GREENHOUSE GAS MANAGEMENT PLAN

City of Edmonton
2019 - 2030 Civic Operations

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Executive Summary

Scientific evidence shows that Earth's climate is changing, with the primary cause being the surge in greenhouse gas (GHG) emissions from human activity. In response to this challenge, countries and cities around the world are setting targets and developing plans to reduce their GHG emissions. Most notably, G7 countries have recommended that all developed countries should reduce emissions by 80 per cent or more by 2050. This City of Edmonton Greenhouse Gas Management Plan 2019-2030 Civic Operations is a response to the global threat of climate change. Its mandate comes from a number of City Council directives including: (a) a goal in *The Way We Green* for Edmonton to become "a carbon-neutral city"; (b) Strategic Action 6.10.1 contained in *The Way We Green* that directs the City of Edmonton to establish, implement and maintain "a [civic operations] Greenhouse Gas Management Plan aimed at significantly reducing greenhouse gas emissions from City operations"; and (c) Strategic Direction 4 contained in Edmonton's Community Energy Transition Strategy (C585) that the City of Edmonton will take a lead role in supporting Edmonton's energy transition efforts, including leading-by example in its own civic operations; (d) alignment with the Pan Canadian Framework on Clean Growth and Climate Change, a comprehensive, multi-sectoral plan to meet interim 2030 targets of 30% reduction below 2005, as a part of demonstrating Canada's commitment to The Paris Agreement and its 2050 targets; and (e) alignment with the Edmonton Declaration's commitments for Greenhouse Gas planning and reporting. This plan "leads by example" — adopting and demonstrating high standards of sustainable, energy conserving, climate change mitigation practices that are encouraged throughout the community.

This plan proposes three GHG reduction scenarios by 2030, each with accompanying conceptual capital and operating budgetary requirements covering the next three 4-year budget cycles:

- **Scenario One:** Achieve 30% below 2005 levels by 2030. This target scenario is the minimum acceptable scenario and would align with the Government of Canada's Pan Canadian Framework for Clean Growth and Climate Change's 2030 target; (a 153,000 tonne reduction by 2030);
- **Scenario Two**: Achieve 50% below 2005 levels by 2030. (a 237,000 tonne reduction by 2030);
- **Scenario Three**: Achieve carbon neutrality for all of City operations, a highly conceptual scenario. (a 449,000 tonne reduction by 2030)

For each target scenario, the plan proposes different levels of deployment of the following greenhouse gas mitigation options above and beyond business as usual. These options include:

- Accelerated building energy retrofits;
- Accelerated deployment of microgeneration solar photovoltaics on City buildings and sites;
- Accelerated LED street lights replacements;
- Replacement of diesel buses with electric; and
- The purchase of renewably generated (green) electricity.

The recommended portfolio of options are supported by best available data and information on capital requirements, lifecycle cost benefit analysis, and further informed by extensive input and advice from corporate project planning, design, engineering, and project delivery staff. The recommended options reflect ambitious but achievable rates of increased deployment that considers various constraints and minimization of impacts and disruptions to City services and programming.

The rigorous analysis and consultation used in developing this report found that the business case actions from a Financial Return on Investment (FROI) standpoint, ranging from strongest to weakest, were building energy retrofits, LED street lights, electric buses, large microgeneration solar photovoltaics, and renewable (green) electricity investment. All of the options related to investing in City assets have positive net present value benefits over a 20 year period from a FROI standpoint. Only green electricity, green natural gas and carbon offsets have negative NPVs, as they are simply premiums paid over a specific period. These premiums were estimated based on the key principles outlined in Appendix C.

Analysis and consultation determined that building retrofits, although having a very strong lifecycle cost benefit, has a deployment rate that is largely impacted and constrained by the need to minimize building shutdown periods and disruption to City services and programming. Secondly, the analysis showed that the average building energy retrofit can only reasonably achieve a 35% GHG reduction. The same types of issues (e.g., scalability, deployability, impact on internal capacity and resources) are true for solar photovoltaics, electric buses, and to a lesser extent LED street lights. The purchase of green electricity from off-site wind and solar farms was the best option for aggressive reductions in the City's GHG emissions, and the least impacted by the above mentioned constraints. It cannot be emphasized enough that a portfolio of options is needed to achieve even the minimum acceptable GHG reduction target of 30% below 2005 levels by 2030.

Of all of the carbon abatement options proposed, the future cost of electric buses is considered the most uncertain due to this technology being in the early stages of market transformation. This is as compared to building retrofits, LED street lights and even solar photovoltaics which are considered mature technologies (e.g., soft project or labour costs becoming more of a dominant cost driver than hard costs of the technologies) and for which hard prices are not expected to experience substantial decreases in future years. The incremental difference in capital between electric and diesel buses will narrow and eventually reach parity. But it is uncertain how quickly this will happen. The current incremental capital estimates in the cost analysis is quite conservative in that future decreases in incremental cost have not been incorporated.

GHG REDUCTION TARGET SCENARIO	TOTALS OVER THREE BUDGET CYCLES (2019-30)	BUILDING RETROFIT	SOLAR PV	LED STREET LIGHT	ELECTRIC BUS	GREEN ELECTRICITY	GREEN NATURAL GAS	CARBON OFFSETS	TOTAL
Scenario 1 30% below 2005 (153,000 tonnes)	Tonnes GHG reduced	45,000	10,000	5,500	17,800	72,900	-	-	151,200
	Capital Costs	$80M	$46M	$20M	$194M	-	-	-	$340M
	Operating Cost*	Minimal with respect to ongoing operating of assets. 15 to 25% internal resource needs on PM side already accounted for within Capital Costs				Starting in 2023: 3.9M/yr	-	-	Starting in 2023: $3.9M/yr
	FROI NPV Benefit	$105M	$9M	$25M	$52M	-$61M	-	-	$130M
Scenario 2 50% below 2005 (237,000 tonnes)	Tonnes GHG reduced	Same as 30% reduction scenario				169,000	-	-	247,000
	Capital Costs					-	-	-	$340M
	Operating Costs**					By 2030: $9.75M/yr	-	-	By 2030: $9.75M/yr
	FROI NPV Benefit					-$115M	-	-	$76M
Scenario 3 Carbon Neutral*** (449,000 tonnes)	Tonnes GHG reduced	60,000	15,000	5,500	17,800	159,000	49,000	136,000	442,300
	Capital Costs	$106M	$69M	Same as 50% reduction scenario		-	-	-	$389M
	Operating Costs**	Minimal with respect to ongoing operating of assets. 15 to 25% internal resource needs on PM side already accounted for within Capital Costs				By 2030: $9.75M/yr	By 2030: $4.8M-$8.7M/yr	By 2023: $6.8M/yr	$19.1M-$30.5M/yr
	FROI NPV Benefit	$140M	$13M	Same as 50% reduction scenario		-$115M	-$95 to -$171M	-$98M	-$154M to -$78M

Assumptions based on one conceptual Green Electricity Purchase example:

**One 20 year contract starting in 2023, electricity consumption coverage of ~40% assumed to be a 50/50 split of wind and solar. Operating costs include existing $1.5M base budget for green electricity purchases.*

***Multiple 20 year electricity contracts. The first with incrementally increasing funds up until 2023. The second two in 2023 and 2027 are constant amounts each year. Operating costs include existing $1.5M base budget for green electricity purchases.*

**** Carbon neutral refers to the overall scenario target not a specific aspect of the plan such as carbon neutral buildings.*

****Multiple (three) 20 year electricity contracts. The first with incrementally increasing funds up until 2023. The second two in 2023 and 2027 are constant amounts each year; One 20 year renewable natural gas contract starting in 2027, 100% coverage; One 20 year carbon offset contract starting in 2027; coverage of all remaining greenhouse gas emissions.*

1. Purpose

The purpose of this plan is to propose a comprehensive strategy and action plan for reducing greenhouse gas (GHG) emissions from The City of Edmonton's civic operations and contributing to Edmonton's long-term goal of carbon-neutrality. The various initiatives proposed in this plan (and their underlying assumptions) have been reviewed and verified by an external consultant — Stantec Inc.

1.1. Background, Mandate and Strategic Alignment for Developing the Plan

Since approval of the City of Edmonton's Strategic Plan - *The Way Ahead* by City Council in 2009, climate change mitigation through reduction of civic operations and community GHG emissions has been a part of the City Administration's mandate. Since July 2010, GHGs from City operations has been one of the performance measures reported under Corporate Outcome 8: The City of Edmonton's Operations is Environmentally Sustainable.

Furthermore, on July 20, 2011, Edmonton City Council approved *The Way We Green* plan which included: a) a goal for Edmonton to become "a carbon-neutral city" and b) Strategic Action 6.10.1 directing the Administration to establish, implement and maintain "a City Operations Greenhouse Gas Management Plan aimed at significantly reducing greenhouse gas emissions from City operations."

Implementation of *The Way We Green* led to development of a detailed strategic framework and action plan to mitigate climate change and reduce community greenhouse gas emissions between 2012 and 2014. The result was Edmonton's Community Energy Transition Strategy, community targets in terms of greenhouse gas emissions reductions, energy efficiency and resilient energy systems for 2035, and a detailed 8 Year Action Plan - approved by City Council in April 2015.

Both *The Way We Green* and Edmonton's Community Energy Transition Strategy instruct the City to "lead by example" to achieve its sustainability and resilience goals, and recognizes that the City must model the way for sustainable living that it wants to encourage in the community.

The city has "lead by example" by developing the *Change for Climate Edmonton Declaration* (2018) which commits to "establishing, implementing, and maintaining GHG inventories, targets, action plans and reporting mechanisms consistent with the Paris Agreement and commitments made through the Global covenant of Mayors for Climate and Energy".

The city has also lead by example in development of transformational initiatives including:

- Development of Blatchford which will turn 535 acres in the heart of Edmonton into one of the world's largest sustainable communities. The neighbourhood will create an opportunity for 30,000 residents to live a unique and sustainable lifestyle. The community will incorporate best practices for sustainable urban design including increasing density; prioritizing design that promotes walking, cycling or transit; creating a mix of housing, retail, commercial and public spaces; and incorporating significant park and green spaces.
- Support for a Downtown District Energy system. In 2017, ENMAX released a Design Basis Document

that outlines the design, construction, and operation of a potential Downtown District Energy System (DES), which would provide cost-effective and environmentally responsible thermal energy to individual buildings in the downtown core. City Council has approved additional funding to further advance the design of this system in order to make informed decisions on the potential future construction of this system. Additional work being conducted in 2018 will also include assessment of City buildings, in the area of the District Energy system, for deep green retrofits that would compliment a possible district energy system.

The new City of Edmonton Greenhouse Gas Management Plan (2019-2030 Civic Operations) was developed in accordance with the implementation of the Edmonton's Community Energy Transition Strategy and 8 Year Action Plan, specifically under *Tactic 4.7.15B: Update the City Operations Greenhouse Gas Management Plan.*

The main drivers for the need to update the 2012 Plan include:

- **Changes in inventory and reporting best practices** recommends the inclusion of GHG emissions from public transit assets and operations. These GHG emission sources were excluded in previous municipal / public section greenhouse gas inventory protocols and therefore management plans. The 2012 Plan was developed based on the ICLEI *International Local Government GHG Emissions Analysis Protocol* (IEAP) (Version 1.0, October 2009)[1]. However, since the development of the 2012 Plan, the older protocol has become obsolete and been replaced by *The Climate Registry (TCR) General Reporting Protocol*[2] (Version 2.1, January 2016) as the best practice for local government greenhouse gas emissions quantification and reporting.

- **Strengthening the alignment with emerging federal and provincial policies and programs.**
  - **Pan Canadian Framework**: To demonstrate Canada's commitment to the Paris Agreement, the federal government led the collaborative development of The Pan Canadian Framework for Clean Growth and Climate Change - a collective plan to grow the economy while reducing emissions and building resilience to adapt to a changing climate. The plan aims to reduce greenhouse gas emissions by 30% below 2005 by 2030 and was endorsed by eight provinces (including Alberta) and three territories in fall 2016. The City's 2012 Plan has a baseline year of 2008.
  - **Alberta's Climate Leadership Plan; and Renewable Electricity Plan (REP):** Alberta's Climate Leadership Plan provides both a framework and funding sources through the introduction of the carbon levey to accelerate climate change action in the province. The REP is expected to add 5,000 megawatts of renewable electricity capacity by 2030, enable accelerated shut-down of coal fired generation and will put Alberta on a path to achieve its target of 30% renewable electricity by that time.

- **The Way Ahead Renewal:** Includes review and update of corporate outcomes, performance measures, and targets; an opportunity to affirm Council commitment to climate change mitigation;

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[1] *ICLEI. 2009. International Local Government GHG Emissions Analysis Protocol (IEAP) (Version 1.0, October2009)* *http://archive.iclei.org/fileadmin/user_upload/documents/Global/Progams/CCP/Standards/IEAP_October2010_color.pdf*

[2] *The Climate Registry. 2016.General Reporting Protocol for the Voluntary Reporting Program. (Version 2.1, January 2016)* *http://www.theclimateregistry.org/tools-resources/reporting-protocols/general-reporting-protocol/*

The Climate Registry. 2010. Local Government Operations (LGO) Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories (Version 1.1, May 2010). https://www.arb.ca.gov/cc/protocols/localgov/pubs/lgo_protocol_v1_1_2010-05-03.pdf

- **Better data and information; changing technologies; improved internal processes:** improved energy management platform, routine building energy audits to support improved integration of energy retrofits with routine capital rehabilitation program, greater understanding and industry capacity of building energy modeling for existing buildings; emerging technologies like electric buses, along with dramatic price decrease in technologies like solar photovoltaics, LED lighting, etc.

Based on the drivers outlined above and the Energy Transition Plan's strategic direction of dynamic steering, this compels Administration to review and revise dated assumptions and previous cost benefit results that no longer apply.

2. Principles & Approaches Used to Develop This Plan

This plan applies the following approaches, including but not limited to those proposed in The Way We Green and Edmonton's Community Energy Transition Strategy:

- **Acknowledge that there is an environmental cost to emitting carbon dioxide that is not reflected in traditional economic models and pricing systems**; (Refer to Section 3: The Cost of Carbon)
- **Apply best management practices to ensure its investment and operating decisions are informed by triple-bottom-line analyses, financial lifecycle analyses** to understand cost and benefits of investment options over their life spans including cost of carbon and other externalities in these analyses; and application of consistent, conservative methodologies for estimating future energy prices.
- **Recommends a hierarchical investment approach** that where possible, prioritizes in the following order "Avoid" (avoiding wasteful energy and carbon-intensive practices and/or purchasing or construction of new assets), "Reduce" (improve energy efficiency), "Replace" (replacing high carbon energy sources with low carbon sources) and "Offset" (where action is taken to reduce GHG emissions in one place to offset emissions that occur elsewhere).
- **Use a dynamic / adaptive steering approach**. As we proceed with the civic operations GHG Management Plan, we understand the need for flexibility. While the initiatives outlined in this Plan represent our best solutions today, we expect the solutions will evolve over time as: (a) new technologies and information emerge and/or (b) social, economic and environmental conditions change. As such, the Plan applies a phased and flexible approach to GHG management, careful not to place all "eggs in one basket" nor take high risk positions that could lock in sub-optimal solutions. Moreover, it calls for a dynamic steering approach that includes: (a) continual surveillance of risks, opportunities and performance, (b) timely feedback loops, (c) continual evaluation of next-steps and (d) ability to alter course quickly as new information and opportunities emerge
- **Collaborative, integrated implementation approach.** This plan was developed through a year long collaborative process not only with those involved in planning, design and delivery of infrastructure projects, but also with key internal City stakeholders involved in delivery of essential community building, social / cultural / recreational programming as well as emergency services. This plan was developed in recognition that GHG emissions reductions must be carried out in a balanced manner that considers and addresses impacts to the quality and level of services and programming that the City provides to its citizens.

3. The Cost of Carbon

How much should the City of Edmonton be willing to pay to reduce or avoid a tonne of GHG emission? This complex question is being considered by organizations around the world. The key point of agreement is that GHG emissions cause a wide range of damage that is not reflected or compensated for in the price of the fossil fuel consumed. It is argued that these externalities[3] should, in some way, be factored into the policy and investment decisions made by organizations, including local governments. Incorporating a "social cost of carbon" into cost benefit analysis is an approach that can be used to internalize these costs.

Environment Canada[4] describes the concept and derivation of the Social Cost of Carbon:

> *"The Social Cost of Carbon (SCC) is a term used to describe an estimate of the monetary value in a given year of worldwide damage that will occur over the coming decades and centuries from emitting one additional tonne of carbon dioxide (CO2) emissions. Specifically, the SCC represents the marginal damage of an additional tonne of CO2 emitted into the atmosphere in a given year, expressed in dollars, based on an assumed global CO2 emissions path.*
>
> *To calculate the SCC, it is necessary to project the impacts of the assumed global CO2 path on the climate (e.g., temperature, precipitation and weather events). It is then necessary to determine the physical impacts associated with those climate impacts (e.g., sea levels, agriculture, forests, water availability, pests). An economic value then needs to be placed on the physical impacts to generate a monetary value for the emission.*
>
> *Once the SCC values are generated, multiplying the appropriate SCC value for a given year by the total expected CO2 emissions reductions (or increases) for that year, and then summing the discounted values over the time period considered for analysis, allows these GHG benefits (or costs) to be considered within cost-benefit analysis…*
>
> *The SCC values increase over time, as emissions accumulate in the atmosphere and the cost associated with an additional tonne of CO2 emissions increases."*

Although an internal social cost of carbon has not been established and formally adopted by the City of Edmonton for use in triple bottom line lifecycle cost benefit analysis and decision making processes, the concept of SCC is applied to the cost benefit analysis supporting this Plan.

The Unit Net Present Value Cost or Benefit (per tonne of carbon abated over the lifespan of the abatement measure) of various options is compared to the Net Present Value 50th (reflecting average probable climate change impacts) and 95th percentile SCC values (reflecting lower probability, worst case, high-cost climate change impacts) for 2019 and 2030 to indicate whether the investment makes sense from a Sustainable Return on Investment perspective over those future 12 years. If the Unit Net Present Value Cost or Benefit of a particular option is less costly than the SCC value, it makes sense to proceed. If the Unit Net Present Value Cost or Benefit of a particular

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[3] An externality is a cost or benefit conferred upon an agent who was not part to the transaction. The presence of externalities leads to a sub-optimal allocation of resources as the full costs to society are not taken into account in agents' decision making.
[4] Environment and Climate Change Canada. 2016. Technical Update to Canada's Social Cost of Greenhouse Gas Estimates March 2016.

option is more costly than the SCC value, it means it may not be the most appropriate to invest in that particular option at this time from a climate change mitigation perspective. That said the SCC does not consider other desired outcomes of advancing energy efficiency and clean growth such as promoting local economic diversification, improving economic productivity and competitiveness, etc.

4. Description of the City's reporting program

To estimate GHG emissions, from corporate operations, the City applies the *TCR Local Government Operations (LGO) Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories* (Version 1.1, May 2010) (the TCR Protocol). The TCR Protocol identifies a number of GHG emissions sources that should be included in a municipal government's GHG Inventory.

Buildings Emissions: Includes GHG emissions from owned and leased[5] facilities where the City pays utility costs.

Fleet Emissions: Includes emissions from all vehicles operated by City departments, including Transit operations.

Streetlights Emissions: Includes greenhouse gas emissions from electricity used to power roadway lights, traffic lights and signals, lane lights, security lights, and miscellaneous lighting throughout Edmonton.

Landfill Emissions: Includes emissions from three landfills that are owned by the City of Edmonton: Beverly Landfill (Rundle Park), South Side (Millwoods Golf Course) and Clover Bar Landfill.

Water and Wastewater Treatment and Drainage Emissions: Emissions from water and water treatment, and drainage are not included in the City of Edmonton's inventory given that responsibility for these operations resides with EPCOR. Based on legal review, EPCOR, although a corporation wholly owned by The City of Edmonton, has a governance structure that might not meet the protocol's definition of "operational control". EPCOR has reported its energy use and GHG emissions voluntarily to the City. EPCOR will establish a GHG Management Plan with associated policy, procedures, action plans, reduction targets, and performance metrics. The reduction targets and performance metrics associated with Water, Wastewater, and Drainage in the City of Edmonton will be brought forward to City Council for approval as part of the Performance Based Rates ("PBR") application process. Capital projects and operating activities required to achieve the reduction targets will be brought forward in PBR applications or potentially as a Non-Routine Adjustment ("NRA") when significant reduction opportunities are identified outside the PBR cycle. The various reduction scenarios presented in the management plan excludes emissions from EPCOR.

Green Electricity: includes displacement of electricity consumed by the corporation through the purchase of renewable energy credits. Section 8.1 of this report provides greater detail on green electricity. The purchase of green electricity from off-site wind and solar farms is the single most cost efficient (from an intial cost perspective) and expedient option for aggressive reductions of the City's GHG emissions, and the least impacted by the constraints of city operations noted throughout this report.

[5] *This could include facilities where the City is the leasee (Scope 1 or 2 emissions) or the leasor (Scope 3 emissions).*

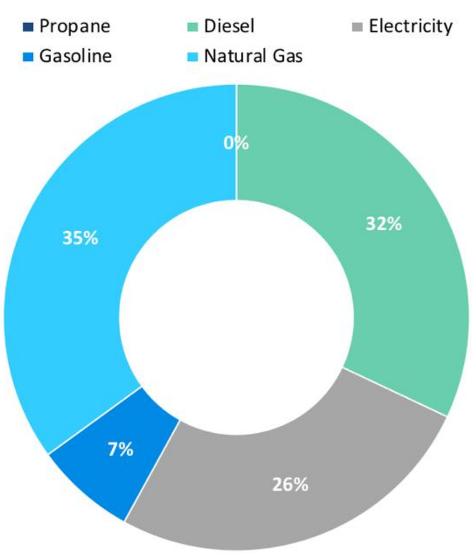
5. Review of the City of Edmonton's Civic Operations Energy Assets

Table 1 and Table 2, and Figure 1 and Figure 2 below present quantities and percent breakdowns of the energy use and GHG emissions by fuel type and City asset type.

Table 1: Energy Use by Fuel Type Consumed and City of Edmonton Asset Type (2016)

ASSET TYPE	ELECTRICITY (KWH)	NATURAL GAS (GJ)	GASOLINE (GJ)	DIESEL (GJ)	TOTAL (GJ)
Buildings	165,613,385	1,318,717	-	-	1,914,925
Street Lights	76,611,562	-	-	-	275,802
Fleet	34,688,303[6]	-	221,225	1,123,893	1,470,042
Waste Management Facilities*	28,585,597	142,534	6,125	143,066	394,646
Water & Wastewater Treatment	Included in EPCOR's energy use and GHG inventory (Appendix A)				
Drainage**	5,910,361	48,091	16,740	31,893	118,033
Total	311,409,208	1,509,342	244,090	1,298,852	4,173,448

**Includes all Waste Services buildings and fleet related to collections, processing and disposal.*
***Drainage energy use and Greenhouse Gas Emissions will be transferred to EPCOR for the 2017 reporting year and are therefore not included in forecasting and savings estimates.*



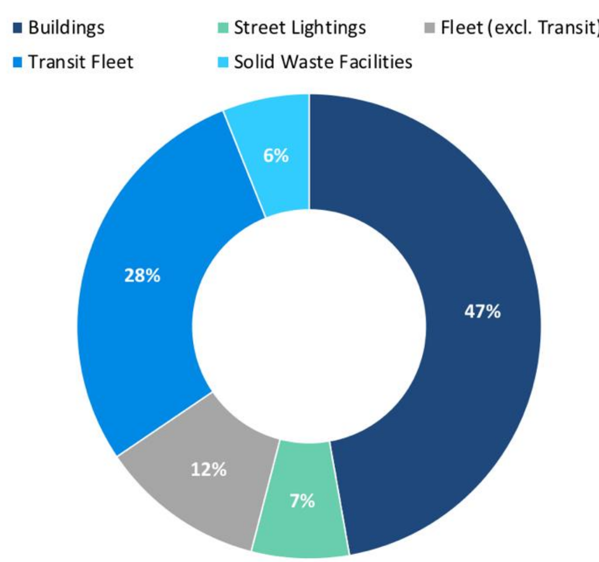


Figure 1: Percent Breakdown of Energy Use by Fuel Type and by GHG by Asset Type (2016)

Table 2 identifies City assets that both created and reduced emissions in 2016. The City of Edmonton's urban forest includes trees and vegetation planted at City-owned properties and right of way, Renewable Energy Certificates (RECs) are certificates that the City currently purchases to offset its electricity emissions. Further discussion is provided on RECs in section 8.1 of this report.

[6] *LRT train operations only*

Table 2: GHG Emissions and Reductions by Fuel Type Consumed and City of Edmonton Asset Type, tCO2e (2016)

ASSET TYPE	ELECTRICITY	NATURAL GAS	GASOLINE	DIESEL	METHANE	CARBON DIOXIDE	TOTAL
Emissions							
Buildings	157,333	68,675	-	-	-	-	**226,008**
Street Lightings	72,781	-	-	-	-	-	**72,781**
Fleet (excl. Transit)	-	-	12,364	19,993	-	-	**32,357**
Transit Fleet	32,954	-	3,516	59,863	-	-	**96,333**
Solid Waste Facilities	27,156	7,423	440	10,345	-	-	**45,364**
Drainage	5,615	2,504	1,194	2,350	-	**-**	**11,663**
Landfills	-	-	-	-	36,242	**-**	**36,242**
Emissions Subtotal	**295,839**	**78,603**	**17,515**	**92,551**	**36,242**	**-**	**520,750**
Reductions							
Urban Forest	-	-	-	**-**	-	(3,484)	**(3,484)**
Renewable Electricity Credits	-	-	-	**-**	-	(72,891)	**(72,891)**
Total	**295,839**	**78,603**	**17,515**	**92,551**	**36,242**	**(76,375)**	**444,375**

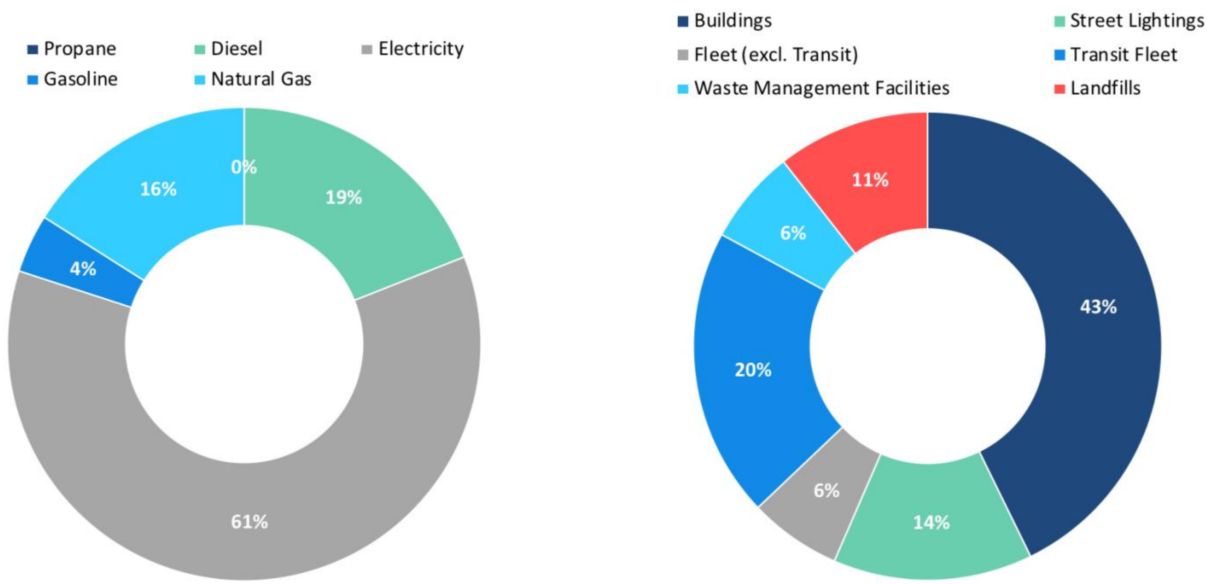


Figure 2: GHG Emissions Percent Breakdown by Fuel Type and by Asset Type (2016)

6. Baseline Greenhouse Gas Emissions Forecast

The Business-As-Usual Forecast assumes the following reductions are already in place through existing City policies and programs:

- Implementation of C532 Sustainable Building Policy;
- Completion of $9Million of energy retrofit to City-owned buildings over 2015-18 budget and
- Conversion of street light fixtures to LED (approx. 4,000 units/year).

Two other driving factors for decreasing greenhouse gas emission from City operations that are not directly related to City interventions are the year over year decrease in landfill gas emissions from the City's 3 closed landfills, and the expected decrease in the carbon intensity of the provincial electricity grid or 'greening the grid[7]' due to the phasing out of coal plants and developing more renewable energy.

The reductions from these 'Business As Usual' factors are summarized in Table 3 below.

Table 3: Anticipated Business As Usual Greenhouse Gas Reductions from City of Edmonton Civic Operations

GHG MITIGATING ACTIONS	FIRST YEAR OF PROGRAM OR WHEN REDUCTIONS BEGIN TO BE REALIZED	RATE OF DEPLOYMENT PER 4 YEAR BUDGET CYCLE	TOTAL GHG REDUCED PER YEAR BY 2030 DUE TO IMPLEMENTATION OF THE ACTION
City Policy C532 Standard - Minimum 40% better energy and greenhouse gas savings as compared to Code[8]	2021	10 to 15 buildings*;	11,000 tonnes
1% for on-site energy generation	2021	10 to 15 buildings*;	3,400 tonnes
Energy retrofit of existing buildings during 2015-18 cycle	2017	10 to 15 building projects**	10,000 tonnes
LED Street Light Replacement	2012	4,000 units /year of various street light types (e.g., arterial, collector, local, alley)	5,100 tonnes
Total GHG Reduced based on CoE initiatives			**29,500 tonnes**
Emissions reduced from closed City-owned landfills			8,300 tonnes
Emissions reduced from City's electricity consumption due to greening the grid.			140,400 tonnes
Total Reductions not attributed to CoE initiatives			***148,700 tonnes***
Total Reductions			**178,200 tonnes**

** Estimated based on 34 new buildings proposed in the 10 year capital plan; and approx. 50 buildings built between 2005 and 2016 that were over 500 sq.m. It should be noted that these savings are reductions from the business as usual. New construction will increase the total carbon emissions of the city however alignment with C532 will reduce these emissions to 11,000 tCO2e less than construction to code.*

[7] *Climate Leadership Plan, https://www.alberta.ca/climate-leadership-plan.aspx*
[8] *2011 National Energy Code for Buildings (as adopted by the Alberta Building Code)*

***Based on extrapolation of the number of buildings covered by the energy audits, the GHG savings potential of those buildings, the capital cost of achieving those savings and the 2015-2018 funding for energy retrofits. And confirmed by IIS in completion of the first retrofits that this savings is reflective of actual savings. Refer to capital cost and carbon abatement potential from the 'Modified Sample' in Table 20.*

Under the Business-As-Usual Scenario, Civic Operations GHG emissions by 2030 would be 6% higher than in 2005 (Figure 3). The modest increase in greenhouse gas emissions over the next 12 years is predominantly attributed to the decrease in the carbon intensity of the provincial electricity grid from 1,000 g/kWhr in 2005 to what is anticipated to be ~420g/kWhr by 2030, based on full implementation of the province's Renewable Electricity Program[9]. Even under previous grid factor forecasts generated in 2014, prior to change in provincial government, introduction of the Renewable Electricity Program and no accelerated shutdown of coal, the grid factor was still expected to decrease to 520 g/kWhr. It should be noted that under this older or worst case scenario, the City's civic operations GHG emissions by 2030 would be ~16% higher than in 2005.

Figure 3 presents the emissions forecast based on the business-as-usual scenario.

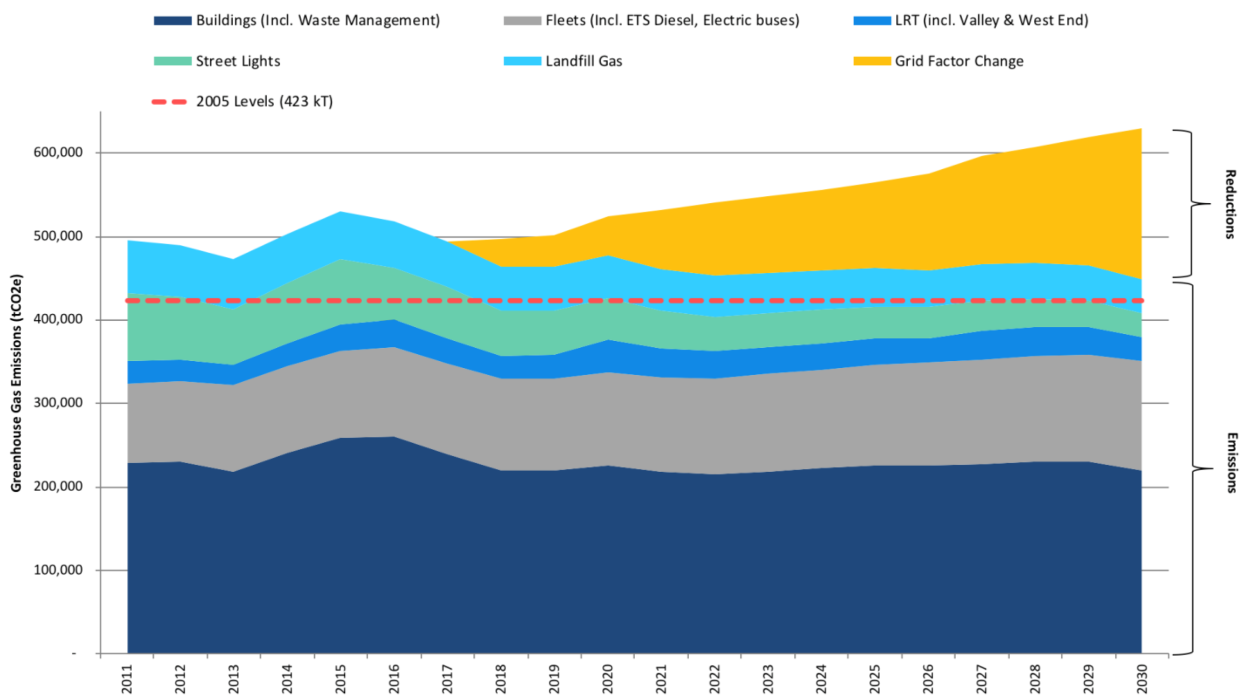


Figure 3: Forecast of Annual Greenhouse Gas Emissions – Business-As-Usual Scenario

Appendix B provides the asset specific forecasts under the Business As Usual scenario and outlines the assumptions used to support the projected energy and greenhouse gas emissions up to 2030.

[9] *Government of Alberta. Renewable Electricity Program. https://www.alberta.ca/renewable-electricity-program.aspx*

7. Cost Benefit Analysis Findings

7.1. A Consistent Cost Benefit Approach

In support of a portfolio approach to reducing Greenhouse Gas emissions across the corporation, a consistent approach was developed and used to compare various GHG abatement options and their associated lifecycle cost benefits.

The best available and most current capital costs, along with energy and GHG savings and cost savings, and operations and maintenance savings data were compiled from recently commissioned building energy audits, business cases, and or schematic design reports in regards to the following options:

- Building energy retrofits;
- Small scale (e.g., 20 kW on a fire hall) and large scale (e.g., 650 kW on a bus garage) microgeneration, building-mounted solar photovoltaic systems;
- Heat and power cogeneration for buildings;
- Electric buses;
- LED street lights;
- Green electricity from new wind or solar farms.

Input parameters on current and future utility rates and carbon levy, current and forecasted electricity grid factors, and discount rate were standardized to ensure "apples-to-apples" comparison of cost benefit outputs.

The cost benefit output parameters include: simple payback period, rate of return, unit carbon abatement cost, net present value benefit to cost ratio, and unit net present value per tonne of carbon abated. Refer to Appendix E for descriptions and equations of the various cost benefit output parameters.

7.1.1. Cost Benefit of Building Energy Retrofits

Table 4 summarizes the cost benefit results for building retrofits only. A sample of 17 buildings out of the total of 24 recently commissioned energy audits were reviewed. The 17 buildings are a representative sample of the City-owned real estate portfolio and covers firehalls, libraries, community centres (e.g., seniors centre), leisure centres (e.g., smaller neighbourhood pool and arena facilities), transit centres, police stations, and industrial / operations facilities (e.g., ecostations, vehicle / bus storage and repair shops). Seven of the 24 were excluded to prevent over representation of certain building types and size – specifically ecostations, transit centres and firehalls).

The "All Samples" results shown in the following table covers the 17 buildings. The "Modified Sample" consists of 11 buildings. It excludes the Mitchell bus garage[10] and five buildings under 1,000 square meters in gross floor area. The rationale was that an accelerated energy retrofit program would be focused on the largest and most energy or greenhouse gas intensive buildings to realize higher absolute energy and GHG savings, as evidenced by Figure 4, which indicates that there is up to a 100 times difference in absolute GHG reduction potential between the largest of buildings (e.g., bus barn) as compared to the smallest of buildings (e.g., transit centre, firehalls).

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[10] Mitchell Garage's audit found an unusually high GHG reduction potential. It has been removed to prevent over-estimation of the GHG reduction potential of the overall City-owned building portfolio.

The cost benefit results between the two different samples were fairly similar, but overall, the modified sample which is intended to better reflect a focused energy retrofit program did provide slightly better cost benefit outcomes.

Table 4: Summary of Findings from Review of Recent Building Energy Audits

	ALL SAMPLES		MODIFIED SAMPLE	
PARAMETER	AVERAGE	MEDIAN	AVERAGE	MEDIAN
Start of Operation (year)	1974	1974	1973	1975
Square Meters	5004	2137	5618	2346
Energy Use Intensity (ekWh/m2)	1249	960	1388	1003
% Energy Savings Potential relative to baseline (1st yr)	37%	39%	36%	36%
% GHG Reduction Potential relative to baseline (1st yr)	36%	35%	34%	37%
Unit Carbon Abatement Cost	$136	$123	$112	$116
NPV/tCO2e over 20 Years	$111	$88	$118	$90
Simple Payback (years)	9.9	9.2	10.1	9.1
Discounted Payback (at 2.5%) (years)	10.8	9.4	11.6	9.4
Cost Benefit Ratio (NPV Benefits / Capital Cost)	2.0	0.6	2.5	0.6
Rate of Return (Based on Discounted Payback)	9.2%	10.6%	8.6%	10.9%

Table 4 shows that on average building retrofits (based on the modified sample) can achieve approximately 35% in both energy savings and greenhouse gas reduction, with simple payback periods of about 9 years, net present value benefit to cost ratio over 20 years of 3 and rate of return of 9%. Therefore, the business case for achieving GHG reductions from a financial return on investment is very strong.

It should be noted that connection to any existing or future district energy system would be considered in these types of energy retrofits. However development of the district energy system itself is not considered in this report.

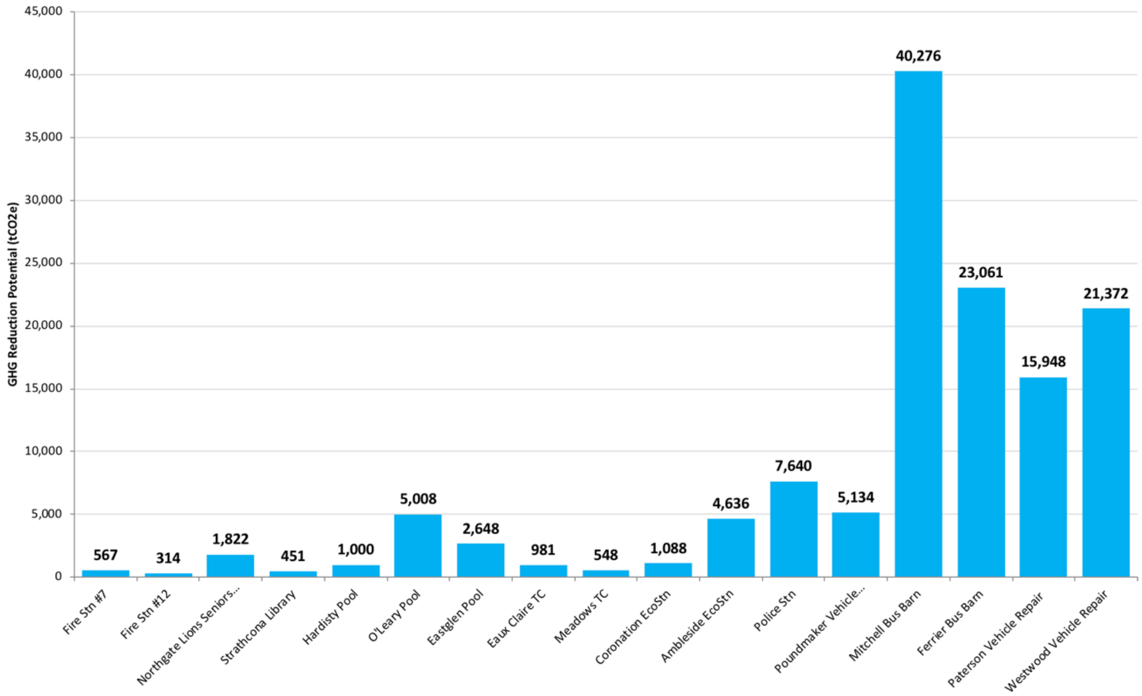

Figure 4: Lifetime Greenhouse Gas Reduction Potential of Various City Buildings Based on Audit Recommended Energy Upgrades

7.1.2. Comparative Lifecycle Cost Benefit between various Carbon Abatement options

The following three figures provide a comparison of the lifecycle cost benefit outcomes for various carbon abatement options. The analysis shows that heat and power cogeneration, building energy retrofits and LED street lights are the top three options for carbon abatement, followed by large scale microgeneration solar photovoltaics and electric buses. Small scale solar photovoltaics have the lowest lifecycle benefits. Green electricity premiums are excluded from Figures 5 to 7 because they are simply premiums paid on top of the base electricity rate, which no cost recovery component.

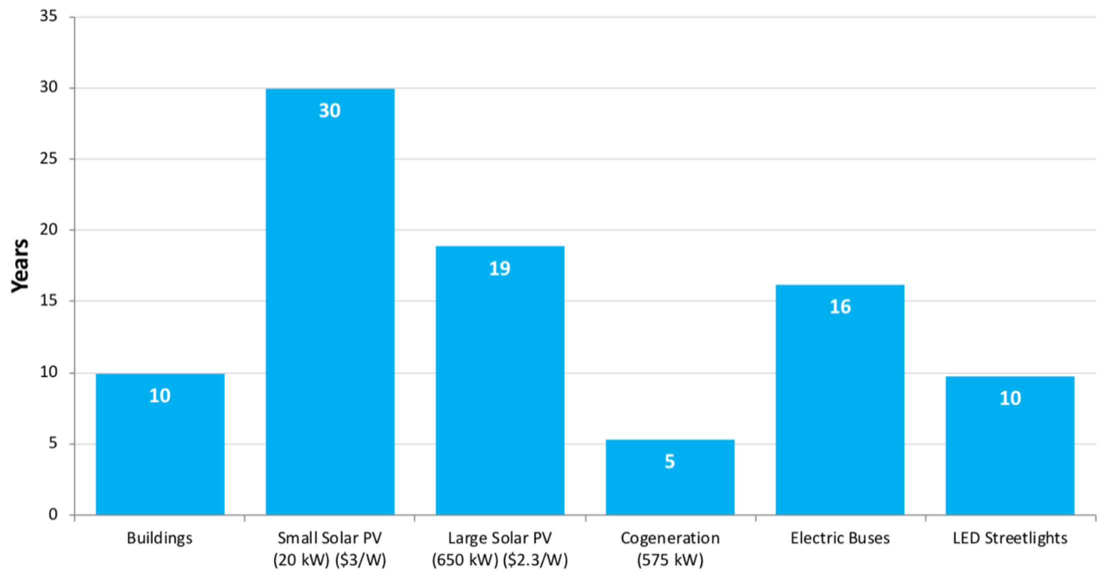

Figure 5: Simple Payback Periods of various Carbon Abatement Options

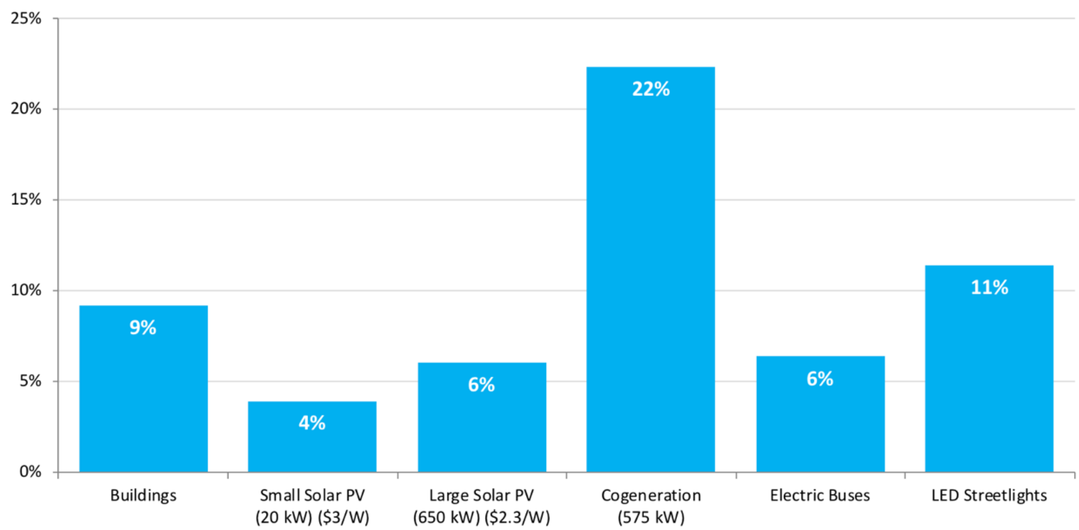

Figure 6: Rate of Return (based on discounted payback) of Various Carbon Abatement Options

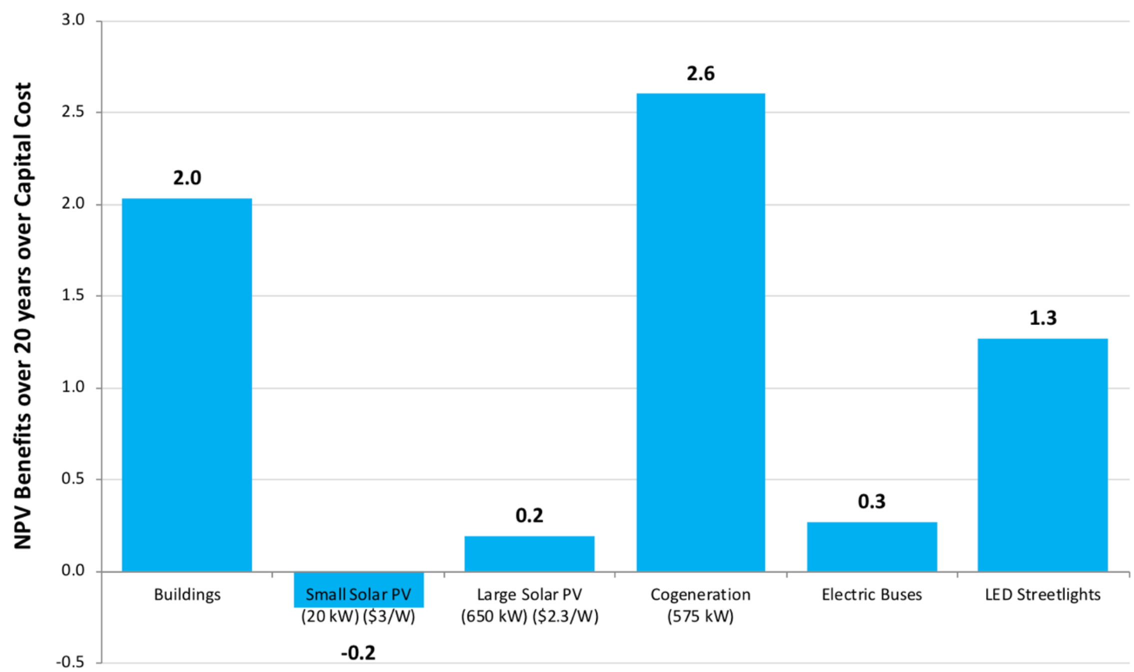

Figure 7: Net Present Value Benefit to Cost Ratio of Various Carbon Abatement Options

Figure 8 compares the Unit Net Present Value Benefit (per tonne of carbon abated over the lifespan of the abatement measure) of various options with the Net Present Value 50^{th} percentile (reflecting average probable climate change impacts). The 95^{th} percentile SCC values (reflecting lower probability, worst case, high-cost climate change impacts) for 2019 and 2030 is $216/tonne and $291/tonne, respectively. They were not shown on the figure as the Unit Net Present Values of the various options except for green electricity purchased from new solar utilities exceeded the 2030 50^{th} percentile SCC values. This figure helps to show whether the investment makes sense from a Sustainable Return on Investment perspective over those future 12 years. If the Unit Net Present Value Cost or Benefit of a particular option is less costly than the SCC value, it makes sense to proceed. If the Unit Net Present Value Cost or Benefit of a particular option is more costly than the SCC value, it means it may not be the most appropriate to invest in that particular option at this time from a climate change mitigation perspective. The data below is able to demonstrate that there is a strong Sustainable Return on Investment business case to invest in all of the carbon abatement options proposed within the 2019-2030 timeframe under even the average probable climate change impacts scenario, with the exception of small scale microgeneration and green electricity purchased from new large scale utility solar. All options would be considered cost effective when compared to the 95^{th} percentile SCC values for 2019 ($216/tonne) and 2030 ($291/tonne)

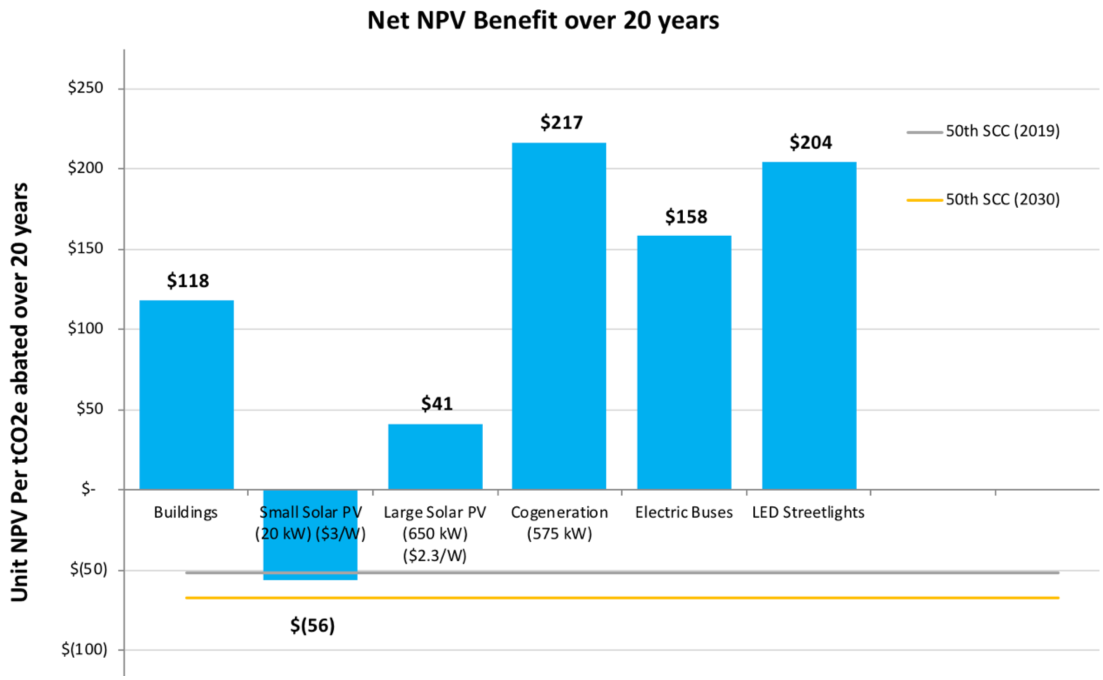

Figure 8: Unit Lifecycle Cost Benefit (NPV) of Various Carbon Abatement Options versus Social Cost of Carbon

7.2. Limitations of Cogeneration

Generating electricity with natural gas through technology like cogeneration can substantially reduce carbon emissions as compared to consuming electricity from the current electricity grid. Due to the relatively high electricity prices compared to natural gas, this solution is also very effective at reducing utility costs. Cogeneration is the most cost effective when implemented and sized to operate in facilities that have consistently high year round heating loads, such as pools. For this reason, Cogeneration cannot be widely applied throughout all City buildings. As well, as the grid gets cleaner, the ability for cogeneration to reduce GHG emissions diminishes. Cogeneration equipment typically has a life of 15 years; therefore if implemented in the near future, cogeneration could provide effective GHG reductions. For these reasons, it is recommended that cogeneration be explored on a project by project basis as a part of the broader building retrofit program, but the civic operations greenhouse gas management plan would not be recommending a specific cogeneration program.

7.3. Uncertainty of future cost of electric buses

Of all of the carbon abatement options proposed, the future cost of electric buses is considered the most uncertain due to this technology being in the early stages of market adoption. Building retrofits, LED street lights and even solar photovoltaics, in comparison, are considered mature and prevalent technologies, where soft project and labour costs are becoming or have become more of a dominant cost driver than hard costs of the technologies. For these technologies, the hardware or equipment cost is not expected to experience substantial decrease in future years. The incremental difference in capital between electric and diesel buses is expected to dramatically narrow in future years. But it is uncertain how quickly this will happen. The Plan’s cost analysis is quite conservative in that future anticipated decreases in incremental cost have not been incorporated.

7.4. Uncertainty in availability of incentives

Historically, provincial incentives or rebates for municipalities to carry out building energy upgrades or on-site solar installations have been administered by the Municipal Climate Change Action Centre (MCCAC). For instance, the currently (2017) active Alberta Municipal Solar Program offers between $0.55/W to $0.90/W depending on total installed capacity of the system, and helps to cover up to 25% of eligible expenses. However, these incentives are first come first serve. If available, they could help improve the business case of a single or a small number of projects, but the City would not be able to depend on a 25% rebate over a large portfolio of projects that cost several or tens of millions of dollars. More recently, the newly established Energy Efficiency Alberta has rolled out a number of rebates for businesses, non-profit and institutional sectors to upgrade their facilities' lighting, and mechanical systems. But similar to the MCCAC programs, the funding is not at levels where a large municipality such as Edmonton can depend on to offset capital costs for large scale deployment of energy upgrades across its building portfolio in a significant way.

Despite uncertainty in availability of incentives the city should make every effort to use available incentives in the work included in this plan, both to reduce capital costs of projects and to help lead by example. Appendix E includes more information on incentive programs.

7.5. Sensitivity Analysis

Three different scenarios were evaluated as part of a sensitivity analysis to better understand the implications of different parameters on lifecycle cost benefit.

- Discount rate of 5%: this rate was determined by doubling the discount rate recommended by the City of Edmonton Finance Department at the time of plan development.
- Fuel escalation rate of 5%
- Fuel escalation rate of 10%

For each scenario, only the specific parameter in question was changed in the base case, with all other input parameters remaining the same.

Appendix F provides summaries of the effects these changing parameters have on discounted payback period, rate of return, net present value benefit to cost ratio and unit net present value benefit per tonne of carbon abated over 20 years. In general the various financial return on investment metrics for all carbon abatement options will decrease slightly when the discount rate is increased from 2.5% to 5%, while the metrics improved as the fuel escalation increased.

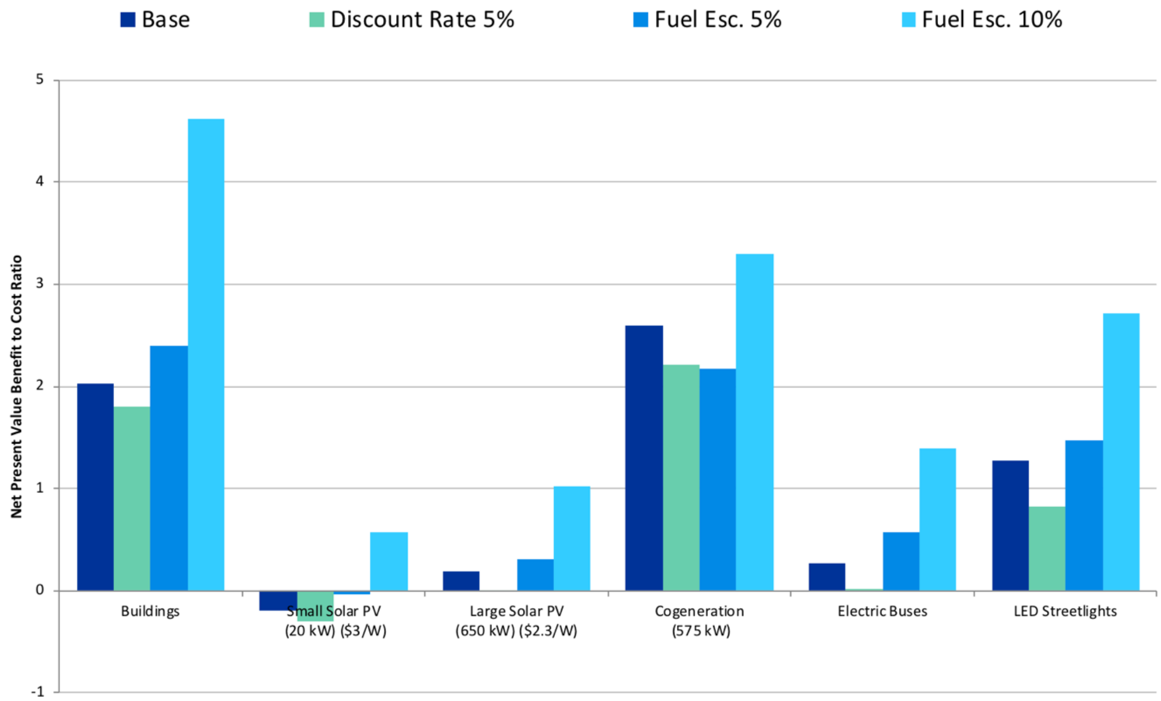

Figure 9: Sensitivity Analysis Results for Net Present Value Benefit to Cost Ratio

8. Greenhouse Gas Reduction Target Scenarios

Three greenhouse gas reduction scenarios were explored to identify ways that the City of Edmonton could reduce its greenhouse gas emissions from civic operations:

- 30% below 2005 baseline by 2030, to align with the Pan Canadian Framework targets;
- 50% below 2005 baseline by 2030: Target achieved through implementation of Scenario 1 plus additional green electricity purchase only;
- Carbon neutrality by 2030.

Each scenario is accompanied by: greenhouse gas reduction initiatives across buildings, fleets, street lighting and green energy procurement; the associated preliminary capital and operating budget requirements for the next three budget cycles to achieve those initiatives; and the lifecycle cost benefits of meeting the specific target. Detailed methodology and assumptions used to determine the cost benefits of various energy conservation and greenhouse gas abatement options are found in Appendix E. Scenarios 1 and 2 were developed and supported by the best available cost information on energy conservation and abatement options that are currently available and technically feasible for large scale implementation. Scenario 3 is heavily dependent on access to significant quantities of renewable or low carbon natural gas and alternative vehicle fuels that are not yet widely available from local or even regional markets. For instance, in 2017 there was no market in Alberta to produce and sell renewable natural gas or biodiesel with significantly lower carbon content. The technology might exist to produce these products, but the local/regional market signals and supportive policy framework are not there to enable deployment at a level that could even meet the City's fuel consumption levels. Therefore scenario 3 is more theoretical and highly conceptual at this time, requiring effort and investment by the City to catalyze development of this emerging industry.

8.1. Background on green electricity procurement

Similar to other public sector organizations within Alberta (e.g., City of Calgary, Alberta Infrastructure), the purchase of renewable energy certificates[11] has been a significant component in the City of Edmonton's greenhouse gas emissions management framework to date. Under the 2012 City Operations Greenhouse Management Plan, to achieve the targets set in the Plan to reduce greenhouse gas emissions to 50 percent of 2008 levels by 2020, approximately two thirds of the emissions reductions would be attained through the purchase of renewable energy certificates. Between 2013 and 2016, annual purchases of renewable energy certificates ranged between 20,500 tonnes to 72,900 tonnes (only accounts for approximately 5 to 15% of the City's total emissions), at an average unit cost of $9 to $10 per tonne per year.

The current criteria used by the City for buying renewable energy certificates include:

- must be produced in Alberta;
- rigorously verified and certified by a reputable organization; and
- the least cost of the choices meeting criteria a and b.

Current renewable energy certificates are purchased year to year from wind, hydro, and biomass facilities within the province. Although this procurement approach is **very cost effective, it could be considered insufficient for demonstrating true incremental greenhouse gas reductions that are above business as usual.** To demonstrate the City's leadership and commitment to greening the electricity grid, a green electricity

[11] *Renewable energy certificates are the financial or transactional products that represent the quantity of renewable or green electricity that is purchased by an organization. An organization must purchase the certificates from a renewable electricity facility(ies) in order to claim that its organization uses renewable electricity.*

agreement that is tied to specific new facility(ies) is necessary in order to meet the criteria of 'additionality'. Other than 'additionality', other guiding principles or evaluation criteria for green electricity could include: potential impact on local energy resilience, cost effectiveness, and mitigation of long term electricity price volatility. Descriptions of these principles or criteria are found in Appendix C.

8.2. Scenario 1: 30% below 2005 by 2030

To achieve the Pan Canadian Framework Target of 30% below 2005 levels by 2030, Table 5 identifies the additional initiatives needed to achieve GHG reductions above and beyond the business-as-usual scenario.

Table 5: Proposed Initiatives to Achieve a Reduction of 30% Greenhouse Gas Emissions below 2005 levels by 2030 from City of Edmonton Civic Operations

ADDITIONAL GHG REDUCTION INITIATIVES	BUSINESS-AS-USUAL DEPLOYMENT PER 4 YEAR BUDGET CYCLE	PROPOSED ADDITIONAL DEPLOYMENT PER 4 YEAR BUDGET CYCLE	TOTAL NUMBER OF PROJECTS, OR INSTALLATIONS (2019-2030)	TOTAL REDUCTIONS PER YEAR BY 2030, BASED ON ANTICIPATED GREENING GRID
Energy retrofits of existing buildings	0[12]	~35 buildings	~100 building projects	45,000 tonnes
Accelerated microgen solar PV program[13]	10 to 15 buildings; or 2.4MW	An additional ~6.9 MW (equivalent to 27 NHL rinks; 44,000 sq.m of roof, wall or ground space)	20 MW (equivalent to 6% of total civic operations electricity use)	10,000 tonnes
Electric Buses	0[14]	220 buses/per cycle starting in 2023	440 buses	17,800 tonnes
LED Street Light Replacement	4,000 units/year of various street light types (e.g., arterial, collector, local, alley)	46,000 units of "low hanging fruit" street lights types (over 1 budget cycle)	46,000 units	5,500 tonnes
Renewable Electricity Procurement	n/a	-	45% of corporate electricity consumption (2030)	72,900 tonnes
Total Reductions	-	-	-	151,200 tonnes

Table 6 below outlines the budgetary requirements along with the lifecycle cost benefit in terms of net present value over the next 20 years for the portfolio of proposed projects to reach the 30% reduction strategy. Methodology, assumptions and analysis on the capital cost and lifecycle cost benefit is found in Appendix E.

Many of the energy audit reports did not include project soft costs, such as additional fees to cover detailed design, project contingencies, and City's internal technical support and project management into the cost estimates of the recommended upgrades. Therefore, an additional 15% for project soft cost was applied to the studies' estimated capital costs for energy retrofits, cogeneration and solar photovoltaics. The feasibility study on upgrades of one existing and one proposed bus garages to accommodate electric buses included 25% for project soft costs and contingencies due to high project complexities. The LED street lighting cost estimate included a 17% overhead.

[12] The 2015-18 capital budget did include a $9 million profile for building energy retrofits however this funding was not approved to continue beyond 2018.
[13] See section 9.1 Alignment of Solar Projects for more information.
[14] One time purchase of 40 busses between 2017-2023 not an ongoing BAU deployment.

Table 6: Budgetary Requirements and Lifecycle Cost Benefit of Additional Initiatives to Achieve a 30% Reduction in GHG Emissions below 2005 levels by 2030

			TOTAL FUNDING BETWEEN 2019-2030 (TODAY'S DOLLARS)		
ADDITIONAL GHG REDUCTION INITIATIVES	**BUSINESS-AS-USUAL FUNDING PER 4 YEAR BUDGET CYCLE**	**ADDITIONAL FUNDING PER 4 YEAR BUDGET CYCLE**	**CAPITAL (ADDITIONAL)**	**OPERATING**	**NET PRESENT VALUE BENEFITS OVER 20 YEARS**
Energy retrofits of existing buildings	n/a	$26.7 Million	$80 Million*	-	$105 Million
Accelerated microgen solar PV program	~$7 Million**	~$15.3 Million	$46 Million***	-	$9 Million
Electric Buses	n/a	**Building infrastructure:** $80 Million over 2 to 3 cycles: **Buses:** $57 Million over 2 cycles	***Building Infrastructure*** ***:*** $80 Million ***Buses:*** $114 Million	-	$52 Million
LED Street Light Replacement	$3 Million	$6.5 Million if divided over 3 cycles	$20 Million	-	$25 Million
Green Electricity Procurement (New Wind: $20/MWh premium; New Solar: $40/MWh premium) 50/50 solar/wind split assumed, includes $1.5M base funding	-	$15.6Million****	-	$3.9 Million	-$61 Million
Total New Cost	-	-	$340 Million	-	$130 Million

**Total cost estimated based on capital cost of $7.5 Million to achieve 6.3 Tonnes/year of offsets (2016's grid factor), applying a soft project cost factor of 15% and extrapolating it to 45,000 tonnes (assuming 2030 grid factor of 0.42) (Refer to Appendix E: Table 18)*
*********based C532 Policy's 1% dedicated capital to on-site energy generation; and each installation being able to offset on average 5% of the energy use amongst each new capital building projects, and unit install cost of $2.75/W*
****based on current large scale microgeneration solar PV installation (e.g., 650 kW) cost of $2.3/W, solar generation potential of 1,150 kWh/kW/year and including a soft project cost factor of 15%*
***** Total summed operating cost for four years of green electricity procurement.*

Figure 10 shows the Forecast of the Annual Greenhouse Gas Emissions under the 30 Percent Reduction Scenario.

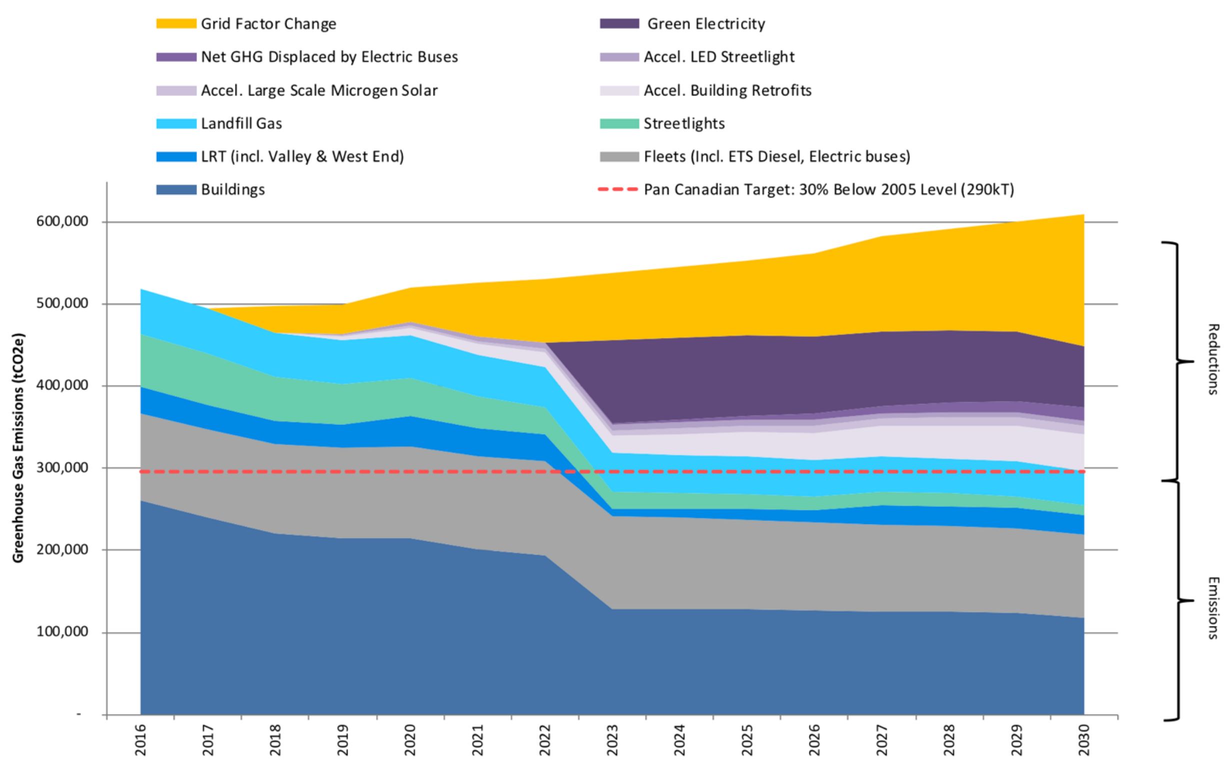

Figure 10: Forecast of Annual Greenhouse Gas Emissions – 30 Percent Reduction Scenario[15]

8.3. Scenario 2: 50% below 2005 by 2030

If the City of Edmonton proposes to exceed the Pan Canadian Framework and further demonstrate leadership to achieve a more aggressive reduction target – i.e., achieve a 50% below 2005 levels by 2030, additional reductions should happen through increased green electricity purchase.

One scenario is to simply increase the green electricity purchased from ~50% of the electricity consumed by the City to 100% of the corporate consumption. The details of this purchase methodology are provided in Appendix C. Scenario 2 does not propose any additional capital investments in City assets. Table 7 provides an overview of the GHG savings from Scenario 2.

Table 7: Additional Initiatives to Achieve a GHG Reduction of 50% Below 2005 Levels by 2030 (Scenario 2)

ADDITIONAL GHG REDUCTION INITIATIVES	BUSINESS-AS-USUAL RATE OF DEPLOYMENT PER 4 YEAR BUDGET CYCLE	ADDITIONAL DEPLOYMENT PER 4 YEAR BUDGET CYCLE	TOTAL NUMBER OF PROJECTS, OR INSTALLATIONS (INCL. BAU)	TOTAL REDUCTIONS PER YEAR BY 2030, BASED ON ANTICIPATED GREENING GRID (ABOVE BAU SCENARIO)
Energy retrofits of existing buildings	0[16]	~35 buildings	~100 building projects	45,000 tonnes
Accelerated microgen solar PV program[17]	10 to 15 buildings; or 2.4MW	An additional ~6.9 MW (equivalent to 27	20 MW (equivalent to	10,000 tonnes

[15] *Exact timing and rate of green electricity purchase will impact the wedge reduction intermittent profile although the 2030 outcome will remain unaffected.*
[16] *The 2015-18 capital budget did include a $9 million profile for building energy retrofits however this funding was not approved to continue beyond 2018.*
[17] *See section 9.1 Alignment of Solar Projects for more information.*

		NHL rinks; 44,000 sq.m of roof, wall or ground space)	6% of total corporate electricity use)	
Electric Buses	0[18]	220 buses/per cycle starting in 2023	440 buses	17,800 tonnes
LED Street Light Replacement	4,000 units/year of various street light types (e.g., arterial, collector, local, alley)	46,000 units of "low hanging fruit" street lights types (over 1 budget cycle)	46,000 units	5,500 tonnes
Green Electricity Procurement	-	-	~100% of civic operations electricity consumption (2030)	169,000 tonnes
Total Reductions	-	-	-	247,000 tonnes
Grayed out denotes same level of deployment as prescribed in 30% reduction target scenario				

Table 8 below outlines the budgetary requirements along with the lifecycle cost benefit in terms of net present value over the next 20 years for the portfolio of proposed projects in Scenario 2. This scenario proposes the same level of capital investment as Scenario 1. But the long term net present value cost benefit for Scenario 2 is lower than Scenario 1 and could potentially be in the negative because the additional green electricity purchased. As green electricity is simply a premium paid on top of existing electricity cost, the greater the purchase, the greater the cost; and this additional cost is not offset by any additional positive NPV benefits that could be realized from additional capital investments in energy efficiency of City assets.

Table 8: Budgetary Requirements and Lifecycle Cost Benefit of Proposed Incremental Greenhouse Gas Reduction Initiatives to Achieve a 50% below 2005 Levels by 2030 (Scenario 2)

			TOTAL ADDITIONAL FUNDING BETWEEN 2019-2030 (TODAY'S DOLLARS)		
ADDITIONAL GHG REDUCTION INITIATIVES	BUSINESS-AS-USUAL FUNDING PER 4 YEAR BUDGET CYCLE	ADDITIONAL FUNDING PER 4 YEAR BUDGET CYCLE	CAPITAL	OPERATING	NET PRESENT VALUE BENEFITS OVER 20 YEARS
Energy retrofits of existing buildings	n/a	$26.7 Million	$80 Million*	-	$105 Million
Accelerated microgen solar PV program	~$7 Million**	~$15.3 Million	$46 Million***	-	$9 Million
Electric Buses	n/a	Building infrastructure: $80 Million over 2 to 3 cycles: Buses: $57 Million over 2 cycles	Building Infrastructure: $80 Million Buses: $114 Million	-	$52 Million
LED Street Light Replacement	$3 Million	$6.5 Million if divided over 3 cycles	$20 Million	-	$25 Million
Green Electricity Procurement (New Wind: $20/MWh	-	See table below	-	See table below	-$115 Million

[18] *One time purchase of 40 busses between 2017-2023 not an ongoing BAU deployment.*

premium; New Solar: $40/MWh premium)					
Total New Cost	n/a	--	$340 Million	See table below	$76Million
Grayed out denotes cost reflect same level of deployment as prescribed in 30% reduction target scenario					

*Table 9: Green Electricity Purchase - Potential Phased Approach goal 100% Coverage of 2030**

BUDGET CYCLE	CONTRACT TYPE	INCREMENTAL INCREASE	TOTAL COST**
Phase 1 (2019-2022)	One fixed term new asset with incremental increases in annual agreement amount..	$500,000/year incremental increase on top of starting base of $1.5M/year.	2019: $2M 2020: $2.5M 2021: $3M 2022: $3.5M **Total: $11M**
Phase 2 (2023-2026)	One fixed term new asset agreement.	$2M increase in 2023.	2023: $5.5M 2024: $5.5M 2025: $5.5M 2026: $5.5M **Total: $22M**
Phase 3 (2027-2030)	One fixed term new asset agreement.	$4.25M increase in 2027	2027: $9.75M 2028: $9.75M 2029: $9.75M 2030: $9.75M **Total: $39M**

**See Appendix C for administrative procurement cost discussion and other relevant risks, guiding principles and assumptions.*
*** Includes $1.5M base funding.*

Figure 11 shows the Forecast of the Annual Greenhouse Gas Emissions under the 50 Percent Reduction - Scenario 2: Increased Green Electricity Purchase

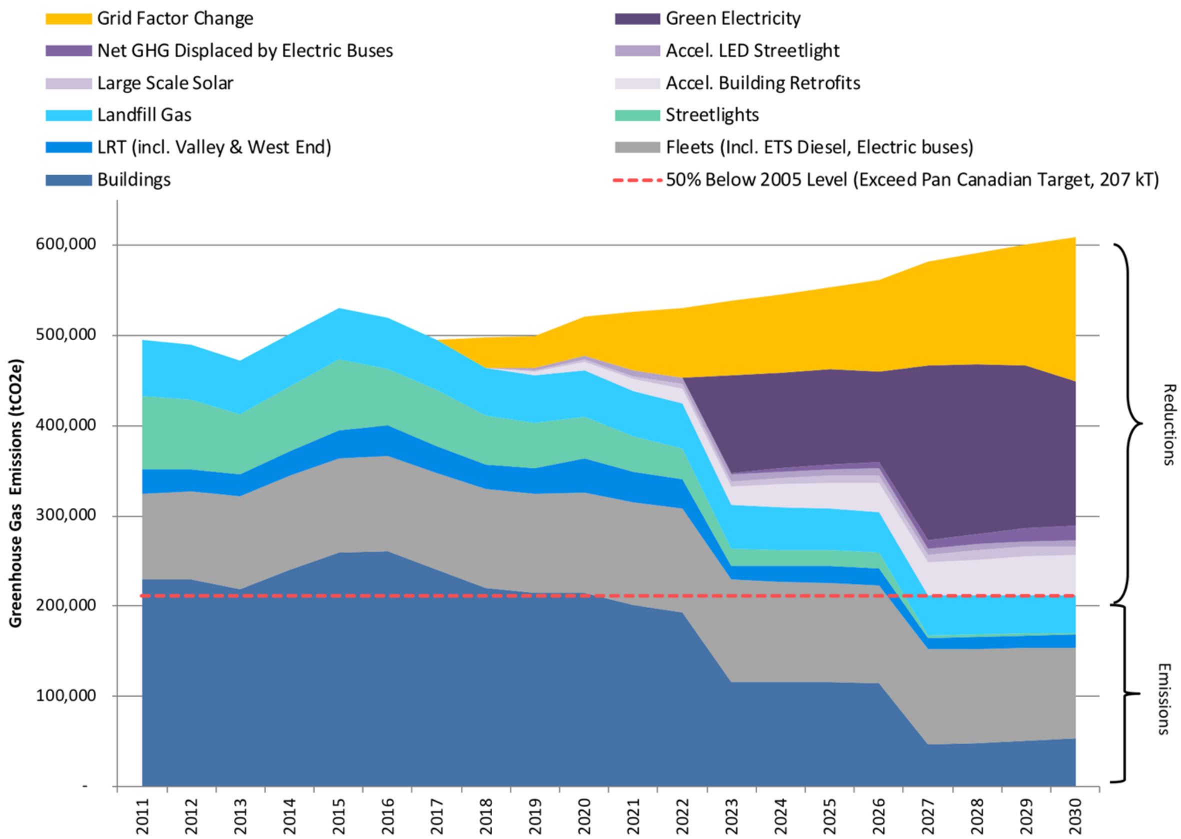

Figure 11: Forecast of Annual Greenhouse Gas Emissions – 50 Percent Reduction Scenario 2: Increased Green Electricity Purchase[19]

8.4. Scenario 3: Carbon Neutral

This last scenario simply builds upon Scenario 2 and further reduces the remaining tonnes through the purchase of renewable natural gas to offset 100% of natural gas use by buildings, and carbon offsets to offset all emissions from vehicle fleets.

Table 10: Proposed Incremental Greenhouse Gas Reduction Initiatives to Achieve Carbon Neutrality by 2030

ADDITIONAL GHG REDUCTION INITIATIVES	BUSINESS-AS-USUAL RATE OF DEPLOYMENT PER 4 YEAR BUDGET CYCLE	ADDITIONAL DEPLOYMENT PER 4 YEAR BUDGET CYCLE	TOTAL NUMBER OF PROJECTS, OR INSTALLATIONS (INCL. BAU)	TOTAL REDUCTIONS PER YEAR BY 2030, BASED ON 2030 GRID FACTOR (ABOVE BAU SCENARIO)
Energy retrofits of existing buildings	0[20]	~45 buildings	~135 building projects	60,000 tonnes
Accelerated microgen solar PV program	10 to 15 buildings; or 2.4MW	An additional 10 MW (equivalent to 40 NHL rinks; 45,000 sq.m of roof, wall or	30 MW (equivalent to 9% of total civic operations electricity	15,000 tonnes

[19] *Exact timing and rate of green electricity purchase will impact the wedge reduction intermittent profile although the 2030 outcome will remain unaffected.*

[20] *The 2015-18 capital budget did include a $9 million profile for building energy retrofits however this funding was not approved to continue beyond 2018.*

		ground space)	consumption)	
Electric Buses	0[21]	220 buses/per cycle starting in 2023	440 buses	17,800 tonnes
LED Street Light Replacement	4,000 units/year of various street light types (e.g., arterial, collector, local, alley)	46,000 units of "low hanging fruit" street lights types (over 1 budget cycle)	46,000 units	5,500 tonnes
Green Electricity Procurement	-	-	100% of civic operations electricity consumption by or before 2030	159,000 tonnes
Green Natural Gas	-	-	100% of civic operations natural consumption by or before 2030	49,000 tonnes
Other Carbon Offsets	-	-	-	136,000 tonnes
Total Reductions (excl. Grid Factor Change)	-	-	-	442,300 tonnes
Grayed out denotes same level of deployment as prescribed in 50% reduction target scenario				

Table 11: Budgetary Requirements and Lifecycle Cost Benefit of Proposed Incremental Greenhouse Gas Reduction Initiatives to Achieve Carbon Neutrality for City operations by 2030

			TOTAL ADDITIONAL FUNDING BETWEEN 2019-2030 (TODAY'S DOLLARS)		
ADDITIONAL GHG REDUCTION INITIATIVES	**BUSINESS-AS-USUAL FUNDING PER 4 YEAR BUDGET CYCLE**	**ADDITIONAL FUNDING PER 4 YEAR BUDGET CYCLE**	**CAPITAL**	**OPERATING**	**NET PRESENT VALUE BENEFITS OVER 20 YEARS**
Energy retrofits of existing buildings	N/A	$35 Million	$106 Million	-	$140 Million
Accelerated microgen solar PV program	~$7 Million	~$20 Million	$69 Million	-	$13 Million
Electric Buses	n/a	Building infrastructure: $80 Million over 2 to 3 cycles: Buses: $57 Million over 2 cycles	Building Infrastructure : $80 Million Buses: $114 Million	-	$52 Million
LED Street Light Replacement	$3 Million	$6.5 Million if divided over 3 cycles	$20 Million	-	$25 Million
Green Electricity (New Wind: $20/MWh premium; New Solar: $40/MWh premium)	-	See table below	-	See table below	-$115 Million
Renewable	-		-		-$95 Million to

[21] *One time purchase of 40 busses between 2017-2023 not an ongoing BAU deployment.*

Natural Gas; ($5 to $9/GJ premium)					-$171 Million
Carbon Offsets ($50/tonne)	-		-		-$98 Million
Total New Cost	n/a	-	$389 Million	See table below	-$154M to -$78M

*Table 12: Green Electricity, Renewable Natural Gas, & Carbon Offsets- Phased Approach**

BUDGET CYCLE	TYPE	ELECTRICITY CONSUMPTION	2019-2022 BUDGET CYCLE	2023-2026 BUDGET CYCLE	2027-2030 BUDGET CYCLE
Up to 50% coverage (2023 consumption)	Green Electricity**	173,000 MWhr	2019: $2M 2020: $2.5M 2021: $3M 2022: $3.5M **Total: $11 Million**	2023: $5.5M 2024: $5.5M 2025: $5.5M 2026: $5.5M **Total: $22 Million**	-
	Renewable Natural Gas	649,000 GJ	-	$3.2 to $5.8 Million	-
	Carbon Offset	72,500 tonnes	-	$3.6 Million	-
100% of consumption (2030)	Green Electricity**	376,000 MWhr	-	-	2027: $9.75M 2028: $9.75M 2029: $9.75M 2030: $9.75M **Total: $39 Million**
	Renewable Natural Gas	964,000 GJ	-	-	$4.8 to $8.7Million
	Carbon Offset	136,000 tonnes	-	-	$6.8 Million
Total Estimated Budget	-	-	$11 Million	$25.6 to 31.4 Million	$50.6-54.5Million
Grayed out denotes same level of deployment as prescribed in 50% reduction target scenario					

**Please review potential phased green electricity purchase schedule as proposed in scenario 2.*
*** Includes base funding of $1.5M.*

Figure 12 shows the Forecast of the Annual Greenhouse Gas Emissions under Scenario 3 – Carbon Neutral.

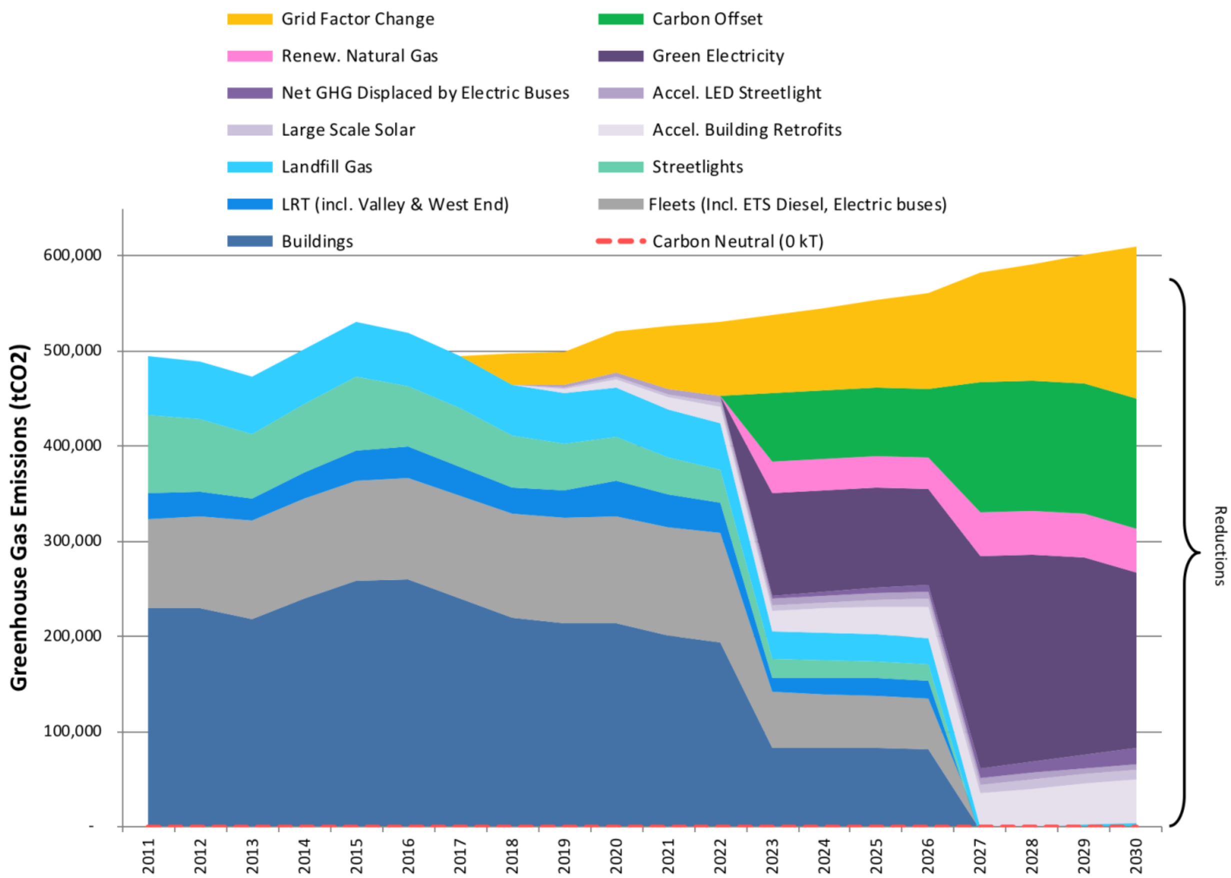

Figure 12: Forecast of Annual Greenhouse Gas Emissions – Carbon Neutral Scenario[22]

8.4.1. Discussion on viability of Renewable Natural Gas and Carbon Offsets and Preliminary Cost Estimates

There is very limited information on the cost of renewable natural gas. Typically, natural gas is considered renewable if it is derived from biogas, which is produced from decomposing organic waste from forestry, landfills, agricultural waste and wastewater from treatment facilities. Consultation with local experts in Alberta indicated that the limited biogas that is generated from these processes is typically combusted to generate electricity rather than added to the natural gas distribution system. Provinces such as British Columbia, Quebec and Ontario have well developed renewable natural gas policy and programs, which are currently lacking in Alberta. This has slowed bioenergy capital investments locally. In terms of pricing, only one local energy provider consulted was willing to indicate that renewable natural gas projects could be developed to meet the City’s natural gas consumption at a unit cost of $8 to $12 per GJ. The price of natural gas (energy only excl. delivery) that the City currently pays is closer to $3 per GJ. This suggests a premium of $5 to $9/GJ.

A carbon offset is when one party receives credits for reducing their greenhouse gas emissions and these credits can then be purchased by another party to "offset" their emissions levels.

[22] *Exact timing and rate of green electricity purchase will impact the wedge reduction intermittent profile although the 2030 outcome will remain unaffected.*

Alberta is one of the few jurisdictions in North America to have a highly regulated carbon offset market. To qualify for offset credits, projects must follow strict government approved protocols that ensure emissions reductions are real, demonstrable, and quantifiable, additional to what would have occurred otherwise and registered on the Alberta Emission Offset Registry. Once registered, the offsets can be sold to Alberta's large emitters, regulated under the Specified Gas Emitters Regulation (replaced by the Carbon Competitiveness Incentive (CCI) regulation in 2017), that have not met their provincially mandated reduction obligation. The price facilities pay for the offsets is market driven so the price varies.

Carbon offset is a necessary option for City of Edmonton in order to meet an aggressive and ambitious target like carbon neutral or zero emissions from all City operations. However, instead of being a large emitter with reduction obligations under the Carbon Competitiveness Incentive (CCI) Regulation, the City would be voluntarily choosing to participate in the regulation and purchase offset credits from other activities that have voluntarily reduced their emissions in Alberta. There are over two dozen[23] types of voluntary carbon reduction activities that have protocols to enable carbon offsets to be quantified and sold. The City of Edmonton's anaerobic digester is an example of an ideal voluntary activity for generating offsets. However, if the City were to quantify and sell these offsets, then these reductions would not be able to be claimed against the City's own greenhouse gas inventory. The City's composting facility has been generating and selling carbon offsets in the hundreds of thousands of tonnes since 2007, but because they were sold, the City has not been able to claim the reductions against its own inventory. That said, a project can only be viable as a offset project typically for 7 years and sometimes up to 12 years on a case by case basis. The time limit ensures that these projects can demonstrate additionality.

Carbon offsets can be a viable, and market driven solution not only for the City to meet its climate change goals, but when the City buys offsets, it can be a way to incentivize local clean growth and build capacity for emerging technologies and practices to take root and become business as usual over time. In fact, as discussed, one of the limitations of energy retrofits in City buildings is the need to mitigate disruptions to City operations, services/programming for residents. But carbon offsets is a way for the City to "outsource" carbon reduction from energy efficiency upgrades to private building owners and property managers whom are looking to revitalize their properties for a myriad of reasons. The City can claim the offsets, while the energy efficiency becomes more normalized in the industry and community.

[23] *Alberta Environment and Parks. Offset Credit System Protocols. http://aep.alberta.ca/climate-change/guidelines-legislation/specified-gas-emitters-regulation/offset-credit-system-protocols.aspx*

9. Enabling Change

There are many essential enabling and continuous improvement activities, programs and projects that are currently happening, and will need to happen for this plan to be realized. The city will need to integrate the greenhouse gas reduction practices identified in this plan into all aspects of its decision making and support behaviour change.

A successful civic operations greenhouse gas management framework will take concerted, persistent, collaborative, and integrated effort and a multitude of activities, programs and projects that take place across the corporation, with participation from all departments and branches. Each of the 14,000 City staff play a role in helping to reduce the City's greenhouse gas footprint through their day to day behaviour and habits in a City building or vehicle, and their decision making in regards to selection and procurement of equipment, fleet, and contracted services. Although this Plan, its targets and the proposed budget is focused on capital projects and larger impact technological interventions to reducing the City's civic operations greenhouse gas footprint, it is important to recognize that there is a myriad of ongoing and emerging initiatives intended to either address the human behaviour side to climate change mitigation or pilot new emerging technologies.

A few examples of these initiatives include:

Office of Energy Management:

- **Energy 101 "the basics"** – a new web-based energy literacy training platform that is currently being rolled out as part of onboarding of new staff;
- **Submetering pilots** for tenant areas within City buildings – to increase energy literacy and promote energy conserving behaviour amongst tenants;
- **EMPR (City energy management performance reporting framework).** EMPR is made up of three parts in order to provide reliable energy performance reporting for city buildings and consuming assets.
    - Online viewing of energy profiles for City assets. Including benchmark values.
    - A mechanism to perform internal energy reviews to measure performance and actual outcomes for City assets (includes: GHG emissions and energy efficiency/utilization indexes).
    - Identify energy management standards, methods and protocols to forecast and evaluate the outcomes from the implemented energy retrofits.

Fleet and Facility Services

- **Right-Sizing Guidelines** to encourage branches, especially those with sizable fleets to make conscientious decisions about purchasing, assigning and using vehicles that are right-sized and not over-sized for the job.
- **GPS Telematics Project** – intended to integrate the different GPS systems and analytical platforms currently used across the corporation, improve and leverage data collection and analysis to improve fleet safety, support route optimization, improve fuel economy. All of which have positive implications on fuel consumption.

Parks and Roads Services

- **Small scale fuel switching** - Switching from carbon-fuel based to electric parks maintenance equipment like lawn mowers, trimmers/cutters;

- **Off Grid Solar for Small Seasonal Buildings** – using solar panels with batteries to power lighting and provide electricity to small, seasonal parks maintenance sheds;

Community and Recreation Facilities

- **REALice technology pilot** – a water deration technology currently being piloted at a City arena that can enable high quality ice surfaces to be made using cold water as compared to conventional practice of hot water flooding.

9.1. Electrification of City fleets

The City's fleet is predominantly comprised of light and heavy trucks with a small portion of passenger cars. Table 13 provides a breakdown of the City's fleet composition. In addition, the City also operates approximately 930 low-floor and DATS buses as part of the Edmonton Transit System.

Table 13: City Fleet Composition[24], 2016

TYPE OF VEHICLE	NUMBER OF VEHICLES	PERCENT OF FLEET
Cars	**488**	**12%**
General duty	*33*	*0.8%*
Edmonton Police Service	*455*	*11.3%*
Light trucks/SUVs/Vans	**1550**	**39%**
General duty	*1041*	*25.9%*
Edmonton Police Service	*509*	*12.7%*
Heavy trucks	**663**	**16%**
Rented vehicles (predominantly light trucks)	**919**	**23%**
Other self-propelled	**400**	**10%**
Total	**4,020**	

Passenger cars are currently the most feasible to switch immediately to electric vehicles with more than 25 models available in Canada at various price points. The remaining City fleet, consisting of light trucks, SUVs, vans and heavy trucks, currently lacks electric options; however the market is changing quickly. For example, in early 2017, Ford announced that it will be introducing 13 electric vehicles to its model fleet by 2022, including an F-150 Hybrid, Mustang Hybrid, a plug-in hybrid Transit Custom van, and a fully electric SUV with an estimated range of 480 kilometres[25]. Tesla has indicated that they will be expanding their market offering, with a fully electric pickup truck in development.

Based on the principle of dynamic and adaptive steering, rather than provide conceptual targets for electrification of City fleet based on very limited current market information and little or no electric options on

[24] *Excludes shop equipment, trailers, non-self-propelled vehicles and historical vehicles*
[25] *Ford Motor Company. 2017. Ford Adding Electrified F-150, Mustang, Transit by 2020 in Major EV Push. https://media.ford.com/content/fordmedia/fna/us/en/news/2017/01/03/ford-adding-electrified-f-150-mustang-transit-by-2020.html*

the majority of the City fleet, the actions in 1st budget cycle of the Plan (2019-2022) will be more focused on monitoring trends and changes in market conditions as outlined in section 10 below.

10. From Concept to Implementation – Steps Towards Implementation of An Action Plan

There are five key areas that the City will need to focus on regardless of the scenario chosen for greenhouse gas reduction from City civic operations: governance and accountability, implementation support, enabling and empowerment, strategic alignment, dynamic and adaptive steering, and aligning EPCOR. These items are not specifically an implementation plan rather they support the foundations of implementation, and the parallel operations that enable implementation.

<table>
<tr><th colspan="3">FOUNDATIONS OF IMPLEMENTATION</th></tr>
<tr><th></th><th></th><th>Timeline</th></tr>
<tr><td colspan="3">Governance and accountability
Description: Activities and initiatives that enable effective executive and organizational oversight, clarifies roles and responsibilities in plan implementation</td></tr>
<tr><td></td><td>Establish cross-corporate governance and accountability process to provide oversight for plan implementation, ongoing monitoring and evaluation, include but not limited to:
● Create or assign to appropriate Branch Steering Committee;
● Establish Internal Working Group(s);
● Establish Performance Measures Framework which include tactics on how to deal with budget shortfalls and how to optimize project choice to maximize GHG reductions;
● Establishing area (to be defined) specific GHG reduction targets (potentially tied to ENVISO);
● Identifying senior management responsible for targets (potentially tied to ENVISO);
● Preparing a prioritized list of detailed actions to achieve those targets (potentially tied to ENVISO);
● Develop reporting requirements and processes (potentially tied to ENVISO's);
● Establish ENVISO roles and responsibilities, and
● Development of ENVISO procedures;
● Develop master plans for implementation pieces as appropriate.
● Develop a standardized method/approach as to how actions should be prioritized over others that account for GHG reductions, for example Sustainable Return On Investment or multi-criteria decision making frameworks.

Implement the governance and accountability process (2019)

Draft and establish an Administrative Directive to support the Civic Operations Greenhouse Gas Management Plan Implementation and Energy Management services provided by Office of Energy Management</td><td>2018-2019</td></tr>
<tr><td colspan="3">Strategic Alignment
Description:
a) Activities involving collaboration with other business units to ensure energy transition perspectives and existing/emerging policies, practices or desired outcomes are appropriately considered and integrated into other corporate or cross-department strategies and policies.
b) Activities involving collaboration, influencing and or monitoring of upcoming provincial and federal policies.</td></tr>
</table>

	Contribute to and support the development of the corporate real estate (or land governance) strategy (Real Estate Branch) and lifecycle management strategy (Infrastructure Planning and Design Branch) Monitor, assess, align or integrate new provincial / federal policies into management plan review and implementation including, but not limited to, Alberta Bioenergy Policy Review, Capacity Market, Pan Canadian Clean Fuel Standard.	2019-2030
Dynamic Steering, Adaptive Management		
	Monitor and leverage emerging financial rebates, incentives, and funding that may be available to City to undertake the action(s). Monitor trends and changes in market conditions such as decreases in cost or increase in availability of electric vehicles, energy storage, alternative fuels, etc. Monitor internal funding allocation surplus, asks and shortfalls in order to reach GHG reduction targets.	2019-2030

PARALLEL OPERATIONS THAT ENABLE IMPLEMENTATION

Parallel Implementation Support *Description: Activities and initiatives that support effective, efficient, and integrated project delivery. These are in addition to the implementation plans that will be developed in 2018-2019 through support of steering committees and internal working groups as noted in governance and accountability.*		
Buildings:	Ongoing improvements to integration of energy upgrades with capital renewal. Ongoing refinement of Terms of Reference / Scope of Work for building audits performed by third parties. Includes ongoing refinement of energy modeling requirements for existing buildings.	Ongoing
	Develop procedure, in alignment with C532 Sustainable Building Policy, to assess for building need as part of the new building planning process. This helps reduce impact by making sure that only what is needed is built.	Develop: 2019-2022;
	Identify, assess, and implement learning pilots for existing City buildings that are suitable for deep retrofits and netzero energy pilots	Plan: 2019-2022; Implement: 2023-2030;
	City Office of Energy Management:	
	● Implement program to set Internal Measurement and Verification Plans (MVP). Establishes centralized, reliable energy performance monitoring and tracking for consuming assets: ○ MVPs set for whole-facility performance tracking across the life cycle of the asset. MVPs are set to compliment submetering to track outcomes for isolated energy conservation measures ○ MVP framework follows best practices standard (IPMVP)	MVP and Sub-meter implementations start 2018
	● Continue implementation of City integrated energy management performance reporting framework (City EMPR) for consuming assets: ○ Implement internal MVPs (measurement framework) for centralized,	EMPR is ongoing starting

<table>
<tr><td></td><td>reliable tracking and reporting
○ Complete City Submeter Pilot to track performance for City buildings and tenant spaces within City-owned buildings. Includes develop and implement cost model and submetering standards / procedures
○ Complete enhancement to information and communication interfaces to support data collection and data exchange for submetering; City EMPR and Community Benchmarking for City buildings
● Develop and establish best practice standards to evaluate and prioritize ongoing energy conservation measurements /energy upgrades;
● Implement and learn from behavioural audits to optimize awareness and education, and working procedures for City consuming assets;

Develop and implement energy use and reporting procedures for City-owned leased to others buildings (Scope 3 buildings – considered outside City's operational control as per protocol), and buildings that are leased by the City (considered within City's operational control, as per inventory protocol and need to be included in the corporate inventory). (2018-2019)</td><td>2018. Plan, consult, develop 2018 Implement 2019

Ongoing and started in 2018</td></tr>
<tr><td>Fleets:</td><td>Monitor and review results of GPS telematics project implemented fleet-wide; explore using data and the platform to design programs to improve driver behaviour, route optimization, etc.

Develop fuel use and reporting procedures for contracted fleets (Scope 3) including residential waste collection, long haul for waste disposal, DATs, parks and roads services, etc. (2018-2019); Implement the procedures (2020 onwards)</td><td>Complete project: 2018-2019 Plan, Design, Implement new programs: 2019-2022

Plan, Consult, Design: 2018-2019; Implement: 2020</td></tr>
<tr><td>Street Lighting:</td><td>Explore and implement adaptive lighting pilots; Determine an estimation methodology with EPCOR to enable anticipated electricity reductions be accounted for in the billings</td><td>2018-2020</td></tr>
<tr><td rowspan="4">Green electricity</td><td>Development of green electricity procurement plan and process including:
Project initiation; Project governance and steering</td><td>2018-2019</td></tr>
<tr><td>Attain subject matter support; development and issuance of RFPs
Selection and negotiations</td><td>2018-2020</td></tr>
<tr><td>Execution, construction of new facilities</td><td>2021-2022</td></tr>
<tr><td>Start of operation for new facilities</td><td>2023-2024</td></tr>
<tr><td>Other renewable and alternative fuels</td><td>Ongoing and staggered approach as technologies and opportunities emerge.

Explore, monitor market trends, and assess other potential renewables and alternative fuels and carbon offset opportunities. (e.g., investigate feasibility of additional methane extraction for generation of renewable natural gas from Cloverbar landfill, 2019-2020)

Further pursue most viable options (Plan, Design, Consult);

Execute on most viable options</td><td>Ongoing

2020-2027

2022-2030</td></tr>
<tr><td colspan="3">Enabling and Empowerment</td></tr>
</table>

Description: Activities and initiatives that are intended to build awareness or knowledge or emerging best practices or technologies, helps change attitudes, promotes positive cultural change, and builds capacity to implement the necessary new policies or processes.		
Buildings	Continue roll out of Energy 101, an energy literacy and awareness online course required as part of onboarding of new staff;	2019-2030
Fleet	Undertake a study to update the City's understanding of the options available to the City with respect to alternative fuel vehicles and renewable fuel options. Develop a working group comprised of branch level fleet coordinators to understand how alternative fuel vehicles, fleet righting-sizing, and purchase avoidance can be included decision-making processes around fleet assets.	TBD
Street Lighting	Implement adaptive street lighting pilots; Review and update metering or consumption estimation methods to ensure fair charges for reductions in street light electricity consumption;	TBD
Waste Management	**TBD**	TBD
Urban Forest	Review the methodology for quantifying the GHG reductions from the City's urban vegetation. Identify gaps and a strategy to refine as needed.	2019-2022
Scope 3 Emissions:	TBD	TBD
Aligning EPCOR DT and EWSI (wholly owned subsidiaries of the City of Edmonton)		
	Establish formal EPCOR Corporate GHG Management Policy – Q1 2018 Identification of potential GHG reduction projects and activities within each EPCOR Business Unit – Q1 2018 and ongoing Establish formal procedure to share EPCOR GHG emissions data with City – Q2 2018 Establish EPCOR GHG reduction targets aligned with identified projects and activities – Q2 2018 Incorporate GHG performance metrics in 2022-2026 Wastewater Performance Based Rate (PBR) Application – 2021 Incorporate GHG performance metrics in 2022-2026 Drainage PBR Application – 2021 Incorporate GHG performance metrics in 2024-2028 Water PBR Application – 2023	Dates provided inline.

Appendix A: EPCOR 2016 Inventory

Assumptions and caveats:

- Data includes EPCOR operations and activities within the City of Edmonton
- Data includes EPCOR Water, EPCOR Distribution & Transmission, EPCOR Technologies – Drainage is not included at this time
- Data includes emissions from buildings, plants, fleet, SF6
- Calculations follow the "Climate Registry General Reporting Protocol for the Voluntary Reporting Program Version 2.1 January 2016"
- Electricity factors are taken from updates published by Climate Registry (climateregistry.org) – factors align closely to generating factors, Climate Registry does not publish separate consumption factors
- Data values are preliminary and subject to change as internal process and procedures are created and refined

Table 14: 2016 Emissions by Asset Type

SCOPE 1 GHG EMISSIONS	TONNES	SCOPE 2 GHG EMISSIONS	TONNES	ASSETS INCLUDED
Building Heat	2,336	Building Electricity	4,452	NSC, SSC, Tech, TTC, Tower
Plant Heat	7,941	Plant Electricity	109,089	GBWWT, WTPs
Vehicle Fleet	6,095	-	-	-
SF6	59	-	-	-
Sub-total Scope 1	16,431	Sub-total Scope 2	113,541	-
-	-	**Total Scope 1 & 2**	**129,972**	-

Table 15: 2016 Emissions by Business Area

SCOPE 1 GHG EMISSIONS	TONNES	SCOPE 2 GHG EMISSIONS	TONNES
EPCOR Water	7,941	EPCOR Water	109,089
EPCOR Electricity	1,835	EPCOR Electricity	2,991
EPCOR Technologies	442	EPCOR Technologies	1,148
EPCOR Fleet	6,095	-	-
EPCOR Tower	117	EPCOR Tower	313
Sub-total Scope 1	16,430	Sub-total Scope 2	113,541
Total Scope 1 & 2	-	-	**129,971**

Table 16: 2016 Energy Use Raw Data by Asset Type

SCOPE 1 RAW DATA	-	SCOPE 2 RAW DATA	-
Building Natural Gas (GJ)	41,712	Building Electricity (KWH)	5,635,445
Plant Natural Gas (GJ)	141,797	Plant Electricity (KWH)	138,087,606
Sub-total Natural Gas (GJ)	183,509	Sub-total Electricity (KWH)	143,723,051
Vehicle Fleet Gasoline (L)	891,757	-	-
Vehicle Fleet Diesel (L)	1,490,077	-	-
SF6 (Kg)	2	-	-

Appendix B: Asset-specific Forecasts under Business As Usual

Table 17: Forecast of Annual Civic Operations Greenhouse Gas Emissions– Business-As-Usual Scenario

YEAR	BUILDINGS	FLEETS (INCLUDE ETS BUSES)	LRT (INCL. VALLEY & WEST END)	STREET LIGHTS	LANDFILL GAS	*TOTAL EMISSIONS	GRID FACTOR CHANGE**
2005 Baseline	196,933	75,868	11,680	74,216	65,040	423,737	
2016	260,587	106,521	32,954	72,781	55,780	528,624	-
2017	239,832	108,025	30,002	62,329	54,605	494,793	-
2018	220,156	109,569	27,522	53,790	53,450	464,488	33,287
2019	220,263	110,284	28,547	52,497	52,315	463,906	37,066
2020	226,200	111,871	38,185	50,597	51,195	478,048	46,034
2021	218,036	113,377	34,340	45,008	50,110	460,870	71,651
2022	215,212	115,009	32,256	41,824	49,045	453,346	86,762
2023	219,044	116,764	31,803	40,802	47,990	456,403	91,610
2024	222,596	118,566	31,259	39,686	46,980	459,086	97,331
2025	226,271	120,422	30,719	38,602	45,960	461,974	103,301
2026	226,697	122,302	29,483	36,674	44,990	460,146	114,571
2027	227,586	124,245	36,072	34,941	44,045	466,890	130,131
2028	230,253	126,264	35,130	33,697	43,095	468,439	139,028
2029	230,193	128,323	33,545	31,868	42,180	466,109	152,420
2030	220,037	130,366	29,717	27,965	41,280	449,366	180,932

**This is the total emissions and does not include the grid factor change. The difference between the total emissions and the grid factor change is the amount that must be reduced to achieve carbon neutrality.*
***Grid factor changes calculated form 2018 onwards.*

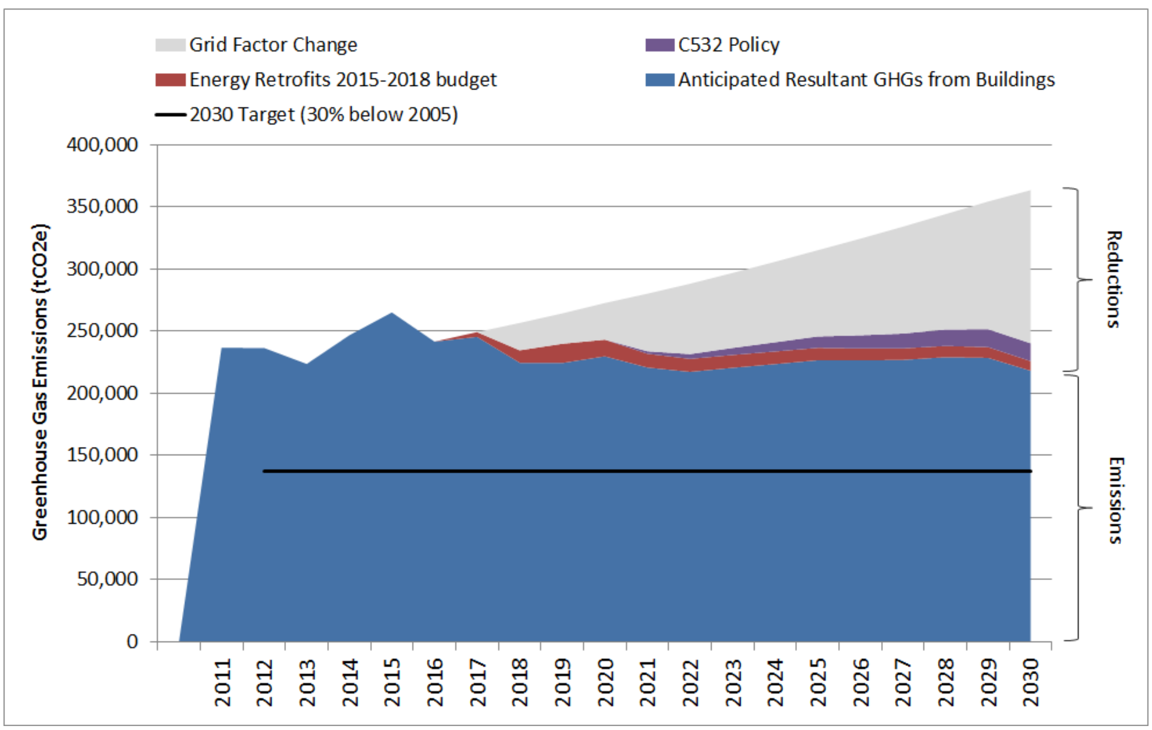

Figure 13 - Building Emissions

Table 18: Building Emissions

YEAR	EMISSIONS			REDUCTIONS FROM BUSINESS-AS-USUAL PRACTICES & POLICIES		
	ELECTRICITY	NATURAL GAS	TOTAL	ENERGY RETROFITS 2015-18 BUDGET	C532 POLICY STANDARDS*	GRID FACTOR CHANGE
2005 Baseline	141,592	55,341	196,933	-	-	-
2016	184,489	76,098	260,587	-	-	-
2017	164,427	75,405	239,832	3,864	-	-
2018	144,274	75,882	220,156	9,566	-	21,445
2019	143,890	76,373	220,263	14,877	-	23,757
2020	147,602	78,598	226,200	12,475	-	28,744
2021	137,408	80,628	218,036	10,264	1,544	45,409
2022	133,694	81,518	215,212	9,680	2,925	55,797
2023	136,622	82,422	219,044	9,553	4,334	59,773
2024	139,255	83,341	222,596	9,400	5,694	64,416
2025	141,996	84,275	226,271	9,249	7,012	69,330
2026	141,472	85,225	226,697	8,902	8,125	77,957
2027	141,396	86,191	227,586	8,590	9,176	86,540
2028	143,081	87,172	230,253	8,382	10,255	93,764
2029	142,024	88,169	230,193	8,033	11,100	104,218
2030	130,854	89,183	220,037	7,189	11,160	125,382

**This reduction is from new construction as compared to how much energy the buildings would consume if built to code. The building GHG emissions takes into consideration the increase in emissions from new construction. City Policy C532 Standard - Minimum 40% better energy and greenhouse gas savings as compared to Code[26]*

Assumptions and Forecast Methodology:

1. Applied the average historical percent increase in building electricity consumption from 2012 to 2016 to 2017 to 2030.
2. Applied the average historical percent increase in building natural gas consumption from 2012 to 2016 to 2017 to 2030.
3. This historical increase was inclusive of capital growth. The planned 10 year outlook for rate of growth (or new buildings) is similar to the 2012-2016 growth rate and therefore the energy related to that growth is forecasted forward.
4. Applied anticipated greenhouse gas reductions of 13,760 tonnes (as per CR_4057; based on 2016 grid factors) from existing energy retrofits under the 2015 to 2018 budget cycle; assumed 25% of the reductions realized in 2016; 50% by 2017; 75% by 2018; and 100% by 2019; Due to limited data, assumed 50% of the 2015-18 came from electricity savings and 50% came from natural gas savings; however, this assumption is validated by the latest round of the building energy audits;
5. Assumed $9M funding from energy retrofits from 2015 to 2018 would not proceed to future year budget cycles and is therefore not included in the business as usual case.
6. Waste management – process facility related projects such as the LED lighting replacement in the Edmonton Composting Facility, Refuse Derived Fuel dryer and the Anaerobic Digester Facility were accounted for separately based on energy use projections from Waste Services; but accounted for in the 2015-2018 energy retrofit column.

[26] *2011 National Energy Code for Buildings (as adopted by the Alberta Building Code)*

7. Growth from new construction was assumed to be 20% less energy intensive based on implementation of C532 Sustainable Building Policy.Note that although the Policy standard is to achieve 40% minimum better than the energy code, analysis showed that the City was already building on average 20% better in energy savings and greenhouse gas emissions better than the mandatory code, therefore, an incremental improvement of 20% was applied to the new growth;
8. An additional 5% reduction in energy intensity of new building construction based on the 1% for on-site energy generation. Analysis from the C532 policy review showed that a 1% dedicated project capital can deploy on-site solar sized to meet 3.5 to 12 percent of a buildings energy needs or cogeneration sized to meet up to 30% of a buildings energy needs.

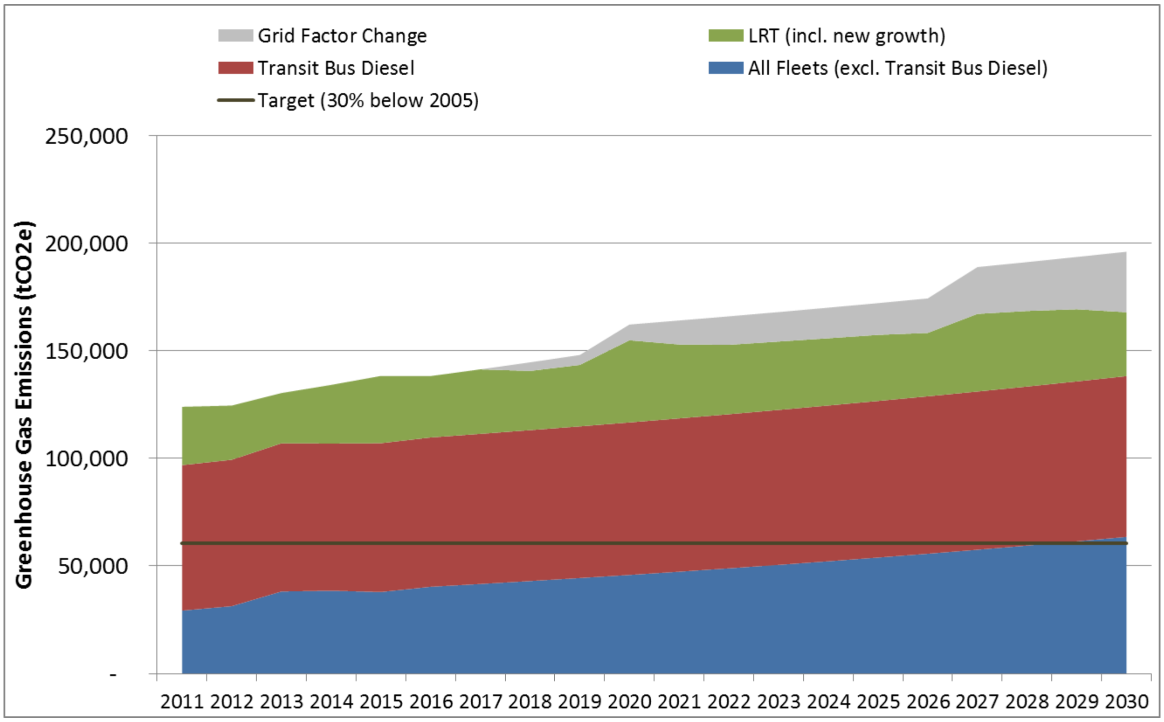

Figure 14: Fleet Emissions

Table 19: Fleet Emissions

YEAR	EMISSIONS				REDUCTIONS
	ALL FLEETS (EXCL. TRANSIT BUS DIESEL)	TRANSIT BUS DIESEL AND ELECTRIC	LRT (INCL. NEW GROWTH)	TOTAL	GRID FACTOR CHANGE
2005 Baseline	25,034	62,514	11,680	99,228	-
2016	37,595	68,926	32,954	139,475	-
2017	38,734	69,291	30,002	138,027	-
2018	39,912	69,657	27,522	137,091	4,008
2019	41,131	69,153	28,547	138,831	4,871
2020	42,393	69,478	38,185	150,056	7,622
2021	43,698	69,678	34,340	147,716	11,640
2022	45,050	69,959	32,256	147,265	13,816
2023	46,449	70,315	31,803	148,567	14,289
2024	47,897	70,669	31,259	149,825	14,858
2025	49,397	71,025	30,719	151,141	15,422
2026	50,951	71,351	29,483	151,785	16,714

2027	52,559	71,686	36,072	160,317	22,519
2028	54,226	72,039	35,130	161,394	23,494
2029	55,952	72,371	33,545	161,868	25,135
2030	57,740	72,626	29,717	160,083	29,098

Assumptions and Forecast Methodology:

1. Applied the historical average percent increase to diesel, gasoline, and propane consumption from 2012 to 2016, to 2017 to 2030;
2. Applied the anticipated electricity consumption for the LRT Valley Line Expansion of 15,000,000 kWhr/year for the downtown to Millwoods leg in 2020; and an additional 15,000,000 kWhr/year for the downtown to West Edmonton leg in 2026. Note that the original consumption estimate from Transportation was 9,400,000 kWhr for the Millwoods leg, which seems to be underestimated based on comparison in length and number of stops to the existing system. Therefore a 1.5 times estimation factor was applied to the Millwoods leg and assumed that the west leg will have similar consumption levels. The electricity and natural gas consumption of the LRT stations is assumed to be a part of the growth in buildings energy use. Note: OEM is meeting with engineering and transit to review contract terms to determine additional charges that may apply for primary power.
3. 40 busses will be replaced by electric busses in the business as usual case.

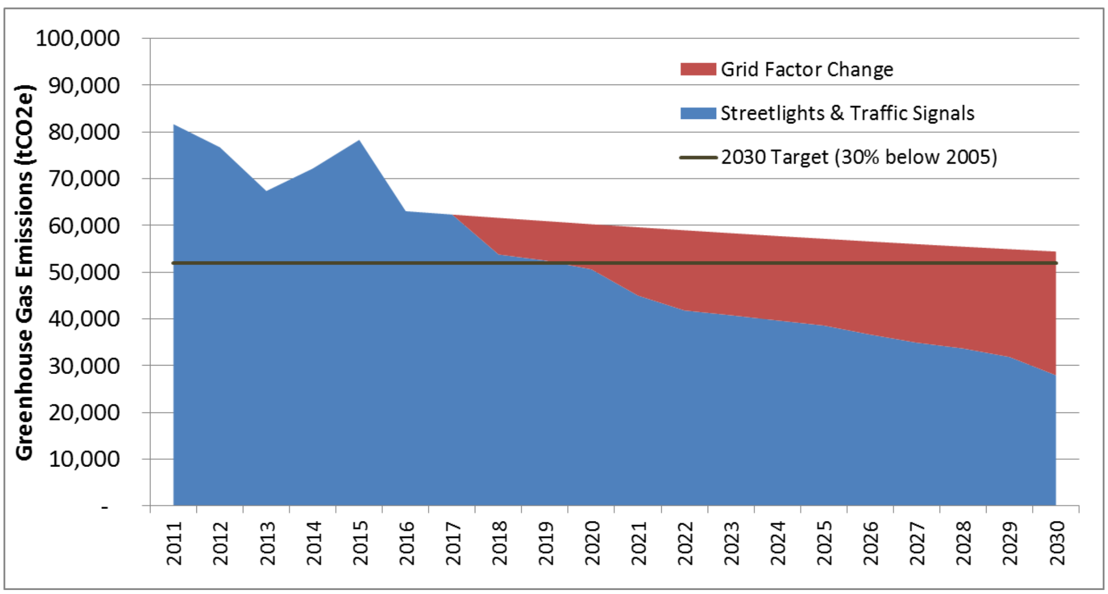

Figure 15: Street Light Emissions

Table 20: Street Light Emissions

YEAR	TOTAL STREETLIGHTS & TRAFFIC SIGNALS EMISSIONS	GRID FACTOR CHANGE (REDUCTIONS
2005 Baseline	74,216	
2016	63,051	
2017	62,329	-
2018	53,790	7,834
2019	52,497	8,439
2020	50,597	9,668

2021	45,008	14,602
2022	41,824	17,148
2023	40,802	17,547
2024	39,686	18,056
2025	38,602	18,549
2026	36,674	19,900
2027	34,941	21,071
2028	33,697	21,770
2029	31,868	23,067
2030	27,965	26,452

Assumptions and Forecast Methodology:

1. Applied the average percent differences to electricity consumption for each category of lighting (lane lights, security lights, traffic lightings, signals, streetlights and miscellaneous lighting) from 2012 to 2016, to 2017 to 2030.
2. LED street light conversion of ~4,000 units per year began in 2011, so the historical streetlight data between 2011-2016 already accounts for this program. Therefore additional reductions attributed to the conversion program were not applied.
3. Despite growth in absolute numbers of fixtures the energy consumed has reduced for most lighting types due to efficiency upgrades to all new and old fixtures. Therefore absolute energy consumption is decreasing.

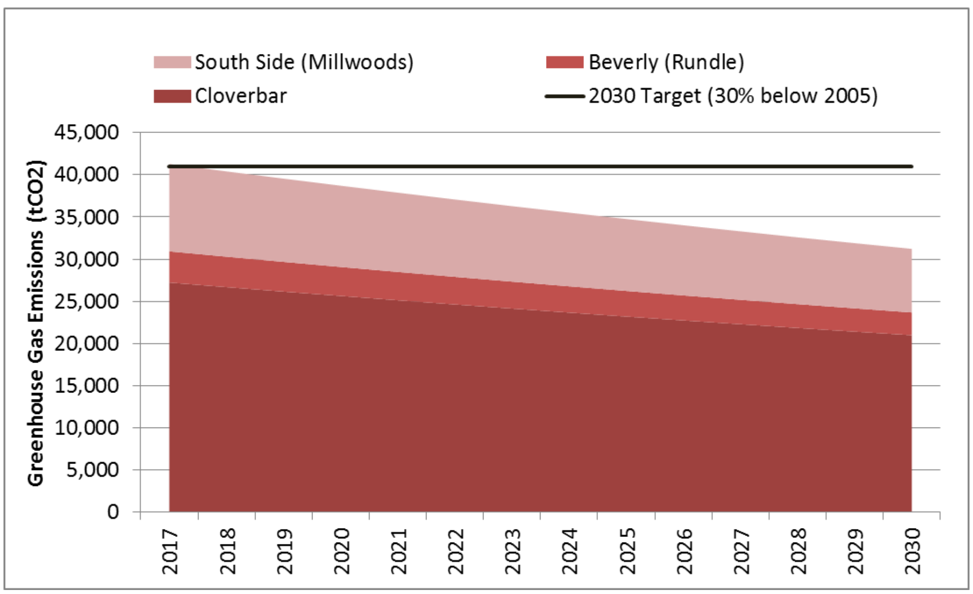

Figure 16: Landfill Gas Degradation

Table 21: Landfill Gas Degradation

YEAR	CLOVERBAR	BEVERLY (RUNDLE)	SOUTH SIDE (MILLWOODS)	TOTAL LANDFILL EMISSIONS
2005 Baseline	40,385	6,530	18,125	65,040*
2016	36,745	5,010	14,025	55,780
2017	36,015	4,890	13,700	54,605

2018	35,305	4,770	13,375	53,450
2019	34,605	4,660	13,050	52,315
2020	33,920	4,550	12,725	51,195
2021	33,245	4,440	12,425	50,110
2022	32,590	4,330	12,125	49,045
2023	31,945	4,220	11,825	47,990
2024	31,310	4,120	11,550	46,980
2025	30,690	4,020	11,250	45,960
2026	30,085	3,930	10,975	44,990
2027	29,490	3,830	10,725	44,045
2028	28,905	3,740	10,450	43,095
2029	28,330	3,650	10,200	42,180
2030	27,770	3,560	9,950	41,280

**Total emissions from Cloverbar, Beverly, and South Side.*

Assumptions and Forecast Methodology:

1. All three City-owned landfills are closed and not accept new waste;
2. Consult with waste services in regards to methodology or protocol used to estimate landfill gas production.

Appendix C: Guiding Procurement Principles and Operationalization Considerations for Green Electricity

These guiding principles are intended for any form of Green electricity procurement at the City of Edmonton. As such they will be used for the purchase of renewable energy certificates or other future mechanism(s) employed to procure green electricity in accordance with CoE Procurement Policy's and Procedures which include compliance with Trade Agreements, Legislation and Internal processes.

While this plan provides high levels for costs and projections for carbon reduction potential it is not intended to be a formal procurement methodology for these carbon reduction through green electricity procurement. The implementation of this part of the plan should be completed with the high level budget, required targets, and following points taken into consideration:

Additionality / Incentivize New Clean Growth

The green energy procured must be able to demonstrate that the green energy generated is over and above business as usual and that there is an actual incremental reduction in greenhouse gases from baseline. For instance, purchasing of renewable energy credits on a year to year basis from existing renewable energy facilities that have been in operation for many years would not be able to demonstrate additionality. Renewable energy credits generated from a new facility that came to be through a financial commitment from the City and or other co-investors to purchase the credits or to provide the upfront capital (e.g., joint venture, grant;) would demonstrate additionality.

Local Resilience and Asset Tied

The green energy procured should be as local and as proximal to Edmonton as much as is economically possible, in order to positively impact local clean growth and economic diversification, as well as contribute to building resiliency in the local energy system.

Price Volatility Mitigation

Depending on the financial mechanism, whether the purchase is only for the environmental attributes (e.g., RECs or carbon offsets) or for the electricity supply as well, there may be co-benefits in a long term green electricity supply agreement such as protection against future price volatility, and the expected increases to the carbon levy. Furthermore, investment in on-site or microgeneration renewable energy on City-owned assets can directly help offset the utility costs incurred by a City asset. These benefits should be considered when procuring green electricity.

Cost effectiveness

In instances where all factors between two green energy options are considered equal such as in scale, proximity and type, etc., preference should be given to projects that have lower overall unit cost to purchase.

Consider various green energy instruments

Renewable Energy Certificates is a financial instrument that can only be used to offset electricity, whereas carbon offsets and the purchase of renewable natural gas can be used to offset other source of carbon emissions. As the provincial grid gets greener, it is important that the procurement approach addresses biofuel, green natural gas, and carbon offsets which can be used to reduce or offset the emissions from natural gas and fleet.

Portfolio Approach
It is important to recognize that some of the guiding principles outlined above are competing priorities. Large scale wind is the most cost effective, but would do little for local economic growth or to build local energy transition support and opportunities. Conversely, the higher the number of contracts or projects initiated, the higher the administrative cost to quantify and verify the RECs or carbon offsets, which will impact cost effectiveness. Although one or two large scale utility projects outside of the City could be much more cost effective as compared to a number of smaller utility-sized solar, biogas or biomass installations within the city, yet, the smaller facilities dispersed throughout the City would have more visibility, builds more awareness of change, and also potentially enable the economic benefits to be shared with local industry and other community partners. For these reasons, using a portfolio approach and further contemplation to include a dedicated carve out for smaller installations that could engage or involve the community is needed to best meet all desired outcomes.

Additional Considerations:
Risks
Green premium pricing is typically tied to a green asset (solar install, wind farm, etc.) investment that requires long payback periods and longer contract terms. This introduces a high risk scenario because the market is expected to undergo rapid change during the applicable period for the plan. The period presented 2019-2030 represents an unknown amount of risk because greening pricing contracts are changing as the electricity market is expected to rapidly change and potentially become more unstable during that time. The economic outcomes realized from greening pricing contracts will vary based on market conditions and timing of the contract. It should also be mentioned that other entities in Alberta and Canada will be moving forward with carbon reduction plans during this time which may create demand and supply issues in developing the resources in line with the plans timelines.

Administrative Costs
The economic impact to City administration costs for diverse contract scenarios is not included in the figures provided in this plan. When developing a procurement strategy these values will be material and must be considered as the City currently incurs minimal overhead costs to manage the electrical power supply for City operations. The new costs will impact as ongoing operating expenses (accounting; settlement and contract management and additional costs for regulatory reporting).

Appendix D: Greenhouse Gas Reduction Target Scenarios – Data Tables

Table 22: Forecast of Annual Greenhouse Gas Emissions Reductions– 30 Percent Reduction Scenario

	ANTICIPATED REDUCTIONS (TCO2E)					
YEAR	BUILDING RETROFITS	LARGE SCALE MICROGEN SOLAR	ACCEL. LED STREETLIGHT	ELECTRIC BUSES	GREEN ELECTRICITY[27]	GRID FACTOR CHANGE
2019	4,654	1,397	2,308	-	-	35,215
2020	9,198	2,723	4,498	-	-	42,984
2021	13,163	3,673	6,067	-	-	65,328
2022	17,092	4,600	7,598	-	-	77,278
2023	21,241	5,669	7,492	1,653	101,317	81,404
2024	25,309	6,686	7,364	3,374	99,582	86,304
2025	29,320	7,666	7,236	5,160	97,864	91,426
2026	32,965	8,408	6,945	7,184	93,924	101,236
2027	36,536	9,103	6,683	9,322	90,384	115,371
2028	40,188	9,850	6,509	11,460	88,023	123,110
2029	43,453	10,346	6,215	13,907	84,052	134,834
2030	45,419	10,000	5,506	17,375	74,466	159,933

Table 23: Forecast of Annual Greenhouse Gas Emissions Reductions– 50 Percent Reduction Scenario Increased Green Electricity Purchase

	ANTICIPATED REDUCTIONS (TCO2E)					
YEAR	BUILDING RETROFITS	LARGE SCALE MICROGEN SOLAR	ACCEL. LED STREETLIGHT	ELECTRIC BUSES	GREEN ELECTRICITY[28]	GRID FACTOR CHANGE
2019	4,654	1,397	2,308	-	-	35,215
2020	9,198	2,723	4,498	-	-	42,984
2021	13,163	3,673	6,067	-	-	65,328
2022	17,092	4,600	7,598	-	-	77,278
2023	21,241	5,669	7,492	1,653	108,584	81,404
2024	25,309	6,686	7,364	3,374	106,725	86,304
2025	29,320	7,666	7,236	5,160	104,884	91,426
2026	32,965	8,408	6,945	7,184	100,661	101,236
2027	36,536	9,103	6,683	9,322	193,734	115,371
2028	40,188	9,850	6,509	11,460	188,673	123,110
2029	43,453	10,346	6,215	13,907	180,162	134,834
2030	45,419	10,000	5,506	17,375	159,616	159,933

[27] Approximate based on GHG remaining after reduction efforts completed. Actual purchased amounts may differ slightly depending on purchase schedule pursued.
[28] Approximate based on GHG remaining after reduction efforts completed. Actual purchased amounts may differ slightly depending on purchase schedule pursued.

Table 24: Forecast of Annual Greenhouse Gas Emissions Reductions – Carbon Neutral Scenario

	ANTICIPATED REDUCTIONS (TCO2E)							
YEAR	ACCEL. BUILDING RETROFITS	ACCEL. LARGE SCALE SOLAR	ACCEL. LED STREETLIGHT	ELECTRIC BUSES	GREEN ELECTRICITY[29]	RENEW. NATURA L GAS	CARBON OFFSET	GRID FACTOR CHANGE
2019	6,205	1,397	2,308	-	-	-	-	35,215
2020	12,264	2,723	4,498	-	-	-	-	42,984
2021	17,550	3,673	6,067	-	-	-	-	65,328
2022	22,790	4,600	7,598	-	-	-	-	77,278
2023	28,321	5,669	7,492	1,653	76,006	33,099	72,534	81,404
2024	33,746	6,686	7,364	3,374	74,704	33,099	72,534	86,304
2025	39,094	7,666	7,236	5,160	73,416	33,099	72,534	91,426
2026	43,953	8,408	6,945	7,184	70,460	33,099	72,534	101,236
2027	48,714	9,103	6,683	9,322	165,458	46,003	136,420	115,371
2028	53,584	9,850	6,509	11,460	161,135	46,003	136,420	123,110
2029	57,937	10,346	6,215	13,907	153,866	46,003	136,420	134,834
2030	60,559	15,000	5,506	17,375	136,321	46,003	136,420	159,933

[29] *Approximate based on GHG remaining after reduction efforts completed. Actual purchased amounts may differ slightly depending on purchase schedule pursued.*

Appendix E: Lifecycle Cost Benefit Methodology and Findings

Objective

Leveraging existing City data, develop a consistent approach to compare the GHG abatement options and cost benefit of these various measures across asset types.

Method

Capital costs, energy and GHG savings were gathered and compiled from various recently completed building energy audits; business cases, feasibility studies and or schematic design reports for cogeneration, electric buses, internal cost benefit analysis on LED street lights, and preliminary estimates from ENMAX in regards to renewable electricity credits for new large scale wind or solar facilities;

Data Analysis/Sources

	SOURCE(S)
Buildings	Energy Audit Reports commissioned by the City, conducted by WSP, Morrison Hershfield, MCW, Williams Engineering. 17 Energy audits on various building types commissioned by IIS in 2017: • Firehalls, 1 Police Station (MH) • Leisure Centres, 2 Transit Centres (MCW) • Transit Garages, 2 Vehicle Repair Shop, 2 EcoStation (Williams Engineering) • 1 Library, 1 Seniors Centre (WSP) • Terwillegar Recreation Centre CHP Schematic Design Report June 2017
Microgeneration solar photovoltaics	Energy Audit Reports commissioned by the City; Terwillegar Recreation Centre CHP Installation and Schematic Design Report, conducted by Clark Engineering. ENMAX submission to "Development of a Local Renewable Energy Certificate Market" RFI (Jan 2017)
Electric buses	Electric Bus Feasibility Study (June 2016) by Marcon; Electric Bus Transit Facility Assessment Study by WSP; Verbal Communication with Paul Netzband, Project Lead for Electric Bus Procurement Project, Council Report (CR_5145 – Electric Bus Procurement Update)
Electric passenger vehicles	Desktop research
LED street light replacement	Network Operations' Internal Cost Benefit Analysis spreadsheets for LED streetlight replacement.
Green Electricity	ENMAX submission to "Development of a Local Renewable Energy Certificate Market" RFI (Jan 2017) Email and Verbal Communication with ENMAX - Preliminary cost estimates from ENMAX in regards to renewable energy certificates from new wind or solar facilities;
Renewable Natural Gas	Email and Verbal Communication with ATCO Gas
Other Types of Carbon Offsets	Current and Future carbon levy prices set by provincial and or federal government

Approach and Assumptions

Parameter Assumptions

- Current and future utility rates and carbon levy; current and forecasted electricity grid factors; application of relevant provincial incentives; and discount rate were made standardized to ensure that that the cost benefit outputs can be compared "apples-to-apples"
- Capital and any maintenance costs / savings were taken directly from the audit and other reports with no detailed review;
    - **Note:** Incremental O&M Costs / Savings were not consistently included in the reports, but whatever was available was used in the cost benefit analysis;
- No inflation applied to capital cost estimates;
- Cost benefit analysis excluded ECMs related to education and operational behaviours;

Buildings-specific

- If the modeled results for energy and GHG savings differed from the additive results, modeled results were used in the analysis
- **Didn't review** the energy audit costs in conjunction with the building conditions audit to address redundant costs or figure out the truly incremental cost of the energy related upgrades

Discount Rate

- Discount Rate set at 2.5% as recommended by finance department.

Utility Rates and Fuel Costs

- 2017 to 2019 Electricity Price of $0.11/kWhr (includes delivery and energy charges) based on rate of the current electricity supply agreement with ENMAX, assuming that there will be a minimum 1 year contract extension;
- EDC Associates' Q3 2017 for pool and capacity under the "Capacity Market and 5,000 MW of Renewables" scenario was used for energy (and capacity) portion of the electricity from 2020 to 2031.
- ENMAX advised that the delivery vs. energy charge is approximate 50% / 50%, therefore the total electricity price for 2020 to 2032 was estimated by doubling the forecasted energy (and capacity) prices, and a 1% yearly fuel escalation rate was applied for 2032 and beyond.

Table 25: EDC Associates Price Forecast for Energy Cost and Estimated Total Electricity Price (Energy and Delivery) Forecast for City of Edmonton

Year	Unit Charge ($/MWh)			CoE Electricity Price (Delivery & Energy)
	Capacity Charge	Pool Price	Energy + Capacity	
2017		$22.06	$22.06	$ 110
2018		$47.96	$47.96	$ 110
2019		$49.43	$49.43	$ 110
2020		$52.93	$52.93	$ 106
2021	$31.34	$38.88	$70.22	$ 140
2022	$30.79	$41.31	$72.10	$ 144
2023	$31.45	$42.52	$73.97	$ 148
2024	$33.10	$42.53	$75.63	$ 151
2025	$33.78	$43.21	$76.99	$ 154
2026	$34.29	$43.51	$77.80	$ 156
2027	$35.64	$44.47	$80.11	$ 160
2028	$36.08	$44.86	$80.94	$ 162
2029	$36.74	$45.14	$81.88	$ 164
2030	$37.31	$46.30	$83.61	$ 167
2031	$36.81	$48.18	$84.99	$ 170

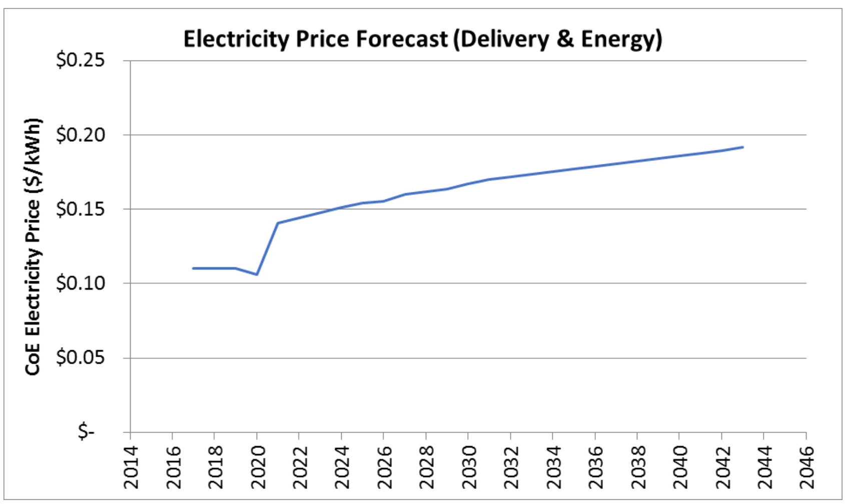

Figure 17: Total Electricity Price (Energy and Delivery) Forecast for City of Edmonton

- 2017 Natural Gas based on AB Energy Regulator's forecast (2017-2026) for energy, 1% yearly increase after; 2017 delivery charged based on OEM data for 2016, 1% yearly increase.
- Price forecasts for diesel and gasoline pegged to expected price escalation for crude oil WTI (between 2018 to 2031), 1% escalation applied for 2032 and beyond

Table 26: Total Natural Gas and Vehicle Fuel Price Forecast

	Natural Gas			Vehicle Fuel		
Year	AER Forecast (Energy	Delivery Cost Estimate	Total Price ($/GJ)	Cost Escalation	Diesel ($/L)	Gasoline ($/L)
2017	$ 2.99	$ 2.10	$ 5.09	13.1%	$ 0.86	$ 0.90
2018	$ 3.22	$ 2.12	$ 5.34	4.1%	$ 0.89	$ 0.93
2019	$ 3.25	$ 2.14	$ 5.39	3.9%	$ 0.93	$ 0.97
2020	$ 3.33	$ 2.16	$ 5.49	2.8%	$ 0.96	$ 1.00
2021	$ 3.45	$ 2.19	$ 5.64	2.0%	$ 0.97	$ 1.02
2022	$ 3.62	$ 2.21	$ 5.83	2.0%	$ 0.99	$ 1.04
2023	$ 3.80	$ 2.23	$ 6.03	2.0%	$ 1.01	$ 1.06
2024	$ 3.99	$ 2.25	$ 6.24	2.0%	$ 1.03	$ 1.08
2025	$ 4.18	$ 2.27	$ 6.45	2.0%	$ 1.05	$ 1.10
2026	$ 4.38	$ 2.30	$ 6.68	2.0%	$ 1.08	$ 1.12
2027	$ 4.42	$ 2.32	$ 6.74	2.0%	$ 1.10	$ 1.14
2028	$ 4.47	$ 2.34	$ 6.81	2.0%	$ 1.12	$ 1.17
2029	$ 4.51	$ 2.37	$ 6.88	2.0%	$ 1.14	$ 1.19
2030	$ 4.56	$ 2.39	$ 6.95	2.0%	$ 1.16	$ 1.21
2031	$ 4.60	$ 2.41	$ 7.02	2.0%	$ 1.19	$ 1.24
2032	$ 4.65	$ 2.44	$ 7.09	1.0%	$ 1.20	$ 1.25
2033	$ 4.70	$ 2.46	$ 7.16	1.0%	$ 1.21	$ 1.26
2034	$ 4.74	$ 2.49	$ 7.23	1.0%	$ 1.22	$ 1.28
2035	$ 4.79	$ 2.51	$ 7.30	1.0%	$ 1.24	$ 1.29
2036	$ 4.84	$ 2.54	$ 7.38	1.0%	$ 1.25	$ 1.30
2037	$ 4.89	$ 2.56	$ 7.45	1.0%	$ 1.26	$ 1.32
2038	$ 4.94	$ 2.59	$ 7.52	1.0%	$ 1.27	$ 1.33
2039	$ 4.98	$ 2.61	$ 7.60	1.0%	$ 1.29	$ 1.34
2040	$ 5.03	$ 2.64	$ 7.68	1.0%	$ 1.30	$ 1.36
2041	$ 5.09	$ 2.67	$ 7.75	1.0%	$ 1.31	$ 1.37
2042	$ 5.14	$ 2.69	$ 7.83	1.0%	$ 1.32	$ 1.38
2043	$ 5.19	$ 2.72	$ 7.91	1.0%	$ 1.34	$ 1.40

Electricity Grid Factor (Consumption Emission Intensity)

Electricity grid factor: EDC Q3 2017 Forecast (2017-2031), under the “Capacity Market and 5,000 MW of Renewables” scenario, which provided the generation emissions intensity. The consumption emissions intensity is required for the inventorying process. The estimated consumption emission intensities were created based on the EDC Associates generation emissions intensities PLUS an estimated adder that accounts for: transmission line losses, emissions from use of halocarbons and SF6 in electricity equipment required for transmission/distribution. For GHG inventory reporting for the current year, the consumption intensity is as published in Environment Canada's National Inventory Report (NIR) (submission to the UNFCCC). The "adder" was based on the average historical difference between NIR's consumption and generation intensities for 2010-2015. This average difference was then added to the generation intensity forecasted for 2017 to 2031. The grid factor for 2016 was estimated to be the same as the 2017 grid factor.

Beyond 2031, the grid factor was held at 2031 levels due to lack of forecast.

Table 27: Forecasted Emissions of Electricity Grid

Year	Generation Intensity (kg of CO2e/kWh)	Consumption Intensity (kg of CO2e/kWh)
2017	0.69	0.83
2018	0.60	0.72
2019	0.59	0.71
2020	0.58	0.69
2021	0.52	0.62
2022	0.49	0.58
2023	0.48	0.58
2024	0.47	0.57
2025	0.46	0.56
2026	0.45	0.53
2027	0.43	0.51
2028	0.42	0.50
2029	0.40	0.48
2030	0.35	0.42
2031	0.27	0.33
2032	0.27	0.33
2033	0.27	0.33
2034	0.27	0.33
2035	0.27	0.33
2036	0.27	0.33
2037	0.27	0.33
2038	0.27	0.33
2039	0.27	0.33
2040	0.27	0.33
2041	0.27	0.33
2042	0.27	0.33
2043	0.27	0.33

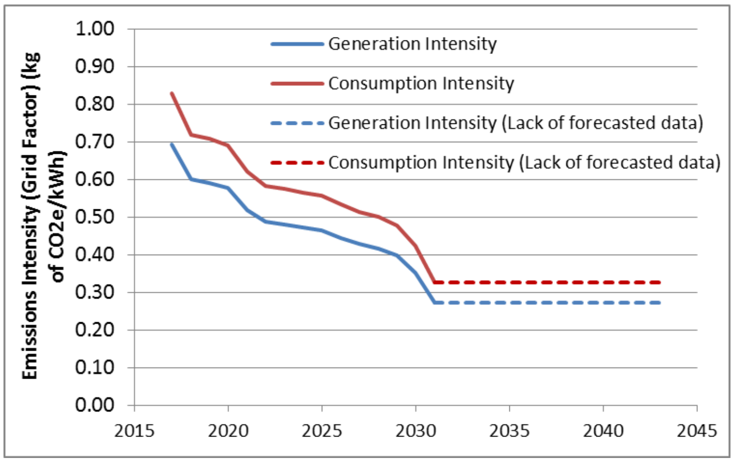

Figure 18: Emissions Intensity of Grid Factor Over Time

Carbon Levy

Carbon levy based on provincial and federal rates until 2022, and stays at 2022 levels beyond 2022.

Table 28: Carbon Levy Rates

YEAR	RATE ($/TONNE)
2017	$20
2018	$30
2019	$30
2020	$30
2021	$40
2022 and beyond	$50

Carbon Levy Explanation

The table below explains the impact from the carbon Levy on City Operations outcomes.
Please note that City operations are only impacted with regards to: Diesel, Gasoline, Natural Gas, and Propane usage as well as a charge per metric tonne on GHG

- As of January 1 st 2017 there is an additional charge of $1.011 per Giga Joule for Natural Gas.
- As of January 1 st 2018 there is an additional charge of $1.517 per Giga Joule for Natural Gas.

Table 29: Carbon Levy Impact on Fuel Price for 2017 vs 2018

TYPE OF FUEL	JAN 1 ST 2017, $20/TONNE	JAN 1 ST 2018, $30/TONNE
Diesel	+5.35 cents/Litre	+2.68 cents/Litre
Gasoline	+4.49 cents/Litre	+2.24 cents/Litre
Natural Gas	+1.011 $/GJ	+0.506 $/GJ
Propane	+3.08 cents/Litre	+1.54 cents/Litre

Incentives

Although incentives are not directly included in the cost benefit analysis in this plan the City should make every effort to use existing and future incentive programs to help offset the capital cost of many of the measures outlined in this plan. A process should be developed to help identify these incentives and make sure that the application process is handled by specific champions at the city.

Taking Action to Manage Energy (TAME+)

- As of October 18, 2017, the TAME+ program is fully subscribed and closed to new applicants.
- The Taking Action to Manage Energy (TAME+) program provides incentives to Alberta Municipalities for custom energy efficiency upgrades to municipal facilities as recommended by detailed energy audits. Participation in the TAME+ program will help municipalities understand how energy is used in their buildings, identify key energy savings opportunities, and implement retrofit projects.
- Participants are eligible to receive an incentive of 60% of capital costs up to a maximum of $500,000 per facility of any size, with a maximum of $1,000,000 of funding per Municipality, for the implementation of energy conservation measures outlined in an approved Detailed Energy Assessment
- Projects must also meet a minimum greenhouse gas reduction performance requirement (abatement rate) of $60 per tonne, measured by dividing total MCCAC implementation funding by a project’s lifetime

greenhouse gas reductions. Funding for projects that have an abatement rate greater than $60/tonne will be pro-rated

Municipal Climate Change Action Centre. 2017. TAME+. http://www.mccac.ca/programs/TAME

Municipal Climate Change Action Centre. 2017. AMSP Guidebook http://www.mccac.ca/sites/default/files/amsp_guidebook_4.pdf

Alberta Municipal Solar Program

- The Alberta Municipal Solar Program (AMSP) provides financial incentives to Alberta municipalities who install grid-connected solar photovoltaics (PV) on municipal facilities or land and complete public engagement for the project.
- Participants are eligible to receive a rebate per watt of total installed capacity ($/W), as per the table below. The rate tier is determined by the total installed capacity of a project submitted through a single AMSP Application. The rebate provided by the MCCAC will not exceed 25% of eligible expenses.

Total Installed Capacity (DC)	Rebate
<10 kilowatts	$0.90/Watt
10 kilowatts to <150 kilowatts	$0.75/Watt
150 kilowatts to <2 Megawatts	$0.60/Watt
2 Megawatts to 5 Megawatts	$0.55/Watt

Note: Funding is available on a first come, first served basis. Municipalities are eligible to submit multiple applications.

Additional Funding Opportunities

- Energy Efficiency Alberta. 2017. Business, Non-Profit, and Institutional Energy Savings Program. https://www.efficiencyalberta.ca/business-non-profit-and-institutional/
- Public Transit Infrastructure Fund (PTIF) should be considered for electric bus purchases and any retrofits that work with transit facilities.
- Federal funding through the Low Carbon Economy Challenge https://www.canada.ca/en/environment-climate-change/services/climate-change/low-carbon-economy-fund/challenge.html

Sensitivity Analysis Conditions

Sensitivity analysis completed on (ranging from most to least conservative):

- Discount rate of 5%;
- Fuel/utility cost escalation at 5% and 10%.

Carbon Abatement Options - Capital Cost, Energy and GHG Savings Assumptions and Calculations

Building Retrofits

Table 30: Average Percent breakdown of GHG Reduction Between Electricity and Natural Gas Based on Recommended Measures from the Building Audits

	2016	2030
Grid Factor (tonnes/kWh)	0.000823	0.000420
% Reduction from Electricity	45.2%	23.2%
% Reduction from Natural Gas	54.8%	54.8%
Total	100%	78%*

**This means if a project was able to reduce 100 units of GHG in 2016, because of the change in grid factor and the split in GHG reductions between electricity and natural gas, by 2030, it would only be able to reduce 78 units of GHG.*

Table 31: Building Energy Retrofit Energy Audit Extrapolation Summary

NUMBER OF BUILDINGS	TONNES OF CO2E REDUCED PER YEAR (2016 GRID FACTOR)	TONNES OF CO2E REDUCED PER YEAR (2030 GRID FACTOR)	CAPITAL INVESTMENT	NPV BENEFITS OVER 20 YEARS
Based on data from recent energy audits				
11*	6,258	4,882	$ 8,607,802**	$11,390,667
Extrapolation to current level of energy retrofit funding (e.g., $9M for 2015-2018)				
12	*6,543*	5,105	*$ 9,000,000*	$11,909,661
Extrapolation to Scenario 1, and 2 (e.g., 45,000 tonnes reduction by 2030)				
35		45,000	$79,000,000	$ 105,000,000

*****Includes 15% project soft cost that was applied to the original project cost of the 11 buildings stated in the building audit reports.***

Energy Retrofit Data Analysis

The below table provides the findings from the analysis that was done to determine which group of energy audit data should be used for plan projections. The rationale for use of the sample set is provided in the report body.

Table 32: Summary of Findings From Recent Energy Audits of City Buildings

	All Samples		Modified Sample	
Parameter	Average	Median	Average	Median
Start of Operation	1974	1974	1973	1975
Square Meters	5004	2137	5618	2346
1st Electricity Savings	273,755	100,000	331,042	122,750
1st Natural Gas Savings	5,966	2,586	5,832	3,621
1st Year Energy Savings	1,931,004	757,091	1,951,057	1,217,219
% Split from Electricity Savings	23%	18%	18%	15%
% Split from Natural Gas Savings	77%	82%	82%	85%
% Energy Savings Potential relative to baseline (1st yr)	37%	39%	36%	36%
Energy Savings Potential (Lifetime)	33,145,825	13,367,822	32,538,109	20,682,751
1st GHG Savings from Electricity	224	82	271	101
1st GHG Savings from Natural Gas	304	132	297	185
1st Year Carbon Savings	529	164	569	330
% Split of GHG Savings (Electricity)	51.3%	49.6%	45.2%	44.3%
% Split from Natural Gas Savings	48.7%	50.4%	54.8%	55.7%
% GHG Reduction Potential relative to baseline (1st yr)	36%	35%	34%	37%
GHG Savings Potential (Lifetime)	7,794	2,648	8,065	4,822
Capital Cost per Project	$612,495	$263,350	$782,527	$301,527
Unit Carbon Abatement Cost	$136	$123	$112	$116
NPV/tCO2e over 20 Years	$111	$88	$118	$90
Simple Payback	9.9	9.2	10.1	9.1
Discounted Payback (at 2.5%)	10.8	9.4	11.6	9.4
Cost Benefit Ratio (NPV Benefits / Capital Cost)	2.0	0.6	2.5	0.6
Rate of Return (Based on Discounted Payback)	9.2%	10.6%	8.6%	10.9%
Carbon Abatement Over 20 Years	7,368	2,150	7,427	3,758

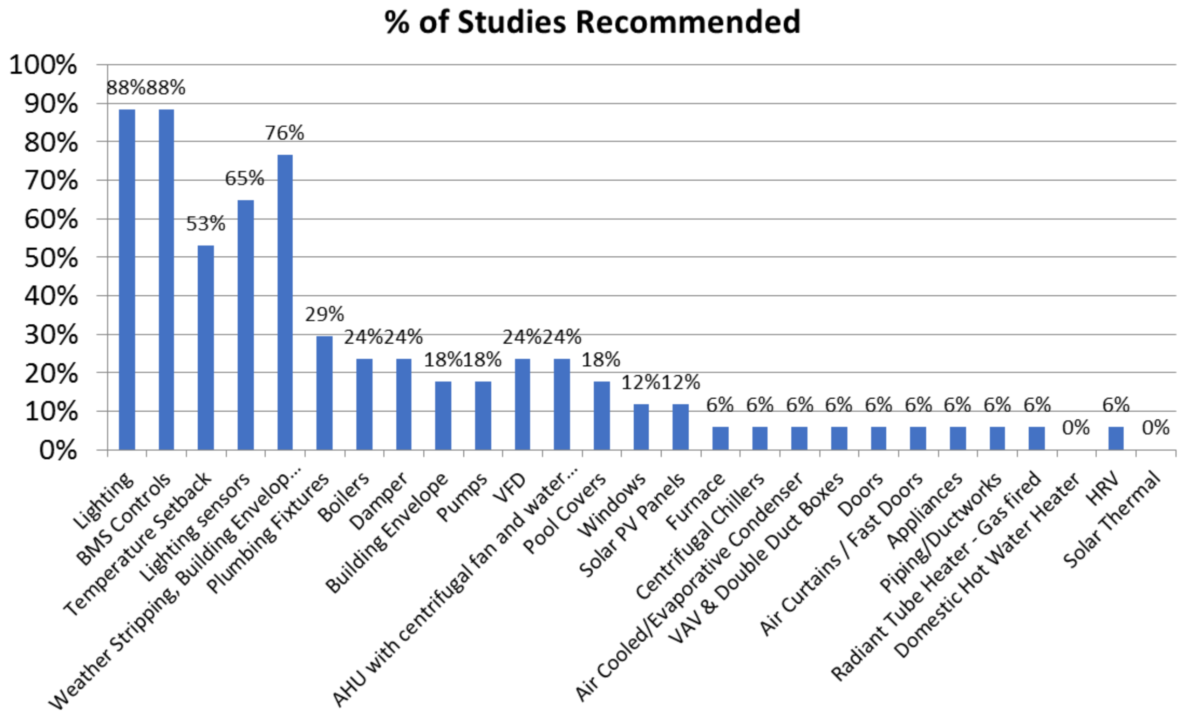

Figure 19: Frequency of Suggested Energy Conservation Measure in Energy Studies Analyzed

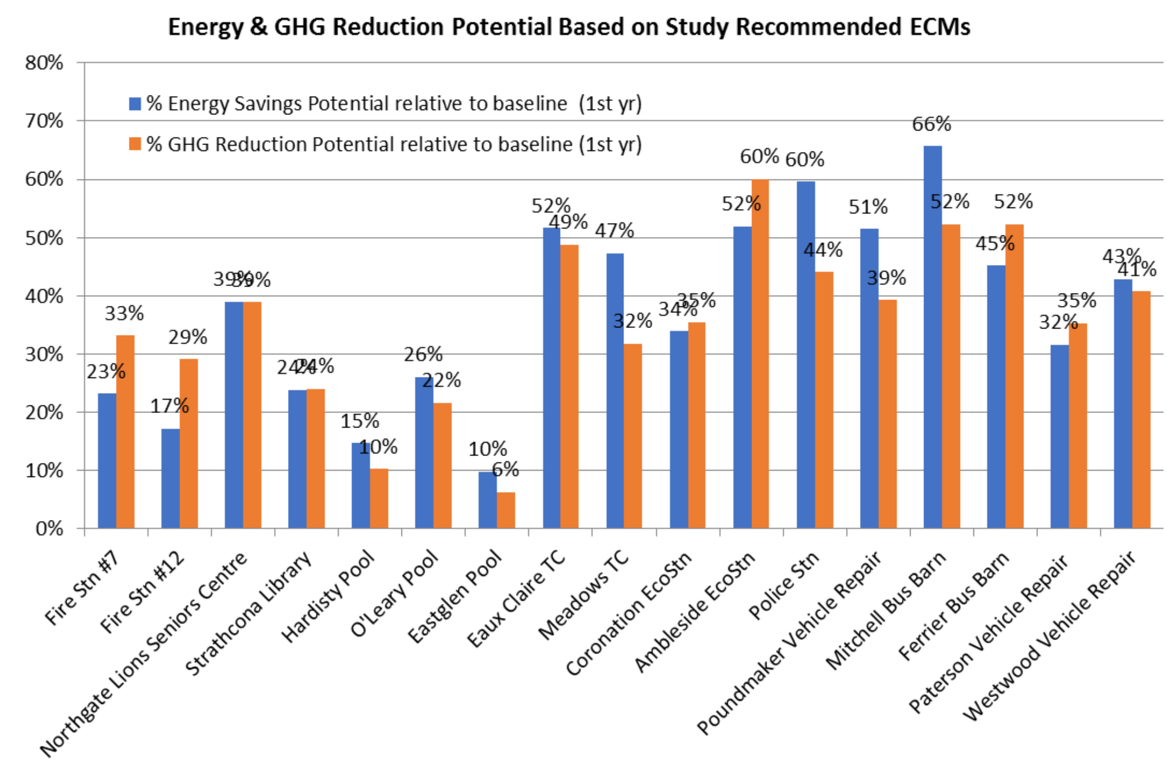

Figure 20: Energy & Reduction potential based on Study Recommended ECMs

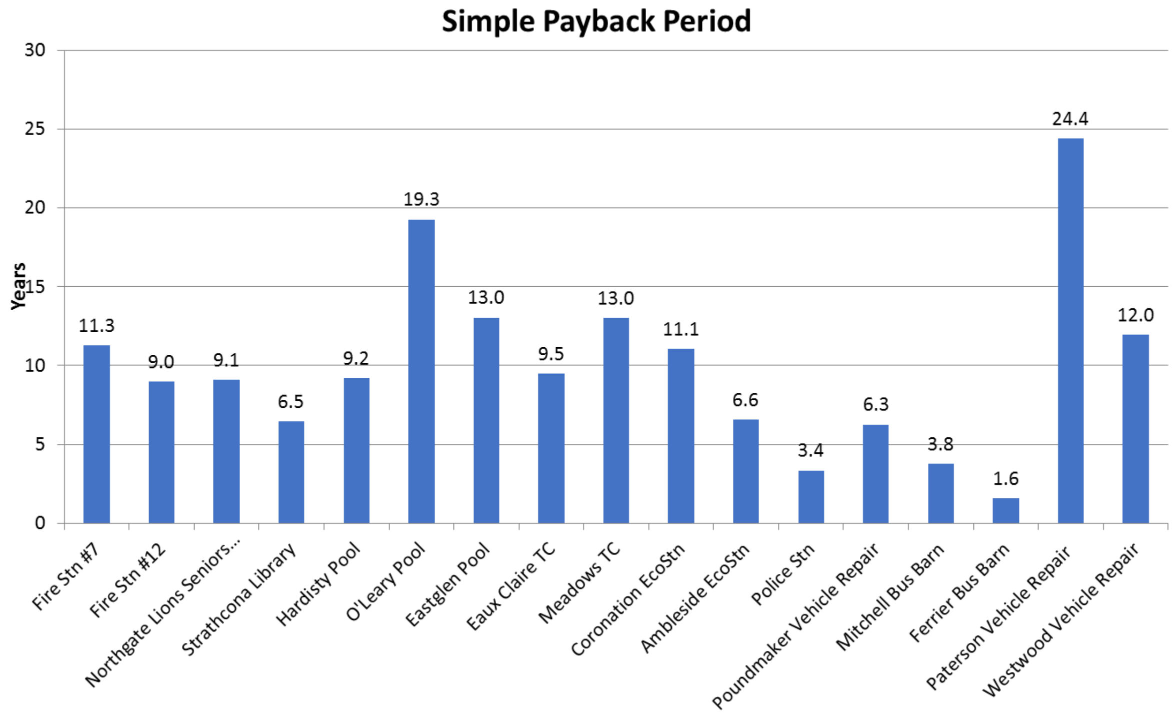

Figure 21: Simple Payback Period of Suite of Measures in Each Facility Studied

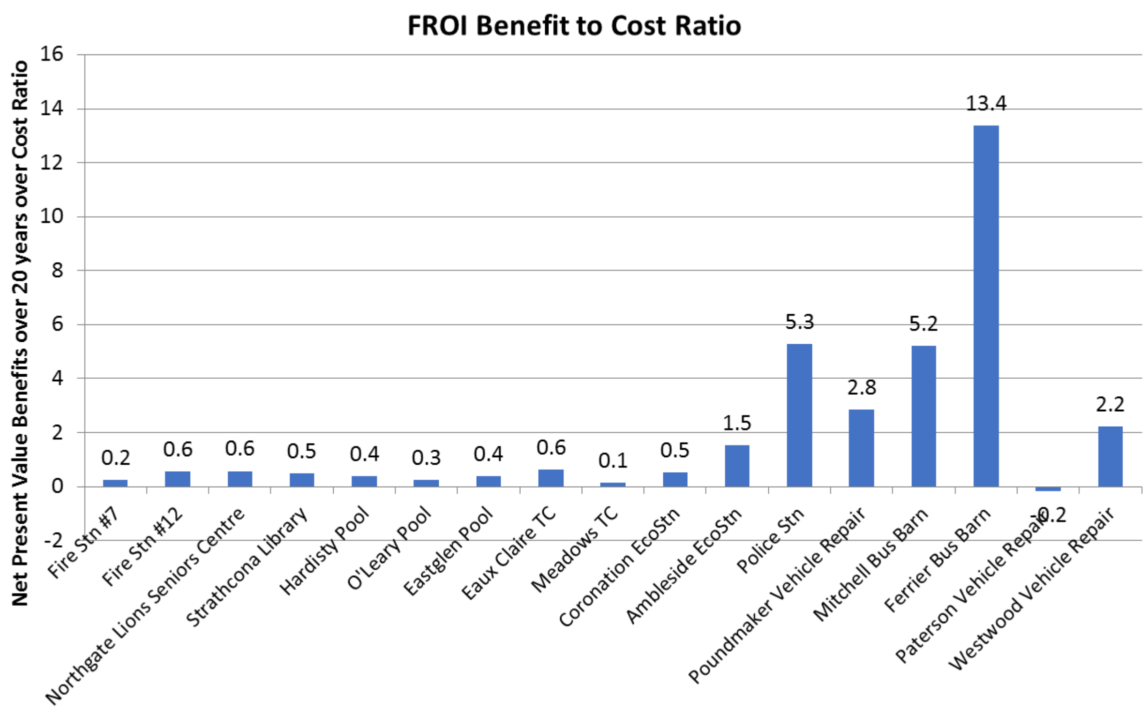

Figure 22: FROI Benefit to Cost Ratio of Suite of Measures in Each Facility Studied

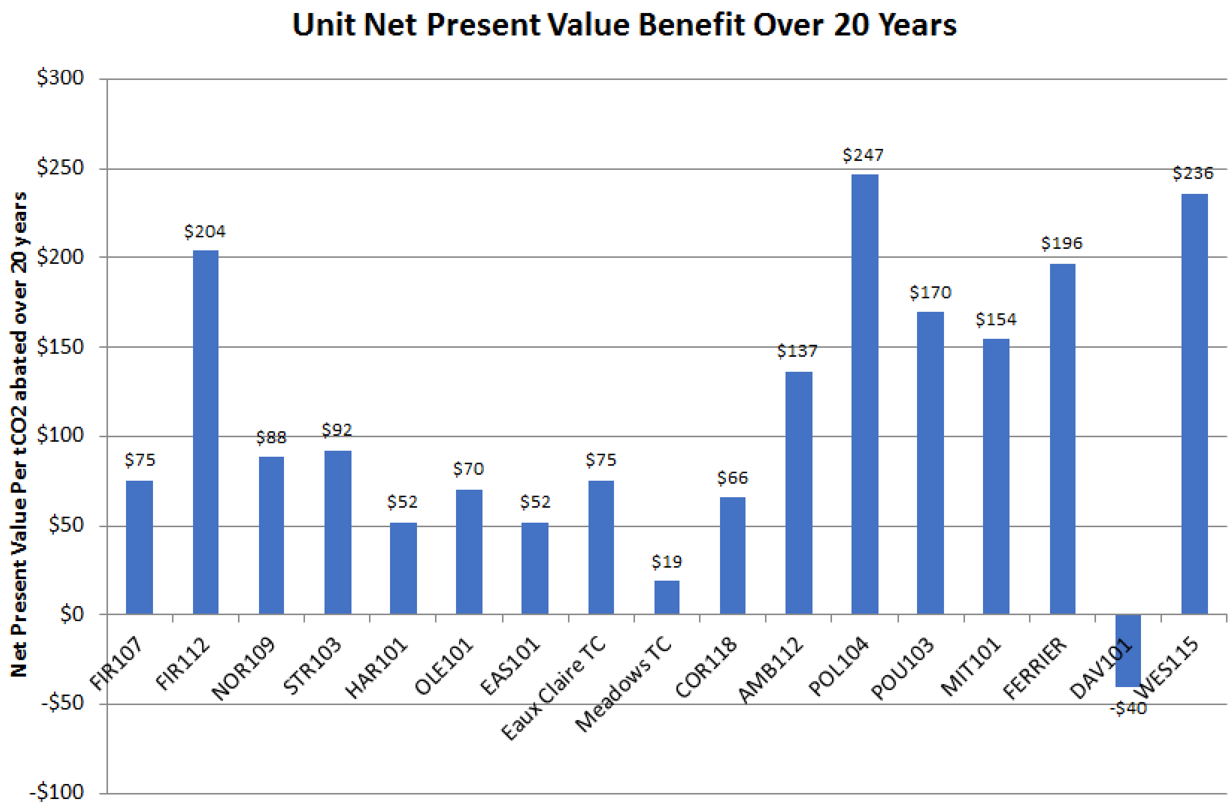

Figure 23: Unit Net Present Value Benefit Over 20 Years of Suite of Measures in Each Facility Studied

Cogeneration Calculations

- Capital Cost: $1,186,000
- Project Soft Cost = 15%
- Total Capital Cost = $1,363,900
- Installed capacity: 575 kW
- Estimated Equipment Lifepsan: 15
- Yearly Maintenance Cost: $86,282
- Building to be installed in: Terwillegar Rec Centre

Table 33: Cogeneration Energy Greenhouse Gas Savings Percentage

CURRENT YEARLY ENERGY USE		ANTICIPATED ENERGY SAVINGS AND GHG REDUCTION	
Electricity Use (kWh)	10,635,238		
Natural Gas Use (GJ)	45,948	% of energy savings (First yr)	-11%
Total Energy Use (ekWh)	23,399,592	% of GHG savings (First yr)	22%

Table 34: Cogeneration Energy Greenhouse Gas Savings

NATURAL GAS SAVINGS (GJ)	ELECTRICITY SAVINGS (KWH)	TOTAL ANNUAL ENERGY SAVINGS (EKWH)	ANNUAL NATURAL GAS CARBON SAVINGS (TCO2E)	ANNUAL ELECTRICITY CARBON SAVINGS (1ST YEAR TCO2E)	TOTAL ANNUAL CARBON SAVINGS (TCO2E)
(26,748)	4,793,472	-2,637,122	(1,364)	3,834.8	2,470.6

LED Streetlight Calculations

- Units remaining to be replaced: 46,000
- Average unit type = S72
- Average replacement = a 195W unit replaced with 127W unit
- Run hours per year = 11.46 hrs/day*365
- Material (incl. 17% overhead) = $294.50/unit X 1.17 = $344.57/unt
- Contractor labour = $82.40/unit
- Total Cost per unit = $426.97
- **Total Capital Cost: $19,640,000**
- Estimated Equipment Life span: 20
    - Note: equipment has not yet been tested for full rated life span therefore 20 years is based on rated value not City of Edmonton experience.
- Yearly Maintenance Cost Savings:
- Decrease in planned inspection and replacement = ~19% of the 46,000 units X $26.12/units = $228,289
- Decrease in random average relamp cost of older lamps = ~11.5% of 46,000 units X $65.49/units = $346,442
- Total yearly maintenance cost savings = $574,731

Table 35: LED Streetlight Energy Greenhouse Gas Savings Percentage

CURRENT YEARLY ENERGY USE		ANTICIPATED ENERGY SAVINGS AND GHG REDUCTION	
Electricity Use (kWh)/unit	816		531
		% of energy savings (First yr)	35%
		% of GHG savings (First yr)	35%

Table 36: LED Streetlight Energy Greenhouse Gas Savings

CARBON REDUCTION FOR SCENARIO 1, 2, AND 3							
YEAR	PROJECT GRID FACTOR (TCO2E/ KWHR)	NATURAL GAS SAVINGS (GJ)	ELECTRICITY SAVINGS (KWH)	TOTAL ANNUAL ENERGY SAVINGS (EKWH)	ANNUAL NATURAL GAS CARBON SAVINGS (TCO2E)	ANNUAL ELECTRICITY CARBON SAVINGS (1ST YEAR TCO2E)	TOTAL ANNUAL CARBON SAVINGS (TCO2E)
2019*	0.000709		3,254,500	3,254,500		2307	2307
2030	0.000420		13,018,000	13,018,000		5,506	5,506

**Full rollout completed by 2022*

Solar Photovoltaics Calculations

Table 37: Solar PV Carbon Reductions Calculations

		SMALL SCALE	LARGE SCALE
Installed Capacity (kW)		19	650
Installed Cost:		$3/W (Incl. project soft cost)	$2.3/W (Incl. project soft cost)
Capital Cost:		$57,000	$1.5M
Yearly Maintenance Cost		$500	$3000
Solar generation potential (kWh/kW/yr of installed capacity)		1150	1150
Electricity import avoided annually (kWh)		19 kW x 1150 kWh/kW/yr = 21,850 kWh	650 kW x 1150 kWh/kW/yr = 747,500 kWh
Carbon Reduction for Scenario 1, and 2			
Total Installed Capacity	20 MW - Large Scale		
		Calculation (approximated)	**Value**
Total Installation Cost		20MW x $2.3/W x 1,000,000 W/MW=	$47 Million for report purposes.
Carbon Reduction by year	**Grid Factor**		
2019	0.000704	20 MW x 1150 kWh/kW x 0.704 kg/kWh=	16192 tonnes
2030	0.000420	20 MW x 1150 kWh/kW x 0.420 kg/kWh=	9660 tonnes approximated to 10,000 tonnes for report purposes.

Electric Bus Calculations

Table 38: Electric Bus Assumptions

ASSUMPTIONS (MARCON - USED)					
Distance traveled per bus per year	49450	km	**Total Maintenance & Servicing Cost**		
Mileage of Diesel buses	0.49	L/km	Diesel	$ 0.783	per km
Mileage of Trickle Charged	1.25	kwh/km	Electric	$ 0.546	per km
Mileage of En Route Charged	1.38	kwh/km	Labour cost increases	3%	
Number of buses purchased	40				

Revised Assumptions based on conversation with Paul Netzband, Project Lead, Electric Bus Procurement Project (Oct 23, 2017)

Incremental Capital Cost:

- Incremental cost per bus could range from $75,000 to $350,000 - but likely between $100,000 to $200,000 USD; $200,000 USD is used in the analysis, with an exchange rate of 1.3 applied from USD to CAD
- $260,000 for incremental capital cost between diesel and electric bus (ONLY)

Infrastructure Upgrade Cost:

- Infrastructure upgrade cost based on Electric Bus Transit Facility Assessment Study (WSP)
- Centennial Upgrades = $30.8 Million for 100 electric bus
- NETG upgrades = $42 Million for 100 electric bus
- Charge infrastructure for 200 buses in total, but times 2 because only half of the buses are charging at a time, so can serve around 400 in total.
- $182,000 per bus for Capital Upgrade / Charging Infrastructure Requirements

Table 39: Electric Bus Carbon Reductions Calculations

CARBON REDUCTION FOR SCENARIO 1, 2 AND 3								
YEAR	DIESEL EMISSIONS FACTOR (TCO2E/L)	GRID FACTOR (TCO2E/ KWHR)	PER	NET CHANGE IN DIESEL USE(L)	NET CHANGE IN ELECTRICITY USE (KWH)	ANNUAL DIESEL CARBON SAVINGS (TCO2E)	ANNUAL ELECTRICITY CARBON SAVINGS (TCO2E)	TOTAL ANNUAL CARBON SAVINGS (TCO2E)
2019	0.002786	0.000704	1 bus	-23,835	61,813	66.4	-43.5	22.9
2030	0.002786	0.000420	1 bus	-23,835	61,813	66.4	-26.0	40.4
2030	0.002786	**0.000420**	**440 bus**					**17,800**

Cost Benefit Results of various Carbon Abatement Options

The graph below compares the unit upfront capital carbon abatement cost for various types of energy conservation measures. This measure is calculated as: total upfront capital cost divided tonnes of CO2e abated over lifespan of energy conservation measure. It is **only** a measure of capital efficiency and ignores any cost recovery potential from utility and or O&M savings.

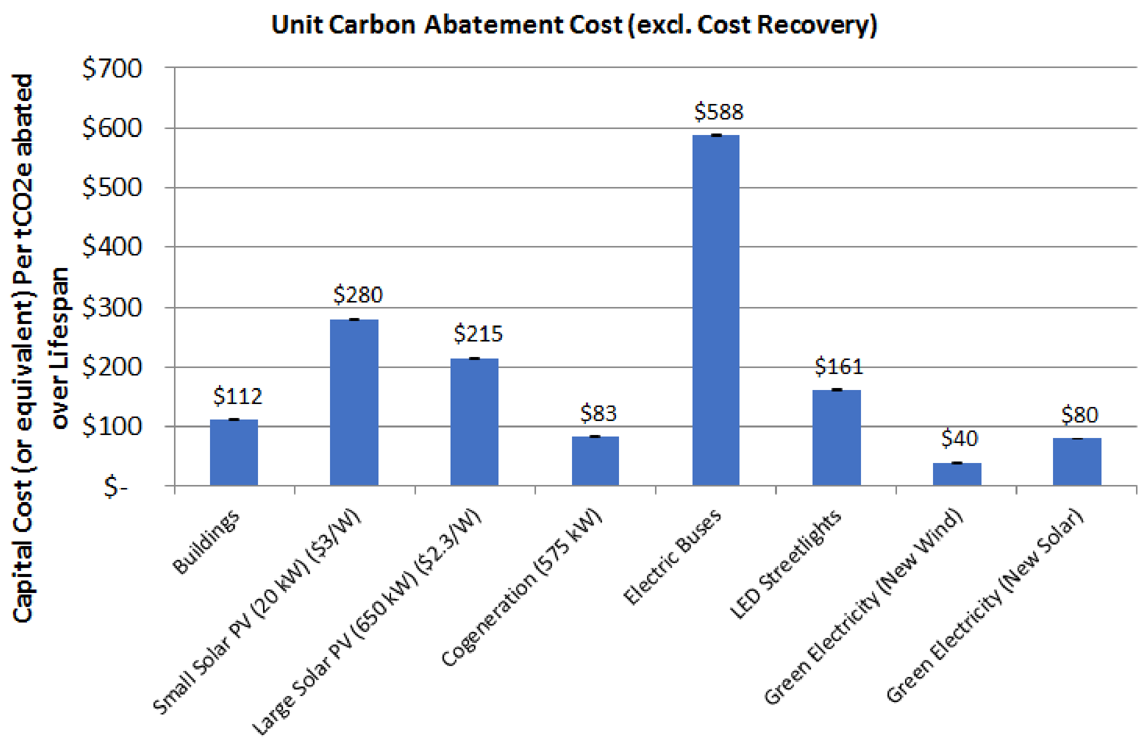

Figure 24: Carbon Abatement Costs

The second graph below compares the simple payback of the various energy conservation measures. The data shows that all of the displayed energy conservation measures have potential paybacks, even with the relatively higher upfront capital requirements in the case of electric buses and LED streetlights.

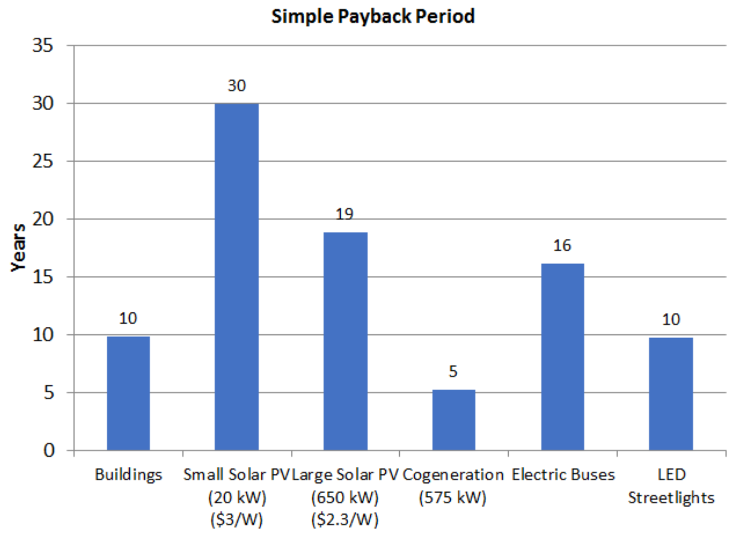

Figure 25: Simple Payback Periods of Various Carbon Abatement Options

The third graph below compares the discounted payback of the various carbon abatement options. The discounted payback analysis included application of future fuel cost increases, planned carbon levy increase as well as a modest discount rate of 2.5%. The simple and discounted payback periods are very similar because the projected increases in fuel cost and carbon levy are essentially offset by the discount rate.

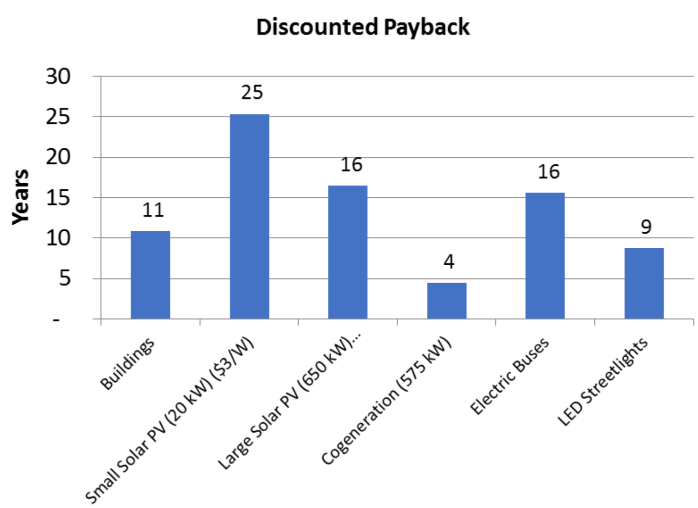

Figure 26: Discounted Payback of Various Carbon Abatement Options

The fourth graph below compares the unit net present value per tonne of GHG abated. This measure is calculated as: (Net present value of the utility and O&M savings over 20 years - upfront capital cost) divided by tonnes of CO2e abated over 20 years or life of the ECM (whichever is shorter). This is a measure of financial cost benefit as it considers cost recovery. The graph shows positive net present value for nearly all types of energy conservation measures. Again, both electric buses and LED street lights had positive net present value even though they had high upfront capital carbon abatement costs (refer to graph above).

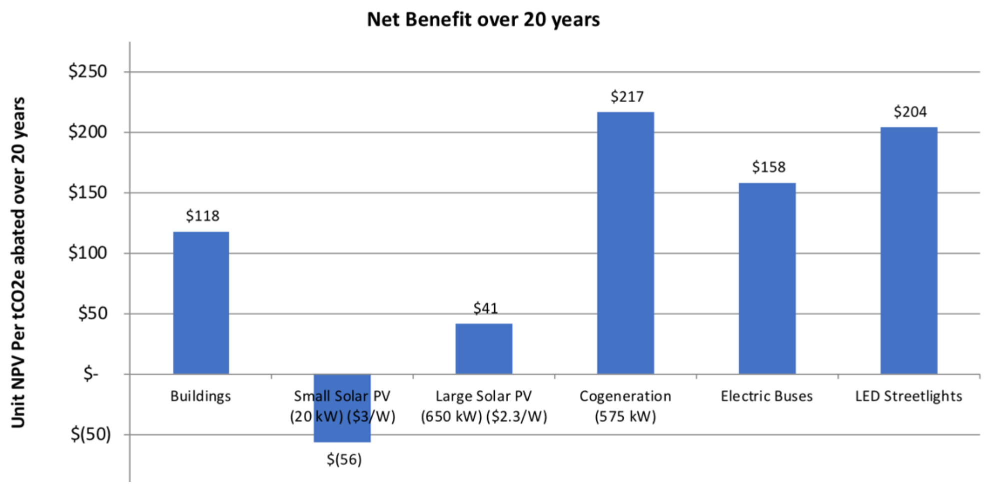

Figure 27: Net Benefit over 20 Years of Various Carbon Abatement Options

The fifth graph below compares net present value benefit to cost benefit ratio of various GHG abatement options. This is a financial return on investment measure that is calculated as: (Net present value of the utility and O&M savings over 20 years - upfront capital cost) divided by upfront capital cost. The higher the ratio is the greater the potential for cost recovery.

The graph shows positive net present value benefit to cost ratios for nearly all types of GHG abatement options. Electric buses had positive net present value benefits even though it had high upfront capital carbon abatement costs (refer to graph above).

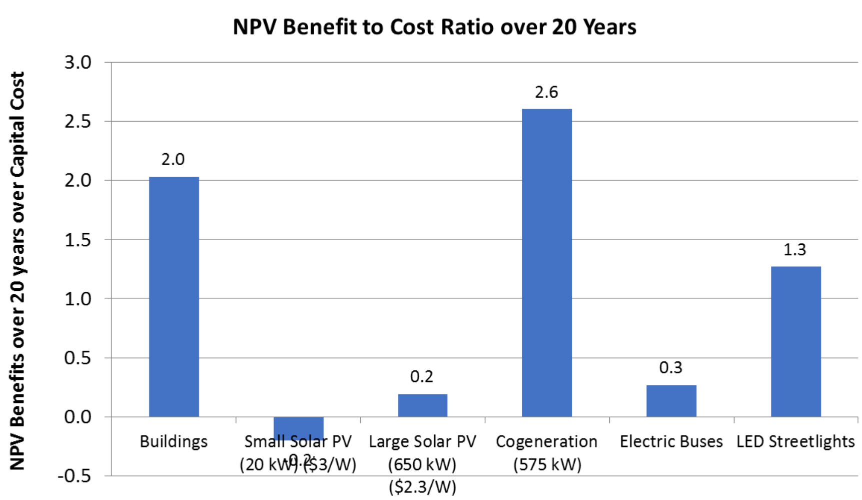

Figure 28: NPV Benefit to Cost Ratio Over 20 years of various Carbon Abatement Options

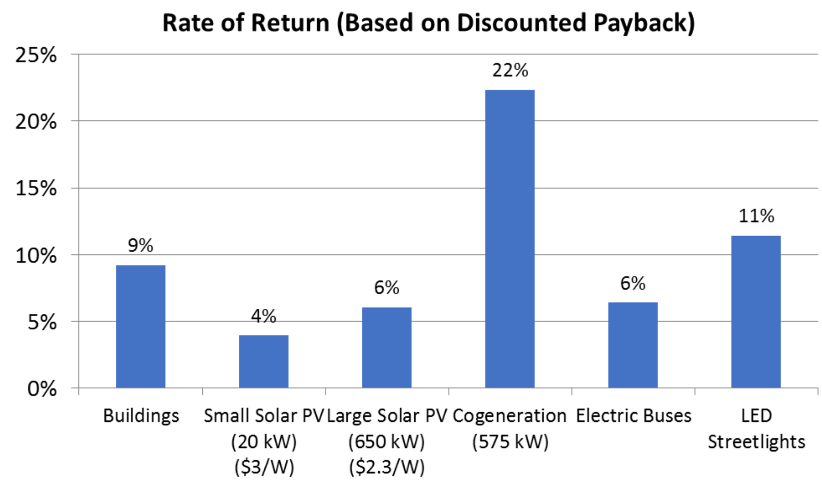

Figure 29: Rate of Return of Various Carbon Abatement Options

Appendix F: Sensitivity Analysis

Table 40: Discounted Payback Period (Note: in case of blank value, payback exceeds life of measure)

	BASE	DISCOUNT RATE 5%	FUEL ESC. 5%	FUEL ESC. 10%
Buildings	11	13	10	7
Small Solar PV (20 kW) ($3/W)	25			17
Large Solar PV (650 kW) ($2.3/W)	16	20	16	13
Cogeneration (575 kW)	4	5	5	5
Electric Buses	16	19	13	11
LED Streetlights	9	10	9	8
Green Electricity (New Wind)	n/a			
Green Electricity (New Solar)				

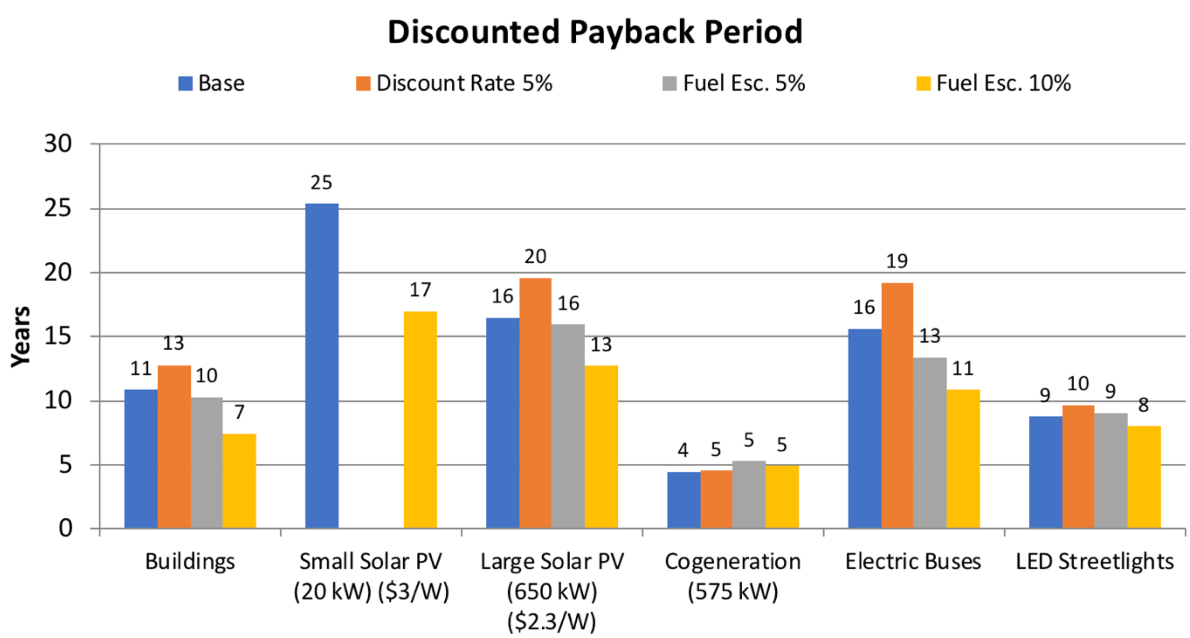

Figure 30: Discounted Payback Period (Note: in case of blank value, payback exceeds life of measure)

Table 41: Rate of Return (Based on Discounted Payback) (Note: in case of blank value, payback exceeds life of measure)

	BASE	DISCOUNT RATE 5%	FUEL ESC. 5%	FUEL ESC. 10%
Buildings	9%	8%	10%	13%
Small Solar PV (20 kW) ($3/W)	4%			6%
Large Solar PV (650 kW) ($2.3/W)	6%	5%	6%	8%
Cogeneration (575 kW)	22%	22%	19%	20%
Electric Buses	6%	5%	7%	9%
LED Streetlights	11%	10%	11%	12%
Green Electricity (New Wind)	n/a			
Green Electricity (New Solar)				

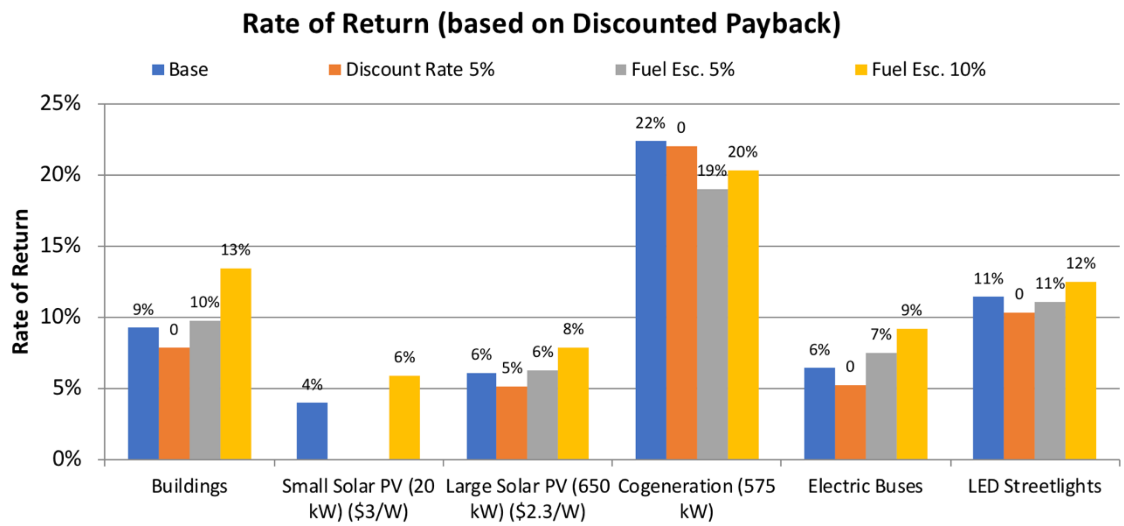

Figure 31: Rate of Return (Based on Discounted Payback) (Note: in case of blank value, payback exceeds life of measure)

Table 42: FROI Net Present Value to Cost Ratio

	BASE	DISCOUNT RATE 5%	FUEL ESC. 5%	FUEL ESC. 10%
Buildings	2.0	1.8	2.4	4.6
Small Solar PV (20 kW) ($3/W)	-0.2	-0.3	0.0	0.6
Large Solar PV (650 kW) ($2.3/W)	0.2	0.0	0.3	1.0
Cogeneration (575 kW)	2.6	2.2	2.2	3.3
Electric Buses	0.3	0.0	0.6	1.4
LED Streetlights	1.3	0.8	1.5	2.7

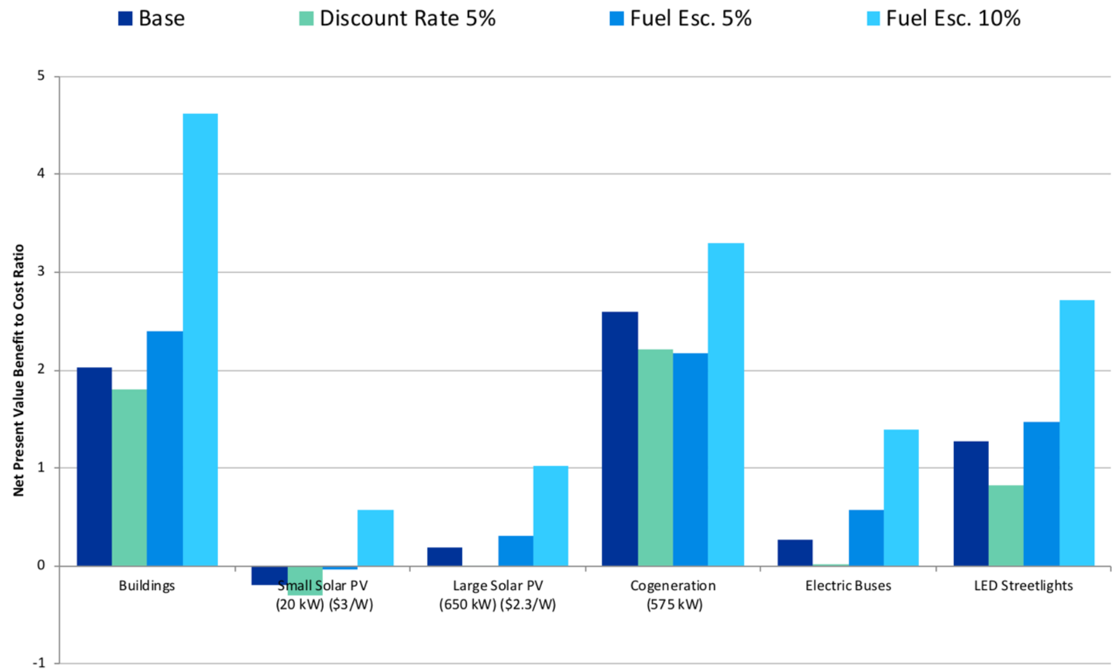

Figure 32: Net Present Value to Cost Ratio

Table 43: Net Present Value per tCO2e Over 20 Years

	BASE	DISCOUNT RATE 5%	FUEL ESC. 5%	FUEL ESC. 10%
Buildings	$109	$75	$142	$254
Small Solar PV (20 kW) ($3/W)	-$76	-$100	-$38	$87
Large Solar PV (650 kW) ($2.3/W)	$41	-$3	$67	$221
Cogeneration (575 kW)	$217	$185	$181	$275
Electric Buses	$158	$13	$336	$818
LED Streetlights	$204	$132	$237	$438
Green Electricity (New Wind)	-$40	-$33	-$40	-$40
Green Electricity (New Solar)	-$80	-$65	-$80	-$80

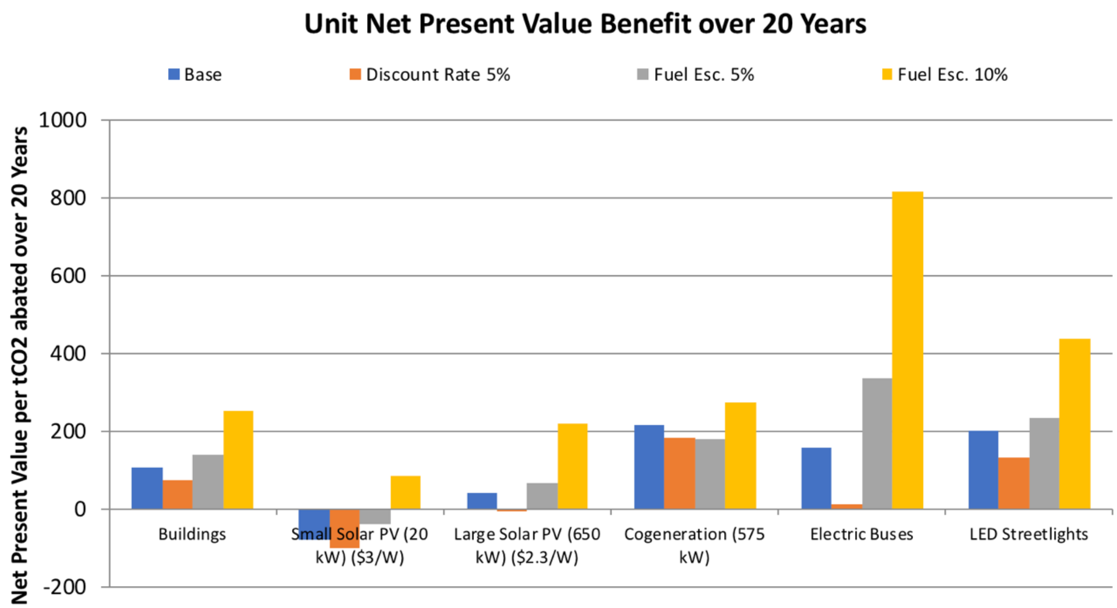

Figure 33: Unit Net Present Value Benefit Over 20 Years

Appendix G: Glossary and Equations

Greenhouse Gas (GHG): Gases such as carbon dioxide, methane and nitrogen oxide which actively contribute to the atmospheric greenhouse effect. Greenhouse gases also include gases generated through industrial processes.

Carbon-neutral: refers to achieving net zero carbon emissions by balancing a measured amount of carbon released with an equivalent amount sequestered or offset, or buying enough carbon credits to make up the difference

Carbon Offset/Credit: A reduction in emissions of carbon dioxide or greenhouse gases made in order to compensate for or to offset an emission made elsewhere.

tCO2e: tonnes of carbon dioxide equivalent. The idea is to express the impact of each different greenhouse gas in terms of the amount of CO2 that would create the same amount of warming.

Net Zero Energy Building: A building/site where the total amount of energy used on an annual basis is roughly equal to the amount of renewable energy created on the site.

Financial Return on Investment: measures the gain or loss generated on an investment relative to the amount of money invested.

Green Electricity: electricity sourced from renewable energy sources such as hydro, wind, and solar power. Procuring green electricity from the electricity grid can logistically be achieved through a number of contractual arrangements; however, the mechanism for any organization to claim the environmental attribute created from the carbon reduction that occurs as a result of displacement of fossil fuel sourced electricity is a renewable energy certificate (RECs). These RECs are generally purchased as a premium above the negotiated retail price of the electricity. The purchase of RECs can be coupled or decoupled from the electricity services contract. The outcome of the investment in RECs is increased market viability of renewable energy projects which decreases local, regional and global carbon emissions. The organization that makes the investment in the RECs is able to legitimately, transparently, and in alignment with international standards, claim that reduction within their own emissions inventory.

Social Cost of Carbon: An estimate of the economic damages associated with a small increase in carbon dioxide emissions (conventionally one metric tonne).

Lifecycle Cost Benefit Analysis: The analysis entails an assessment of key building elements on a lifecycle, apply net present value methodology, include energy costs and maintenance costs (above business-as-usual), include element replacement costs over the lifespan, and apply a City-approved discount rate.

Sustainable Return on Investment (SROI): An enhanced form of lifecycle cost benefit analysis that provides a triple-bottom line view of the a project's economic results and monetizes all relevant social and environmental impacts related to the given project, and provides the equivalent financial metrics. Refer to Consultant Design Manuals and RFP specifications for most current project-specific requirements.

Description and Equations of Cost Benefit Parameters

Simple Payback Period

Description: This parameter provides an indication of the cost recovery potential, in terms of the period of time it will take to recovery the upfront investment based on anticipated savings in operations, maintenance and utility or fuel costs from the 1st full year of implementing a specific measure.

Equation:
Simple payback period = Upfront capital investment / Savings after 1st full year of implementation

Unit Carbon Abatement Cost

Description: This parameter provides an indication of the capital efficiency as it relates to carbon abatement and does not consider cost recovery.

Equation:
Unit Carbon Abatement Cost = Upfront capital investment / total tonnes of carbon abated over the lifespan of the measure

Net Present Value Benefit over 20 years to Cost Ratio

Description: This parameter indicates the level of cost recovery relative to the initial investment. This analysis incorporates anticipated changes in utility or fuel prices, operations and maintenances cost changes, and applies a discount rate to reflect the value of money in the future. The higher the ratio, the higher the rate of cost recovery relative to the initial investment.

Equation:
Net Present Value Benefit over 20 years to Cost Ratio = (Net Present Value of Anticipated Savings over 20 years or lifespan of the measure (whichever is less) – Upfront Capital Investment) / Upfront capital investment

Unit Net Present Value Benefit

Description: This parameter indicates a unitized NPV benefit per tonne of carbon abated over 20 years. This analysis incorporates anticipated changes in utility or fuel prices, operations and maintenances cost changes, and applies a discount rate to reflect the value of money in the future. The higher the unit NPV per tonne of carbon abated, it means the more monetary benefit being returned to the City for implementing a measure.

Equation:
Unit Net Present Value Benefit = (Net Present Value of Anticipated Savings over 20 years or lifespan of the measure, whichever is less – Upfront capital investment) / Total tonnes of carbon abated over 20 years or lifespan of the measure, whichever is less

Appendix H: Social Cost of Carbon

The following Social Cost of Carbon values were derived from those published by Environment and Climate Change Canada[30]. The 50th and 95th percentile values published were discounted at 3% and with a base year of 2012. The values in the table and figure below used in the cost benefit analysis was undiscounted, then discounted at 2.5% and with a base year of 2017.

Table 44: Social Cost of Carbon (Modified from: Environment and Climate Change Canada)

	50TH PERCENTILE		95TH PERCENTILE	
YEAR	UN DISCOUNTED	DISCOUNTED** (BASE YEAR 2017)	UN DISCOUNTED	DISCOUNTED (BASE YEAR 2017)
2016	$46		$188	
2017	$48	$48	$200	$200
2018	$51	$50	$214	$208
2019	$54	$52	$227	$216
2020	$57	$53	$242	$224
2021	$60	$54	$255	$231
2022	$63	$56	$268	$237
2023	$66	$57	$283	$244
2024	$69	$58	$298	$250
2025	$73	$60	$313	$257
2026	$77	$61	$329	$264
2027	$80	$63	$346	$271
2028	$84	$64	$364	$277
2029	$88	$66	$382	$284
2030	$93	$67	$401	$291
2031	$97	$69	$422	$298
2032	$102	$70	$443	$306
2033	$107	$72	$464	$313
2034	$112	$74	$487	$320
2035	$117	$75	$511	$328
2036	$123	$77	$536	$335
2037	$129	$79	$561	$343
2038	$135	$80	$588	$350
2039	$141	$82	$616	$358
2040	$148	$84	$645	$366
2041	$155	$85	$673	$372
2042	$162	$87	$703	$379
2043	$169	$89	$733	$386
2044	$177	$91	$765	$393
2045	$185	$92	$798	$400
2046	$193	$94	$832	$407
2047	$202	$96	$868	$414
2048	$211	$98	$905	$421
2049	$220	$100	$943	$428
2050	$230	$102	$983	$435

[30] *Environment and Climate Change Canada. 2016. Technical Update to Canada's Social Cost of Greenhouse Gas Estimates March 2016. http://publications.gc.ca/site/eng/9.629765/publication.html*

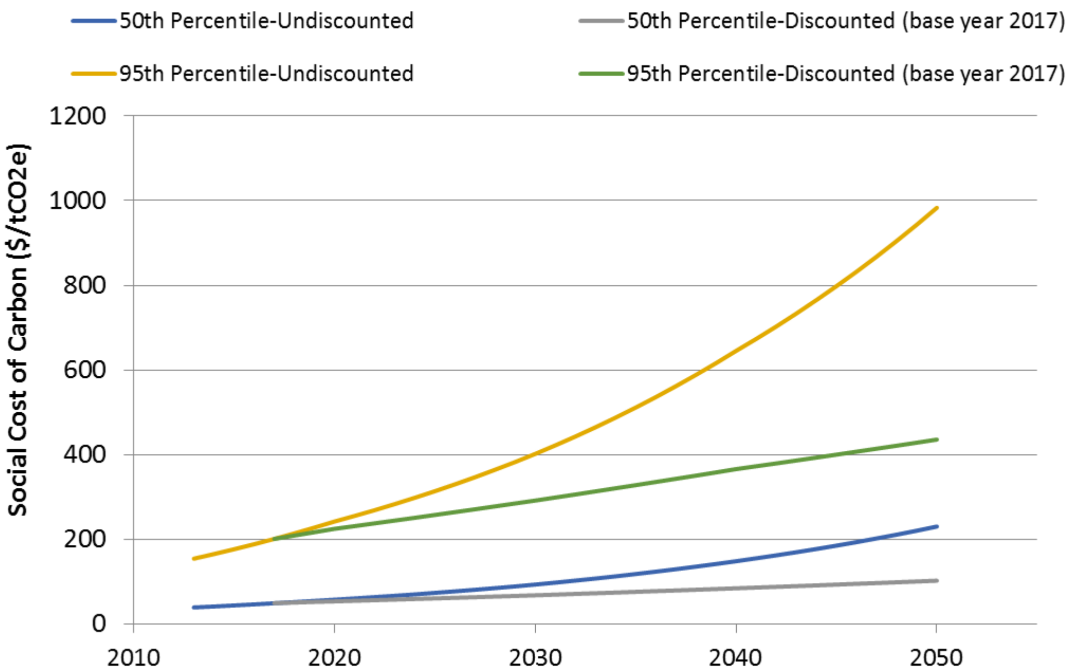

Figure 34: Social Cost of Carbon