
WHITE PAPER

The Economics of Additional R-Value

A Cost-Benefit Analysis of Insulation Upgrades in SIP and Stick-Framed Construction

1. Executive Summary

Every wall and roof assembly — panelized or framed — obeys the same law of physics: heat flow through the opaque envelope is proportional to $1/R$. Each additional unit of thermal resistance therefore saves less energy than the one before it. Structural insulated panels do not repeal that law. What they change, decisively, is the cost of each delivered unit of resistance and what comes bundled with it.

This white paper examines the cost-benefit calculus of adding R-value in three envelope systems — walls and roofs alike — common to the Northeast: SIP construction, conventional stick framing with cavity insulation, and stick framing upgraded with exterior continuous insulation (CI). Three findings emerge:

- ▶ Nominal R-value overstates stick-frame performance by 25–35%. Oak Ridge National Laboratory (ORNL) whole-wall testing shows a 2×6 wall with R-19 fiberglass delivers approximately R-13.7 once thermal bridging through the 15–27% of the wall that is lumber is counted. A SIP delivers essentially its rated value, because only about 3% of the panel area is dimensional lumber.
- ▶ The marginal cost per delivered R-value strongly favors the SIP thickness ladder. Stepping up a SIP core thickness delivers additional whole-wall R-value at roughly one-third to one-half the cost per R-value of adding the first layer of exterior CI to a framed wall — once the CI system's furring, long-fastener cladding attachment, window buck extensions, and flashing complexity are included.
- ▶ Airtightness is the benefit that conduction math cannot see. ORNL blower-door testing measured a SIP test room approximately fifteen times more airtight than an identical stick-framed room. In framed construction, comparable airtightness is a separate scope of work with its own labor cost and inspection risk. In SIP construction it arrives bundled with the envelope.

The practical conclusion for Climate Zone 5: the highest-value decision is choosing a continuous-insulation envelope at all. Once inside the SIP system, a 6-1/2" wall (whole-wall $\approx$ R-21–23) sits at the economic sweet spot; 8-1/4" is justified for net-zero targets, propane or electric-resistance heat, and maximum HVAC downsizing.

2. The Physics of Diminishing Returns

Steady-state conductive heat loss through an opaque assembly is $Q = A \cdot \Delta T / R$. Because R sits in the denominator, doubling the R -value halves the heat flow — but each successive increment buys less. Moving from R -10 to R -20 cuts conductive loss by 50%. Moving from R -20 to R -30 cuts the remainder by 33%. Moving from R -40 to R -50 cuts it by only 20%. The same R -10 increment saves ten times more energy at the bottom of the curve than near the top.

Annualized for a heating climate, energy lost per square foot of envelope — wall or roof — is approximately $24 \times \text{HDD} / R$ (Btu per square foot per year). Hartford's 1991–2020 climate normal is 5,880 heating degree days (base 65°F); the coastal corridor from Fairfield County through Long Island runs nearer 4,800. Using a 6,000-HDD Hartford-area planning figure, Table 1 shows annual conductive loss per square foot of assembly at whole-assembly R -values corresponding to the standard SIP thickness ladder.

Whole-Wall R (Assembly)	Btu/sq ft·yr Lost	Marginal Btu Saved vs. Prior Step
R-14 (≈ 4-1/2" SIP)	10,286	—
R-23 (≈ 6-1/2" SIP)	6,261	4,025
R-30 (≈ 8-1/4" SIP)	4,800	1,461
R-37 (≈ 10-1/4" SIP)	3,892	908
R-45 (≈ 12-1/4" SIP)	3,200	692

Table 1 — Annual conductive heat loss per square foot of opaque envelope (wall or roof) at 6,000 HDD. The first thickness step saves nearly six times the energy of the last.

The table makes the diminishing-returns problem concrete: the jump from R -14 to R -23 saves roughly 4,000 Btu per square foot per year, while the equally “thick” jump from R -37 to R -45 saves under 700. Code-minimum walls and roofs in Climate Zone 5 already sit past the knee of this curve. Any honest cost-benefit analysis must therefore focus not on how much nominal R -value an assembly claims, but on what each unit of delivered R -value costs — and what else arrives with it.

3. Nominal vs. Whole-Wall R-Value: The ORNL Research

The foundational study is Kosny, Desjarlais, and Christian, Whole Wall Rating/Label for Structural Insulated Panels: Steady-State Thermal Analysis (Oak Ridge National Laboratory Buildings Technology Center, 1999). Using guarded hot-box testing per ASTM C236 combined with calibrated finite-difference modeling, ORNL measured the thermal performance of complete wall sections — including studs, plates, headers, corners, and interface details — rather than the insulation material alone. The same principle governs roof assemblies: rafters bridge batt and spray-foam insulation exactly as studs do in walls, so the “whole-wall” metric generalizes to any opaque assembly.

Assembly	Nominal / Clear-Wall R	Whole-Wall R (Delivered)
2×4 @ 16" o.c., R-11–13 fiberglass	R-11–13	R-9.6
2×4 @ 24" o.c., R-13 fiberglass	R-13	R-9.8
2×6 @ 24" o.c., R-19 fiberglass	R-19	R-13.7

Assembly	Nominal / Clear-Wall R	Whole-Wall R (Delivered)
3-1/2" EPS SIP	R-15.2 (clear wall)	R-13.9 – 14.1 ✓
6" EPS SIP (later ORNL summary)	R-21–23	≈ R-21 ✓
9-1/2" double-stud, dense-pack cellulose (BSC)	R-33 nominal	R-30.1

Table 2 — Whole-wall R-values from ORNL hot-box testing and Building Science Corporation's High-R Walls Case Study Analysis. Framed walls lose 25–35% of nominal value to thermal bridging; SIPs lose 7–8%.

Two structural facts drive the divergence. First, framing fraction: studies place the lumber fraction of a stick-framed shell at 15–27% of wall area (ORNL/Carpenter measured ~27% in production housing; an ASHRAE survey averaged ~25%). Wood at roughly R-1.25 per inch short-circuits the cavity insulation beside it. A SIP shell, by contrast, is roughly 3% dimensional lumber — confined to splines, plates, and openings. Second, installation quality: field-installed batts are cut, compressed, and voided around wiring and openings; a molded foam core has no installation grade below Grade I.

Cavity insulation in a framed wall delivers only about 65–75% of its nominal thermal resistance once bridging is counted. A SIP core delivers essentially face value — and EPS and GPS cores gain R-value as temperatures fall, so the rated 75°F value is conservative precisely when a Zone 5 envelope works hardest.

4. Airtightness: The Benefit Conduction Math Cannot See

R-value comparisons, however carefully corrected for thermal bridging, capture only conduction. ORNL's side-by-side test-room study (Christian and Petrie, 2002, for the SIPA/Reiker project) measured the other half of the story: at 50 pascals of depressurization, the wood-framed test room leaked 126 CFM while the SIP room leaked approximately 9 CFM — the SIP room was roughly fifteen times more airtight. In ORNL's Lenoir City, Tennessee zero-energy Habitat for Humanity homes, SIP envelopes achieved natural infiltration below 0.1 ACH versus 0.2–0.25 for comparable framed homes.

Industry sources commonly attribute up to 40% of residential heat loss to air leakage. That specific figure originates in SIPA and manufacturer materials rather than peer-reviewed literature and should be quoted as an industry estimate — but the direction and rough magnitude are not in dispute, and the EPA's ENERGY STAR program has provided concrete third-party acknowledgment by waiving the blower-door test requirement for homes with complete SIP envelopes.

For the economics of added R-value, airtightness changes the frame of the question. In stick construction, reaching 1.5–3.0 ACH50 requires a dedicated air-sealing scope — gaskets, sealants, tapes, blower-door testing, and frequently remediation — that is priced, scheduled, and inspected separately, and whose result varies with crew and weather. In SIP construction, airtightness of 1.0–1.5 ACH50 is a routine outcome of standard joint sealing. The framed wall must buy separately what the panel includes.

One honest caveat belongs in every client conversation: SIP airtightness is achievable, not automatic. It depends on disciplined spline sealing, tape, and detailing. This is an argument for integrated design-fabrication-installation responsibility — a single accountable party for the envelope — rather than an argument against the system.

5. How Each System Buys Additional R-Value

5.1 The SIP Thickness Ladder

In a SIP, the expensive components — OSB skins, adhesive lamination, engineering, fabrication, crane time, and installation labor — are purchased at the first inch. Moving up the thickness ladder buys more of the cheapest component in the assembly: foam. Published pricing reflects this. A common industry heuristic holds that each added inch of core (roughly R-8 at EPS's ~R-3.8/inch) adds only about 5% to panel cost, and published price ladders show each nominal thickness step adding roughly 25–30% to panel material cost while the installed cost of the wall — crane, crew, sealing, schedule — stays essentially flat.

Nominal Panel	Rated R (EPS, 75°F)	U-Factor	Relative Panel Cost
4-1/2"	R-15	0.066	Baseline
6-1/2"	R-23	0.043	≈ +25–30%
8-1/4"	R-30	0.033	≈ +25–30% over 6-1/2"
10-1/4"	R-37	0.027	Larger step — see note
12-1/4"	R-45	0.022	Larger step — see note

Table 3 — EPS SIP thickness ladder. R-values and U-factors per Premier SIPs published data at 75°F mean temperature; relative panel material cost from published price ladders (installation, freight, and fabrication additional).

Cost scaling stays roughly linear up the ladder until above 8-1/4", where a meaningful step increase appears. Three mechanisms drive the nonlinearity: spline and plate lumber must match core depth, forcing wider dimensional lumber or LVL splines; thicker panels consume more flatbed cube, so fewer panels ship per load; and pre-routed electrical chases become deeper and costlier to fabricate. These are real costs and should be disclosed — but even with them, the thick-panel steps remain far cheaper per delivered R-value than any framed alternative. The same ladder applies to roof panels, which typically run one to two thickness steps above the walls of the same building and carry a modest premium over wall panels of equal thickness for engineering and handling.

5.2 Graphite Polystyrene (GPS / Neopor®) Cores

Graphite-enhanced EPS delivers approximately R-4.7 per inch at 75°F — rising to about R-5.0 per inch at 40°F — versus roughly R-3.6–3.8 for white EPS: a 20–25% improvement per inch of thickness. The core premium runs roughly 5–15% per square foot, partially offset by the ability to hit a target R-value with a thinner, lighter, cheaper-to-ship panel. GPS is the right recommendation where wall thickness, freight distance, or a specific U-factor target governs — and its cold-weather gain means rated performance is conservative for Zone 5 winters.

5.3 The Stick-Framed Paths to Higher R

A framed wall has three routes to higher delivered R-value, and each carries systemic cost that the bare material price conceals. Framed roofs face the same arithmetic — rafters bridge exactly as studs do, and cathedral assemblies add venting and depth constraints of their own.

- ▶ Deeper framing (2×4 to 2×6): a modest material upcharge that buys only about R-2.2 whole-wall, because the deeper studs bridge more aggressively even as the cavity grows. Measured per delivered R-value, this is the weakest upgrade in residential construction.
- ▶ Exterior continuous insulation: rigid foam or mineral wool over the sheathing is the effective fix for thermal bridging, but the installed cost runs several times the bare board price because CI drags a system behind it: furring strips (which alone can cost as much as the insulation),

long-fastener cladding attachment, window and door buck extensions at every opening, WRB and flashing redesign, and coordination among framing, insulation, and siding trades.

- ▶ Double-stud walls: material-efficient for bulk R (dense-pack cellulose at ~R-3.5–3.8/inch in a deep cavity), reaching whole-wall R-30+ at modest material cost. The systemic price is a second framing operation, lost interior floor area, longer schedule — and airtightness still purchased separately.

6. Cost per Delivered R-Value

Normalizing every upgrade path to cost per delivered whole-wall R-value — indexed to the first SIP thickness step — puts the systems on one axis. The ratios below are planning-grade estimates assembled from published pricing; live quotes will vary with freight, market, and design.

Marginal Upgrade	Δ Whole-Wall R	Relative Upgrade Cost	Relative Cost per Delivered R-Value
SIP 4-1/2" → 6-1/2"	≈ +8	1× (baseline)	1× ✓
SIP 6-1/2" → 8-1/4"	≈ +6	≈ 1×	≈ 1.3× ✓
SIP 8-1/4" → 10-1/4"	≈ +6	≈ 1.3–1.5×	≈ 1.7–2×
SIP 10-1/4" → 12-1/4"	≈ +7	≈ 1.5–1.8×	≈ 1.7–2×
2×6 wall + R-5 exterior CI	≈ +5	≈ 3–4×	≈ 4–6×
2×6 wall + R-10 exterior CI	≈ +10	≈ 4–6×	≈ 3.5–5×
2×6 → double-stud (bulk R)	≈ +23	material low; labor, floor area, air sealing extra	material-cheap; systemically higher

Table 4 — Marginal cost per delivered whole-wall R-value, indexed to the first SIP thickness step (= 1×). Exterior CI on a framed wall costs three to six times as much per delivered R-value as stepping up a SIP core.

How to read the table — take the “2×6 wall + R-5 exterior CI” row as an example. Adding a nominal R-5 layer of continuous insulation to a framed 2×6 wall raises the wall's delivered whole-wall performance by about 5 R (second column). Doing so costs roughly three to four times as much as the baseline upgrade — stepping a SIP from 4-1/2" to 6-1/2" — shown in the first row (third column). And because the CI upgrade spends more money for less added R (+5 versus the SIP step's +8), each unit of R-value it actually delivers costs roughly four to six times as much as a unit delivered by the SIP step (fourth column). The fourth column is the one that matters: it is the price of performance, normalized so any two rows can be compared directly.

The pattern is unambiguous. Adding delivered R-value inside a SIP is cheap because no new trades, fasteners, or details are introduced — the panel simply arrives thicker. The first layer of exterior CI on a framed wall is expensive per R-value precisely because it introduces a new construction system. Double-stud walls become competitive for bulk R on materials alone, but pay in framing labor, floor area, schedule, and a still-separate air-sealing scope.

7. Energy Prices and Payback in Climate Zone 5

Connecticut and the surrounding Zone 5 markets carry among the highest delivered energy prices in the United States, and the cost of a delivered unit of heat varies enormously by fuel. Indexed to

natural gas — the cheapest common fuel in the region — the relative cost of delivered heat is approximately:

Heating Fuel / System	Relative Cost of Delivered Heat	Assumption
Natural gas (95% AFUE)	1× (baseline)	confirm local utility rate
Air-source heat pump	≈ 1.4×	COP 2.75 at current CT electric rates
Heating oil (85% AFUE)	≈ 1.7×	mid-2026 CT statewide median
Propane (90% AFUE)	≈ 2.1×	mid-2026 CT market
Electric resistance	≈ 3.8×	current CT electric rates

Table 5 — Relative cost of delivered heat by fuel, Connecticut market, indexed to natural gas. The more expensive the client's fuel, the faster every envelope upgrade pays back.

Applying these relative fuel costs to the marginal SIP step from 6-1/2" to 8-1/4" (saving ~1,461 Btu per square foot of panel per year at 6,000 HDD, against the modest per-square-foot panel premium):

Fuel	Relative Annual Savings	Simple Payback
Propane	2.1× baseline	≈ 15–20 years
Heating oil	1.7× baseline	≈ 20–25 years
Heat pump	1.4× baseline	≈ 20–25 years
Natural gas	1× (baseline)	≈ 30–35 years

Table 6 — Conduction-only simple payback for the 6-1/2" → 8-1/4" SIP wall upgrade, 6,000 HDD, at current Connecticut fuel prices.

Read correctly, Table 6 is a statement of honesty, not weakness: the marginal thickness step above whole-wall R-23 has a long conduction-only payback, exactly as the 1/R physics predicts — and the equivalent framed-wall upgrade at three to five times the cost per R-value pays back proportionally worse. The economic case that is strong is the first move into the SIP envelope, which bundles the airtightness benefit, permits smaller and cheaper HVAC equipment at construction time, and delivers whole-wall performance that a nominal-R framed wall never achieves. Conduction-only math cannot see those benefits; the client's utility bill and Manual J calculation can.

8. Code Compliance Context

The 2021 IECC prescriptive path for wood-framed walls requires R-13+5ci or R-20 in Climate Zone 4, and R-20+5ci, R-13+10ci, R-30 cavity, or R-20ci in Zones 5–6 — the code itself now assumes continuous insulation in cold climates. The alternative U-factor path sets a maximum of approximately U-0.060 in Zone 5 and U-0.045 in Zone 6 for wood-framed walls.

SIPs comply most naturally through the U-factor and UA-alternative paths, where whole-wall performance counts. A 6-1/2" EPS SIP at U-0.043 clears the Zone 5 requirement with nearly 30% margin and satisfies Zone 6 outright; an 8-1/4" panel at U-0.033 exceeds both comfortably. The same logic governs roofs: a 12-1/4" EPS roof panel at U-0.022 passes the Zone 5 ceiling maximum of U-0.026 under the same path. Connecticut's State Building Code is based on the 2021 IECC; New

York enforces the 2020 ECCCNY (2018 IECC base with amendments) plus the optional NYStretch code; Massachusetts layers its Stretch and municipal Specialized (net-zero) codes over a 2021-IECC base. In every one of these jurisdictions, the U-factor compliance path is a mandatory acceptance — a code official may not insist on the prescriptive cavity-R table when the assembly demonstrates equivalent or better U-factor performance.

9. The Economic Optimum: Where to Stop

The cost-optimal literature — Building Science Corporation's High-R wall analyses, GreenBuildingAdvisor's diminishing-returns work, Energy Vanguard's climate-zone modeling, and the PNNL/DOE cost-effectiveness studies behind IECC code development — converges on a practical band: in cold climates, the economically defensible whole-wall stopping point is roughly R-30 to R-40; for roofs, where code and cost-optimal targets run higher (ceiling R-49–60 territory), the stopping point sits correspondingly higher — which is why SIP roof panels typically run one to two thickness steps above the walls. Beyond those points, the next dollar is better spent on air sealing, windows, or mechanical systems.

The SIP twist on that standard advice is that the usual first destination for the diverted dollar — air sealing — is already bundled with the panel envelope. A SIP builder has effectively pre-purchased the air-sealing scope that the cost-optimal literature tells framed-wall builders to fund before adding insulation. The marginal dollar in a SIP project therefore moves directly to windows, mechanical ventilation (the ERV/HRV that every tight envelope requires), and right-sized heat-pump equipment.

Secondary benefits round out the analysis. Right-sized HVAC equipment — typically one to two sizes smaller than an equivalent framed home requires — recovers part of the panel premium at construction time, and runs longer, quieter, better-dehumidifying cycles thereafter. Comfort, acoustic attenuation, cavity-condensation resistance, and documented envelope performance at resale all accrue to the continuous-insulation side. Incentives sharpen the timing: the federal 45L builder credit (larger for Zero Energy Ready certification than for ENERGY STAR) applies only to qualifying homes acquired before July 1, 2026 under the One Big Beautiful Bill Act's revised termination date, and state programs — Energize CT, NYSEERDA's low-rise new-construction incentives, and Mass Save — continue to subsidize high-performance envelopes.

10. Conclusions and Recommendations

- ▶ Lead with delivered R and airtightness, not nominal R. The honest comparison is whole-wall to whole-wall: a nominal R-19/R-21 framed wall delivers ~R-13.7; a 6-1/2" SIP delivers ~R-21–23 plus an envelope roughly fifteen times tighter.
- ▶ Default to 6-1/2" walls in Climate Zone 5. Whole-wall R-21–23 clears the U-factor compliance path with margin and sits at the knee of the cost-optimal curve.
- ▶ Recommend 8-1/4" where it earns its premium: net-zero and Passive House targets, propane or electric-resistance heating, maximum HVAC downsizing, or Zone 6 sites in the Litchfield hills and upstate New York.
- ▶ Treat 10-1/4"+ panels as premium, roof-driven, or program-driven choices, and disclose the above-8-1/4" cost step (spline lumber sizing, freight cube, chase fabrication) candidly.
- ▶ Offer GPS/Neopor® cores as the thinner-higher-R alternative wherever wall thickness, freight, or a hard U-factor target governs.

- ▶ Show clients Table 4. One-third to one-half the cost per delivered R-value, with no added trades, is the clearest single statement of the SIP economic advantage over framed walls chasing the same performance.

11. Sources

- ▶ Kosny, J., Desjarlais, A., and Christian, J. Whole Wall Rating/Label for Structural Insulated Panels: Steady-State Thermal Analysis. Oak Ridge National Laboratory Buildings Technology Center, 1999.
- ▶ Christian, J. and Petrie, T. Heating and Blower Door Tests of the Rooms for the SIPA/Reiker Project. Oak Ridge National Laboratory, 2002.
- ▶ Building Science Corporation. High-R Walls Case Study Analysis (BA-1005).
- ▶ 2021 International Energy Conservation Code, Tables R402.1.2 and R402.1.3.
- ▶ Premier SIPS. Published R-Value / U-Factor / Weight tables. sips.premierbuildingsystems.com.
- ▶ U.S. Energy Information Administration. Electric Power Monthly, 2026; Connecticut heating-oil price surveys.
- ▶ GreenBuildingAdvisor: The Diminishing Returns of Adding Insulation; Energy Vanguard: The Diminishing Returns of Adding More Insulation.
- ▶ SIPA. R-Values in the Real World. sips.org.

Caveats:

The “40% of heat loss from air leakage” and “up to 33% smaller HVAC” figures circulate in SIPA and manufacturer materials rather than peer-reviewed studies and are presented as industry estimates. The “~5% cost per added inch” heuristic derives from cost-guide aggregators. All pricing is planning-grade for 2025–2026 and should be confirmed by live quote, particularly freight for thick panels. Payback figures are conduction-only and deliberately understate the full SIP case. Both wall systems face the identical 1/R diminishing-returns curve — the SIP argument is not an escape from physics; it is a lower cost per delivered R-value, and an airtight envelope included in the price.