July 19, 2014

Economic Analysis TAG

Re: Energy Code change proposals 15-E029 and 15-E036

Summary

- The cost and modeling information included in the proposal 15-E029 is taken from work I have done as part of regional energy code energy savings evaluation work for Bonneville Power Administration (BPA) and Northwest Energy Efficiency Alliance (NEEA).
- The retail prototype was chosen for the proposal savings because more CMU wall is located there than any other type. Warehouse has very little CMU wall (Table 1).
- The warehouse model used in the minority report has 66% of it space conditioned to 45 °F which is representative of semi-heated spaces which are not required to have wall insulation. The remaining warehouse space is heated to 60 °F. This is not representative of a majority of CMU wall.
- New modeling has been completed using new recently developed regional prototypes.
- Base case CMU is critical assumption. New model results using the National Concrete Masonry Association Tek 6-1 B values are presented to Table 3 and results using ASHRAE 90.1 block U-values are presented in Table 4.
- The new results differ from the proposal results but savings are still significant (Tables 3 and 4). NCMA based results show higher savings.
- Using the OFM calculator the new savings and costs from the proposal are found to have positive net present savings (Table 5).

Detail

The cost and modeling information included in the proposal 15-E029 is taken from work I have done. The cost data were developed as part of a study for the Bonneville Power Administration of savings and costs of "future codes" in the Northwest (Kennedy, 2012). As part of that work a cost estimator was hired to develop cost data for various wall configurations.

The savings data are taken from model runs completed several years ago during a previous code cycle for discussions of this same issue. The simulation model used was DOE2.1E and the building model was the small retail prototype from a suite of regional prototypes that were developed to estimate northwest energy code energy savings for the Northwest Energy Efficiency Alliance. The baseline CMU performance was taken from the National Concrete Manufacturers Association (NCMA) Tek 6-2B assuming a 110lb CMU block (interpolating between 105 and 115) with 50% of the cores grouted.

The prototype models used were derived from old BPA prototypes with envelope, lighting and equipment efficiencies updated to average regional values based upon the NEEA 2005 New Commercial Construction Survey (NEEA NC) (Baylon et al., 2009). The survey collected detailed data on 347 buildings in the northwest that had construction starts between 2002 and 2004 (building completion ~2005).

Several factors have large impacts on model results of any envelope improvement. Heating set point is high on this list as is HVAC system sizing and fan behavior. A semi-heated warehouse will have a very different change in energy use for an envelope change than will a fully heated space. Table 1 shows the distribution of CMU walls in the NEEA NC buildings by building type for Washington (147 buildings) and the NW region as a whole (ID, MT, OR, WA). CMU wall predominantly occurs retail, education, and other heated space types. The regional CMU wall distribution does have a significant portion in warehouses but these are dominated by unheated warehouse where insulation would not be required.

The DOE warehouse reference model, used in the minority report for one of the two reported savings numbers, has 2,550 ft^2 of heated office, 15,000 ft^2 fine storage heated to 60 °F and 34,500 ft^2 of bulk storage heated to 45 °F. Clearly this is not representative of typical CMU walls. The bulk storage area (66% of the total wall area) is semi-heated space where wall insulation would likely not be required. This inflates the cost and dilutes the savings. The 60 °F fine storage would be representative of the some portion of the heated warehouse CMU wall. It is not clear whether the office walls, which are a separately defined type in the model, were also modeled as CMU. Grocery is a bit more representative but in general is a very atypical building type.

New Modeling

For the 2012 code cycle, NEEA adopted new models based upon the PNNL 90.1-2007 evaluation models but utilizing eQUEST as a simulation engine. The PNNL 90.1 prototypes are based upon the DOE Reference prototypes. The WWR, envelope insulation, and lighting power were adjusted for regional data from the NEEA NC and adjusted for the WSEC 2009 code. Using average rather than code maximum results captures more typical behavior. Field studies have consistently found lighting power to be less than code maximum and in general, code maximum lighting power results in less heating hours and decreased savings from what would occur in actual buildings.

For new estimates of CMU wall energy use and insulation savings, the stand-alone retail model was used, specifically, the standalone retail model representing the post-WSEC 2012 case. Modeling was done using the Seattle and Spokane TMY2 weather files. The model assumes gas heating which is the form of heat in more than 95% of retail floor area. The base case is the current WSEC 2012 code requirement for core fill insulation and savings are presented for the proposed WSEC 2015 language.

As a result of the extremely low average-R value of the CMU wall with insulation in the un-grouted cores, energy savings are dramatically impacted the by the assumed CMU performance. The difference between R2.5 and R3 is 17% more heat flow and results in 25%-35% more savings for the measure being evaluated. Table 2 presents the CMU block wall assumptions used in the modeling. The first values are taken from ASHRAE 90.1, Appendix A and generally provide higher estimates of the base case wall performance and therefore represent a conservative calculation of savings. The NCMA Tek6-2B (National Concrete Masonry Association, 2009) CMU values assuming 48% grouted cores result in a core fill wall with 15% higher heat loss.

The chosen grouted core to insulated core ratio is another important variable. The ASHRAE values are based on some unknown factor. The NCMA tables provide fully grouted block and fully insulated block values and suggest using standard parallel path heat loss methods assuming a chosen grout pattern. The typical grouting pattern in the northwest leads to 37.5% of the cores being grouted in a clear field. Overall grouting fraction is higher than the clear field value since extra grouted cores occur for structural reasons for corners, around wall openings, and interior and exterior structure attachment points.

Other points that would diminish performance of the baseline wall and lead to more savings from insulation than estimate here include:

- Oak Ridge National Laboratory research indicating average whole wall performance was 25% below the clear field numbers (Kosny et al. 2001).
- NEEA NC found 73% of CMU walls in the northwest are 8” block, 5% were 10” and 12” block, and 22% are 6” and 4”. The substantial fraction of smaller dimensions means that a substantial fraction of qualifying walls will have reduced base case thermal performance from what is presented here.
- I have used the NCMA suggested method for combining the grouted core and insulated core numbers. Given the high conductance of the block, the zone method would be more appropriate and would result in ~10% lower average performance of the base wall.

The ending wall performance dictated by E029 to be U-0.09 and by E036 to be U-0.078. The u-value of a CMU wall with R13 wood frame, the basis of one of the costing numbers, varies from U-0.082 to U-0.085 depending upon whether 105lb or 115lb blocks are used and whether ASHRAE or NCMA block u-values are used. This assumes standard 23% framing factors, advanced framing (18% frame) will result in u-values from U-0.078 to U0.081. The modeled ending performance of U0.088 underestimates savings from the frame wall that is costed as part of E029. It is understood that there are several possible insulation strategies and that other strategies meeting code but not achieving the same performance as the frame wall will be used.

For E036 the costed wall falls slightly short of the required performance except when using 18% framing and the ASHRAE 90.1 values. To achieve the U0.078 performance more generally some additional change is required. For the walls that can do the cheaper fiberglass blanket the additional cost to get to U0.078 (E036) is trivial. For the walls that require an interior wall board surface there will be a more significant added expense. The cheapest for this particular wall is to use an R15 batt rather than R13 where the incremental cost is \$0.08/ft^2 using current costs and a home improvement store.

Equipment sizing is another significant factor. Any change to the envelope results in a change to the peak heating and cooling and therefore a change in the required equipment size, air handler flow, and fan power. Fan energy savings are a significant contributor to envelope measure savings. It is unclear whether resizing was considered in the minority report but it is considered here.

Fan operation assumptions are also very important to the magnitude of predicted savings. Prior to the WSEC 2012, fans were generally assumed to operate continuously to deliver code mandated ventilation during occupied hours. With the 2012 code, spaces over 10,000 ft^2 served by single zone equipment and any single zone DX equipment 10 tons and larger were required to have fans slow down to 60% power or have half the units turn off. By reducing fan power this change reduces the impact of changes in HVAC size.

The DOAS requirement in the draft WSEC 2015, if adopted, will require the heating and cooling system be separate from the ventilation system and require that the heating and cooling fans cycle off when heating and cooling are not required. This reduction in fan run time means the impact of changes in fan size will be limited to the heating and cooling cycles rather than all occupied hours.

Simulations have been done assuming continuous fan operation and cycling operation. Current code requirements fall half way in between these two cases and the new code with DOAS provision would be closely represented by the cycling operation case.

The primary assumptions in this work are: 1) blocks are 115 lb., 2) blocks are 8" thick, and 3) thermal performance for CMU blocks is determined from NCMA Tek 6-2B, and separately ASHRAE 90.1, appendix A.

Table 3 presents results separately for fan operating continuous during occupied hours and for fan cycling with heating and cooling. Results are presented for 115 lb. /ft^3 CMU blocks. These results differ from those presented with the proposal. This difference is expected when changing building models with newer characteristics and simulation models. It highlights the fact that results for wall insulation can be impacted by lots of external factors. Table 4 presents the OFM calculator output for Seattle using \$3.02 /ft^2 incremental cost detailed in the proposal and a 25 year measure life. Both wall systems will need to be repainted during their life. Depending upon the situation the frame wall sheet rock will actually need to be replaced. The reduced measure life results in a \$3.02 /ft^2 future cost to refresh the GWB.

One economic issue not addressed in this work is cost savings from reduced HVAC system capacity. Insulation leads to reduced loads. Assuming the number of units does not change and only the capacity is changed, and using a $300/ton incremental cost for capacity change the capital cost of the HVAC equipment would be reduced by $0.10 to $0.20 based upon the analysis here. If the number of units were reduced then cost savings would be on the order of 10 times higher but this would likely be the exception.

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Tables

Table 1. Percent of CMU Wall Area by Building Type

Building Type	WA	All NW
Assembly	5.22	3.20
College	0.00	2.97
Education	15.54	16.80
Grocery	6.66	4.29
Health Services	2.07	1.31
Hospital	1.32	1.12
Institution	2.36	5.59
Office	3.42	2.64
Other	0.00	1.16
Residential/Lodging	7.72	3.84
Restaurant / Bar	0.00	0.29
Retail	52.08	38.12
Warehouse	3.61	2.35
Warehouse-Semi Heated	0.00	0.50
Warehouse-Unheated	0.00	15.82
Total	100.00	100.00

Table 2. CMU Thermal Traits – 8" Block Partially Grouted Cores

Block Type	Source	C-factor (Btu/h·ft²·°F)	Thickness (feet)	Conductivity (Btu/h·ft·°F)	Block Density (lbs. / ft³)	R-value[1]
115 lb. CMU, uninsulated	NCMA Tek 6-2B	1.026	0.667	0.684342	93.67	1.82
115 lb. CMU, un-grouted cores insulated		0.654	0.667	0.436218	93.67	2.38
115 lb. CMU, uninsulated	ASHRAE 90.1, Appendix A	0.82	0.667	0.54694	93.67	2.07
115 lb. CMU, un-grouted cores insulated		0.5	0.667	0.3335	93.67	2.85
105 lb. CMU, uninsulated		0.76	0.667	0.50692	88.41	2.17
105 lb. CMU, un-grouted cores insulated		0.46	0.667	0.30682	88.41	3.02

1 Including air films

2 Assuming 48% of cores are grouted and using NCMA parallel path method of combining solid grouted and insulated core numbers. Using more appropriate zone method would leak to 12% lower R-values.

Table 3. Energy Savings from CMU Wall Insulation, 115 lb. CMU, NCMA Tek 6-2B Values (*all values normalized per ft² of wall area*)

Climate	Fan Mode	Case	HVAC Electric (kWh/ft²)	HVAC Gas (kBtu/ft²)	Cooling Cap (Btu/ft²)	Annual Savings Electricity (kWh/ft²)	Annual Savings Natural Gas (kBtu/ft²)	Annual Savings Energy ($/ft²)
Seattle	Fans Operate During Occupied	grout-perlite	2.47	24.27	13.72	-----	-----	-----
		grout-air-R9int	1.22	7.31	7.84	1.252	16.962	$0.255
	Fans Cycle with Heat/Cool	grout-perlite	1.10	21.90	13.72	-----	-----	-----
		grout-air-R9int	0.78	2.36	7.84	0.319	19.542	$0.203
Spokane	Fans Operate During Occupied	grout-perlite	3.71	32.38	15.68	-----	-----	-----
		grout-air-R9int	1.61	11.18	8.03	2.103	21.200	$0.363
	Fans Cycle with Heat/Cool	grout-perlite	1.65	30.07	15.68	-----	-----	-----
		grout-air-R9int	0.98	4.63	8.03	0.679	25.439	$0.286

Table 4. Energy Savings from CMU Wall Insulation, 115 lb. CMU, ASHRAE Values (*all values normalized per ft² of wall area*)

Climate	Fan Mode	Case	HVAC Electric (kWh/ft²)	HVAC Gas (kBtu/ft²)	Cooling Cap (Btu/ft²)	Annual Savings Electricity (kWh/ft²)	Annual Savings Natural Gas (kBtu/ft²)	Annual Savings Energy ($/ft²)
Seattle	Fans Operate During Occupied	grout-perlite	2.04	21.34	11.17	-----	-----	-----
		grout-air-R9int	1.19	7.36	7.84	0.850	13.97	$0.196
	Fans Cycle with Heat/Cool	grout-perlite	0.97	18.28	11.17	-----	-----	-----
		grout-air-R9int	0.77	2.38	7.84	0.201	15.89	$0.161
Spokane	Fans Operate During Occupied	grout-perlite	3.09	28.87	13.52	-----	-----	-----
		grout-air-R9int	1.59	11.26	7.84	1.506	17.605	$0.282
	Fans Cycle with Heat/Cool	grout-perlite	1.48	25.58	13.52	-----	-----	-----
		grout-air-R9int	0.97	4.69	7.84	0.511	20.893	$0.231

Table 5. OFM Calculator Output for 115lb 8" CMU [1]

			Initial Construction Costs ($)	PV Construction Costs ($)	Baseline PV of Utility Costs ($)	Proposed PV of Utility Costs ($)	Net Present Savings ($)	Baseline PV of Carbon Costs ($)	Proposed PV of Carbon Costs ($)	Total Net Present Savings ($)
NCMA Block										
	Seattle									
		Fans Continuous	$3,020	$4,801	$15,516	$5,840	$4,875	$6,505	$2,491	$8,889
		Fans Cycling	$3,020	$4,801	$11,233	$2,832	$3,600	$4,610	$1,235	$6,974
	Spokane									
		Fans Continuous	$3,020	$4,801	$21,717	$8,305	$8,611	$9,142	$3,524	$14,229
		Fans Cycling	$3,020	$4,801	$15,766	$4,207	$6,758	$6,485	$1,809	$11,434
ASHRAE 90.1 Block										
	Seattle									
		Fans Continuous	$3,020	$4,801	$13,319	$5,786	$2,732	$5,753	$2,465	$5,840
		Fans Cycling	$3,020	$4,801	$9,503	$2,815	$1,887	$3,906	$1,227	$4,565
	Spokane									
		Fans Continuous	$3,020	$4,801	$18,829	$8,287	$5,741	$7,908	$3,514	$10,135
		Fans Cycling	$3,020	$4,801	$13,599	$4,206	$4,592	$5,602	$1,807	$8,840

1 Cost and savings are for 1000 ft^2 of CMU wall moving from vermiculite core fill insulated blocks to uninsulated CMU with interior R9 wall to get an ending u-value of 0.088.

References

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