CogenS

BY JIS ENERGY

2026 MODULE VALIDATION REPORT

Heat-Pump Boiler, validated against EnergyPlus

A commercial air-to-water or water-to-water heat-pump boiler behaves like no other heating plant: its capacity and its efficiency both fall as the weather turns, and they are worst on exactly the day the building needs the most heat. This report establishes that the CogenS engine reproduces that behaviour, scenario by scenario, against the reference engine the industry already trusts.

Six stages. 587 scenarios. 5,407 individually scored gates. Five stages compared head-to-head with EnergyPlus 26.1 on a closed hydronic plant loop; the sixth scored against operating envelopes published by eight manufacturers.

SCENARIOS
587
no scenario excluded

PASS RATE
587/587
100 percent

GATES SCORED
5,407
individually, per case

CORE MODEL
0.12%
worst vs EnergyPlus

DEFROST ENERGY
0.10%
worst vs EnergyPlus

OPERATING ENVELOPE
0.00 °C
18 published vendor points

Reference: EnergyPlus 26.1 · ASHRAE Guideline 14-2023

Last updated 2026-07-29

STAGE 1 · CORE MODEL

Capacity and efficiency, point for point

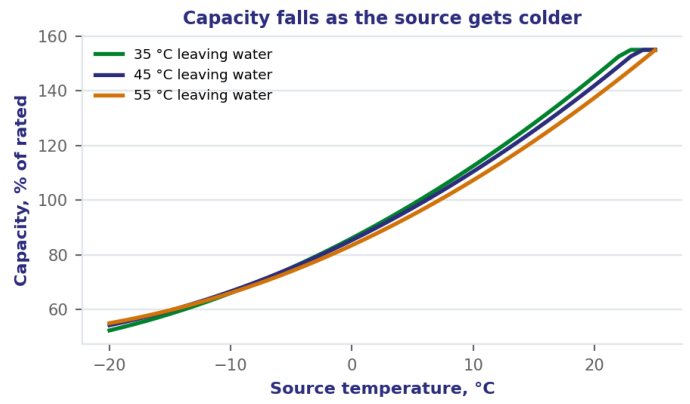
336 scenarios across two source types, four leaving-water setpoints, eight source temperatures and three compressor control types

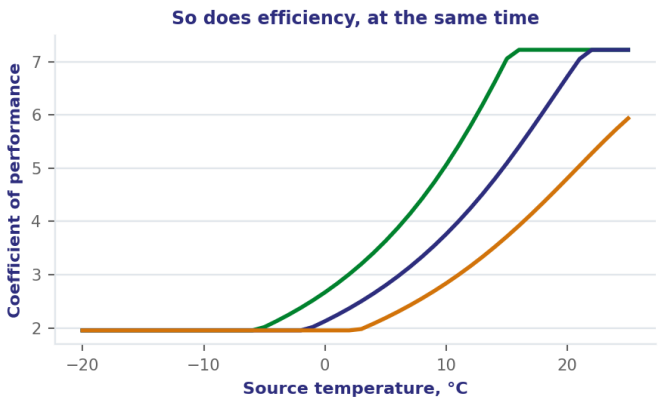
SCENARIOS
336 of 336 pass

REFERENCE
EnergyPlus 26.1, isolated plant loop

RUN TIME
approx. 2 minutes

A heat-pump boiler is not a boiler with a different fuel. Its capacity and its efficiency both move with two temperatures at once, and they move the wrong way for a project: the coldest hour of the year is when the building wants the most heat and when the machine can make the least of it. Both engines read the identical curve coefficients, so any difference here is a difference in how the two models apply them.





Gate	Tolerance	Result
Total heat delivered	plus or minus 5 percent (ASHRAE Guideline 14-2023)	**+0.01 to +0.12 percent across all 336 scenarios**
Total electricity consumed	plus or minus 5 percent	**+0.01 to +0.12 percent**
Peak electricity demand	plus or minus 10 percent	**+0.01 to +0.12 percent**
Hourly NMBE on heat and electricity	plus or minus 10 percent	**worst 0.13 percent**
Hourly CV(RMSE) on heat and electricity	30 percent or less	**worst 0.12 percent**

All 336 scenarios pass every gate. Heat delivered and electricity consumed both land within 0.13 percent of EnergyPlus, against a 5 percent band. The two engines are reporting the same machine to within a fifth of one percent.

STAGE 1B · FULL YEAR

8,760 hours, four climates, real weather

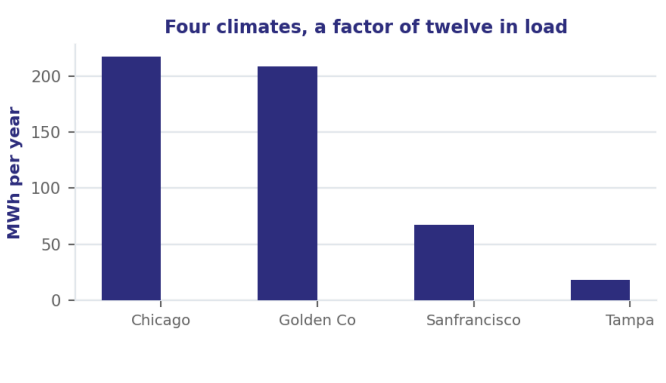
Chicago, Golden, San Francisco and Tampa, from 218 MWh to 17.9 MWh of annual heating, with no climate excluded

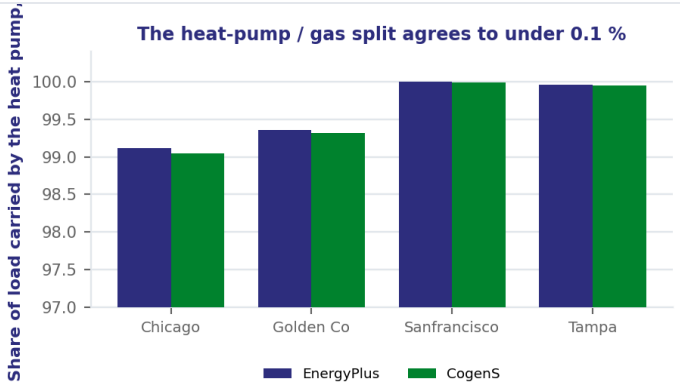
SCENARIOS
8 of 8 pass

REFERENCE
EnergyPlus 26.1, annual on TMY3 weather

RUN TIME
approx. 30 seconds (8 annual EnergyPlus runs)

Every other stage is a controlled probe at one condition. This is the one where the mechanisms interact the way they do on a real project: capacity and efficiency fall together as the weather turns, the bank stages up and down as the load swings, and the gas auxiliary picks up whatever the heat pump cannot. Both engines receive the identical 8,760-row hourly load file, so a load difference can never be mistaken for a model difference.





Gate	Tolerance	Result
Annual heat delivered by the heat pump	plus or minus 5 percent	**+0.06 to +0.92 percent**
Annual heat-pump electricity	plus or minus 5 percent	**-0.85 to +0.47 percent**
Share of the annual heating load carried by the heat pump	plus or minus 5 percent	**-0.08 to -0.01 percent — the two engines agree on the heat-pump-versus-auxiliary split to under a tenth of a percent**
Annual auxiliary heat and fuel	absolute-energy gate at 1 percent of the annual heating load (trivial-energy regime, named on the gate)	**worst 0.08 percent of annual load**
Peak heat-pump electricity	plus or minus 10 percent	**worst 3.44 percent**
Hourly NMBE on delivered heat	plus or minus 10 percent	**worst 0.94 percent**
Hourly CV(RMSE) on delivered heat	30 percent or less	**worst 14.57 percent**

The two engines agree on how much of the year's heating the heat pump carried, as opposed to the gas auxiliary, to within 0.08 percent. That split is the number a heat-pump boiler project turns on: it decides the electricity bill, the gas bill and the emissions result at the same time.

STAGE 2 · STAGING

Banks of two, three and four modules

96 scenarios across four load levels, four source temperatures and two compressor control types

SCENARIOS
96 of 96 pass

REFERENCE
EnergyPlus 26.1, multi-module plant

RUN TIME
approx. 33 seconds

Commercial heat-pump boilers are almost always specified as a bank of modules rather than one large machine, because modularity is how the plant holds its efficiency at part load. This stage checks that the engine brings on the right number of modules and prices the result correctly.

Delivered heat matches to under two tenths of one percent, which means the two engines stage identically. Bank electricity is scored under the federal relaxed band for one reason, stated plainly: sharing load equally across running modules and filling each module before starting the next are both real control laws, both deliver identical heat, and they differ on electricity by up to 11 percent because the cycling penalty is not linear in load. CogenS supports both and names which one a project uses.

Gate	Tolerance	Result
Bank heat delivered	plus or minus 5 percent	**+0.04 to +0.19 percent — the two engines stage the same number of modules and deliver the same heat**
Bank electricity	plus or minus 15 percent (FEMP Measurement and Verification, applied for the documented load-sharing difference)	**-4.20 to +9.71 percent**
Peak bank heat	plus or minus 10 percent	**worst 0.19 percent**
Peak bank electricity	plus or minus 15 percent	**worst 9.71 percent**
Hourly NMBE on bank heat	plus or minus 10 percent	**worst 0.20 percent**
Hourly CV(RMSE) on bank heat	30 percent or less	**worst 0.19 percent**

All 96 scenarios pass. The quantity a building actually experiences, delivered heat, is scored strictly and matches to 0.19 percent.

STAGE 3 · OPERATING ENVELOPE

The number a simplified model misses

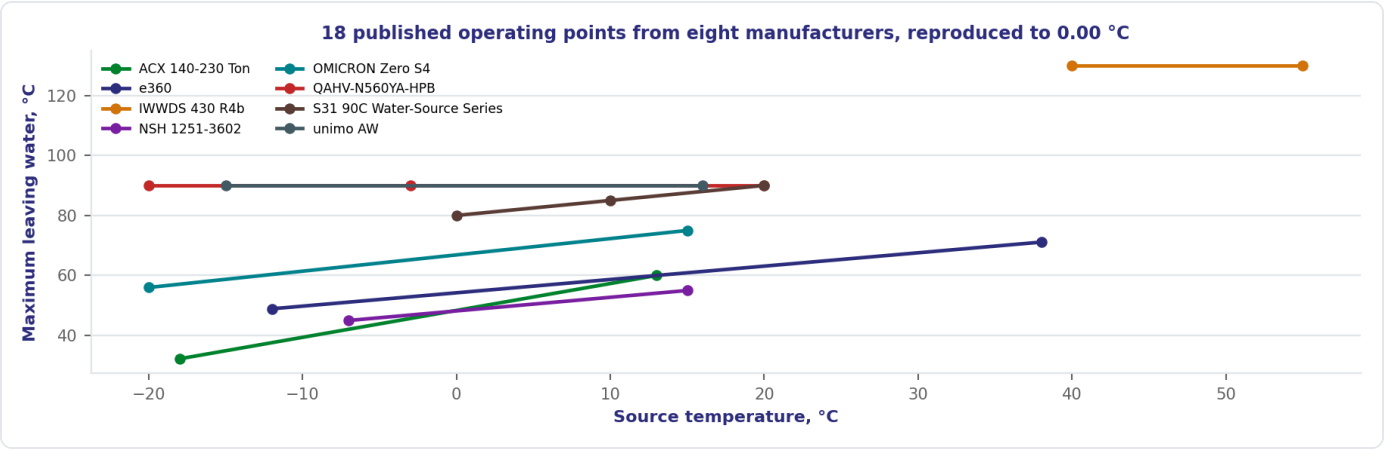
18 operating points published by eight manufacturers, across air-source, carbon-dioxide, water-source and waste-heat machines

SCENARIOS
9 of 9 pass

REFERENCE
Published vendor envelopes, 8 makers

RUN TIME
under 1 second

The hottest water a heat pump can make is not a fixed nameplate number. It falls as the source gets colder. A Trane air-source machine makes 140 degrees Fahrenheit of fluid at 55 degrees Fahrenheit outdoor air, but only 90 degrees Fahrenheit at 0 degrees Fahrenheit. A model that assumes the machine always makes its rated water temperature will show a design day the plant cannot deliver, and will under-size the auxiliary that has to cover the gap. The economics of the project turn on exactly that gap.



Gate	Tolerance	Result
Maximum leaving water temperature at each published source temperature	plus or minus 1.0 degree Celsius	**0.00 degrees Celsius across all 18 published points**
The envelope caps leaving water below setpoint when it should	the cap must engage	**engages correctly**
Auxiliary heat covers the shortfall when the envelope caps supply below setpoint	energy balance closes to 0.1 percent	**closes exactly**
A fixed-temperature model understates auxiliary demand	the difference must be demonstrable	**demonstrated**

All 18 published points reproduce to 0.00 degrees Celsius against a 1.0 degree band. This stage is scored against manufacturer data rather than EnergyPlus because EnergyPlus's envelope field was found, across eight plant configurations, not to restrict output in the released version. The vendors' own published envelopes are the stronger reference, and they are public.

STAGE 4 · DEFROST

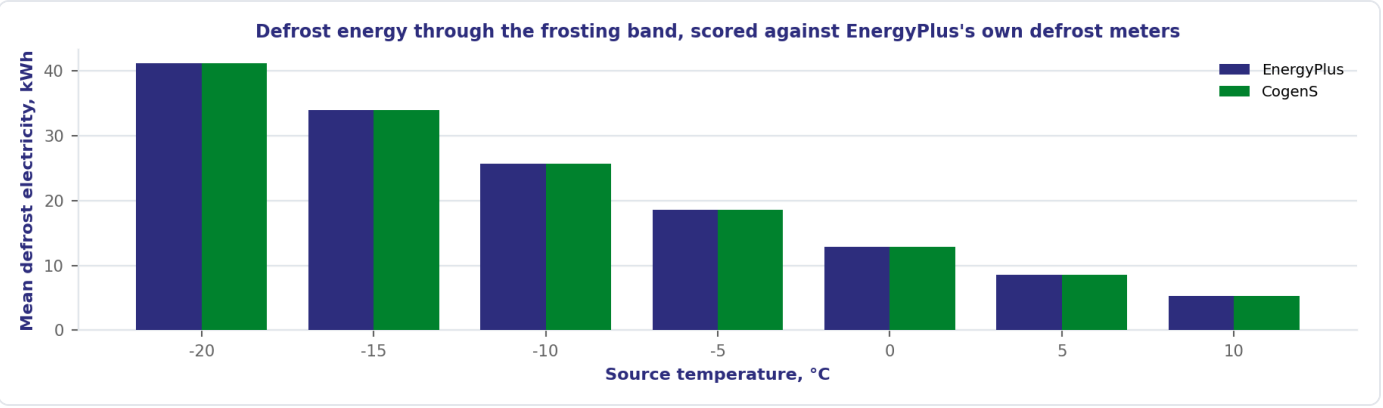
The cost a spreadsheet never sees

96 scenarios through and below the frosting band, at two setpoints, two machine sizes and three control types

SCENARIOS	REFERENCE	RUN TIME
96 of 96 pass	EnergyPlus 26.1 defrost meters	approx. 33 seconds

Below about 5 degrees Celsius an air-source machine accumulates frost on its outdoor coil and must periodically reverse to clear it. It costs twice: the compressor runs to melt the frost, and the heat to do it comes out of the building's own hot water. In a cold climate the machine spends thousands of hours in that band.

EnergyPlus meters defrost separately from compressor electricity, so each term is scored on its own rather than inferred from a total that could come out right for the wrong reasons.



Gate	Tolerance	Result
Defrost electricity	plus or minus 5 percent	**+0.02 to +0.10 percent across the 84 scenarios inside the frosting band**
Defrost heat load taken back from the water	plus or minus 5 percent	**+0.02 to +0.10 percent**
Total electricity including defrost	plus or minus 5 percent	**-0.19 to +0.10 percent**
Total heat delivered	plus or minus 5 percent	**worst 0.10 percent**
Peak defrost electricity and heat load	plus or minus 10 percent	**worst 0.10 percent**
Hourly NMBE on defrost electricity and heat load	plus or minus 10 percent	**worst 0.10 percent**
Hourly NMBE and CV(RMSE) on total electricity	plus or minus 10 percent NMBE, 30 percent CV(RMSE)	**worst 0.20 percent NMBE**

Defrost electricity and the heat taken back out of the loop both match EnergyPlus to 0.10 percent, across 96 scenarios and 1,272 individually scored gates.

STAGE 5 · AUXILIARY

Where the operating cost is decided

42 scenarios across seven source temperatures, three load levels and two setpoints

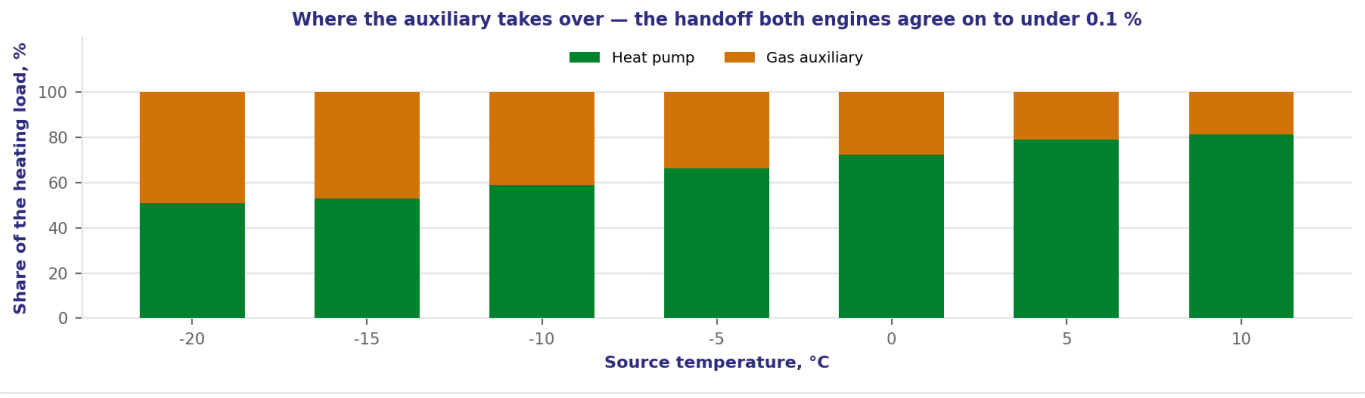
SCENARIOS
42 of 42 pass

REFERENCE
EnergyPlus 26.1, heat pump + boiler

RUN TIME
approx. 14 seconds

Every kilowatt-hour the heat pump cannot deliver is bought as gas instead, at a different price and a different emissions factor. Getting the handoff point wrong by a few degrees of outdoor air moves the annual gas bill by a large fraction.

A heat pump can fall short in two independent ways, and they need different remedies. It can run out of capacity. Or it can run out of temperature: plenty of capacity, but the operating envelope caps how hot it can send the water. The auxiliary sits downstream in series and lifts the water the rest of the way, so the two heat streams add up to the load rather than stacking on top of it. A model that tracks only the capacity shortfall is blind to the second case entirely.



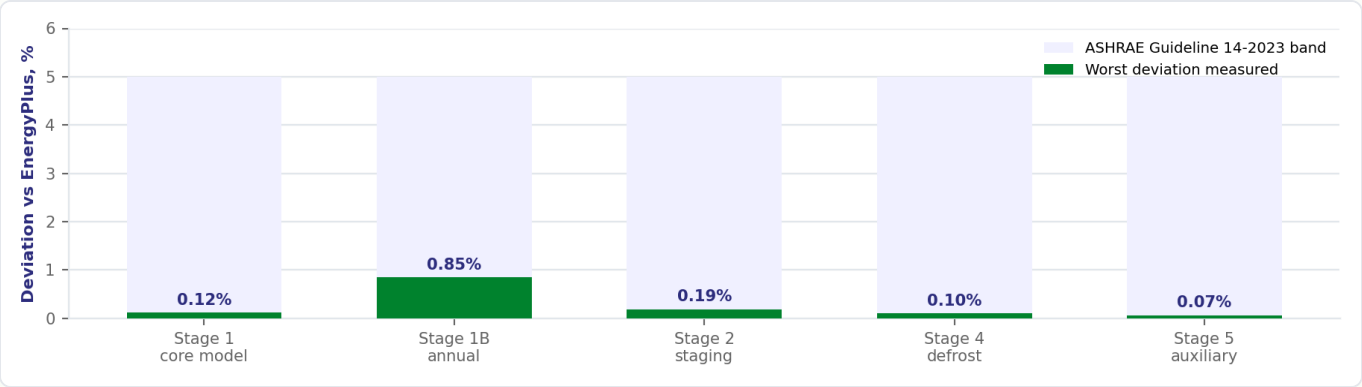
Gate	Tolerance	Result
Heat delivered by the heat pump	plus or minus 5 percent	**-0.00 to +0.07 percent**
Heat delivered by the auxiliary	plus or minus 5 percent	**+0.00 to +4.96 percent**
Share of the load carried by the heat pump	plus or minus 5 percent	**worst 0.07 percent — the handoff point matches**
Auxiliary fuel	plus or minus 5 percent	**worst 4.96 percent**
Peak auxiliary heat and fuel	plus or minus 10 percent	**worst 4.96 percent**
Peak heat-pump heat and electricity	plus or minus 10 percent	**worst 4.41 percent**
Hourly NMBE on every stream	plus or minus 10 percent	**worst 5.22 percent**

The split between heat-pump and auxiliary heat matches EnergyPlus to under a tenth of one percent. The engine reports which of the two limits bound each hour, so a project can see whether adding capacity or raising the achievable water temperature is what would actually reduce its gas use.

VALIDATED AGAINST THE REFERENCES THE INDUSTRY TRUSTS

Every number here is reproducible

Each of the 587 scenarios ships a complete audit pack: the inputs, both engines' hourly output, a side-by-side comparison, the gate results, the EnergyPlus input file that produced the reference, and a workbook carrying live tolerance formulas. An independent engineer can recompute every figure in this report rather than take it on trust.



EnergyPlus 26.1 · US Department of Energy

The reference building-energy engine. Free and open source: any engineer can download it and re-run every case in this report.

ASHRAE Guideline 14-2023 · ASHRAE

Defines the tolerance bands used throughout: annual energy within 5 percent, peak within 10 percent, hourly NMBE within 10 percent, hourly CV(RMSE) within 30 percent.

FEMP Measurement and Verification · US Department of Energy

The federal relaxed band, applied only where two correct models differ on a documented convention, and named on the gate.

Published manufacturer envelopes · Eight equipment vendors

Trane, Mitsubishi, Nyle, Mayekawa, Aermec, Swegon, Ochsner and H.Stars operating envelopes, read from public catalogs.

The full test matrix, with every parameter swept and every gate scored, is published at jisenergy.com/validation-cogens-engineering-rigor/heat-pump-boiler/