TECHNICAL MEMORANDUM

Construction Insulation Value Calculator

Methodology, material data, and EnergyPlus export reference

Prepared by University of Idaho Integrated Design Lab

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Applies to `idlboise.com/sites/default/files/design-tools/Insulation_Calculator/construction-insulation-value-calculator.html`

1. Purpose and scope

This memo documents the methodology, source data, and EnergyPlus export behavior of the Construction Insulation Value Calculator — a browser-based tool that builds layered wall, roof, and floor assemblies and reports their thermal resistance and heat-loss coefficient. It is intended for use at the schematic-design stage, before detailed energy modeling is warranted, and revives the graphic envelope-analysis methods of Brown & DeKay's Sun, Wind & Light as a fast, interactive tool.

The calculator computes steady-state, one-dimensional heat flow through a series of material layers. It is a design-exploration and teaching instrument, not a compliance or simulation engine. Its results are appropriate for comparing layer choices, sizing insulation, and understanding the difference between a wall's center-of-cavity resistance and the whole-wall value it actually delivers. The EnergyPlus export bridges this schematic stage to detailed simulation.

2. Governing equations

Each layer's thermal resistance is its thickness divided by its conductivity. Resistances add in series, so the assembly total is the sum of all layers plus the interior and exterior surface air films, and the overall heat-loss coefficient is its reciprocal:

```
R_layer  =  t / k
R_total  =  R_se  +  Σ R_layer  +  R_si
U        =  1 / R_total
```

where t is layer thickness (m), k is thermal conductivity (W/m·K), giving a layer resistance in m²·K/W; `R_se` and `R_si` are the exterior and interior surface film resistances (Section 3).

The engine runs internally in SI and converts for display. The R-value conversion and the per-inch insulating value commonly cited in IP practice are:

```
R(IP)     =  R(SI) × 5.678
k(IP)     =  k(SI) × 0.5778
R/in(IP)  =  0.14422 / k(SI)
```

That is, 1 m²·K/W equals 5.678 ft²·°F·h/Btu, and 1 W/m·K equals 0.5778 Btu/(hr·ft·°F). The R/in expression gives the effective IP resistance per inch of a material's thickness.

Division-by-zero conditions that plagued the original spreadsheet (empty rows, missing conductivity) are guarded throughout; a layer with no conductivity contributes zero resistance rather than an error.

3. Surface air films

Real R-value calculations include the thin boundary layers of still and moving air at the interior and exterior faces. The tool applies ASHRAE standard surface resistances, selected automatically from the assembly's orientation (which sets the direction of heat flow) and the exterior exposure. Surface films can be switched off to reproduce the legacy spreadsheet, which omitted them.

Surface condition	RSI ($m^2 \cdot K/W$)	R (IP)
Interior — wall (horizontal flow)	0.12	0.68
Interior — roof / ceiling (flow up)	0.11	0.61
Interior — floor (flow down)	0.16	0.92
Exterior — winter, 15 mph (6.7 m/s)	0.030	0.17
Exterior — summer, 7.5 mph (3.4 m/s)	0.044	0.25
Still air (interior partition exterior)	0.12	0.68

Interior film resistance rises as heat flow turns downward (a floor traps a thicker still-air layer than a wall), which is why the floor value exceeds the wall value. Exterior film resistance falls as wind speed rises. These values are added once per assembly, not per layer.

4. Material library

The tool ships with roughly three dozen common building materials. Conductive materials are defined by thermal conductivity and a default thickness; set-resistance items (air spaces, membranes, glazing units, hollow concrete block, carpet) are defined directly by an R-value because their resistance is not a simple function of thickness. Any material can be overridden, and custom entries accept either a conductivity or a fixed resistance.

Conductivities, densities, and specific heats are representative values drawn from the ASHRAE Handbook—Fundamentals material-property tables and the Sun, Wind & Light appendix. They are intended for schematic comparison and should be confirmed against manufacturer data for design. The complete data set appears in Appendix A.

5. Framing factor (parallel-path method)

A framed assembly carries heat through two parallel paths: the insulated cavity and the solid framing members (studs, joists, rafters), which act as thermal bridges. The center-of-cavity R-value ignores the bridge and overstates performance. With framing mode enabled, the tool applies the parallel-path method: it computes each path's U-factor and area-weights them.

```
R_framing  =  R_total  −  R_cavity-layer  +  ( t_cavity / k_framing )
U_whole    =  FF · U_framing  +  (1 − FF) · U_cavity
R_whole    =  1 / U_whole
```

where *FF* is the framing fraction (the share of wall area that is solid framing). The cavity layer is the insulation the framing interrupts; the framing path replaces that layer's resistance with the resistance of the framing member at the same depth. All other layers — sheathing, continuous exterior insulation, finishes, films — are identical in both paths, so continuous insulation is correctly credited to the whole assembly. Typical framing fractions are provided as presets:

Framing preset	Framing fraction
Wood studs, 16 in o.c.	0.25
Wood studs, 24 in o.c.	0.22
Advanced framing, 24 in o.c.	0.18
Roof rafters, 24 in o.c.	0.10
Floor joists, 16 in o.c.	0.13
Custom	user-entered

Steel framing. The parallel-path method overstates whole-wall R for steel framing, because steel's high conductivity spreads heat laterally. For steel-framed assemblies the result should be treated as an upper bound; ASHRAE's zone method (with correction factors) is required for an accurate U-factor. The tool flags this whenever steel framing is selected.

6. EnergyPlus export

The tool generates a ready-to-paste IDF snippet. Each layer maps to the appropriate EnergyPlus object, and the layers are assembled into a Construction ordered from the outside face inward, matching EnergyPlus's convention.

Layer type in tool	EnergyPlus object	Key fields emitted
Conductive layer (k)	Material	Roughness, Thickness, Conductivity, Density, Specific Heat, absorptances
Fixed-R opaque (membrane, CMU, carpet)	Material:NoMass	Roughness, Thermal Resistance, absorptances
Air space	Material:AirGap	Thermal Resistance
Glazing unit	WindowMaterial:SimpleGlazingSystem	U-Factor (from unit R); SHGC + visible transmittance as placeholders
Full assembly	Construction	Ordered Outside Layer → Inside Layer (exterior to interior)

Surface films are deliberately excluded from the exported Construction — EnergyPlus computes interior and exterior film coefficients at runtime from surface orientation, wind, and the convection algorithm. The IDF header reports both the material-only (no-film) and with-film resistance so the user can cross-check against EnergyPlus's Envelope Summary, which lists “U-Factor no Film” and “U-Factor with Film.”

Density and specific heat are included on every `Material` object so the exported materials are valid for a dynamic (conduction-transfer-function) simulation, not merely a steady-state U-factor.

Framed assemblies

When framing mode is active, the export emits three constructions instead of one: a cavity construction and a framing construction (to be modeled as two surfaces with areas in the ratio of the framing fraction), plus a single whole-wall equivalent construction. The equivalent replaces the cavity layer with a framing-averaged material whose effective conductivity reproduces the area-weighted whole-wall U-factor, and whose density and specific heat are area-weighted between the insulation and the framing — convenient for a single U-equivalent surface, at the cost of smearing the dynamic mass.

Glazing units do not belong in an opaque Construction. If present, they are emitted as a WindowMaterial:SimpleGlazingSystem stub with a U-factor derived from the unit resistance and placeholder solar-heat-gain and visible-transmittance values the user must set per product; they are left out of the opaque Construction and flagged.

7. Limitations and scope boundaries

- Heat flow is one-dimensional and steady-state. Without framing mode, the result is a center-of-cavity value that does not weight parallel paths.
- The parallel-path framing method supports a single framed layer; double-stud walls and cross-strapping (multiple framed layers) are not resolved automatically, and the method is an upper bound for steel.
- Moisture transport, air leakage and infiltration, and dynamic thermal-mass effects are not modeled. Mass effects are captured only when the assembly is exported to EnergyPlus for simulation.
- Glazing-unit entries exist for opaque-assembly comparison and teaching; real fenestration is modeled separately in EnergyPlus.
- Built-in conductivities, densities, and specific heats are typical reference values and should be confirmed against manufacturer data for design.

8. Validation

Every build is validated headless with Playwright before release. The validator confirms branding and structure, checks that the reference 2×6 batt wall computes to R-20.9 / U-0.048 (center-of-cavity) with an IP-to-SI ratio of 5.679, that the section and contribution visuals render, that enabling framing reports a whole-wall R-15.7 at 25% framing with the expected derating, that steel framing raises the upper-bound warning, that the generated IDF is well-formed with no NaN or undefined values, that the page does not overflow horizontally on a 390-pixel mobile viewport, and that there are no console errors.

9. References

- Brown, G. Z. & DeKay, M. *Sun, Wind & Light: Architectural Design Strategies*, 3rd ed. Hoboken, NJ: Wiley.
- ASHRAE. *Handbook—Fundamentals* — surface (film) resistances and thermal properties of building and insulating materials.
- U.S. Department of Energy. *EnergyPlus Input/Output Reference* — Material, Material:NoMass, Material:AirGap, Construction, and WindowMaterial:SimpleGlazingSystem objects.

Appendix A. Material property data

A1. Conductive materials

Defined by thermal conductivity *k*. R/in is the effective IP resistance per inch of material thickness, `0.14422 / k`.

Material	k (W/m·K)	R/in (IP)	Density (kg/m³)	Sp. heat (J/kg·K)	Roughness
Insulation					
Fiberglass batt	0.043	3.35	12	840	Rough
Mineral wool batt	0.038	3.80	40	840	Rough
Cellulose, loose-fill	0.04	3.61	45	1380	Rough
EPS rigid foam	0.036	4.01	25	1400	MediumRough
XPS rigid foam	0.029	4.97	35	1400	MediumSmooth
Polyiso, foil-faced	0.023	6.27	30	1470	Smooth
Closed-cell spray foam	0.024	6.01	40	1470	MediumRough
Open-cell spray foam	0.038	3.80	8	1470	MediumRough
Masonry & concrete					
Concrete, dense (cast)	1.73	0.08	2300	880	MediumRough
Concrete, lightweight	0.53	0.27	1280	840	MediumRough
Brick, common	0.73	0.20	1920	790	MediumRough
Brick, face	1.3	0.11	2080	790	MediumRough
Stucco / cement plaster	0.72	0.20	1860	840	Rough
Stone (limestone/granite)	2.3	0.06	2560	790	Rough
Soil / earth (damp)	1.4	0.10	1500	1260	Rough
Wood & sheathing					
Softwood lumber (stud)	0.12	1.20	510	1380	MediumSmooth
Hardwood	0.16	0.90	720	1255	MediumSmooth
Plywood	0.12	1.20	545	1210	MediumSmooth
OSB sheathing	0.13	1.11	650	1210	MediumSmooth
Wood-fiber sheathing	0.055	2.62	400	1300	MediumRough
Boards & finishes					
Gypsum board (drywall)	0.16	0.90	800	1090	Smooth
Cement board	0.25	0.58	1150	840	MediumRough
Plaster, gypsum	0.22	0.66	1120	840	Smooth
Acoustic ceiling tile	0.058	2.49	290	1340	MediumRough
Metals					
Steel (stud / structure)	50	0.003	7850	500	Smooth
Aluminum	210	0.001	2700	880	Smooth

A2. Set-resistance items

Defined directly by an R-value rather than by thickness and conductivity. Thickness, where editable, affects only the section drawing, not the resistance.

Item	RSI (m²·K/W)	R (IP)	Roughness
Masonry & concrete			
Concrete block (8 in, hollow)	0.20	1.14	Rough
Boards & finishes			
Carpet + fibrous pad	0.37	2.10	Smooth
Glazing & air			
Single glazing (unit)	0.16	0.91	Smooth
Double glazing, air (unit)	0.33	1.87	Smooth
Double low-E, argon (unit)	0.56	3.18	Smooth
Triple low-E (unit)	0.90	5.11	Smooth
Air space, ¾ in+ (non-reflective)	0.16	0.91	MediumRough
Air space, reflective (1 side)	0.30	1.70	MediumSmooth
Membranes & roofing			
Asphalt shingles	0.08	0.44	Rough
Built-up roofing	0.06	0.33	Rough
Vinyl / fiber-cement siding	0.11	0.62	MediumSmooth
Building wrap / membrane	0.01	0.06	Smooth

All conductivities, densities, and specific heats are representative ASHRAE Handbook—Fundamentals and Brown & DeKay values for schematic use; confirm against manufacturer data for design.