Building Envelope FORUM

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Can you Believe Energy Savings Forecasts

By: Tony Woods

Introduction

"Yes," says TonyWood. "Especially when your project includes an upgrade to the building envelope."

The relationship between high performance building envelopes and improved energy efficiency, especially lower energy operating costs per square foot, has been accepted for some time by most engineers in the building envelope fraternity, but forecasting the energy and cost savings has been at best an inexact science.

Recently, three factors have helped improve forecast accuracy: recognition and acceptance of the step-by-step assessment and calculation procedures being used to predict savings, new understanding of the relationship between performance of the building envelope and performance of the building's mechanical/HVAC systems and proven savings from a growing inventory of documented projects, especially ESCO contracts.

The Building Science Behind the Savings

Before we get into the dollars and cents, we need to take a brief look at the science. Air leakage through the building envelope can lead to unnecessary heat loss in winter or heat gain in summer, condensation and moisture damage in hidden cavities, rain penetration, poor indoor temperature and humidity control, not to mention excessive energy consumption.

Air can leak directly through roofs and exterior walls, but most often it travels through the joints of assemblies such as roof/wall junctions, parapets, low level soffits, the intersections of different cladding systems, and through numerous internal vertical and horizontal pathways.

Two conditions are needed for air to leak. First there must be a hole, gap or crack from one side of the envelope to the other. Second, there must be an air pressure differential, for which there are three causes: wind, stack effect and the HVAC system.

Wind pressurizes the windward side of the building and depressurizes the back, sides and roof. It can account for up to 25 per cent of total leakage; it cannot be controlled, only reduced by plugging the holes in the envelope.

Stack or chimney effect is a buoyancy phenomenon where warm inside air rises through the building and exerts continuous pressure against the roof and upper parts of the exterior walls. The resulting lower pressure at the bottom of the building actually sucks in air.

The third source of pressure differential is the mechanical system itself. Mechanical engineers and on-site managers often choose to bring in makeup air to increase pressure and overcome this infiltration at the base of the building. Unfortunately, this increases pressure at the top, causing greater exfiltration problems in that area. This over-pressurization at the top of the building cannot be controlled at the same time as controlling infiltration at the base of the building. The only solution is to seal air leaks at the top and the bottom of the building. When the building envelope allows air leakage, the mechanical system has to take the brunt.

"If a large amount of the conditioned air is escaping from the building, the heating system is working overtime and energy costs are increased," says Dean Brigham, business development manager for Comstock Canada Ltd., a national design-build construction, multi-trade contracting and facilities management firm. "A building with proper envelope sealing can benefit from a heating system that is 20-30 per cent smaller, and usually less expensive, than one with uncontrolled air leakage. Eliminate the stack and you get a typical four- to five year payback in natural gas savings coming directly out of reduced heating demand, with the option to upgrade the plant with smaller, more efficient capacity which yields annual net savings."

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Assessment and Calculation

Calculating potential energy savings is a 3-stage process: a field survey, estimating air-leakage flow rate and appropriate corrective measures, then calculating potential savings and cost/benefit analysis.

The air leakage assessment method uses simple procedures for evaluating infiltration and exfiltration flows. The airflow through the building envelope depends on the size of air leakage path and the operating pressure differential between the conditioned space and the outdoors. The objective of the field survey is to record the air leakage paths in the building and to define the equivalent total air leakage area. It may include visual observations, in-situ window assembly air leakage tests and blower door tests.

Calculating air leakage flow rates are based on measurement of effective pressure differentials across the building envelope. This is based on the combined effects of the stack, wind and mechanical pressures, hourly weather data for the location (mainly outdoor temperature and wind speed and directions) and the operating schedule of the indoor air distribution system.

The whole building energy simulation uses these air leakage flow rates to calculate the building heat loss/heat gain and to estimate peak demand and energy use. Proposed retrofit air sealing measures are applied to the base model and provide estimated potential reductions in both demand and consumption savings.

The best way to describe this is with a real-life example of a condominium building in Mississauga, Ontario.

Field Survey

Major air leakage paths were discovered in this building at exterior doors, window joints, duct penetrations, interior doors, roof/wall intersections, conduits passing through floors and elevator shafts and vents on the roof.

Air sealing measures that would reduce the heating load and improve occupant comfort included: weather-stripping common area doors (especially smoke shaft, stairwell, exterior and underground doors and those to roof/elevator, garbage and mechanical room), re-weather-stripping windows, sealing and caulking soffit/wall joints, fire cabinets and around windows.

Air Leakage Flow Rates

In Figure 1, we can see that this condominium has an air leakage area of about 5.4185 m2 (58.3 ft2) or about 2.9 cm2/m2 of envelope area – which shows that the building envelope can be described as 'loose' (CMHC Surveys of mid- and high-rise apartment buildings. CMHC, Ottawa) using this classification:

- Tight building – less than 0.7 cm2 /m2 of building envelope area
- Average – 0.7 to 1.6 cm2 /m2 of building envelope area
- Loose – 1.7 to 3.6 cm2 /m2 of building envelope area

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Figure 1

Air-sealing Measures	Number	W/S m	Caulk m	W?S m2/m	Seal m2/m	W/S m2	Seal m2	Total m2	
Doors	Exterior	43	262.13	301.45	0.00045	0.00012	0.1180	0.0362	0.0362
		63	384.05	441.66	0.0003	0.00005	0.1152	0.0221	0.1373
Conduits		11				0.00006		0.0007	0.0007
Windows Awning	W/S		11,333.68	10.003.54	0.0003	0.00009	3.4001	0.9003	4.3004
Walls				10.67	0.00045	0.0003		0.0032	0.0032
Elect Recep	Sealing	68				0.0001		0.0168	0.0168
Shafts Mechanicals	Pipes Elect Service shaft	21 100				0.0008 0.007991		0.0168 0.7992	0.0168 0.7992
							3.633	1.7852	5.4185

The total air leakage area (5.418 m2) was distributed as per the field observations. Major air leakage paths were found at the below grade and the ground floor levels and at the top floor and penthouse level. The estimated monthly average air leakage rate is shown in Figure 2. The heating season is assumed from mid September to end of May. Higher indoor/outdoor temperature differences

Month	Airleakage Rate, m3/s
January	14.58
February	13.85
March	10.20
April	7.29
May	4.37
September	5.83
October	8.75
November	10.20
December	14.14

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Estimates of Energy and Cost Savings

Estimated total cost of air leakage control measures to upgrade this condo was $99,846. Assumptions used to estimate (Determination of Peak Demand and Energy Savings Associated with Air Leakage Measures for High-rise Apartment Buildings, Ontario Hydro, by Scanada Consultants Limited) energy and cost savings included: Air sealing measures would be about 60 per cent effective in curtailing air leakage based on previous field experience;

- Weather data based on 30-year climate normals and monthly average weather data for Mississauga;
- Fuel prices and calculated cost savings using utility data provided for the building;
- Building operating data and schedules as provided by property management;
- Overall building interactive effects (solar and internal gains and other loads) and purchased space heating consumption estimated at about 67 per cent of total heat losses;
- Retrofit measures assumed to reduce overall air leakage by 40 per cent.

Energy analysis also showed that the air sealing measures would reduce the peak space heating demand by about 275 kW (about 940 kBtu/hr) on coldest days during the winter months.

Figure 4 shows the summary of potential energy cost savings associated with air sealing measures. In this building, air-sealing upgrades would reduce the utility bills (mainly natural gas) by $20,580 every year, resulting in a simple payback period of about 4.9 years. The annual space heating cost savings would be about 14 per cent of the total natural gas bill.

	Heating Cost Savings ($)	Installation ($)	Cost Payback Period (Years)
1 peel condominmim	$20,580	$99,846	4.9

This example shows energy cost reduction potential with a generally acceptable return on investment. These cost-effective retrofits, however small in terms of overall energy cost, can result in other significant benefits, such as improved durability of the structure, increased comfort and satisfaction of tenants, elimination of interior condensation, improved quality of the indoor environment and enhanced fire and smoke safety and security.

Building Envelope Upgrades Prove They Reduce HVAC Costs

The Mississauga condo example described shows how controlling air leakage can reduce heating load and therefore energy consumption. Energy service professionals, energy management consulting firms, incentive providing utilities and government departments are using the calculations described in this article to make decisions in favour of envelope upgrades.

Engineers working for these companies know that 'if the envelope is tight and the ventilation right,' heating and cooling systems can be downsized significantly and the control system can do its job more efficiently.

Proof of the connection between a retrofitted building envelope and reduced HVAC operating costs is available from many documented projects. Simple air sealing of roof/wall joints in Toronto single storey schools has delivered 17 per cent average energy cost reductions; perimeter air sealing of highrise apartments in Ottawa and Toronto showed an average of more than 10 per cent in electrical demand and about 9 per cent in consumption.

The Brooke-Claxton 17-storey federal government building in Ottawa was the subject of an air leakage control and boiler retrofit in the early 1990s.

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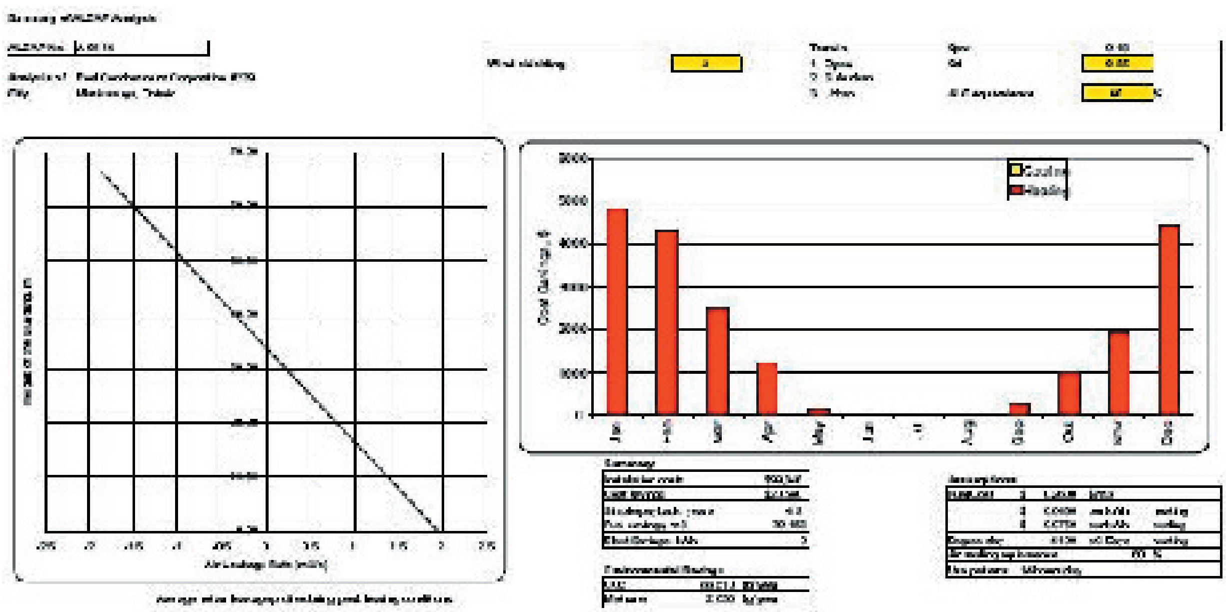
The air sealing measures improved the overall air tightness of the buildings by about 32 per cent. In turn, this reduced the peak heating demand by 12 per cent. The building's five boilers were at the end of their service life and due for replacement. The reduction in peak heating demand enabled the mechanical engineer to specify just four boilers. The capital cost savings were considerable—a 260kW reduction at approximately $100/kW equalling $26,000. Annual energy consumption savings were over $33,000.

Another Ottawa retrofit, a 12-storey apartment building on the Richmond Road, resulted in an even greater reduction in peak heating demand—17 per cent. Again, the plan included comprehensive air sealing, but this time the 4 boilers were repaired, re-tuned and the control strategies adjusted. Make-up air distribution on each floor was rebalanced. The consultants estimated that the reduced long-run cycles for the renovated boilers added at least 10 years to the boilers' service life.



About the author:

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