	378%
	GR	86%	GR	194%	GR	257%	GR	370%
Kansas City, MO	ID	90%	ID	198%	ID	242%	ID	374%
	BM	89%	BM	188%	BM	228%	BM	346%
	GR	85%	GR	139%	GR	161%	GR	227%
Fresno, CA	ID	88%	ID	197%	ID	263%	ID	380%
	BM	85%	BM	184%	BM	246%	BM	347%
	GR	85%	GR	179%	GR	236%	GR	331%
Chicago, IL	ID	91%	ID	198%	ID	236%	ID	372%
	BM	88%	BM	180%	BM	215%	BM	330%
	GR	84%	GR	128%	GR	146%	GR	210%
Bozeman, MT	ID	92%	ID	162%	ID	183%	ID	278%
	BM	89%	BM	176%	BM	203%	BM	320%
	GR	85%	GR	116%	GR	128%	GR	188%
Boise, ID	ID	90%	ID	197%	ID	239%	ID	370%
	BM	88%	BM	181%	BM	218%	BM	328%
	GR	85%	GR	147%	GR	172%	GR	244%
Atlanta, GA	ID	88%	ID	197%	ID	257%	ID	375%
	BM	87%	BM	188%	BM	243%	BM	351%
	GR	85%	GR	166%	GR	210%	GR	292%

Gas Only

Hi-Demand

E-Saver

HP Only

Comfort Metric (%) by City and Mode — Split by Install Location
(each cell: top band = Indoor (ID), middle = Garage (GR), bottom = Basement (BM))

Toronto, ON	ID	95.7%	ID	99.2%	ID	95.9%	ID	82.4%
	BM	95.8%	BM	99.1%	BM	95.6%	BM	80.7%
	GR	95.9%	GR	99.0%	GR	90.8%	GR	53.5%
San Diego, CA	ID	97.7%	ID	99.8%	ID	97.1%	ID	91.5%
	BM	97.8%	BM	99.7%	BM	97.0%	BM	90.8%
	GR	97.7%	GR	99.8%	GR	97.0%	GR	91.0%
Portland, OR	ID	96.7%	ID	99.5%	ID	96.0%	ID	87.2%
	BM	96.7%	BM	99.5%	BM	95.9%	BM	85.4%
	GR	96.8%	GR	99.6%	GR	95.7%	GR	83.2%
Port Huron, MI	ID	96.0%	ID	99.3%	ID	96.1%	ID	84.5%
	BM	96.2%	BM	99.4%	BM	95.8%	BM	83.1%
	GR	96.4%	GR	99.2%	GR	93.2%	GR	67.8%
Palm Springs, CA	ID	98.7%	ID	99.9%	ID	96.5%	ID	92.3%
	BM	98.7%	BM	99.8%	BM	96.8%	BM	92.4%
	GR	98.8%	GR	99.9%	GR	95.7%	GR	91.2%
Orlando, FL	ID	98.3%	ID	99.8%	ID	97.5%	ID	93.8%
	BM	98.5%	BM	99.8%	BM	97.5%	BM	93.5%
	GR	98.6%	GR	99.9%	GR	97.5%	GR	93.7%
Oakland, CA	ID	97.0%	ID	99.7%	ID	96.4%	ID	88.9%
	BM	97.1%	BM	99.6%	BM	95.8%	BM	87.2%
	GR	96.9%	GR	99.6%	GR	95.8%	GR	86.7%
Los Angeles, CA	ID	97.7%	ID	99.7%	ID	97.0%	ID	91.0%
	BM	97.6%	BM	99.7%	BM	96.8%	BM	90.3%
	GR	97.6%	GR	99.7%	GR	96.5%	GR	90.3%
Kansas City, MO	ID	96.6%	ID	99.4%	ID	96.1%	ID	87.0%
	BM	96.5%	BM	99.5%	BM	96.0%	BM	85.5%
	GR	96.8%	GR	99.4%	GR	93.7%	GR	74.4%
Fresno, CA	ID	97.8%	ID	99.8%	ID	97.0%	ID	91.1%
	BM	97.7%	BM	99.8%	BM	96.7%	BM	90.1%
	GR	97.7%	GR	99.7%	GR	96.7%	GR	89.6%
Chicago, IL	ID	96.2%	ID	99.4%	ID	96.0%	ID	84.6%
	BM	96.4%	BM	99.4%	BM	95.6%	BM	82.9%
	GR	96.4%	GR	99.2%	GR	92.9%	GR	64.6%
Bozeman, MT	ID	95.6%	ID	99.0%	ID	94.6%	ID	73.6%
	BM	95.8%	BM	99.1%	BM	95.4%	BM	78.6%
	GR	95.7%	GR	98.8%	GR	91.5%	GR	53.8%
Boise, ID	ID	96.5%	ID	99.4%	ID	96.0%	ID	85.5%
	BM	96.5%	BM	99.5%	BM	95.4%	BM	83.6%
	GR	96.5%	GR	99.2%	GR	94.5%	GR	77.6%
Atlanta, GA	ID	97.4%	ID	99.7%	ID	96.6%	ID	89.8%
	BM	97.6%	BM	99.8%	BM	96.3%	BM	89.2%
	GR	97.3%	GR	99.7%	GR	96.4%	GR	87.6%

Gas Only

Hi-Demand

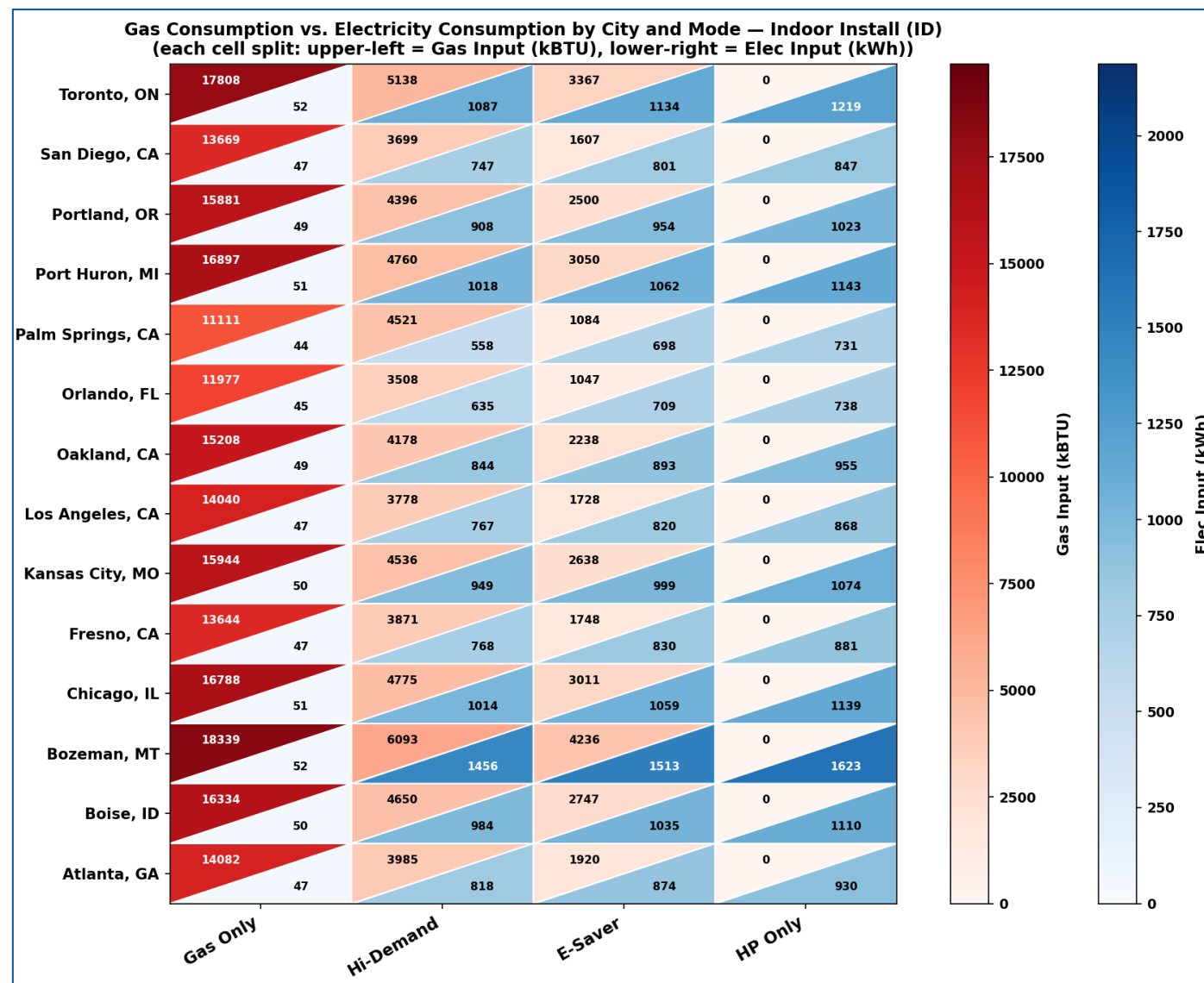
E-Saver

HP Only

Dual-Fuel Heat Pump Water Heater Modeling Results

Annual Energy Consumption

- Colder climates have higher energy consumption in all operating modes.
- HP only mode has the higher electricity consumption.
- Relative to Gas only mode, E-Saver mode achieves the largest gas savings (typically 75-80%) vs. 60-70% for Hi-Demand mode.
- Hi-Demand mode increases gas consumption across all simulated locations and installations, enabling faster tank recovery and reducing the duration of sub-105 °F hot water delivery.



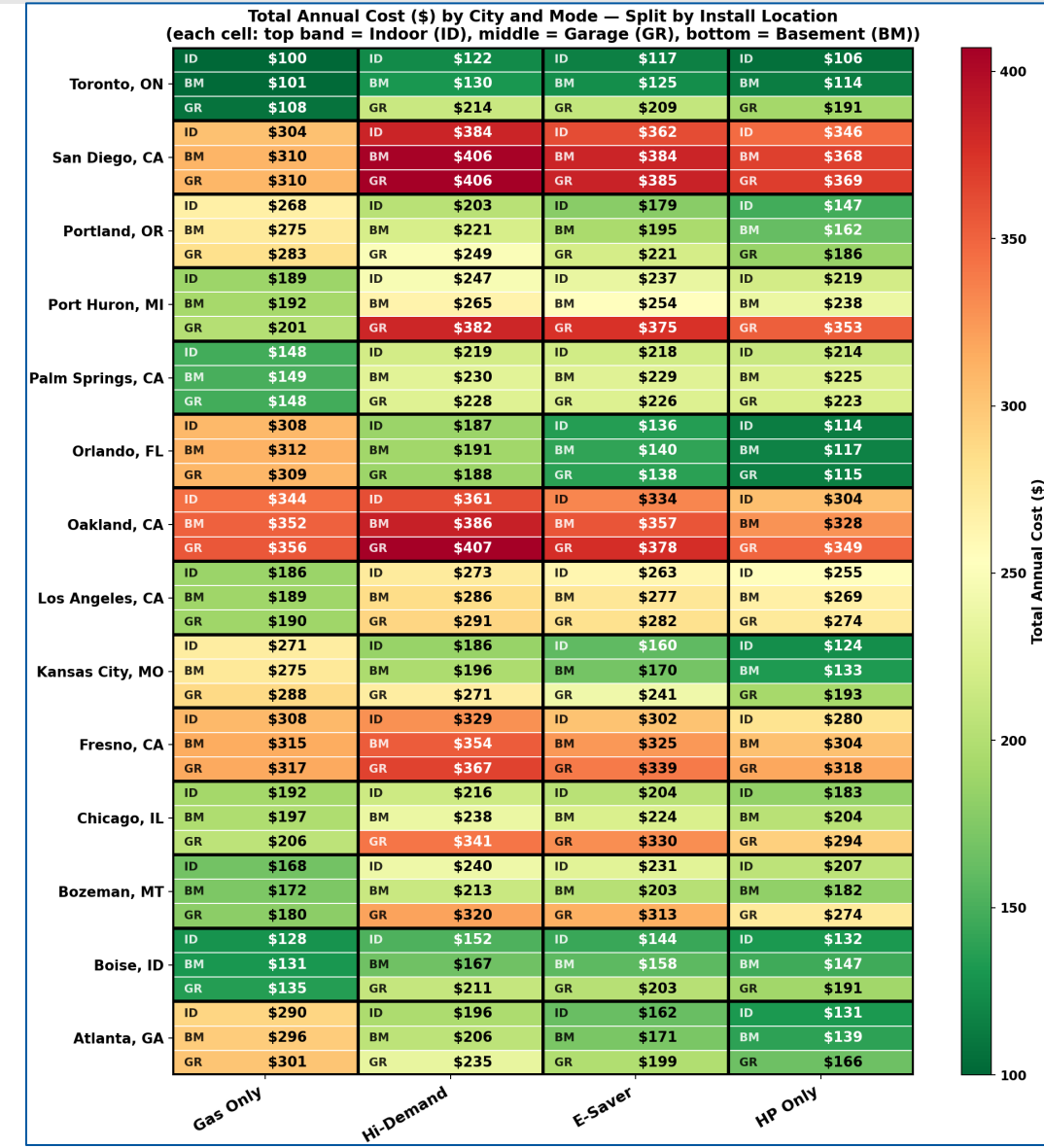
Dual-Fuel Heat Pump Water Heater Modeling Results



Annual Operating Cost

- Cost: Indoor (ID) < Basement (BM) < Garage (GR).
- This suggests that installing the unit in a conditioned indoor space improves heat pump performance and reduces energy consumption.
- Cold climate cities benefit the most from dual-fuel modes.

When comfort is considered, regions with high electricity prices may favor hybrid operation over full electrification.



Dual-Fuel Heat Pump Water Heater Modeling Results



Annual Emissions

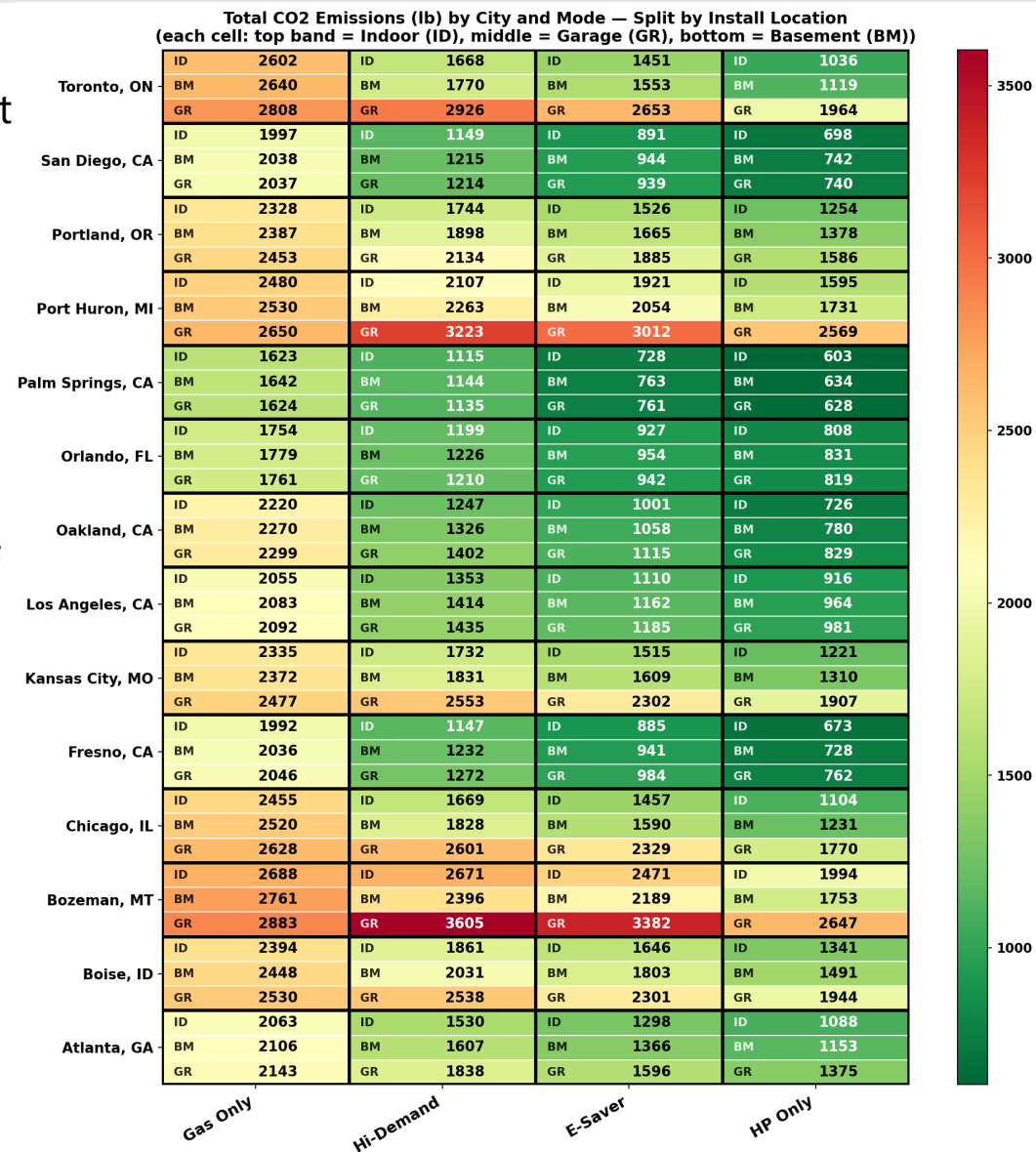
- HP Only produces the lowest CO₂ emissions but not always the lowest cost

Examples (Indoor): Switch from Gas only to HP only mode.

- Oakland: 2220 → 726 lb CO₂ (67% reduction)
- Toronto: 2602 → 1036 lb CO₂ (60% reduction)

- Compared to Gas Only, E-Saver reduces emissions by about 30-60%, depending on climate.
- Compared to Gas Only, California cities achieved the largest percentage of emissions reductions.

Across all climate zones, the DF-HPWH reduces the annual CO₂ emissions compared with Gas-only mode.



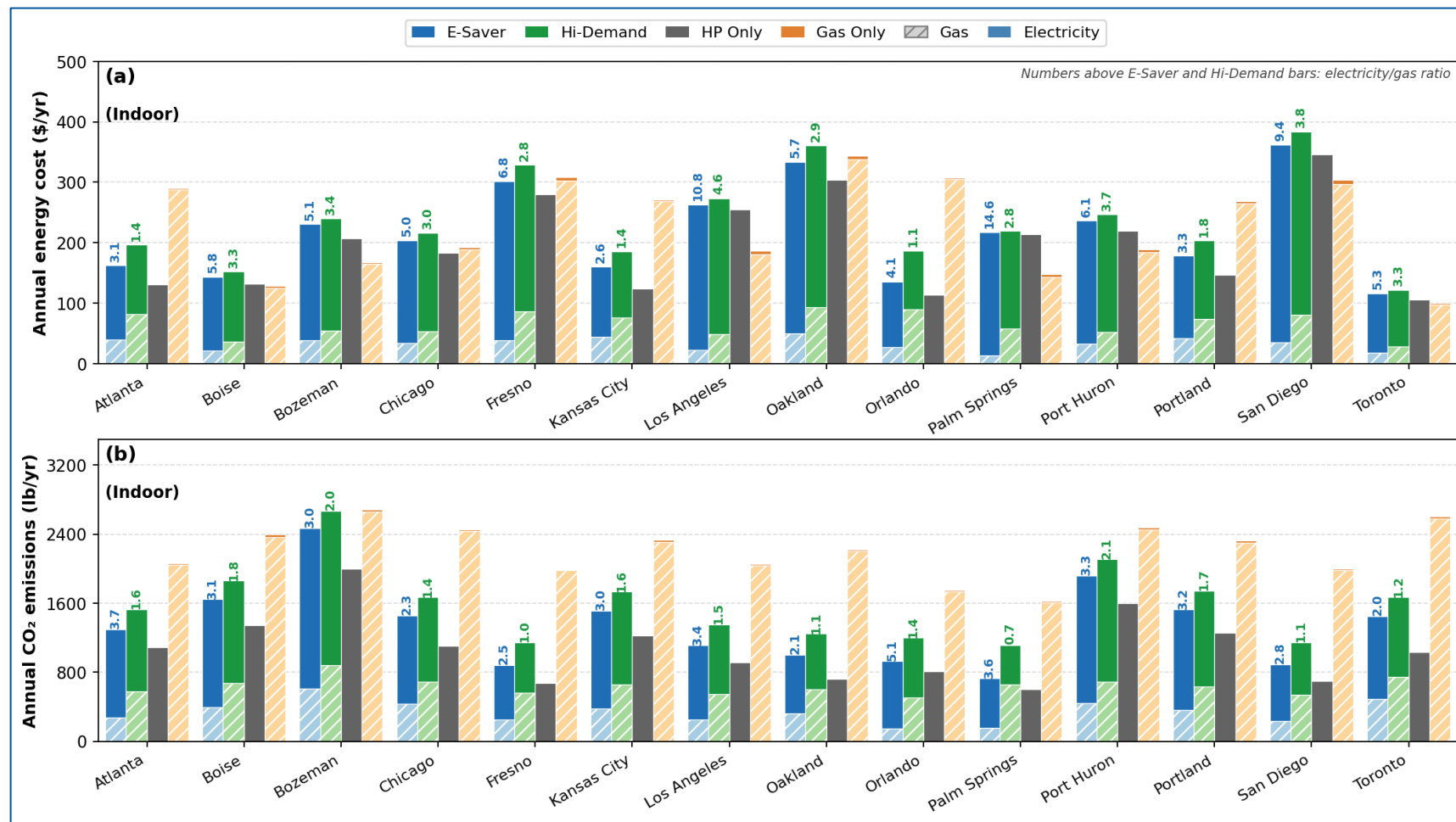
Dual-Fuel Heat Pump Water Heater

Modeling Results Indoor installation

An electricity-to-gas cost ratio of 3.0 means that for every \$1 spent on natural gas, the end user would spend \$3 on electricity.

Electricity to Gas ratios above the bars

- The ratio is higher for E-Saver mode.



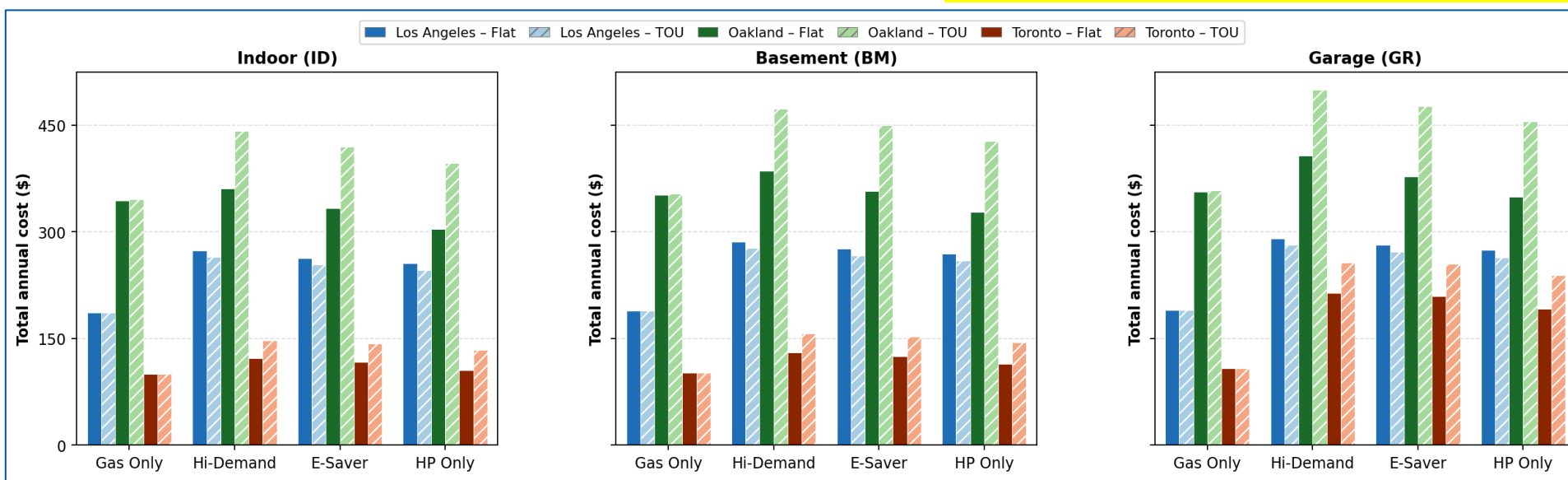
Dual-Fuel Heat Pump Water Heater

Time-of-Use rates

The unit does not switch, and the goal was to explore the potential...

- As expected, the Gas Only mode is unaffected by the electricity rate because electricity consumption is negligible.
- In Los Angeles, TOU pricing has only a minor influence on total annual operating cost because the standard electricity rate is 0.302 \$/kWh while the average TOU is about 0.293 \$/kWh.
- Oakland shows a different trend. The TOU increases annual operating costs for all heat pump-assisted modes, with the largest increase observed for HP Only operation. **These results indicate that a large fraction of water heating demand occurs during high-price electricity periods.**

FUTURE: TOU based control mode within E-Saver/Hi-Demand.



Dual-Fuel Heat Pump Water Heater

Modeling Results Comparative Analysis

Baseline DHW systems that were modeled

Baseline DHW Systems	Tank Size (gallon)	UEF and FHR	Capacity
Gas Tank Water Heater	50	UEF = 0.62 and FHR = 75 gal	60 MBH
Electric Tank Water Heater	50	UEF = 0.92 and FHR = 75 gal	2 elements of 5.5 kW each
240V Hybrid/Electric HPWH	50	UEF = 4.5 and FHR = 77 gal	5.5 kW upper element and 3.6 kW lower element
120V Hybrid/Electric HPWH	50	UEF = 3.2 and FHR = 59 gal	2 elements of 0.9 kW each

- We simulated 14 locations for E-Saver and Hi-Demand mode in indoor and basement installations.
- 5 bedroom/3 bathroom and 3 bedroom/2 bathroom buildings.
- For 5 bedroom/3 bathroom: 120 V HPWH baseline was excluded because it does not meet the DHW load.

Dual-Fuel Heat Pump Water Heater

Modeling Results Comparative Analysis

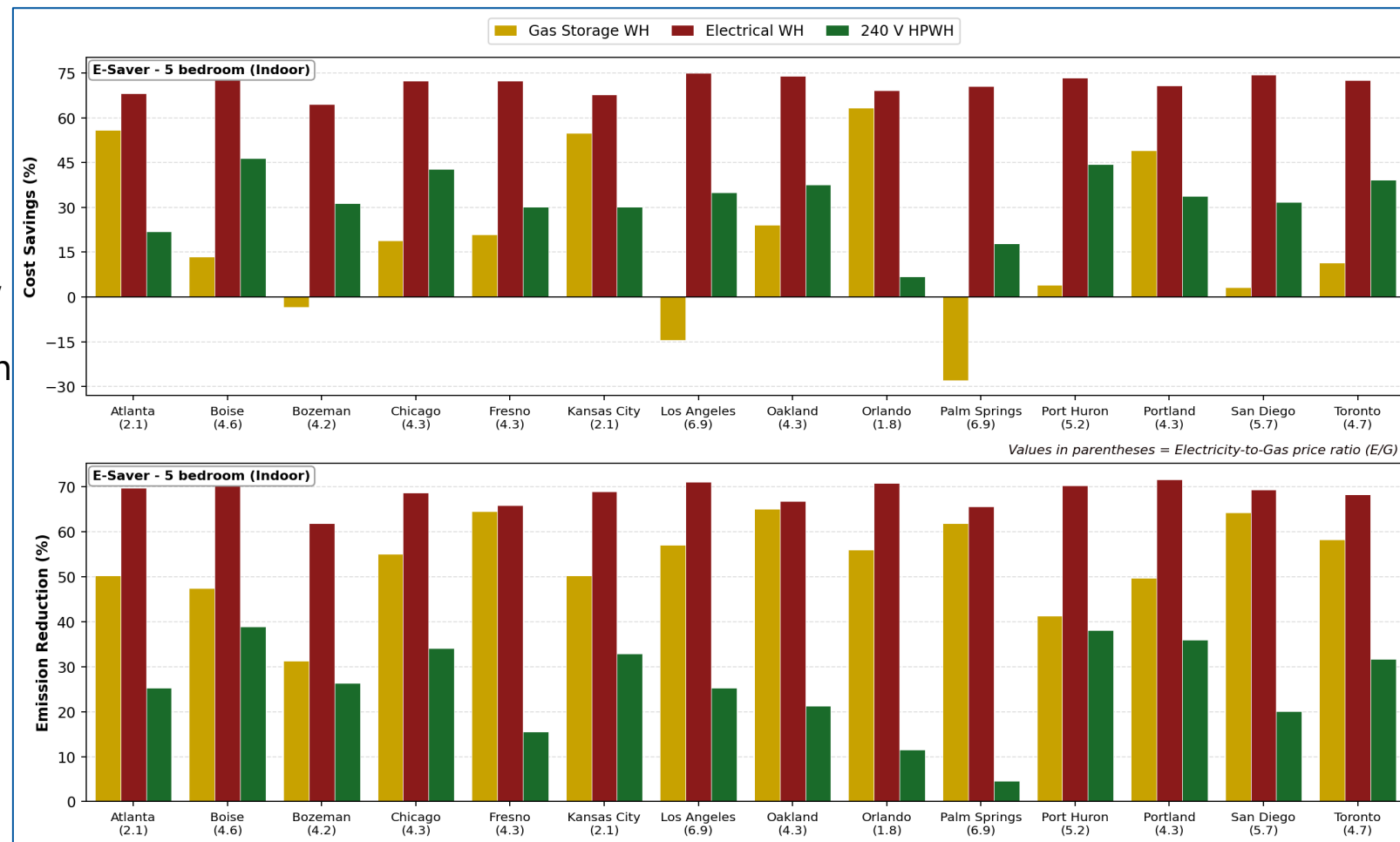
Cost Savings:

- Compared to electric resistance water heaters, cost savings range from 63–75%.
- Compared to gas storage water heaters, cities with low E/G ratios, such as Orlando, Atlanta, and Kansas City (E/G = 1.8-2.1) achieve cost savings of 47–63%. Cities with high E/G ratios (more than 6.5) show cost increases (Palm Spring and Los Angeles).
- Costs are operational and do not include fixed meter charges.

Emissions Reductions:

- Compared to electric resistance and gas storage water heaters, emissions are reduced across all cities by 32-75%.

5-bedroom/3-bathroom – E-Saver – Indoor Installation



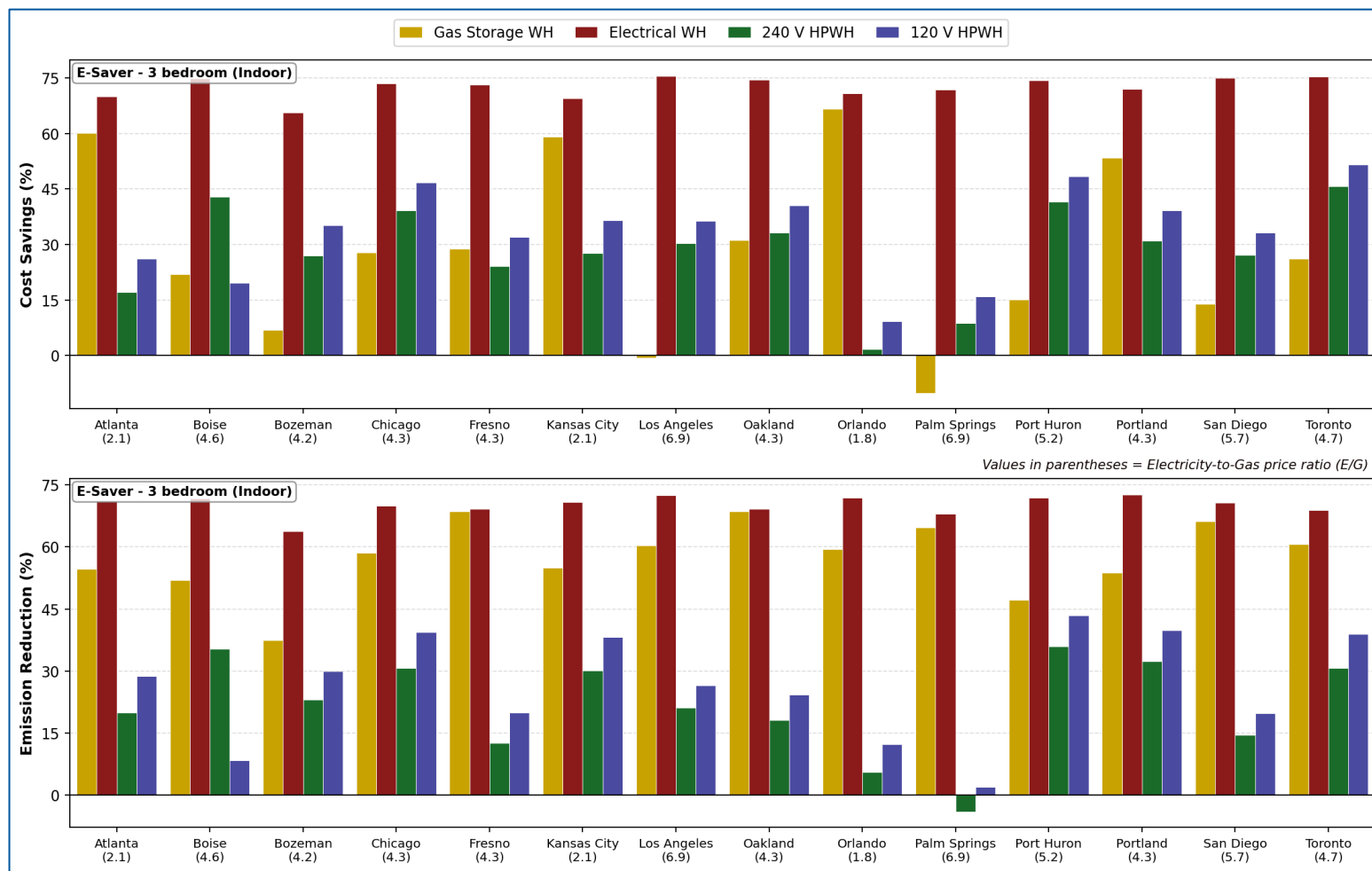
Dual-Fuel Heat Pump Water Heater

Modeling Results Comparative Analysis

Compared to both 120V and 240V HPWH:

- Compared to 240 V HPWH, cost savings are 2–43%, and emission reductions are –4 to 36%
- Compared to 120 V HPWH, there are cost savings and emission reductions in every city:
 - Cost savings of 9–48%
 - Emissions reductions of 2–43%,

3-bedroom/2-bathroom – E-Saver – Indoor Installation



Dual-Fuel Heat Pump Water Heater

Conclusions

- The FHR and UEF were measured to be 98 gallon and 3.8, respectively.
- Rated compressor capacity of 402 W and rated COP of 3.5.
- A high-fidelity, physics-based model was developed and validated. It can simulate the complex interaction among the heat pump, gas burner, stratified storage tank, ambient conditions, and standby losses.
- In general, dual-fuel modes balance between efficiency, comfort, emissions and costs.
- E-Saver mode balanced the energy efficiency and comfort metric, while the Hi-Demand mode achieved higher delivery hot water temperature.
- Heat pump only mode achieved the highest energy efficiency (approaching 400%), but at lower comfort metric.
- Relative to Gas only mode (as a baseline for condensing WH), E-Saver mode can shift about 75% of natural gas consumption to heat pump operation vs. about 65% for Hi-Demand mode.
- The cost savings and emission reductions are mainly based on the E/G ratio and climate conditions.

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Connectivity potential

Demand Response Validation

navien

NXW700 Series

Dual Fuel Hybrid Heat Pump Water Heater

Top award winner at 2026 Integrated Home Competition



www.integratedhome.org

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Experimental Results

Demand Response Validation

- Following installation, communication testing was performed using a SkyCentrics CTA-2045 EcoPort Cellular Module, as shown in the Figure.
- The communication interface operated as intended, and command signals were successfully received by the DF-HPWH controller.
- The testing confirmed proper communication between the CTA-2045 module and the water heater control system.
- Built-in WiFi



CTA-2045 Module installed on the DF-HPWH.

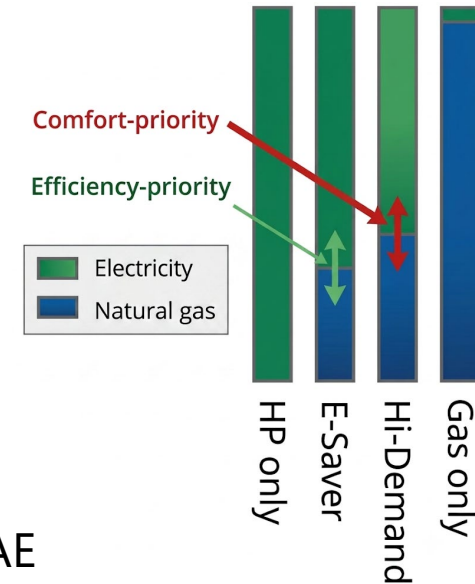
FUTURE WORK...

- Performance characterization and validation of the unit during DR events.
- Develop and integrate advanced time-of-use fuel flexibility control strategies.

Dual-Fuel Heat Pump Water Heater

Recommendations and FUTURE WORK

- **Product development**
 - Laboratory evaluation of intelligent water heating
 - Validate electric demand response functionality.
 - Develop a Time of Use mode.
- **Modeling**
 - Leverage the robust first-order model that GTI Energy has created to incorporate into modeling tools like EnergyPlus. This will allow practitioners in the industry to accurately simulate DF-HPWHs and allow for their inclusion in EE programs, future IECC and ASHRAE building codes for compliance purposes etc.
- **Programmatic**
 - Create a public web-based tool that will use customized home-specific inputs to provide optimized DFHPWH data [energy, emissions, operational modes] for utilities, EE program managers, contractors and building owners on DFHPWHs installed in their homes.
- **Field validation**
 - Real-world performance and installation challenges.
 - On-site optimization and deployment of the best operating mode.



Dual-Fuel Heat Pump Water Heater

Acknowledgements



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Alliance



Enbridge



SEMCO

Now seeking partners for
coordinated utility pilots for NXW700

Contact: Jason LaFleur jlafleur@gti.energy

GTI Energy team including Lee Van Dixhorn,
Ramy Abdelhady, Ph.D, Alejandro Guada,
Ramanathan Dharmarajan, Jason LaFleur



Source: AI generated

Could dual-fuel water heating offer
a Swiss army knife level of benefits?