2026 VALIDATION REPORT · THERMAL ENERGY STORAGE

84 of 84 scenarios PASS against EnergyPlus — hot and chilled, charge and discharge

The CogenS stratified thermal-storage engine, cross-validated head-to-head against DOE EnergyPlus 26.1 `WaterHeater:Stratified` across the complete duty cycle at a 15-minute timestep. Five stages, 84 scenarios. Three independent metrics per scenario. Chilled-water storage validated against EnergyPlus for the first time.

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SCENARIOS PASS

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ENERGYPLUS-VALIDATED STAGES

0.07 K
BEST CHILLED THERMOCLINE RMSE

15 min
VALIDATED TIMESTEP

Stage rollup

Stage	Scope	Scenarios	Pass	Reference
4	Standby thermal decay — isolated tank, heaters disabled. Hot: 90 °C into 20 °C ambient. Chilled: 5 °C in a 25 °C plant room, so the tank GAINS heat. 168 h	12	**12**	EnergyPlus 26.1
4b	Hot-water storage, discharge duty — draw-cycled, thermocline forms and relaxes	18	**18**	EnergyPlus 26.1
4c	Chilled-water storage, discharge duty — cold drawn from the bottom, warm return at the top	18	**18**	EnergyPlus 26.1
4d	Hot-water storage, charge duty — plant supply displaces the tank from the top down	18	**18**	EnergyPlus 26.1
4e	Chilled-water storage, charge duty — chiller filling the tank overnight	18	**18**	EnergyPlus 26.1

Why three metrics, not one

A storage tank can hold exactly the right total energy and still be useless to a building, because what a plant actually receives is the temperature at the port it draws from. So every scenario is scored on three independent quantities rather than a single energy total:

Metric	What it tests	Why it matters commercially
Tank-mean temperature	Bulk energy balance — does the tank hold the right amount of energy?	Sets how much stored capacity a project can claim.
Thermocline stratification	Is the energy in the right *place* in the tank?	A well-mixed tank delivers lukewarm water; a stratified one delivers usable water for longer.
Delivered supply temperature	The temperature at the node serving the load	The dispatch logic reads this to decide whether the tank can serve the load at all, so an error here propagates straight into annual savings.

Results — complete duty cycle

Both engines were driven with the **same energy**: EnergyPlus runs first, and its own per-interval heat transfer becomes the CogenS request. That removes "did they even move the same amount of energy?" as a confound, so what is scored is purely how each engine distributes that energy through the tank.

Duty	Mode	Pass	Thermocline RMSE	Tank-mean |NMBE|	Supply temp |NMBE|
Discharge	Hot water	**18 / 18**	0.83 – 1.81 K	≤ 1.21 %	≤ 1.80 %
Discharge	Chilled water	**18 / 18**	0.07 – 0.18 K	≤ 3.91 %	≤ 3.85 %
Charge	Hot water	**18 / 18**	0.79 – 2.05 K	≤ 1.51 %	≤ 0.51 %
Charge	Chilled water	**18 / 18**	0.10 – 0.25 K	≤ 2.49 %	≤ 1.20 %

Gates: ASHRAE Guideline 14 — NMBE ±10 %, CV(RMSE) ≤30 %. Thermocline spread is normalized on the tank's operating band (30 K hot, 9 K chilled); see How the stratification metric is normalized.

Why charge is validated separately

A real storage tank charges every night and discharges every day. Validating only the draw side would leave half of that cycle unmeasured — and would never execute the charge path through the engine at all. Stages 4d and 4e are the geometric mirror of 4b and 4c: the ports swap ends, the tank starts discharged, and the plant's supply water displaces it the other way.

The temperature that matters also changes with the duty. On discharge it is what the building receives. On charge it is what returns to the boiler or chiller, because that sets the plant's entering-water temperature and therefore its efficiency — which is what determines the cost of filling the tank in the first place.

Measured against the previous engine

The same 72-scenario charge-and-discharge matrix — the four cycling stages, excluding standby — was run against the engine CogenS shipped before this release. It passes 19 of 72. Both sets of numbers are published rather than the older one quietly superseded.

Duty & mode	Current engine	Previous engine	Thermocline RMSE (prev.)
Discharge, hot	**18 / 18**	**6 / 18**	2.05 – 11.44 K
Discharge, chilled	**18 / 18**	**0 / 18**	5.56 – 8.24 K
Charge, hot	**18 / 18**	**6 / 18**	3.57 – 12.29 K
Charge, chilled	**18 / 18**	**7 / 18**	1.60 – 2.98 K

On hot-water service its bulk energy was fine. That is exactly why it went unnoticed.

Hot-service tank-mean error stays within 3.33 % — well inside the band, which is why a standby-only validation suite passed it. What it could not do was put that energy in the right *place*: thermocline error reached 12.29 K, and the delivered chilled-water supply temperature drifted by up to 59.6 %. On chilled service even the bulk energy failed, at 23.7 – 24.2 %.

An energy-balance self-check cannot find this class of error, because the balance still closes. Only a cross-simulation comparison against an independent engine exposes it.

Why 15 minutes is the validated timestep

EnergyPlus simulates a stratified tank internally at 15 minutes. A 15-minute project timestep is therefore the only like-for-like comparison — both engines advance on the same cadence, so any remaining difference is model behaviour rather than an artefact of comparing different step sizes.

CogenS supports 15, 20, 30 and 60-minute timesteps and the choice is the user's. 15 minutes is the one the engine is validated at, and because it matches the reference cadence it is also the most accurate: moving from a 60-minute step to 15 reduces thermocline error from 1.26–1.95 K to 0.83–1.81 K on hot service and from 0.18–0.26 K to 0.07–0.18 K on chilled, with no change to the engine.

How the stratification metric is normalized

Thermocline spread is the difference between the top and bottom node temperatures. Its mean tends toward zero as a tank cycles harder and re-homogenises between draws, so normalizing an error against that mean — the usual convention for an energy series — produces a percentage that explodes as the denominator collapses while the absolute error stays flat or improves.

Spread is therefore normalized against the tank's operating temperature band, a fixed physical scale independent of the model output. Absolute error in kelvin is published alongside every percentage in this report so the reader can check the normalization rather than take it on trust.

Honest limitations

What this validation does not cover

Media. Sensible-heat water storage only. Phase-change and ice-storage media are not modelled.

Geometry. Vertical cylindrical tanks. Horizontal and irregular vessels are out of scope. Stratification is resolved at five nodes, matching the reference configuration; finer node counts are supported by the engine but not separately validated.

Timesteps. 20- and 30-minute steps are supported by the validation harness but have not yet been run. The 60-minute step was measured and remains inside every gate, with a modestly larger thermocline error than 15 minutes.

Residual. A thermocline difference of roughly 0.8 to 2.1 K persists on hot-water storage at 15 minutes. It is inside the Guideline 14 band and is believed to be a genuine model difference from EnergyPlus — most likely its inlet-jet mixing treatment — rather than a numerical artefact, since it does not reduce under further refinement of the internal solve.

Reference engines and standards

Reference	Role
DOE EnergyPlus 26.1.0 `WaterHeater:Stratified`	Independent stratified-tank simulation engine; 5-node configuration with the use-side port wired for both charge and discharge duty.
ASHRAE Guideline 14	Acceptance bands — NMBE ±10 %, CV(RMSE) ≤30 %.

Harness credibility was established before any new stage was built, by reproducing the existing published standby reference in the validation environment: EnergyPlus ΔT of 12.256 °C against the published 12.26 °C.

CogenS™ by JIS Energy — Thermal Energy Storage Module Validation Report. Every scenario, parameter and gate in this report is published in full at **jisenergy.com/validation-cogens-engineering-rigor/thermal-storage/** with the complete test matrix.

Reproduce any stage: `python validation/tes/run_subhourly.py --minutes 15 --duty both --variant both`