SPFA
SPRAY POLYURETHANE FOAM ALLIANCE

Counting Carbon:
Demand a Better Insulation in Your Next Home

Spray Polyurethane Foam (SPF) insulation is clearly a better insulation choice.

The environment, and the impact our decisions have on it, are top of mind these days. We consider environmental impact, using terms like embodied carbon, carbon footprint, life-cycle analysis and use-phase when we make purchase decisions. None more important than our homes.

Let's consider SPF insulation and compare it to fiberglass insulations.

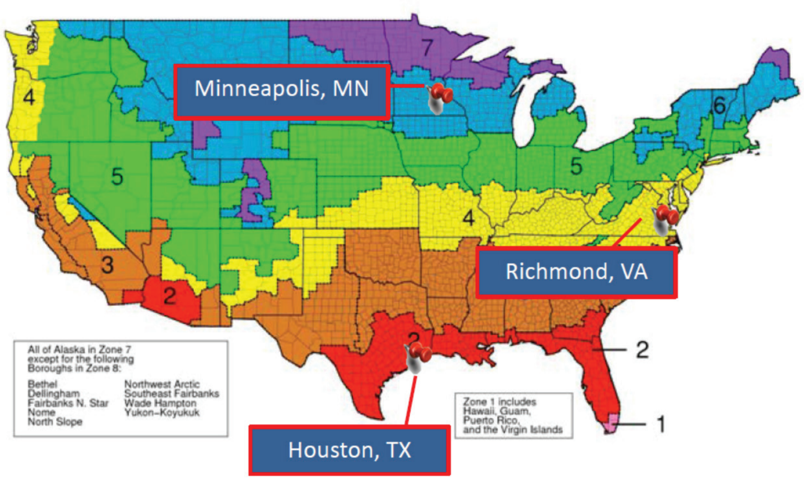
Although foam plastic insulations have a higher initial environmental impact than fiberglass insulations, their higher R-values and inherent air impermeability saves additional energy when installed at the same R-value as fiberglass insulations. The ability of SPF to seal wall cavities and provide a vapor, thermal and air control layer eliminate the need for additional vapor retarders and barriers in cold climates. When closed cell spray polyurethane foam (ccSPF) is used, staggered double wall construction and extra-thick wall and roof construction to achieve increased R-value requirements are not needed. You can build with less wood and still have a resilient, energy efficient home.

Scope of the Use-Phase Study

In a recent study[i], two environmental impacts were evaluated over a 75-year period: Cumulative energy demand and global warming potential. These impacts were estimated for a typical new 2,512 square foot home insulated and air-sealed to the 2018 International Energy Conservation Code (IECC)[ii] constructed in three different US climate zones:

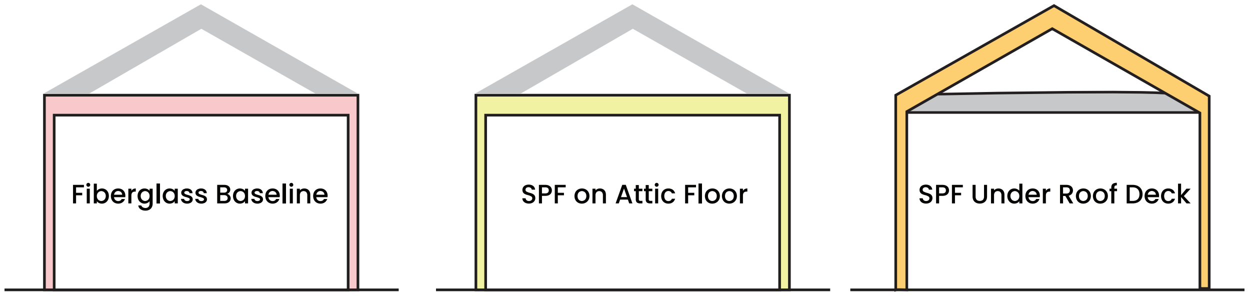
- **Houston, TX (hot-humid climate Zone 2)**
- **Richmond, VA (mixed climate Zone 4)**
- **Minneapolis, MN (cold climate Zone 6)**

Locations of Homes on IECC Climate Zone Map



Insulation Application Methods

The homes were equally insulated according to 2018 International Energy Conservation Code (IECC) requirements in their respective climate zones using fiberglass as a baseline and various types of spray polyurethane foam (SPF) insulation. The homes using SPF were insulated on the top floor ceiling (attic floor) creating a vented attic design and beneath the roof deck to create an unvented attic design. Unvented attic designs are often used to bring ductwork and HVAC equipment located in the attic inside the thermal envelope of the building.



Insulation Applications Modeled in this Study

Insulation Requirements

Using the insulation requirements from the 2018 IECC, the total number of insulation functional units (FU's) were determined for the home in each climate zone. These functional units are shown in lines 2-4 of the table below.

Note that since more insulation is required by the energy code in a building in Minneapolis than the same building in Houston, the Minneapolis home will have more functional units of insulation than the same home in Houston, making a city-to-city comparison difficult.

		HOUSTON, TX (Hot-Humid)			RICHMOND, VA (Mixed)			MINNEAPOLIS, MN (Cold)		
		Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck
1	**Insulation Requirements[1]**									
2	Wall Insulation FUs	534	534	534	822	822	822	1,401	1,401	1,401
3	Ceiling Insulation FUs	819	819		1,057	1,057		1,057	1,057	
4	Roof Deck Insulation FUs			1,513			1,951			1,951

1. Minimum insulation requirements for 2018 IECC for the 2512 SF home. Homes in Richmond and Minneapolis at conditioned areas of 3,651 SF to include insulated basements. Wall cavity insulation for Minneapolis set to R34.1 to provide same U-factor as R20 cavity insulation and R5 continuous insulation.

Environmental Impact of Insulation

We know how much insulation (functional unit) is required. To determine the environmental impact of that much, of that kind of insulation, we multiply the number of functional units (how much) by the environmental impact assigned to that specific insulation (how bad). Each material is required to provide an independent Environmental Product Declaration (EPD) which identifies several different environmental impacts for that product.

For our study, the final number represents the insulation environmental impact 'spent' to insulate the building.

The total building Global Warming Potential (GWP) impact is shown in lines 7-12 and the cumulative energy demand is shown in lines 14-19 of the table below.

		HOUSTON, TX (Hot-Humid)			RICHMOND, VA (Mixed)			MINNEAPOLIS, MN (Cold)		
		Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck
6	**GWP (1000 kg CO_2)**									
7	Fiberglass Insulation (baseline)[2]	1.63			2.27			2.27		
8	High-Pressure Open-Cell SPF		2.24	3.39		3.11	4.59		4.07	5.55
9	2K-LP Closed-Cell SPF (HFC)		48.38	73.20		67.19	99.14		87.90	119.86
10	2K-LP Closed-Cell SPF (HFO)		5.16	7.88		7.16	10.57		9.37	12.78
11	High-Pressure Closed-Cell SPF (HFC)		27.31	41.32		37.93	55.96		49.62	67.66
12	High-Pressure Closed-Cell SPF (HFO)		5.63	8.52		7.82	11.54		10.23	13.95
13	**Energy Demand (MJ)**									
14	Fiberglass Insulation (baseline)[2]	20.6			28.6			28.6		
15	High-Pressure Open-Cell SPF		58.9	89.1		81.8	120.7		107.0	145.9
16	2K-LP Closed-Cell SPF (HFC)		124.9	188.8		173.3	255.8		226.7	309.2
17	2K-LP Closed-Cell SPF (HFO)		123.4	186.6		171.3	252.8		224.1	305.6
18	High-Pressure Closed-Cell SPF (HFC)		144.1	218.0		200.0	295.2		261.7	356.9
19	High-Pressure Closed-Cell SPF (HFO)		149.2	225.6		207.0	305.5		270.8	369.3

2. Fiberglass insulation environmental impacts are aggregate values from individual product specific EPDs.

Energy Savings from Insulation

Energy modeling was performed using EnergyGauge[iii] to estimate the HERS score and annual energy use of the home in each of the three building designs, in each of the three climate zones in terms of natural gas (therms) and electricity (kWh).

The HERS (Home Energy Rating System) score is an index that reflects the energy efficiency of a home. A score of 100 means the home meets the 2006 International Energy Code requirements. Typical existing homes more than 20 years ago have scores in the range of 120 to 150. Newer energy efficient homes have scores in the 50-70 range. A HERS score of zero corresponds to a zero-energy home.

These results are provided in lines 21-23 in the table below.

		HOUSTON, TX (Hot-Humid)			RICHMOND, VA (Mixed)			MINNEAPOLIS, MN (Cold)		
		Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck
20	**Annual Energy Use**									
21	HERS Score[3]	66	63	58	66	66	60	64	61	56
22	Total Natural Gas (therms)	302	263	244	499	486	437	890	801	720
23	Total Electric (1000 kWh)	10.90	10.80	10.10	10.20	10.20	9.50	9.80	9.80	9.20

3. It was assumed that the home insulated with air-permeable fiberglass insulation will meet the minimum 2018 IECC requirements for air-sealing (5.0 ACH_{50} in Houston, 3.0 ACH_{50} in Richmond and Minneapolis. In most cases, additional air barrier materials and systems will be needed to meet air leakage limits in the building code, but are conservatively not included in the environmental impact for fiberglass insulation.

Environmental Benefit from Insulation

Homes insulated with SPF insulation will typically have reduced air infiltration and lower HERS scores and additional annual energy savings (lines 25 and 26) compared to the same home insulated to the same R-value with fiberglass. This additional energy savings is then converted to annual environmental impact reductions, cumulative energy savings and global warming reduction based on regional energy sources typically used for heating and cooling, as shown in lines 29 and 30 of the table below. These net impacts represent the **annual environmental benefit** of SPF over fiberglass insulation.

		HOUSTON, TX (Hot-Humid)			RICHMOND, VA (Mixed)			MINNEAPOLIS, MN (Cold)		
		Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck
24	**Annual Energy Savings (SPF vs FG)**									
25	Gas Savings (kWh/yr)		1,143	1,699		381	1,817		2,608	4,981
26	Electric Savings (kWh/yr)		139	857		(2)	698		(3)	657
27	Total Energy Savings (kWh/yr)4		1,282	2,556		379	2,515		2,605	5,638
28	**Annual Environmental Impact Reduction**									
29	GWP (kg C02/yr)		349	950		84	871		589	1,556
30	Cumulative Energy (MJ/yr)		4,433	13,855		938	12,375		6,609	19,896

4. The total additional energy savings from SPF compared to fiberglass (line 27) is always positive in all climate zones, which directly impact the annual energy cost.

Environmental Payback of SPF Compared to Fiberglass Insulation

The time it takes for the additional energy savings of SPF to recover the initial environmental impact is calculated as the 'payback' or recovery period. For each SPF insulation installation, and climate zone, the GWP impact payback period is calculated in lines 33-37. Similarly, the cumulative energy demand recovery period is calculated in lines 39-43.

		HOUSTON, TX (Hot-Humid)			RICHMOND, VA (Mixed)			MINNEAPOLIS, MN (Cold)		
		Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck	Fiberglass Insulation (baseline)	SPF on Attic Floor	SPF under Roof Deck
31	**Environmental Impact Recovery (years)[5]**									
32	**GWP**									
33	High-Pressure Open-Cell SPF		2	2		10	1		3	2
34	2K-LP Closed-Cell SPF (HFC)		134	75		773	75		145	76
35	2K-LP Closed-Cell SPF (HFO)		10	7		58	6		12	7
36	High-Pressure Closed-Cell SPF (HFC)		74	42		425	41		80	42
37	High-Pressure Closed-Cell SPF (HFO)		11	7		66	6		14	8
38	**Cumulative Energy Demand**									
39	High-Pressure Open-Cell SPF		9	5		57	7		12	6
40	2K-LP Closed-Cell SPF (HFC)		24	12		154	18		30	14
41	2K-LP Closed-Cell SPF (HFO)		23	12		152	18		30	14
42	High-Pressure Closed-Cell SPF (HFC)		28	14		183	22		35	16
43	High-Pressure Closed-Cell SPF (HFO)		29	15		190	22		37	17

5. Environmental impact recovery (payback) period calculated by dividing the total environmental impact of the insulation by the annual impact reduction from using that insulation.

Interpretation of Results

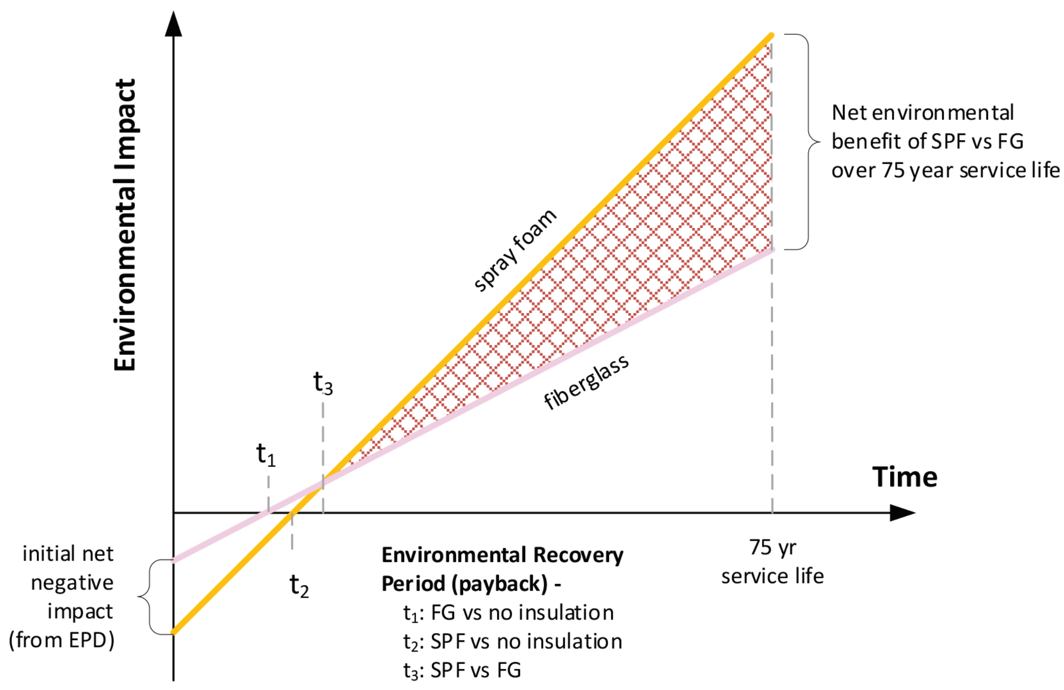
Let us look at the environmental impact when we own these homes over a period.

The chart below shows environmental impact on the vertical axis and time on the horizontal axis.

First, let us draw a line representing our baseline - a building with no insulation. In this case, there is no environmental impact penalty as there is no insulation material to consider and there is no energy savings as a direct benefit of insulating the structure and therefore, no corresponding reduction of environmental impact from the building during its service life. This is shown by the horizontal axis.

Next, let us consider the use of fiberglass insulation, shown by the pink line. There is an initial environmental impact penalty from the insulation at the time of installation.

During the use phase of the insulation, the initial environmental impact is recovered or offset by the energy savings. When the product impact line crosses the time axis, the use of that specific insulation has recovered its initial impact; this recovery period is usually only a few months regardless of insulation type.



Environmental Impact of Insulation Choice

Now consider the use of SPF insulation, shown by the orange line. In most cases the initial environmental impact penalty for SPF will be greater than fiberglass insulation. However, SPF is air impermeable, fully adhered to the sheathing and framing members within the cavity, will not sag over time or suffer convective loss as the material gets thicker like fiberglass insulation. These additional energy saving benefits account for the steeper slope of the orange line. You get more benefit in a shorter period.

At some point during the 75-year insulation service life[iv], the environmental impact line from SPF will cross the environmental impact line of fiberglass. The time (in years) at which this intersection occurs is referred to as the "environmental recovery period". Beyond this environmental recovery period, the use of SPF insulation will have a greater positive environmental impact for the building when compared to fiberglass insulation.

What does this mean for the homeowner?

Let's consider a home in Houston, TX insulated with HFO closed-cell SPF (ccSPF) in an unvented attic.

1. The initial GWP impact from the high-pressure closed-cell SPF using HFO insulation is found (line 12) as 8.52 metric tons CO_2 from the chart.
2. The initial GWP impact from the fiberglass insulation is found (line 7) as 1.63 metric tons CO_2 from the chart.
3. The additional GWP reduction from ccSPF used under the roof deck instead of fiberglass on the attic floor is (Line 29) 950 kg CO_2/year.
4. The GWP payback is the GWP impact of the SPF less the GWP impact of the fiberglass insulation divided by the annual GWP reduction using SPF: 8,520-1,630) /950 or 7.2 years, as shown in Line 37. (7 years from the chart)

In the example, closed-cell SPF was used in an unvented attic in Houston, TX, A GWP payback of 7 years is predicted by the model. During the remainder of its 75-year service life (67 years), spray foam will prevent the release of 68 years x 950 kg CO_2/year or 64.6 metric tons of CO_2. According to the EPA, an average car releases 4.6 metric tons of CO_2 per yearv. In this example, simply choosing SPF instead of fiberglass reduces Global Warming Potential equivalent to removing 14 cars from the road.

Let us consider a home in Minneapolis, MN insulated with HFO closed-cell SPF (ccSPF) in an unvented attic.

1. The initial GWP impact from the high-pressure closed-cell SPF using HFO insulation is found (line 12) as 14.0 metric tons CO_2 from the chart.
2. The initial GWP impact from the fiberglass insulation is found (line 7) as as 2.2 metric tons CO_2 from the chart.
3. The additional GWP reduction from ccSPF used under the roof deck instead of fiberglass on the attic floor is (Line 29) 1,556 kg CO_2/year.
4. The GWP payback is the GWP impact of the SPF less the GWP impact of the fiberglass insulation divided by the annual GWP reduction using SPF: (13,950-2,270)/1,556 or 7.5 years, as shown in Line 37. (8 years from the chart)

In the example, closed-cell SPF was used in an unvented attic in Minneapolis, MN, A GWP payback of 8 years is predicted by the model. During the remainder of its 75-year service life (68 years), spray foam will prevent the release of 67 years x 1,556 kg CO_2/year or 104 metric tons of CO_2. According to the EPA, an average car releases 4.6 metric tons of CO_2 per year. In this example, simply choosing SPF instead of fiberglass reduces Global Warming Potential equivalent to removing 23 cars from the road.

It is also important to note that the **total annual energy savings from SPF versus fiberglass (line 27) is always positive in all climate zones**. This annual energy savings translates directly to reduced annual energy costs for the homeowner, which can vary by regional energy sources and pricing.

The choice of insulation is clear.

REFERENCES

[i] *"SPF Residential Energy Modeling Analysis June 2020"*, Sustainable Solutions Corporation, Royersford, PA www.sustainablesolutionscorporation.com

[ii] 2018 International Energy Conservation Code, International Code Council https://codes.iccsafe.org/content/IECC2018

[iii] EnergyGauge USA –Energy Modeling Software for Residential Energy Code Compliance, Energy Analysis and Rating. https://www.energygauge.com/energygauge-usa/

[iv] Under the North American PCR (Product Category Rules) for building insulation, the service life of building insulation is assumed to be 75 years. This is based on the nominal service life of a typical building enclosure before renovation or demolition. It is expected that if left undisturbed, building insulation could exceed the service life defined in the PCR.

[v] Greenhouse Gas Emissions from a Typical Passenger Vehicle November 2019. www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

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www.sprayfoam.org

About the SPFA

Founded in 1987, the Spray Polyurethane Foam Alliance (SPFA) is the voice, and educational and technical resource for the spray polyurethane foam industry. The Alliance is a 501(c)6 trade association comprised of contractors, manufacturers, and distributors of polyurethane foam, related equipment, and protective coatings, inspections, surface preparations, and other services. The organization supports the best practices and the growth of the industry through a number of core initiatives, including: educational programs and events; a Professional Certification Program; technical services and publications; federal and state advocacy; and networking opportunities.