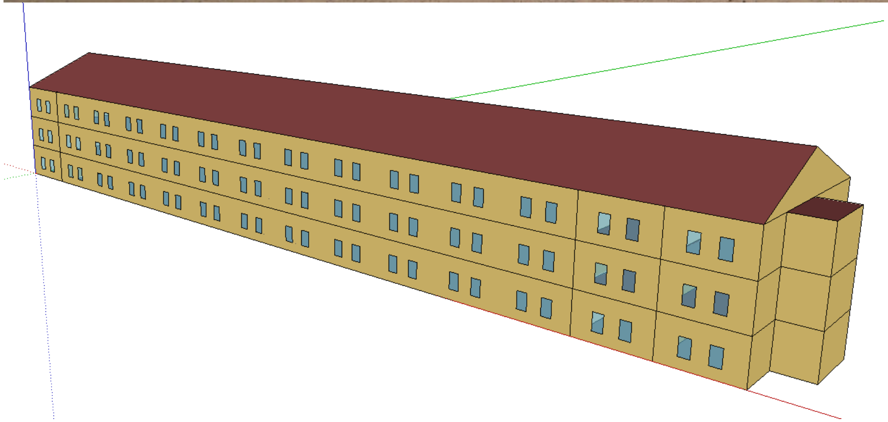
Building Envelope Insulation Optimization - Modeling Results Barracks

Richard Liesen, Ph.D.
USACE ERDC-CERL



US Army Corps of Engineers

Outline

- Describe integrated energy optimization process for buildings

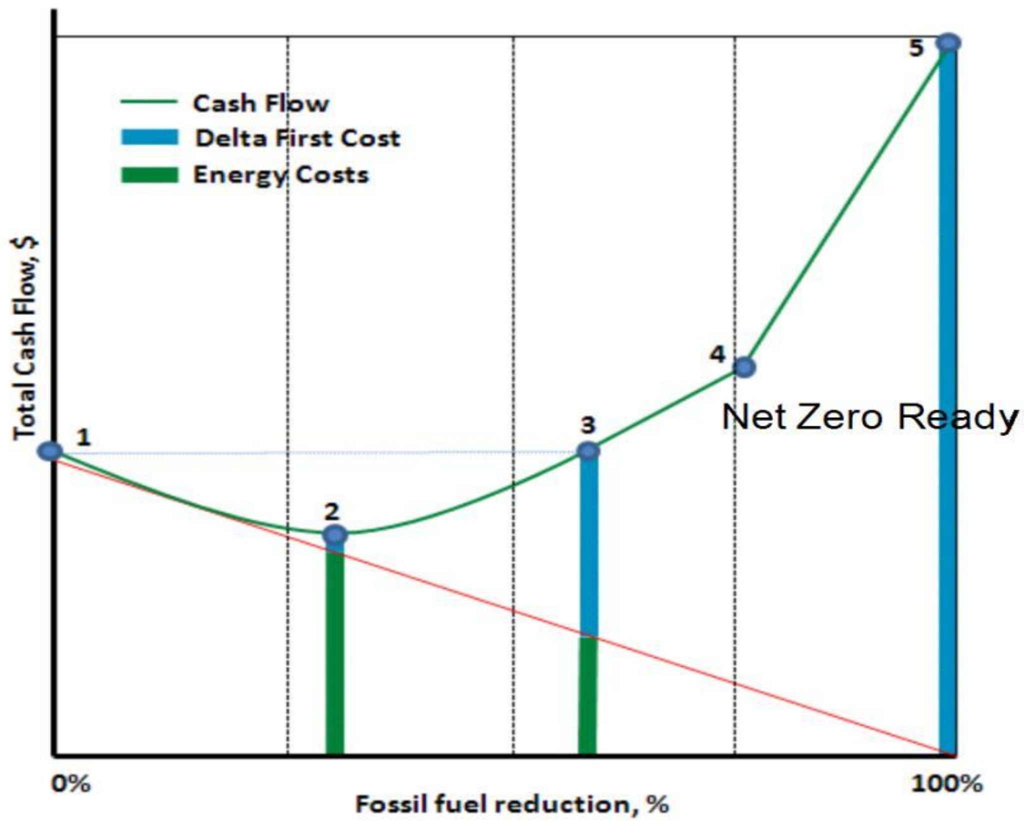
- Demonstrate this process for building retrofits.

- Understand how energy optimization process can be applied to barracks/dormitories in typical DOE climate zones.

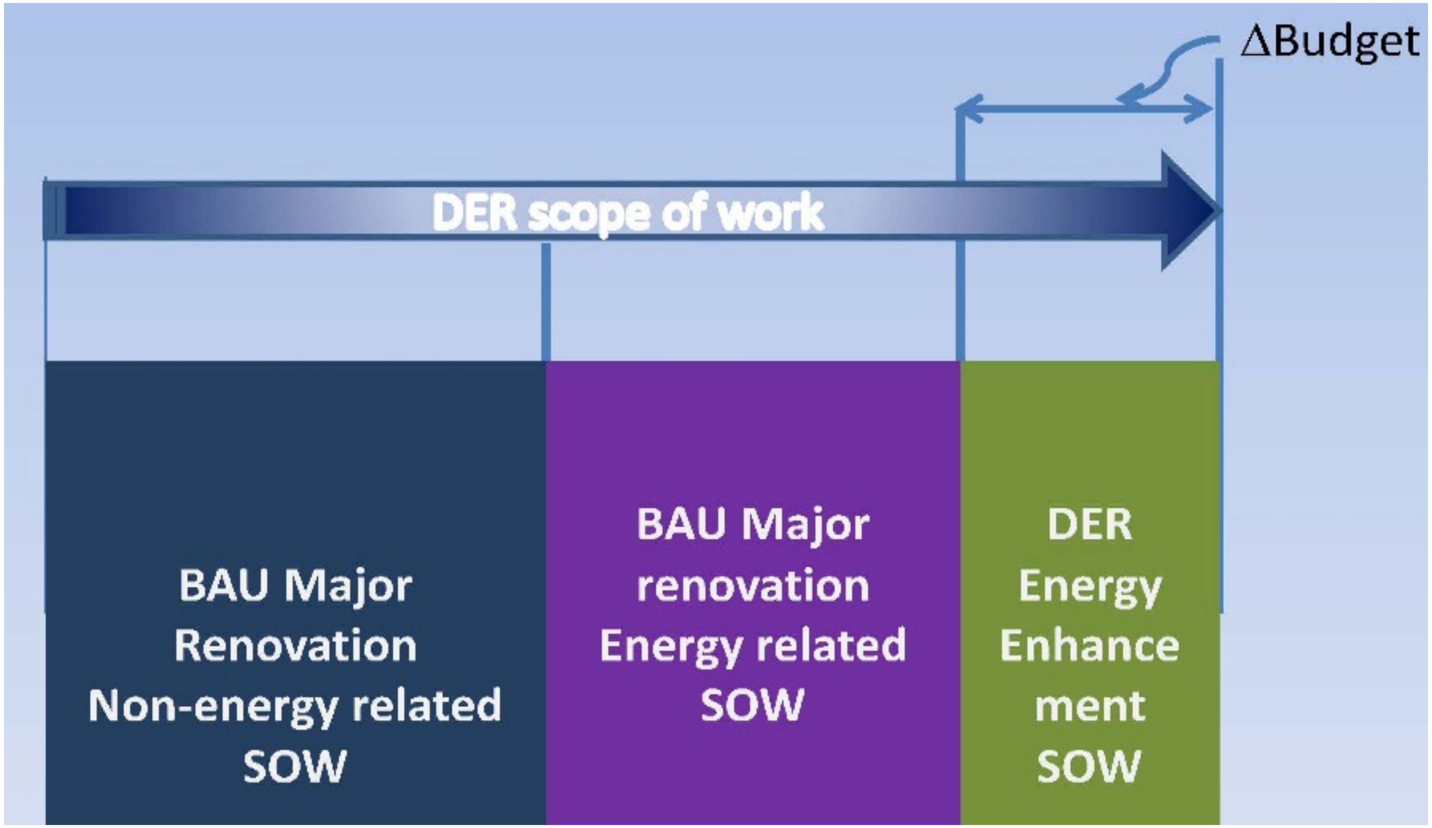
Cost-Optimizing Zero Energy Buildings

Integrating EEM's that are Net Zero Ready Cost Effective

- 1. business as usual or the base case
- 2. least life cycle cost option
- 3. achieved the same total annual cost as your base case building, but the building at point 3 is more energy efficient and often more comfortable.
- 4. is the Crossover Point: where generating renewable energy is more cost-effective than additional Energy Efficiency Measures or **Net-Zero Ready. Point 4 is normally at 60% to 80% savings depending on building and location**



Scope of Work DER Project



- The budget increase allowance (Δ Budget) compared to the budget allocated for a major renovation project (base case budget)

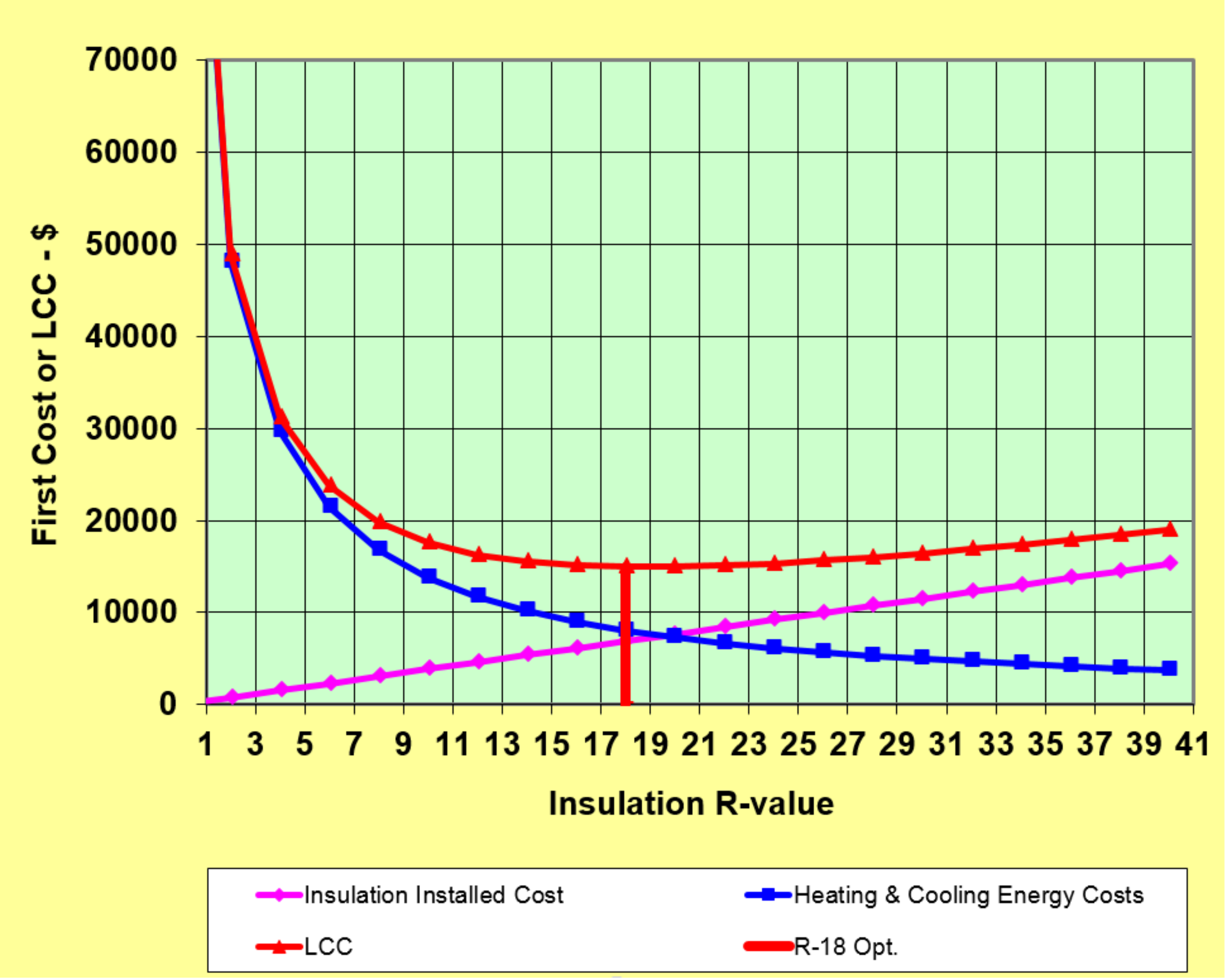
What is the Right Level of Insulation?

- 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 Optimization uses national average fuel prices at $1.22/therm and $0.09/kWhr.
- What if the energy prices “Doubled”, or the average national prices went to $2.44/therm and $0.18/kWhr. **Look at the Risk Factor of increasing energy prices.**
- For Advanced Insulation options push Optimization towards Point 4.

Insulation Specifications

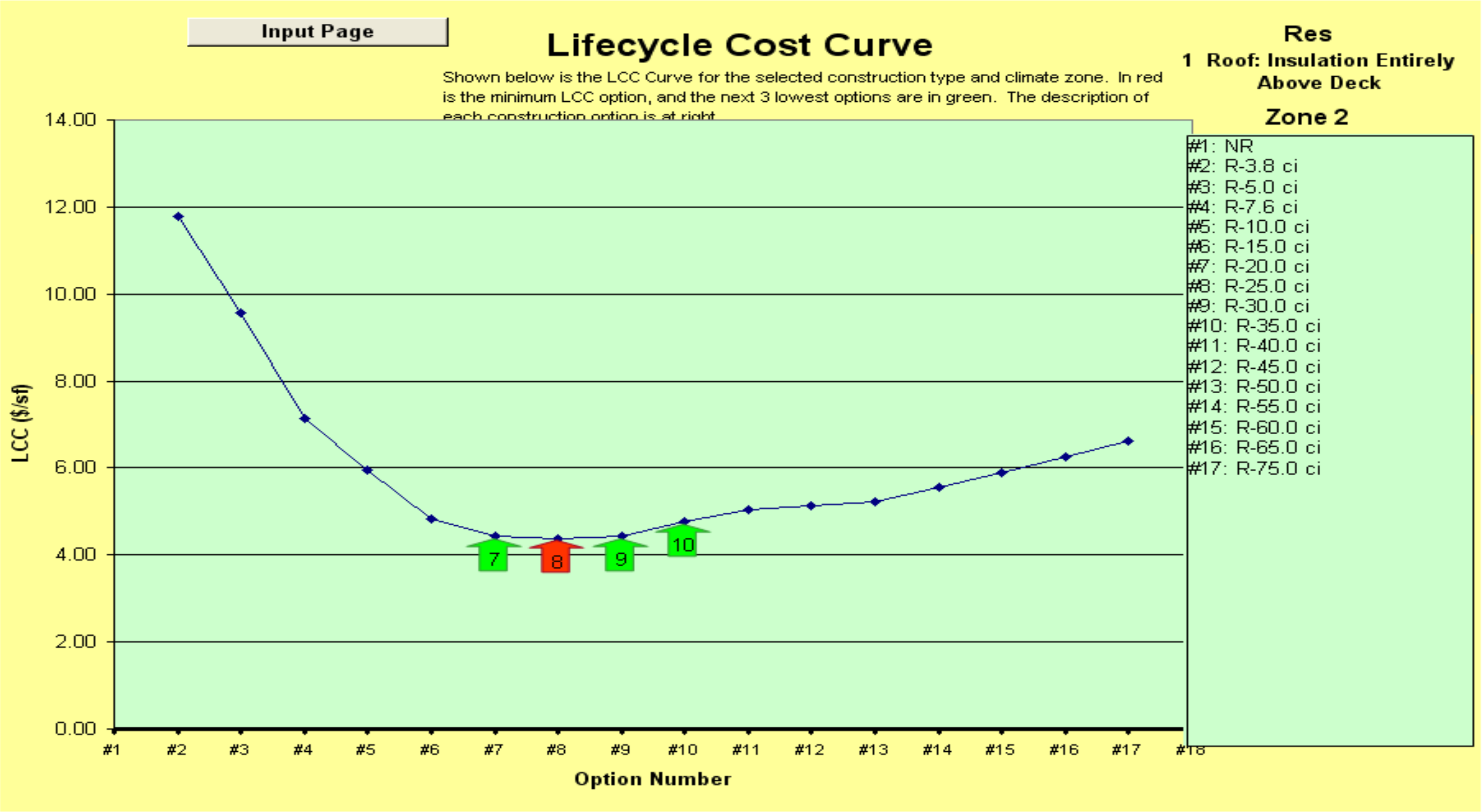
Country	Climate zone	Roof U-value W/(m²*K) (Btu/(hr*ft²*°F)	Roof R-value (m²*K)/W (hr*ft2*°F)/Btu	Wall U-value W/(m²*K) (Btu/(hr*ft²*°F)	Wall R-value (m²*K)/W (hr*ft2*°F)/Btu
Austria	4	0.23 (0.041)	4.4 (25)	0.24 (0.043)	4.17 (23)
	7	0.159 (0.028)	6.3 (36)	0.135 (0.024)	7.4. (42)
China	2a	0.53 (0.093)	1.9(11)	0.96(0.169)	1.0(6)
	3a	0.53 (0.093)	1.9(11)	0.60(0.106)	1.7(9)
	3c	0.53 (0.093)	1.9(11)	0.96(0.169)	1.0(6)
	4a	0.38(0.067)	2.6(15)	0.48(0.084)	2.1(12)
	7	0.30 (0.053)	3.3(19)	0.31(0.054)	3.2(19)
Denmark	5a	0.10 (0.018)	1 (57)	0.15 (0.026)	6.7 (38)
Estonia	6a	0.11 (0.02)	9.1 (52)	0.17 (0.03)	5.9 (33)
Germany	5a	0.14 (0.025)	7.1 (40)	0.17 (0.03)	5.9 (33)
Latvia	6a	0.16 (0.029)	6.3 (35)	0.19 (0.033)	5.3 (30)
UK	4a	0.13(0.023)	7.7 (44)	0.22(0.039)	4.5(26)
	5a	0.13(0.023)	7.7 (44)	0.22(0.039)	4.5(26)
USA	1	0.16 (0.029)	6.3 (35)	0.76 (0.133)	1.3 (8)
	2	0.14 (0.025)	7.1 (40)	0.38 (0.067)	2.6. (15)
	3	0.12 (0.022)	8.3 (45)	0.28 (0.050)	3.6 (20)
	4	0.12 (0.022)	8.3 (45)	0.23 (0.040)	4.3 (25)
	5	0.11 (0.020)	9.1 (50)	0.19 (0.033)	5.3. (30)
	6	0.09 (0.0167)	11.1 (60)	0.14 (0.025)	7.1. (40)
	7	0.09 (0.0154)	11.1 (65)	0.11 (0.020)	9.1 (50)
	8	0.08 (0.0133)	12.5 (75)	0.11 (0.020)	9.1 (50)

LCC Optimization Curves



Roof Optimization Curve

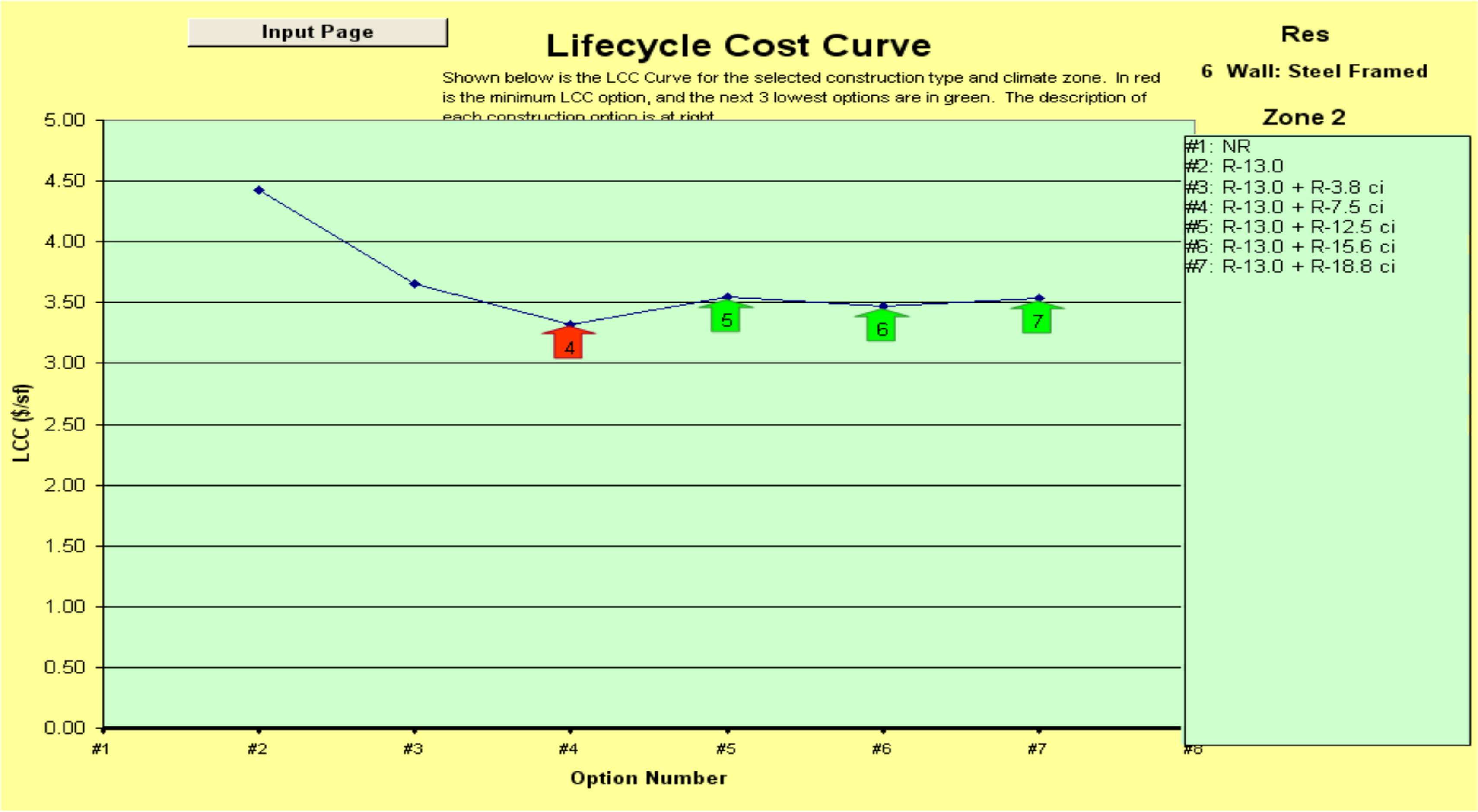
Business as Usual - Roof Insulation



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

Wall Optimization Curve

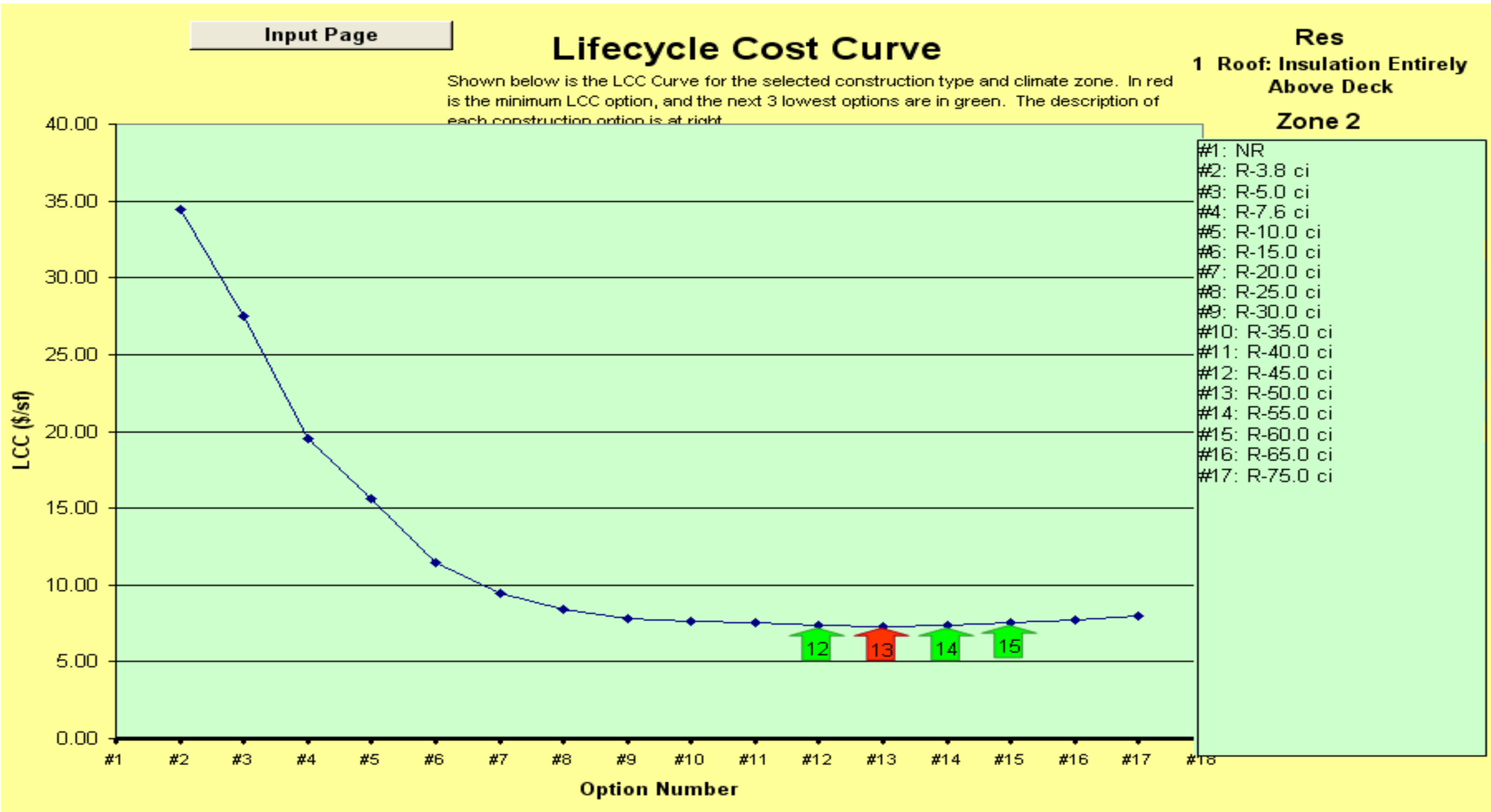
Business As Usual - Wall Insulation



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

Roof Optimization Curve

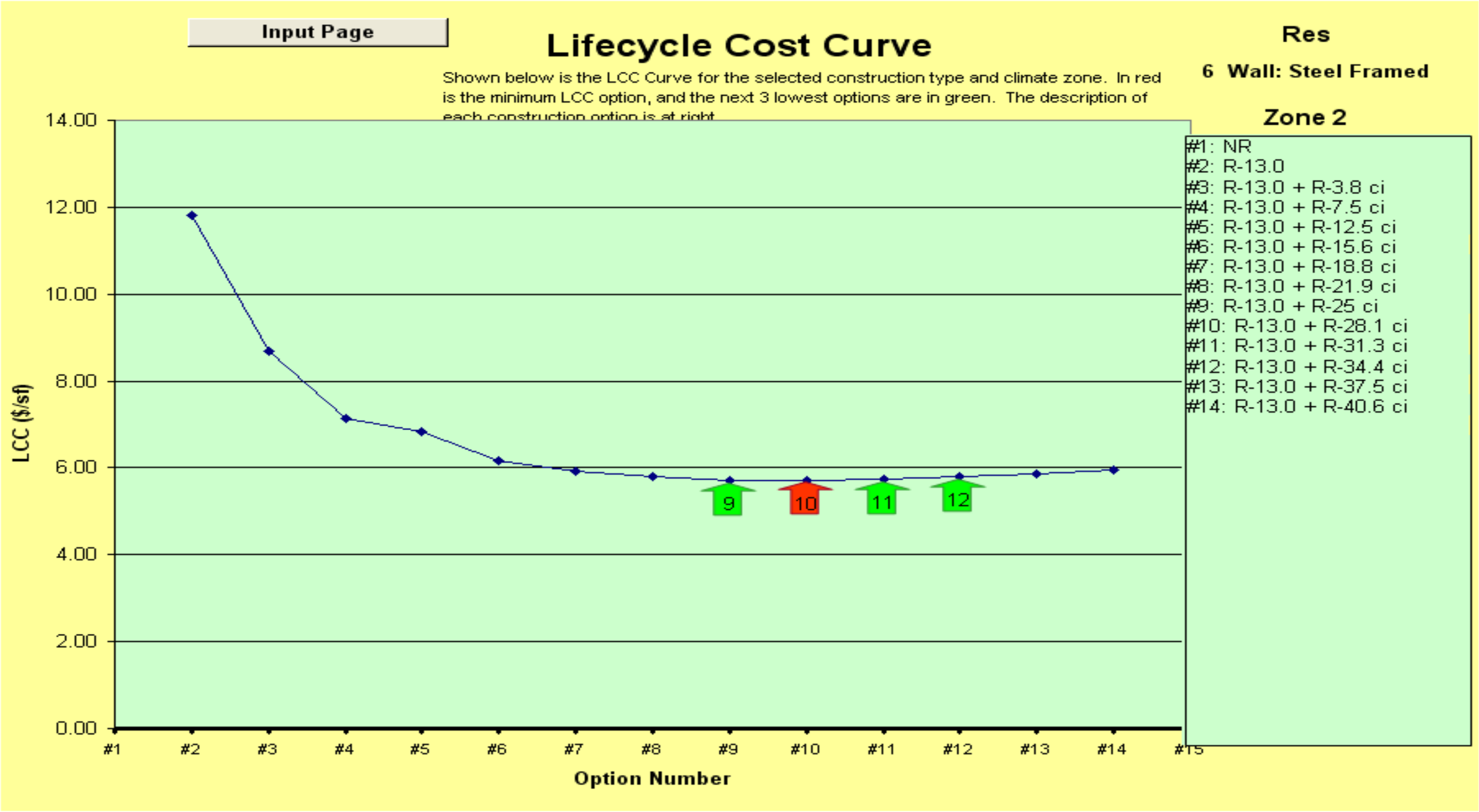
Fuel Prices Doubled - Roof Insulation



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

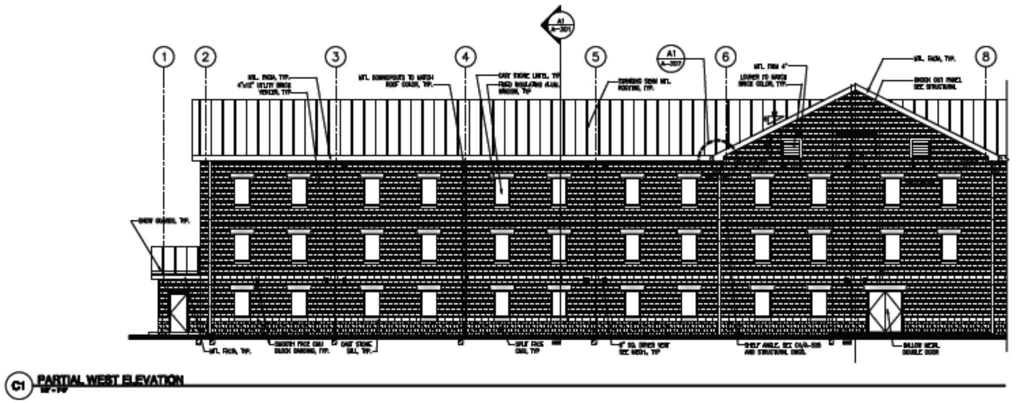
Wall Optimization Curve

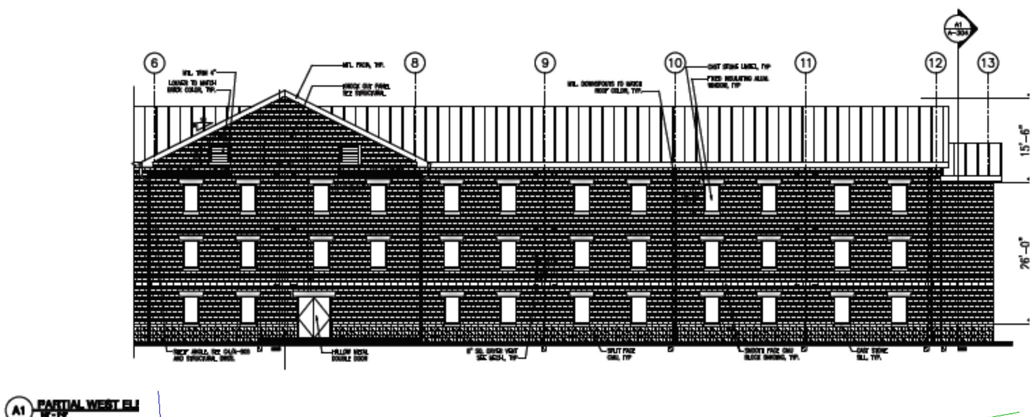
Fuel Prices Doubled - Wall Insulation



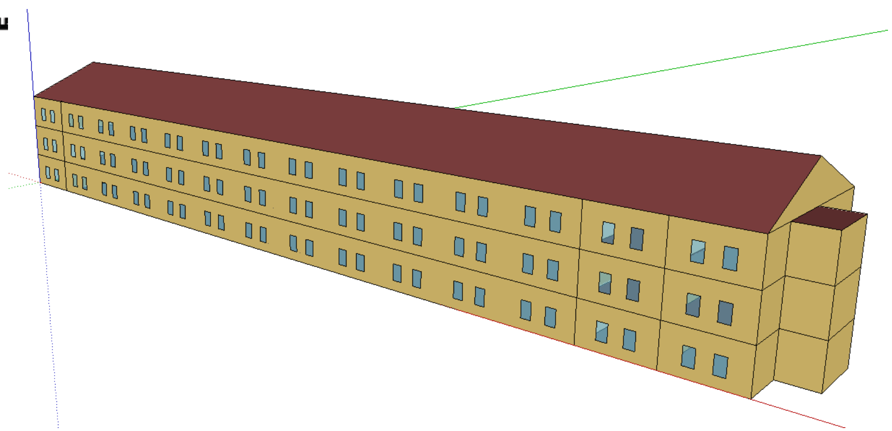
CZ=2 (Houston, TX) Wall Insulation at R_{eff}=33-39

Barracks (UEPH) Prototype Studied





- Barracks project
- Similar to a Dormitory or Apartment Building
- Selected as "representative" by COS – Ft Worth District



EnergyPlus Rendering of model

Energy Conservation Measures Simulated for Barracks

- **Modeled EEM's**
  - Increased insulation levels, advanced windows, increased air tightness – 0.25 cfm/ft2; high traffic entrance vestibule;
  - Improved lighting systems
  - Advanced HVAC systems; Dedicated Outside Air System for ventilation, pressurization and make-up air, with Condenser heat recovery and Energy Recovery Ventilators, occupancy controlled ventilation
  - Advanced to Premium appliances and equipment
  - Separate ventilation for living area and laundry facilities
  - cool roofs in climates 1-5 and window shading
  - Reduced flow fixtures for Domestic Hot Water efficiency

HVAC Options Simulated

- DOAS (Dedicated Outside Air System) with condenser reheat and individual room fan coils for soldier comfort
- Central exhaust which is used for heat recovery to pre-condition the ventilation air, Energy Recovery at 80%.
- High efficiency chiller package
- High efficiency condensing boilers
- High efficiency fans and pumps.
- High efficiency Domestic Hot Water (DHW)

Barracks Energy Results

Climate Zones

3A

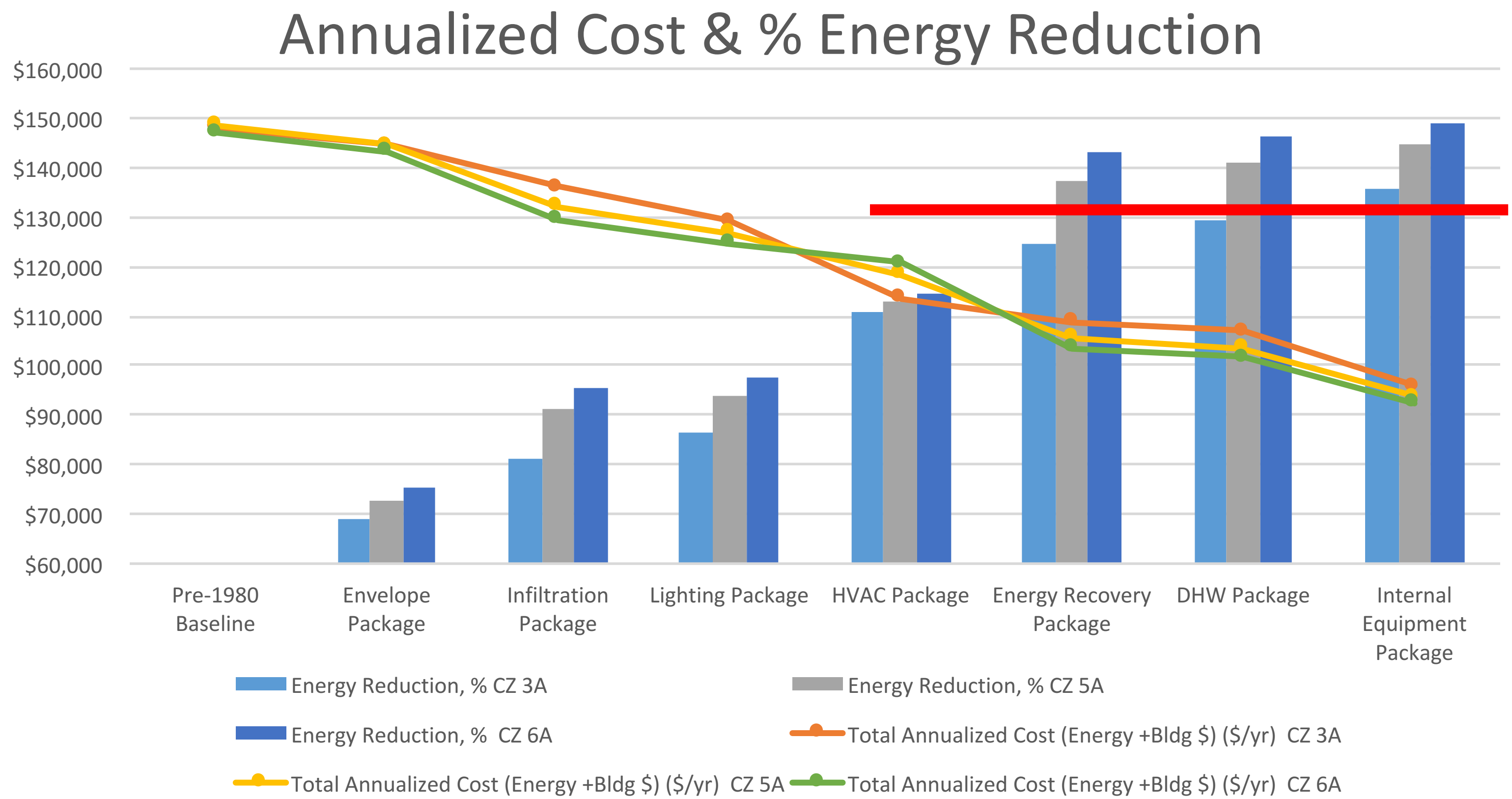
Scenarios	Site Electricity Reduction (%)	Site Gas Reduction (%)	Site Total Intensity(kBtu/ft2)	Site Total Energy (kBtu)	Site Total Energy Reduction (%)	Total Bldg Investment ($)	Total Annualized Cost (Energy +Bldg $) ($/yr)
Baseline	0	0	129	7,061,851	0	0	$ 147,928
ASHRAE 90.1 2010 Base Case	16%	18%	107	5,885,241	17%	0	$ 123,836
Baseline plus 50%	51%	55%	61	3,326,607	53%	$ 999,680	$ 95,998

5A

Scenarios	Site Electricity Reduction (%)	Site Gas Reduction (%)	Site Total Intensity(kBtu/ft2)	Site Total Energy (kBtu)	Site Total Energy Reduction (%)	Total Bldg Investment ($)	Total Annualized Cost (Energy +Bldg $) ($/yr)
Baseline	0	0	162	8,878,804	0	0	$ 148,539
ASHRAE 90.1 2010 Base Case	12%	23%	131	7,193,863	19%	0	$ 124,905
Baseline plus 50%	48%	66%	66	3,615,830	59%	$ 1,054,457	$ 93,863

6A

Scenarios	Site Electricity Reduction (%)	Site Gas Reduction (%)	Site Total Intensity(kBtu/ft2)	Site Total Energy (kBtu)	Site Total Energy Reduction (%)	Total Bldg Investment ($)	Total Annualized Cost (Energy +Bldg $) ($/yr)
Baseline	0	0	179	9,779,338	0	0	$ 147,113
ASHRAE 90.1 2010 Base Case	8%	24%	143	7,858,308	20%	0	$ 124,151
Baseline plus 50%	46%	68%	67	3,685,397	62%	$ 1,136,622	$ 92,376

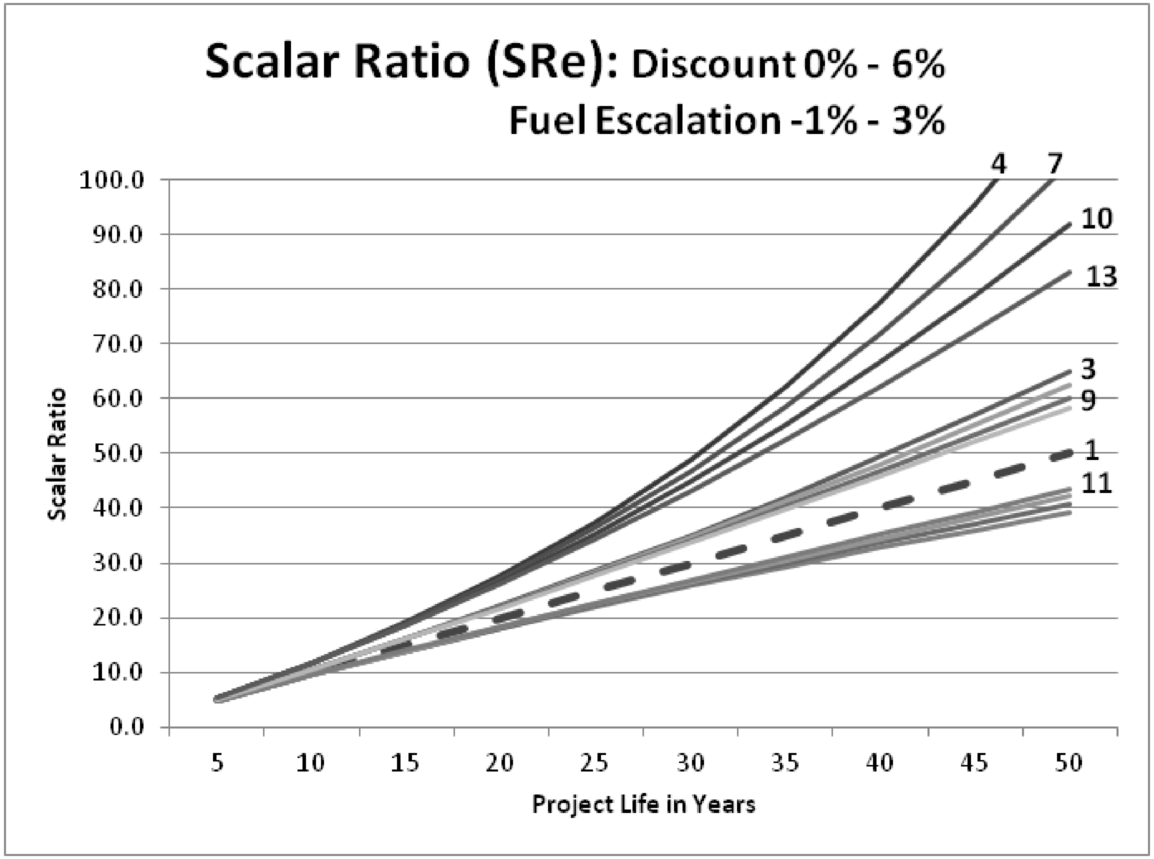


Package	Energy Reduction, % CZ 3A	Total Annualized Cost (Energy +Bldg $) ($/yr) CZ 3A	Energy Reduction, % CZ 5A	Total Annualized Cost (Energy +Bldg $) ($/yr) CZ 5A	Energy Reduction, % CZ 6A	Total Annualized Cost (Energy +Bldg $) ($/yr) CZ 6A
Pre-1980 Baseline	0.0	$ 147,928	0.0	$ 148,540	0.0	$ 147,113
Envelope Package	6.4	$ 144,590	9.0	$ 144,723	10.7	$ 143,379
Infiltration Package	15.0	$ 136,180	22.0	$ 132,222	25.0	$ 129,581
Lighting Package	18.5	$ 129,275	23.7	$ 126,753	26.2	$ 124,649
HVAC Package	35.7	$ 113,676	37.2	$ 118,370	38.0	$ 120,688
Energy Recovery Package	**45.1**	$ 108,954	**54.1**	$ 105,591	**58.1**	$ 103,567
DHW Package	**48.4**	$ 106,995	**56.7**	$ 103,657	**60.4**	$ 101,638
Internal Equipment Package	**52.9**	$ 95,998	**59.3**	$ 93,863	**62.3**	$ 92,376

Scalars and Scalar Ratio (SR)

Single Present Value Factor

Δ Budget $_{max}$ = SR_E [Δ Energy ($)] + S_M [ΔMaint] + S_L [ΔLease Revenue]



- The Scalar = Σ of annual present worth factors over project study life to produce a single present value factor (see McBride 1995 for detailed development). Discount factor is ratioed with the fuel cost scalars to form the SR used in economic analysis.

Scalar Ratio (SR)

Single Present Value Factor

No.*	Economic Life (yrs)		5	10	15	20	25	30	35	40	45	50
	Discount	Escalation										
1	0%	0%	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
2	0%	-1%	4.9	9.5	13.9	18.0	22.0	25.8	29.4	32.8	36.0	39.1
3	0%	1%	5.2	10.6	16.3	22.2	28.5	35.1	42.1	49.4	57.0	65.1
4	0%	3%	5.5	11.8	19.2	27.7	37.6	49.0	62.3	77.7	95.5	116.2
5	2%	-1%	4.9	9.5	13.9	18.1	22.2	26.2	30.0	33.6	37.2	40.7
6	2%	1%	5.1	10.5	16.2	22.1	28.2	34.6	41.2	48.1	55.2	62.5
7	2%	3%	5.5	11.8	18.9	27.1	36.4	46.9	58.7	71.9	86.6	103.0
8	4%	-1%	4.9	9.5	14.0	18.3	22.4	26.5	30.5	34.4	38.3	42.2
9	4%	1%	5.1	10.5	16.1	22.0	28.0	34.1	40.5	46.9	53.5	60.2
10	4%	3%	5.5	11.7	18.7	26.6	35.4	45.0	55.4	66.7	78.9	91.8
11	6%	-1%	4.9	9.5	14.0	18.4	22.6	26.9	31.0	35.2	39.3	43.4
12	6%	1%	5.1	10.5	16.1	21.8	27.7	33.7	39.8	45.9	52.1	58.4
13	6%	3%	5.4	11.6	18.6	26.2	34.4	43.2	52.5	62.3	72.5	83.0

- Focus on SR=15 and the delta energy savings for UEPH analysis.

$$\Delta \text{ Budget}_{max} = SR_E [\Delta \text{ Energy } (\$)]$$

Barracks Energy Results & SR Analysis

Renovation with a 15 Year Budget

Scenarios	Site Total Intensity (kBtu/ ft2)	Site Total Energy (kBtu)	Site Total Energy Reduction (%)	Total Bldg Delta Investment ($)	Total Utility Cost ($/yr)	Total Savings Budget 15 Yrs ($)	SR=12	SR=14	SR=18
Baseline CZ 3A	129	7,061,851	0	0	$147,928	-	-	-	-
Baseline plus 50% CZ 3A	61	3,326,607	53%	$ 999,680	$ 71,006	1,153,830	923,064	1,076,908	1,384,596
Baseline CZ 5A	162	8,878,804	0	0	$148,539	-	-	-	-
Baseline plus 50% CZ 5A	66	3,615,830	59%	$1,054,457	$ 67,501	1,215,570	972,456	1,134,532	1,458,684
Baseline CZ 6A	179	9,779,338	0	0	$147,113	-	-	-	-
Baseline plus 50% CZ 6A	67	3,685,397	62%	$1,136,622	$ 63,960	1,247,295	997,836	1,164,142	1,496,754

Conclusions

- Scalar Ratio:
  - allows for a quick economic calculation once the analysis is complete
  - makes it easier to calculate and monitor the economic calculations
  - allows for quick comparison of a region or country for economic stringency, i.e., US value compared to a European value

- Without Scalar Ratio:
  - need to evaluate a table of individual economic parameters to determine stringency