CHAPTER 8

Business Case for Green Buildings for Owner-Operators

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1 Introduction

The oil embargo of 1973 thrust the burgeoning green building movement into the public spotlight ('White Paper on Sustainability', 2003). At the time, sustainable development focused primarily on energy efficiency ('White Paper on Sustainability', 2003). Starting in the 1980s, the green building movement began to consider a wider range of environmental and social issues (Kibert & Kibert, 2008). However, it is only as of the 1990s that the return on investment of various sustainable building strategies has become more clearly understood ('White Paper on Sustainability', 2003). Although the results can vary significantly from project to project, the underlying trends are undeniable, and as it turns out, the greatest return on investment is not achieved through those measures traditionally believed to be the most profitable.

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2 Understanding the Lifecycle Cost of Ownership

2.1 Lifecycle Cost Defined

To understand the financial benefits of sustainable building practices, one must first understand the lifecycle costs of owning and operating a building. The lifecycle of a project can be broken down into seven stages: project development; planning; implementation; commissioning; operation; modernization and deconstruction (Hugger, Fuchs, Stark & Zeumer, 2007). During the first stage, project development, the business case for the project is defined, including the use, financing mechanisms and targeted service life of the building. This is followed by the planning stage, which starts with the preliminary design of the project, the implementation plan, the final design and ends with the tendering process. The third stage, implementation of the project, consists of the construction process up to the pre-occupation of the building. Commissioning, the fourth stage of the building lifecycle, includes the optimization of the building's systems and the training of building operators. Commissioning closes out the construction process through the verification of the functionality of construction elements such as the building envelope, mechanical systems and electrical systems. Ongoing commissioning, however, would continue until the end of the building's service life. The operation stage follows commissioning and is defined as the period during which the building is occupied and maintained. For owner-occupied buildings, the costs associated with this phase include the wages and salaries of building occupants.

Although the importance of both initial and ongoing commissioning has only recently gained widespread recognition (Barnes, Noerika, Bruceri, Summers, et al., 2012), the first five stages of the lifecycle of a project are for the most part taken into consideration by real estate owners, and their implications are well understood by the market.

Modernization is the penultimate stage of a building's lifecycle wherein it is recognized that the building, or a portion of it, will eventually reach the end of its useful life. This can be driven by numerous factors such as the obsolescence of the building's materials or systems, or changing market desires with respect to building design. Regardless of the driving force behind modernization, it is imperative to consider its implications as early as the development stage. Otherwise, inherent features of the initial design of the building might impose costly and wasteful limitations on any future retrofitting project. By recognizing the inevitability of a future renovation of a building, the initial project should be designed so as to optimize the balance between the first cost of the project, including its environmental impact, and the future financial, operational and environmental impacts of retrofitting the original design. Of course, the same logic would apply to the optimization of the design of the retrofitting project as well. Materials, equipment and assemblies should be chosen in such a way as to minimize the lifecycle impact of their eventual replacement and disposal.

The seventh and final stage of a building's lifecycle is deconstruction. No building will last forever. As such, it remains important at the project development phase to take into consideration the eventual environmental, economic and social impacts of demolishing the building.

Employing a holistic analysis of the cost implications of decisions at each stage of a building's lifecycle, portfolio managers and building owners can more accurately target the most advantageous design, construction, operation and maintenance strategies.

2.2 Impact of Sustainability on the Lifecycle Cost

To maximize the potential return on investment from sustainable building practices in the commercial sector, it is important to consider the lifecycle cost of a commercial building. By the mid-1990s it had already been determined that land acquisition, project design and construction costs represent only approximately 2 percent of the 30-year lifecycle cost of a commercial building, followed by a mere 6 percent for all operating costs, including heating, cooling, maintenance and cleaning services (Romm, 1994). Most surprising, however, was the finding that 92 percent of all the money spent on owning, operating and occupying a building over a 30-year period goes to the salaries of the people working within its walls (Romm, 1994). A 2002 study of state employee-occupied buildings in California (Kats, Alevantis, Berman, Mills, & Perlman, 2003), and a 2015 analysis of business costs for offices in the United Kingdom (Property Data Report, 2016), reaffirmed these ratios of operating costs to building occupant salaries.

The implications of the disproportionate lifecycle cost of building occupants' salaries versus construction, operations and maintenance costs are significant. Whereas traditional sustainable building practices attempted to justify the construction cost premium of going green for owner-operators with the resulting savings from energy and water efficiency (Kats et al., 2003), the true savings were hidden in the productivity of the building occupants. Even with the knowledge that building occupant efficiency represents the largest potential return on investment, construction professionals and developers still gravitate toward the 'hard' savings that can be calculated for every joule of energy and liter of water saved through improvements in building efficiency. When the true lifecycle costs of different sustainable design measures are considered, the scale tips heavily toward the less tangible building occupant productivity gains resulting from the sick day that is not taken (Miller, Pogue, Gough, & Davis, 2009), or the increase in employee focus, creativity and attention (MacNaughton et al., 2017). Leadership in Energy and Environmental Design (LEED) certification for new buildings, for example, has been associated with a 0–3 percent increase in construction cost (Mapp, Nobe, & Dunbar, 2011), a 13 and 16 percent reduction in energy and water use respectively (Kuzimeko, 2014), and a 5.24 percent increase in building occupant productivity (Miller et al., 2009). A 2011 study of 6153 buildings found LEED certification to contribute to a real estate sales premium of as high as 26 percent (Fuerst & McAllister, 2011). When considering these numbers, the decrease in operating costs would be enough to justify the premium paid for a LEED certified construction. Similarly, the increased sales value of the building would also be enough to offset the additional construction costs of a certified project. It is, however, the 5.24 percent increase in employee efficiency, documented by Miller, Pogue, Gough and Davis, which represents the most interesting return on investment for an owner-occupied building. Using Romm's 30-year lifecycle cost of ownership of a building, a 3 percent construction premium resulting in a 5.24 percent increase in employee productivity would represent an 8.035 percent return on investment.

For existing buildings, it is possible to see similar benefits to those of a new construction built to the LEED standard. Simple and cost-effective strategies such as improving the quality of natural and artificial light can produce significant returns on investment. A 2004 comparison of 11 studies by Carnegie-Mellon University attributed a 3.2 percent increase in employee productivity to an improvement in lighting design (Carroll, 2013). Similarly, improvements to indoor air quality can be achieved by increasing ventilation rates and upgrading air filters at little to no cost, while potentially doubling the cognitive performance of building occupants (Allen et al., 2015). In the proceedings of the Fifth International Conference for Enhanced Building Operations, an analysis of four buildings pursuing LEED Existing Buildings Operations and Maintenance certification found that the cost of improving the sustainable performance of the buildings to meet the certification requirements was offset by the resulting operational savings alone in as little as six months (Iczkowski, 2005).

2.3 Financial Tools to Accurately Assess Return on Investment

To properly assess and compare the initial and future cost implications of decisions affecting each phase of a building's lifecycle, it is important to use the appropriate financial formulas. Most financial equations are based on the simple principle that an amount of money available today is worth more than that same amount available tomorrow, also known as the time value of money. How much more that money is worth depends on the discount rate, a percentage value which incorporates interest rates, inflation and uncertainty risk. Two commonly used equations when assessing the value of a design decision in a construction project are the 'Discounted Payback Period' (DPP) and the 'Net-Present Value' (NPV). The DPP is a formula that evaluates the period of time needed for the return on investment to equal the sum of the initial investment, or in other words, the time it would take for a cost-savings measure to pay itself off.

$$DPP = \ln\left(\frac{1}{1-\frac{O_1 \times r}{CF}}\right) \div \ln\left(1+r\right)$$

$$O_1 = \text{Initial Investment}\left(\text{Out flow}\right)$$

$$r = \text{rate}$$

$$CF = \text{Periodic Cash Flow}$$

(Finance Formulas, n.d.-a)

This equation does not account for the lifecycle of the investment and so does not consider the period of time after the breakeven point. Put differently, after the initial investment has paid itself off, its residual annuity is not considered. An acceptable payback period is usually set arbitrarily based on what the market considers acceptable for a given type of investment (Besley & Brigham, 2016). Conversely, NPV is an equation that calculates the present value of an investment based on the return over the lifecycle of that investment.

$$NPV = -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_T}{(1+r)^T}$$

$$-C_0 = \text{Initial Investment}$$
$$C = \text{Cash Flow}$$
$$r = \text{Discount Rate}$$
$$T = \text{Time}$$

(Finance Formulas, n.d.-b)

As such, the NPV of an investment gives a more realistic assessment of the actual value of a design decision.

To better understand the difference between DPP and NPV, take, for example, the choice between two options to replace a building's ventilation unit. Unit A costs $15,000, has annual operating savings of $3000 when compared to the existing unit and has a useful life of ten years. Unit B costs $19,000, has an annual operating savings of $2500 when compared to the existing unit, and has a useful life of 18 years. Assuming the client considers eight years to be the maximum acceptable DPP, which unit would represent the most sound investment? At an annual discount rate of 5 percent, the DPP for Unit A is 5.9 years and for Unit B is 9.8 years. If a building owner were to base their decision on the acceptable market DPP, Unit A would be the obvious choice. However, if the building owner were also to consider the NPV of the savings from Unit A versus Unit B, their decision would not be as clear-cut. Over Unit A's ten-year useful life, its $3000 annual savings would be worth $23,165.20 today. For Unit B, the $2500 annual savings, over its 18-year useful life, would be worth $29,223.97 today. Unit B, however, costs $4000 more than Unit A. Unit A's lifecycle cost, when the NPV of its annual savings is considered, would be $15,000−$23,265.20= −$8265.20 versus Unit B's lifecycle cost of $19,000−$29,223.97= −$10,223.97. As such, when considering the NPV of the savings from each unit, instead of the DPP, Unit B is the clear winner.

As the example above illustrates, the DPP does not present the full picture on which to base an investment strategy. Why should a ventilation unit with an 18-year useful life be required to pay off its additional cost in under 8 years simply because that is what the market deems to be acceptable? When taking a lifecycle approach to investment strategies, the focus shifts from a short-term perspective to a long-term perspective and the door opens to truly sustainable decisions.

3 Challenges Posed by Regional Economics

The prices of utilities vary greatly from region to region and often do not reflect the true cost of their production and distribution (Casten & Meyer, 2004). When pursuing energy and water conservation measures in jurisdictions where prices are low, and therefore direct financial returns are also low, it can be hard to defend any additional investment required based purely on the social and environmental arguments for resource conservation. A more pragmatic approach would be to identify synergies between energy or water efficiency and operating costs or revenues. When a financial argument can be made for measures to improve the efficient use of resources, there is little room for debate as to whether to integrate them into a project's design. The difficulty lies in identifying and quantifying the return on investment of a decrease in water or energy use when it is not directly linked to the cost of the utility itself.

It is important to consider water and energy efficiency not only based on their present-day financial and environmental merits but also on their ability to reduce exposure to the risks associated with climate change. As global weather patterns shift, consistent and relatively inexpensive access to potable water and energy may no longer be commonplace (Finley & Schuchard, 2011). As such, reducing the operational resource requirements of a building may be an effective way of buffering against future resource scarcity.

3.1 Low Energy-Cost Regions

There are numerous regions around the world where the cost of energy remains relatively inexpensive. Montreal, for example, has the lowest cost of electricity of any major North American city at an average residential rate of $0.0722 CAD per kWh (Hydro Quebec, 2016). When compared to New York City (NYC) at an average of $0.295 CAD, or San Francisco at $0.310 CAD (Hydro Quebec, 2016), it is evident that a cost-effective measure to improve energy efficiency in NYC has no guarantee of being profitable in Montreal. In such low energy-cost regions, the argument for energy efficiency may be weak if considering the savings in energy alone. However, as previously presented, measures to improve energy efficiency are often accompanied by other benefits.

When focusing on the quality of the building envelope to reduce heating and cooling requirements, the benefits of improving thermal performance can extend far beyond energy savings. Strategies like airtightness, over-insulation and high-performance windows and doors should outlast the efficiencies of high-performance mechanical equipment simply by virtue of their comparative service lives. The airtightness of a building will also contribute to the longevity of the building's envelope and structure by reducing the accumulation of vapor in the envelope assembly, thereby reducing the risk of mold growth and of the premature decomposition of the building materials (Sandberg, Bankvall, Sikander, Wahlgren, & Larsson, 2007). Additionally, improvements in airtightness can improve indoor air quality by reducing the infiltration of outdoor contaminants such as airborne particulate matter and radon. Airtightness also improves the acoustic performance of the envelope and reduces drafts, contributing to higher levels of occupant comfort (Sandberg et al., 2007). When combining an airtightness strategy with the over-insulation of the building envelope and high-performance windows and doors, the interior surface temperature of the envelope can be maintained within 4 °C of the ambient room temperature and further contribute to occupant comfort by eliminating the sensation of temperature differences within the room, also known as radiative thermal asymmetry (Olesen, Fanger, Jensen, & Nielsen, 1972). The most interesting application of these strategies is to pursue Passivhaus levels of envelope performance where the resulting space conditioning requirements drop to a level for which heating and cooling can be supplied uniquely by conditioning the minimum fresh air requirements of the building. In such a scenario, not only can the space conditioning energy demand of the building drop by upward of 80 percent ('Energy Efficiency of the Passive House Standard', 2015) but the initial construction and ongoing maintenance costs can be significantly reduced by eliminating all of the decentralized heating and cooling systems that would normally be required to guarantee occupant comfort in a traditional building.

In low energy-cost regions it is important to consider both the 'hard' savings calculated from reduced energy demand and the simplification of mechanical systems, as well as the less tangible savings and revenue streams that result from increased occupant comfort, higher rates of employee productivity, better tenant retention rates and reduced risk exposure to the impacts of climate change.

3.2 Low Water-Cost Regions

Many jurisdictions, such as the city of Guadalajara in Mexico, still provide potable water to local businesses and residents at little to no cost ('International Statistics for Water Services', 2016). However, even for buildings in these areas, there is still a business case to be made for water saving measures. It is important to recognize that water conservation can also contribute to energy conservation. In residential projects, domestic hot water can represent an energy demand of 21 kWh per square meter of treated floor area per year (Hastings & Wall, 2007). For projects targeting Passivhaus levels of performance, or in locations having low space heating and cooling requirements, this can represent more than the energy required to heat or cool the building. As such, introducing water saving measures such as low-flow showerheads and faucets can help reduce both water consumption and energy consumption simultaneously. Similarly, by optimizing the size, length and insulation of hot water distribution pipes, standby heat losses through the pipes can be reduced, which in turn would reduce the volume of water wasted while awaiting hot water to reach the point of use.

In commercial and industrial buildings, cooling towers represent the largest source of water consumption (Henderson, 2015). This water requires costly chemical treatment to avoid corrosion, scale formation, fouling and microbial contamination of the cooling tower. Reducing water losses from drift, poorly managed blowdown, basin leaks and overflows ultimately results in a reduction in makeup water and the costs associated with its treatment (U.S. Department of Energy, n.d.). To further reduce the operating costs and water consumption of cooling towers, water can be recycled from sources in the building that require little or no pre-treatment, such as air handler condensate. This strategy is particularly effective given that air handlers usually generate the greatest volume of condensate when cooling tower loads are at their highest (U.S. Department of Energy, n.d.).

Depending on the nature of a given building and its operations, a variety of synergies can be applied to reduce operating costs through water efficiency measures, as illustrated by the domestic hot water and cooling tower examples earlier. To make an effective business case for water efficiency in low water-cost regions, it is important to take a holistic view of the resource consumption by both the building and the activities within it to maximize the return on investment of any measure to improve efficiency.

4 Sustainability for New Versus Existing Building Stock

The most sustainable building is the one that is never built. In Europe, buildings represent 47 percent of greenhouse gas emissions, with just under 11 percent of emissions attributed to their construction (Eurostat, 2016) and the remaining 36 percent to their ongoing operation (Directorate-General for Energy, 2017). New construction methods, materials and equipment, however, can create increasingly efficient buildings. As such, the challenge for developed countries lies in leveraging the embodied energy of existing buildings by improving energy efficiency, water efficiency and indoor environmental quality, to achieve a lifecycle environmental impact inferior to that of constructing new buildings. Although building construction and operation represent 25 percent of total global emissions (Lucon et al., 2014), less than one third of the 2015 Paris Agreement signatories included details of how more ambitious performance targets for the building sector would contribute to meeting their greenhouse gas emission targets (Olear, 2016).

4.1 Implications of Improving Sustainability of Existing Buildings

Working with existing buildings is significantly more complex than building from the ground up. In an existing building, the homogeneity of the composition of the elements making up the structure and building envelope can be difficult to ascertain with 100 percent accuracy. Moreover, the technologies and methods used at the time of original construction can be incompatible with newly developed technologies and strategies that would significantly improve energy performance, or reduce water consumption. It is therefore critical for building professionals to have both a deep understanding of building science and a sound knowledge of common issues arising in high-performance retrofits.

When deciding between renovating a building or replacing it with a new one, owners are often confronted with difficult environmental, economic and social considerations. While conserving the majority of the building elements may prove to be the most environmentally sustainable decision with respect to the embodied energy and resources that went into its construction (National Trust for Historic Preservation, 2011), it may prove uneconomical when considering the long-term maintenance and operation costs of a building well into its service life (Gorse & Highfield, 2009). Conversely, the most economical choice may be to conserve the majority of the building when factoring in both construction and operation costs but prove to be disadvantageous when considering the revenue stream dictated by the market rental rates of a building with an outdated design or infrastructure (Gorse & Highfield, 2009). It is therefore important for building owners to perform a lifecycle analysis to assess both the environmental impacts as well as the lifecycle cost of ownership of retrofitting a building versus constructing a new one.

Depending on the size of the building, its age, structure and the general condition of the building envelope, it may be more cost effective and efficient to do away with the existing building entirely and rebuild from the ground up. This may be attributed to a variety of factors, such as the investment of time and money associated with modeling and understanding the existing building, structural modifications required to meet new design requirements and constant adjustments to the design and timeline to account for surprises discovered during a renovation. However, for taller buildings made of steel or concrete, where the structure represents between 20 percent and 25 percent of the project construction cost ('Cost Challenges of Tall Buildings', 2010), it is often more cost effective to conserve an existing building's structure and to transform it to meet the new project's needs rather than to demolish the building entirely. With the structure representing upwards of 90 percent of the embodied energy of these types of buildings ('Tall Buildings in Numbers', 2009), the benefits of reuse extend beyond the financial advantages. The challenge rests in making the business case to conserve building elements that are either not cost effective to reuse or recycle or that have an impact on the aesthetics of the final project.

Improvements to the thermal performance of an existing building envelope can present a host of issues. For example, when increasing the insulating value of a roof, it is imperative to verify that the roof structure has been adequately sized to bear the full weight of the seasonal snow load. The original structural design may have assumed a constant melting of the snow resulting from heat loss through the roof assembly and may consequently have been undersized. Similarly, improvements to the thermal performance of a load bearing masonry wall may compromise the structural integrity of the wall assembly if the original design depended on the heat lost through the wall to dry the assembly and avoid interstitial condensation.

Similarly, when addressing water efficiency in existing buildings one must consider that the drainage pipes may have been designed for toilet drainage volumes as high as 26 liters per flush (U.S. Environmental Protection Agency, 2015) and can lack the necessary slope to ensure the adequate displacement of sewage when low-flow fixtures at 4.8 liters per flush are installed ('Can Your Plumbing System Handle a Low-Flow Toilet?', n.d.). This can result in recurring blockages and the resulting blame being placed on the functionality of the low-flow toilet as opposed to the drainage system of the building. When replacing traditional urinals with waterless, or ultra-low flow models, care must be taken to ensure that either the maintenance staff has the knowledge and capacity to guarantee the proper ongoing maintenance of the urinals, or that the drainage pipes are regularly flushed out with volumes of water great enough to avoid blockages caused by the crystallization of uric acid or sludge build-up. In a new construction, this would simply involve designing the urinals' drain downstream from a toilet or sink. In a renovation project, however, this might entail completely redoing the drainage lines for the entire washroom.

4.2 Commissioning

Commissioning is the process for achieving, evaluating and documenting that a building's systems and assemblies meet the objectives and criteria of the owner (ASHRAE, 2012). In other words, commissioning ensures that the components of a building are designed, installed, tested and can be operated in such a way as to meet the operational needs of the building occupants. Proper commissioning starts early in the design phase of a new project and should continue at least ten months into the occupancy of the building to ensure that systems continue to operate as designed and benefit from the initial warranty period if ever they do not (U.S. Green Building Council, 2016). Retrocommissioning is a term used for the commissioning of a building that had not previously been commissioned. Recommissioning is the reapplication of the commissioning process to a building previously commissioned and is normally carried out every 3–5 years (United States Environmental Protection Agency, 2008). Conversely, ongoing commissioning refers to real-time, or near real-time, tracking of the performance of building systems. Both recommissioning and ongoing commissioning are ways of ensuring that commissioned building systems continue to operate optimally over their service lives. Regardless of the stage or frequency at which commissioning is performed, it can represent the most cost-effective way to improve energy efficiency (United States Environmental Protection Agency, 2008).

Commissioning of buildings is important because their operational and occupancy patterns change over time and influence the optimal performance parameters of their mechanical, electrical and control systems. Buildings occupied for as little as two or three years can be the best candidates for retrocommissioning ('Retrocommissioning for Better Performance', 2006). A 2004 case study conducted by the Energy Systems Laboratory at Texas A&M University found that the heating and cooling requirements of buildings increased by 12.1 percent over as little as two years due mainly to component failure and control changes (Claridge et al., 2004). Issues related to the functionality of the overall HVAC system are the most common deficiencies, with air handling and distribution being the most prevalent (Mills et al., 2004).

The benefits of commissioning have been well documented and can extend beyond energy savings. Commissioning has been shown to extend equipment life, reduce maintenance costs, improve the thermal comfort of building occupants and enhance indoor air quality (United States Environmental Protection Agency, 2008). A study of 22 buildings, published in 2011 by Michaels Energy, found a 15 percent savings in electricity consumption resulting from retrocommissioning. Similarly, a 2004 study of 150 existing buildings of various usage types found that commissioning led to average energy savings of 18 percent, with a 15 percent median savings and a simple payback period of 0.7 years (Mills et al., 2004). The same study found that energy savings were not strongly correlated with the energy intensity of the building prior to commissioning. This indicates that buildings did not have to be inefficient to show significant improvements following commissioning. The size of the building, however, was shown to be positively correlated with the return on investment of commissioning and although the smaller buildings were able to achieve cost-effective commissioning, it was more challenging (Mills et al., 2004).

4.3 Deep Retrofits

The challenge with improving the sustainability of existing buildings is that improvements in energy consumption and water consumption rarely involve replacing only one component, whereas ongoing maintenance and renovations rarely require working on more than one element of the building at any given time. The service lives of each building components making up an assembly can vary significantly. As such, it can be difficult to take a linear approach to improving the sustainable performance of a building. It is rare, for example, that the exterior siding of a building requires replacing at the same time as the windows. It is therefore important to plan accordingly in order to leverage the end of life of each building component and obtain the most interesting lifecycle return on investment. Furthermore, any work performed on the building should be designed such that the service life of the work be at least equal to that of the entire building, or so that the work be easily replaced. This will facilitate future retrofits, helping reduce both their cost and environmental impact.

Existing building renovation projects do not normally benefit from the budgetary largesse or logistical freedom to vacate a building, strip its envelope and mechanical systems and retrofit from scratch. It can be extremely costly, or impossible, to relocate existing building occupants without disrupting business operations and services. For this reason, deep retrofits may be most pragmatic if performed in planned stages. To minimize the financial and environmental lifecycle impact of the retrofit, the stages should be primarily based on the service life of those building elements targeted for improvement. Each stage should consider the other building components affected by the modification of the building element in question, as well as contribute to the future overall performance of the building above and beyond the improvement of the replaced element itself. A building owner looking to improve the energy efficiency of their property would first assess the remaining service life of the building elements that primarily affect energy consumption, such as windows, opaque envelope assemblies, ventilation systems and lighting. Similarly, a building owner targeting improved water efficiency would assess the remaining service life of building elements such as washroom fixtures and water towers.

For example, take a developer that has just acquired a poorly insulated building in which the windows have reached the end of their service life. The developer would like to take the opportunity to improve the energy efficiency of the building by properly insulating the envelope, but can only access sufficient funding to replace the windows this year, and then insulate the building in two years. Given that the windows are failing, the developer has no choice but to proceed with their replacement and chooses a higher performing model to help reduce thermal losses. To fully benefit from the better performance of the windows and contribute to the future performance of the building, the developer should use the optimal window installation detail based on the future insulated envelope. As a general rule, a window assembly's thermal performance is maximized when the window is centered in the wall assembly's insulating layer (Hines et al., n.d.). As such, if the developer's future plans are to insulate the building from the outside, the windows should be stepped toward the outside of the envelope in an effort to place them closer to the center of the future insulation layer. This strategy might sacrifice the short-term thermal performance of the window installation due to the less than optimal location in the existing wall assembly; however, the long-term performance of the building envelope will be significantly improved once the new insulation is installed.

To facilitate a staged retrofit, Passivhaus, through its EnerPHit certification program, provides an energy-modeling tool to evaluate the performance of the building for each state of its development. Care must be taken to structure the retrofit's interventions in such a way as to ensure the integrity of the building's assemblies and the health of its occupants are not compromised by the staggered nature of the modifications to the building.

4.4 Retrofits and Green Certification Rating Systems

The challenges of working with existing buildings versus designing from scratch are well recognized by the construction industry, and the sustainable certification bodies are no exception. LEED BD + C certification distinguishes between new construction projects and major renovations by setting higher energy performance targets for new builds in both the Minimum Energy Performance prerequisite and the Optimize Energy Performance credit. The Passivhaus certification makes a similar distinction with its EnerPHit certification program for existing buildings. Given the extremely demanding minimum performance criteria for a Passivhaus new build of an energy demand of 15 kWh/m^2 per year, or a 10 W/m^2 energy load, the EnerPHit targets are significantly more forgiving at 25 kWh/m^2 per year for projects in cool temperate climates and 30 kWh/m^2 per year for those in a cold climate. Additionally, EnerPHit offers an alternative compliance path based solely on the prescriptive thermal performance of the windows, ventilation system and opaque assemblies of the building envelope.

The disparity between the energy performance requirements of new construction projects versus major renovations can be mainly attributed to the limitations imposed by both the building envelope, if it is conserved, and the building structure. The orientation, shaping, massing and shading of the building can be the most cost-effective design strategies for optimizing energy performance, and, in a major renovation, are for the most part unchangeable. Moreover, the existing structure often includes major thermal bridges that are nearly impossible or too costly to eliminate, such as cantilevered concrete balconies or the junction between structural concrete columns and their footings. By adjusting the performance requirements of the certification to recognize the limitations of a retrofit project, the green certification programs avoid penalizing owners and developers working with existing buildings. To this, programs like LEED and Building Research Establishment Environmental Assessment Method (BREEAM) also encourage the reuse of buildings by awarding points for projects looking to retrofit historic buildings, refurbish abandoned buildings or to conserve large percentages of an existing building's structure and envelope. Passivhaus takes a slightly different approach by allowing projects to precertify through the EnerPHit program for a multi-phased retrofit with the end goal of achieving the required performance levels. These approaches not only encourage more building owners to pursue a green certification of their buildings, they also promote more sustainable development by rewarding projects in a way that considers their lifecycle impact and cost of ownership, as opposed to only their operational efficiency.

5 Conclusion

The green building movement has come a long way since the 1970s. Over the years, numerous green certification programs have been developed to guide building professionals, owners and developers through the process of constructing sustainably. Additionally, new tools, such as lifecycle analysis, have enabled building professionals to more accurately weigh the environmental, social and economic impacts of various building strategies.

In developed countries, working with existing buildings has become an ever more important strategy to mitigate the effects of the built environment on resource depletion and greenhouse gas emissions. However, strategies to significantly improve the sustainability of existing buildings can be complex, costly and risky if not properly executed. Properly designing and staging deep retrofits can help reduce costs and mitigate exposure to risk. Similarly, cost-effective actions such as commissioning have shown disproportionately large impacts on the functionality, comfort and resource consumption of buildings.

Whether working with existing buildings or designing new ones, the business case for sustainable construction has been strengthened by an increasing pool of research, with the productivity of building occupants now taking center stage. As the market comes to consider the true lifecycle cost of various construction approaches, the once altruistic pursuit of environmentally sustainable building practices is being driven to an ever-greater degree by economic forces.

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