

R-Values Compiled from Manufacturers' Data

by Peter P. Nuspl, PhD ⁱ ⁱⁱ ⁱⁱⁱ

This article has four objectives: 1. Present a representative compilation of manufacturers' data of R-values for Structural Insulated Panels (SIP) and Insulated Concrete Forms (ICF) with four types of panels and explanations: EPS is Expanded PolyStyrene, PUR is PolyURethane and Straw is wheat or rice straw; also stud walls with sprayed foam polyurethane (SFP) are included. 2. Compare the R-values and make observations. 3. Provide approaches to achieve other desired R-values. 4. Indicate future areas of reporting. Although performance as indicated by R-values is the main topic of this article, there are other factors in making selections of materials: flexibility, cost, availability, delivery to the job site, installation cost and speed, durability, and others.

Chart of R-Values

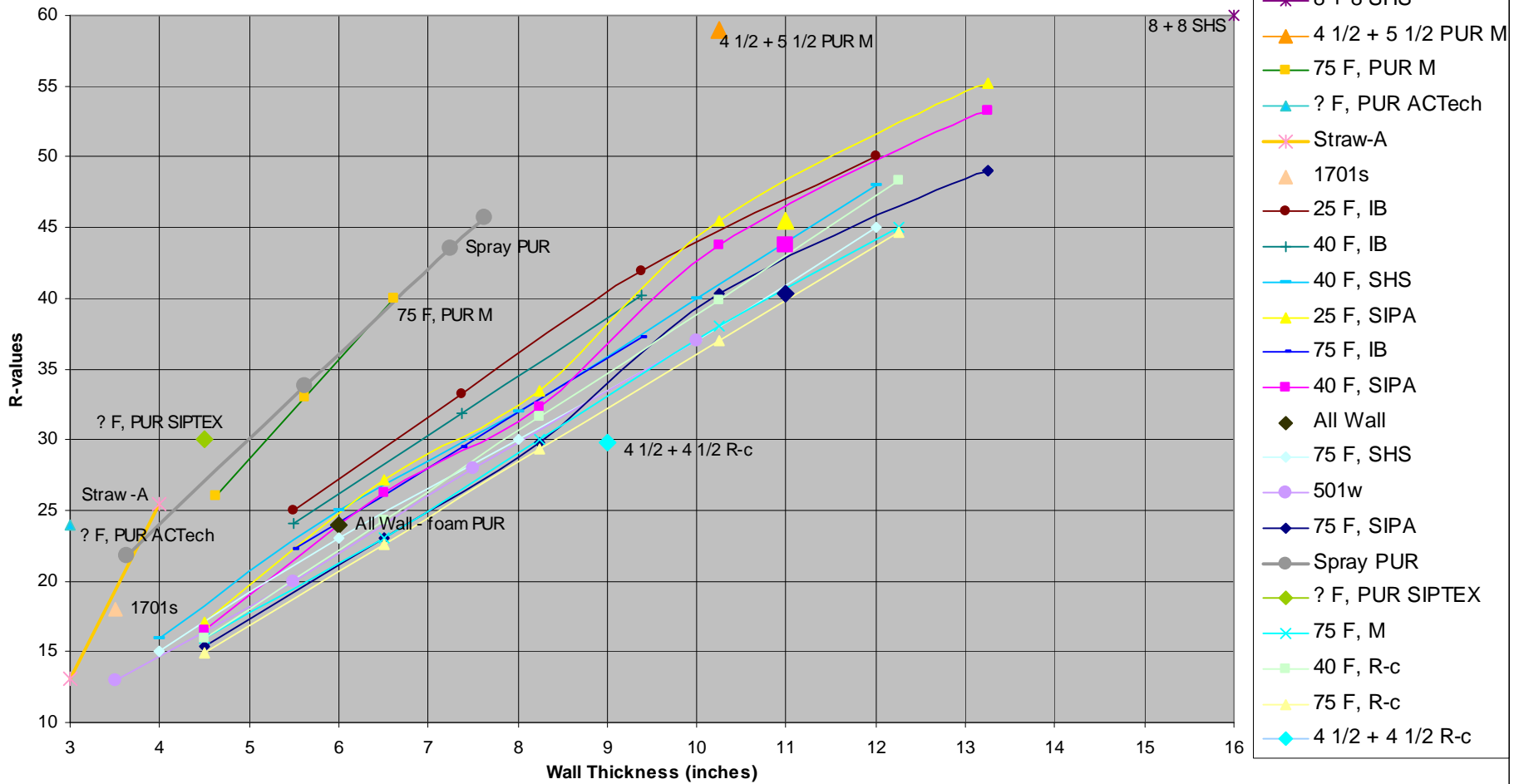
Resistance to heat flow, R, is usually indicated as R-n, where n is the R-value – the higher the R-value the better the insulation. The units of R-value and RSI-value are discussed below. There is quite a controversy in the building industry on the validity of using R-value as an indicator of performance; however it is the current manufacturer, builder and regulator practice. With the exception of 501w SPF (open-celled) by BioBased, all of the insulation material reported here is “solid”, or so-called closed cell: trapped air bubbles are small and stay in place. In addition to resisting conduction of heat, convection by air movement is minimal so steady-state R-values are applicable in actual conditions, and radiation is not a major factor in insulation. Vapor penetration through these insulation materials is very low, and moisture does not accumulate.

The charts provide a composite view of reported R-values. As reported, the R-values for three (outside) temperatures, 75 F, 40 F and 25 F are shown; generally R-values improve somewhat for lower (outside) temperatures and are lower in hot conditions.

- In the chart for SIPs, the multiple sets of curves (using solid lines) in the center are for EPS SIPs; there is a small anomaly (slightly higher) at 10 ¼ inches in each of the data sets by SIPA (the SIP Association): the larger symbols to the right of each curve would make them consistent with the trend. [This anomaly has been drawn to SIPA's attention; no response has been received.] Murus reports that its 75 F R-values are based on measurements. Most of these data points appear to be calculated from R-values per inch; the author does not subscribe to this approach and the U.S. Federal Trade Commission (FTC) prohibits the use of “R-value per inch”.
- The data points and solid lines up and to the left are for PUR SIPs; clearly, higher insulation is provided in less thickness. ACTech, Better Building Products and Tiger Foam do not explicitly report the applicable temperature; it can be assumed to be 75 F. It should be noted that the All Wall system uses PUR as insulation and concrete as structure; it is both a SIP and an ICF.
- The highest insulation is achieved by the newest product, a straw-based insulation in a SIP by Agriboard Industries.

- Three additional data points are shown for composite SIP walls or roofs. As a first estimate, it is acceptable in the industry to add the R-values for such composite structures. A double wall of 4-inch panels ($4\frac{1}{2} + 4\frac{1}{2}$) yields almost R-30; a double stud wall of $7\frac{1}{4}$ is estimated at R-44 when using PUR, with additional insulation from drywall and siding. A combination of ($4\frac{1}{2} + 5\frac{1}{2}$) SIPs has R-59, and a double ceiling/roof of ($8 + 8$) inches each achieves R-60.

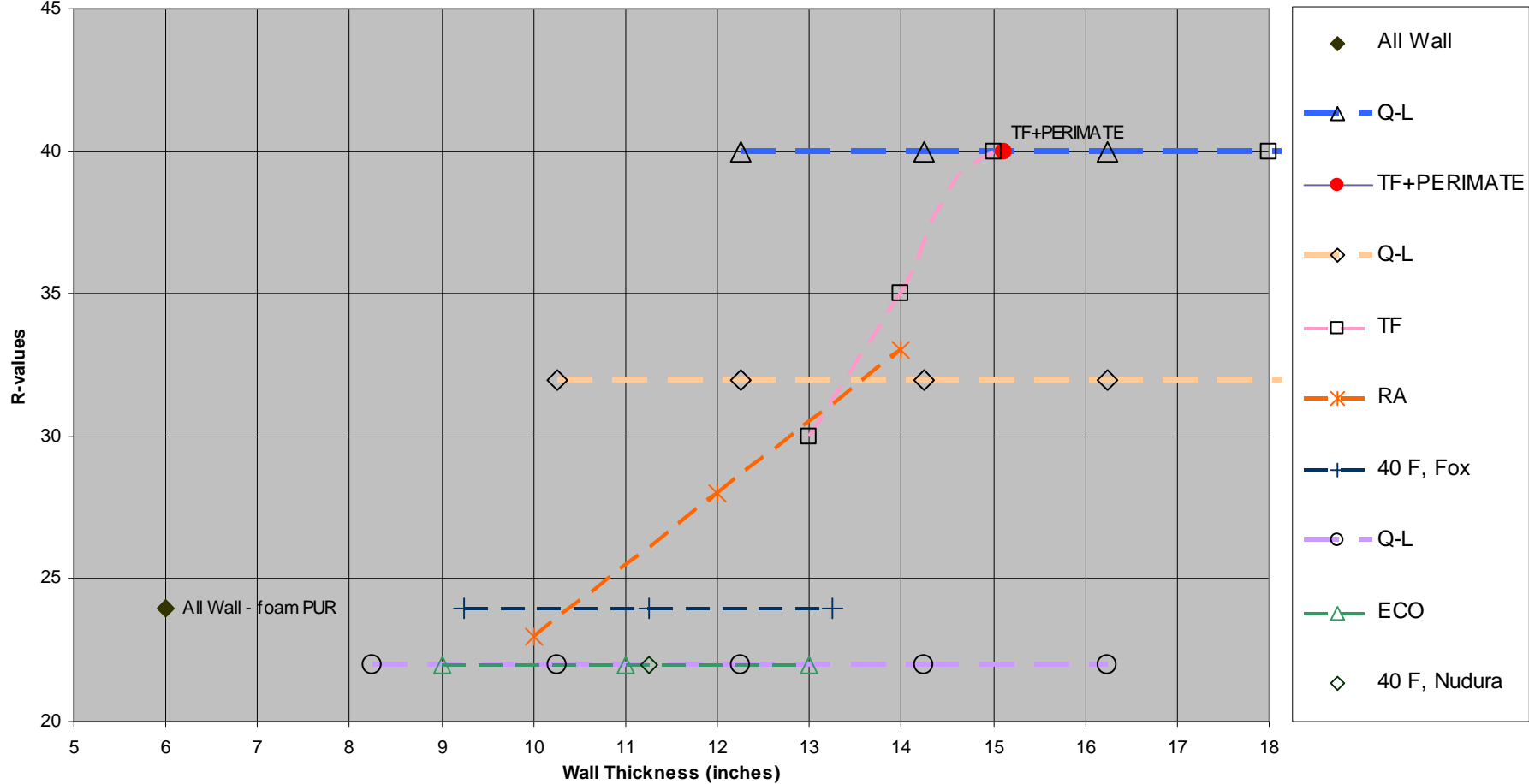
R-values of SIPs using Straw, PUR or EPS



ACTech	ACTechpanels	R-c	R-control	Spray	Tiger Foam Insulation
IB	IB Panels	SHS	SIP Home Systems	501w, 1701s	BioBased
M	Murus	SIPTEX	Better Building Products	Straw-A	Agriboard
	SIPA	Structural Insulated Panel Association (USA)			
	SPFA	Spray Polyurethane Foam Alliance (USA)			

- In the chart for ICFs, the six dashed lines in the lower right of the chart are for EPS ICFs. For three target R-values by Quad Lock, there are different concrete thicknesses for required strength. Other R-values can be achieved by selecting inside and outside panel thicknesses. The Fox Block system has R-24. Fox Block, Quad-Lock and Rastra consist of horizontal elements; the TF system uses vertical elements. The Rastra system consists of building blocks; RASTRA® is a concrete form system that is made of a lightweight material called THASTYRON™ (a composite of re-cycled polystyrene and cement), and three thicknesses as shown are available. Agriboard also suggests its SIP can be an ICF, but it is not usual to use a wood product below grade.
- A composite ICF wall is also illustrated: the 13” TF System + 2.1” STYROFOAM PERIMATE™, with a total R-40. *It is noteworthy that concrete has very low insulation value (here assumed R-0) but concrete has a range of R-values from R-0 to R-<1 per inch.*

R-values of ICFs using PUR or EPS



ECO	Eco-Block	RA	Rastra
Fox	Fox Blocks	Q-L	Quad-Lock
PERIMATE	Dow	TF	TF Systems

ICFA Insulating Concrete Forms Association (USA)

Comparing R-Values

The charts provide graphic comparison and contrast of wall thicknesses and R-values available; there are three types of SIPs represented: EPS, PUR and straw. For EPS SIPs, the chart shows about a spread of 3 in R-values at a given temperature for the same wall thickness. The more conservative curves by R-control can be compared to the higher values by IB Panels. For PUR SIPs, the ACTech SIP is the thinnest at 3 inches but note that inner and outer skins are thin metal panels having R-0. At R-22, a simple stud wall exceeds the minimum R-19 required by most codes; however the quality and uniformity of the spray application can be problematic. At R-30, PUR SIPTEX appears to give the best insulation for a 4 ½” wall thickness, but the corresponding test temperature is not given. The TF ICF wall at 18 inches uses four thinner (and cheaper) EPS panels. The newest EPS, and perhaps the “greenest”, is made by Agriboard Industries which has SIPs with two thicknesses made of wheat or rice straw (agricultural byproduct) and OSB (oriented strand board).

How to Get Other R-Values

The reported SIP and ICF thicknesses are available as products from these companies. So, how can other R-values be obtained? Another way to get close to R-30 is to form a composite wall of two 4 ½ EPS SIPs by R-c. A double stud wall can yield up to R-46, but the studs need to be staggered so that thermal bridging by the studs is avoided. To get close to R-60 in a ceiling/roof, a composite of 4 ½ and 5 ½ PUR SIPs by Murus can be used. Likewise, R-60 can be achieved by combining two 8-inch EPS SIPs by SHS. TF Systems has other R-values available by selecting 2 ½, 3, 4 or 4 ½ inch EPS panels. Also, a concrete wall with R-40 can be achieved by adding more insulation to the basic Vertical TF wall, as with PERIMATE™.

Here is a note on units of R-value. Although R-values are almost always expressed without units, the imperial unit is ft²·°F·h/BTU. The SI (Système Internationale) unit for RSI-value is Kelvin meter square per watt (K·m²/W). The conversion factor is 1 ft²·°F·h/BTU ≈ 0.1761 K·m²/W, or 1 K·m²/W ≈ 5.67446 ft²·°F·h/BTU. For example, R-16 means that 16 square feet of this material will lose one BTU per hour when the temperature difference is one degree Fahrenheit. Another way to interpret this: a square foot allows heat flow at one BTU per hour when the temperature difference is 16 F. The R-value RSI-2.8 is equivalent to R-16.

Also, some sources and specifications give the U-value or U-factor, which is just the inverse of the R-value. The coefficient of heat conductivity, k, for a material is in units of W/mK; this coefficient is published as per meter or per foot and is usually applied to homogeneous materials.

$$1 \text{ W/(mK)} = 1 \text{ W/(mC)} = 0.85984 \text{ kcal/(hr mC)} = 0.5779 \text{ Btu/(hr ft F)}$$

Future Reports

There are clearly additional topics which need attention as builders and owners focus more and more on green building, affordable housing and life-cycle operations.

- Windows, skylights and doors are major problems with heat loss due to their relatively low R-values and potential for air infiltration. A compilation of data from major suppliers will be prepared soon.
- Cost information is difficult to get, and even more problematic when comparing data on materials.
- Cost/benefit analyses are claimed by some proponents of SIPs and ICFs, but there is apparently no consistent method of analyses and there would appear to be “selective” reporting of results. The author hopes to construct a reasonable analysis and make comparisons based on a typical model house; a documented, unbiased report should be of great interest to regulators, associations, builders and owners.
- A significant aspect of the Green Building movement is to have solar applications. Comparisons of thermal collectors (flat-plate and evacuated tubes) are being prepared. Also, there are several types and many manufacturers of photovoltaic (PV) panels, in size from garden lights to arrays that produce several kilowatts for the home owner; consumers would likely appreciate an unbiased view.
- An article on elevation (tilt) angles for thermal and PV collectors will explain the benefits of getting the tilt angles right for a specific location, including the effects of shadowing. The benefits of adjustable tilt angles will be explained. The advantages and costs of elevation tracking, azimuth tracking, and sun-tracking will be covered.

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ⁱ Dr. Peter Nuspl is a retired professional engineer with extensive experience in modeling, designing, calculating and simulating. He is an accomplished author and lecturer. Peter is a strong proponent of solar thermal for domestic hot water and space heating; he encourages selective uses of solar PV. Dr. Nuspl is a consultant on solar thermal and has a proprietary calculation of tilt angles for thermal and PV collectors in the USA and Canada. He is avidly looking into solar cooling for single-family houses.

Peter is currently designing a set of ECO-friendly single-family houses, and intends to start construction on one in 2009. These house designs will have solar features in combinations not now available: conservation, collection, storage and distribution; these houses also have other “green” features, such as high insulation values, sustainable materials (cedar, pine, fir, bamboo, glycol and straw-based or soy-based SIPs, water management).

ⁱⁱ If requested, Dr. Nuspl will prepare a metric and SI version of these data and chart, and include other manufacturers worldwide. He can be contacted at peter07@comcast.net.

ⁱⁱⁱ Dr. Nuspl has no affiliation with any of these manufacturers nor with associations. As an independent consultant and designer, he occasionally recommends and specifies one or more of these or other products.