Savings by Design: Benefits of Live Energy Modelling in Integrated Design Charrettes

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Abstract

Savings by Design is a program delivered by Enbridge and Sustainable Buildings Canada which helps commercial builders design and construct high performance buildings. The program offers expert support and financial incentives during the design, construction and commissioning stages of a project. The program starts with a two hour visioning session which identifies the objectives and performance goals for the project. The visioning session is followed by a full day integrated design charrette. The builder, architect and design engineers are brought together with third-party experts in areas identified as priorities during the visioning session. A key component of the charrette is the use of live energy modelling. An energy model is prepared beforehand and updated live during the charrette in response to suggestions and ideas generated by the participants.

As part of the energy modelling team for the Savings by Design program, we reflect on our experiences with the live energy modelling process. We find that live energy modelling creates a powerful feedback loop that focusses the design team on high impact measures and educates participants on the relative importance of different energy saving strategies. Significant energy saving opportunities were realized in all 19 charrettes carried out to date. We share lessons learned from our participation in the Savings by Design program and offer suggestions to other modellers interested in participating in an integrated design process. We discuss what we see as the strengths and weaknesses of the live energy modelling process and present the results of a post-charrette survey given to program participants.

1 Introduction

Savings by Design is a market transformation program operated by Enbridge Gas Distribution for commercial and residential builders in Ontario. The objective of the Savings by Design program is to have new buildings achieve an energy performance level that is at least 25% better than what is required by the 2012 Ontario Building Code (OBC).

A key advantage of Savings by Design is that the program engages builders in an integrated design process supported by live energy modelling. Over the past year and a half, we have been fortunate to be involved in this process as one of the energy modelling and facilitation teams working with the program. Our experience with the program has taught us that live energy modelling is an excellent tool for driving rapid increases in energy performance within the context of an integrated design charrette. All of the commercial buildings in the program to date have achieved significant improvements in energy performance. We have also found that live energy modelling acts as a powerful educational tool for charrette participants. In their responses to a survey given to participants in the program, personal professional development was cited as a key benefit of the Savings by Design program.

2 The Savings by Design Process

The Savings by Design program starts with a half-day visioning session. Participants in the visioning session usually include the owner or a representative of the owner, program facilitators and a representative from Enbridge. The purpose of the visioning session is identify the project's goals, the design priorities, and opportunities for improvements in environmental performance. After the visioning session, available design information, which can include preliminary floor plans and envelope assemblies, along with mechanical and electrical design briefs, is shared by the owner with the energy modelling team. Two energy models are created from this early design information: the building code model and the proposed design model. The code model is based on Section 11 of ASHRAE 90.1-2010, as modified by the OBC supplementary standard SB-10. The code model has the same building size, shape and orientation as the proposed design. Operating schedules and setpoints are likewise identical. The performance of the envelope, lighting and HVAC systems are defined by the prescriptive requirements of ASHRAE 90.1-2010 as modified by SB-10. In this way, the characteristics of the code model are defined by the prescriptive path of the OBC. The proposed model is based on the proposed design, and components of the proposed design that have yet to be defined are modelled according to the prescriptive requirements of the OBC. The annual energy consumption of each model is calculated over a full weather year. These two energy models form the basis of the integrated design charrette that follows. The integrated design charrette is a full-day session attended by the owner, the design team, third-party experts, an energy modeller, program facilitators, and Enbridge representatives. The charrette is designed to identify and evaluate strategies to meet environmental and energy performance goals. For buildings that achieve a 25% improvement in energy performance beyond the 2012 version of the Ontario Building Code, Savings by Design will provide $0.20 per cubic metre of projected natural gas savings up to a maximum of $50,000. The performance incentive is based on an energy model created after the charrette from the final submitted design. Savings by Design also offers a commissioning incentive amount which is set to 20% of the performance incentive, up to a maximum of $5,000.

3 Modelling Resources

The modelling tool that is used in the design charrette is eQuest v3.64. The eQuest building energy analysis tool is a graphical user interface built on top of the DOE-2.2 simulation engine. eQuest is an industry standard building energy modelling tool that is freely available to the public, widely used throughout the building energy modelling community, and well supported by thorough technical documentation. One of the advantages of eQuest is that it can perform annual energy simulations within seconds, making it an appropriate choice for a live modelling environment which demands immediate results. The Savings By Design program has chosen eQuest as its approved software package for documenting the energy savings upon which financial incentives are based.

eQuest has limitations that must be addressed through external calculations. Notably, eQuest does not address envelope insulation details and instead applies uniform thermal transmittance values to external wall elements. To account for thermal bridging from slab edges, parapets, and other thermal short-circuits, wall U-values are adjusted in accordance with published heat transfer models (see, for example, Morrison Hershfield (2011)) developed to quantify the impact of thermal bridges. Similarly, the thermal characteristics of complex framing and glazing configurations are not easily captured by eQuest. To address this, the fenestration expert attending the charrette often provides U-values for various proposed glazing and framing configurations. The glazing and framing U-values are based on manufacturer's specifications and on FramePlus calculations. These U-values can then be entered into eQuest by finding the best match for the glazing from the DOE2 glass library and by setting the frame conductance and frame width to the appropriate values.

4 The Integrated Design Charrette

Once the energy models have been created, Enbridge hosts a full day integrated design charrette. Participants from the project team can include the owner (or a representative), architects and design engineers, project managers, landscape architects, interior designers, sub-contractors, etc. Enbridge provides facilitators, energy modellers and third-party experts in key areas identified as priorities during the visioning session, such as building science and envelope performance or lighting or mechanical design.

The integrated design charrette starts with an overview of the project, usually given by the owner or by a member of the project team. This overview is followed by a report from the energy modeller on the energy performance of the proposed design. The charrette then splits into two groups which focus on energy performance and sustainability respectively. The sustainability group looks at environmental performance across a range of categories from site selection and stormwater management to indoor environmental quality and water usage. The energy group focusses on changes to the proposed design that would improve the energy performance.

The Energy Charrette

The energy charrette starts after a presentation from the energy modeller. The modeller provides the group with an overview of the energy modelling process and presents the results of the first round of modelling of the proposed design and the code building. In general, as is illustrated in Figure 1 which shows the pre-charrette energy performance for 19 buildings, most buildings entering into the Savings by Design process are not yet at the 25% performance level. The median starting performance over 19 charrettes from 2012 and 2013 was 3.5% better than code, leaving a median performance gap of 21.5%.

The presentation of the results typically includes a discussion of the areas of highest energy use and highest potential impact. The group discussion proceeds from this starting point, as the participants discuss and analyze various ideas. As facilitators, we often start the discussion by looking at elements of the proposed design which drive the loads in the building, such as the wall assembly design, orientation of the building, and window performance, and then move on to those elements of the design which meet the loads, such as the HVAC systems and central plant components. By reducing loads first, the design team can exert more leverage over the energy performance at a lower first cost. HVAC components can often be downsized, helping to offset the costs of improvements in other areas. Whenever the group settles on an idea that they are interested in pursuing, changes are made to the energy model in real time and the impacts of those changes are communicated back to the group as quickly as possible. This live modelling process is a key component of the energy charrette that drives the discussion forward and helps to rapidly focus the group on those measures which can have the greatest impact on energy performance.

Benefits of the Energy Charrette

The design charrette provides a rare and valuable opportunity to bring the project team together with third-party experts and energy modellers. Almost all aspects of the design affect

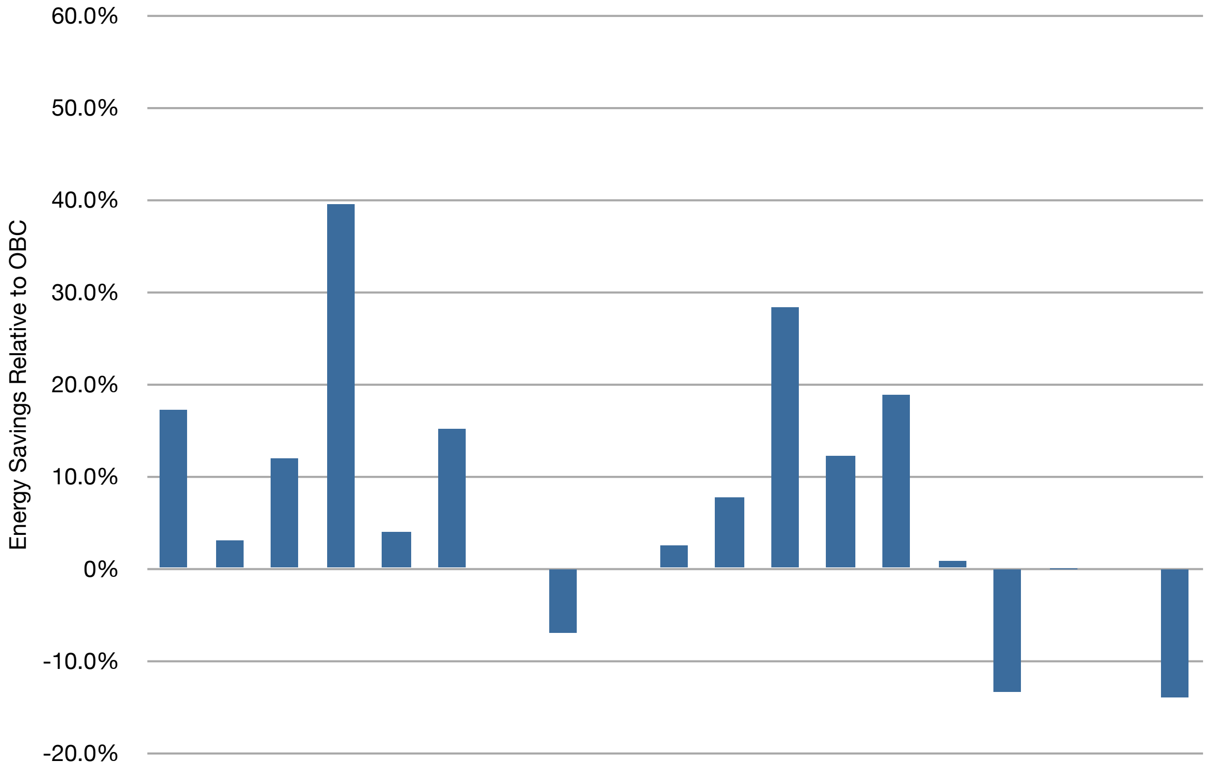

Figure 1: Pre-charrette performance of 19 buildings relative to the 2012 OBC

the energy performance of the proposed model: the building site, the building orientation and size, the envelope design and wall assemblies, window construction and glazing performance, the mechanical design, including the ways in which heating, cooling and ventilation are distributed throughout the building, the electrical design, including the lighting layout and lighting fixture selection, and so on. As is well known and broadly discussed in the green building community, breaking down silos between the different disciplines involved in building design and construction is key to a holistic approach that allows the design team to address environmental performance from a whole building perspective. In an integrated design charrette, each participant brings their unique expertise and perspective to bear on a shared problem. The design team benefits from third-party expertise on key performance issues, and the energy modelling team benefits from immediate feedback on which measures are more and less achievable within the constraints of the project.

We have seen countless examples of the benefits of this dynamic interdisciplinary process. Take, for example, the analysis of solar heat gain in a multi-unit residential building planned for a dense urban site in Ottawa. Because of the constraints of the site, one of the longest faces of the building runs along a pedestrian sidewalk and faces west-north-west. The ground floor spaces at street level are designed for retail and have large windows. In addition, the residential spaces above the ground floor have glass balcony doors and many windows. As a consequence, the wall has an overall window to wall ratio of over 50%. This wall will therefore experience high solar gains in late afternoons and early evenings in the summer and little to no solar gains in the winter. The window expert at the charrette suggested reducing the solar heat gain coefficient in these windows, and energy modelling showed that this reduction could yield a 3% improvement in the whole building energy performance. The mechanical engineer at the meeting picked up on the discussion of this result and suggested reexamining the sizing of the in-suite water source heat pumps specified for the units. He remarked that downsizing of the cooling capacity of the heat pumps in these west-north-west facing units could lead to significant cost savings. In this way, a no-cost improvement in the design led to a reduction in up-front capital costs, while reducing the annual operating costs. The connection between the energy-saving specification of the glazing and the cost-saving specification of the HVAC equipment was facilitated by interpersonal connection: the window expert, the architect, the energy modeller, and the mechanical engineer together were able to make a strong case for a design intervention that led to notably better building performance.

The integrated design charrette allows for informed decision making where the impacts of various proposals on energy, cost, timeline, and constructibility can be considered together. In this way, the design team can seek out and propose interventions which have a significant impact on performance, which are cost effective and achievable, and which are more likely to be adopted.

Energy Performance Results

Each and every one of the nineteen buildings which has gone through a charrette in the Savings by Design process has been able to achieve an energy performance level that is at least 25% better than the 2012 Ontario Building Code requirements. On average, the improvements suggested over the course of the charrette took buildings from a performance level of 7% to a performance level of 35%, an increase in performance of 28%. As is shown in Figure 2, some of the buildings achieved a performance improvement of over 50%. Although the project team is not required to adopt the measures discussed in the charrette or to pursue the incentives offered by Enbridge, the results demonstrate that dramatic improvements in energy performance can be made over the course of a single day in an integrated design charrette. A key element in the success of this process is the use of live energy modelling, which provides the group with immediate feedback on the impact of the design changes suggested around the table during the discussion.

Figure 2: Charrette performance improvement of 19 buildings relative to the 2012 OBC

Benefits of Live Energy Modelling

We have found that live energy modelling in integrated design charrettes acts as a powerful educational and design tool. By showing the relative importance of different interventions for a particular building, energy modelling allows the design team to see which aspects of the design are driving high energy consumption and focusses the discussion on those aspects that have the biggest impact on performance. These results are often counter-intuitive and can be surprising to the participants and to the energy modellers alike. Many of the participants in the Savings by Design charrettes have never had the experience of working closely with an energy modeller. As energy modellers, we have also found the charrettes to be an excellent learning experience. Much of the energy modelling we are asked to do in other contexts is carried out near the end of the design period for compliance purposes when there is little room for changes to the design, and it has been exciting and effective to engage in this early-stage integrated design process. Our participation in these charrettes has given us a better sense of the constraints that developers and design teams are operating under and of the goals that they are working toward. It has been illuminating to participate in discussions on program requirements, envelope construction techniques, availability and pricing of HVAC equipment, and the constraints put in place by property lines and square-footage requirements for residential development. It has been our experience that project teams are open to and welcoming of feedback on their designs and on potential design changes, and are interested in the effects of these design changes on the modelled energy performance.

Challenges and Tips for Practitioners

One of the main challenges in carrying out energy modelling during a charrette is that some modelling changes are time-consuming to make. It can also be difficult to participate in the ongoing lively discussion while simultaneously making changes to the energy model. Some of the more surprising results require double-checking of modelling inputs and often demand thoughtful consideration. It can be difficult to give the energy model the attention it demands in the context of a live discussion where the other participants are looking to the energy modeller for quick results and for clear guidance.

Our experience has taught us that advance preparation is key to a successful charrette. We usually model a number of different potential measures in advance of the charrette so that we can more quickly provide feedback on the effects of these measures during the charrette and offer a clear analysis of the results. It is also helpful to make use of global parameters and the parametrization capabilities in eQuest to quickly tune or change different values, especially those that are entered at the space or zone level. We have used global parameters to define the frame conductance (which is defined for every individual window) to allow for quick changes to the thermal performance of window frames, and the lighting power density to allow for quick changes to the lighting power, for example. It has also been our experience that it is valuable to have a facilitator who can move the discussion along while allowing the energy modeller to stay focussed on modelling.

5 Challenges for the Savings by Design Program

One of the challenges that the program works hard to address is the need to hold the integrated design charrette at an early stage of the design process when there is still sufficient flexibility to make the changes required to achieve the energy performance goal. This challenge is especially acute for multi-unit residential buildings, where sales have often started in advance of the charrette based on floor plans and renderings which do not get turned into an official design for construction purposes until after enough units have sold and financing has been secured. On the flip side, from the perspective of the energy modeller, there are advantages to having the design far enough along to have something to work with in advance of the charrette.

One of the areas in which we have observed the most resistance to change is in envelope design. Many wall assemblies are specified with batt insulation between steel studs, between concrete slabs extending to the exterior face of the wall. Thermal bridging by the steel studs and through the exposed slab edges, especially in walls with a large number of corners as is common in multi-unit residential construction, drops the insulating value of the wall to well below 50% of the rated thermal resistance of the batt insulation. Many building designs favour large window areas, and curtain walls with poor thermal performance are often specified. In urban areas, the site is usually highly constrained by property lines and hydro wire setbacks which specify the shape, size and orientation of the building. In addition, the understandable desire of the developer to maximize square footage puts severe constraints on the thickness of the wall. In this context, interventions in systems and central plant components that do not affect the floor plan or architectural design are often favoured. To address these challenges within the Savings by Design program, third-party experts in envelope design and window manufacturing are often invited to participate in the charrettes. There is much that can be done to tweak or improve a wall assembly and eliminate thermal bridging without changing the thickness of the wall. For example, fibreglass clips can replace continuous metal z-girts in an exterior insulation layer, and thermal breaks in window frames and careful attention to the type and placement of low-emissivity coatings can dramatically improve the performance of windows and curtain wall systems. Often these changes offer the additional benefit of contributing to the durability of the wall assembly by reducing the likelihood of moisture accumulation at cold spots.

There is of course the continuing problem of the separation between up-front capital costs and operating expenses in most projects being built in Ontario today. There is often a reluctance on the part of developers to engage in measures that increase capital costs even if the payback on reduced operating expenses is relatively short. This is also, in large part, the problem that the Savings by Design program is attempting to address. By offering an integrated design charrette which encourages project teams to look for cost-effective energy saving strategies, and by offering financial incentives for projected natural gas savings, Savings by Design can help to overcome some of the financial barriers to better energy performance. It has also been encouraging to see a number of developers pursuing lower operational costs for the marketing benefits that ensue. One condominium developer, for instance, told us that they were advertising lower condo fees, supported in part by lower energy costs, as part of their sales strategy.

Ultimately, it is up to the owner and the project team to decide whether to adopt the strategies put forth in the charrette. As the program goes forward it will be interesting to see if the combination of up-front financial incentives and long term operational cost savings is sufficient to encourage owners and designers to carry through on meeting the program's goal of achieving a level of energy performance that is 25% better than a building built to meet the prescriptive requirements of the 2012 OBC.

6 Post-Charrette Survey

Participants from the project team are surveyed after each charrette in order to gather feedback on the program. The results, shown in Figure 3, have been very positive, with the overwhelming majority of participants indicating that they were "very likely to build on what they had learned," and that they were "very likely to participate in this process again". One of the most encouraging responses is that many participants found the workshop to be extremely beneficial to their personal professional development and to their company's interests.

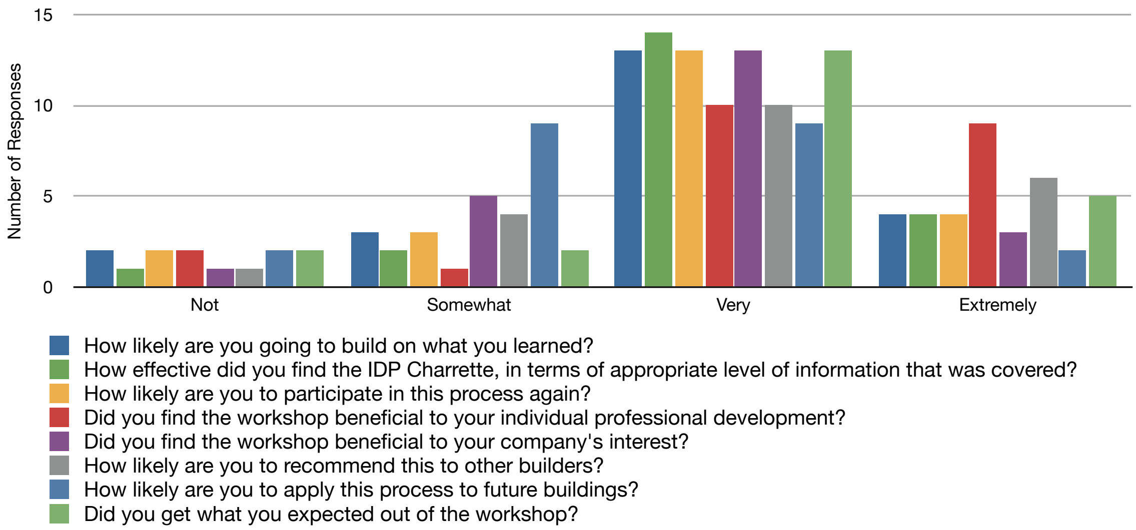

Figure 3: 2013 commercial buildings survey results

7 Conclusions

The nineteen building projects that entered into the Savings by Design program in 2012 and 2013 and participated in the integrated design charrettes started with an average energy performance that was 7% better than that required by the Ontario Building Code. Over the course of one day, in design charrettes guided by live energy modelling and supported by third party expertise, the charrette teams were able to improve the performance of the various building designs to an average level of 35% better than that required by the OBC, representing a performance improvement of 28%. All nineteen of the buildings were able to achieve the energy performance target of 25% better than code, and some of the buildings were able to achieve a performance improvement of over 50%. The results of these charrettes show that the Savings by Design process gives the design team a powerful tool for analyzing and quickly improving the energy performance of their design. By giving participants immediate feedback on the impact of design changes as they are suggested and debated in the charrette, live energy modelling is able to focus the discussion on those measures that improve performance the most. The sharing of knowledge and expertise among a diverse group of experts is key to the success of the process and to the professional growth of all of the involved participants.

8 Acknowledgements

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9 References

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