Deeper Thinking: Changing our mindset with building energy audits to look for deeper carbon reduction strategies

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ABSTRACT

For over 30 years, commercial energy audits have been the cornerstone of energy reduction programs for existing buildings. In the last several years, the global importance of climate change has shifted the focus from strictly energy use and cost reduction to carbon reduction. This has resulted in a new approach of exploring and implementing deep carbon retrofits.

This paper will focus on several key areas:

- A comparison of energy audits and deep carbon retrofit studies in the commercial sector
- Sample scope of work for a deep carbon retrofit study
- Objectives and benefits of a deep carbon retrofit to shift the mindset of practitioners and building owners
- The practical challenges of implementing deep carbon retrofits
- The benefits of a low carbon grid in pursuing electrification
- Key factors to achieve results in deep carbon retrofits

Successful case studies of deep carbon retrofits shared in this paper include those from a community center, private office buildings, a laboratory, as well as an advanced education institute. We will discuss how these organizations were able to achieve carbon reductions in the 50-90% range.

Introduction

"The global transition from fossil fuels to renewable and clean energy is gaining momentum, and cities and urban areas are at the forefront of this movement (Simon Fraser University 2020)." Governments, through policies and energy codes, can provide the pathways. As practitioners, engineering and construction professionals have a great responsibility and opportunity to reduce carbon output at a much more aggressive rate than generations past.

According to the Intergovernmental Panel on Climate Change (IPCC), by aiming to limit global warming to 1.5 degree Celsius above pre-industrial levels, we can avoid catastrophic climate change impacts to natural and human systems. Federal and regional governments have adopted specific targets to reduce GHG emissions in accordance with the IPCC. Practitioners and building owners can create a healthier, more sustainable planet by investing in deep carbon retrofits (DCR) to maximize energy efficiency and reduce greenhouse gas and carbon emissions.

This paper provides a detailed comparison between an energy audit and a deep carbon retrofit study (DCRS) and a full scope of what a DCRS entails. The objectives and benefits of shifting to low carbon are also discussed with a focus on the rising trend of "responsible investing." The role stakeholder engagement plays in a retrofit will be included as well as specific suggestions on how this can be done. Unique challenges of DCRs such as disruption to building operations are also shared in this paper. Lastly, we will review several case studies spanning recreation, office building, laboratory and advanced education sectors which have successfully implemented DCRs and achieved carbon reductions in the 50-90% range.

Historically the term deep energy retrofit (DER) has been used to describe a whole-building analysis and retrofit process aiming to reduce on-site energy consumption by at least half. While DERs often focus on larger upgrades that may have an extended return on investment, they typically do not focus on carbon reduction. For this reason, we differentiate between a DER and a DCR based on the increased focus on carbon reduction. By way of example, a DCR may involve switching from fossil fuel to low-carbon electricity for heating. This may not reduce energy but will have a significant carbon reduction.

Under its National Deep Energy Retrofit (NDER) program, the United States General Services Administration (GSA) awarded ten Energy Saving Performance Contracts (ESPC) projects with the objectives of using innovative and renewable energy technologies and moving buildings toward net zero energy consumption (Shonder, 2014).

The results from the projects showed the following:

- The average of 38.2% savings over baseline energy use was more than double the average savings of 19% seen in a group of 80 recently awarded federal ESPC projects.
- The level of energy savings in the NDER projects was unrelated to energy price.
- The level of energy savings proposed for individual projects was unrelated to any of the factors one might expect to drive higher savings, including pre-retrofit EUI, the amount of appropriated funding available as a one-time payment from savings, or the length of the post-acceptance performance period.
- Energy savings in the NDER projects appears to have been achieved through conventional means: by surveying the facilities to determine energy savings opportunities and combining the available opportunities into feasible pay-from-savings projects.
- The level of savings proposed appears to be more a function of the conservation measures available at each location, and the skill of the ESCOs (energy service companies) at identifying them.
- Deeper energy savings do come at a cost, however. The results from the NDER program show that to achieve higher levels of energy savings, ESCOs must invest more per Btu saved.
- The establishment of the Project Management Office (PMO) appears to be another factor in obtaining higher energy savings. By providing a central source of assistance for contracting, technical, and pricing issues, the PMO helped to standardize the ESPC review and award process.

Although the deep energy retrofit focus showed impressive results, the emphasis on energy, and not carbon, is seen in a review of available literature.

The extension applied in this paper is to go beyond energy reductions and include carbon reductions in the mandate for major retrofits moving forward. Instead of looking only at energy use as an approach to reducing climate impact, a DCR takes this one step further by looking at the climate impact of the building more completely.

Similarities and differences - energy audit versus deep carbon retrofit study

Primarily, both a traditional energy audit and a DCRS have the objectives of reducing waste and maximizing energy efficiency through optimizing existing infrastructure, upgrading energy consuming assets and assessing measures that yield an acceptable return on investment. Seeking opportunities to recover waste heat is also a commonality shared by both an energy audit and a DCRS. The findings from both types of studies can include low-cost operations and maintenance opportunities, short and long-term payback energy conservation measures and, where applicable, demand response strategies.

A DCRS extends beyond the traditional energy audit when practitioners and building owners start exploring what more can be done to reduce greenhouse gas emissions, carbon emissions and the impact on our environment. The focus shifts to a longer-term perspective where decision-makers look beyond saving dollars to reducing climate impact of their operations. While an acceptable return on investment for projects identified in an energy audit might be based on positive net present value, an acceptable return on investment for projects identified in a DCRS might be based on a threshold for dollar invested per ton of carbon dioxide saved. This is a key difference in the decision-making process between the two study types.

Further, a DCRS may investigate fuel switching to a lower carbon energy source, not just for economic benefits but for the purpose of reducing carbon emissions as well. Fuel switching to electrical energy is particularly attractive in areas where there is a clean electrical grid or opportunities for clean energy generation on site. This approach can be hard to justify in areas where natural gas is dominant for heating but can be achieved through further innovation. Lastly, a DCRS looks for ways that an organization can build resiliency through generating clean renewable energy on-site to become more self-sufficient.

Table 1 below helps to illustrate some of the key differences between a traditional energy audit, a DER study and a DCRS.

Table 1. Key differences between energy audit, DER study and a DCRS

Characteristic	Energy Audit	Deep Energy Retrofit Study	Deep Carbon Retrofit Study
Measures to minimize waste	x	X	x
Measures to maximize efficiency	x	X	x
No-cost / Low-cost measures	x	Limited focus	Limited focus
Measure investment criteria	ROI / Simple payback	ROI / Life cycle cost	ROI / Life cycle cost & Environmental impact
Investment outlook	Short – Medium	Medium – Long	Long
Climate impact focus	Low	Low	High
Energy resiliency		X	x
Example measures	Controls improvements, Boiler upgrades, Variable Frequency Drives on pumps/fans,	Boiler upgrades, Variable Frequency Drives on pumps/fans,	Fuel switching, Heat pumps, Co-generation,

Characteristic	Energy Audit	Deep Energy Retrofit Study	Deep Carbon Retrofit Study
	Lighting upgrades, Heat recovery	Lighting upgrades, Heat recovery, Envelope upgrades	Heat recovery chillers, Significant Envelope upgrades, On-site generation, Biomass heating

Traditional energy audit – examples and characteristics

An effective approach to identifying energy savings in commercial energy audits is to look for ways to meet the needs at the end-use by reducing waste, reducing losses by improving efficiency, followed finally by optimizing the supply of energy. This approach along with methods, forms and tools, is used in the procedures for Commercial Building Energy Audits from ASHRAE (ASHRAE, 2004).

A waste reduction example is Direct Digital Controls (DDC) optimization where savings can be achieved through optimizing schedules, setpoints and sequences to match the needs of the building users. A further example is adding weather-stripping to reduce heat loss around doors.

Examples of efficiency improvements often identified in an energy audit include lighting (LED) retrofits, conversion of constant volume to variable air volume (VAV) systems, and upgrades of plant equipment such as boilers and chillers to higher efficiency units.

Finally, an energy audit would also explore ways to optimize the supply of energy. For example, using exhaust heat recovery to preheat outside air. A typical desired simple payback period from these improvements would range anywhere between two to eight years.

Deep carbon retrofit study – examples and characteristics

Envelope upgrades in commercial buildings such as high-performance windows, and increased insulation for walls and roof replacements are not typically justified based on energy cost savings for most climates and conditions in a building energy study. However, they can be considered in the context of a DCRS where a longer timeframe is expected. Reducing the heating load by increasing insulation values in roof, wall and window, and reducing heating losses by reducing infiltration will reduce the building's carbon footprint. The investment in building envelope is typically justified when a long-term perspective for ownership is in place, and there are additional drivers such as the desire for improvement in comfort, aesthetics, or reducing maintenance.

A DCRS may include switching to a cleaner source of energy with less carbon intensity, also known as fuel switching. For heating applications in jurisdictions with a low carbon electrical grid, this typically means changing the heating source from fuel (natural gas, oil or propane) to electricity. This includes packaged systems like gas fired rooftop units being replaced with heat pumps, as well as more elaborate HVAC retrofits that can see a replacement of fossil fuel based equipment with air to water heat pumps, ground source heat pumps, or distributed Variable Refrigerant Flow (VRF) fan coil systems. Many larger sites, such as hospitals, with coincident heating and cooling requirements, are using heat recovery chillers (HRC) to provide space or domestic water heating when a cooling load exists.

On site electrical generation for the purpose of self-sufficiency and to achieve net zero energy would also fall in the scope of a DCRS. Building owners see this as a resiliency measure, a "non-energy benefit" that supports the business case. This can be achieved for existing buildings through solar power generation, for example.

Other supply systems that may be evaluated for feasibility within a DCRS would include combined heat and power (CHP), also known as cogeneration, where there is concurrent production of electricity and useful thermal energy from a single source. The principle of cogeneration is that an internal combustion engine simultaneously generates electricity and useful heat.

By way of example, a 10 kW CHP plant (classified as micro combined heat and power or mCHP), would provide approximately 10 kW of electrical output in addition to 16 kW of thermal heat. The overall efficiency of this system is around 85% (30% electricity generation efficiency plus 55% thermal generation efficiency).

A DCRS may also include a review of the site's fuel source. Biomass boilers can be used to replace natural gas boilers to reduce carbon emissions. Furthermore, in some jurisdictions, there are also available options to purchase renewable natural gas (RNG), using captured methane emissions.

RNG is derived from biogas, which is generated from decomposing organic waste from landfills, agricultural waste and wastewater from treatment facilities. The biogas is captured and cleaned to create carbon neutral RNG. The use of RNG helps to reduce GHG emissions by reducing the amount of conventional natural gas needed and by reducing emissions when methane is captured and repurposed as RNG, rather than being released directly into the atmosphere (FortisBC 2020).

Another distinct characteristic of a DCRS is to view the integration of long-term capital upgrades to replace outdated or end-of-life equipment. This provides an opportunity to consider low-carbon strategies as part of the facility's equipment renewal plan. Low-carbon strategies are easier to justify when evaluating the option against the incremental cost over a "like for like" capital replacement.

Sample Scope of Work for Deep Carbon Retrofit Study

The purpose of a DCRS is to identify available technologies, strategies, and investments required to reduce greenhouse gas emissions to meet specific reduction targets.

A DCRS typically requires a significantly greater effort than an ASHRAE Level 2 energy audit. The scope will usually require the inspection of all relevant systems and a detailed analysis that considers all cross dependencies using a holistic approach. This may include components such as the building envelope, HVAC, plumbing, building automation, electrical systems (lighting, plug loads and elevators) and renewable energy systems. A Building Energy Model and calibrated simulation will often be required to indicate that the project consultants have considered the interaction of the building elements and their cross dependencies.

Typically, a DCRS will present the findings in multiple categories or options based on organizational priorities. An example of these options may include:

1. Typical Retrofit – retrofit opportunities for the relevant systems with a positive net present value (ones that would be presented in a typical energy audit scope)
2. Maximum energy/GHG savings – a bundle of measures that will yield the maximum possible savings and surpasses Option 1 requirements that approaches net zero energy and/or net zero carbon (the technically feasible deep carbon retrofit option)

3. Custom and optimized solution – a balanced approach with a positive Net Present Value (NPV) that is a fusion of Option 1 and 2 and provides the best return on investment while meeting the organization's objectives for carbon reduction (the financially feasible deep carbon retrofit option).

As the capital cost of the measures bundle exceeds the typical financial criteria for approving an energy project, one can merge the bundled measures with the facilities capital upgrade plan to prepare evaluations based on incremental cost. For example, the financial analysis may be conducted on NPV utilizing a 25-year expected life with the objective of maximizing the NPV and the GHG reduction considering the additional cost beyond a "like for like" replacement. Many organizations are also developing internal carbon policies to account for the costs of external damage caused by carbon emissions. This sets a price on carbon that is then used in their internal financial analysis and improves the business case for DCRs. Finally, third party financing options can be reviewed to support expenditures for DCRs.

Equally important to the technical analysis is the buy-in and positive participation of the client in the DCRS process. The level of retrofit necessary to achieve a significant reduction in carbon output in an occupied facility is extremely challenging and requires dedication by the owner and continuous communication between the parties. This topic is discussed further in the next section.

Stakeholder Engagement

One way to achieve stakeholder engagement and buy-in is to conduct workshops to review concepts on the feasibility of undertaking DCRs. These sessions will create an opportunity to review the DCRS process with contribution from project management, energy management, operations teams, and the clients' technical and financial staff.

The first workshop, held near the start of the DCRS, would aim to create a common vision for the different teams coming from the different organizations. The workshop objectives may include the following:

1. Understand the project scope of work and goals.
2. Understand each team and its role.
3. Understand the building existing systems and staff priorities for capital replacement and other system improvements.
4. Review potential energy conservation measures.
5. Identify project challenges and solutions for the presented potential measures.

A second workshop following the initial analysis and preparation of measures in draft may be conducted to collectively understand and review the options and results. The workshop objectives may include the following:

1. Introduction to the energy model results
2. Presentation of energy efficiency and carbon reduction measures with elaboration of their pros and cons
3. Present life cycle costing and environmental analysis results
4. Provide an opportunity for stakeholders to discuss the feasibility of the proposed measures and results with the project's team, as well as how the proposed measures align with their priorities for equipment capital replacement and building system improvements
5. Review implications of the measures on tenants, heritage compliance, building codes and other related areas

6. Opportunity to get buy-in and support from skeptical stakeholders by addressing project barriers with all participants.

Mindshift – shifting financial investments to low-carbon

A key objective of a DCRS is to shift the focus of industry practitioners (energy consultants, mechanical and electrical engineers, contractors, commissioning authorities and building owners) from short-term efficiency upgrades to long-term retrofits that reduce climate impact.

Most federal and regional governments across North America have adopted specific targets to reduce GHG emissions, with many targets aligned with the IPCC recommendations. To achieve these targets most jurisdictions have implemented climate action plans. Buildings are a major contributor to GHG emissions and therefore the practitioners working in this sector have a great responsibility and opportunity to dedicate resources for meeting these targets.

A key benefit for building owners to look for deeper carbon reductions is the ability to attract the growing number of socially conscious investors. Environmental, Social and Governance (ESG) criteria have been growing in popularity. This works as a set of standards which investors can use to evaluate and rank their investments (Kell 2018). Within this criteria, environmental criteria consider how a company performs as a steward of nature (Chen 2020). "Responsible Investing" is now taking on greater importance for global investors. Asset managers need to respond with a plan to address the impact their building has on the environment.

BlackRock, the world's largest asset manager, shares that climate change has become the top issue raised by clients. As a response to their investors, fund managers increasingly say they consider ESG issues in their broad investment strategy. The approach maximizes investors' returns as it avoids companies who have not addressed climate change risks and vulnerabilities and therefore are more likely to record big losses (Associated Press, 2020).

"Over time, companies and countries that do not respond to stakeholders and address sustainability risks will encounter growing skepticism from the markets, and in turn, a higher cost of capital," Founder and CEO of BlackRock, Laurence Fink wrote. "Companies and countries that champion transparency and demonstrate their responsiveness to stakeholders, by contrast, will attract investment more effectively, including higher-quality, more patient capital." Applying this philosophy should encourage more investments in low-carbon reduction strategies for building retrofits.

Another example in the shifting mindset around this issue, is that of some municipalities issuing green bonds to provide financing for green building projects that demonstrate carbon reductions. For example, the City of Vancouver issued green bonds in 2018 to finance several new and retrofit low carbon green building projects (City of Vancouver, 2018). The green bonds are an environmental and social investment tool which will support sustainable infrastructure in the city for future generations.

Challenges of implementing deep carbon retrofits

While DCRs are likely to yield greater energy and carbon reductions than an energy audit in commercial buildings, they are also more challenging to implement. Often the types of DCR measures implemented require major renovation, which can be disruptive to building operations, especially when comprehensive HVAC system changes are involved. Tenants may need to temporarily relocate during the implementation phase if the space is being disrupted for an envelope upgrade or comprehensive HVAC retrofit.

Depending on where a building is located and how it is classified, there may be restrictions on how the building exterior can be altered. For example, a structure with a heritage building designation may require a heritage approval before anything can be altered, even if there are inefficient single pane windows in place.

The changes to building systems as part of a DCR will often require additional training for building operators. For example, a heat recovery chiller or CO_2 refrigerant heat pump may be new technology to operators, requiring operations and maintenance practices to be modified. Further, optimized control sequences for new systems need to be well understood by operators through comprehensive training. This will help to ensure measure persistence and avoid new control settings being over-ridden due to a lack of understanding. Once again, involving these operators in the Stakeholder Engagement phase of a DCRS is paramount to the project success.

Another challenge for practitioners working in various jurisdictions is the requirement to understand the carbon content of electricity. In some jurisdictions, electricity in generated from low or non-carbon sources such as hydroelectricity. When one "electrifies", they are reducing indirect carbon emissions knowing that the source of electricity is clean. However, if the source of electricity is from thermal sources, the DCR may look at more distributed generation through on-site generation with solar photovoltaic, fuel cells, cogeneration, or other sources of power. Thus, the decisions around electrification will be impacted by the electrical grid in the jurisdiction of the project or site-specific power purchase agreements.

DCR solutions are often innovative and tend to be more complicated than "like for like" capital replacement projects. These solutions require design consultants with specialized expertise in addition to forward-thinking clients that understand and support the solutions suggested by their consultants. Furthermore, successful commissioning of innovative and complex systems can be challenging. Effective collaboration between designers and building operators is critical. This can be aided with the use of commissioning providers as well as competent building operators with strong building automation skills.

As more DCR projects are completed, their success stories need to be promoted and published to increase the confidence of other building owners and operators to try these solutions.

Successful Case Studies

Municipal Facilities

Kitsilano Community Centre

In 2015, the City of Vancouver (COV) used Prism Engineering Limited (Prism) to conduct energy studies with a focus on recommissioning (RCx) for six of their community centres, COV's top greenhouse gas emitters. COV aspired to improve the existing building systems' performance but their primary motivation was carbon reduction. The RCx study at Kitsilano Community Centre revealed control measures to enhance HVAC efficiency and optimize operation and identified capital upgrades that had potential to reduce over 80% of the site's emissions, which aligned with COV's aggressive emission reduction targets.

Kitsilano Community Centre's HVAC system consisted of a combination of original construction hydronic system, three oversized natural gas boiler systems and supplemental gas-fired air handling units that had been added in previous retrofits. The systems installed during previous retrofits overlapped with the original system, in terms of service area and heating capacity, making the HVAC system oversized and inefficient. With major space heating components and the building automation system past their expected useful life, there was an opportunity to perform a DCR that integrated the whole facility into a single HVAC system, removing unnecessary equipment heating capacity, while taking advantage of the ice rink waste heat. With a strong business case, the City was able to present the project's benefits and get stakeholders' buy-in.

In 2017, Prism prepared a detailed design and specifications to retrofit the HVAC systems in both the rink and the community centre facilities, with an integrated ice plant heat recovery system connected to a central heating plant serving the two buildings. The project was constructed in 2018 and was fully commissioned by October 2018.

To optimize performance, variable flow heat recovery chillers were installed to allow continuous chiller operation at design load as well as partial load.

The new heat recovery system was designed to be the primary heating system for the complex. The existing rink boilers are reconfigured to provide supplementary heat to the source side of the heat recovery system in the event heating load exceeds ice plant heat rejection. In this configuration, the boilers cannot supply heating water to the buildings' heating systems directly, making the heat recovery chillers the primary source of heat. The energy savings will be sustained since the heat pumps cannot be bypassed.

These measures combined have cut GHG emissions by 82% based on actual 2019 weather normalized billing data and nearly eliminated the need for natural gas to heat the facility. The relatively clean electricity grid in BC was a large factor in the significant GHG emission reductions achieved. Figure 1 below shows the significant decrease in GHG emissions from base year 2015 to post-retrofit year 2019.

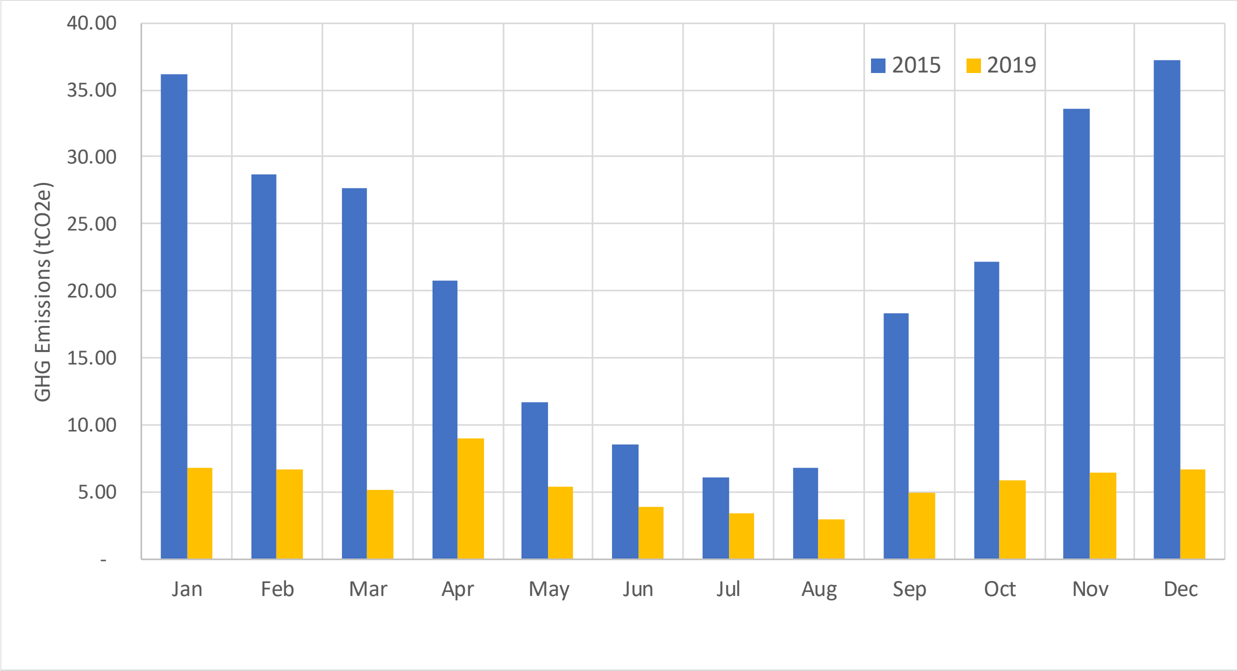

Figure 1: GHG Emissions Reductions at Kitsilano Community Centre

Through the Kitsilano Community Centre project, one key learning was how clear and regular communications and updates helped to build excitement within the City. Prism helped to prepare a case study that shared what was happening and momentum continued to build through implementation and post-implementation as the project savings became visible and measurable.

These lessons can apply to municipal buildings across the country. Jenny Gerbasi, president of the Federation of Canadian Municipalities, reinforces that “Municipalities across Canada are on the frontlines — we find ourselves dealing with increasingly extreme weather from floods to droughts to heavy rains and ice storms, but the truth is municipalities are also at the forefront of climate solutions,” (O’Connor 2018).

“Local governments influence about half of Canada’s greenhouse gas emissions and we’re modelling some of Canada’s most innovative green solutions. Local governments best understand the needs on the ground and the solutions that work. Scaling up these local solutions is vital to Canada to be able to meet its climate goals (O’Connor 2018).”

Office Buildings/Laboratory

Canadian Federal Government Office Buildings - Deep carbon retrofit studies

In 2017, Prism Engineering carried out four Deep Carbon Retrofit Studies (DCRS) for Brookfield Global Integrated Solutions (BGIS) at Federal Government office buildings in the Pacific Region with subconsultant RDH (Building Envelope).

The intent of the DCRS was to provide retrofit options that will achieve greenhouse gas emissions and energy use reductions that are aligned with the government of Canada’s reduction targets. The analysis included preparation of four option packages intended to achieve the following:

- Option A: Energy performance that exceeds The National Energy Code of Canada for Buildings 2011 by 24% and GHG reduction of 40% compared to 2005/2006 baseline.
- Option B: Better performance than Option A, resulting in a positive NPV over 25 years.
- Option C: Carbon reductions achieving near carbon neutrality.
- Option D: Optimized combination between Options B and C that provides the best value.

The recommended retrofit projects were selected to achieve energy and emission targets, taking into consideration that retrofits will be carried out in an occupied building. The measures were confirmed to be technically feasible, resulting in the least disruption possible to tenants. The recommended retrofit options were selected to also align with the building’s five-year capital plan, such that renewal of end-of-life equipment was considered.

This project included recommended demand side measures for the building envelope and environment systems and the use of renewable energy sources. Integration of the measures with the capital budget for building renewal also allowed for improved financial performance resulting in recommending a package of measures with greater reductions in GHG emissions. This process also identified items recommended to be added to the capital budget plan.

The package of measures identified and evaluated to achieve deeps savings included the following measures in Table 2 below.

Table 2. Recommended measures for achieving deep carbon reductions

Category	Measure	Sub-measure
Building Envelope	Add exterior wall insulation	Remove stucco & brick cladding
		Apply membrane to concrete block
		Add insulation with low-conductivity cladding attachment, new cladding
		Add interior wall insulation if heritage
	Add roof insulation	Coordinate with roof renewal needs
	Replace windows with triple glazing in low-conductivity frames	Thermal break required for higher performance
	Comprehensive air barrier detailing as part of enclosure renewals	Full self-adhered membrane over concrete block walls
		Key is detailing at all interfaces – windows, wall to roof, penetrations
Mechanical	Carbon Dioxide DHW Heat Pump heating	
	Boiler Upgrade	Install new condensing boilers
		Redesign heating water system with variable primary flow
	Energy Recovery Ventilation (ERV)	Duct all exhaust to a common duct
		Use of existing duct system to supply at low pressure to all floors
		Use of existing VAV boxes to isolate unoccupied zones
		Oversize fan capacity to allow free cooling
		Install Reverse Flow heat recovery system
	Retrofit existing HVAC system with air source or water source Variable Refrigerant Flow (VRF) fan coil system	
	Install **evacuated tubes** solar panels to generate heat for building heating system	
	Install geo exchange field under outdoor parking lot	
Electrical	Full lighting system upgrade	Replace all linear fluorescent (T8), CFL, and incandescent luminaires with new LED luminaires
		Utilize Low Glare, High CRI, Dimmable LED Luminaires in office areas to ensure occupant comfort
		Utilize bi-level LED luminaires in stairwells that automatically switch between 100% and 50% based on occupancy

		Install solar light tubes in roof of building to provide natural light
	Lighting control system upgrade	Occupancy/vacancy sensors in private office, washrooms, storage rooms
		Personal lighting control over workstation
		Smaller lighting zones in open office area to allow lights to turn off when unoccupied. Utilize occupancy sensors for automatic control
	Elevator modernization	Replace cabs (LED lighting and "Sleep Mode"). Upgrade geared traction system to gearless system, with regenerative technology.
	Solar photovoltaic (PV)	Install PV panels on roof of building

Depending on the site, each building had a package of measures selected. The DCR studies showed the economic and technical feasibility of reducing GHG emissions by over 90% at each of the sites.

Pacific Environmental Science Centre

Environment and Climate Change Canada (ECCC) were in search of solutions that would reduce energy consumption and GHG emissions at the Pacific Environmental Science Centre (PESC) building in North Vancouver, British Columbia, Canada.

PESC houses The Pacific Yukon Laboratory for Environmental Testing and has specialized laboratory facilities providing chemical, biological, toxicological and toxicogenomic analysis in support of many departmental programs at ECCC. The lab equipment required is very energy intensive, specifically the constant air volume fume hoods used to exhaust air while the lab equipment is operating.

A series of projects were undertaken by Prism Engineering to improve energy efficiency and reduce carbon emissions:

- Between 2014 and 2016 two studies were undertaken to investigate various options for upgrading the ventilation system including the fume hoods within the facility, in addition to the natural gas fired heating plant.
- Between 2017 and 2018 a deep carbon retrofit was undertaken, implementing a series of measures that would have a significant impact on GHG emissions at the site. Specifically, these measures included:
  - The replacement of hydronic heating boilers with dual return condensing boilers,
  - Upgrading the domestic hot water heating plant with new condensing water heaters
  - Hydronic system upgrades for optimizing efficiency (with dual return condensing and variable speed pumping)
  - An automated controls strategy: demand-based controls for lab equipment, zone isolation, common spaces return air, unoccupied temperature setback and optimum start.
- In 2019 a second DCR phase was undertaken, this time focusing on the chiller systems at the site. Based on the options identified, ECCC plans to implement an air sourced heat pump system to provide cooling through the summer and operate in heating mode in the

winter. This will further reduce natural gas requirements for the facility, therefore deepening the associated carbon reduction. Detailed design has been completed and the new system is expected to be operational by early 2021.

As can be seen in Figure 2, combined project savings of 33% in natural gas was observed in the 2018/2019 year compared to the baseline, resulting in GHG emission reductions of 32%. A further 13% savings is projected for the 2020/2021 year from the second DCR phase, resulting in an overall projected reduction of 46%. The remaining fuel use is "offset" through the purchase of Renewable Natural Gas from FortisBC.

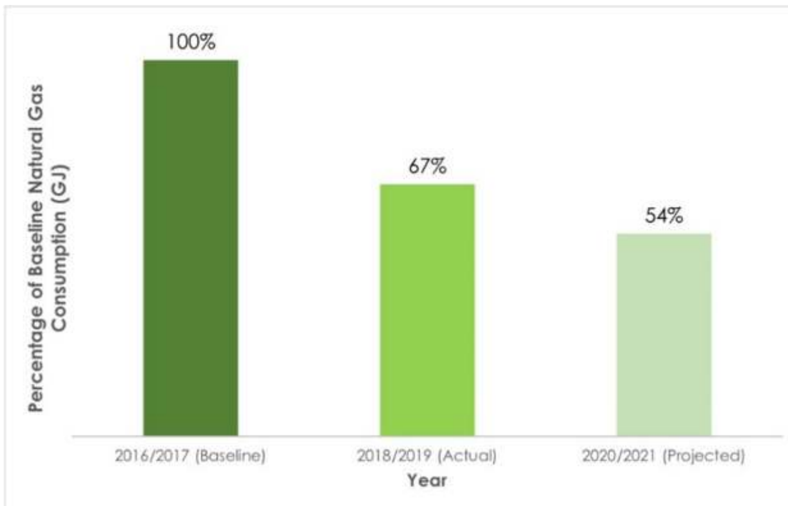

Figure 2: Natural Gas Savings Results at PESC

The carbon reduction observed at PESC is attributed to not just the capital upgrades made to the building but also the control automation strategy that was implemented. Additionally, the positive change in user behavior played a large factor in the savings achieved. The staff were introduced to new operating procedures and educated on the impact they can make for energy conservation through strategic communications including posters and prompts.

Advanced Education

Langara College

The oldest building on Langara's Vancouver campus – 'A' Building was the least energy-efficient and consumed nearly 75% of total campus energy use. Following an assessment of mechanical and electrical systems in 2016, most of the equipment in 'A' Building was considered end-of-life. To understand and prioritize upgrades, Prism Engineering evaluated options and energy savings potential of a renewed HVAC system considering both low energy and low carbon options.

A comprehensive retrofit from a constant volume reheat system to a variable air volume system was undertaken. The components of the existing air handling units were replaced/upgraded, and the many reheat coils were replaced with 140 VAV boxes with reheat to reduce the air flow to the zones when they are unoccupied or partially occupied (using carbon dioxide sensors). An innovative "fan wall" technology was included in the project. New pumps, valves and piping were installed to renew all system components. Controls were also upgraded to provide zone demand feedback to further optimize setpoints and system operation

This option had the lowest estimated budget ($2M) and was the only option that could be implemented without shutting down a large portion of the areas supplied by the upgraded HVAC system – construction was completed with minimum disruption to staff and students. The project was commissioned and fully operational in 2019.

Air balancing and commissioning were critical components to achieve deep carbon reductions. Some of the key lessons learned from the project include the following:

- Be ready for incentive programs: having projects ready on the shelf allows for quick applications
- There are significant synergies between capital renewal and energy upgrades
- Further energy enhancement opportunities may be possible during construction that can be incorporated into a project
- A team approach with facility staff, contractors and consultants helps identify issues and speed up resolution
- Commissioning is critical to deliver on full energy savings potential

Although a full year's post-retrofit data is not yet available, initial results from the retrofits indicate carbon reductions exceeding 50% have been occurring.

Conclusions

Building energy audits have been part of the energy management landscape for over forty years. Deep energy retrofits have been referred to in the residential sector for approximately ten years and has seen some adoption in the commercial sector. As climate change becomes increasingly paramount, deep carbon retrofits (DCRs) offer practitioners an opportunity to go beyond energy retrofits in search for solutions with the greatest carbon reduction for commercial buildings.

Deep carbon retrofits make the most financial sense when combined with asset renewal. Since a large expenditure is often needed, a low carbon option is often worth considering due to the incremental cost over a "like for like" replacement. Some organizations may also choose a phased approach to achieving low carbon over time as funding becomes available for retrofits.

Some of the key considerations presented in this paper are:

- An acceptable return on investment for projects identified in a DCRS might be based on a threshold for dollar invested per ton of carbon dioxide saved.
- Deep carbon retrofits provide resiliency by reducing carbon output and can be considered a "non-energy benefit."
- Deep carbon retrofits can be extremely challenging and require dedication by the owner and continuous communication between the parties.
- To ensure long term success, optimized control sequences for new systems need to be well understood by operators through comprehensive training.
- Tenants may need to temporarily relocate during the implementation phase if the space is being disrupted for an envelope upgrade or comprehensive HVAC retrofit.
- Successful commissioning of innovative and complex systems is challenging but can be overcome with a skilled group of practitioners.

Recommendations

There does not appear to be readily available guidelines to define deep energy retrofits (DER) or deep carbon retrofits (DCR) from recognized organizations in the industry. A standard definition and scope should be created.

For deep carbon retrofits, we recommend the following strategies be applied:

- Conduct workshops to get buy in and to address barriers from skeptical stakeholders.
- Use deep carbon retrofits to attract the growing number of socially conscious investors.
- Use a detailed facility's equipment renewal plan to incorporate equipment upgrades as a part of deep carbon retrofits
- Promote a collaborative and constructive relationship between designers and building operators to ensure successful commissioning efforts.
- Apply internal carbon pricing policies as part of a business case review process.
- Involve operators in the stakeholder engagement phase of a DCRS
- Enlist design consultants with specialized expertise that understand and support deep carbon retrofit solutions.

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