ENERGY EFFICIENCY, CONSERVATION, AND SUSTAINABILITY FOR BUILDINGS

CAPSTONE FINAL REPORT

APRIL 12, 2017

Prepared for: The City of Toronto, Department of Environment and Energy
Prepared by:

Table of Contents

1.0 Background and Project Scope

TransformTO, the City of Toronto's collaborative project and climate action plan, has set the ambitious goal of reducing the City's greenhouse gas emissions by 80% by 2050.[1] Buildings play an especially large role in the City's carbon footprint, as they contribute to the majority of Toronto's emissions. Moreover, around 80% of buildings today will still be operating by 2050. Among the City's large buildings, Toronto has specifically identified the commercial sector as one of the major source of emissions. A primary component of Toronto's strategy to address this problem going forward will be the Energy and Water Reporting and Benchmarking (EWRB) requirement for large buildings (greater than 50,000 square feet), which will be enacted by Ontario's Ministry of Energy starting in 2018.[2] The EWRB will cover privately owned commercial, multi-residential and some industrial buildings, which will report their energy performance data via the ENERGY STAR Portfolio Manager.[3] With a provincial benchmarking system in place and a greater availability of energy performance data, the City will be able to pursue more targeted carbon reduction strategies for commercial buildings so it can meet its emissions goals.

Our client has highlighted building retrofits as a major policy option among *TransformTO's* sustainability strategies for commercial buildings in the short and long terms. He engaged us to recommend best practices of retrofitting policy in other cities with similar governance frameworks (advised by him) through a jurisdictional scan. The team was also asked to recommend other potential programs and regulations that could contribute to the energy efficiency of buildings in this sector, such as retrocommissioning of already existing large buildings and the application of green building codes in renovations. Furthermore, with the 2018 implementation of the EWRB in mind, we were asked to pay particular attention to how benchmarking systems in other cities interacted with their energy efficiency policies for large commercial buildings. As such, we used a multi-criteria scorecard in our research to inform our recommendations of best practice in programs and regulations. The scorecard evaluated our target cities' policies according to five categories: GHG emission reduction, supporting city policies, ease of implementation, co-benefits, and the cost or marginal abatement. After collating the results of our evaluations through the scorecard, we were asked by the client to recommend the highest-scoring policies.

The following will first cover the results of our initial broad jurisdictional scan, its methodology and how our scorecard narrowed our focus down to four cities: Denver, Vancouver, Boston, and New York. The next section will then go over in detail the most innovative policies identified in these cities. The report will conclude with some key takeaways from our research, why we chose Vancouver's model as the most appropriate for Toronto in the short-term, and how the City could potentially integrate ideas from the other three cities in the long-term.

2.0 Jurisdictional Scan

2.1 All Cities Considered

In light of the three possible actions modeled by the City of Toronto in its plan – retrofits for commercial and office buildings, the application of the **Toronto Green Standard** to building renovations, and the ongoing retrocomissioning of commercial and institutional buildings – we examined policies already implemented by a range of jurisdictions. We initially focused on 12 North American cities with comparable governance frameworks, politics, and economies: Vancouver, BC; Austin, TX; Atlanta, GA; Boston, MA; Denver, CO; Chicago, IL; Montreal, QC; Philadelphia, PA; Portland, OR; New York City, NY; Seattle, WA; and Washington, DC. They were identified based on their existing retrofit and sustainability programs, in cooperation with City of Toronto staff. Although many jurisdictions across Europe, Australia, and New Zealand are implementing retrofitting policies, we excluded them from the analysis because of major differences in governance, energy needs, and, in certain cases, climate and city layout. Additionally, most European cities which have implemented retrofit programs did so earlier than their North American counterparts and are now well ahead on emissions reductions from buildings. As such, American and Canadian cities provide better points of reference for Toronto, though certain lessons can still be drawn from overseas jurisdictions.

2.2 Methodology for Final Selection

To evaluate the strength and effectiveness of the programs adopted by each of the 12 cities initially selected, we developed a scorecard which assesses initiatives based on GHG emissions reductions, the presence and strength of supporting city policies, ease of implementation, co-benefits, and costs. The first half of the scorecard examines performance management and evaluates cities based on the presence of dedicated funding for their retrofit and efficiency programs, the availability of public reporting and performance tracking, the number of city staff dedicated to implementing the program in question, and procurement and construction policies for new buildings based on a benchmarking standard. This section yields a maximum score of 3. The second portion of the scorecard focuses on the co-benefits associated with each program. Unlike the first section, it does not numerically score cities based on their performance. Rather, it sets out the potential benefits of their programs across indicators like public health, energy consumption, marginal abatement of GHG emissions achieved, employment, poverty, household energy costs, and the monetary and political costs of implementation. As such, the second portion of the scorecard presents a more qualitative overview of each program. The information needed to score each jurisdiction was obtained through a combination of publicly available reports and, whenever possible, interviews with officials in each of the cities.

Using the scorecard, we selected the four cities with the best-performing programs out of the original 12 jurisdictions. In addition, we selected one program in each of the final four cities on which to focus based on performance, impact, and adaptability to Toronto's political and economic realities.

- Denver (**Energize Denver**)
- Vancouver (**Existing Building Upgrade Mechanism Model**)
- Boston (**Greenovate Boston**)
- New York (**One City Built to Last**)

Although each of these jurisdictions share certain commonalities with Toronto and have innovative programs which could be emulated by the City, they have slightly different funding structures and relationships with their respective state or provincial governments.

3.0 Cities

3.1 Denver

Denver was among the first large cities in the United States to identify the wide-reaching impacts of climate change and create formal policies to combat the threats. In 2007, the City released its original Climate Action Plan, which included a program that aimed to increase the energy efficiency on a per square foot basis for commercial and institutional buildings. Denver identified these buildings as key targets because they were the single largest contributor of GHG emissions, creating 5.11 million metric tons of CO2e in 2005, or 35% of all emissions (Figure 1). Initially, the City recommended that buildings within the City of Denver comply with the Leadership in Energy Environmental Design (LEED) Silver standard or the Energy Star equivalent[4]. It also offered a voluntary benchmarking system, however it only saw a 5% participation rate[5].

Since then, Denver has updated its overall sustainability goals and climate action plan, and intensified its recommendations for commercial and institutional buildings. Overall, the City has a goal of reducing total greenhouse gas emissions by 80% by 2050. More specifically, it has developed Energize Denver, a mandatory energy efficiency program for commercial, institutional and multifamily buildings to achieve its updated goals[6]. Beginning June 1st, 2017, buildings over 50,000 square feet must submit an annual report that includes assessing their energy performance using the ENERGY STAR Portfolio Manager tool, and the same requirements will apply to buildings over 25,000 square feet beginning June 1st, 2018 (Figure 2)[7]. Moreover, the least efficient buildings will be required to take additional action to improve their energy efficiency by pursuing strategies such as retro-commissioning, energy audits, lighting upgrades, and sub-metering of tenants through Xcel Energy, which when combined with benchmarking, are expected to contribute to 40% of all building energy efficiency (Figure 3)[8]. By 2020, the City hopes to cut emissions in the building sector by as much as 25% and energy consumption of buildings by 10% with benchmarking and transparency playing a key role[9].

Initially, Energize Denver required property owners to improve energy efficiency in their buildings every five years in addition to the benchmarking requirements[10]. Each building owner would have the choice to pursue one of the following areas of improvement: improving their energy-use intensity score by 15% from a 2016 baseline; engaging in a retro-commissioning study and implementing the findings, which must realize a return on investment in no more than 2½ years; or, engaging in an ASHRAE audit (the American Society of Heating, Refrigerating, and Air-Conditioning Engineers) and implementing the recommended upgrades[11]. This proposed policy was met with stiff resistance from building owners and industry groups and as a result, was removed from the final version of the regulations. Still, the City of Denver has not scrapped this idea completely; it is considering implementing these rules once the benchmarking program is established and they begin receiving data, giving them a better perspective on what needs to be changed[12].

To enforce its benchmarking program, Denver's Department of Environmental Health (DEH) is responsible for reviewing the data submitted to identify problems such as alerts from ENERGY STAR, Energy Use Intensity outside a normal range, abnormal ENERGY STAR Portfolio Manager scores, gross floor areas that differ significantly from the tax assessor's records, and number of workers, operating hours, or other building use details that are well outside of the normal range[13]. DEH has been granted permission to assess a maximum civil penalty and has discretion on whether to issue penalties, however the City is focused on changing building owners' behaviors and getting them to comply rather than punishing those that do not adhere to the rules. Instead, DEH will take the following year-by-year steps to assist owners in complying with the requirements of Energize Denver's Energy Efficiency Program[14]:

Year 1: DEH will offer in-person training to building owners on benchmarking, and will provide personalized responses to questions with any owners who have not complied

Year 2: DEH will continue with its one-on-one outreach program to help building owners correct their errors or comply to the requirements

Year 3: DEH will provide additional education and outreach to those still not complying, possibly requiring these owners with continuing trouble to submit a certificate of proficiency in benchmarking

Year 4: DEH may consider requiring a professional engineer to sign off on the scores of buildings that continue to have problems with benchmarking

To successfully implement its program, the City of Denver requires financial support. Although the Office of Sustainability itself has minimal funds of USD302,204, its broader Department of Environmental Health, which plays an important role in Energize Denver's monitoring and enforcement, has funds of USD47,123,730. Moreover, Public Works, which manages things like infrastructure sustainability projects, has funds of USD125,486,886. The City of Denver also manages grants totalling USD100-200 million, with Public Works and the Department of Public Health having two of the largest grant portfolios[15]. From the federal level, Colorado has been awarded USD24,064,962 from the Environmental Protection Agency for 2017[16], a portion of which is then allocated to the City of Denver.

The co-benefits of Energize Denver's benchmarking program include energy savings of 2-3% each year for building owners[17], however very little have been quantified beyond that due to the complex and intertwined nature of the program, the absence of strong data on energy efficiency work to date, as well as the lack of resources. The City of Denver has, however, calculated that if USD340 million is invested in this program, it could expect USD1.3 billion in energy savings over 10 years as well as 4,000 local jobs using the following methodology[18]:

Total Investment ($Bn) = **Number of buildings/units (4) (#)** X **Share of pre-1980 buildings/units (2,4) (%)** X **"Quick Hit" retrofit cost per building/unit (3) ($)** / **"Deep" retrofit cost per building/unit, if applicable (3) ($)**

3.2 Vancouver

Vancouver was selected as a city of focus as the client requested a further examination of the City's energy efficiency upgrade requirements for certain building permits. While the idea for this regulation first appears in city documents in 2012, it wasn't fully implemented until the 2014 revision of the City's Building By-Law, which took effect January 2015.[19] When the Energy Retrofit Strategy for Existing Buildings was presented to Council in mid-2014, staff estimated the City had 5,200 commercial and institutional buildings with over 114 million square feet of space, and it sought to focus on 422 large commercial buildings representing 61% of commercial floorspace.[20] In the same report, staff noted the strong leadership of the local chapter of building industry association BOMA in energy efficiency initiatives.[21]

The upgrade mechanism model that the City ultimately settled on is relatively simple to follow: building permit applicants for existing buildings must upgrade five building systems (Fire & Life Safety, Structural, Non-Structural, Accessibility, and Energy) to predetermined design levels based on the type and category of project, the size of the space, and other requirements spelled out in a series of flow charts in the Building By-Law. Figures 6 and 7 show the types of projects subject to the mechanism and a sample flow chart a building permit applicant would follow to determine the design levels. Each system's design level has a corresponding objective statement as well as some design details to guide the permit applicant. Figure 8 shows the objective statements for each Energy design level. The Energy design levels include equivalencies to the **BOMA BESt program**. The BESt program claims to be the "largest environmental assessment and certification program for existing buildings in Canada," and covers several areas of sustainability, including energy, water, air, comfort, health and wellness, and waste as well as more operational area including custodial, purchasing, site, and stakeholder engagement.[22]

The reason why BOMA's program is included in the upgrade mechanism is because the whole idea was developed through close collaboration between the City of Vancouver and the local BOMA chapter which has been particularly active in the sustainability space. The healthy relationship between this city and its local BOMA chapter is somewhat unusual according to the team's assessment of other jurisdictions. This close collaboration should be of interest to the City of Toronto as it seeks to foster industry participation and support in the design and implementation of its building energy efficiency programs and regulations.

Building benchmarking generates the data needed to inform some of the design dictated by the upgrade mechanism while further cooperation with the local BOMA chapter has facilitated healthy working relationships between the City of Vancouver and some of the worst-performing of the 422 large commercial buildings identified as a priority area in its 2014 strategy. The City has cataloged a series of provincial and utility incentive programs to partly finance the transformation of these buildings, however it no longer offers its own incentive programs for commercial building retrofits.

While the City hasn't identified any co-benefits specific to its existing building energy efficiency strategy besides cost savings to building operators and owners through reduced energy consumption, the same co-benefits uncovered in other programs that improve building design and reduce energy consumption can be extrapolated to this program.

3.3 Boston

Boston emerged as one of the best scoring cities in our jurisdictional scan for a number of reasons. Even before the scan, the fact that Boston was rated as the number one city in America for energy efficiency policies according to the American Council for an Energy-Efficient Economy's scorecard was promising. Boston employs a range of both regulations and incentive programs to meet its ambitious energy-efficiency and emissions goals. Our client was particularly interested in Boston's plan to incentivize the installation of co-generation systems – also known as combined heat and power (CHP) – in both its new large buildings and institutions (LBI), as well as its already existing ones. Co-generation systems:

> "…generate electricity and thermal energy in a single, integrated system. Heat that is normally wasted in conventional power generation is recovered as useful energy. While the conventional method of producing usable heat and power separately has a typical combined efficiency of 45%, CHP systems can operate at levels as high as 80%.[23]

They are a particularly viable option in cities that have long winters or exist in predominantly cold climates, as they are most suitable for high heat-demand buildings. As such, their applicability to in Toronto's context is evident.[24]

Boston's Climate Action Plan has a target of reducing the greenhouse gas emissions of its LBIs by 12.5% by 2020 from a 2014 baseline.[25] As part of its strategy to meet this target, it wants to increase the amount of its LBI's using co-generation systems from 10% to 15%. According to our calculations, achievement of this 5% increase in co-generation would lead to about a 1.9% reduction of emissions from the City's 2014 LBI baseline, or approximately 0.06 million metric tonnes.[26]

According to an interview with a city official who works on "Greenovate Boston's" programs, incentivizing co-generation installation requires coordinated cooperation between a series of mandatory and voluntary structures that start at the state level. The primary funding structure for the co-generation systems is a state-level, voluntary Public Benefits Fund run by Massachusetts called the Energy Efficiency Fund.[27] What is most significant about the voluntary nature of this fund is that its primary financial source comes from a mandatory state-wide tax. By law, all electricity used is taxed at $0.0025 per kilowatt-hour, or a quarter of a cent. The Energy Efficiency Fund, with assistance from minor private proceeds, currently sits at around $2.1 billion USD; its funds are designated to cover the marginal cost of equipment change to co-generation systems.[28]

Our interviews with city officials also revealed that the Energy Efficiency Fund was not the only voluntary-mandatory policy interaction facilitated by the state for building energy efficiency. One of the other major incentive structures existing for co-generation installation is the Mass Save Fund. It provides a range of incentives for building owners, from tax rebates to free energy assessments. The regulatory authority behind Mass Save's existence is Massachusetts's energy resource standard, which mandates that all utility providers in the state must invest 1.5% of their electric sales in to energy efficiency.[29] As a result, the main sponsors of Mass Save are the state's major utilities such as Berkshire Gas, Blackstone Gas Company and Liberty Utilities.[30] Boston's commercial and industrial sector has received a total of $23,975,997 in electric incentives from this fund, saving an annual rate of 111,226 MWh use.[31]

Another important mandatory aspect of Boston's commercial building energy-efficiency strategy is its Building Energy Reporting and Disclosure Ordinance. It mandates that all commercial buildings over 35,000 sqft report their energy and water use through Portfolio Manager, whose data is published annually and publically online. This is then used to penalize non-compliance, as well as for outreach to the worst performing buildings with some of the incentives described above.

The Greenovate staff revealed some general co-benefits associated with co-generation systems. City staff indicated that Boston does not have a robust co-benefit criterion, nor does it pour significant resources in to measuring them. However, they indicated that co-generation installation's primary co-benefits are related to thermal pollution reduction, resilience and social equity. Naturally, the recycling of heat reduces thermal run-off from buildings, thus reducing unnecessary heat pollution in dense urban areas and bodies of water. The resilience co-benefits come from the fact that co-generation systems are often installed to run compounds and groups of buildings such as hospitals and condominium groupings—these can be "island-able" when primary grids are disrupted by natural disaster, for example. Lastly, social equity co-benefits come from installation on compound and building groupings as well; since individual buildings do not need their own power and heating systems, more room exists in them to accommodate city policies such as affordable housing.

3.4 New York City

New York aims to reduce its GHG emissions by 80% relative to 2005 standards by 2050 (**80 by 50**)[32]. In working toward that goal, the City has placed particular emphasis on using retrofitting, behavioral changes, and improved standards for new structures to cut 62% of emissions from buildings. To achieve this, in 2014 New York introduced the **One City Built to Last** program, which encompasses medium to large buildings over 25,000 square feet[33]. 52% of its buildings are commercial, industrial, or institutional; as such, they will be responsible for a reduction of 12.9 MMtCO_2e by 2050[34].

One City Built to Last is noteworthy in part because of the emphasis it places on using municipal buildings to demonstrate leadership in retrofitting and retrocomissioning. The **Department of Citywide Administrative Services (DCAS)** is allocating funding to "high value efficiency projects identified by City agencies through a competitive selection process", and is trying to reach as many agencies as possible through that approach[35]. To date, the City has launched retrocomissioning studies on 250 of its 4000 buildings, is conducting energy audits on 300 others, and is actively making energy upgrades to another 200[36]. Built to Last also includes provisions for training about 2000 municipal staff, building operators, and supervisors to provide them with the knowledge needed to operate the more complicated heating, cooling, water, and electrical systems often installed in the retrofitting process[37]. The City also provides low-cost training to private building managers and dedicates special attention to reaching out to those who speak English as a second language[38]. Aside from the provision of training, New York provides support to building owners through the **NYC Retrofit Accelerator**. The program serves as a platform for the municipal government to work one-on-one with the owners of various types of buildings to identify potential incentives and best practices for retrofits[39].

One of the most innovative elements of Built to Last is its commitment to using public buildings to trial and demonstrate cleantech and renewable energy. The municipal government is using its buildings as testing grounds for innovative processes and products, and will provide data, case studies, and best practices for their implementation[40]. It aims to install 100 MW of rooftop solar capacity on hundreds of public buildings over the next decade, beginning with 24 schools[41]. As such, the City will take the lead on solar energy adaption as it targets the addition of 250 MW of solar capacity by private sector actors[42]. The program is also focusing on improving the energy efficiency and standards of community housing developments in partnership with the federal government – specifically the Department of Housing and Urban Development – and private investors. The commitment to cleantech and renewable energy leadership in the building retrofit plan explicitly aims to generate co-benefits by fostering the growth of a cleantech innovation hub in New York City. **Innovative Demonstrations for Energy Adaptability** (IDEA), the portion of Built to Last dedicated to cleantech innovation, is designed to share detailed findings and data on the City's experience with new technologies with other building operators who might be willing to adopt them, in partnership with the New York State Energy Research and Development Authority[43]. If successful, IDEA is also likely to create new cleantech jobs in New York, though the municipal government has not provided an estimate on how many new positions might be generated[44].

New York hopes to meet the costs of One City Built to Last in part through the projected long-term savings of $8.5 billion achieved through energy conservations and retrofitting[45]. Nevertheless, most elements of the program, as well as New York's other retrofit and energy efficiency initiatives, rely on cooperation with major utilities and the state and federal governments. The State of New York has launched a Green Bank to help fund retrofit programs: in light of the Ontario government's plan to launch a similar initiative[46], Toronto could work with New York City to identify best practices for funding projects as Ontario's Green Bank comes online. The City also intends to examine the possibility of using Qualified Energy Conservation Bonds (QEBC) to sponsor upgrades[47].

Benchmarking relies on **ENERGY STAR** standards. Detailed performance data are reported annually and are made available by the City on a public website, and commercial buildings larger than 50,000 square feet must conduct energy audits and retrocomissioning every 10 years[48]. In addition to the reporting mandated by Built to Last, New York maintains the **NYC Carbon Challenge**, a voluntary program which calls on commercial and institutional building operators to reduce emissions by 30% below 2005 levels within a 10 year timeframe[49]. This program provides an opportunity for commercial and institutional buildings to demonstrate leadership on emissions reductions and has so far garnered 50 major participants, including many of New York's major universities, hospitals, and property managers[50]. As such, it could have an outsize impact despite the small number of actors which have signed onto it. This provides a further example of a voluntary program boasting ambitious emissions reduction standards operating in conjunction with a city-lead initiative which mandates reporting and compliance.

4.0 Industry Perspective

4.1 Industry Organizations

Based on interviews with a building energy efficiency advocacy organization, the City of Toronto is best advised to introduce an extensive suite of complementary tools to achieve the maximum possible reduction in building GHG emissions.[51] Washington D.C.'s program, which was initially considered for this report but rejected due to its immense scale, was developed through extensive stakeholder engagement including such parties as the Interval Group, the Institute for Market Transformation, various building owner and operator organizations, and several local sustainability groups. The result was the introduction of several concurrent programs and regulations including benchmarking, retrocomissioning, auditing, financing, and it also included massive investments in district energy systems.[52]

While the Washington D.C. programs are expected to be effective in the City's building emissions reduction targets, they come at a huge financial and political cost which is likely untenable in the City of Toronto context. For high-impact medium-term programs, the experts pointed to the importance of gathering data and developing frameworks for engaging with the market which leverage data produced by benchmarking programs.[53] Viewed through this lens, the Vancouver was seen as an effective way to use benchmarking data to engage with the industry, however the experts warned that unless the requirements are finely tuned to the different types and sizes of buildings, they could elicit significant push-back from industry.

This led to the point about engaging with building owners in a way that creates opportunity for them, which is something that New York has done especially well through programs like its retrofit accelerator.

While the experts doubted the sustainability and transferability of the accelerator in a city like Toronto, the idea to connect building owners with the services and trades needed to sustain an economy of energy-efficient buildings has a lot of merit, especially insofar as it has shown to attract services providers who have gone as far as to do initial retrofit work at a loss in order to foster relationships with building owners which will sustain through years of building retrofits and upgrades.[54]

4.2 Building Owners

Based on interviews with Toronto building owners, there are mixed sentiments surrounding benchmarking and building retrofits in general. They are primarily concerned with the payback of the project, particularly because they require significant funds from either the capital or operating budgets. In fact, some of the largest commercial building owners in the city, such as Omers and Oxford, have been described as having "deep pockets but short arms", since they have the capabilities to pour on the funds to projects that are considered attractive, however they are frugal and do not pursue a range of possible projects[55].

Many building owners are engaging with the programs provided by Toronto Hydro and Enbridge, which helps when prioritizing projects; by bundling incentives and applying it to larger projects, these companies can get a quicker payback with a higher value. For instance, a project that initially had a payback of up to 12 years and a value of $20,000 was able to reduce its payback down to 3 years and increase the value to $40,000 through bundling all available incentive programs together[56]. Still, they see these incentives as coupons that help them decide whether to pursue a project, but additional financial motivation should not be the primary driver as there is value is retrofitting.

There is significant reluctance when discussing mandatory benchmarking, however, since it is seen as something that simply adds additional roadblocks for building owners and hesitation on whether it makes a difference in emissions. For instance, building owners have been able to make the least energy efficient buildings LEED certified because they understood how to manipulate the rules and maneuver around the requirements[57]. At the end of the day, building owners are able to abide by mandatory regulations without positively contributing to the sustainability cause. Still, if the mandatory program brings more accountability and a certain level of public scrutiny, it has the opportunity to make a positive impact. Overall, it is possible to positively engage building owners and have them effectively follow mandatory programs, bringing positive results to energy efficiency. In order to have a favorable relationship, however, it is important for the program to be data-driven, systematic and unified. Moreover, it is important for key building owners to be involved in the conversation from the beginning so that there is minimal pushback when regulations become more restrictive.

5.0 Key Takeaways

5.1 Co-Benefits

It is well known that energy efficiency improvements bring a broad range of non-energy and non-climate benefits (Figure 4), however most cities in North America find it challenging to quantify and systematically assess these advantages due to the lack of critical data and the shortage of mature methodologies. Still, determining how to measure these benefits is of vital importance, as it could substantially change the priority order or financial viability of sustainability project options. Although there is reluctance for North American cities to look at Europe for guidance on energy efficiency since Europe is more advanced in this area, and it has different regulatory environments and governance structures, there are important lessons that can be learned in terms of quantifying co-benefits and incorporating them in the decision-making process.

According to the European Council for an Energy Efficient Economy (ECEEE), energy efficiency measures can be quantified and included in cost-benefit assessments that support decision-making processes, and although co-benefits are in a broad sense universal, their values vary by location[58]. Benefits can be categorized in the following groups: health effects, ecological effects, economic effects, service provision benefits and social/political effects (Figure 5)[59]. Methodologies to quantify these benefits range from statistical analyses, literature reviews, statistic time-series analyses, NPV analyses, elasticity estimates, multivariate linear regression models, authors' estimates, among others[60]. After determining and quantifying the physical indicators through these methodologies, there is also an opportunity to determine the monetary indicators[61].

Still, the assumptions used vary across categories and overall aggregated impact of the benefits of CO2 emission mitigation is the commercial building sector on the costs of mitigation potential continues to be challenging. To have a comprehensive assessment of the impacts of CO2 emission mitigation and monetary estimates for each of the benefits and each of the regions of the world, there is still work to be done in creating a common approach. The following formulas, which have been developed by the ECEEE, should be considered as a starting point:

Supply curve to estimate the cost of CO2 mitigation of a technological option:

$$AC_{it} = \frac{I_i \times a_i - \sum_{j-1}^{n} B_{itj}}{\Delta E_{it}}$$

where

AC_{it} average costs of energy conserved in year t due to application of technology i
I_i investment costs of technology i
a_i annuity factor of technology i
ΔE_{it} energy conserved in year t due to application of technology i
B_{itj} monetized co-benefit j in year t due to application of technology i

The annuity factor:

$$a_i = \frac{(1+DR)^{n_j} \times DR}{(1+DR)^{n_j} - 1}$$

where

DR discount rate
n_j lifetime of technology i

$$B_{itj} = \Delta E_{ti} \cdot \alpha_{ij} \cdot P_{jt}$$

where

ΔE_{it} energy conserved in year t due to application of technology i
α_{ij} energy elasticity of co-benefit j due to application of technology i
P_{jt} a monetary estimate associated with a unit of co-benefit j in year t

These calculations are broad and cannot encompass all the nuances of sustainability projects in buildings and must be used with caution. The formulas do not account for overlap of co-benefits, or the fact that one may be a product of another, resulting in double counting[62]. Moreover, monetizing life, health and comfort is subjective and can be highly controversial. Still, it is possible to synthesize existing information to quantify improvements in energy-efficiency in buildings, and will only become more feasible as benchmarking programs expand across the world, providing more relevant data.

5.2 Abatement

Each program analyzed in this report measures CO_2 reductions and abatement against a different base year and have set varying deadlines for reductions. Moreover, it is very difficult to determine how much of a given city's abatement target will have been met by a common date. As such, it can be very challenging to compare targets and abatement strategies set by different cities in a meaningful way. The lack of common base years and emissions deadlines also complicates cost comparisons. When the City of Toronto seeks to implement marginal abatement strategies, it should be weary of relying too heavily on the targets or experiences of other jurisdictions. Additionally, estimating marginal abatement can be notoriously difficult and is often quite subjective[63]. Despite these challenges, the City of Toronto can still benefit greatly from examining the policies adopted by other jurisdictions and by studying their implementation.

5.3 Incentives

Our research revealed to us the inherent tradeoffs that exist between regulating and incentivizing energy efficiency in buildings. Our client preferred recommendations that were mandatory and regulation-focused, and it was clear that they are indeed effective instruments. Regulations and mandatory requirements are the cheapest and fastest strategies for governments to drive investments in retrofitting, because they place the costs and responsibilities on the building-owners and tenants themselves. However, they do carry the risk of upsetting industry groups and causing building owners to avoid buy-in. For instance, several of the interviews with city officials that we conducted during our research suggested that industry groups such as BOMA often vehemently opposed simply regulation on its own and in many cases, threatened non-compliance.

Our jurisdictional scan suggested that incentives play a vital role in many of the cities that did well in our scorecard. They can be as simple as myheat.ca, which maps the level of heat loss in Alberta homes and publishes the results for free online.[64] This allows household owners to pursue energy efficiency practices in their homes without the need for regulation. Our research has also shown that incentive structures can be much more complicated and diverse, ranging from free energy audits, to tax rebates and credits, to multibillion-dollar state-level energy efficiency funds. In other words, diverse incentive structures, such as public funds and revenues from fines, can be very useful in meeting ambitious emissions and energy-efficiency targets. Although regulation might be the focus of the short-term, Toronto should not overlook the usefulness of incentive tools in its long-term sustainability strategy.

6.0 Final Recommendation

After the preliminary analysis and deep-dive into a select number of cities, it is recommended that Toronto begins by pursuing a strategy like what is seen in Vancouver. Still, there is opportunity to incorporate portions of all the programs analyzed in Toronto over the long-term.

6.1 Why Vancouver

One of the most important aspects of Vancouver's approach which is important to a successful building emissions reduction strategy in Toronto is the positive working relationship fostered with the local chapter of BOMA by working closely with them to develop building standards that achieved the City's energy efficiency goals while keeping BOMA happy.

The main way that Vancouver was able to keep BOMA happy was through tiered requirements for efficiency upgrades depending on size and type of building. The industry association viewed this as a fair way to make building owners take responsibility for upgrading their buildings without; it doesn't force small building owners to make huge investments, but it also doesn't let big buildings off the hook.

While it is worth acknowledging that the City of Toronto, unlike Vancouver, does not have the right to maintain a separate building code from the rest of the province, Toronto could experiment with making energy efficiency upgrades a requirement for the issuance of building permits for renovations, retrofits, change of major tenant, etc. The City has already pushed the envelope in this area and should consult its legal counsel to advise on the practicality of such upgrade requirements.

Although it's a separate initiative, the City of Vancouver and BOMA established a good working relationship around energy efficiency and the City has leveraged BOMA to help bring the worst-performing large buildings to the table to talk about how they can contribute towards the City's goals. In this sense, Vancouver is using both strict regulations in the building permit requirements area, but also using a softer touch by engaging with BOMA and nudging some of the worst-performing buildings towards existing incentives available through the province of British Columbia and through provincial utilities.

6.2 Long-Term: Combining Ideas

6.2.1 Denver

Although the City of Denver is targeting to cut emissions by 25% by 2020, the most significant decrease of all the cities analyzed, it is not considered feasible for the City of Toronto because of the additional resources it has from the federal, state and municipal level, allowing it to allocate more FTEs and capital to the program. Still, there are interesting components that the City of Toronto should consider in its own program, particularly since Denver is relying primarily on benchmarking and transparency for improving energy efficiency among its commercial buildings. Most notably, Denver is allocating minimal fines as punishment of not participating in benchmarking. Rather, it is planning on working with non-complying buildings to instill behavioural changes and ensure they are participating effectively within 4 years. This requires several employees and would be a cost to the City, however will certainly increase participation and mitigate the risk of building owners simply paying fines to avoid mandatory benchmarking. Another attractive idea that the City of Denver has not yet implemented but is considering is the idea of requiring buildings to take steps towards increased energy efficiency every five years. As Denver saw, it would be difficult to gain the support of the industry and building owners, however it would be an effective way of rapidly improving energy efficiency among commercial buildings.

6.2.2 Boston

Boston’s energy efficiency policies for buildings are considered very effective, but they did not make our final recommendation because of how instrumental the state of Massachusetts is for their efficacy. As the previous section for Boston demonstrated, the city’s commercial building-owners have a wide array of well-funded incentives available to encourage deep retrofits. These incentives structures have complex and robust relationships with public and private funding structures that generate revenues from mandatory state-wide regulations, such as a quarter-cent tax per kilowatt hour and an energy efficiency resource standard.

Ontario’s policies currently do not reflect such a complex network of incentives and regulations. However, it is slowly introducing the building blocks that could assist in developing a similar system to Massachusetts’s in the future. As discussed, it is introducing a mandatory benchmarking system for large buildings by 2018, and we have been hearing discussions about the introduction of a provincial “Green Bank” sometime in the near future. Toronto’s policymakers in sustainability departments should stay cognizant of Ontario’s progress in developing mandatory regulation and incentive structures for the large building sector. They should also try to work with the province in accelerating their development as much as possible, and perhaps try to propose using the city as a smaller-scale platform for pilot projects in this spirit. As Boston’s example shows, the dichotomy of state-level regulation and incentives for the commercial sector is a policy system to be seriously considered in the long-term

6.2.3 New York City

One City Built to Last is notable for the emphasis it places on using the retrofitting and retrocomissioning of municipal buildings to advance cleantech innovation in New York City. While it is difficult to quantify the benefit which might arise from the City using its structures to test cleantech prototypes and establishing improved information sharing mechanisms with other large building operators, it is likely to provide a major co-benefit. Moreover, the vision of using retrofits to achieve leadership in a certain industry, aside from the reduction of emissions linked to buildings, is unique amongst the municipal policies examined in this report. Toronto could seek to emulate this aspect of One City Built to Last, especially in light of the alignment between the federal, provincial, and municipal governments on driving new sources of innovation in the economies of Toronto and Greater Toronto Area.

In addition, New York City's retrofit program relies to an extent on funding provided through the Green Bank introduced by the New York state government. At present, it has received $1 billion from the Green Bank to sponsor retrofits, retrocomissioning studies, and other projects under Built to Last. Since Ontario is expected to introduce its own Green Bank, Toronto should carefully study the model employed by New York state – and look to the other forms of financing used by New York City, notably Qualified Energy Conservation Bonds, as alternative or supplementary sources of funds.

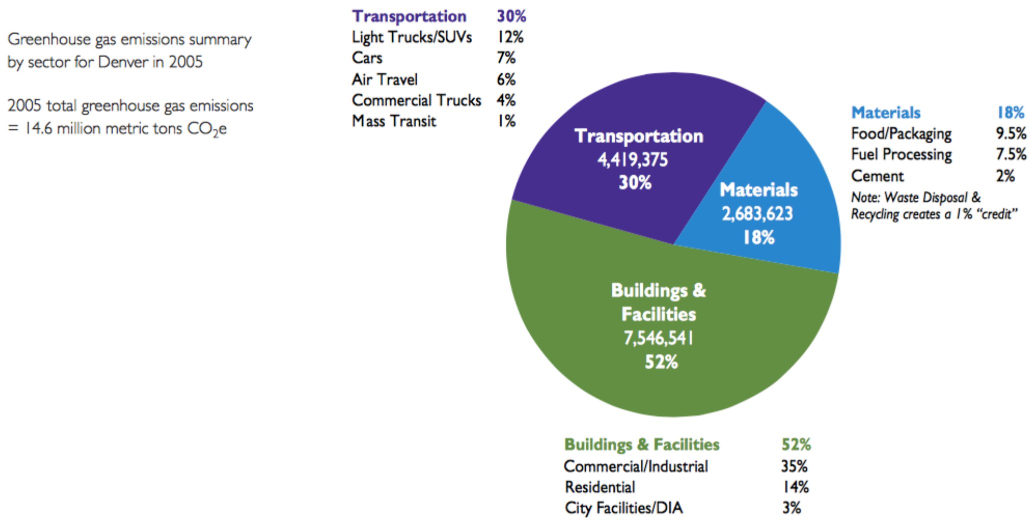
6.3 Risk and Mitigation

There are several risks to be considered when implementing any of the programs analyzed, as seen in the table below:

Category	Risk Factor
Financial Risk	Costs associated with design, construction, certification and maintenance of retrofit is too costly for individual companies
	Financial loss if the building does not perform as expected and does not repay as predicted by the model
	Inaccurate investment estimate of retrofitting project
Market Risk	Lack of knowledge in the lending industry (financial institutions, private investors, etc.) regarding green buildings and the payback of retrofitting
	Tenants do not value retrofits done in their buildings and will not pay a premium for it
	Buildings owners rally together and push back on government requirements
Industry Risk	Lack of knowledge regarding retrofitting projects among the involved parties
	Lack of materials needed for these highly-specialized construction projects
	Skilled workers may not be available to handle the specialized nature of retrofitting projects (lack of capacity)
Project Risk	Buildings may be included to pay fines rather than comply with benchmarking and retrofitting, which would not provide any benefits to energy efficiency
	Business disruption to tenants resulting in a lack of cooperation
	Lack of knowledge of retrofitting resulting in incorrect installation/construction
Measurement risk	Difficulty in measuring the changes made by retrofitting; lack of appropriate data
	Establishment of improper measurements

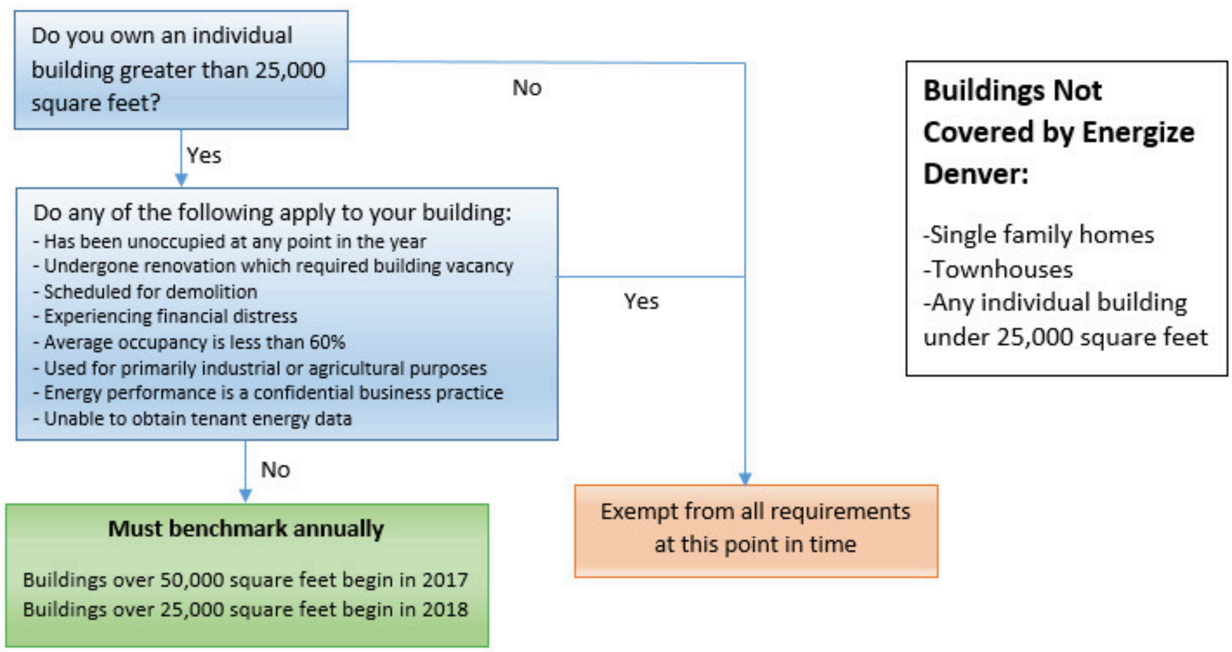
These risks are all possible, however simple proactive measures can be used to mitigate many of them. It is recommended that the City of Toronto communicates and consults with key stakeholders including industry leaders, building owners, financial institutions and the construction industry. By maintaining an open dialogue across these groups, many risks can be avoided or minimized. For instance, this will reduce pushback from industry groups and building owners, it will ensure that the construction industry in Toronto is aware of the shift in demand for construction projects, and financial institutions will understand the shift in financing needs. Still, this shift will require patience across all stakeholders as all will see significant changes.

Figure 1



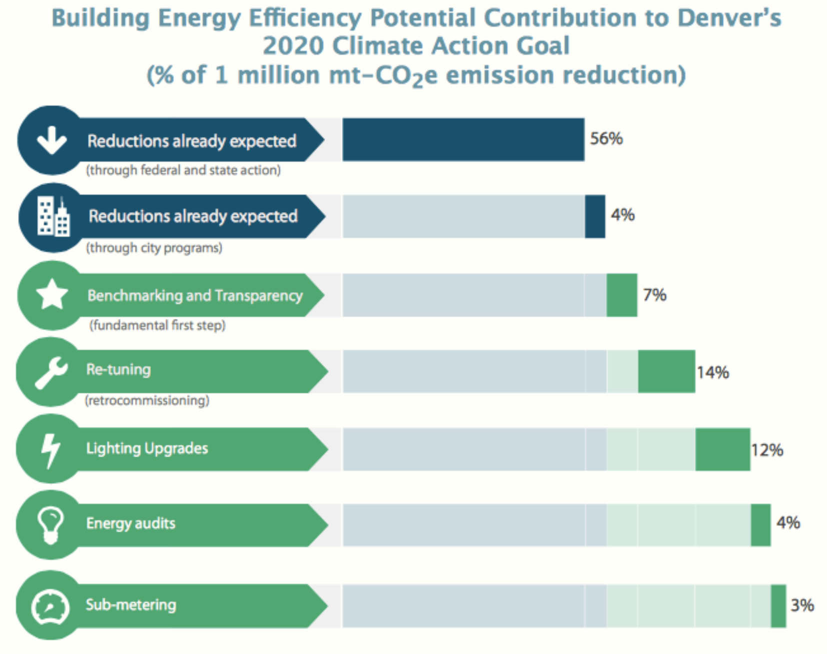
Source: http://www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/Climate1/DenverClimateActionPlan_2005_Original.pdf

Figure 2



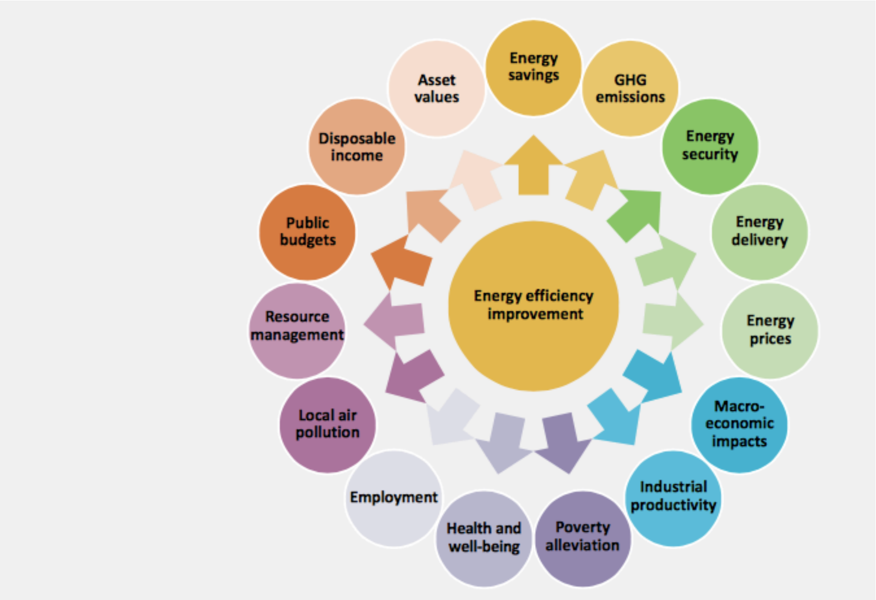
Source: https://www.denvergov.org/content/denvergov/en/environmental-health/environmental-quality/Energize-Denver/CommercialMultifamilyBuildingBenchmarking.html

Figure 3



Source:
http://www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/Climate1/CAP%20-%20FINAL%20WEB.pdf

Figure 4



Note: This list is not exhaustive, but represents some of the most prominent benefits of energy efficiency identified to date.
Source: Unless otherwise noted, all material in figures and tables in this chapter derives from IEA data and analysis.

Source:
http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf

Figure 5

Typology of benefits of energy efficiency and distributed energy use in the buildings sector and selected indicators for their potential quantification

Category	Non-energy subcategory	Examples of concrete benefits, and potential indicators for quantification
Health Effects	Reduced mortality	Higher employment, more working days due to reduced mortality. Mortality is reduced through improved indoor and outdoor air pollution, and through reduced thermal stress in better buildings (hot and cold).
	Reduced morbidity	Avoided hospital admissions, medicines prescribed, restricted activity days, productivity loss. Morbidity is reduced through the impacts above, as well as through better lighting, mold abatement, thoughtful ergonomics etc.
	Reduced physiological effects	Learning and productivity benefits due to better concentration, savings due to avoided "sick building syndrome".
Ecological Effects	Reduction of indoor air pollution	Similar to reduced morbidity. Indoor air quality improves through the reduction of incompletely combusted fossil fuels and biomass, through better ventilation that eliminates gaseous wastes and toxic fumes from buildings materials and activities.
	Reduction of outdoor air pollution	Similar to reduced morbidity but this category is broader including, for instance, avoided damage to building constructions. Outdoor air pollution is brought down through reduced fossil fuel burning, the minimization of the heat island effect in warm periods through reduced local energy consumption, etc.
	Construction and demolition (C&D) waste reduction benefits	Waste rate reduced due to such a vital part of "green buildings" initiative as C&D waste management that includes carefully planned "reduction, reusing, and recycling waste generated from building construction, renovation, deconstruction, and demolition" as defined by the US Environmental Protection Agency.
	Increased urban vegetation	In the case of green roofs and walls.
Economic Effects	Lower energy prices	Decrease in fuel and energy prices due to reduced energy demand driven by energy efficient measures implemented.
	Decreased energy bill payments	Lower energy consumption, on average, results in decreased payments for consumed energy.
	Higher lifetime earnings	Higher salaries and, as a consequence, higher living standards.
	New business opportunities	New market niches for energy service companies (ESCOs) resulting in higher GDP growth.
	Employment creation	Reduced unemployment through hiring workers for ESCOs (as a consequence, reduced dole payments).
	Rate subsidies avoided	Decrease in the number of subsidized units of energy sold. In most developing countries energy for the population is subsidized heavily. If energy is used more efficiently, substantial subsidies can be avoided.
	Lower bad debt write-off	A decrease in the average size of bad debt written off and a decline in the number of such accounts due to reduced energy bills that become affordable for more households.

	Enhanced ability to rent out or sell energy-efficient space, higher price of real estate.	Higher real estate and rental prices due to the fact that a weatherized unit becomes more appealing with regard to its environmental and economic performance.
	Improved energy security	Reduced dependence on imported energy; reduced military spending related to the securing of energy import sources.
	Avoided costs to support the human health, working environment, and building facilities	Avoided costs of mortality, hospital admissions, medicines prescribed, restricted activity days, insurance costs, productivity loss, building maintenance.
	Improved productivity	GDP/income/profit generated as a consequence of new business opportunities and employment creation (see above).
Service Provision Benefits	Transmission and distribution loss reduction	Lower energy consumption caused by energy efficiency measures results in a smaller amount of energy (e.g, electricity, gas) transported to the household; hence the elimination of energy losses.
	Fewer emergency (gas) service calls	Saving staff time and resources necessary for attending the emergency calls due to installation newer and more energy-efficient and reliable gas appliances.
	Utilities' insurance savings	Decrease in the insurance costs of utility companies as a result of fewer gas leakages and faulty appliances
Social/Political Effects	Improved social welfare and fuel poverty alleviation	Reduced expenditures on fuel and electricity; level of reduced fuel / electricity debt; changed number of inadequate energy service level related damages such as excess winter (or summer) deaths.
	Safety increase: fewer fires	Reduced number of fires and fire calls due to the renovation of HVAC – heating, ventilation and air-conditioning systems (fewer gas leaks, short circuits, etc.).
	Increased comfort	Normalizing of humidity and temperature indicators; air purity; reduced heat stress through reduced heat islands (less local energy consumption and evapotranspiration from urban greenery in case of green walls and roofs)
	Increased awareness	(Conscious) reductions in energy consumption resulting from installation of real-time pricing meters as a part of a "green building"; higher demand for energy efficiency measures due to a possible "keeping-up-with-the-Joneses" effect.
	Increased political popularity	Political leadership introducing wide-scale energy-efficiency measures benefiting the population have reportedly gained popularity and votes
	Benefits to disadvantaged social groups	With high-efficiency and clean cooking, African women and children can save the average of 8 km walking and several hours a day that they spend on firewood collection (Goldemberg 2000). Instead, children can go to school or women enter the workforce

Source:
http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2009/Panel_1/1.316/pBaper

Figure 6

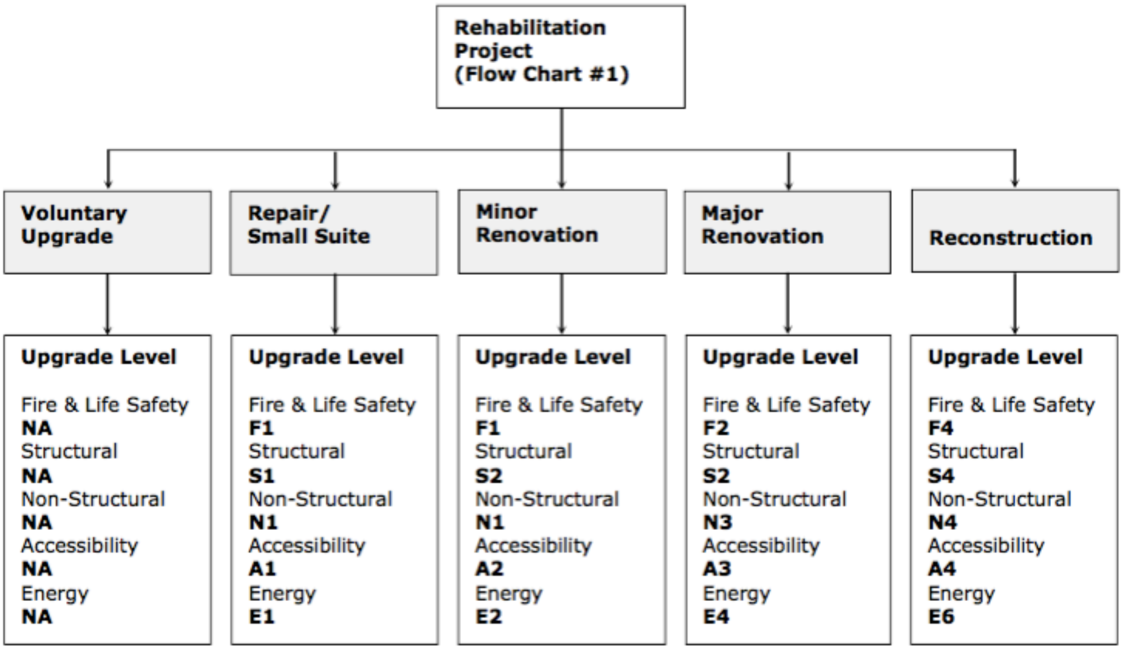
Table from Vancouver Building By-Law showing the project types and related categories of work subject to the Existing Building Upgrade Mechanism Model included in the 2014 update to the Vancouver Building By-Law.

Table A-11.2.1.2.A **Project Types and Related Categories of Work**			
Project Type	**Rehabilitation** (*See Flow Chart No. 1*)	**Change of Major Occupancy** (*See Flow Chart No. 2*)	**Addition** (*See Flow Chart No. 3*)
Categories of Work	Voluntary Upgrade Repair/Small Suite Minor Renovation Major Renovation Reconstruction	Change of Major Occupancy Classification Change of Major Occupancy Classification to a Small Suite	Major Horizontal Addition Minor Horizontal Addition Major Vertical Addition Minor Vertical Addition

Source: http://app.vancouver.ca/bylaw_net/Report.aspx?bylawid=10908

Figure 7

One of the flowcharts from the Vancouver Existing Building Upgrade Mechanism Model incorporated into the Vancouver Building By-Law showing the required design level of the five systems covered by the upgrade mechanism: Fire & Life Safety, Structural, Non-Structural, Accessibility, and Energy.



Source: http://app.vancouver.ca/bylaw_net/Report.aspx?bylawid=10908

Figure 8

Table of objective statements for each design level of Energy upgrades.

TABLE A-11.2.1.2.C
DESIGN UPGRADE LEVELS FOR ENERGY EFFICIENCY (E)

Design Level	Objective Statement	Solution Location	Solution
E1	Review and maintain, or upgrade, basic energy efficiency equipment or components. Limit the probability of inefficient energy performance of *buildings* or *building* components	Project Area	Select 1-L1 in Table A-11.2.1.2.D (see notes)
E2	Review and maintain, or upgrade, a basic energy efficiency sub-systems. Limit the probability of inefficient energy performance of *buildings* or *building* components	Project Area	Select 1-L1 and 1-L2 in Table A-11.2.1.2.D (see notes)
E3	Review and improve energy performance of a basic energy efficiency system. Limit the probability of inefficient energy performance of *buildings* or *building* components	Project Area	Select 2-L3 and 2-L4 in Table A-11.2.1.2.D (see notes)
E4	Review and improve energy performance of an integrated energy efficiency system. Limit the probability that, as a result of the renovation of a *building* the use of energy will be inefficient	Project Area	Select 2-L3 and 2-L4and 1-L5 in Table A-11.2.1.2.D (see notes)
E5	Review and bring to present VBBL energy requirements. Limit the probability that, as a result of the renovation of a *building* the use of energy will be inefficient	Project Area	Select 1-L6 in Table A-1.2.1.2.D (see notes)
E6	Reconstruct building to meet energy efficiency requirements of present Vancouver Building By-Law. Limit the probability that, as a result of the renovation of a *building* the use of energy will be inefficient	Entire Building	L7 in Table A-11.2.1.2.D

N.B. The accompanying note to this table states: "BOMA BESt (Path 1) may be substituted as the solution for Design Level E2 and BOMA BESt (Path 2) may be substituted as the solution for Design Levels E3, E4 or E5. BOMA BESt is a Canadian industry standard for commercial building sustainability certification. Official certification documentation produced by BOMA would be required for acceptance as an alternative acceptable solution option."

Source: http://app.vancouver.ca/bylaw_net/Report.aspx?bylawid=10908

Sources

[1] Overview, TransformTO, accessed April 10, 2017, http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=ba07f60f4adaf410VgnVCM10000071d60f89RCRD.

[2] City of Toronto, Energy Reporting and Benchmarking, accessed April 9, 2017, http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=0be5ddb0842cb410VgnVCM10000071d60f89RCRD.

[3] Ibid.

[4] City of Denver, Denver Climate Action Plan, 2005, accessed April 10, 2017, http://www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/Climate1/DenverClimateActionPlan_2005_Original.pdf.

[5] Denver Business Journal, "Denver energy-efficiency plan for commercial buildings draws heat, praise," May 24, 2016, accessed April 10, 2017, http://www.bizjournals.com/denver/blog/real_deals/2016/05/denver-energy-efficiency-plan-for-commercial.html.

[6] City of Denver, Energize Denver: Energy Efficiency in Commercial and Multifamily Buildings, accessed April 8, 2017, https://www.denvergov.org/content/denvergov/en/environmental-health/environmental-quality/Energize-Denver.html.

[7] City of Denver, Commercial and Multifamily Building Benchmarking, accessed April 9, 2017, https://www.denvergov.org/content/denvergov/en/environmental-health/environmental-quality/Energize-Denver/CommercialMultifamilyBuildingBenchmarking.html.

[8] City of Denver, Climate Action Plan 2015, accessed April 10, 2017, http://www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/Climate1/CAP%20-%20FINAL%20WEB.pdf.

[9] City of Denver, Climate Action Plan Executive Summary 2015, accessed April 10, 2017, https://www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/Climate1/CAP%20ES%20-%20FINAL%20WEB.pdf.

[10] Denver Business Journal, "Denver City Council passes energy-efficiency rules for commercial buildings," December 20, 2016, accessed April 10, 2017, http://www.bizjournals.com/denver/news/2016/12/19/denver-city-council-passes-energy-efficiency-rules.html.

[11] Denver Business Journal, "Denver energy-efficiency plan for commercial buildings draws heat, praise," Ibid.

[12] Denver Business Journal, "Denver City Council passes energy-efficiency rules for commercial buildings," Ibid.

[13] City of Denver, Commercial and Multifamily Building Benchmarking, Ibid.

[14] Ibid.

[15] City of Denver, Mayor's Budget 2017, accessed April 10, 2017, https://www.denvergov.org/content/dam/denvergov/Portals/344/documents/Budget/Mayors_2017_Budget.pdf.

[16] USA Spending, Environmental Protection Agency: Awards by States/Territories - FY 2017, accessed April 8, 2017, https://www.usaspending.gov/Pages/TextView.aspx?data=AgencyMostFundedStates&agencycode=6800.

[17] City of Denver, Commercial and Multifamily Building Benchmarking, Ibid.

[18] Ibid.

[19] City of Vancouver, Bylaw amendments and additional requirements and revisions to the 2012 BCBC, accessed April 10, 2017, http://app.vancouver.ca/bylaw_net/Report.aspx?bylawid=10908.

[20] City of Vancouver, Energy Retrofit Strategy for Existing Buildings, June 2014, accessed April 10, 2017, http://vancouver.ca/files/cov/Energy-Retrofit-Strategy-for-Buildings-Presentation-for-Council-June-2014.pdf.

[21] Ibid.

[22] BOMA Canada, About BOMA BESt, accessed April 10, 2017, http://bomacanada.ca/bomabest/aboutbomabest/.

[23] Mass Save, Eligible Equipment, accessed March 20, 2017, http://www.masssave.com/en/business/eligible-equipment.

[24] Interview with Greenovate Boston staff, March 24, 2017.

[25] City of Boston, Greenovate Boston 2014 Climate Action Plan Update, accessed April 8, 2017, https://www.cityofboston.gov/eeos/pdfs/Greenovate%20Boston%202014%20CAP%20Update_Full.pdf.

[26] Ibid.

[27] Interview with Greenovate Boston staff, March 24, 2017 & OpenEI, Energy Efficiency Fund (Massachusetts), accessed March 15, 2017, http://en.openei.org/wiki/Energy_Efficiency_Fund_(Massachusetts).

[28] Ibid.

[29] Interview with Greenovate Boston staff, March 24, 2017.

[30] Mass Save, Contributing Sponsors, accessed April 8, 2017, http://www.masssave.com/en.

[31] Mass Save, Suffolk County and City of Boston, accessed March 23, 2017, http://www.masssavedata.com/Public/GeographicSavings.

[32] Mayor's Office of Long-Term Planning and Sustainability, One City Built to Last: Transforming New York City's Buildings for a Low-Carbon Future, 2014, accessed April 8, 2017, http://www.nyc.gov/html/builttolast/assets/downloads/pdf/OneCity.pdf, 5.

[33] Ibid, 15.

[34] Ibid, 22.

[35] Mayor's Office of Long-Term Planning and Sustainability, One City Policies and Programs, 2014, accessed April 8, 2017, http://www.nyc.gov/html/builttolast/pages/policies/policies.shtml

[36] Mayor's Office of Long-Term Planning and Sustainability, One City Built to Last: Transforming New York City's Buildings for a Low-Carbon Future, Ibid, 28

[37] Ibid.

[38] Mayor's Office of Long-Term Planning and Sustainability, One City Policies and Programs, Ibid.

[39] Mayor's Office of Long-Term Planning and Sustainability, One City Built to Last: Transforming New York City's Buildings for a Low-Carbon Future, Ibid, 28.

[40] Ibid, 59.

[41] Ibid, 91.

[42] Ibid, 74.

[43] Ibid, 75.

[44] Ibid, 53.

[45] Ibid, 11.

[46] Ibid, 75.

[47] Ibid, 70.

[48] Ibid, 8.

[49] Ibid, 28.

[50] Ibid.

[51] Interview with IMT official, April 11, 2017.

[52] Ibid.

[53] Ibid.

[54] Ibid.

[55] Interview with Suneel Gupta

[56] Ibid.

[57] Ibid.

[58] European Council for an Energy Efficient Economy, Counting good: quantifying the co-benefits of improved energy efficiency in buildings," 2009, accessed April 8, 2017, http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2009/Panel_1/1.316/paper.

[59] Ibid.

[60] Ibid.

[61] Ibid.

[62] Ibid.

[63] Kesicki, Fabian, and Paul Ekins. 2011. "Marginal Abatement Cost Curves: A Call for Caution." Climate Policy 12 (2): 219-236. doi:10.1080/14693062.2011.582347.

[64] MyHeat, accessed April 10, 2017, https://myheat.ca.