Optimizing Building Insulation Levels :

ASHRAE 90.1 2007 and 2010, ASHRAE 189, AEDG, Army DG, and Passive Haus

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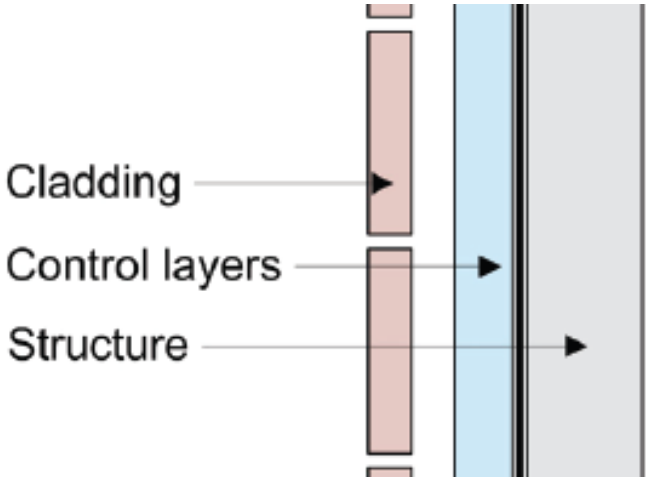
Source: www.buildingscience.com

Source: www.buildingscience.com

Wall Requirements

- Rain Control Layer
- Air Control Layer
- Vapor Control Layer
- Thermal Control Layer
  - In order of priority, if you can't keep the rain out than do not bother with the air, and so on.



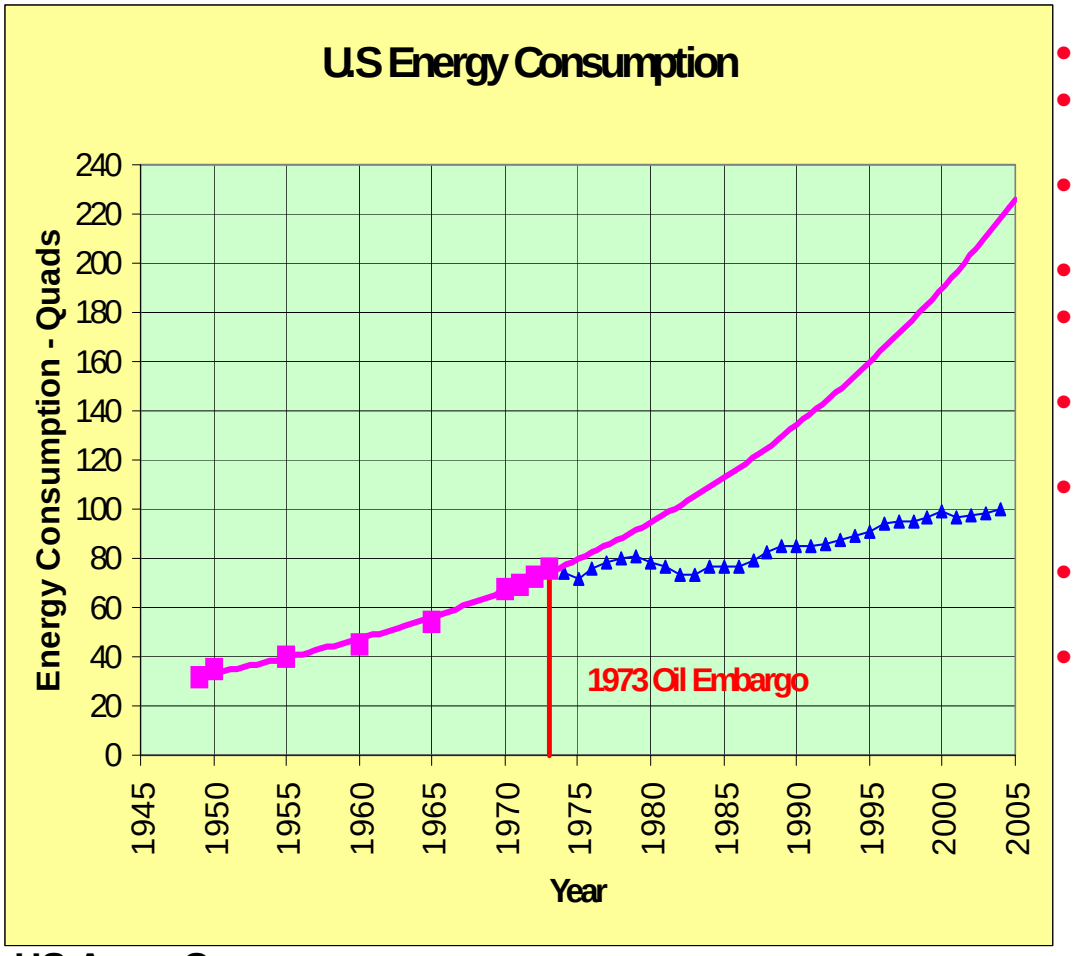
In concept the perfect wall has the rainwater control layer, the air control layer, the vapor control layer and the thermal control layer on the exterior of the structure. The claddings function is principally to act a an ultra-violet screen. Oh, and

Source: www.buildingscience.com

Army Energy Drivers

- **Energy Policy Act of 2005 (EPACT 2005) – 08Aug05**
  - **30% better energy consumption in new construction**
- **Energy Independence and Security Act of 2007 (EISA 2007) – 19Dec07**
  - **Fossil Fuel Consumption Reduction in New Facilities – 55% in 2010 increasing to 100% in 2030**
  - **Energy Reduction Goals for Existing Facilities**
- **Army Energy Security Implementation Strategy of 2009:**
  - **The Strategy establishes five strategic energy security goals and outlines a broad approach for accomplishing them**
- **Executive Order 13514 of 2009 – Federal Leadership in Environmental, Energy, and Economic Performance**
  - **Expands on many of the goals found in previous executive orders and in EISA 2007 and development of greenhouse gas reduction targets**

USA Energy Consumption – Standards Impact

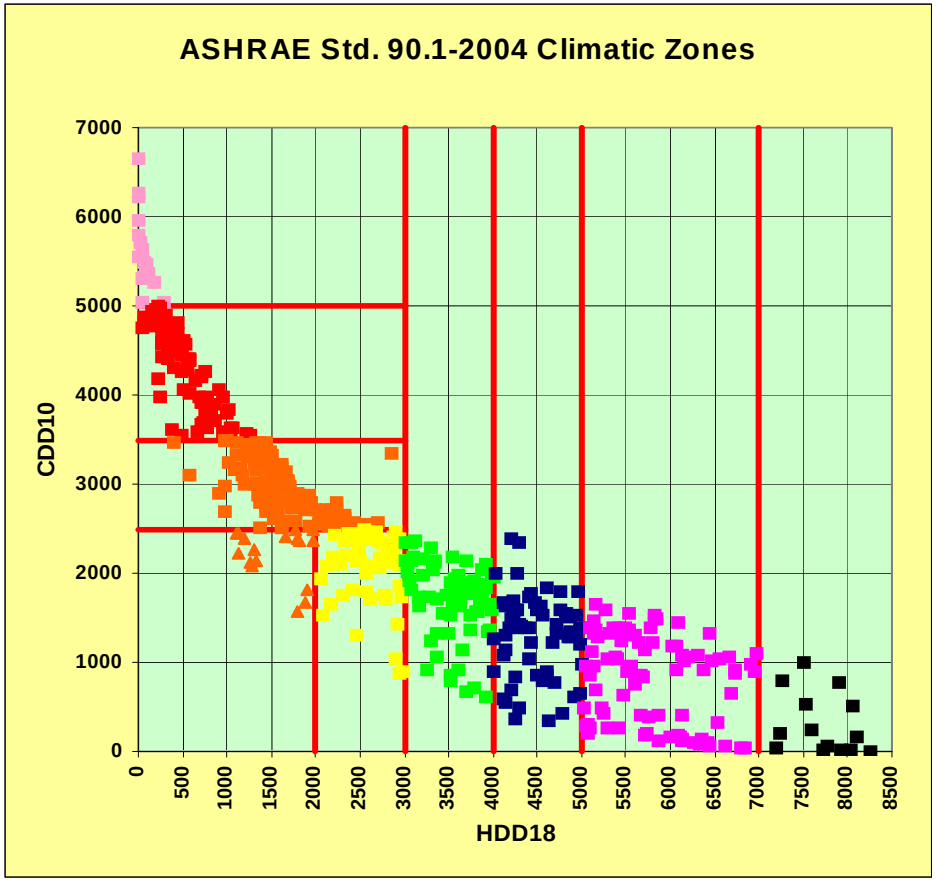


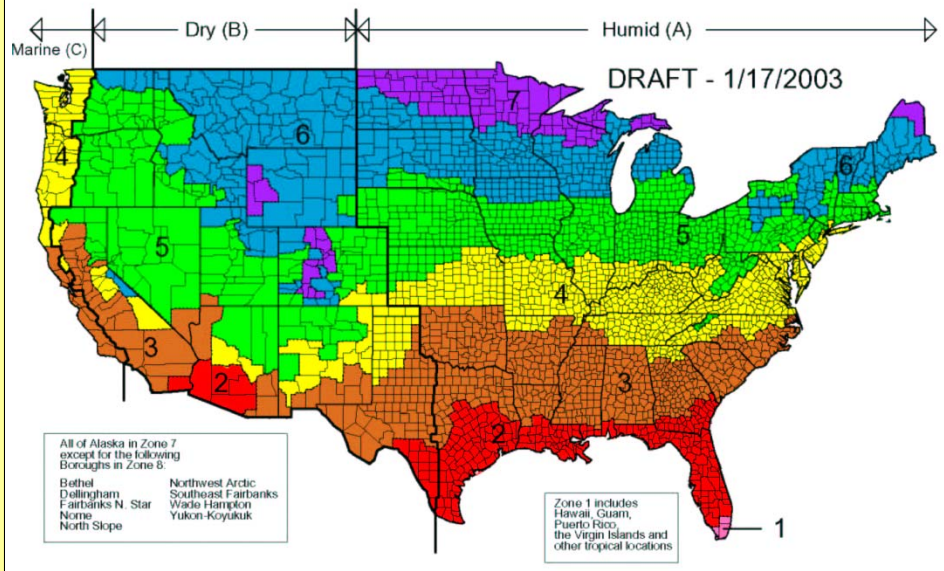
- 1973 Oil Embargo
- 1975 First country-wide building standard developed
- 1977 New standard adopted by many states & cities
- 1980 Model Energy Code established
- 1988 Stricter energy reduction criteria added for homes
- 1989 Foundation walls added for energy requirements
- 1993 Stricter energy reduction criteria for multi-family dwellings
- 1999 Basis for requirements changed to economic analysis
- 2004 New lighting requirements to tighten energy conservation

ASHRAE Standards & Guides

- **Commercial**
  - **New ASHRAE Std. 189.1**
    Sustainability
  - **ASHRAE Std. 90.1**
    - **1989 – Thermal Mass**
    - **1999 – LCC, Classes, R-13**
    - **2001 – 2004 – 2007 – 2010 published the end of this year**
  - **Advanced Energy Design Guides**
    - **Small Office**
    - **Small Retail**
    - **Small Warehouses**
    - **K-12 Schools**
    - **Highway Lodging**
    - **Small Hospitals and Health Care Facilities**
- **Residential**
  - **ASHRAE Std. 90.2**
    - **1993**
    - **2001**
    - **2004**
    - **2007**

Development of DOE Climate Zones for Standards





ASHRAE Methodology for Envelope Criteria Development for Standard 90.1:

The Balanced Economics Approach

Figure 1 LCC for Roof Insulation

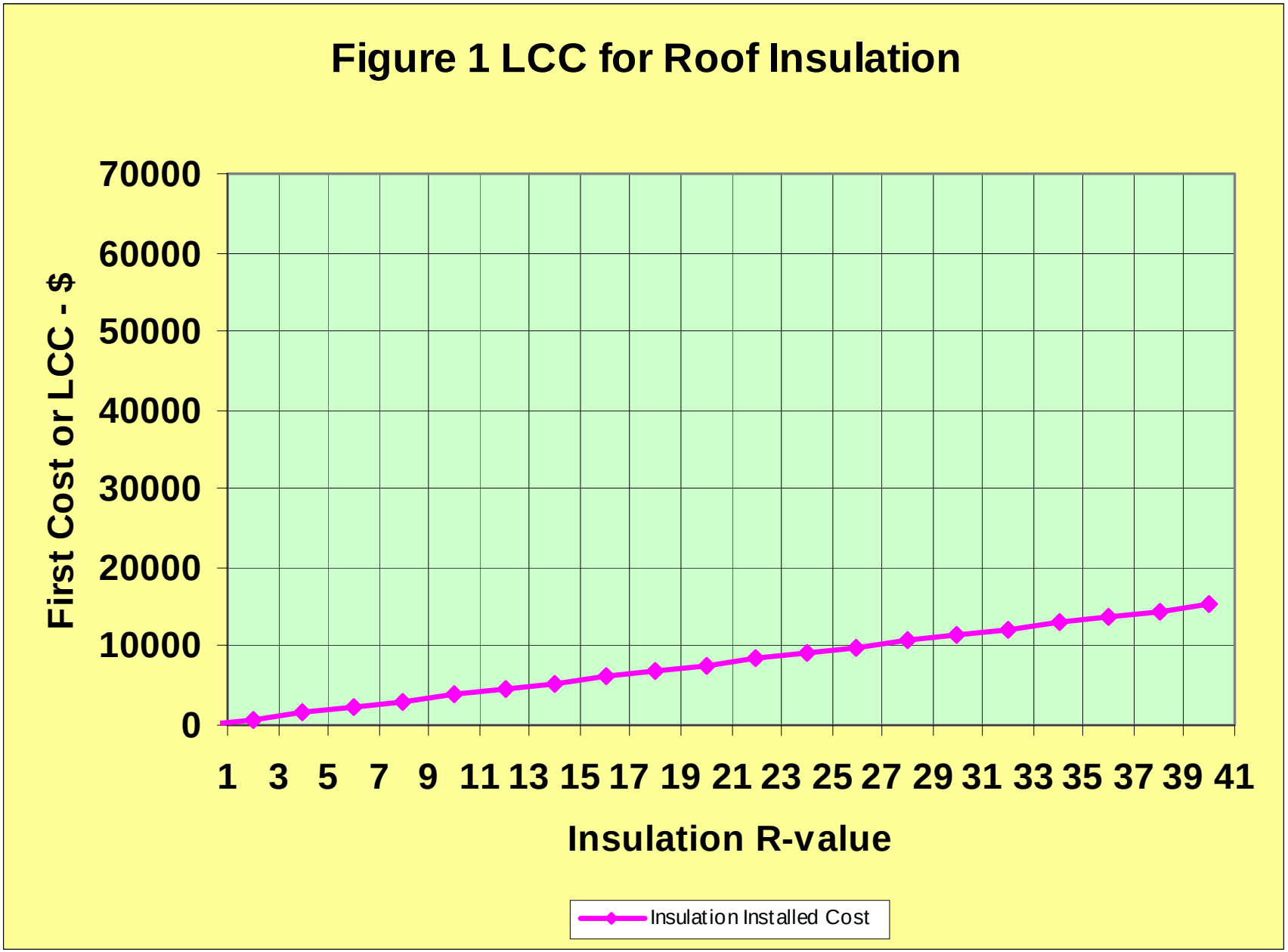


Figure 2 LCC for Roof Insulation

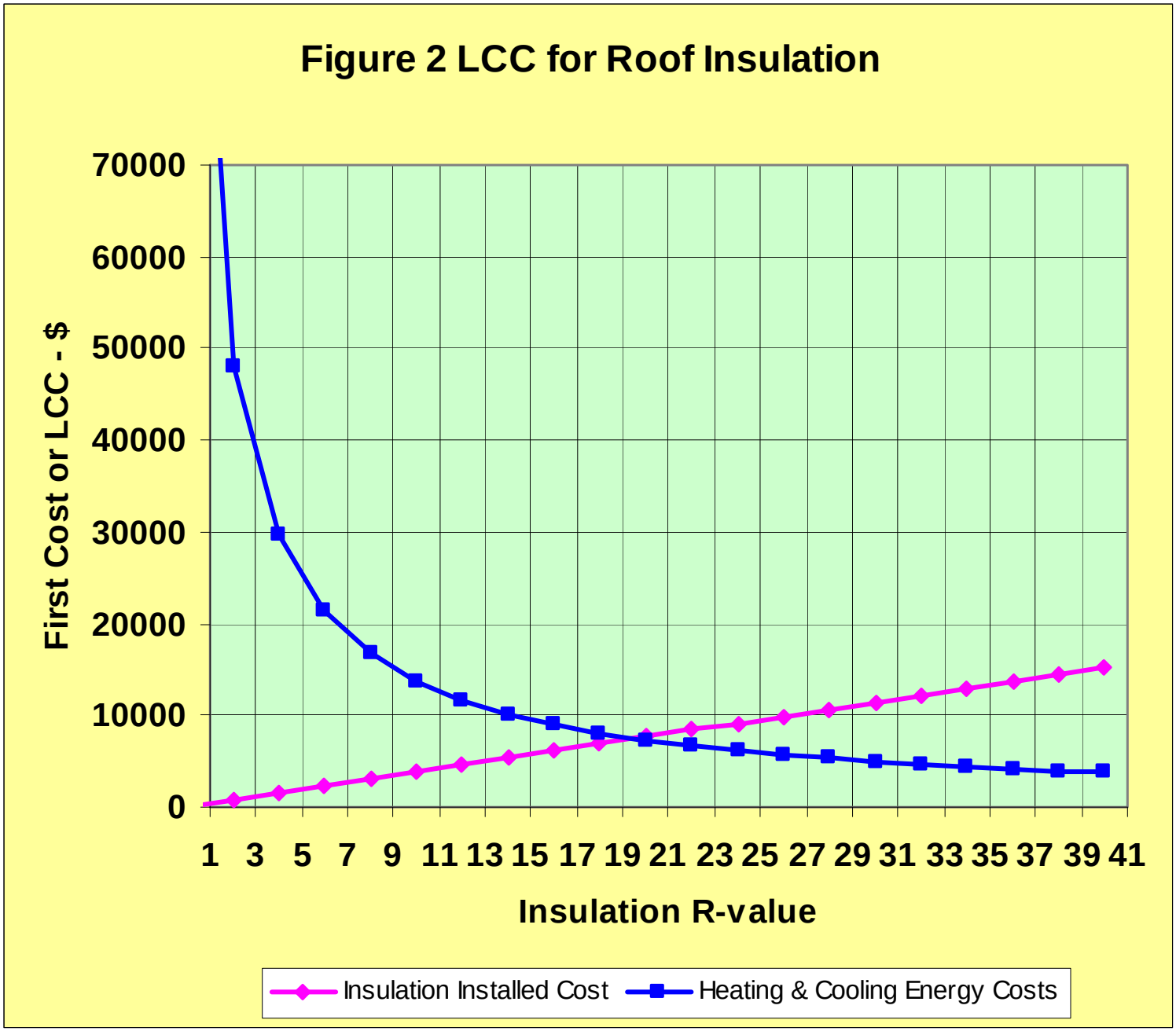


Figure 3 LCC for Roof Insulation

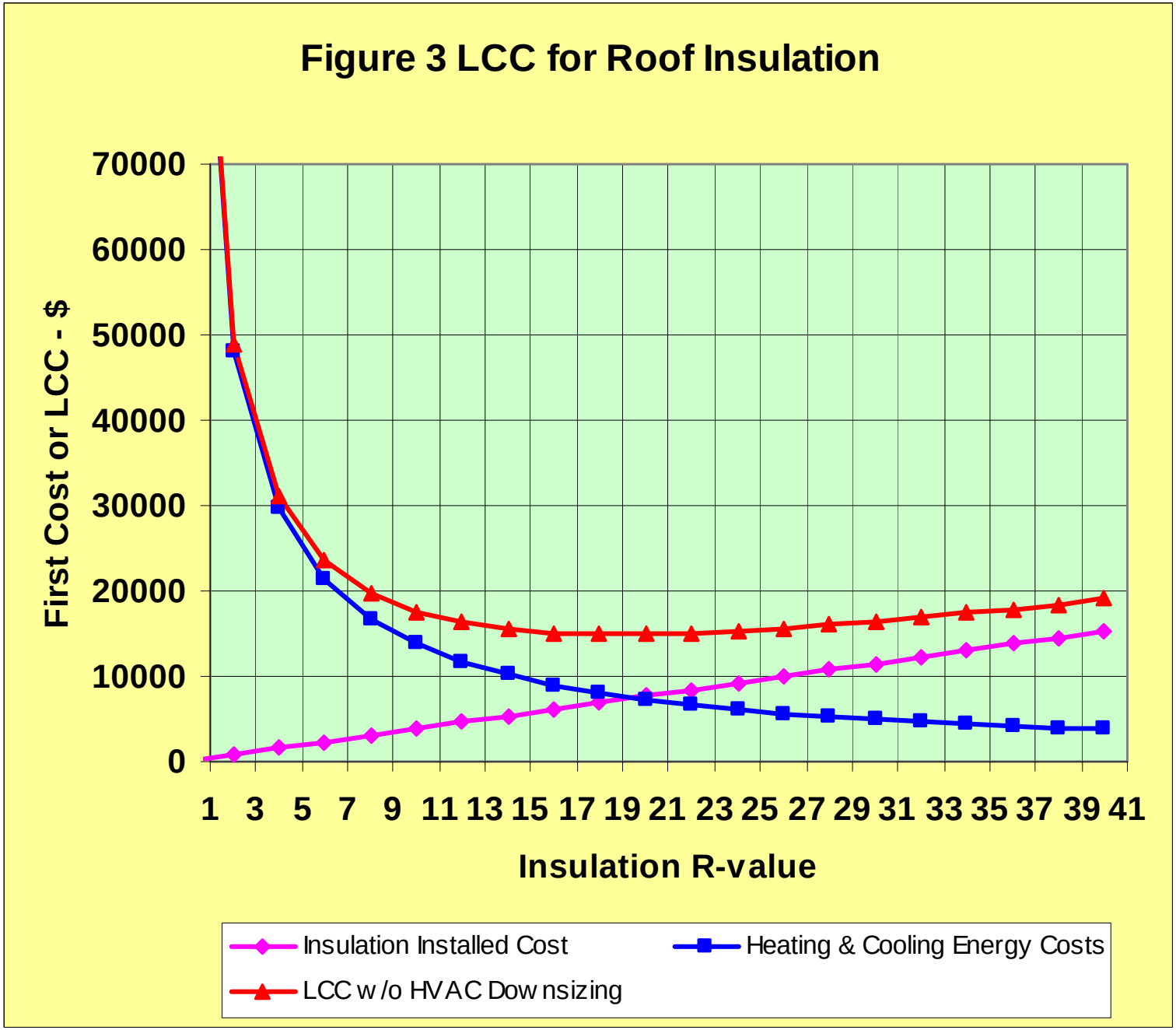
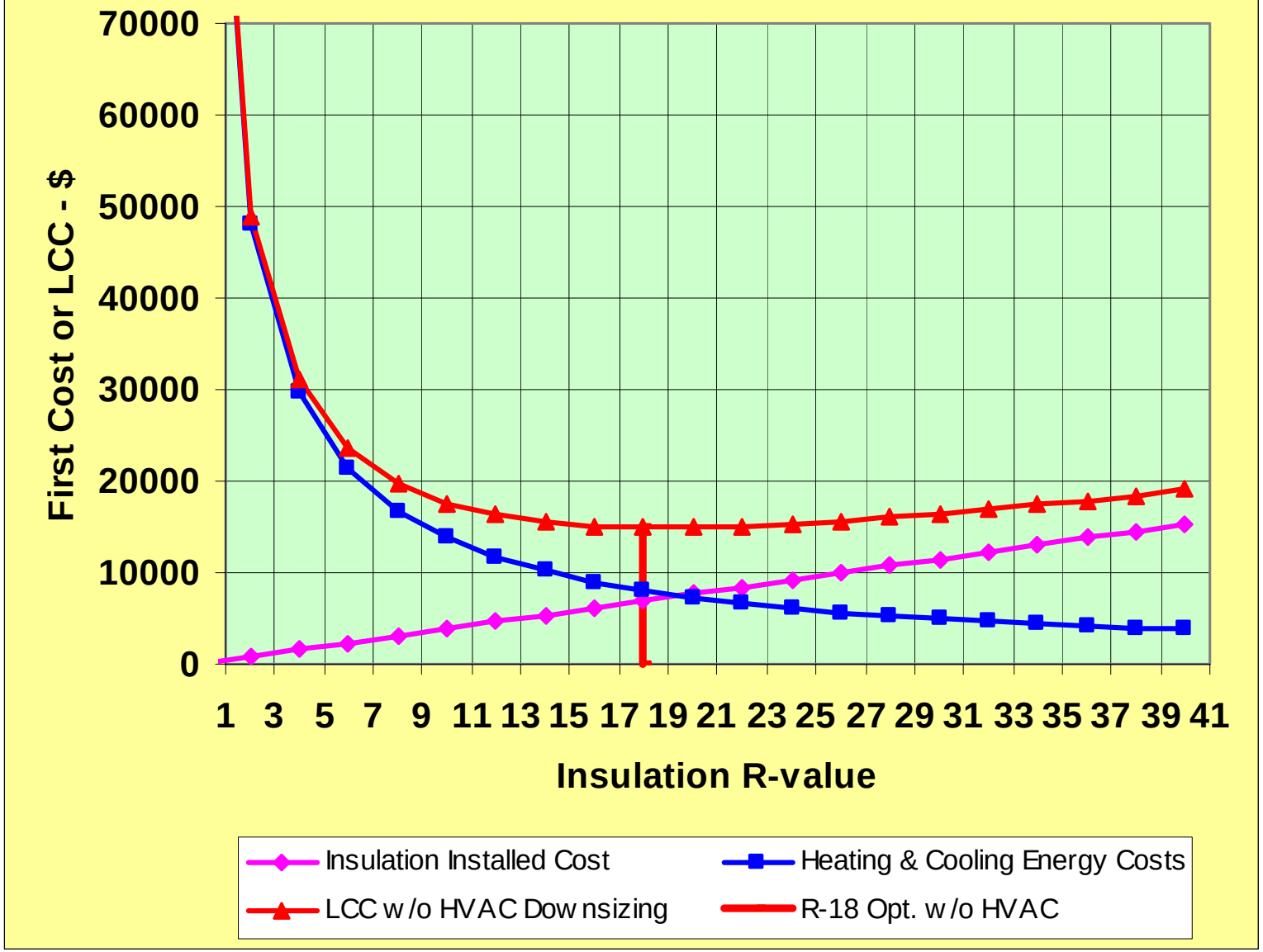


Figure 4 LCC for Roof Insulation



ASHRAE 90.1 2007 Prescriptive Criteria

TABLE 5.5-1 Building Envelope Requirements For Climate Zone 1 (A, B)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.063	R-15.0 c.i.	U-0.048	R-20.0 c.i.	U-0.218	R-3.8 ci
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-1.280	NR
Attic and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.081	R-13.0
Walls, Above-Grade						
Mass	U-0.580	NR	U-0.151[a]	R-5.7 c.i.[a]	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-1.180	NR
Steel-Framed	U-0.124	R-13.0	U-0.124	R-13.0	U-0.352	NR
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.292	NR
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.322	NR	U-0.322	NR	U-0.322	NR
Steel-Joist	U-0.350	NR	U-0.350	NR	U-0.350	NR
Wood-Framed and Other	U-0.282	NR	U-0.282	NR	U-0.282	NR
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.450		U-1.450		U-1.450	

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-1.20	SHGC-0.25 all	U-1.20	SHGC-0.25 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[c]	U-1.20		U-1.20		U-1.20	
Metal framing (entrance door)[c]	U-1.20		U-1.20		U-1.20	
Metal framing (all other)[c]	U-1.20		U-1.20		U-1.20	

US Army Corps of Engineers

ASHRAE - AEDG for Small Office

Climate Zone 1 Recommendation Table

	Item	Component	Recommendation	How-To's in Chapter 4
Envelope	Roof	Insulation entirely above deck	R-15 c.i.	EN1-2, 17, 20-21
		Metal building	R-19	EN1, 3, 17, 20-21
		Attic and other	R-30	EN4, 17-18, 20-21
		Single rafter	R-30	EN5, 17, 20-21
		Surface reflectance/emittance	0.65 initial/0.86	EN1
	Walls	Mass (HC > 7 Btu/ft^2)	No recommendation	EN6, 17, 20-21
		Metal building	R-13	EN7, 17, 20-21
		Steel framed	R-13	EN8, 17, 20-21
		Wood framed and other	R-13	EN9, 17, 20-21
		Below-grade walls	No recommendation	EN10, 17, 20-21
	Floors	Mass	R-4.2 c.i.	EN11, 17, 20-21
		Steel framed	R-19	EN12, 17, 20-21
		Wood framed and other	R-19	EN12, 17, 20-21
	Slabs	Unheated	No recommendation	EN17, 19-21
		Heated	No recommendation	EN17, 19-21
	Doors	Swinging	U-0.70	EN15, 20-21
		Non-swinging	U-1.45	EN16, 20-21
	Vertical Glazing	Window to wall ratio (WWR)	20% to 40% maximum	EN23, 36-37
		Thermal transmittance	U-0.56	EN25
		Solar heat gain coefficient (SHGC)	N, S, E, W - 0.35 / N only - 0.49	EN27-28
		Window orientation	$(A_N * SHGC_N + A_S * SHGC_S) > (A_E * SHGC_E + A_W * SHGC_W)$	A_X–Window area for orientation x EN26-32
		Exterior sun control (S, E, W only)	Projection factor 0.5	EN24, 28, 30, 36, 40, 42 DL5-6
	Skylights	Maximum percent of roof area	3%	DL5-7, DL8, DL13
		Thermal transmittance	U-1.36	DL7, DL8, DL13
		Solar heat gain coefficient (SHGC)	0.19	DL8, DL13

ASHRAE - AEDG for Small Office (Cont.)

Lighting	Interior Lighting	Lighting power density (LPD)	0.9 W/ft²	EL1-2, 4, 8, 10-16
		Light source (linear fluorescent)	90 mean lumens/watt	EL4, 9, 17
		Ballast	Electronic ballast	EL4
		Dimming controls for daylight Harvesting for WWR 25% or higher	Dim fixtures within 12 ft of N/S window wall or within 8 ft of skylight edge	DL1, 9-11, EL6-7
		Occupancy controls	Auto-off all unoccupied rooms	DL2, EL5, 6
		Interior room surface reflectances	80%+ on ceilings, 70%+ on walls and vertical partitions	DL3-4, EL3
HVAC	HVAC	Air conditioner (0-65 KBtuh)	13.0 SEER	HV1- 2, 4, 6, 12, 16-17, 20
		Air conditioner (>65-135 KBtuh)	11.3 EER/11.5 IPLV	HV1- 2, 4, 6, 12, 16-17, 20
		Air conditioner (>135-240 KBtuh)	11.0 EER/11.5 IPLV	HV1- 2, 4, 6, 12, 16-17, 20
		Air conditioner (>240 KBtuh)	10.6 EER/11.2 IPLV	HV1- 2, 4, 6, 12, 16-17, 20
		Gas furnace (0-225 KBtuh - SP)	80% AFUE or E_t	HV1- 2, 6, 16, 20
		Gas furnace (0-225 KBtuh - Split)	80% AFUE or E_t	HV1- 2, 6, 16, 20
		Gas furnace (>225 KBtuh)	80% E_c	HV1- 2, 6, 16, 20
		Heat pump (0-65 KBtuh)	13.0 SEER/7.7 HSPF	HV1- 2, 4, 6, 12, 16-17, 20
		Heat pump (>65-135 KBtuh)	10.6 EER/11.0 IPLV/3.2 COP	HV1- 2, 4, 6, 12, 16-17, 20
		Heat pump (>135 KBtuh)	10.1 EER/11.5 IPLV/3.1 COP	HV1- 2, 4, 6, 12, 16-17, 20
	Economizer	Air conditioners & heat pumps- SP	No recommendation	HV23
	Ventilation	Outdoor air damper	Motorized control	HV7-8
		Demand control	CO_2 sensors	HV7, 22
	Ducts	Friction rate	0.08 in. w.c./100 feet	HV9, 18
		Sealing	Seal class B	HV11
		Location	Interior only	HV9
		Insulation level	R-6	HV10
SWH	Service Water Heater	Gas storage	90% E_t	WH1-4
		Gas instantaneous	0.81 EF or 81% E_t	WH1-4
		Electric storage 12 kW	EF > 0.99 – 0.0012xVolume	WH1-4
		Pipe insulation (d<1½ in./ d≥1½ in.)	1 in./ 1½ in.	WH6

Note: If the table contains "No recommendation" for a component, the user must meet the more stringent of either Standard 90.1 or the local code requirements in order to reach the 30% savings target.

ASHRAE 90.1 2010 1st Public Review

Table 5.5-1 Building Envelope Requirements For Climate Zone "1 (A,B)"

	NONRESIDENTIAL		RESIDENTIAL		SEMIHEATED	
OPAQUE ELEMENTS	**Assembly Maximum**	**Insulation Min.R -Value**	**Assembly Maximum**	**Insulation Min.R -Value**	**Assembly Maximum**	**Insulation Min.R -Value**
Roofs						
Insulation Entirely above Deck	U- 0.048	R-20.0 ci	U- 0.039	R-25.0 ci	U- 0.218	R-3.8 ci
Metal Building	U- 0.035	R-19.0 + R-11 LS	U- 0.035	R-19.0 + R-11 LS	U- 0.115	R-10.0
Attic and Other	U- 0.027	R-38.0	U- 0.017	R-60.0	U- 0.081	R-13.0
Walls, Above Grade						
Mass	U- 0.580	NR	U- 0.151	R-5.7 ci"	U- 0.580	NR
Metal Building	U- 0.147	R-19.0	U- 0.049	R-0.0 + R-19.5 ci	U- 0.186	R-10.0
Steel Framed	U- 0.064	R-13.0 + R-7.5 ci	U- 0.064	R-13.0 + R-7.5 ci	U- 0.352	NR
Wood Framed and Other	U- 0.089	R-13.0	U- 0.051	R-13.0 + R-7.5 ci	U- 0.292	NR
Wall, Below Grade						
Below Grade Wall	C- 1.140	NR	C- 1.140	NR	C- 1.140	NR
Floors						
Mass	U- 0.322	NR	U- 0.322	NR	U- 0.322	NR
Steel Joist	U- 0.350	NR	U- 0.350	NR	U- 0.350	NR
Wood Framed and Other	U- 0.282	NR	U- 0.282	NR	U- 0.282	NR
Slab-On-Grade Floors						
Unheated	F- 0.730	NR	F- 0.730	NR	F- 0.730	NR
Heated	F- 1.020	R-7.5 for 12 in.	F- 1.020	R-7.5 for 12 in.	F- 1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U- 0.700	uninsulated	U- 0.500	insulated	U- 0.700	uninsulated
Non-Swinging	U- 1.450	uninsulated	U- 0.500	insulated	U- 1.450	uninsulated

ASHRAE 90.1 2010 2nd Public Review

Table 5.5-1 Building Envelope Requirements For Climate Zone 1 (A,B,C) (IP)*

	NONRESIDENTIAL		RESIDENTIAL		SEMIHEATED	
OPAQUE ELEMENTS	Assembly Maximum	Insulation Min. R –Value	Assembly Maximum	Insulation Min. R –Value	Assembly Maximum	Insulation Min. R -Value
Roofs						
Insulation Entirely above Deck	U-0.048 0.041	R-20 c.i. R-10 + R-19 FC	U-0.039 0.041	R-25 c.i. R-10 + R-19 FC	U-0.218	R-3.8 c.i.
Metal Building[a]	U-~~0.035~~ 0.027	~~+ R-11 Ls~~ R-38	U-~~0.035~~ 0.027	~~+ R-11 Ls~~ R-38	U-0.115 0.081	R-10
Attic and Other	U-~~0.021~~	~~49~~	U-~~0.017~~	~~60~~	U-~~0.459~~	R-13
Walls, Above Grade						
Mass	U-0.580 0.094	NR R-0 + R-9.8 c.i.	U-0.151[b] 0.094	R-5.7 c.i.[b] R-0 + R-9.8 c.i.	U-0.580 0.352	NR NR
Metal Building	U-~~0.147~~	~~19~~	U-~~0.049~~	~~19.5 c.i.~~	U-~~0.186~~	~~R-10~~
Steel Framed	U-0.064	R-13 + R-7.5 c.i.	U-0.064	R-13 + R-7.5 c.i.	U-0.352	NR
Wood Framed and Other	U-0.089	R-13	0.089 U-~~0.051~~	R-13 ~~+ R-7.5 c.i.~~	U-0.292	NR
Wall, Below Grade						
Below Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.322	NR	U-0.322	NR	U-0.322	NR
Steel Joist	U-0.350	NR	U-0.350	NR	U-0.350	NR
Wood Framed and Other	U-0.282	NR	U-0.282	NR	U-0.282	NR
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.500		U-0.700	
Non-Swinging	U-1.450		U-0.500		U-1.450	

Army Developed Design Guides for 30% Better Prescriptive Solutions for SRM and New Construction Projects: Response to EPACT 2005

Used Equal Energy Approach

Table -3. Battalion HQ - BHQ

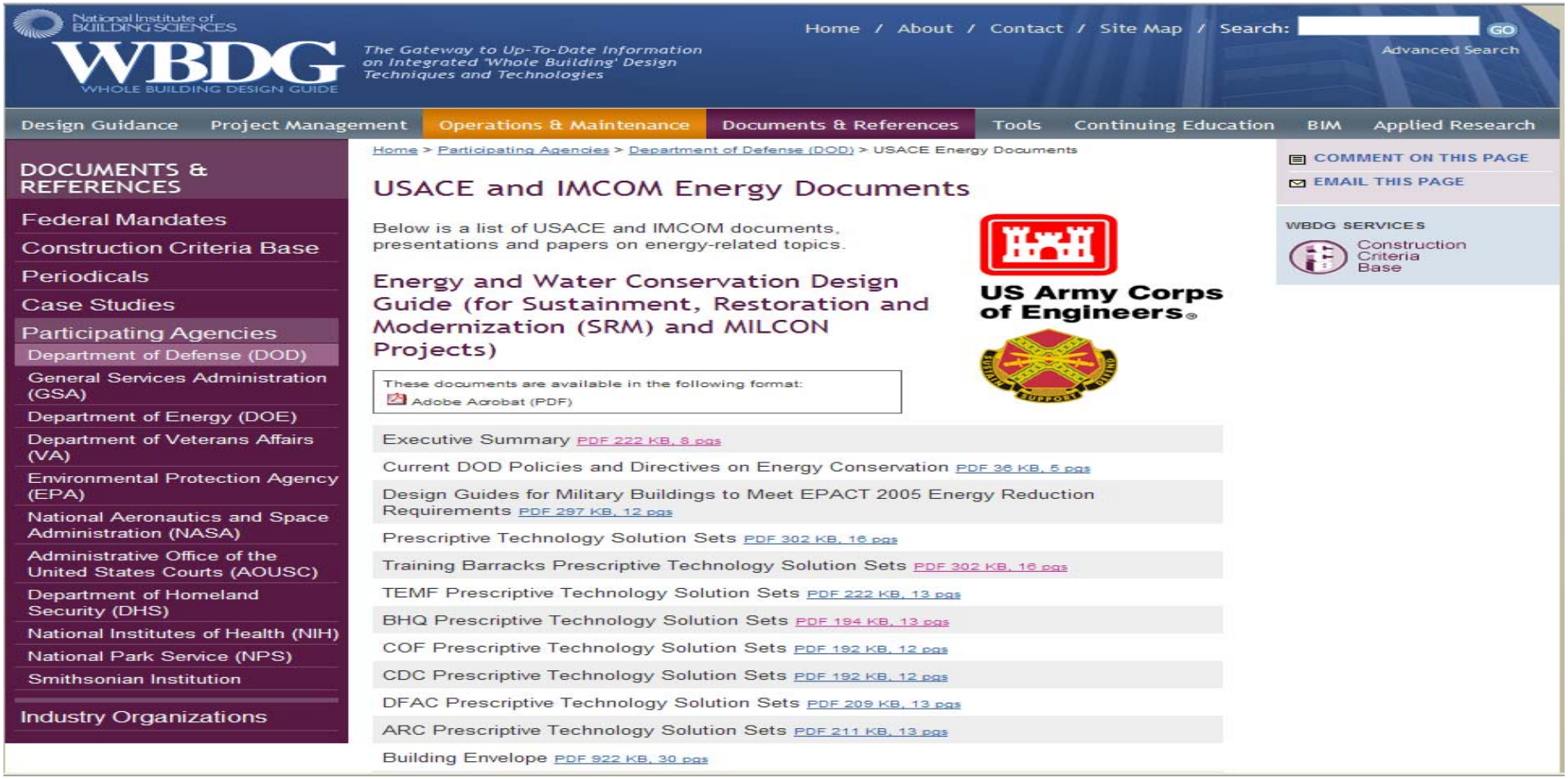
Item	Component(1)	Climate Zones							
		1	2	3	4	5	6	7	8
Roof	*Assembly Max U-value*	U-0.0481	U-0.0388	U-0.0388	U-0.0388	U-0.0325	U-0.0325	U-0.0245	U-0.0245
	Insulation Entirely Above Deck	R-20ci	R-25ci	R-25ci	R-25ci	R-30ci	R-30ci	R-40ci	R-40ci
	Attic and Other	R-30	R-38	R-38	R-38	R-49	R-49	R-60	R-60
	Solar Reflectance (2)	High	High	High	High	High	Low	Low	Low
Walls	*Assembly Max U-value*	U-0.1242	U-0.1242	U-0.1242	U-0.0676	U-0.0676	U-0.0676	U-0.0512	U-0.0373
	Mass	R-6.5ci	R-6.5ci	R-6.5ci	R-13	R-13	R-13	R-19	R-19 + R-3ci
	Steel Framed	R-13	R-13	R-13	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-12.5ci	R-13 + R-18.8ci
	Wood Framed and Other	R-13	R-13	R-13	R-13 + R-3.8ci	R-13 + R-3.8ci	R-13 + R-3.8ci	R-13 + R-7.5ci	R-13 + R-15.6ci
Floors Over Unconditioned Space	*Assembly Max U-value*	U-0.1067	U-0.0739	U-0.0739	U-0.0739	U-0.0521	U-0.0377	U-0.0377	U-0.0377
	Mass	R-6.3ci	R-10.4ci.	R-10.4ci.	R-10.4ci.	R-16.7ci.	R-25.1ci.	R-25.1ci.	R-25.1ci.
	Steel Joists	R-13	R-13	R-13	R-13	R-19	R-30	R-30	R-30
	Wood Framed and Others	R-13	R-13	R-13	R-13	R-19	R-30	R-30	R-30
Slab-on-Grade	*Assembly Max F-value*	F-0.730	F-0.730	F-0.730	F-0.520	F-0.520	F-0.510	F-0.510	F-0.434
	Unheated	NR (3)	NR (3)	NR (3)	R-15.0 for 24 in.	R-15.0 for 24 in.	R-20.0 for 24 in.	R-20.0 for 24 in.	R-20.0 for 48 in
Doors	Swinging	U-0.70	U-0.70	U-0.70	U-0.50	U-0.50	U-0.50	U-0.50	U-0.50
	Non-swinging	U-1.45	U-1.45	U-1.45	U-0.50	U-0.50	U-0.50	U-0.50	U-0.50
Air Tightness (4)	Max Leakage at ±75Pa Blower Test Pressures	0.25 cfm/ft^2	0.25 cfm/ft^2	0.25 cfm/ft^2	0.25 cfm/ft^2	0.25 cfm/ft^2	0.25 cfm/ft^2	0.25 cfm/ft^2	0.25 cfm/ft^2
Vertical Glazing	Window to Wall Ratio (WWR)	10%-20% - East/West 10%-40% - North/South	10%-20% - East/West 10%-40% - North/South	10%-20% - East/West 10%-40% - North/South	10%-20% - East/West 10%-40% - North/South	10%-20% - East/West 10%-40% - North/South	10%-20% - East/West 10%-40% - North/South	10%-20% - East/West 10%-40% - North/South	10%-20% - East/West 10%-40% - North/South
	Thermal transmittance (Assembly Maximum)	U-0.56	U-0.45	U-0.45	U-0.42	U-0.42	U-0.42	U-0.33	U-0.33
	Solar heat gain coefficient (SHGC)	0.25	0.25	0.37	0.39	0.39	0.39	NR (3)	NR (3)
	South Overhangs	Yes; Projection Factor = 0.4	Yes; Projection Factor = 0.4	Yes; Projection Factor = 0.4	Yes; Projection Factor = 0.4	Yes; Projection Factor = 0.4	Yes; Projection Factor = 0.4	Yes; Projection Factor = 0.4	NR (3)

Table 6-1. BHQ Climate Zone 1A Prescriptive Solution Table

Item	Component	Baseline (1)	Recommendation	
			Assembly Max (2)	Min R-Value (2)
Roof	Insulation Entirely Above Deck	R-15	U-0.0481	R-20ci
	Attic and Other			R-30
	Solar Reflectance (3)			Cool Roof for Low Slope & Light color all others
Walls	Mass		U-0.1242	R-6.5ci
	Steel Framed	R-13		R-13
	Wood Framed and Other			R-13
Floors Over Unconditioned Space	Mass		0.1067	R-6.3ci.
	Steel Joist			R-13
	Wood Framed and Other			R-13
Slab-on-Grade	Unheated	NR (4)		NR (4)
Doors	Swinging	U-0.70	U-0.70	Uninsulated
	Non-Swinging	U-1.45	U-1.45	Uninsulated
Infiltration		0.4 cfm/ft^2 @ 75 Pa	0.25 cfm/ft^2 @ 75 Pa (5)	
Vertical Glazing	Window to Wall Ratio (WWR)	Uniform Distribution	10% to 20% – east/west 10% to 40% – north/south	
	Thermal transmittance	U-1.22	U-0.56	
	Solar heat gain coefficient (SHGC)	0.25	0.25	
	South Overhangs	None	Yes; Projection Factor = 0.4	
Interior Lighting	Lighting Power Density (LPD)	1.0 W/ft2	≤ 0.9 W/ft^2	
	Occupancy Controls		Manual On/Auto Off (all periodically occupied spaces)	
	Daylighting Controls	None	Perimeter Zones	
	Plug Load Lighting		Compact Fluorescent (CFL) with electronic ballast	
	All Ballasts		Electronic	
HVAC	Air Conditioner	PSZ-AC 12.0 SEER	PSZ-AC 14.0 SEER	
	Gas Furnace	80% E_t	90% E_t	
	ERV	None	None	
	All equipment		Variable Speed pumps, fans, etc.	
Economizer		NR	NR	
Ventilation	Outdoor Air Damper	Motorized Control	Motorized Control	
	Damper Control	NR	NR	
Ducts	Friction rate		0.08 in. w.c./100 feet	
	Sealing		Seal class B	
	Location		Interior only	
	Insulation level		R-6 (6)	

US Army Corps of Engineers

Whole Building Design Guide



http://www.wbdg.org/references/pa_dod_energy.php

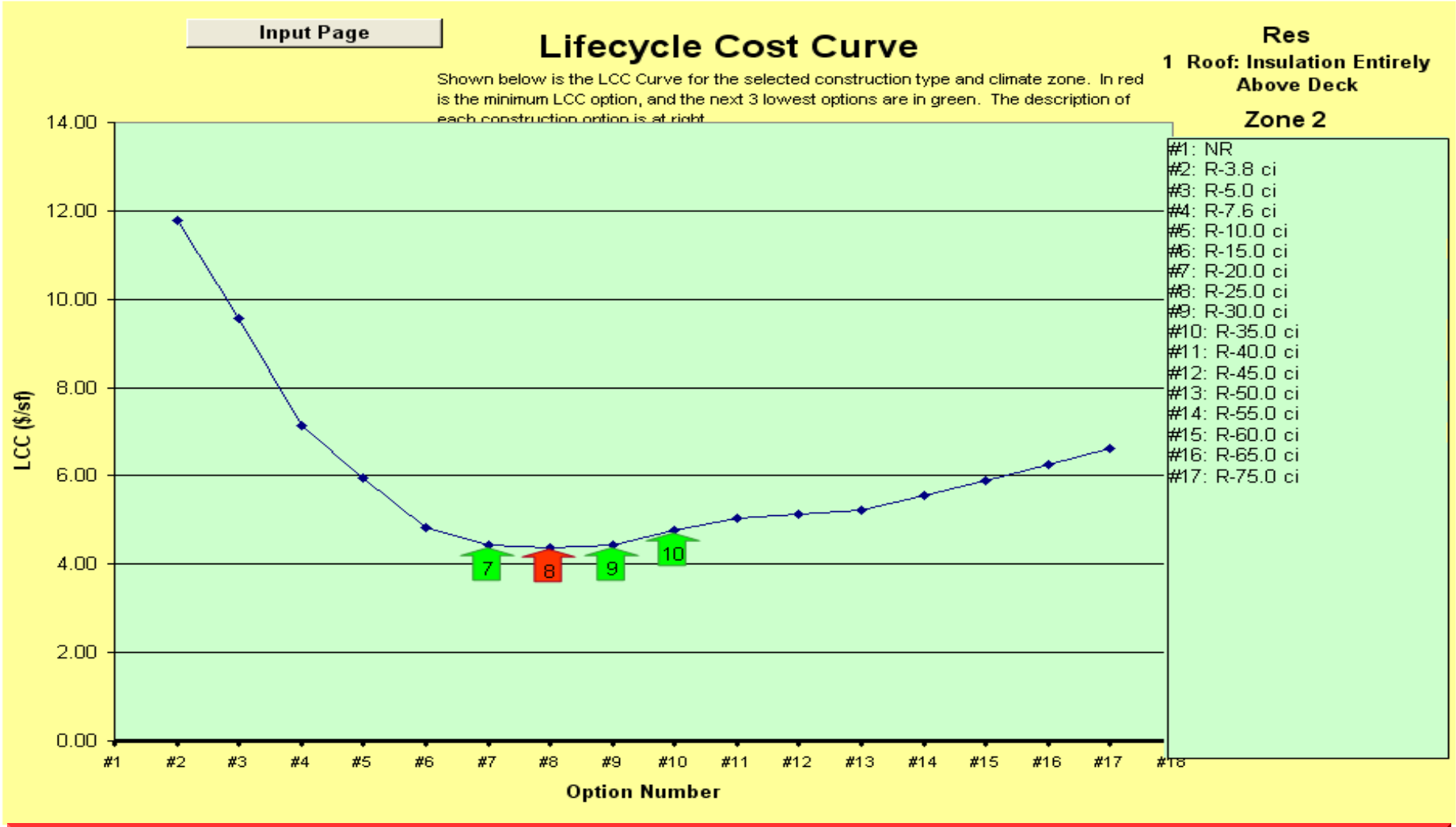
Energy Independence and Security Act of 2007 (EISA 2007) Army Response

What is the Right Level of Insulation for Net Zero Building?

- **BAU – Business As Usual provides the least first cost insulation level.**
- **ASHRAE determines the minimum insulation level that will be mandated by Code using a Life Cycle Cost optimization.**
- **Current ASHRAE Optimization uses national average fuel prices at $1.22/therm and $0.09/kWhr.**
- **What if the energy prices “Tripled”, or the average national prices went to $3.50/therm and $0.30/kWhr? This is the energy security scenario that we must plan for today.**

Current ASHRAE 90.1 Optimization Curve

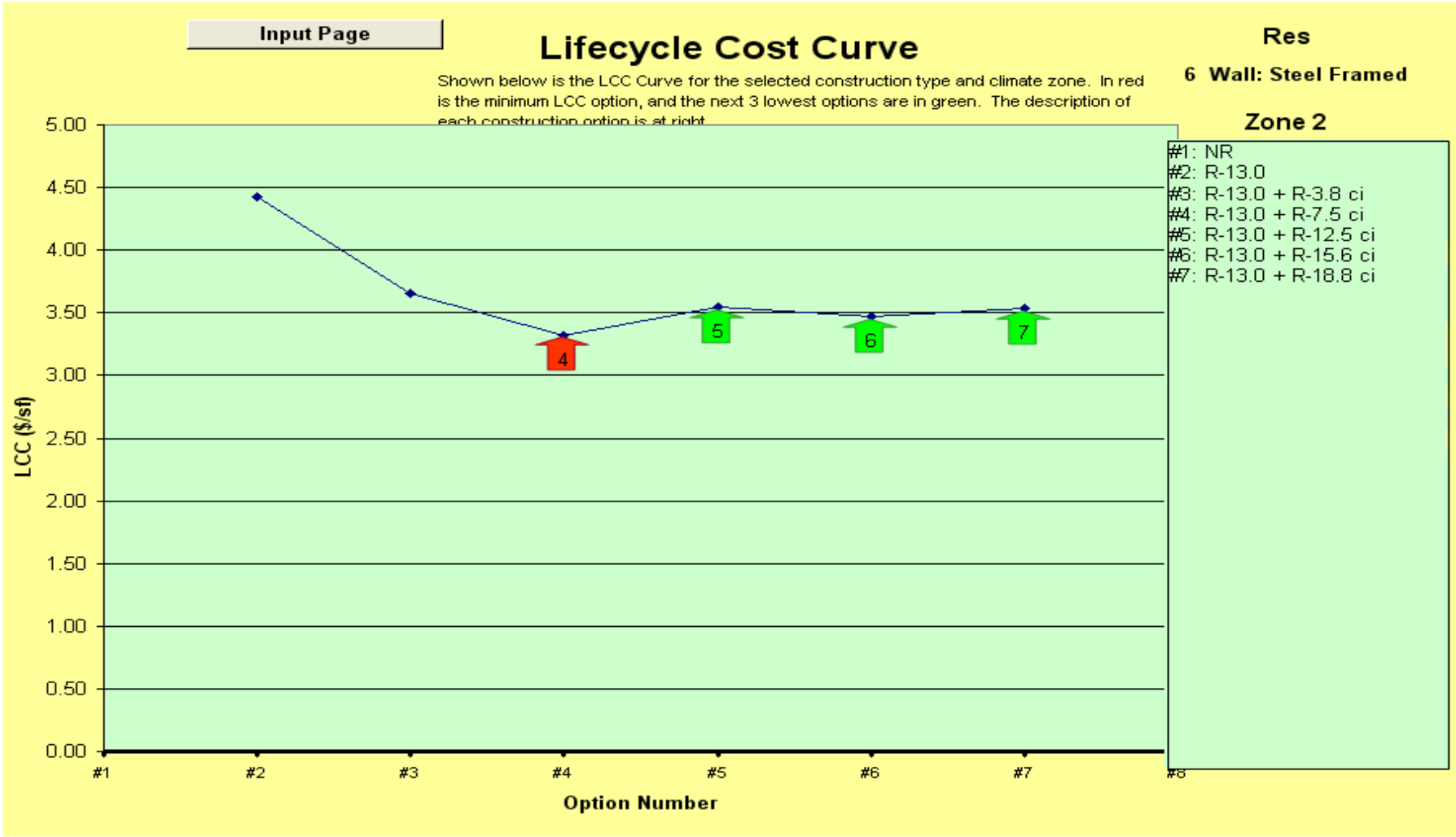
Business as Usual - Roof Insulation



CZ=2 (Houston, TX) Roof Insulation at R=25ci

Current ASHRAE 90.1 Optimization Curve

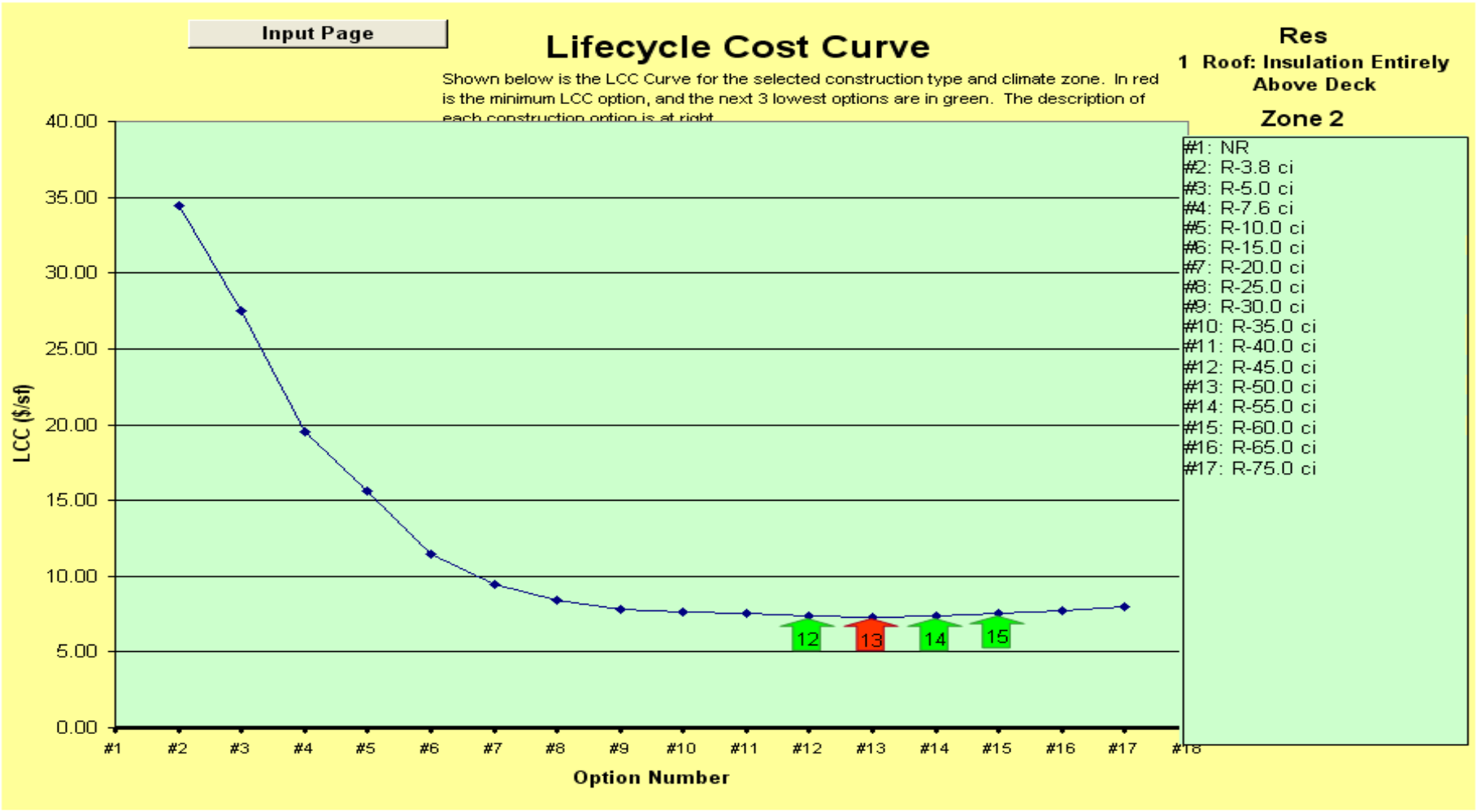
Business As Usual - Wall Insulation



CZ=2 (Houston, TX) Wall Insulation at R_{eff}=15.5

ASHRAE 90.1 Optimization Curve

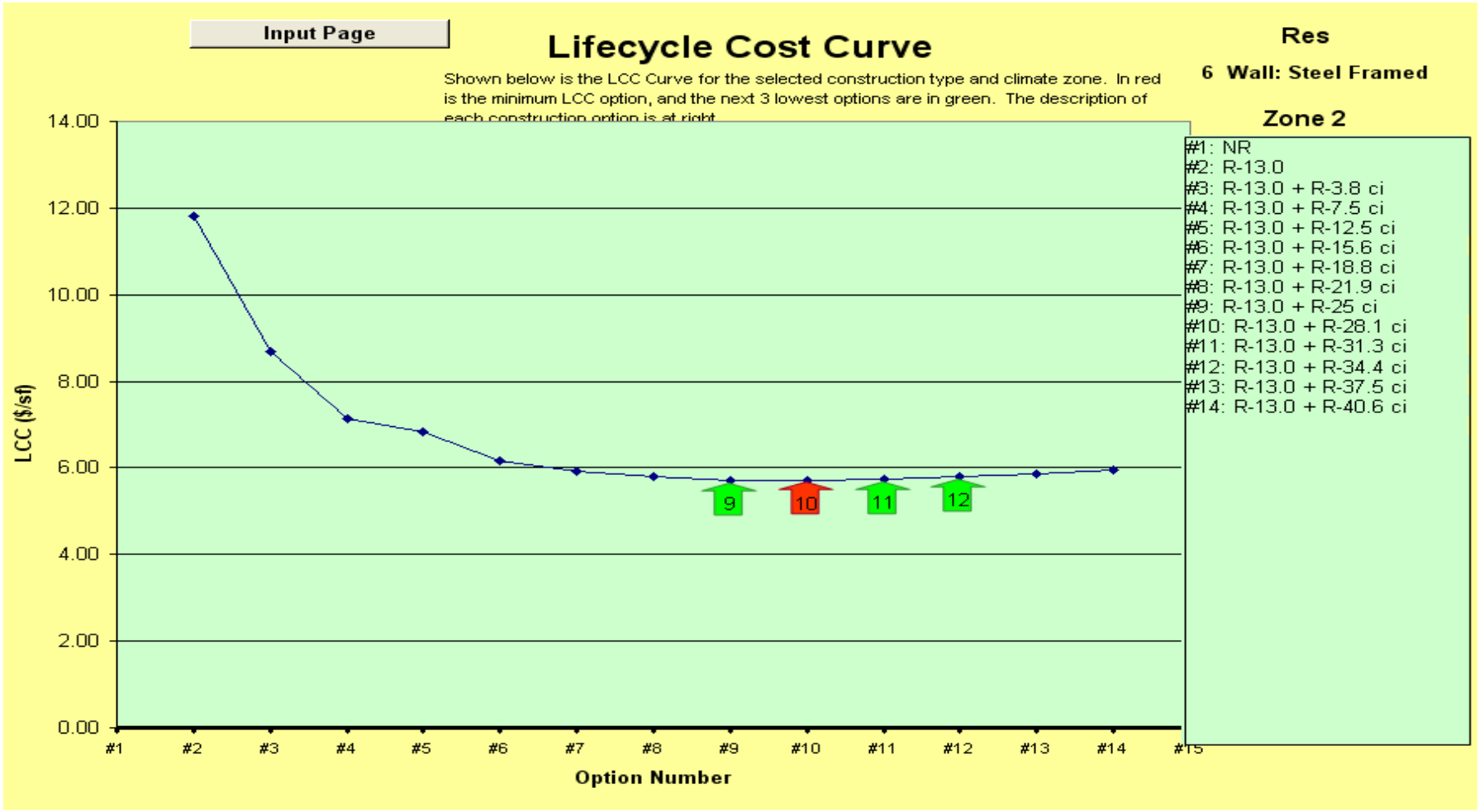
Fuel Prices Tripled! - Roof Insulation



CZ=2 (Houston, TX) Roof Insulation at R=50-60ci

ASHRAE 90.1 Optimization Curve

Fuel Prices Tripled! - Wall Insulation



CZ=2 (Houston, TX) Wall Insulation at R_{eff}=33-39

Passive Haus Insulation Specifications

	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7A	8A
	Miami, FL	Houston, T	Phoenix, A	Memphis, T	El Paso, T	San Franci	Baltimore,	Albuquerqu	Seattle, W	Chicago, IL	Colorado S	Burlington,	Helena, MT	Duluth, MN	Fairbanks,
Wall Insulation [mm]	80	120	120	150	150	100	200	200	150	240	240	300	300	400	450
Roof Insulation [mm]	120	180	180	220	220	150	300	300	220	360	360	450	450	600	675
Foundation Insulation [mm]	50	80	80	90	90	60	120	120	90	144	144	180	180	240	250
Summer Shadowing	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.5	0.5	0.75	0.75	0.75
Walls															
Wall Insulation Passive Haus	**R-19 + R-7.5ci**	**R-19 + R-15ci**	**R-19 + R-15ci**	**R-19 + R-20ci**	**R-19 + R-20ci**	**R-19 + R-10ci**	**R-19 + R-25ci**	**R-19 + R-25ci**	**R-19 + R-20ci**	**R-19 + R-30ci**	**R-19 + R-30ci**	**R-19 + R-40ci**	**R-19 + R-40ci**	**R-19 + R-50ci**	**R-19 + R-60ci**
Wall Insulation Passive Haus [R-value eff]	***R-13.5***	***R-21***	***R-21***	***R-26***	***R-26***	***R-16***	***R-31***	***R-31***	***R-26***	***R-36***	***R-36***	***R-46***	***R-46***	***R-56***	***R-66***
WBDG, Army Specs - Steel Framed Walls	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-18.8ci	R-13 + R-18.8ci	R-13 + R-18.8ci	R-13 + R-18.8ci
WBDG, Army Specs Steel Framed Equivalent R-Value or c.i. Equivalent	*R-15.5*	*R-15.5*	*R-15.5*	*R-15.5*	*R-15.5*	*R-15.5*	*R-15.5*	*R-18.2*	*R-18.2*	*R-18.2*	*R-18.2*	*R-26.8*	*R-26.8*	*R-26.8*	*R-26.8*
Roofs															
Roof Insulation Pasive Haus [R-value eff] cont insulation	**20**	**30**	**30**	**35**	**35**	**25**	**45**	**45**	**35**	**55**	**55**	**70**	**70**	**80**	**90**
WBDG, Army Specs - Steel Framed Walls	R-25	R-25	R-25	R-25	R-25	R-25	R-30	R-30	R-30	R-30	R-30	R-40	R-40	R-40	R-40
Foundation Insulation Passive Haus [R-value eff]	**5**	**10**	**10**	**15**	**15**	**10**	**20**	**20**	**15**	**25**	**25**	**30**	**30**	**35**	**40**

Passive Haus Window Specifications

	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7A	8A
	Miami, FL	Houston, TX	Phoenix, AZ	Memphis, TN	El Paso, TX	San Francisco, CA	Baltimore, MD	Albuquerque, NM	Seattle, WA	Chicago, IL	Colorado Springs, CO	Burlington, VT	Helena, MT	Duluth, MN	Fairbanks, AK
Windows															
Passive Haus Window Specifications															
U-Value	0.26	0.26	0.26	0.26	0.26	0.26	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
SHGC	*0.25*	*0.25*	*0.25*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.49*	*0.49*	*0.49*	*0.49*	*0.49*	*0.49*
VT	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50	> 0.50
ASHRAE 90.1-2010 Window Specifications															
U-Value	0.73	0.50	0.50	0.46	0.46	0.46	0.38	0.38	0.38	0.38	0.38	0.36	0.36	0.29	0.29
SHGC	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.30*	*0.30*	*0.30*	*0.30*	*0.30*	*0.35*	*0.35*	*0.40*	*0.40*
Min VT/ SHGC	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
ASHRAE 189.1 Window Specifications															
U-Value	1.20	0.75	0.75	0.55	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.35	0.35
SHGC	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.35*	*0.35*	*0.35*	*0.35*	*0.35*	*0.40*	*0.40*	*0.45*	*NR*
VT	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
ASHRAE 90.1 -2007 Window Specifications															
U-Value	1.20	0.75	0.75	0.65	0.65	0.65	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.45	0.45
SHGC	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*NR*	*NR*
VT	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
ASHRAE 90.1 -2004 Window Specifications															
U-Value	1.22	1.22	1.22	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.46
SHGC	*0.25*	*0.25*	*0.25*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*	*0.49*	*0.49*	*0.49*	*0.49*	*0.49*	*NR*
VT	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

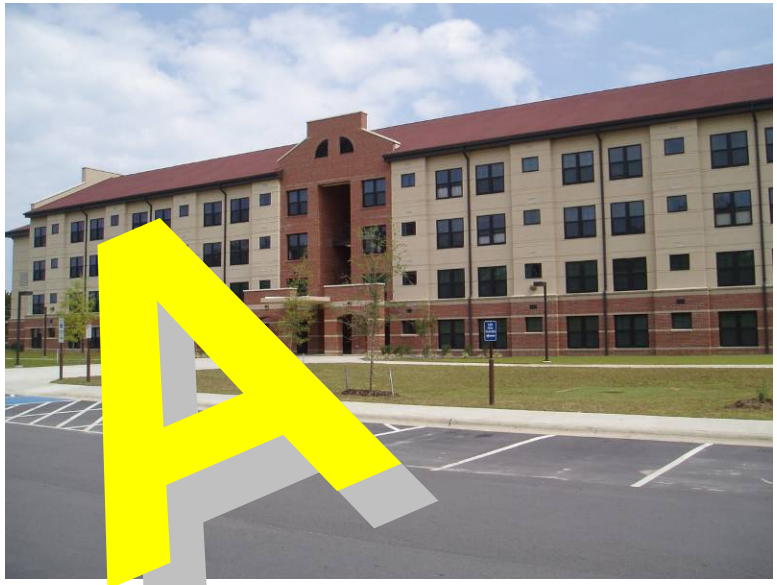
Gross to Net Floor Area Conversion with added Insulation

- **Wall thickness increases will be different depending on climate region.**
- **Wall thickness with Passive Haus insulation levels is determined with a 6” thick steel frame with R-19 in the wall cavity and additional continuous insulation(ci) on the exterior, plus the façade thickness.**
- **Up to R-60 in CZ=8. R-60ci ranges from 15” for EPS or 12” for XPS**
  - **EPS = R4/inch & XPS = R5/inch**

Optimized Building Insulation Levels :

ASHRAE 90.1 20[illegible]
2010, AS[illegible]E 189,
Army D[illegible] and [illegible]assiv[illegible]s

Q&A



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