LIFE-CYCLE ASSESSMENT (LCA) FOR SPRAY POLYURETHANE FOAMS

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AGENDA

- **Definitions**
- **Goal and Scope**
- **Inventory Analysis**
- **Impact Assessment**
- **Interpretation and Value**
- **Next Steps**
- **Acknowledgements**

What is Life-Cycle Assessment ?

Life-Cycle Assessment (LCA) is a technique to assess environmental impacts associated with *ALL* stages of a product's life

What is Life-Cycle Assessment ?

LCAs prevent a narrow outlook on environmental concerns (single-attribute evaluations) by:

- Utilizing a recognized global methodology that provides a **transparent, holistic and balanced** approach to product evaluation
- Compiling an **inventory of all** energy/material inputs and environmental releases
- Evaluating the **potential impacts** associated with all inputs and releases
- Interpreting the results to help customers make informed and **technically sound decisions**

What is Life-Cycle Assessment ?

The International Standards Organization (ISO) provides a structured process to assure fair, credible and transparent LCA results

Relevant (ISO) LCA Documents

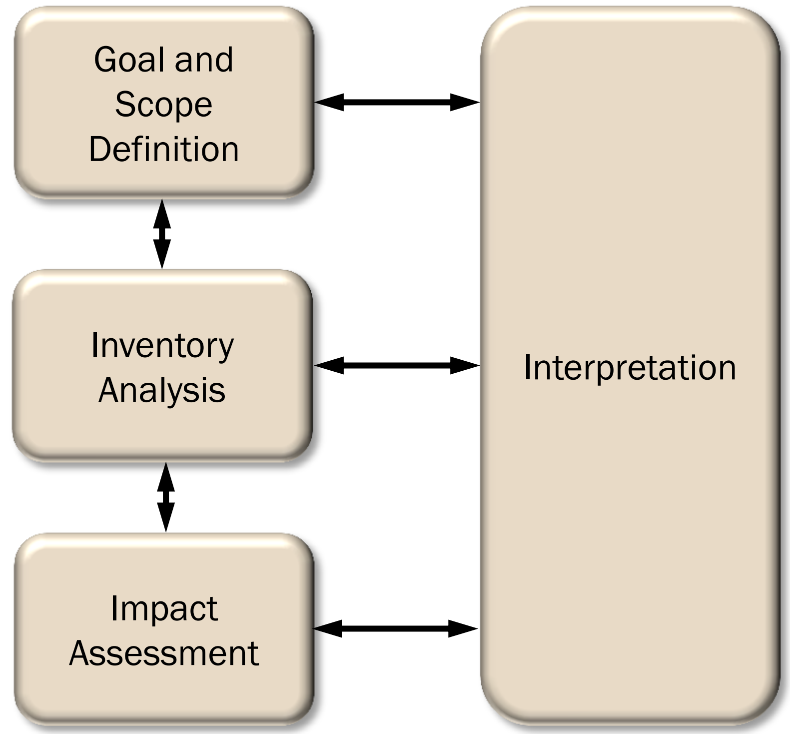
1. ISO 14040: *Environmental Management—Life Cycle Assessment—Principles and Framework, Second Edition;* International Organisation for Standardisation, 2006.

2. ISO 14044: *Environmental Management—Life Cycle Assessment—Requirements and Guidelines, First Edition;* International Organisation for Standardisation, 2006.

What is Life-Cycle Assessment ?

Four basic stages of LCA

flow diagram from ISO 14040 Standard



Goal and Scope Definition

Goal

- **Enterprise/Industry:** Develop environmental strategy for products and services
- **Manufacturing:** Create and improve sustainable manufacturing processes
- **Customers:** Use materials and processes based on LCA results and avoid single-attribute product selection. Evaluate environmental impact, and provide LCA/EPD credits for sustainable building programs.

Goal and Scope Definition

Scope

- Functional Unit
- System Boundaries
- Assumptions and Limitations
- Allocation Methods
- Environmental Impact Categories

Goal and Scope Definition

Scope: Functional Unit

- Defined by the primary function fulfilled by a product system
- Enables equal comparison of alternative product systems
- Determines the reference flow on which amounts of inputs and outputs are calculated

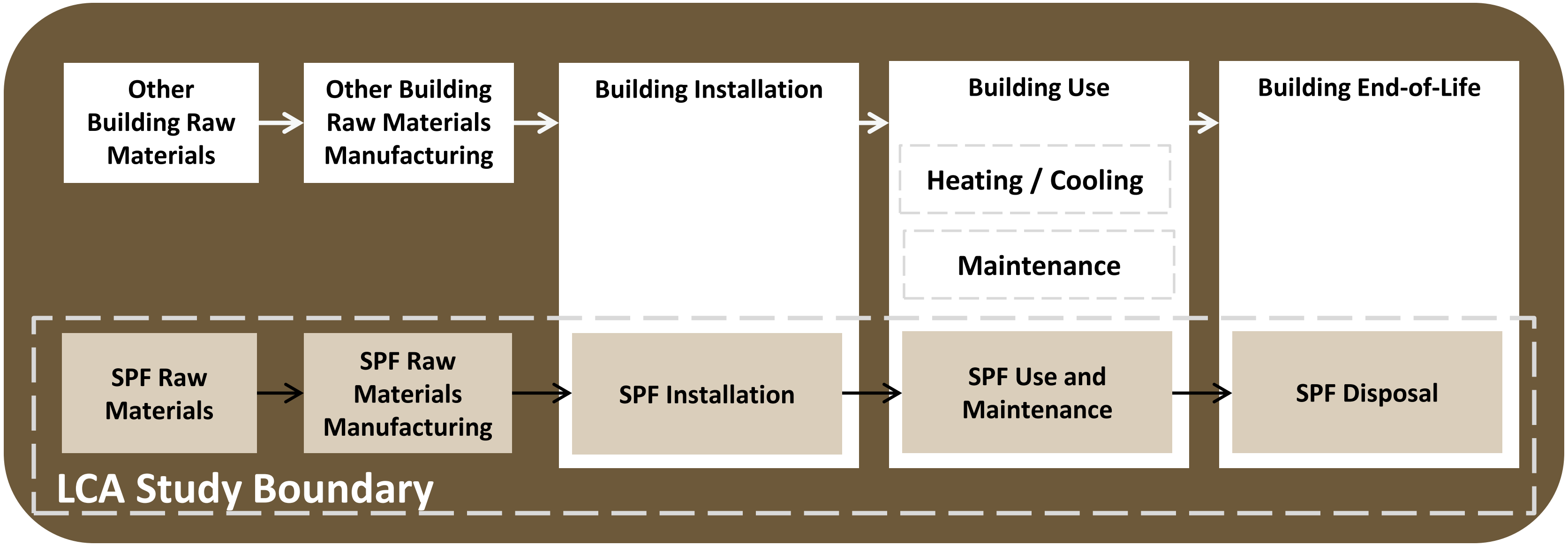
- For all building insulation products, the functional unit is defined by a new Product Category Rule document[1] (2011):

1m² of insulation material with a thickness that gives a design thermal resistance R_{SI} = 1 m²K/W and with a building service life of 60 years

Goal and Scope Definition

Scope: System Boundaries

Defines what precisely what materials and processes are to be included in the LCA



Goal and Scope Definition

Scope: Assumptions and Limitations

Defines the time, technology and geographic limits of the data

- **Time:** Raw material and process data < 5 years old
- **Technology:** Three generically-formulated SPF products
- **Geography:** United States
- **Data:** Primary data from industry sources, other raw materials from recognized sources (GaBi, NREL LCI databases)
- **Cut-off Rules:** Ignore energy, materials or emissions <1% if not environmentally relevant

Goal and Scope Definition

Scope: Allocation Methods

Defines allocation of resource consumption and environmental impacts from joint production of materials used for other processes

Goal and Scope Definition

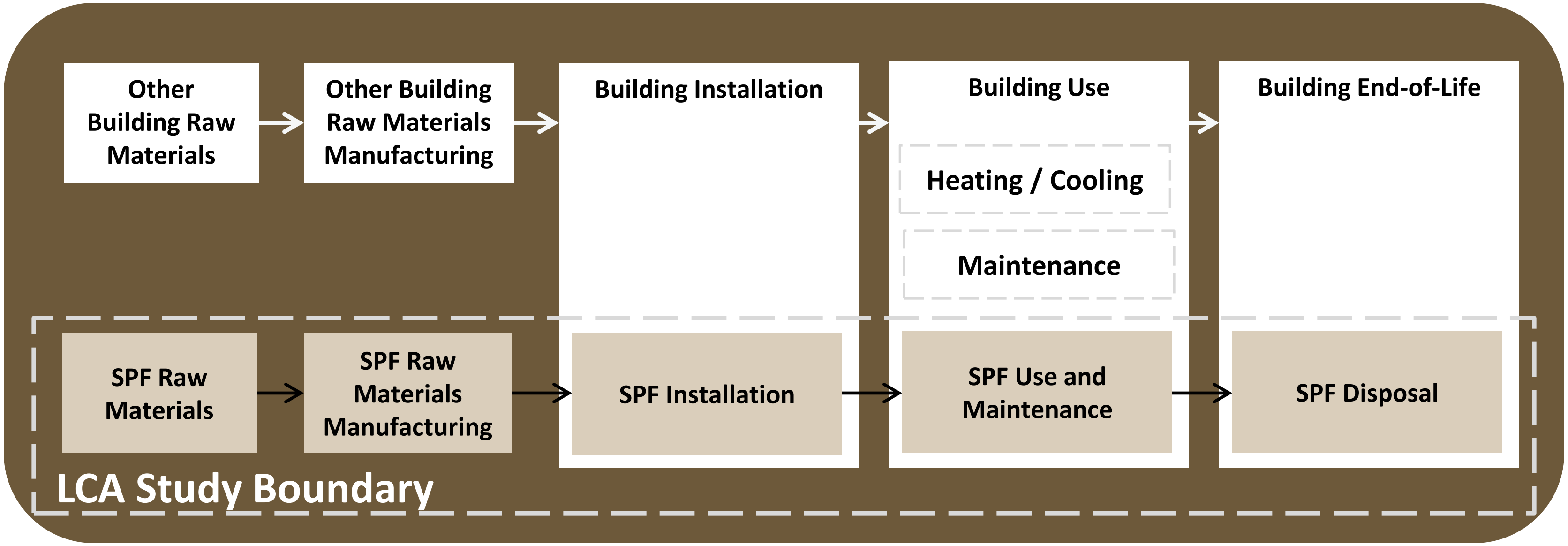
Scope: Environmental Impact Categories

Defines environmental impacts per functional unit per *Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts* (TRACI) 2.0 methodology, except USETox and PEI special energy flow

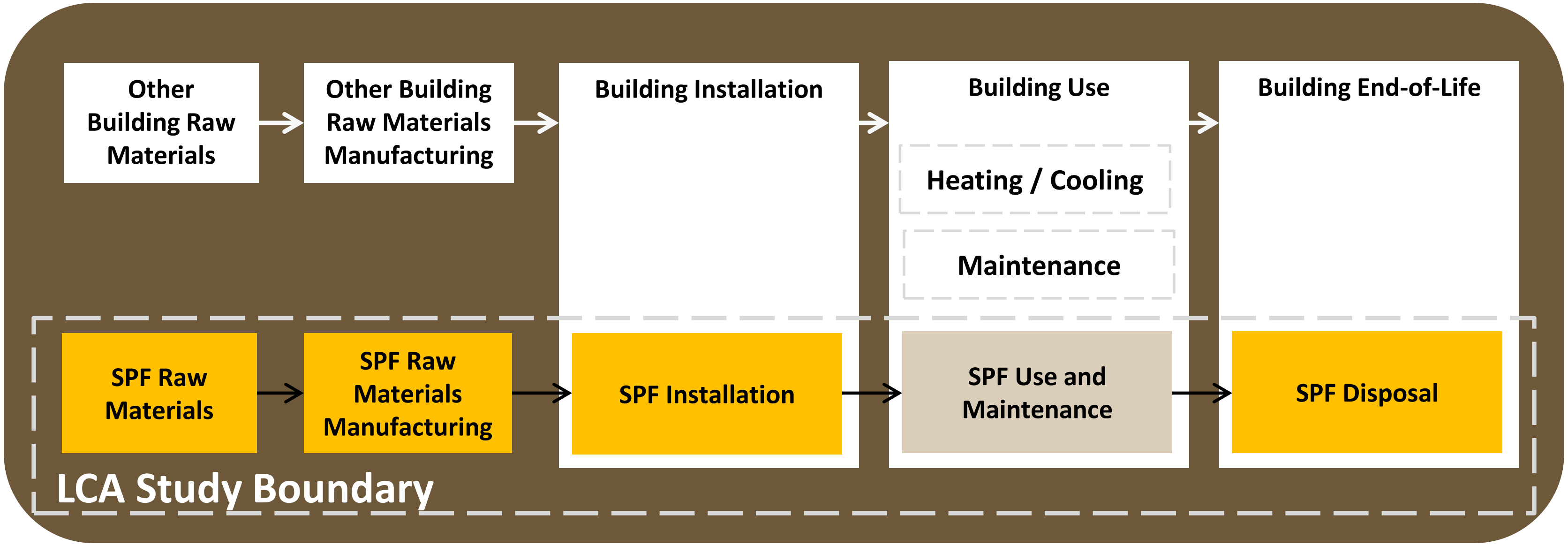
Impact Category Characterization Factor	Description	Unit
Global Warming Potential (GWP)	A measure of greenhouse gas emissions, such as CO_2 and methane.	kg CO_2 equivalent
Eutrophication Potential (EP)	Eutrophication covers all potential impacts of excessively high levels of macronutrients, the most important of which nitrogen (N) and phosphorus (P)..	kg Nitrogen equivalent
Acidification Potential (AP)	The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H^+) concentration in the presence of water, thus decreasing the pH value.	mol H^+ equivalent
Photochemical Ozone Creation Potential (POCP)	A measure of emissions of precursors that contribute to ground level smog formation (mainly ozone O_3),	kg O_3 equivalent
Ozone Depletion Potential (ODP)	A measure of air emissions that contribute to the depletion of the stratospheric ozone layer.	kg CFC-11 equivalent
Additional Inventory/Impact Category	**Description**	**Unit**
Primary Energy Demand (PED) [1]	A measure of the total amount of primary energy extracted from the earth, expressed in energy demand from non-renewable or renewable resources	MJ

[1] PED is a special inventory flow created by PEI using the concept of "primary energy"

Inventory Analysis



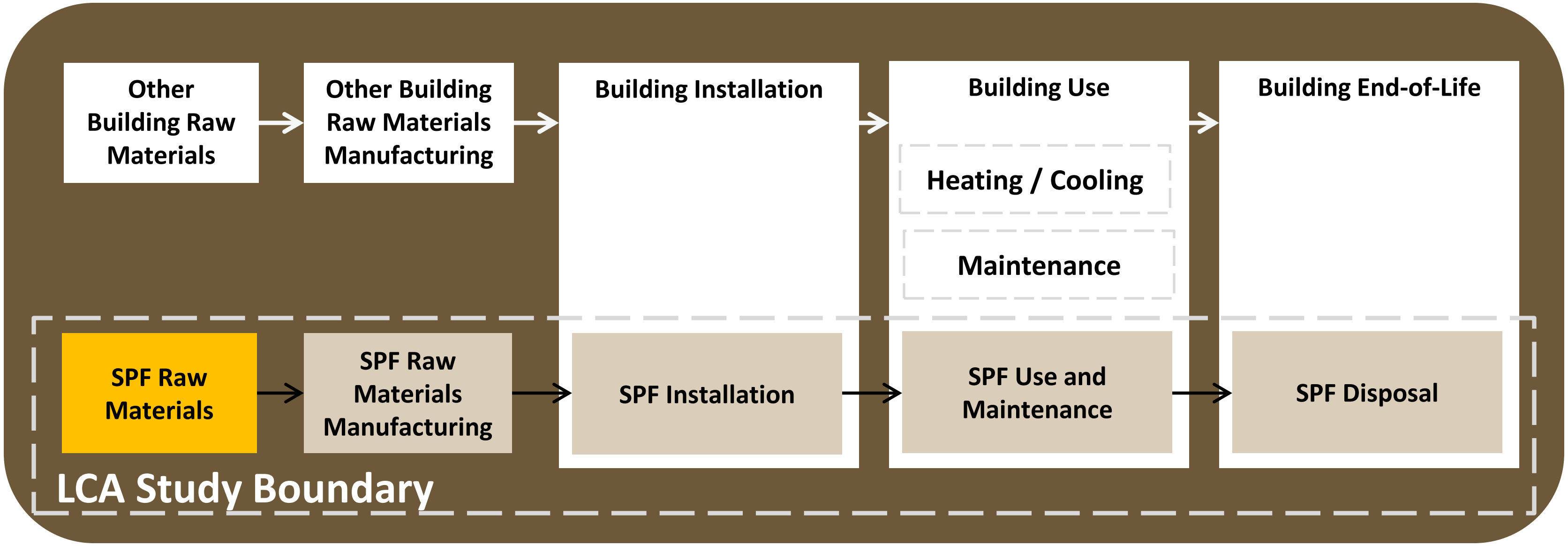
Inventory Analysis



Work completed by PE International

- Detailed in separate report to be made available to SPFA members
- Independently reviewed by 3-person Critical Review Panel

Inventory Analysis

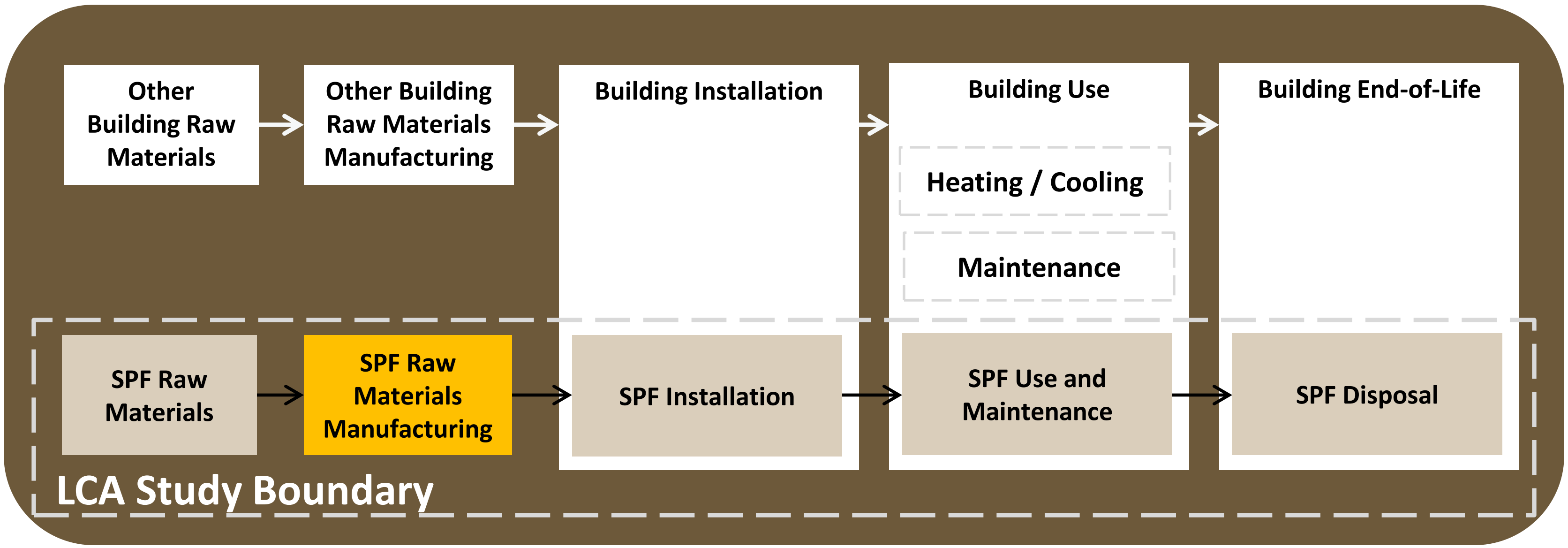


SPF Raw Materials

- Includes A-side MDI and B-side polyols and additives
- Obtained from LCI data from GaBi and other reputable sources

PE INTERNATIONAL
EXPERTS IN SUSTAINABILITY
Five Winds
STRATEGIC CONSULTING

Inventory Analysis



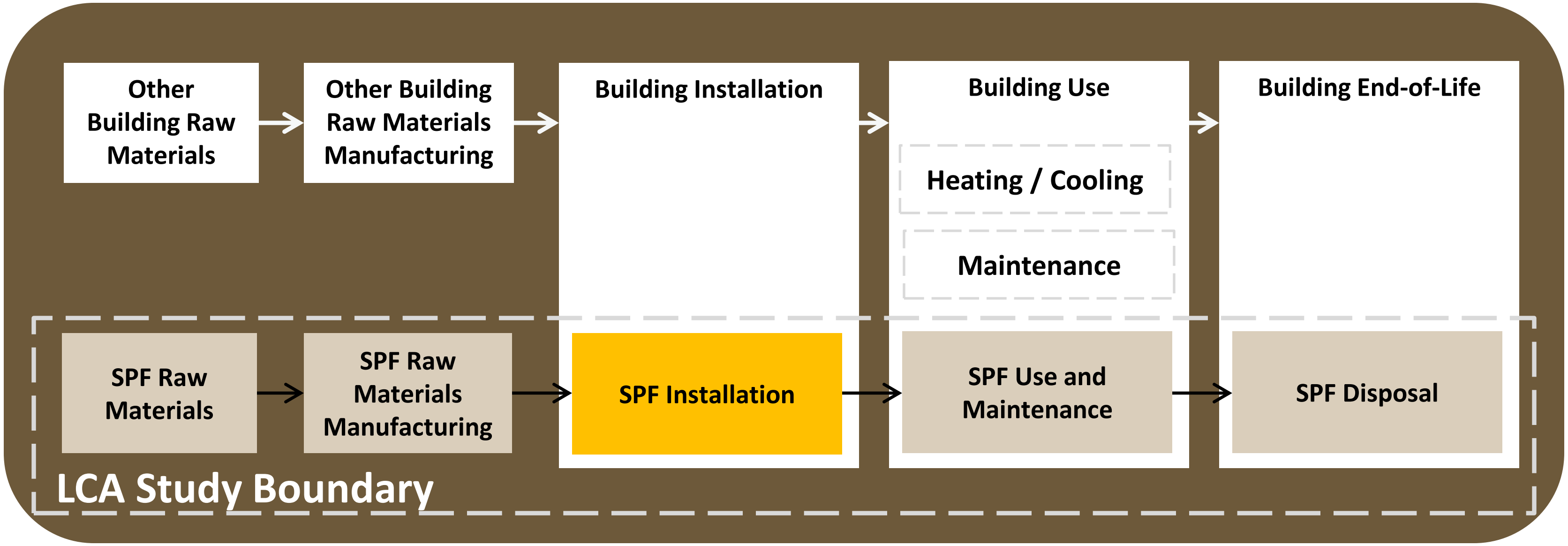
SPF Raw Materials Manufacturing

- Includes transportation, blending and packaging of raw materials by formulator
- Data from six different formulators was obtained via survey
- Generic formulations provided by SPFA and CPI

Inventory Analysis

SPF Formulations		Low-Density Open Cell	Medium-Density Closed-Cell	Roofing
Density (lb/ft3)		0.5	2.0	3.0
Thermal Performance (R/inch)		3.6	6.2	6.2
Polyol	Polyester	-	45%	35%
	Mannich	-	30%	45%
	Compatibilizer	10%	-	-
	Polyether	35%	-	-
Fire Retardant	TCPP	25%	4%	8%
	Brominated	-	6%	-
Blowing Agent	Reactive (H_2O)	24%	2%	<2%
	Physical (HFC)	-	9%	7%
Catalyst	Amine	6%	3.00%	2%
	Metal	-	<1%	<1%
Surfactant	Silicone	<1%	1.00%	1%

Inventory Analysis



SPF Installation

- Includes materials transportation, high-pressure application, PPE/consumables and factors such as trim waste and product yield
- Data from several SPF contractors was obtained by PEI

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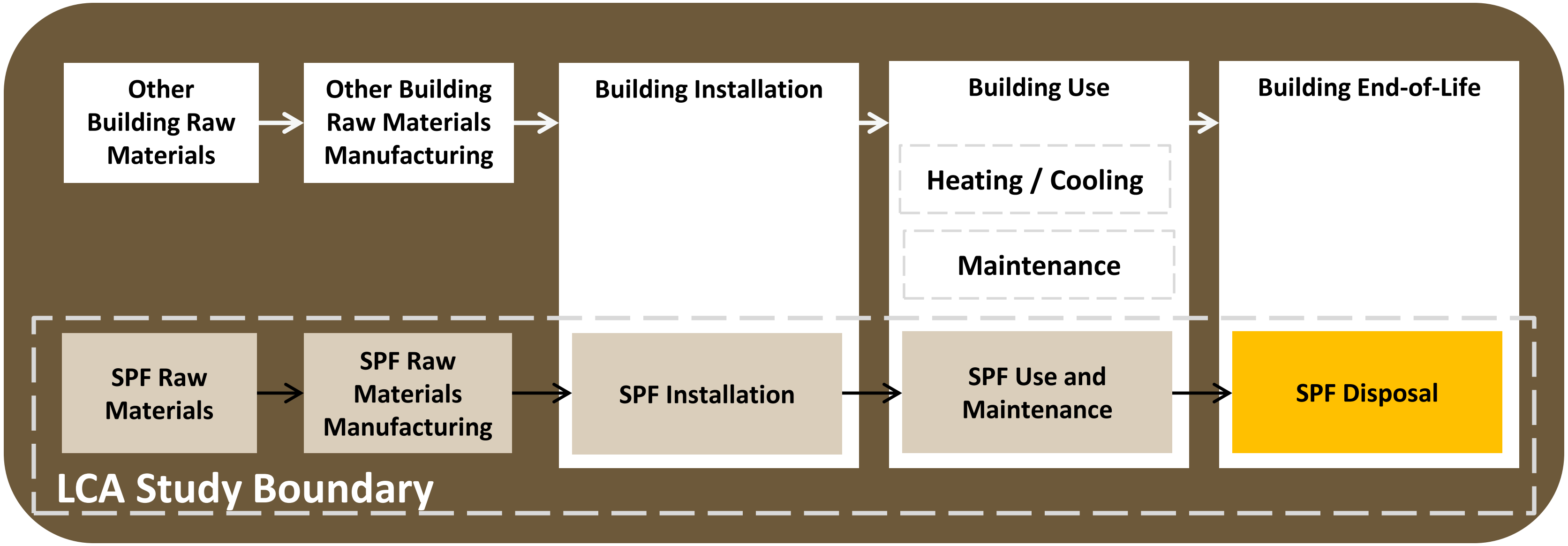
Inventory Analysis



SPF Disposal

- Conservatively assumes all foam will go to landfill when building is demolished

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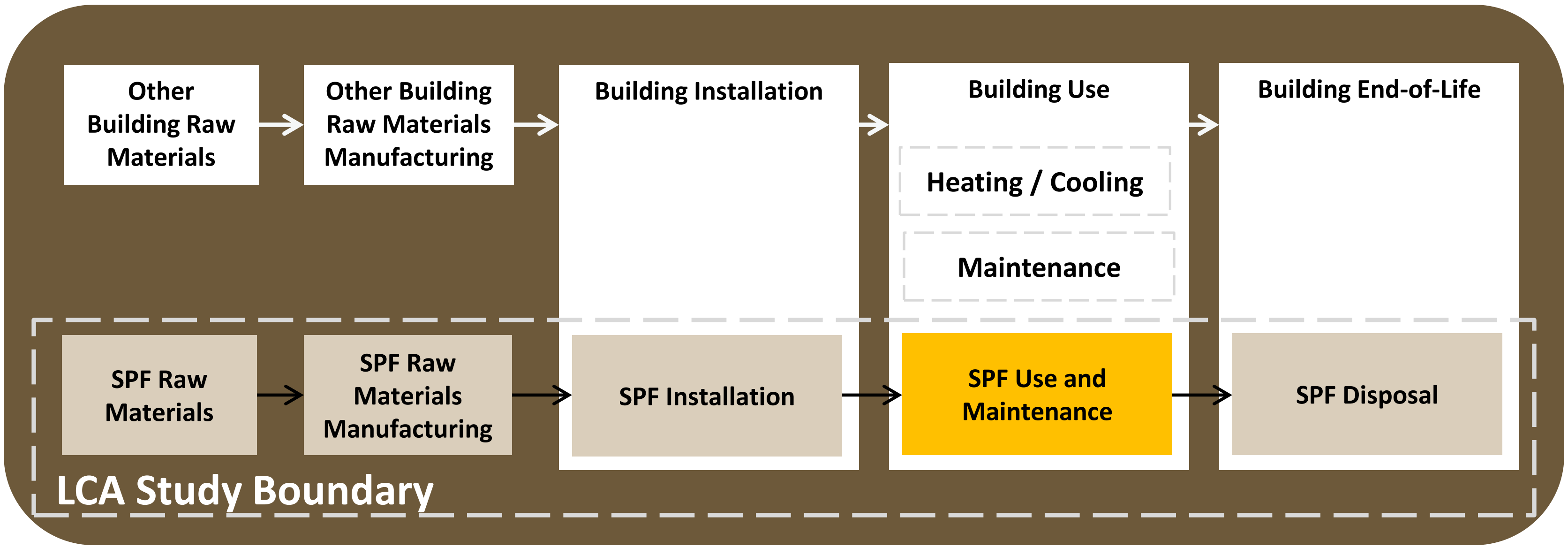
Inventory Analysis



SPF Use and Maintenance

- Performed detailed energy modeling of typical new residential home with SPF insulation to 2009 I-code
- Performed detailed energy modeling of typical existing commercial building with SPF roofing system added (R20)
- Three representative climate zones considered (MN, VA, TX)

SustainableSolutions CORPORATION

Inventory Analysis

Use-Phase

- All results included in detailed report from Sustainable Solutions.
- Noticeable residential energy savings due to reduced air leakage, especially in colder climates
- Moderate commercial building energy savings from additional SPF roof insulation

Inventory Analysis

SPF Use-Phase Energy Modeling

New Residential Home

- 2434 SF with typical home
- Two-story
- Wood-frame construction
- Insulated to IRC 2009 per climate zone
- Air-leakage rates from SPF vs fibrous insulation included in model performed using EnergyGauge software

	Houston (IECC Zone 2A)			Richmond (IECC Zone 4A)		Minneapolis (IECC Zone 6A)	
	No insulation	Spray Foam		No insulation	Spray Foam	No insulation	Spray Foam
	Baseline	attic floor	UVA	Baseline		Baseline	
Attic Floor Insulation Thermal Resistance	0	R30		0		0	
Roof Deck Insulation			R30	0	R38	0	R49
Wall Construction	2x4 16”oc	2x4 16”oc	2x4 16 oc	2x4 16” oc	2x4 16” oc	2x4 16” oc	2x4 16” oc
Wall Insulation (cavity) Thermal Resistivity	0	R13	R13	0	R13	0	R19
Ventilation	Exhaust	ERV (78% 55 cfm)	ERV (78% 55 cfm)	Exhaust	ERV (78% 55 cfm)	Exhaust	ERV (78% 55 cfm)
Air infiltration (ACHn)	0.32	0.1	0.1	0.33	0.1	0.43	0.1
HERS Score	129	88	75	122	70	138	66
Annual Cooling (kWh)	7087	4781	3489	3665	2439	1933	1062
Annual Heating (kWh)	2667	934	782	778	482	1732	807
Annual Heating (therms)	0	0	0	994	244	2217	579

Inventory Analysis

SPF Use-Phase Energy Modeling

Existing Commercial Building

- 10,000 SF post-1980 strip-mall building
- Existing roof assembly R-values of R4 and R12 assumed on underside of roof deck
- Additional roofing SPF added to create R20 roof assembly per ASHRAE 90.1-2010
- Air-leakage rates from SPF vs fibrous insulation NOT included in model performed using EnergyPlus software

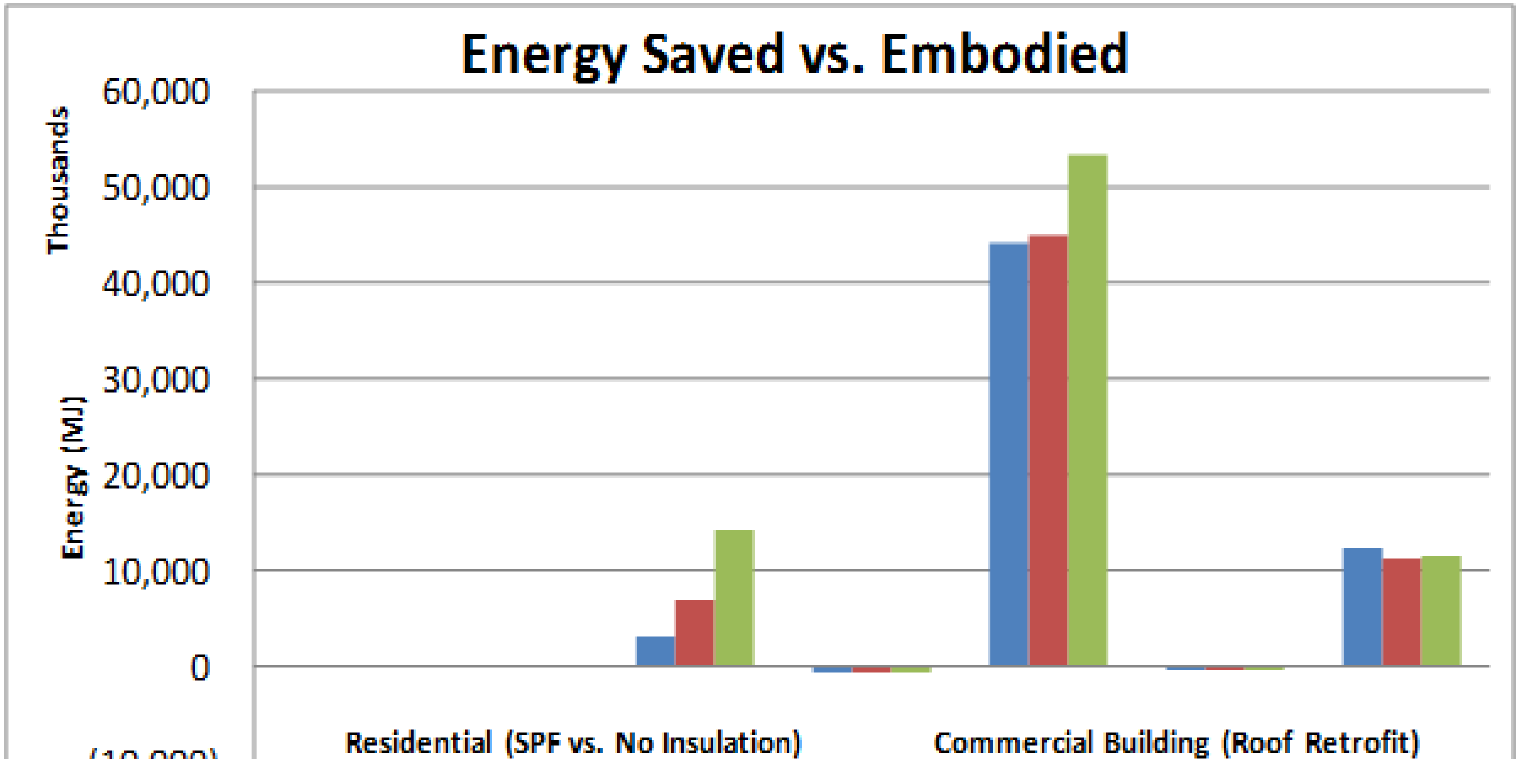
	Houston (IECC Zone 2A)			Richmond (IECC Zone 4A)			Minneapolis (IECC Zone 6A)		
	R4 Baseline	R12 Baseline	R20 with added SPF	R4 Baseline	R12 Baseline	R20 with added SPF	R4 Baseline	R12 Baseline	R20 with added SPF
Roof Deck Insulation Thermal Resistance	R4	R12	R20	R4	R12	R20	R4	R12	R20
Ventilation Fans (kWh)	20	16	14	18	14	13	21	18	17
Space Cooling (kWh)	123	101	92	107	87	78	101	87	81
Annual Heating (therms)	2900	2500	2300	9800	8400	8000	23,000	20,000	19,100

Impact Assessment

Cradle-to-Grave, including Use-Phase

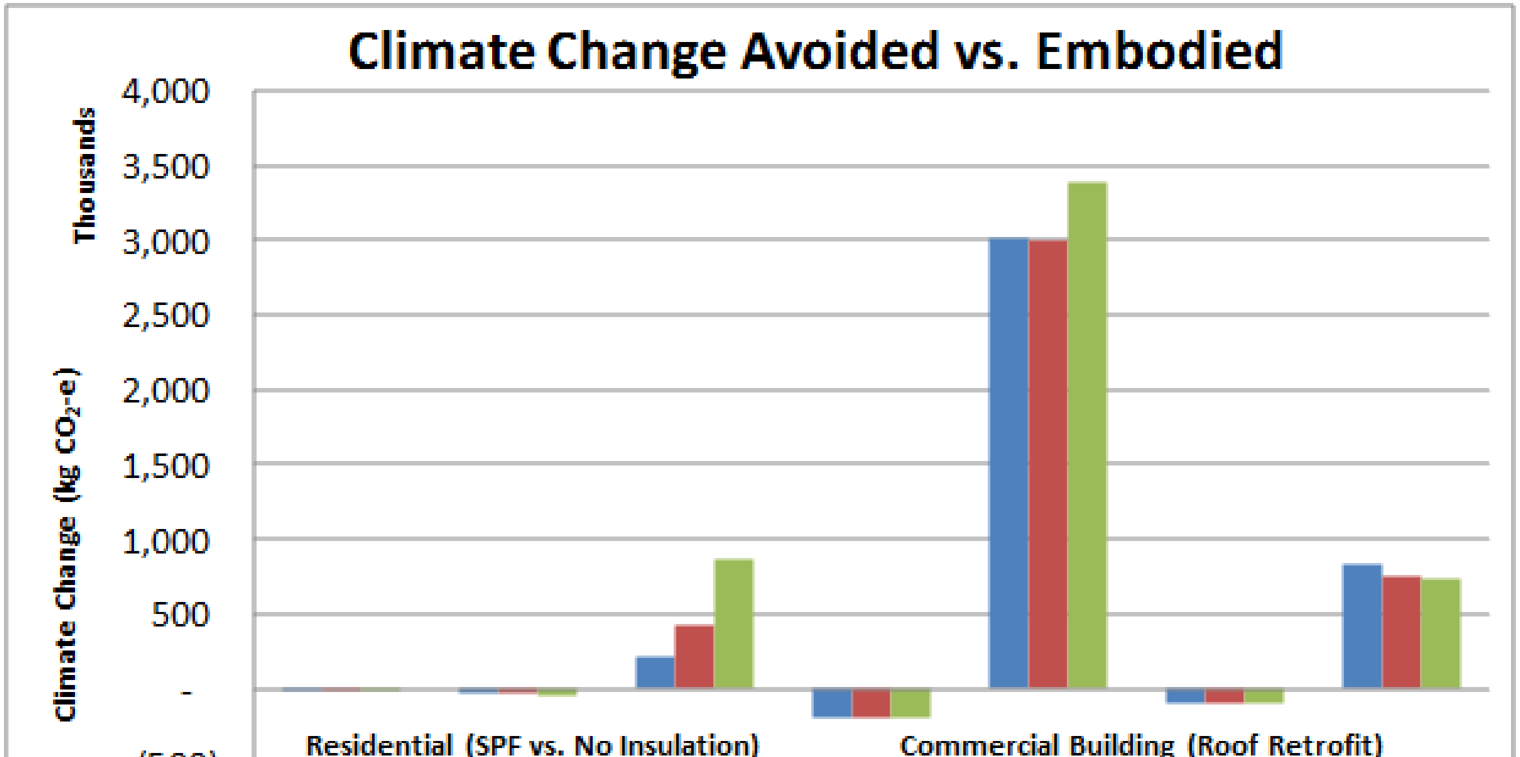
- Primary Energy from non-renewable resources
- Climate Change
- Acidification
- Eutrophication
- Ozone Depletion
- Smog Creation

Impact Assessment



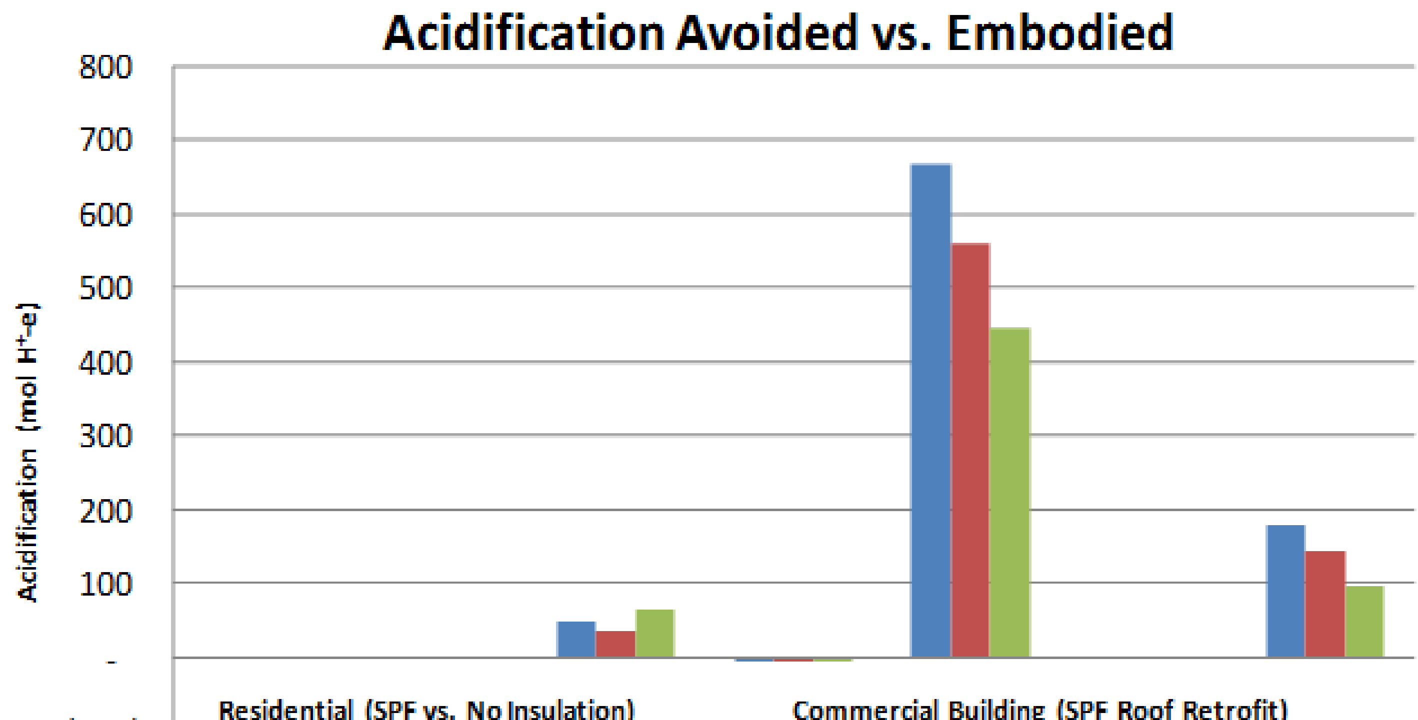
	OC-Embodied	CC-Embodied	Residential Saved	R4-R20 Embodied	R4-R20 Saved	R12-R20 Embodied	R12-R20 Saved
Houston	(46,634)	(92,588)	2,971,391	(804,334)	44,264,207	(402,167)	12,130,480
Richmond	(53,791)	(106,799)	6,861,794	(804,334)	45,092,301	(402,167)	11,294,047
Minneapolis	(72,640)	(144,223)	14,101,602	(804,334)	53,231,945	(402,167)	11,518,486

Impact Assessment



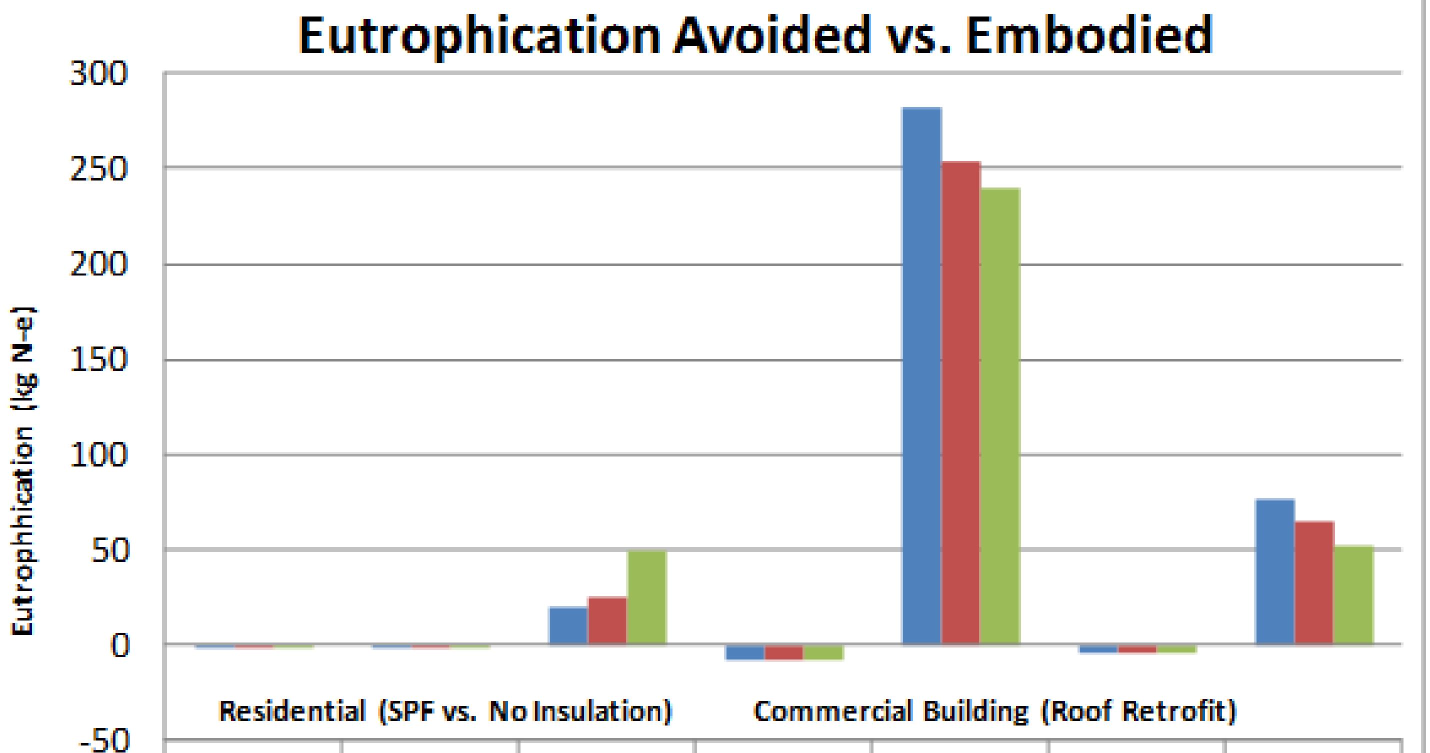
	OC-Embodied	CC-Embodied	Residential Avoided	R4-R20 Embodied	R4-R20 Avoided	R12-R20 Embodied	R12-R20 Avoided
Houston	(2,225)	(26,956)	205,423	(201,967)	3,018,338	(100,983)	824,689
Richmond	(2,567)	(31,093)	422,128	(201,967)	2,991,984	(100,983)	752,929
Minneapolis	(3,467)	(41,989)	860,775	(201,967)	3,387,501	(100,983)	733,611

Impact Assessment



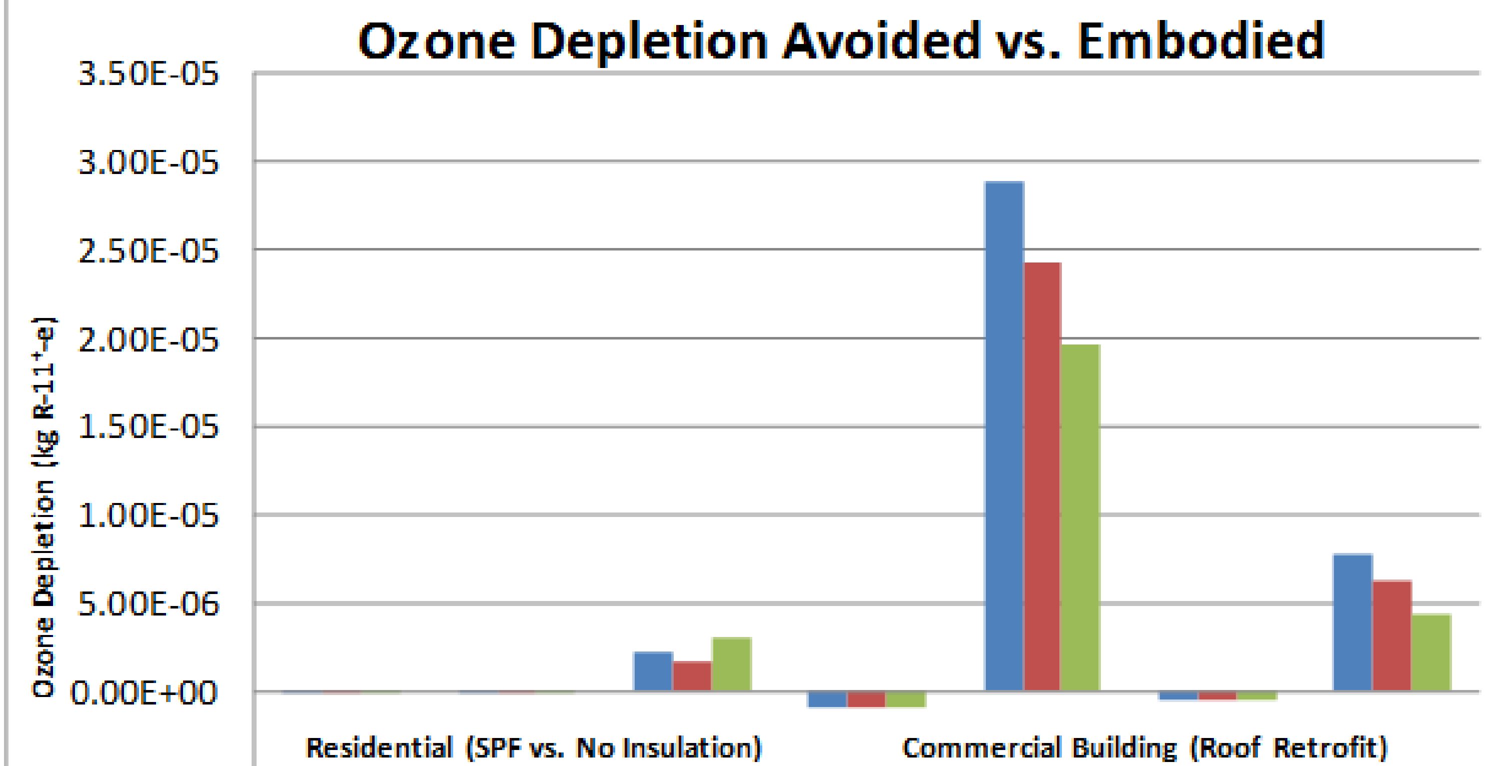
	OC-Embodied	CC-Embodied	Residential Avoided	R4-R20 Embodied	R4-R20 Avoided	R12-R20 Embodied	R12-R20 Avoided
Houston	(366)	(761)	48,969	(6,306)	667,754	(3,153)	179,337
Richmond	(422)	(878)	35,927	(6,306)	557,951	(3,153)	144,977
Minneapolis	(570)	(1,185)	63,887	(6,306)	445,195	(3,153)	97,239

Impact Assessment



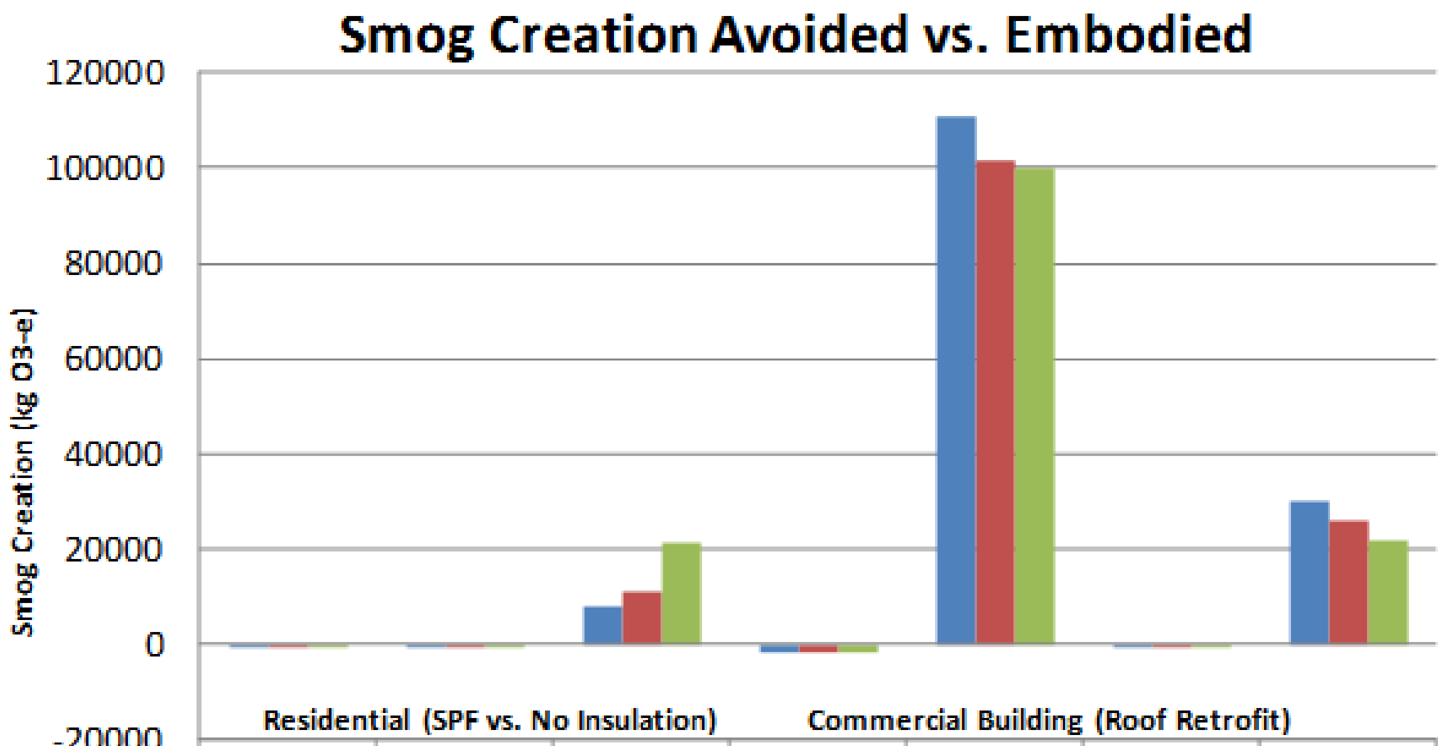
	OC-Embodied	CC-Embodied	Residential Avoided	R4-R20 Embodied	R4-R20 Avoided	R12-R20 Embodied	R12-R20 Avoided
Houston	(0.40)	(0.88)	20.05	(7.83)	282	(3.92)	76
Richmond	(0.46)	(1.01)	25.03	(7.83)	253	(3.92)	65
Minneapolis	(0.62)	(1.37)	48.69	(7.83)	240	(3.92)	52

Impact Assessment



	OC-Embodied	CC-Embodied	Residential Avoided	R4-R20 Embodied	R4-R20 Avoided	R12-R20 Embodied	R12-R20 Avoided
Houston	-4.76E-05	-1.08E-04	2.11E-03	-9.71E-04	2.89E-02	-4.85E-04	7.76E-03
Richmond	-5.49E-05	-1.24E-04	1.63E-03	-9.71E-04	2.43E-02	-4.85E-04	6.30E-03
Minneapolis	-7.41E-05	-1.68E-04	2.93E-03	-9.71E-04	1.96E-02	-4.85E-04	4.29E-03

Impact Assessment



	OC-Embodied	CC-Embodied	Residential Avoided	R4-R20 Embodied	R4-R20 Avoided	R12-R20 Embodied	R12-R20 Avoided
Houston	(87)	(175)	7,823	(1,566)	110,810	(783)	30,028
Richmond	(100)	(202)	10,911	(1,566)	101,544	(783)	25,918
Minneapolis	(135)	(272)	21,501	(1,566)	100,080	(783)	21,740

Interpretation

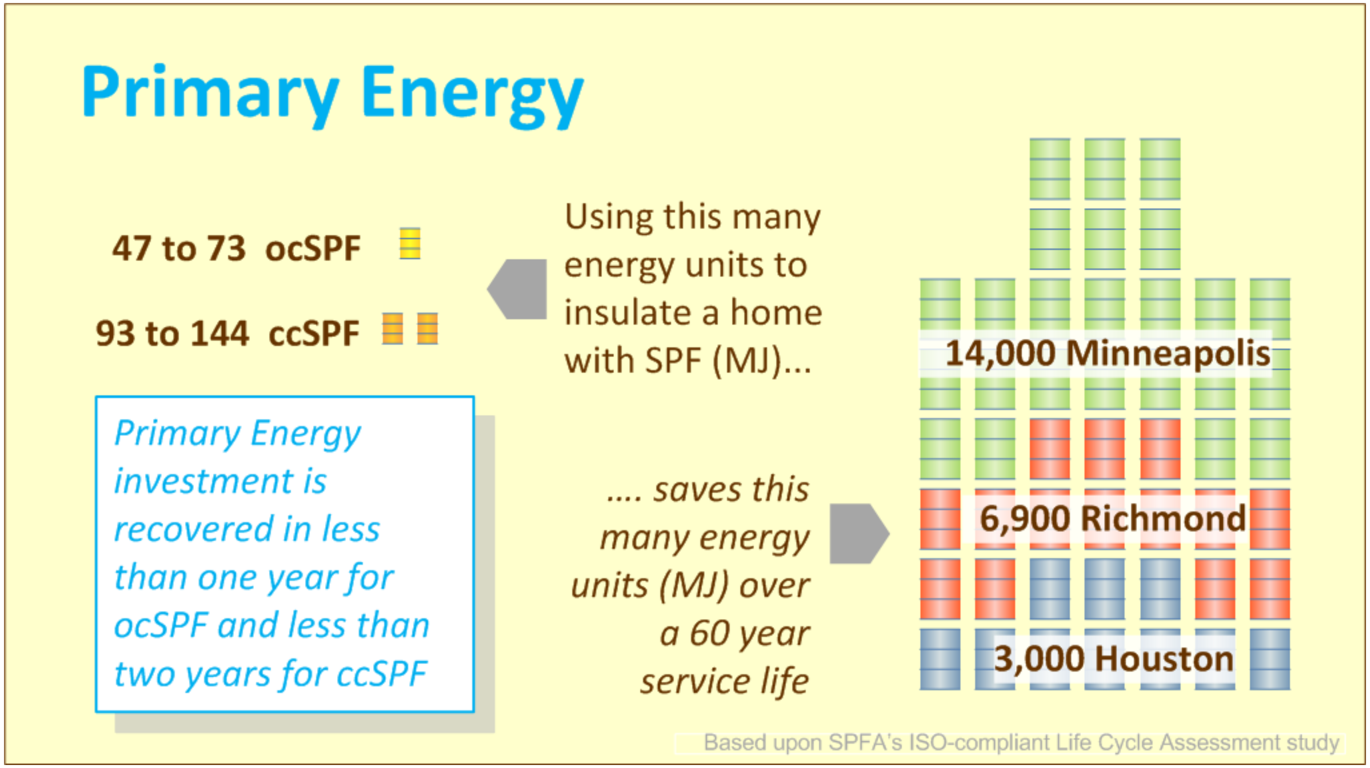
Environmental impacts avoided in the use-phase overwhelm the impacts of the other life-cycle phases

Application	SPF Type	Ratio & Payback	Houston			Richmond			Minneapolis		
			Energy	GHG	other [1]	Energy	GHG	other [1]	Energy	GHG	other [1]
Residential Insulation	Open-Cell SPF	Avoided/Embodied	**64**	**92**	35 - 134	**128**	**164**	23 - 109	**194**	**248**	31 - 159
		Payback (Yr)	**0.9**	**0.7**	0.4 - 1.7	**0.5**	**0.4**	0.6 - 2.6	**0.3**	**0.2**	0.4~1.9
	Closed-Cell SPF	Avoided/Embodied	**32**	**7.6**	19 - 64	**64**	**14**	13 - 54	**98**	**21**	17 - 79
		Payback (Yr)	**1.9**	**7.9**	0.9 - 3.2	**0.9**	**4.4**	1.1 - 4.8	**0.6**	**2.9**	0.8~3.6
Commercial Roofing	Roofing SPF R4 --> R20	Avoided/Embodied	**55**	**15**	29 - 106	**56**	**15**	25 - 89	**66**	**17**	20 - 71
		Payback (Yr)	**1.1**	**4**	0.6 - 2.0	**1.1**	**4.1**	0.7 - 2.4	**0.9**	**3.6**	0.8~3.0
	Roofing SPF R12 --> R20	Avoided/Embodied	**30**	**8.2**	16 - 57	**28**	**7.5**	13 - 46	**29**	**7.3**	8.7 - 31
		Payback (Yr)	**2**	**7.3**	1.1 - 3.8	**2.1**	**8**	1.3 - 4.7	**2.1**	**8.3**	1.9~6.9

[1] Other impact Categories include Acidification, Eutrophication, Ozone Depletion and Smog Creation

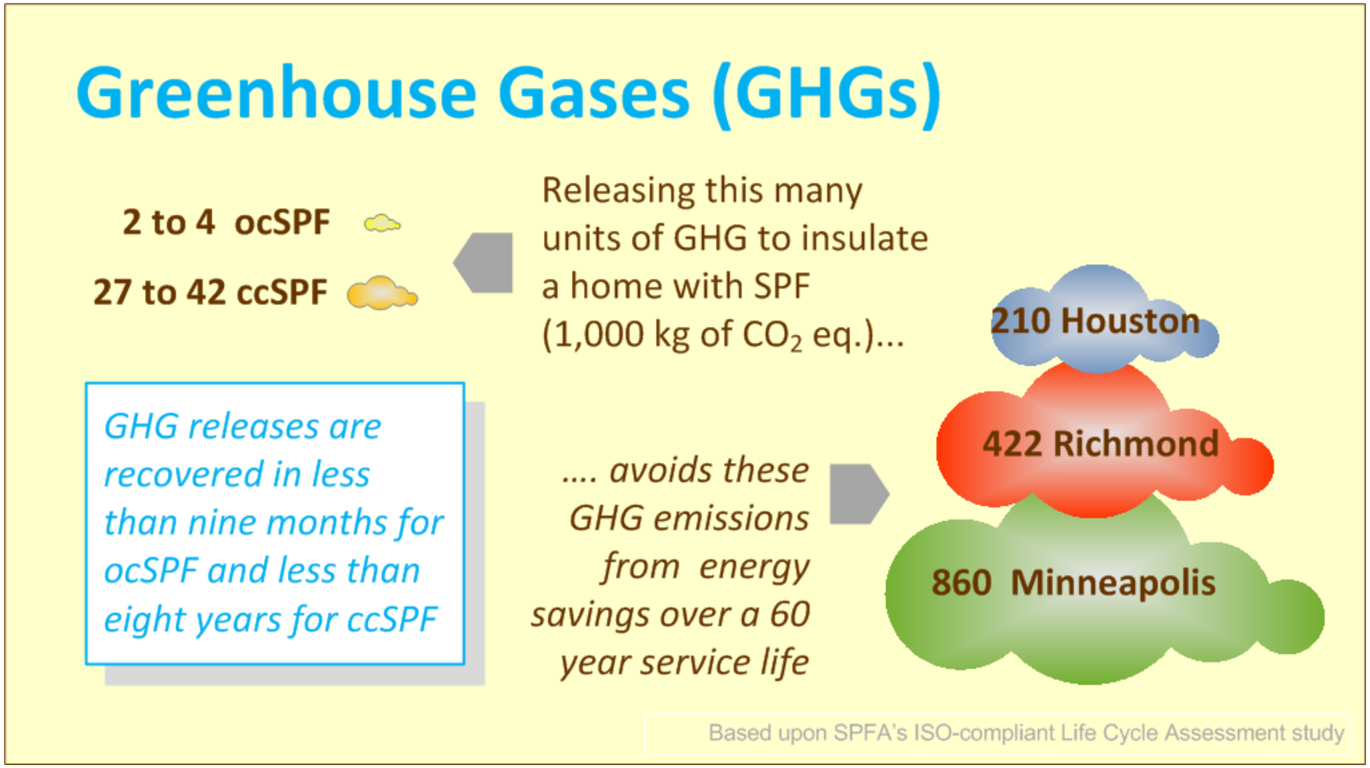
Interpretation

Environmental impacts avoided in the use-phase overwhelm the impacts of the other life-cycle phases



Interpretation

Environmental impacts avoided in the use-phase overwhelm the impacts of the other life-cycle phases



Interpretation

IMPORTANT NOTES ON RESULTS:

Payback times may be shorter; analysis does not include impacts of :

- Reduced framing depth and structural improvements for MD-SPF
- Vapor retarder needed for LD-SPF in cold climates

Product-specific attributes will affect results

- Coverage Rate
- R-value
- Density
- Raw Materials

Interpretation

Comparison with other Insulations…

- Data for other insulations published in LCA Databases

Before comparison of environmental impacts, check:

- Functional Unit
- Data Quality and Completeness
    - geographic region
- Study Boundary
    - cradle/end-of-life
    - cradle/gate, etc.
- Peer-Reviewed Process

Interpretation

Project Documents

Several documents will be publically available summarizing the key results from this project….

- Detailed Technical Report (SPFA) on website
- Summary Brochure (SPFA) on website
- Technical Paper and Presentation (CPI Paper)
- Environmental Product Declaration (EPD) mid 2013
- U.S. LCI Database Entry
- EPD template for material suppliers done

Acknowledgements

History

- LCA project initially started in Nov 2008-June 2009
- Resumed Nov 2010 to Present

Project Volunteers

- George Pavlovich and Shen Tian of Bayer MaterialScience for technical leadership
- Project Sponsor Reviewers

Funding Sources

- $130k sponsorship from 17 SPFA-member suppliers
- $50k from SPFA General Budget
- $5k from ACC BCMIT Program towards CRP costs

Acknowledgements

SPFA Supplier Sponsors

Industry Association Sponsors

Questions?