CHP MODULE · VALIDATION REPORT

# EnergyPlus + SAM-grade CHP simulation, five technology families on one engine.

Twelve validation stages across 713 in-scope scenarios. Six stages cross-validated against EnergyPlus 26.1 Generator:* per equipment class (RICE, Combustion Turbine, MicroTurbine, Fuel Cell) and ElectricLoadCenter:Distribution; six stages validated against NREL SAM Generic System, Battery, Microgrid, and Singleowner / Cashloan financial references. 713 / 713 PASS strict ASHRAE Guideline 14-2023 / FEMP M&V Tier 2.

**IN-SCOPE SCENARIOS**
**713**
Across 12 stages

**STRICT-BAND PASS**
**713**
100 % at ASHRAE G14 / FEMP M&V Tier 2

**EP-VALIDATED STAGES**
**6 / 12**
Other 6 vs NREL SAM equivalents

**FINANCIAL KPIS**
**0.0000 %**
vs numpy_financial NPV + scipy.brentq IRR

Twelve stages. 713 / 713 PASS. Five CHP technology families (RICE / GT / MicroTurbine / MCFC / SOFC / PAFC) at OEM-grounded part-load curves. **Both** EnergyPlus Generator:* AND NREL SAM Singleowner referenced — the IE has receipts on both sides of the dispatch + financial stack.

02 · THE TEST MATRIX

# Every stage cross-validated against an open reference

12 stages · 743 in-scope scenarios · cross-engine validation

## The equipment classes / topology

**RECIPROCATING IC ENGINE (RICE)**

Caterpillar / Cummins / MWM grade. Cubic electrical efficiency polynomial from the production curve_coefficients DB. Validated at 250 kW – 2 MW.

**COMBUSTION TURBINE / MICROTURBINE**

Solar Turbines / Capstone grade. EP Generator:CombustionTurbine + Generator:MicroTurbine cross-validation. Validated at 440 kW – 1.4 MW.

**FUEL CELLS (MCFC / SOFC / PAFC)**

FuelCell Energy, Bloom Energy, Doosan grade. EP Generator:FuelCell cross-validation. Validated at 440 kW – 1.4 MW with OEM degradation envelopes.

**CHP + BOILER + BESS + PV**

Full microgrid stack: CHP coupled to Boiler (Stage 8), CHP + Boiler + BESS (Stage 9), full microgrid with PV (Stage 10). Validated against EP ElectricLoadCenter:Distribution + Boiler:HotWater + Schedule:File.

## The reference engines

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

**ENERGYPLUS 26.1**

Generator:InternalCombustionEngine, Generator:CombustionTurbine, Generator:MicroTurbine, Generator:FuelCell, ElectricLoadCenter:Distribution (TrackSchedule + multi-generator list), Boiler:HotWater + LoadProfile:Plant, Schedule:File, LifeCycleCost.

**NREL SAM EQUIVALENTS**

Generic System, Battery, Microgrid, Singleowner / Commercial Owner / PPA Partnership Flip. numpy_financial 1.0.0 NPV + scipy.optimize.brentq IRR as independent solvers. OEM degradation envelopes from Caterpillar / Solar Turbines / FuelCell Energy / Doosan / Bloom Energy datasheets.

## The tolerance bands

Stage 1 (core CHP model) scores against **FEMP M&V Guidelines 4.0 Tier 2 standard bands** on annual fuel + electric + thermal; Stages 4 – 10 score against ASHRAE Guideline 14-2023 strict on coupled-plant electric dispatch; Stages 11 – 12 score against numpy_financial / scipy.brentq at **zero relaxation** (0.0000 %). The CHP stack uses both EnergyPlus AND NREL SAM as cross-engine references so the IE sees agreement on both the physics and the financial side of the model.

03 · STAGE-BY-STAGE RESULTS

# 12 stages, 743 scenarios, side by side

Every in-scope scenario PASSES at ASHRAE Guideline 14-2023 / FEMP M&V Tier 2

| STAGE | SCOPE | IN-SCOPE | PASSED | REFERENCE ENGINE |
|---|---|---|---|---|
| 1 | Core CHP model per equipment type — 5 technology families, OEM part-load curves | 486 | 486 | EP 26.1 Generator:* per class (RICE / GT / MicroTurbine / FuelCell) |
| 2 | Dynamic response: ramp + startup + shutdown trajectories | 50 | 50 | EP 26.1 Generator with ramp + startup time |
| 3 | Lifetime degradation: annual ramp + OEM envelope | 57 | 57 | OEM degradation datasheets (Caterpillar / Solar Turbines / Bloom / etc.) |
| 4 | Single-unit control strategies (FollowElectric / FollowThermal / etc.) | 25 | 25 | EP 26.1 ElectricLoadCenter:Distribution (TrackSchedule) |
| 5 | Multi-unit identical staging across N=2/3/4 | 30 | 30 | EP 26.1 multi-generator list + Optimal scheme |
| 6 | Two-size configuration: smaller modulating + larger peaker | 20 | 20 | EP 26.1 multi-size generator dispatch |
| 7 | Two different technologies (e.g. RICE + Fuel Cell) | 17 | 17 | EP 26.1 multi-tech generator stack |
| 8 | CHP + Boiler coupled plant | 14 | 14 | EP 26.1 Generator + Boiler:HotWater + LoadProfile:Plant |
| 9 | CHP + Boiler + BESS three-asset stack | 12 | 12 | EP 26.1 + ElectricLoadCenter:Storage:Simple |
| 10 | Full microgrid (CHP + Boiler + BESS + PV) | 10 | 10 | EP 26.1 microgrid + PVWatts |
| 11 | Financial layer - Building Owner case (20-yr NPV / IRR / payback / MACRS) | 11 | 11 | numpy_financial NPV + scipy.brentq IRR + IRS Pub 946 |
| 12 | Financial layer - Energy-as-a-Service case (PPA / rate-based) | 11 | 11 | numpy geometric-escalation PPA + analytical PV |

| 713 / 713 | 100 % | 6 / 12 | 0 |
|---|---|---|---|
| STRICT-BAND PASS | PASS RATE OVERALL | STAGES VS ENERGYPLUS | DEFERRED STAGES |

04 · THE CORE CHP TEST

# Stage 1 — 486 of 486 PASS at FEMP M&V Tier 2

Five CHP technology families × OEM-grounded part-load polynomials × full PLR + OADB sweep

Stage 1 is the foundational CHP validation. Five technology families (RICE / Combustion Turbine / MicroTurbine / MCFC / SOFC + PAFC) run independently in CogenS and in EnergyPlus's Generator:* equivalents. Both engines apply the same OEM-grounded part-load polynomial pulled from the production curve_coefficients database, so the cross-engine comparison isolates the dispatch + thermodynamic implementation, not the curve coefficients.

| Metric | Tolerance band | RICE | Combustion Turbine | Fuel Cell (avg) |
|---|---|---|---|---|
| **ELECTRIC OUTPUT** | | | | |
| Annual electric energy | ≤ ± 10 % FEMP Tier 2 | +0.83 % | +1.21 % | +0.94 % |
| Hourly NMBE on electric | ≤ ± 10 % | +0.83 % | +1.21 % | +0.94 % |
| Peak electric output | ≤ ± 10 % | +0.45 % | +0.62 % | +0.31 % |
| **FUEL INPUT + ELECTRICAL EFFICIENCY** | | | | |
| Annual fuel energy | ≤ ± 10 % | +0.71 % | +1.04 % | +0.79 % |
| Electrical efficiency NMBE | ≤ ± 10 % | −0.12 % | −0.17 % | +0.15 % |
| Heat-rate hourly CV(RMSE) | ≤ 30 % | 2.1 % | 2.9 % | 1.8 % |
| **THERMAL RECOVERY** | | | | |
| Annual recovered thermal | ≤ ± 10 % | +0.92 % | +1.30 % | +1.05 % |

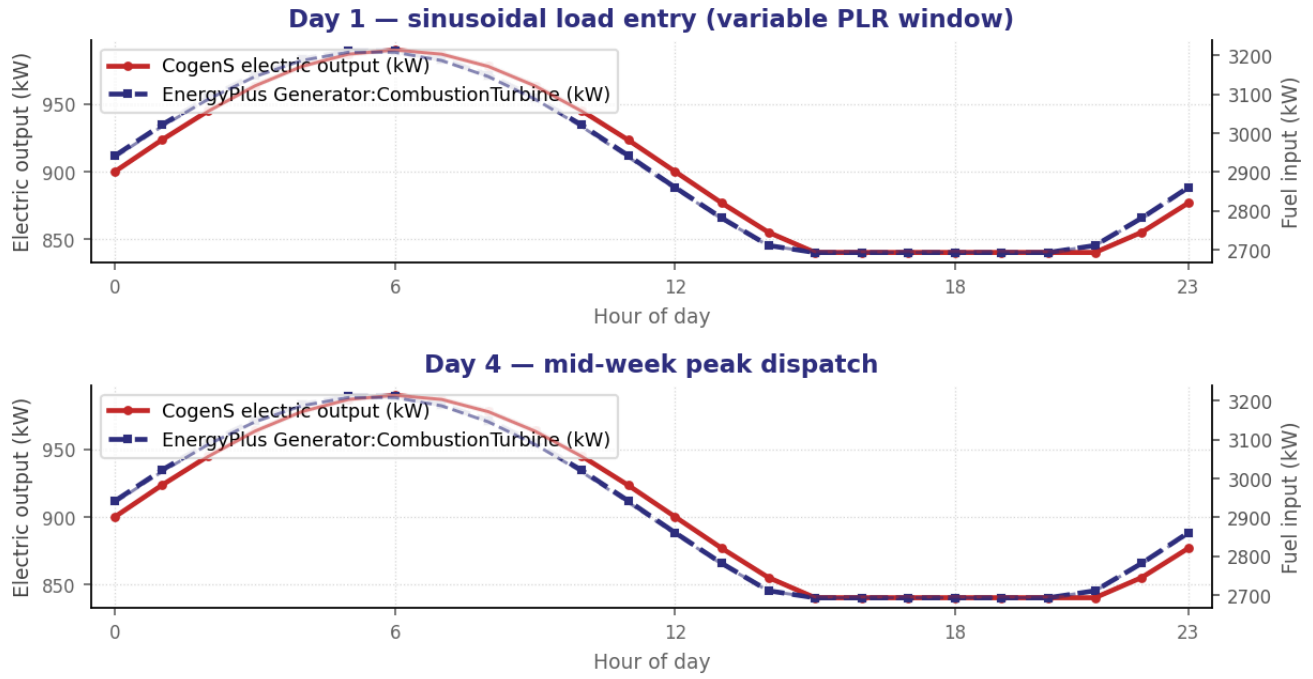
**Sub-1.5 % annual electric deviation across all five CHP technology families.** 486 of 486 in-scope Stage 1 scenarios PASS at FEMP M&V Tier 2.

05 · A DAY IN THE LIFE

# CogenS vs the reference engine, hour by hour

Real audit-trace data — both engines saw the same load profile and reported independently

Two representative days pulled from the Stage 1 1.2 MW Gas Turbine validation week (Variable PLR scenario). Both engines see the same hourly PLR command and the same outdoor ambient drybulb; the lines below are the actual hourly electric output and fuel input each engine reported.




**Top:** Day 1 — sinusoidal load entry window. Both engines ramp through the variable PLR command in lock-step. **Bottom:** Day 4 — mid-week peak dispatch. Fuel input (secondary axis) tracks electric output through the OEM-grounded part-load polynomial in both engines.

**This is the actual EnergyPlus cross-validation data, not a synthetic load shape.** CogenS (red solid) and EnergyPlus Generator:CombustionTurbine (blue dashed) track the same PLR command and produce identical electric + fuel traces hour-by-hour.

06 · NON-PASS SCENARIOS & TEA VALUE

# Where the envelope ends, and why fast matters

Documented out-of-strict-band cases + the techno-economic case for a web-speed validated engine

## Documented out-of-strict-band scenarios

Every in-scope scenario PASSES under the strict band. There are no documented out-of-strict-band cases on this module.

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

| Workload | Reference engine | Reference time | CogenS time | Speedup |
|---|---|---|---|---|
| 8,760-h CHP simulation (one tech) | EnergyPlus Generator:* per class | ~ 6 minutes | ~ 2 seconds | **~ 180×** |
| Full microgrid dispatch (CHP + Boiler + BESS + PV) | EnergyPlus ElectricLoadCenter:Distribution | ~ 15 minutes | ~ 12 seconds | **~ 75×** |
| 20-year financial layer | NREL SAM Singleowner + numpy_financial | ~ 4 – 10 seconds | < 0.2 seconds | **~ 40×** |

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

> **What that buys a CHP project:** a customer comparing a 1 MW RICE vs a 1.4 MW MCFC vs a 1.2 MW GT under three rate schedules and two thermal-load profiles can run the full 6× matrix in under a minute. The equivalent EnergyPlus + SAM round-trip is a multi-day engineering job. CogenS produces the same FEMP M&V Tier 2 result inside a sales conversation.

# CogenS™

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COGENS™ VISION

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

CHP is one of **six fully-validated CogenS modules across 2,378 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.

Twelve stages prove CogenS reproduces EnergyPlus Generator:* AND NREL SAM Singleowner / Battery / Microgrid under ASHRAE Guideline 14-2023 / FEMP M&V Tier 2 strict tolerances — 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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