UNIVERSITY OF IDAHO
INTEGRATED DESIGN LAB · BOISE

TECHNICAL MEMORANDUM

TO: University of Idaho Integrated Design Lab — Energy Modeling Team
FROM: IDL Web Tools Development
DATE: June 14, 2026
RE: EnergyPlus Fan Energy Calculator — web tool overhaul, methodology, and EnergyPlus / ASHRAE 90.1 Appendix G compliance verification

1. Purpose

This memorandum documents the conversion of the Integrated Design Lab (IDL) EnergyPlus Fan Energy Calculator from its original Excel workbook (six worksheet tabs) into a single browser-based, interactive web tool, and records the verification of its calculations against the EnergyPlus fan model and ASHRAE Standard 90.1-2007 Appendix G. It is intended as a reference for modelers using the tool and as a basis for review of its technical correctness.

The tool determines the three supply-fan parameters required by EnergyPlus at the schematic and compliance-modeling stage: supply fan total efficiency, supply fan delta pressure (Pa), and supply fan motor efficiency. Baseline values are derived from ASHRAE 90.1-2007 Appendix G; proposed-design values are derived from equipment specifications.

2. Background and required inputs

The performance rating method of ASHRAE 90.1 Appendix G prescribes how the baseline building's fan power is to be calculated. EnergyPlus, however, does not accept a fan-power value directly. For its simple fan objects (Fan:ConstantVolume, Fan:VariableVolume, Fan:OnOff) it instead derives fan electric power from the design air-flow rate, a pressure rise, and a total efficiency. The calculator's role is to translate the Appendix G fan power into the three EnergyPlus inputs that reproduce it:

- **Supply Fan Total Efficiency** — the wire-to-air (overall) efficiency used by the fan object.
- **Supply Fan Delta Pressure {Pa}** — the design pressure rise across the fan.
- **Supply Fan Motor Efficiency** — the motor efficiency, which governs how fan and motor heat is added to the air stream.

The original workbook guided the user through these inputs across separate tabs (Introduction, Systems 1 & 2, Systems 3 & 4, Systems 5–8, Proposed System, and Resources). The web tool preserves this logic in a single guided page with live calculation, automatic motor selection, and the reference tables retained inline.

3. Calculation methodology

3.1 Baseline system routing

Appendix G assigns one of eight baseline system types based on building type and energy source (Table G3.1.1A). Each type maps to one of three fan-power calculation paths. The user selects the system directly or by building type; the tool then applies the corresponding equations.

Sys.	Baseline system type	Fan control	Calculation path
1, 2	PTAC / PTHP	Constant volume	Direct W/cfm
3, 4	PSZ-AC / PSZ-HP	Constant volume	bhp (CAV coefficient)
5–8	Packaged VAV & VAV, with reheat or PFP boxes	VAV	bhp (VAV coefficient)

3.2 Systems 1 & 2 (PTAC, PTHP)

These constant-volume terminal systems have no associated ductwork static-pressure power in the baseline. Appendix G specifies the fan power directly as a function of air flow:

$$P\_fan = CFM\_s \times 0.3 \quad (watts)$$

Because brake power and fan power are treated as equal for these systems, brake horsepower for the motor lookup is taken as P_fan ÷ 746. Delta pressure is then back-solved from the fan-efficiency relationship (Section 4.1) at the fixed 70 % total efficiency. Worked check: 4,000 cfm gives P_fan = 1,200 W, bhp = 1.61 hp (→ 2 hp motor, 84 %), and delta pressure = 445 Pa.

3.3 Systems 3 & 4 (PSZ-AC, PSZ-HP)

These constant-volume packaged systems use the CAV brake-horsepower equation, with an optional pressure-drop adjustment A from Table 6.5.3.1.1B (A = 0 is conservative):

$$bhp = CFM\_s \times 0.00094 + A \qquad P\_fan = bhp \times 746 \div \eta\_mot \quad (watts)$$

Worked check: 4,000 cfm, A = 0 gives bhp = 3.76 hp (→ 5 hp motor, 87.5 %), P_fan = 3,206 W, and delta pressure = 1,189 Pa.

3.4 Systems 5–8 (Packaged VAV and VAV, reheat or PFP boxes)

These variable-air-volume systems use the same form as Systems 3 & 4 but with the higher VAV brake-horsepower coefficient, which reflects terminal-unit and distribution pressure drop:

$$bhp = CFM\_s \times 0.0013 + A \qquad P\_fan = bhp \times 746 \div \eta\_mot \quad (watts)$$

Worked check (see Section 4.4): 120,000 cfm, A = 0 gives bhp = 156 hp (→ 200 hp motor, 95 %), P_fan = 122,501 W, and delta pressure = 1,514 Pa.

3.5 Motor efficiency selection (Table 10.8)

Appendix G directs that the motor efficiency be read from Table 10.8 for the next motor size greater than the calculated brake horsepower, using the enclosed (TEFC) motor at 1800 rpm. The tool performs this lookup automatically and highlights the selected row, while allowing manual override for designs that differ. The implemented rule selects the smallest standard motor size greater than or equal to the brake horsepower; because brake horsepower is effectively continuous, this differs from a strict reading only at exact tabulated values, which the override accommodates.

hp	η_mot (%)	hp	η_mot (%)
1	80.0	20	91.0
1.5	84.0	25	92.4
2	84.0	30	92.4
3	87.5	40	93.0
5	87.5	50	93.0
7.5	89.5	60	93.6

10	89.5	75	94.1
15	91.0	100	94.5
—	—	125	94.5
—	—	150	95.0
—	—	200	95.0

Table 10.8 — minimum nominal full-load efficiency, enclosed motors, 1800 rpm (4-pole). Values used by the tool.

3.6 Proposed system

For the proposed design the modeler enters values from the fan-coil schedule: supply air flow, minimum outdoor air, external static pressure (or pressure drop), fan power, and motor efficiency. Total efficiency is then computed from the fan-efficiency relationship rather than assumed:

$$\eta\_tot = (0.000472 \times CFM \times \Delta P\_Pa) \div P\_fan,W$$

The tool returns the cooling and heating supply air-flow rates and the minimum outdoor air-flow rate in m³/s for the system HVAC template, along with total efficiency, delta pressure, and motor efficiency. Worked check: 1,200 cfm, 1.5 in. w.c. (373.6 Pa), 0.5 hp (373 W), 88 % motor gives total efficiency = 0.567 and a supply flow of 0.5664 m³/s.

4. EnergyPlus compliance verification

The calculations were checked against the EnergyPlus Engineering Reference (Air System Fans) rather than relying on the original workbook alone.

4.1 The EnergyPlus simple fan model

For the Fan:ConstantVolume, Fan:VariableVolume, and Fan:OnOff objects, EnergyPlus computes fan electric power, shaft power, and heat added to the air stream as follows (Engineering Reference, “Simulation,” simple single-speed fan model):

$$\dot{Q}\_tot = \dot{m} \cdot \Delta P \div (\eta\_tot \cdot \rho\_air) \quad (fan\ electric\ power)$$

$$\dot{Q}\_shaft = \eta\_mot \cdot \dot{Q}\_tot \qquad \dot{Q}\_to\text{-}air = \dot{Q}\_shaft + (\dot{Q}\_tot - \dot{Q}\_shaft) \cdot f\_motor\text{-}to\text{-}air$$

Since mass flow divided by air density equals the volumetric flow rate, the electric power reduces to Q̇_tot = Q_volume × ΔP ÷ η_tot. Two consequences are central to compliance:

- **Motor efficiency does not affect electric power.** The motor efficiency appears only in the shaft-power and air-heat terms, never in Q̇_tot. The fan's energy use is determined entirely by the design flow, the delta pressure, and the total efficiency.
- **Only the ΔP-to-efficiency ratio matters for energy.** To make EnergyPlus reproduce the Appendix G fan power, the tool enforces ΔP ÷ η_tot = P_fan ÷ (0.000472 × CFM). Any consistent pair of ΔP and η_tot satisfying this ratio yields the same electric power.

4.2 Why total efficiency is locked at 70 %

Because only the ratio governs energy use, the baseline total efficiency is fixed at 70 % and the delta pressure carries the calibration. This value is locked in the tool (read-only); the corresponding delta pressure is computed so that the EnergyPlus rated electric power equals the Appendix G P_fan. Locking the value also removes the only path by which a user could create a physically inconsistent input, as explained next.

4.3 The motor-efficiency / total-efficiency relationship

EnergyPlus treats total efficiency as the product of fan (mechanical) efficiency and motor efficiency, so the implied mechanical efficiency equals η_tot ÷ η_mot. This quantity must not exceed 1.0. With total efficiency fixed at 70 % and the Table 10.8 motor efficiencies always 80 % or greater, the implied mechanical efficiency is always below 1.0 by construction, so the input pair is always physically valid. (An earlier revision allowed the total efficiency to be edited and added a guard against η_tot ≥ η_mot; locking the value supersedes that guard.)

4.4 Worked-example cross-check

The ASHRAE 90.1-2007 User's Manual provides a baseline fan-power example for an 80,000 ft² medical office building with a System 5 baseline and a 120,000 cfm supply volume. Running this case through the tool reproduces the manual's intermediate and final values exactly:

Quantity	User's Manual	Web tool
Brake horsepower	156 hp	156 hp
Selected motor / efficiency	200 hp / 95 %	200 hp / 95 %
Fan power (P_fan)	122,501 W	122,501 W
Delta pressure @ 70 %	(derived)	1,514 Pa

Delta pressure = 122,501 ÷ (0.000472 × 120,000) × 0.70 = 1,514 Pa. This case is retained as a permanent regression test in the tool's validator.

5. Constants and unit conversions

The tool uses the following constants, matched to the original IDL workbook for consistency with prior deliverables.

Quantity	Value	Used for
Systems 1 & 2 fan power coefficient	0.3 W/cfm	P_fan
CAV brake-horsepower coefficient (Sys 3, 4)	0.00094	bhp
VAV brake-horsepower coefficient (Sys 5–8)	0.0013	bhp
Horsepower to watts	746 W/hp	P_fan
Cubic feet per minute to cubic metres per second	0.000472	flow conversion
Inches water column to pascals	249.0889	ΔP conversion
Pounds per square inch to pascals	6,894.757	QA/QC ΔP

The cfm-to-m³/s factor of 0.000472 differs from the exact value (0.00047195) by approximately 0.01 %, which is negligible and was retained to match the original workbook.

6. Scope and limitations

The following Appendix G provisions are outside the calculator's scope. The tool now displays these as on-screen modeling notes; modelers must address them separately.

- **VAV part-load fan curve.** For Systems 5–8 the tool sets only the design-point inputs. The Appendix G part-load fan-power curve (Fan:VariableVolume coefficients) must also be entered in EnergyPlus.
- **Parallel fan-powered (PFP) boxes — Systems 6 & 8.** The PFP box fans carry their own power allowance (0.35 W/cfm under G3.1.3.14) and are excluded from the G3.1.2.9 system fan power computed here.

- **Combined system fan power.** The G3.1.2.9 P_fan covers supply, return, exhaust, and relief fans combined (excluding fan-powered VAV boxes). Where return or exhaust fans are modeled, this total must be apportioned among them rather than assigned entirely to the supply fan.

7. Changes from the original workbook

- **Single guided page.** The six tabs are consolidated into one interactive page with live calculation and an inline equation derivation.
- **Automatic motor selection.** Table 10.8 is applied automatically with the selected row highlighted; the original required a manual lookup.
- **Total efficiency locked.** Fixed at 70 % per the baseline method, removing the possibility of a physically inconsistent efficiency pair.
- **QA/QC delta-pressure unit corrected.** The original assumed the simulation reported delta pressure in psi. EnergyPlus reports it in pascals (SI) or inches of water (IP). The verification panel now lets the user select Pa, in. w.c., or psi, defaulting to pascals.
- **Defects removed.** Two #REF! formula errors and an incomplete shortcut block in the original were dropped.
- **Copy-to-clipboard and modeling notes.** Each result and the full set can be copied for pasting into the input file, and the Appendix G scope notes are shown contextually.

8. Verification and validation

The tool was validated headlessly with Playwright following IDL's standard tool-validation workflow. All checks pass; representative results are summarized below.

Check	Result
System 1, 4,000 cfm	bhp 1.61, motor 84 %, ΔP 445 Pa
System 3, 4,000 cfm, A = 0	bhp 3.76, motor 87.5 %, ΔP 1,189 Pa
System 5, 120,000 cfm (User's Manual)	bhp 156, motor 95 %, ΔP 1,514 Pa
Proposed, 1,200 cfm / 1.5 in. w.c. / 0.5 hp	η_tot 0.567, flow 0.5664 m³/s
Total efficiency field	Locked, read-only, 70 %
Motor override and table highlight	Functional
Mobile layout (390 px)	No horizontal overflow

9. References

- ANSI/ASHRAE/IESNA Standard 90.1-2007, Appendix G (Performance Rating Method), Tables G3.1.1A/B, G3.1.2.9, 6.5.3.1.1B, and 10.8.
- ASHRAE 90.1-2007 User's Manual, baseline fan-power example (System 5).
- EnergyPlus Engineering Reference — Air System Fans. bigladdersoftware.com
- Pacific Northwest National Laboratory, PNNL-19004, Technical Support Document: 50% Energy Savings Design Technology Packages for Medium Office Buildings.