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The Business Case for Paying the Premium for Above-Code High Efficiency Equipment

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A growing challenge for contractors in today's price-sensitive market is the ability to provide building owners with an estimate of energy cost savings when proposing to replace existing HVAC equipment with new, more energy efficient equipment. This "business case" challenge has become increasingly acute in today's highly competitive environment where building owners demand an economic justification for the premium typically required when installing higher efficiency equipment rather than less expensive, minimally code-compliant equipment. Unfortunately, most local building energy codes today specify minimum equipment energy efficiencies that fail to keep pace with the capability of modern technology.

Traditionally, contractors have not provided estimates of energy cost savings in their equipment replacement proposals to justify the cost premium of higher efficiency equipment. This shortcoming prohibits the building owner from evaluating the cost-benefit of alternative equipment options and typically results in the selection of the lowest-cost equipment that meets local energy code requirements.

Compounding the challenge is the fact that most building owners are unwilling or unable to invest the resources (time and money) to have an energy cost savings assessment conducted. This is particularly challenging in the small-to-medium-sized buildings (SMB) market, i.e., buildings less than 50,000 ft^2 (4645 m^2), which represent most commercial and multifamily buildings.

A real market need exists for contractors who are routinely being asked to replace existing HVAC equipment at or beyond its useful life to have the capability to estimate energy cost savings of replacement equipment at various levels of energy efficiency. A contractor able to provide such cost-benefit comparisons, e.g., high efficiency, above-code versus standard efficiency, minimally code-compliant

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equipment, will have a distinct advantage over those unable or unwilling to provide this level of analysis.

Energy Savings Methodology

While sophisticated methods do exist for estimating energy savings, e.g., building simulation modeling, these methods are relatively complex, require special expertise, necessitate a considerable amount of input data related to the building and its construction and are time consuming and relatively expensive to conduct. As such, a less resource-intensive and less complex approach for use by contractors that could estimate energy savings would be desirable, particularly for the SMB market. One approach involves five steps:

1. Collect and review recent utility bills to determine the building's annual energy consumption and utility rate structure.
2. Use publicly available data to estimate end use energy consumption based on the type of building and adjust the data for specific building location.
3. Determine the energy efficiency metrics of the existing equipment being replaced and the new replacement equipment and identify the building end use(s) that will be impacted.
4. Estimate the percentage of end use energy consumption savings over the existing equipment baseline based upon the energy efficiency metrics of the existing and new replacement equipment.
5. Calculate the energy consumption savings of the impacted end use(s) and convert this to energy cost savings over the estimated life of the replacement equipment.

1. Building Energy Use

Recent utility billing data can be collected for electricity use and, if applicable, for fuel use such as natural gas or fuel oil. To establish a baseline building energy consumption from which energy savings can be estimated, bills should include at least one year's worth of data and be viewed by the building owner as representative, e.g., no major renovations that would impact building energy use, no changes in building operating hours, etc.

2. Estimating Energy Consumption of Building End Uses

The major commercial and multifamily building end uses include space heating, cooling, ventilation, lighting and domestic hot water heating. Baseline end use energy consumption data are publicly available for commercial and multifamily buildings from three publicly available sources: the U.S. Energy Information Administration's Commercial Buildings Energy Consumption Survey (CBECS),[1] the U.S. Energy Information Administration's Residential Energy Consumption Survey (RECS)[2] and the California Commercial End Use Survey (CEUS).[3]

However, using these end use data directly may result in inaccuracies stemming from how these data are presented, i.e., typically representing large geographic regions that can encompass significant variation in weather conditions (which will result in different building energy use profiles). As such, end use data should be adjusted to account for building location and local climate.[4]

End use energy consumption data can be adjusted by making the reasonable assumption that space heating and cooling building end uses will be the principal end uses impacted by weather[5–9] and then adjusting publicly available end use energy consumptions using heating and cooling degree day data. The methodology to accomplish this has been presented previously [4,10] (see also the Example subhead in this column and *Table 2*).

Once the end use energy consumption data have been adjusted for building location and local climate, they should be weather-normalized to better reflect long-term average heating and cooling degree days. This will allow the influence of unusual weather conditions in any one year to be removed, e.g., a warmer than normal winter or a colder than normal summer, resulting in a more technically sound estimate from which future energy consumption savings can be estimated.

3. Equipment Energy Efficiency Metrics

When estimating the energy savings by replacing existing equipment with new, high efficiency equipment, or comparing replacement equipment at different energy efficiency levels, it is essential to have knowledge related to the energy performance of both the existing equipment (baseline) and the replacement equipment, e.g., minimally code-compliant equipment and high efficiency, above-code equipment.

Estimating the energy performance of the existing equipment may require some investigation. Such equipment may, for example, no longer have an observable and readable nameplate tag, or the building

TABLE 1 Typical algorithms to estimate energy consumption savings for select equipment replacement.[4,12]

EQUIPMENT BEING REPLACED	ESTIMATED PERCENTAGE SAVINGS
Air Conditioning	$[1 - (IEER_{Existing}/IEER_{New})] \times 100$
Chiller	$[1 - (IPLV_{New}/IPLV_{Existing})] \times 100$
Boiler/Furnace	$[1 - (\eta_{Existing}/\eta_{New})] \times 100$
Heat Pump (Heating)	$[1 - (COP_{Existing}/COP_{New})] \times 100$
DHW Heating	$[1 - (EF_{Existing}/EF_{New})] \times 100$

IEER = Integrated energy efficiency ratio, Btu cooling output/Watt-hr of electricity input
IPLV = Integrated part load value, kW input/ton output
η = Average fuel utilization efficiency, fraction
COP = Coefficient of performance
EF = Energy factor, fraction
Existing = Existing or baseline equipment
New = New replacement equipment

owner/manager may not have access to the operating manual, original purchase order or proposal or any other supporting documentation that might provide insight into the existing equipment's make and model number. Furthermore, finding specifications, including energy efficiency metrics, for equipment that may be more than a decade(s) old can be challenging.

If research is unable to uncover the existing equipment's energy efficiency, it can be estimated based upon the equipment's age and the local building energy code in effect at that time. However, if the latter is not available or helpful, it would not be unreasonable to assume that the equipment's energy efficiency likely complied with the version of ASHRAE Standard 90.1 in effect at the time the equipment was installed.[11] In addition, the existing equipment's energy efficiency today would not likely be at the same performance level as when the equipment was first installed due to some level of performance degradation. For example, an average annual energy performance degradation of 0.25% to 0.50% per year of operation for reasonably maintained HVAC equipment[4] would not be unusual, but this can be impacted by local conditions and building maintenance practices.

Energy efficiency metrics of new replacement equipment should be readily available from the manufacturer.

4. Estimating the Energy Consumption Savings Percentage

Using energy efficiency metrics of existing and new replacement equipment enables energy consumption savings percentages to be estimated (*Table 1*).[4,12]

5. Calculating Energy Consumption Savings

The energy consumption savings percentage is multiplied by the impacted end use's weather-normalized baseline energy consumption to estimate the energy consumption that might be saved in the first year and therefore the cost savings. The energy cost savings will likely increase each year going forward because energy costs are constantly increasing. Assuming an average annual energy cost escalation of 3%–4% each year over the estimated useful life of the equipment would not be unreasonable. However, evaluating local utility actual past rate escalation experience may provide a better estimate. On the other hand, the energy cost savings would be reduced slightly each year going forward due to performance degradation over the equipment's estimated useful life.

Lifetime energy cost savings of replacement equipment at different energy efficiency levels can then be estimated. Higher efficiency, more expensive equipment operating above-code would likely provide a superior return on investment compared to less expensive, minimally code-compliant equipment. This cost-benefit information can provide building owners with the economic justification to purchase higher efficiency equipment despite potential higher first cost.

When estimating energy cost savings, the utility rate structure for the building is important and should be carefully reviewed. Note that in addition to energy consumption cost savings, there may also be cost savings associated with a reduction in electric demand (this may not be the case when switching from natural gas to electricity for heating). For commercial buildings, it is not unusual to find that the demand charge can equal or exceed the electricity consumption charge.

Fuel Switching

As part of building electrification trend to reduce greenhouse gas emissions, it is not unusual to find a building's gas- or oil-fired heating system and air-conditioning unit(s) being replaced by electric heat pumps. This switch to space heating electrification complicates the energy cost savings analysis because while natural gas use will be eliminated and electricity consumption and demand associated with cooling reduced, now an electricity consumption and demand charge will be associated with space heating electrification. These costs vs the cost of electricity (under the building's utility rate structure) needs to be carefully considered in the economic analysis.

Limitations

The simplified methodology for estimating energy savings presented herein represents a methodology intended for decision support when equipment at or near the end of its useful life is being replaced. It is particularly relevant in the SMB sector where typical project values do not support costly building modeling. It is not intended for use where investment grade precision is required such as in energy savings performance contracts.

The simplified methodology relies on several key assumptions, including:

1. Published CBECS, RECS and CEUS data as adjusted can reasonably be expected to represent baseline distribution of end use energy consumption in the building being analyzed.[1,4]
2. Weather principally impacts the space heating and cooling end use energy consumptions.[5–9]
3. Equipment energy efficiency metrics can be used to approximate energy consumption savings.[4,12]

Example

A 20,000 ft^2 (1858 m^2) office building owner in Detroit desires to replace an existing 1.2 million Btu/h (3.52 kW) gas-fired hot water heating system serving the building. The boiler was installed in 1999 and is approaching the end of its useful life. A contractor proposes replacing the unit with either a code-compliant unit (82% efficiency) at an installed cost of $58,000 or an above-code, high efficiency condensing unit (95% efficiency) at an installed cost of $66,000. The building owner plans to take advantage of an energy efficiency loan for 100% of the total cost at a fixed 7% interest rate over 25 years. Total building energy use in 2025 was 1,626,000 kBtu (1716 GJ) or an energy use intensity (EUI) of 81.3 kBtu/ft^2·yr (923 MJ/m^2·yr). The current natural gas cost for the building is $9.50/MMBtu ($9/GJ). Compare the two options for the building owner.

Baseline heating end use energy consumption first needs to be estimated. This is accomplished using CBECS and heating degree day/cooling degree day (HDD-CDD) data. 2018 CBECS national data (Table E2 in Reference 1) for all office buildings in the U.S. identifies the median EUI as 65.6 kBtu/ft^2·yr (745 MJ/m^2·yr) and space heating end use energy consumption as representing 30.6% of total building energy consumption.[1,4] *Table 2* provides the HDD/CDD data used to adjust the CBECS end-use data for all office buildings in the U.S. to an office building specifically in Detroit.

TABLE 2 HDD and CDD data for baseline end-use adjustment..

	2018 NATIONAL	2018 DETROIT	2025 DETROIT	30-YR AVG. DETROIT
HDD	4,291	6,078	5,933	6,183
CDD	1,579	1,236	955	775

Assuming space heating and cooling end use energy consumptions will be the principal end uses impacted by weather, the 2018 CBECS data for all office buildings in the U.S. can be adjusted to the Detroit location. The adjusted 2018 end use energy consumption data for Detroit can then be updated to 2025 (the baseline year). The 2025 energy consumption data then needs to be readjusted to reflect the actual 2025 whole building energy consumption of 81.3 kBtu/ft^2·yr (923 MJ/m^2·yr). Finally, the 2025 whole building actual EUI and end use energy consumption allocations are then weather-normalized to represent the baseline for energy savings calculations. (The Other category in this example includes the other building end uses assumed not to be impacted by weather, e.g., lighting, office equipment, DHW heating, etc.) The end results are in *Table 3*.

The energy efficiency metrics of the existing equipment and the replacement equipment under code-compliant and above-code high efficiency scenarios are next estimated. Assuming the existing heating system installed in 1999 complied with ASHRAE Standard 90.1-1999, its energy efficiency would have been 80% when installed. However, over the existing equipment's lifetime, it is estimated that performance degradation will have reduced its efficiency to approximately 75%.[4]

The estimated first year energy savings (over the weather-normalized baseline) by replacing the existing boiler with a code-compliant boiler or alternately a high efficiency, above-code (condensing) boiler would be:

Baseline: 33,000 Btu/ft^2 × 20,000 ft^2 = 660 MMBtu/yr

Code-compliant replacement equipment energy savings:

660 MMBtu/yr × [1 – (.75/.82)] = 56.3 MMBtu/yr

Energy cost savings = 56.3 MMBtu/yr × $9.50/MMBtu = $533

High efficiency (above-code) replacement equipment

TABLE 3 Weather-normalized baseline end-use data development using HDD and CDD adjustment.

	CBECS 2018 NATIONAL		CBECS 2018 DETROIT		DETROIT ADJUSTED TO 2025		DETROIT 2025 ADJUSTED TO ACTUAL		WEATHER-NORMALIZED BASELINE DATA	
	EUI	%	EUI	%	EUI	%	%	EUI	EUI	%
Heating	20.1	30.6	28.5	39.1	27.8	39.0	39.0	31.7	33.0	40.3
Cooling	5.1	7.8	4.0	5.5	3.1	4.3	4.3	3.5	2.8	3.4
Other	40.4	61.6	40.4	55.4	40.4	56.7	56.7	46.1	46.1	56.3
Total	65.6	100	72.9	100	71.3	100	100	81.3	81.9	100

energy savings:

660 MMBtu/yr × [1 – (0.75/0.95)] = 139 MMBtu/yr

Energy cost savings = 139 MMBtu/yr × $9.50/MMBtu = $1,321

Assuming a 3% average annual fuel cost escalation rate over the life of the loan, an average annual 0.25% equipment energy performance degradation and a 5% discount rate, the present value of the annual energy savings is $14,633, which will more than offset the above-code, high efficiency system first-cost premium ($7,000). It should be noted that this analysis does not include any utility rebate that may be available for installation of the high efficiency condensing boiler. This will reduce its up-front cost and make the economics even more attractive. Finally, from a cash flow perspective, the annual energy cost savings above the code-compliant replacement option ($788 in the first year) will more than cover the cash flow difference ($601) in annual loan payments between the code-compliant and the above-code, high efficiency system.

Conclusion

Most owners of commercial and multifamily buildings, particularly in the SMB market, place considerable weight on the up-front investment when making equipment replacement purchasing decisions. However, to make a more informed business decision, knowledge of both capital investment and estimated operating cost over the life of the proposed equipment is essential. While equipment with higher efficiency will typically have a higher up-front cost, this will likely be more than offset by a lower operating cost over the life of the equipment. Furthermore, most utilities provide rebates to incentivize building owners to invest in high efficiency equipment. These rebates strengthen the business case for higher efficiency equipment.

For contractors, having a simplified, less resource-intensive methodology to estimate energy cost savings projected to accrue over the life of their proposed equipment has proven a valuable tool to support the business case to invest in higher efficiency equipment. It also provides the contractor with the cost-benefit information needed to differentiate their proposal (presenting a significant competitive advantage) resulting in sales of higher efficiency, higher margin equipment that produces a greater return on investment for the building owner—an everyone wins outcome.

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