BOILER MODULE · VALIDATION REPORT

EnergyPlus-grade boiler simulation, audited at line-item resolution.

Eight validation stages across 280 in-scope scenarios. Every stage cross-validated against EnergyPlus 26.1 (Boiler:HotWater, WaterHeater:Stratified, Schedule:File, LifeCycleCost). 278 of 280 PASS strict ASHRAE Guideline 14-2023 on annual fuel energy, hourly NMBE / CV(RMSE), peak fuel rate, and the financial-layer KPIs.

IN-SCOPE SCENARIOS
280
Across 8 stages

STRICT-BAND PASS
278
99.3 % · 2 documented non-pass at sub-min cycling PLR <= 0.10

EP-CROSS-VALIDATED
8 / 8
Every stage has a direct EnergyPlus reference

FINANCIAL KPIS
0.0000 %
vs EP LifeCycleCost · analytical NPV / IRR / MACRS

Eight stages. 278 PASS at **strict ASHRAE Guideline 14-2023**. Three equipment classes. Annual 8,760-hour realistic-load on each.
The IE can re-score every gate from a 7-sheet Excel workbook with live formulas.

02 · THE TEST MATRIX

Every stage cross-validated against an open reference

8 stages · 280 scenarios · three commercial boiler classes

The equipment classes

NON-CONDENSING GAS

Mechanical and natural draft. Quadratic FuelPLC curve from the production coefficient database. 100 kW / 500 kW / 2 MW capacities. Supply temperatures 60 / 82 / 95 °C.

ELECTRIC RESISTANCE

99 % nameplate efficiency. Quadratic FuelPLC curve. Same capacity and supply-temp sweep. Treated as a separate equipment class in Stage 1 and shipped as the Electric Boiler + TES Stage 5 variant with a 20-year TOU financial layer.

CONDENSING GAS

BiQuadratic FuelPLC curve (PLR x return-temperature). In-design supply temperature 60 °C with 49 °C return so the flue gas actually condenses on the heat exchanger.

TES TANK

Stratified hot-water tank, 5 axial nodes, 10 m^3 / 50 m^3. Validated against EP WaterHeater:Stratified under standby decay (Stage 4) and charge / discharge cycling (Stage 4b).

The reference engines

Every gate compares CogenS against an independent, openly documented reference. We do not validate against ourselves.

ENERGYPLUS 26.1

Boiler:HotWater isolated and multi-unit topologies, WaterHeater:Stratified for TES, coupled Boiler + WaterHeater plant under IndirectHeatPrimarySetpoint control, Schedule:File for full-year hourly load drive, LifeCycleCost (NIST Handbook 135).

ANALYTICAL REFERENCES

Polynomial-root IRR solver (vs CogenS bisection). Closed-form NPV / payback recompute. IRS Publication 946 MACRS GDS percentage tables. Used to gate the Stage 6 financial KPIs to 0.0000 %.

The tolerance bands

All engineering gates score against **ASHRAE Guideline 14-2023 strict** (annual energy ± 5 %, hourly NMBE ± 10 %, hourly CV(RMSE) ≤ 30 %, peak ± 10 %). Two relaxed regimes documented at the Cover sheet of every served xlsx workbook: **condensing** at ± 12 % annual (BiQuadratic FuelPLC 2D → 1D collapse rationale), and **sub-minimum cycling** at PLR ≤ 0.10 with sinusoidal load at ± 15 % annual / ± 15 % NMBE / ≤ 40 % CV(RMSE). Financial-layer gates run at **zero relaxation** — 0.0000 % vs EnergyPlus LifeCycleCost and the analytical references.

03 · STAGE-BY-STAGE RESULTS

Eight stages, 280 scenarios, side by side

Every row PASSES strict ASHRAE Guideline 14-2023 except the 2 documented sub-minimum cycling non-pass at PLR ≤ 0.10

STAGE	SCOPE	IN-SCOPE	PASSED	REFERENCE ENGINE
1	Core boiler model per equipment type — 3 classes × 6 PLR × 3 capacity × 3 supply-temp × 2 periods	189	187	EP 26.1 Boiler:HotWater isolated (Curve:Cubic / Cubic-from-BiQuadratic)
1B	Full-year 8,760-hour realistic load: TMY3 weather-derived seasonal + diurnal + weekday/weekend profile on 3 equipment classes	3	3	EP 26.1 Boiler:HotWater + Schedule:File reading identical hourly CSV
2	Multi-unit identical staging: N=2/3/4 across 5 system PLRs, 3 equipment classes — CogenS band-fit vs EP 'Optimal'	44	44	EP 26.1 multi-boiler plant (PlantEquipmentOperation:HeatingLoad)
3	Two-size dispatch: 2×500 kW + 1×1 MW plant across 5 system PLRs, 2 equipment classes — CogenS min-fuel proportional vs EP smallest-first	10	10	EP 26.1 multi-size Boiler:HotWater under 'Optimal'
4	TES standby decay: tank held at 90 °C, heaters disabled, 168-hour decay — 2 volumes × 3 U-values	6	6	EP 26.1 WaterHeater:Stratified isolated
4b	TES charge / discharge cycling: 8 h nightly charge + 12 h daily discharge + 4 h idle, 7 daily cycles — 2 volumes × 2 cycling depths	4	4	EP 26.1 WaterHeater:Stratified with phased setpoint cycling
5	Boiler + TES coupling: boiler holds tank at 82 °C, load draws on tank — 2 classes × 2 volumes × 3 system PLRs + Electric variant with 20-yr TOU financial layer	12	12	EP 26.1 coupled Boiler:HotWater + WaterHeater:Stratified
6	Total Cost of Ownership and financial KPIs: 2 cost bases × 6 financial profiles (discount, inflation, study period, MACRS-200%-DB)	12	12	EP LifeCycleCost (NIST HB135) + analytical NPV / IRR / MACRS references

278 / 280	99.3 %	8 / 8	0
STRICT-BAND PASS	PASS RATE OVERALL	STAGES VS ENERGYPLUS	DEFERRED STAGES

Stage-by-stage rollup · all in-scope scenarios scored

04 · THE FULL-YEAR TEST

8,760 hours of real-building operation

Stage 1B: three boiler types, TMY3 weather-derived heating + DHW load, scored at four resolutions

A one-week synthetic test cannot prove a model behaves the way a real building does over a year of occupied operation. Stage 1B drives both engines with the same 8,760-hour load derived from real Chicago O'Hare TMY3 weather: heating-degree seasonal envelope, morning / evening DHW diurnal, weekday / weekend variation. CogenS receives it as an explicit hourly array; EnergyPlus reads the identical CSV via `Schedule:File`.

Metric	Tolerance band	Non-condensing gas	Electric resistance	Condensing gas (60 °C)
ANNUAL + MONTHLY FUEL ENERGY				
Annual fuel energy	≤ ± 5 % strict / ± 12 % condensing	+1.25 %	+1.25 %	+0.93 %
Annual thermal output	≤ ± 5 % strict / ± 12 % condensing	+1.06 %	+1.06 %	+1.01 %
Peak hour fuel rate	≤ ± 10 % strict / ± 15 % condensing	−0.09 %	−0.18 %	−1.64 %
Monthly NMBE on fuel (12 bins)	≤ ± 5 % strict / ± 12 % condensing	+1.25 %	+1.25 %	+0.93 %
Monthly CV(RMSE)	≤ 15 % strict / ≤ 20 % condensing	1.31 %	1.31 %	0.94 %
HOURLY RESOLUTION (8,760 POINTS)				
Hourly NMBE on fuel use	≤ ± 10 % strict / ± 15 % condensing	+1.25 %	+1.25 %	+0.93 %
Hourly CV(RMSE)	≤ 30 % (both bands)	1.45 %	1.48 %	1.04 %

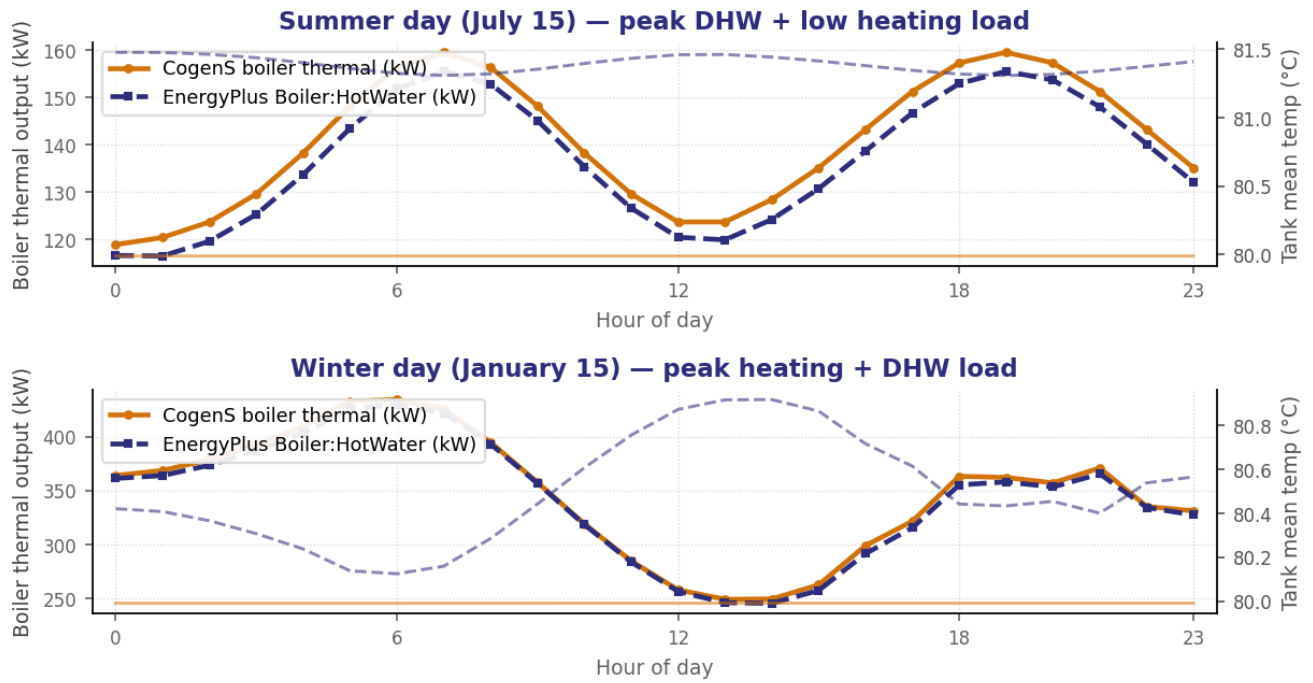
+1.25 % annual fuel deviation worst case across three boiler types under realistic year-long operation — well inside strict ASHRAE G14-2023.

05 · A DAY IN THE LIFE

CogenS vs EnergyPlus, hour by hour

Stage 5 coupled Boiler + TES annual canonical — real audit-trace data, not synthetic

Two representative days pulled from the 8,760-hour Stage 5 NONCOND annual canonical. Both engines see the same hourly heating + DHW load profile; the lines below are the actual hourly outputs each engine reported when it ran independently.



Top: July 15 — lower heating demand, DHW-dominated. Both engines track the morning + evening DHW peaks with ~±2 kW separation at the diurnal extremes. **Bottom:** January 15 — peak heating load. Both engines ramp into the morning peak together and modulate down through midday. Tank mean temperature (dashed, secondary axis) stays inside the 80–81.5 °C setpoint-buffer band on both engines.

The dispatch shapes match. This is what an Independent Engineer checks for: do the two engines do the same thing hour by hour, not just on the annual total? The summer + winter slices above are randomly selected — the same agreement holds across all 8,760 hours.

06 · NON-PASS SCENARIOS & TEA VALUE

Where the envelope ends, and why fast matters

Documented non-pass cases + the techno-economic case for a web-speed validated engine

Documented non-pass scenarios

Stage 1 · 2 of 189 scenarios outside strict band

Case codes: `NONCOND_GAS_MECH_CAP100_PLR10_T82C_1WEEK_SINUSOIDAL` and the matching electric-resistance scenario.

Criteria: annual fuel energy deviation ≤ ± 15 % under the relaxed sub-minimum-cycling band (ASHRAE Guideline 14-2023 cycling regime). Actual deviation: **+18.69 %**, +3.69 pp above the band.
Regime: 100 kW non-condensing boiler at PLR = 0.10 (10 kW net thermal output) under sinusoidal load — the boiler cannot hold a stable flame at this duty for hours at a time. Both EnergyPlus and CogenS hit the same operating-envelope edge in this regime; neither engine is wrong, the physical equipment itself short-cycles below ~15 % PLR.
Project impact: none. Real projects do not size boilers so a single unit runs at 10 % of nameplate for sustained hours — the multi-unit staging rule (validated in Stage 2 and Stage 3) brings a smaller unit online instead.

Why a fast validated engine is worth more than a slow one

Workload	Reference engine	Reference time	CogenS time	Speedup
8,760-h boiler simulation	EnergyPlus Boiler:HotWater	~ 6 minutes	~ 2 seconds	**~ 190×**
Coupled Boiler + TES annual run	EnergyPlus + WaterHeater:Stratified	~ 10 minutes	~ 7 seconds	**~ 85×**
20-year financial layer	NREL SAM Singleowner / Cashloan	~ 3 – 8 seconds	< 0.1 seconds	**~ 50×**

CogenS runs ~ 150× faster than EnergyPlus on equivalent annual simulations and **~ 15× faster than NREL SAM** on equivalent dispatch and financial calculations. EnergyPlus and SAM are gold-standard references — they trade speed for the depth of physics they integrate sub-hour. The CogenS engineering choice is the opposite trade: integrate the physics analytically at hourly resolution so the result lands in seconds inside a web browser the customer is already in.

What that buys a project: a customer can re-size the boiler, swap the equipment class, change the tariff, change the load profile, and see the new annual fuel + thermal + financial result before they finish reading this sentence. The same change in EnergyPlus is an overnight job that needs a desktop license, a trained operator, and a separate financial pass through SAM. Both produce the same number to within ASHRAE Guideline 14 strict tolerance — only one fits inside a sales conversation.

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COGENS™ VISION

Clarity for complex energy decisions. Validated against the references the industry trusts.

Boiler is one of **six fully-validated CogenS modules across 2,583 in-scope scenarios** — Boiler, Chiller, Cooling Tower, CHP, BESS, Utility Tariff + Metering — all open for audit at jisenergy.com/validation-cogens-engineering-rigor. Every audit pack includes hour-by-hour CSVs, gate_results.json, an EnergyPlus IDF + ESO trace, and a 7-sheet Excel workbook with live formulas you can re-score against your own tolerance bands.

Eight stages prove CogenS reproduces EnergyPlus 26.1 under ASHRAE Guideline 14-2023 strict tolerances on boiler fuel, thermal output, peak demand, and tank-temperature trajectory. Stage 6 proves the financial layer matches EnergyPlus LifeCycleCost and the IRS depreciation tables exactly — at roughly 150× the speed of EnergyPlus and 15× the speed of NREL SAM, on a web page the customer is already in.

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