# AFFORDABLE HOUSING ENERGY EFFICIENCY DEMONSTRATION PROJECT

## INTEGRATED ENERGY MASTER PLAN

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FOUNDATION

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# 1 EXECUTIVE SUMMARY

This project is a joint partnership between All One Sky Foundation, the Calgary Housing Corporation (CHC), and Environmental & Safety Management (ESM) and Infrastructure & Information Services (IIS) of the City of Calgary. It is funded through the Council Innovation Fund (CIF).

## 1.1 ENERGY POVERTY IS A REALITY IN CALGARY

Many households experience pressure in paying their utility bills. These pressures are most acute among low-income families and individuals. The poorest 20 per cent of households in Alberta spent about $1,865 on utility bills in 2011, equivalent to about 10 per cent of their after-tax income. In contrast, the richest 20 per cent of households spent under 2.5 per cent of their after-tax income on utility bills (i.e., four times less). This seems grossly inequitable. Worryingly, the figure for the poorest households very likely understates their true ‘energy burden’ and the disparity with the richest households, since utility costs are often included in non-market rents.

The costs incurred to maintain a satisfactory heating regime as a ratio of after-tax household income is often used to measure the extent of energy poverty in a population. In many jurisdictions a household is considered to be ‘energy poor’ if it needs to spend 10 per cent or more of its after-tax income to maintain a satisfactory heating regime. By this definition, about 42,500 households in Calgary are in a state of energy poverty.

## 1.2 ENERGY POVERTY IS A SERIOUS PROBLEM

The poorest households are unlikely to be able to address key factors that determine the energy costs they face—namely, the energy efficiency and age of their home. Addressing these factors requires a level of expenditure that is almost certainly beyond what is affordable for the lowest income families and individuals. They can, nonetheless, more readily adjust expenditures on other goods and services. Faced with such choices, two outcomes of concern arise: a low-income household may either reduce spending on energy at the expense of maintaining an adequately warm home; or it may prioritize spending on keeping the home warm, but reduce spending on other necessities (e.g., food and education) potentially resulting in other forms of deprivation. In either case, low-income households face a lower standard of living, and may experience a range of adverse impacts on health and well-being.

Most of the evidence of health impacts linked to energy poverty relate to living at low temperatures. Key health impacts associated, directly and indirectly, with energy poverty include excess winter deaths, increased incidence of cardiovascular disease, respiratory disease, colds and flu, mental health issues, and accidents in the home, as well as poor nutrition. Elderly people, very young children, and people with a long-term sickness or disability are particularly vulnerable. The adverse impacts of energy poverty extend beyond those related to physical and mental health. A number of wider social impacts have been identified, including social isolation and exclusion, and increased truancy, anti-social behavior and educational attainment.

The persistence of energy poverty in Calgary is also a concern for achieving the goals of the Calgary Community GHG Reduction Plan. The poorest households tend to live in some of the oldest and least energy efficient buildings in Calgary—e.g., only 9 per cent of the nearly 600 buildings with non-market rental units in the city were built within the last 20 years. Buildings constructed before the mid-1980s use, on average, 75-100 per cent more energy per square meter than those built recently. The scope for large energy and GHG emission savings in low-income properties is thus significant. Despite this potential, low-income households are very unlikely to be able to participate in efforts to improve the energy efficiency of their homes. Relative to average households, low-income households need much higher levels of up-front technical and financial assistance to upgrade their homes. In the absence of comprehensive support they will be excluded from any policy push to improve the energy efficiency of Calgary's housing stock. Not only is this an undesirable, regressive outcome, it will compromise the cost-effectiveness of the overall Plan.

## 1.3 REDUCING ENERGY POVERTY IN CALGARY

Tackling energy poverty clearly offers a potential 'win-win-win' for several policy agendas—climate change mitigation and GHG emission reductions, health and well-being, and poverty alleviation. There are three broad types of policy response to take low-income households out of energy poverty, each focused on one of the key drivers of whether or not a household is energy poor: (1) incomes (response—increase incomes); (2) energy prices (response—manage the energy prices faced by the poorest households); and (3) home energy consumption (response—increase home energy efficiency and conservation). Of these options, the latter has been shown to be the most cost-effective way to make sustained reductions in energy burdens.

## 1.4 DEMONSTRATION PROJECT

The Calgary Housing Corporation (CHC) is in the midst of a capital investment program to renew the buildings it manages. Using one of the buildings scheduled for refurbishment in 2014 as a case study, the main objectives of this project are:

- To prove (or disprove) the business case for using comprehensive ('whole building') energy efficiency improvements to
    - reduce the energy burdens faced by low-income households and take them out of energy poverty;
    - free-up cash for property owners to extend capital renewal programs to more sites;
    - reduce GHG emissions cost-effectively;
- To create a replicable model for performing 'whole building' energy efficiency improvements of public and private affordable housing properties in Calgary;
- To develop tools to support the replicable model in practice, including:
    - a Financial Decision Support Tool to assist public and private providers of affordable housing assess the incremental costs, benefits and GHG emission savings of implementing integrated portfolios of energy saving measures;
    - a Tenant Engagement Guide to help public and private providers of affordable housing meaningfully engage their residents on behavioral change for energy conservation; and
- To form partnerships between social service and affordable housing agencies and the energy management and GHG mitigation community.

## 1.5 REPLICABLE MODEL FOR WHOLE BUILDING ENERGY EFFICIENCY UPGRADES

A replicable model for performing 'whole building' energy efficiency improvements of public and private affordable housing properties across Calgary comprises seven tasks:

1. **Select the building(s)**.

The reality is that most owners and managers of low-income housing will have limited financial resources. To maximize the contribution of energy efficiency improvements to energy poverty alleviation for a given level of spend, a number of factors should be considered when selecting sites (e.g., age and energy efficiency of building, past refurbishments or upgrades, unit size, nature or existing capital renewal plan, tenant pays utility bills, etc.). Bearing these factors in mind a CHC property scheduled for refurbishment in 2014—Bankview 1—was selected as a case study.

**Box 1: Case Study Building – Bankview 1**

Bankview 1 building is a low-rise apartment block constructed in 1982. It has a gross conditioned area of 28,312 $ft^2$ (2,630 $m^2$), including the underground parkade with 18 vehicle stalls. There are 26 separate apartments, including 3 in the basement level, each with street-level entry, and 23 units in the three above-ground storeys. Residential suites are individually metered for electricity, but not for natural gas. Residents are obliged to have private contracts for electricity supply, and the CHC divides the natural gas bill based on the floor area of each suite.

The building is in reasonably good condition for its age and the energy consumption is in the middle of the range for similar building types of this vintage.

2. **Review the existing capital refurbishment program for the selected building(s)**.

For deep energy efficiency upgrades to be most cost-effective, the upgrades need to be aligned and integrated with planned building refurbishments and equipment replacement. A key task is to review the existing refurbishment plan for the building, and in particular identify planned upgrades that will have implications for energy use. The focus of the business case is the incremental cost of energy efficiency improvements and the associated incremental energy savings that are additional to the planned capital refurbishment plan for the building.

The existing capital renewal plan for Bankview 1 includes upgrading the insulation in the north and south walls, and replacing all windows and exterior steel doors with moderately more efficient units. These upgrades define the project *Reference Case* against which additional energy efficiency improvements to the building are appraised. Analytically, the situation that could exist following any additional improvements defines the *Low Carbon Case*, while the situation that exists prior to the existing planned upgrades defines the project *Base Case*.

3. **Undertake energy (audit) assessment**.

The third task involves identifying where, and how much, energy is consumed in the building. To this end, ATCO Energy Sense was commissioned to perform a standard energy audit of Bankview 1 in May 2014. The project team separately took infra-red images of the building to identify areas of heat loss. The audit summarized energy use by different systems at the site under Base Case conditions and provided a provisional list of recommended energy efficiency improvements, encompassing communal lighting, the mechanical systems, the building envelope, and communal laundry facilities.

In 2013 energy consumption at Bankview 1 amounted to 2,169 GJ of natural gas and 47,620 kWh of electricity (excluding electricity use in the rental units). The project team separately estimated potable water consumption at 6,505 liters per day. Electricity consumption by residents within the rental units was estimated at 282 kWh per day.

The information provided by the audit and the infra-red images served as a basis for the development of an energy model for the building.

### 4. Build and calibrate energy model.

Buildings are like systems. They comprise many materials and components which work together to determine overall energy use. Evaluating energy efficiency improvements in isolation of each other, and without accounting for external factors (e.g., exposure to sunlight, humidity, and external temperature) will likely (over)understate actual savings and costs. When appraising 'whole building' energy efficiency upgrades it is thus necessary to use a computer simulation model to capture interactions between building components and the influence of external factors. Using architectural, mechanical, and electrical drawings provided by the CHC, the project team developed a comprehensive energy simulation model of Bankview 1 in the Hot2000 software—a free software package available from Natural Resources Canada's CanmetENERGY group. The model was constructed to reflect Base Case conditions and calibrated to match monthly utility bills averaged over the past three years. With the model calibrated to the actual utility billing data, the project team could model the project Reference Case and Low Carbon Case with reasonable confidence.

Whole building energy consumption under the project Base Case is 2,598 GJ. The corresponding GHG emissions are 205 t $CO_2$-eq per year. Whole building energy consumption under the project Reference Case, which includes three planned improvements to the building envelope, is 2,402 GJ. The corresponding GHG emissions are about 5 per cent lower than the project Base Case—at 195 t $CO_2$-eq per year.

### 5. Identify additional energy saving opportunities.

The next task involves identifying energy savings opportunities additional to those in the project Reference Case. In total, twenty-two potential energy efficiency upgrades (encompassing windows, doors, lighting, wall insulation, deck insulation, roof insulation, draft proofing, heating controls, boilers, water heaters, appliances, laundry facilities, and water use in rental units) and two renewable energy projects (solar thermal hot water and solar PV power) were identified for Bankview 1. The chosen upgrades are based on recommendations contained in the energy audit and the project team's own examination of the building and the planned capital renewal plan.

### 6. Iteratively appraise identified opportunities.

The penultimate task consists of, first, evaluating the financial and environmental performance of each identified energy saving opportunity, and second, to create and evaluate portfolios of opportunities for Bankview 1. Energy saving opportunities and portfolios are appraised on the basis of incremental discounted cash flows, where:

Energy savings = Discounted lifetime energy use at building under project Reference Case *less* discounted lifetime energy use at building with energy saving opportunity installed under project Low Carbon Case; and

Costs = Discounted lifetime costs (capital and annual O&M costs, net of available financial incentives) of energy saving opportunity *less* discounted lifetime costs of Reference Case upgrade. Costs are defined to reflect the full price paid by the property owner, including equipment costs, material costs, labor costs, and overhead and profit.

Water savings and reductions in GHG emissions are similarly defined. Opportunities are appraised using a variety of standard financial decision criteria, including Net Present Value (NPV). The analysis is performed using the Financial Decision Support Tool and conducted from two perspectives: (1) *private* (benefits include the dollar value of lifetime utility bill reductions only); and (2) *public* (in addition to private benefits, the dollar value of lifetime GHG emission reductions is included).

Four portfolios of energy savings opportunities were constructed: (1) *LCC-Max* which maximizes lifetime GHG emission reductions, regardless of costs; (2) *LCC-Private* which maximizes NPV to property owners or managers; (3) *LCC-Public* which maximizes NPV from cost-effective reductions in GHG emissions; and (4) *LCC-Social* which maximizes the NPV from cost-effective reductions in GHG emissions and energy poverty.

**Table 1: Financial and Environmental Performance of Low Carbon Case (LCC) Portfolios**

| | LCC-Max | LCC-Private | LCC-Public | LCC-Social |
|---|---|---|---|---|
| Total energy saving projects | 19 | 10 | 12 | 13 |
| Investment costs | $434,900 | $159,500 | $197,200 | $237,800 |
| Lifetime energy savings | $613,700 | $416,900 | $475,900 | $525,800 |
| Lifetime water savings | $116,200 | $116,200 | $116,200 | $116,200 |
| Average annual bill savings | $18,200 | $13,300 | $14,800 | $16,100 |
| Lifetime GHG emission savings | 2,710 t $CO_2$-eq | 1,610 t $CO_2$-eq | 1,950 t $CO_2$-eq | 2,250 t $CO_2$-eq |
| Reduction on Reference Case | 41% | 26% | 31% | 35% |

### 7. Formulate recommendations.

The final task is to formulate a package of recommended energy efficiency, conservation, and clean energy projects for consideration by the property owner or manager for inclusion within a modified capital renewal program for the building. The recommended portfolio of additional energy saving opportunities for Bankview 1—in terms of striking the best balance between (public and private) NPV and lifetime GHG emission savings—is LCC-Public. The portfolio includes:

| | |
|---|---|
| Installing low-flow faucet aerators in all apartments; | Upgrading all windows to achieve R5 and increase window air tightness from CSA A1 to A2; |
| Installing low-flow showerheads in all apartments; | Replacing existing electric clothes dryers with natural gas dryers; |
| Weather stripping and air sealing to increase building air tightness from 'loose' to 'average' (4.5 ACH @ 50 Pa); | Upgrading lighting in apartments (full LED package); |
| Replacing existing communal clothes washing machines with Energy Star qualified appliances; | Installing programmable thermostats in all apartments; |
| Upgrading lighting in common areas (T12 to T8, plus CFL to LED); | Installing a solar PV system, 72 panels with PTC rating of 221 W (15.9 kW installed capacity); |
| Upgrading hot water heaters from existing tanks to condensing units (seeking improvement in efficiency = 30%); and | Upgrading all patio doors with Energy Star in-swing French Doors to achieve R 3.85. |

Annual operating cost savings amount to about $350 per resident. For the poorest 20 per cent of households in Alberta spend, utility bill savings of this magnitude would:

- Cover the cost of health care for 12 weeks;
- Cover the cost of education for 20 weeks;
- Cover the cost of public transport for 26 weeks; or
- Cover the cost of food for four weeks.

## 1.6 THE BIGGER PICTURE

Bankview 1 comprises 26 non-market rental units and is currently “of average efficiency” for its age. There are about 11,760 non-market rental units for low-income families and individuals in the Calgary. About 72 per cent of these units are in buildings roughly the same age as Bankview 1. If these buildings underwent a similar energy efficiency upgrade as part of a planned capital refurbishment program, the outcomes would be very significant:

- Lifetime energy savings of 8.9 PJ;
- Lifetime net benefits for low-income households of $51.6 million in present value terms;
- Average energy bill savings of about $3.9 million per year;
- Average water bill savings of about $0.9 million per year;
- Average total operating cost savings of about $4.8 million per year; and
- Lifetime GHG emission savings of 0.6 Mt $CO_2$-eq.

Clearly, a program of energy efficiency upgrades in low-income buildings at this scale would put a huge dent in energy poverty in Calgary, and generate significant ‘win-win-wins’ for poverty alleviation, health and well-being, and climate change mitigation.

# 2 INTRODUCTION

This project is a joint partnership between All One Sky Foundation, the Calgary Housing Corporation (CHC), and Environmental & Safety Management (ESM) and Infrastructure & Information Services (IIS) of the City of Calgary. It is funded through the Council Innovation Fund (CIF).

## 2.1 WHY THIS PROJECT MATTERS

Poverty is a reality in Calgary. In 2011, the most recent year for which data is available, 87,000 Calgarians lived in poverty (as defined by Statistics Canada's after-tax Low-Income Cut-Off).[1] The incidence of poverty is highest among people under the age of 65 living alone, and among lone-females with children. Disparities between families with the highest incomes and those with the lowest are also very significant and growing. Such income inequality further entrenches poverty and adds to its complexity (United Way, 2012).

Energy poverty is also a real and serious problem in Calgary. Many households experience pressure in paying their utility bills.[2] These pressures are most acute among the poorest households. One of the biggest costs for low-income individuals is affordable housing. In 2011 the poorest 20 per cent of households in Alberta spent about 58 per cent of their after-tax income on shelter (i.e., rent, mortgage, utilities); twice that of the average household. Utility bills are a key shelter cost. The average low-income household spent about $1,820 on water, electricity and natural gas in 2011, or nearly 10 per cent of their after-tax income. In contrast, the average household spent only 4 per cent of their after-tax income on utilities; the proportion is lower still for the richest 20 per cent of households. Worryingly, the figure for low-income households very likely understates their 'energy burden' as heating and water costs are often included in rents. On average, rent accounts for nearly half of the shelter costs faced by low-income households, but only one-fifth of the average household's shelter costs.

These disproportionate 'energy burdens' often impose financial hardship on the poorest households, forcing them to make difficult choices about how to spend their limited income – necessitating trade-offs between heating their homes, paying rent, and buying food and other basic necessities, with adverse consequences for comfort and health. Energy poverty has been shown to contribute, directly and indirectly, to a number of adverse health outcomes (e.g., excess winter mortality, cardiovascular and respiratory disease, colds and flu, mental health, accidents in the home) and social impacts (e.g., isolation, social exclusion, anti-social behavior) (Marmot Review Team, 2011 and Hills, 2011). An inability to pay utility bills is also regarded as the second leading economic cause of home evictions (Cairney and Meredith, 2008). Clearly, taking low-income families and individuals out of energy poverty will have multiple health and social benefits.

Among low-income households the causes of energy poverty vary. Some households may live in buildings that are difficult to adequately heat and have limited resources to improve the condition of the property—in these cases the main cause is relatively high utility bills. Other households may live in more efficient buildings and face relatively low

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[1] On a before-tax LICO basis, the number rises to 117,000. The Low-Income Cut-Off (LICO) is an established indicator of low-income used by Statistics Canada. It represents a threshold level of income below which families devote a larger proportion of (before- or after-tax) income – 20 percentage points or more - to the necessities of food, shelter and clothing than the average family would. LICOs identify families that are substantially worse off on average; families that live in strained circumstances.

[2] Recent surveys have shown that one-in-three Calgarians are concerned about not having enough money for housing, and 80 per cent of Calgarians are concerned about the cost of their natural gas and electricity bills (United Way and City of Calgary, 2011 and C3, 2011).

utility bills—in these cases the main cause is low income. In general, three factors determine whether a household is 'energy poor':

1. Income;
2. Energy prices; and
3. Energy consumption (which in turn depends on the physical characteristics of the home and the lifestyle of the occupants).

Given that energy poverty results primarily from low incomes, high energy prices, and inefficient homes, it follows that there are three possible approaches to take households out of energy poverty:

1. Increase incomes;
2. Manage energy prices faced by low-income households; and
3. Reduce home energy consumption.

Notably, improving the energy efficiency of homes and helping occupants reduce energy use tend to be the most cost-effective ways to make sustained reductions in energy burdens (Hills, 2011 and 2012). The poorest households tend to live in some of the oldest and least energy efficient buildings in Calgary—this is particularly true of privately-owned buildings.[3] Reducing energy consumption in the low-income housing stock should therefore be the central pillar of any long-term strategy to alleviate energy poverty in Calgary.

Alleviating energy poverty by lowering energy consumption is also central to achieving the goals of the Calgary Community GHG Reduction Plan (City of Calgary, 2011).[4] This is primarily a direct consequence of the clear synergies between the two policy areas—where improving the energy efficiency of the low-income housing stock offers a 'win-win' by lowering both energy burdens and GHG emissions. It also ensures that the poorest households are able to benefit from the transition to a low carbon city—resulting in a more equitable (i.e., progressive) overall Plan. This is vital if GHG emission reductions facilitated by the Plan are to yield the desired triple bottom-line (environmental, economic and social) benefits.

## 2.2 OVERVIEW OF PROJECT

### 2.2.1 Project Description

The Calgary Housing Corporation (CHC) has a mandate to deliver safe and affordable housing solutions to meet the needs of Calgarians not served by the marketplace. The CHC is in the midst of a capital investment program to renew the buildings it manages. Using one of the buildings scheduled for refurbishment as a case study, this project examines the technical and economic potential for energy efficiency upgrades (additional to those already planned for the building) and behavioral change for energy conservation to:

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[3] About 80 per cent of low-income families in Calgary and individuals live in homes older than 1980; about 40 per cent live in homes older than 1970. Average homes of these vintages use roughly 75 per cent to 100 per cent more energy per square meter than homes built more recently. Moreover, homes for low-income families and individuals are likely less efficient than the average home.

[4] The Plan seeks to reduce GHG emissions in the city by 20 per cent and 80 per cent below 2005 levels by 2020 and 2050, respectively, and a 50 per cent reduction below 1990 levels by 2036. These reductions are to be delivered through: (a) improvements in energy conservation and efficiency and (b) the development and deployment of low-carbon energy sources (e.g., solar PV, solar water heating).

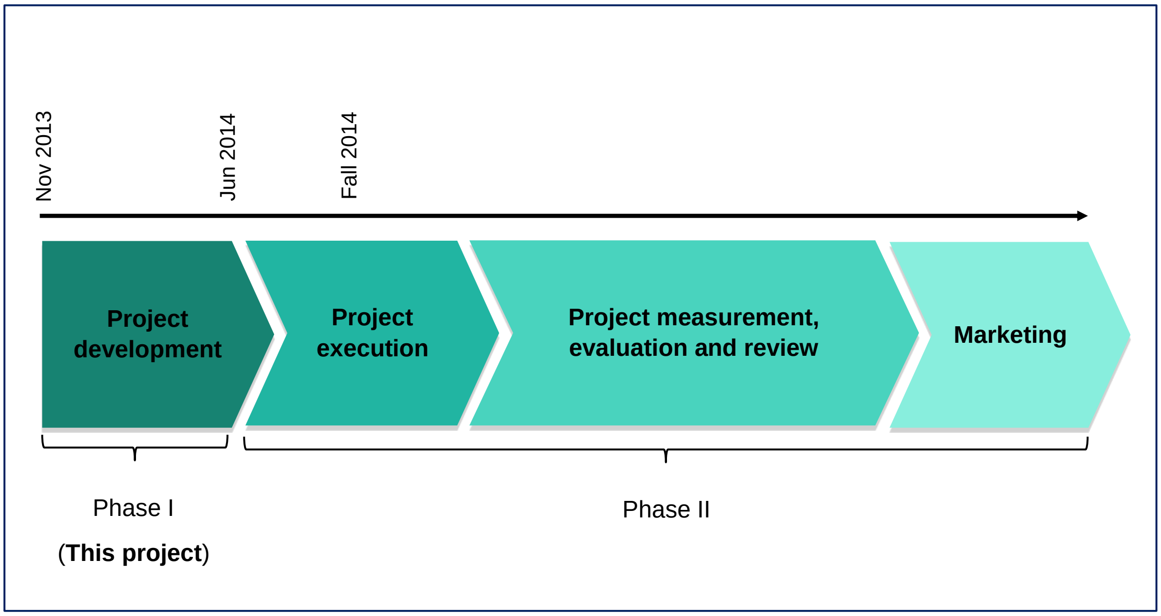
- Reduce the energy burdens faced by low-income residents to move them out of energy poverty; and
- Reduce the CHC's operating costs allowing them to extend the life of select buildings and include more buildings within the budget for the existing capital investment program.

The best time to undertake cost-effective energy efficiency improvements to a building are during planned refurbishments and when existing equipment (e.g., boilers, appliances, etc.) are scheduled for natural replacement. At the same time, failing to consider additional improvements during planned refurbishments will lock-in relatively less efficient equipment and building envelopes for several decades.

The case study developed during this project represents the first phase of a two-phase overall project life-cycle (shown in Figure 1). The research, analysis, and modeling undertaken during Phase I is to serve as the basis for a business case to help raise funds to cover the incremental capital costs of cost-effective energy efficiency, conservation, and low-carbon energy projects identified for the case study building and accepted by the CHC. For the project to move forward to Phase II adequate funds will have to be raised. The outputs of Phase I (outlined in Section 2.2.3 below) are nonetheless significant in their own right, and can be usefully used by the CHC and other public and private providers of affordable housing in Calgary to integrate and encourage sustainable energy use at their properties.

The success of the project as a whole (both Phase I and Phase II) will ultimately be defined by the magnitude of public and private sector dollars that flow to similar projects to mainstream energy efficiency, conservation, and clean energy solutions into the renewal of low-income housing across Calgary. And, over time, the extent to which the energy burdens faced by the poorest households in Calgary are seen to reduce.

Figure 1: Two-phase overall project life-cycle



### 2.2.2 Project Objectives

Through the development of the case study, the objectives of this project are:

- To prove (or disprove) the financial viability of 'whole building' energy efficiency improvements;
- To create a replicable model for 'whole building' energy efficiency improvements of CHC managed buildings and other public and private affordable housing buildings in Calgary;
- To develop tools for defining an integrated portfolio of energy saving measures that balances costs, benefits and GHG emission reductions;
- To reduce building operating costs, and generate financial benefits for property owners and residents;
- To reduce GHG emissions cost-effectively;
- To form partnerships between social service and affordable housing agencies and the energy management and GHG mitigation community;
- To increase awareness among low-income households and their stakeholder communities of the (financial and non-financial) benefits of energy efficiency, conservation, and alternative energy; and
- To assist social housing providers engage their tenants on issues of sustainability, and more specifically on behavioral change for energy conservation.

As noted above, the primary motivation for the project is to help alleviate energy poverty in Calgary by reducing energy consumption in low-income homes, and in doing so, contribute to wider efforts within the city to improve the welfare of low-income individuals and families.

**Box 2: How the project contributes to Council priorities**

Reducing energy consumption in the homes of low income families and individuals can yield multiple triple bottom line (social, economic and environmental) benefits, providing an innovative approach to simultaneously supporting several Council priorities:

- It contributes to the goals of the Calgary Community GHG Reduction Plan by making improvements in energy conservation and efficiency, and through the possible deployment of low-carbon energy technologies;
- It promotes the formation of multi-sector, multi-disciplinary partnerships and generates information for organizations and individuals to make well-informed decisions about energy use;
- It builds the business case for investment in strong communities and empowers a marginalized group of our society. The City of Calgary is committed to creating an inclusive city where all citizens have the ability to participate in economic, social, cultural and political spheres of society, regardless of income; and
- It aligns with CHC's mandate to deliver safe and affordable housing solutions to meet the needs of Calgarians not served by the marketplace, fostering community inclusion and creating an environment that fosters opportunities for residents to realize their full potential.

### 2.2.3 Project Outputs

Three key outputs are developed during the project:

1. An **Integrated Energy Master Plan –** The purpose of this document is:
    - To present the package of recommended energy efficiency, conservation, and clean energy projects for consideration by the CHC for inclusion within a modified capital renewal program for the case study building; and
    - To document results from the analytical process that led to the recommendation of these projects, including results from:
        - The baseline energy assessment;
        - Modelling of the original capital renewal program;
        - The calibrated energy model;
        - The identification and evaluation of individual energy saving measures;
        - The iterative (energy-financial) modeling of synergistic combinations of measures;
        - Derivation of the recommended portfolio of energy saving projects that strikes the best balance between costs, benefits and GHG emission savings; and
        - The incremental capital requirements to implement the portfolio and the resultant cash flows.
2. A **Financial Decision Support Tool –** The purpose of this (Microsoft Excel-based spreadsheet) tool is to assist the CHC and other public and private providers of affordable housing assess the incremental costs, benefits and GHG emission savings of implementing individual or portfolios of energy saving measures. The tool provides estimates of net present value, profitability, and simple payback for future building improvements, based on incremental discounted cash flows between a Reference Case (the building owner's original capital renewal plan) and a Project Case where additional energy saving measures are included. Calculations within the tool will be based on a combination of building specific inputs (to be entered by the user) and embedded default values.
3. A **Tenant Engagement Guide –** The purpose of this guide is to help the CHC and other public and private providers of affordable housing meaningfully engage their residents on behavioral change for energy conservation. Tenant behavior can increase the likelihood of realizing the full projected savings from energy efficiency measures installed as part of a capital renewal project at a building, as well as result in cost and energy savings at buildings where there have been no or minimal upgrades. Low-income tenants face multiple barriers (e.g., food insecurity, language, physical ability, mental health, etc.) and therefore need significant on-site support if energy savings are to be achieved through behavioral change. The guide will provide advice on how best to start a meaningful engagement with tenants on energy conservation, as well as suggest supplementary resources that may be needed to support engagement initiatives and activities. While our primary goal with tenant engagement is to realize increased energy (cost) savings, tenants also benefit from new knowledge, improved relationships, increased confidence and empowerment, and strengthened communities.

Note that the focus of this document is the Integrated Energy Master Plan. The other two project outputs are provided separately.

# 3 ENERGY POVERTY

## 3.1 WHAT IS ENERGY POVERTY?

There are three main ways to define energy poverty:

1. Energy poverty ratio;
2. Eligibility to participate in low-income energy assistance and affordable housing programs; and
3. Low-income High-cost Indicator (LIHC).

### 3.1.1 Energy Poverty Ratio

One commonly used definition of energy poverty is the ratio of energy costs incurred to maintain a satisfactory heating regime as a ratio of after-tax (net) household income. The World Health Organization defines a satisfactory indoor heating regime at minimum temperature thresholds of 21°C for the main living room and 18°C for other rooms for a certain number of hours per day (WHO, 1987). In many jurisdictions a household is considered energy poor if it needs to spend more than 10 per cent of its after-tax income to maintain a satisfactory heating regime. The 10 per cent value is based on the 2001 UK Fuel Poverty Strategy. At the time the Strategy was prepared the median household in the UK spent 5 per cent of its after-tax income on energy and twice that amount was, arbitrarily, judged to be 'unreasonable'.

As noted in Section 2.1 the poorest 20 per cent of households in Alberta spent, on average, about 10 per cent of their after-tax income on utility bills in 2011 (this group of household spent, on average, $1,865 on utility bills in 2011 and their median after-tax income is about $19,000). In 2010 about 42,500 households in Calgary earned less than $20,000 after-tax. This figure provides an approximate indication of how many households in Calgary may be considered energy poor according to this definition.

### 3.1.2 Low-income Energy Assistance and Affordable Housing Programs

Most jurisdictions in Canada and the U.S. operate and fund special energy efficiency and conservation programs for low-income households. This is despite the fact that in many of these jurisdictions low-income households face lower energy burdens than here in Alberta—i.e., they spend less than 10 per cent of their after-tax income on utility bills.

Eligibility to participate in these programs is governed by various definitions, but a household is typically eligible if it has a family income less than 30-50 per cent of the median household income before-tax. Applying these criteria to Calgary equates to approximately 53,000 to 96,000 households being considered eligible for low-income energy assistance (median household income before-tax in 2010 is close to $83,000).

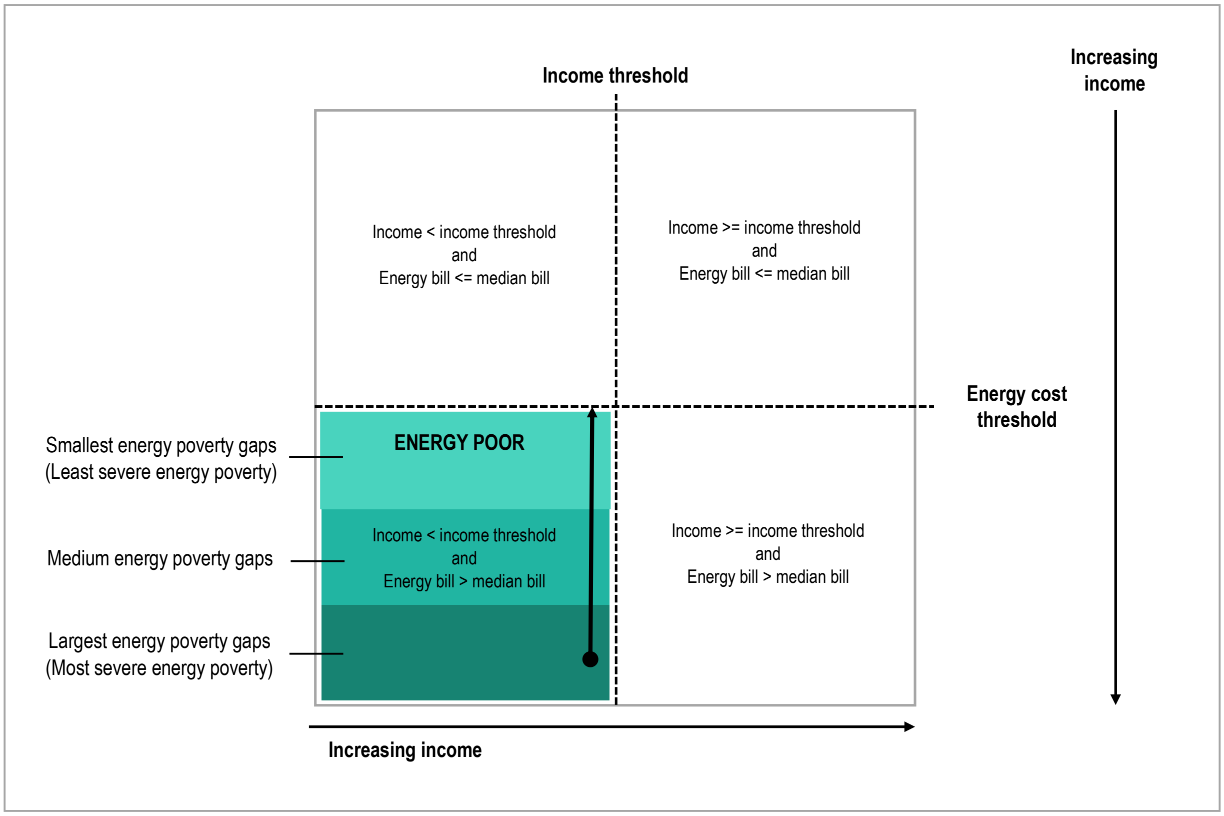
The definition of affordable housing adopted in Calgary targets households with 65 per cent or less of the median household income and who spend 30 per cent or more of their household income on shelter costs. According to 2006 data, this amounts to about 19 per cent (72,200) of all households in the city (Selinger and Noble, 2012).

### 3.1.3 Low-income High Cost Indicator

A new approach to defining energy poverty is based on the Low-income High-cost (LIHC) indicator. The UK Government recently commissioned a review of its strategy for fuel poverty, including how it is defined and measured (Hills, 2011 and 2012). The review concluded that the existing definition of energy poverty, based on the ratio of energy costs incurred to maintain a satisfactory heating regime as a ratio of after-tax (net) household income, had several shortcomings that warranted the development of a new definition.[5] The recommended new definition of energy poverty (illustrated in Figure 2) finds a household to be energy poor if (Hills, 2012):

- They have energy costs to achieve adequate warmth that are above the median level for all households (energy cost threshold); and
- Were they have to spend that amount they would be left with a residual income below the official poverty line (60 per cent of median net of housing costs).

Figure 2: Using the LIHC Indicator to Define Energy Poverty



**Source**: Hills (2012)

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[5] For example, the review found that the traditional approach to defining energy poverty captured many households that were not energy poor—capturing many households on relatively high incomes living in relatively inefficient homes. It also painted a misleading picture of trends over time—understating the extent of the problem when energy prices were low and overstating it when energy prices were high.

A key feature of this approach to defining energy poverty is it allows a distinction to be made between (a) the extent of the problem (i.e., how many households are energy poor) and (b) its depth (i.e., what is the severity of the energy poverty they face). The latter is measured by the energy poverty gap, which is the difference between a household's required energy costs and what those costs would need to be to no longer be considered energy poor (the arrow in Figure 2 depicts the energy poverty gap for a severely affected household). The energy poverty gap can be used to identify those households facing the most severe energy poverty (and also understand why they are in this position). This allows policymakers to design effective, targeted responses.

No matter how energy poverty is defined, it is clear that a significant number of Calgarians are energy poor and stand to benefit from action to alleviate high energy burdens.

## 3.2 WHY IS ENERGY POVERTY A CONCERN?

Energy poverty overlaps three different, but related areas of public policy:

- Poverty alleviation;
- Health and well-being; and
- Climate change mitigation.

Tackling it therefore offers a potential 'win-win-win' for different policy agendas.

### 3.2.1 Poverty

Low-income is a key predictor of energy poverty, along with other factors such as energy efficiency and the size and age of a home. These factors produce variations in homes which mean households—which might otherwise have very similar incomes and composition—have an unequal ability to convert income into warmth and comfort. Put another way, households face very different costs (and thus require very different levels of income) in order to live in an adequately heated home. Low-income households are also unlikely to be able to address those factors that determine the energy costs they face; addressing those factors requires a level of expenditure that is almost certainly beyond what is affordable for the lowest income families and individuals. These families can, nonetheless, more readily adjust expenditures on other goods and services. For example, there is evidence that people on the lowest incomes with hard to heat properties reduce spending on food to keep warm during cold spells (i.e., the 'heat or eat' trade-off). In these circumstances it is easy to see why those concerned with poverty in general may be interested in whether low-income families and individuals have a lower standard of living because of high energy burdens, and whether such burdens might have even pushed them into poverty.

### 3.2.2 Health and Well-being

Low-income families and individuals are faced with different choices or trade-offs as a consequence of their income and energy costs. Some households will have considerable flexibility in making these choices, while others will have limited flexibility. In general, in the latter case, there are two outcomes of concern: a low-income household may either reduce spending on energy at the expense of maintaining an adequately warm home, or it may prioritize spending on keeping the home warm, but reduce spending on other necessities, potentially resulting in other forms of deprivation. In either case, low-income households may experience a range of adverse impacts on health and well-being.

Most of the evidence of health impacts linked to energy poverty relate to living at low temperatures. Key health impacts associated, directly and indirectly, with energy poverty include (Marmot Review Team, 2011):

- Increased likelihood of cardiovascular episodes, resulting in poor physical health and in some cases death;
- Increased likelihood of respiratory disease, with similar physical health outcomes;
- Reduced resistance to infections, such as colds and influenza;
- Increased physical discomfort resulting from living in cold conditions (this can be emotionally distressing in turn leading to wider mental health issues);
- Increased anxiety and stress relating to the cost of trying to keep warm (this can in turn create mental health issues, including depression);
- Poor nutrition with subsequent health consequences;
- Increased likelihood of accidents in the home (e.g., trips and falls) due to a loss of dexterity from cold-induced muscles seizures; and
- Exacerbation of pain experienced by arthritis sufferers.

The adverse impacts of energy poverty extend beyond those related to physical and mental health. A number of wider social impacts have been identified, including (DTI and DEFRA, 2001):

- Social isolation and exclusion (e.g., some energy poor individuals may not be able to afford to participate in certain social activities or they may be reluctant to leave their home because they know they will find it difficult to warm up again once they return, and other individuals may be reluctant to invite friends or family to their homes because it is inadequately heated); and
- Increased truancy, expulsions, and anti-social behavior, with adverse consequences for levels of educational attainment.

Different groups of low-income individuals are more or less vulnerable to the above impacts of energy poverty:

- Elderly people, very young children, and people with a long-term sickness or disability are particularly vulnerable to health impacts;
- Elderly people are particularly vulnerable to social exclusion and isolation; and
- Adolescents are more vulnerable to anti-social behavior and relatively poor educational attainment.

### 3.2.3 Climate Change Mitigation

Improving energy efficiency in buildings is one of the most cost-effective means to reduce greenhouse gas (GHG) emissions (US EPA, 2009, McKinsey and Company, 2009 and 2010). It is also one of four key opportunities identified to have the greatest potential to reduce GHG emissions in Calgary (City of Calgary, 2011). However, programs and projects to increase energy efficiency in buildings, and climate change mitigation polices in general, can raise concerns for energy poverty.

- First, it is important to recognize the distributional consequences of carbon mitigation policies. Many policies that reduce GHG emissions can lead to higher energy prices (e.g., the Specified Gas Emitters Regulations (SGER) in Alberta) which in turn will result in regressive impacts—i.e., impose disproportionate costs on the poorest 20 per cent of households relative to the richest 20 per cent of households. This will only serve to exacerbate energy poverty, unless rising energy costs for low-income households are offset in other ways. If policy-makers are concerned with intra-generational equity, the regressive impacts of such policies on low-incomes households could present a barrier to their implementation, despite the fact they produce net benefits overall; and

- Second, despite energy efficiency being one of the most promising approaches to mitigating GHG emissions, low-income households are unlikely to be able to participate in efforts to improve the energy efficiency of their homes. Low-income families and individuals face many barriers to participate in energy efficiency programs—primarily, a lack of financial means to even partially pay for home envelope or equipment upgrades (most programs require households to pay the up-front costs of eligible upgrades and then reimburse them for a fraction of the cost, typically 10-50 per cent).[6] Low-income households need much higher levels of up-front cost subsidy or even full subsidization to allow them to improve the energy efficiency of their homes; otherwise they will be excluded from any policy push to reduce energy consumption in the housing stock. Besides avoiding potentially regressive effects, inclusion of low-income households in energy efficiency policy is also vital to the overall cost-effectiveness of efforts to reduce GHG emissions. The vast majority of low-income households live in buildings that are not nearly as energy efficient as they could be. About 80 per cent live in (owned, market rental and non-market rental) dwellings older than the mid-1980s. The vast majority of the nearly 600 non-market rental buildings in Calgary are over 20 years old (only 9 per cent units are in buildings built within the last 20 years)(City of Calgary, 2012). Average buildings constructed before 1983 use 75-100 per cent more energy per square meter than homes built recently. The scope for large energy savings and GHG emission reductions in the majority of low-income buildings is thus significant.

A corollary of climate change policy must therefore be a focus on low-income households with high energy burdens and on those living in older, energy inefficient homes.

## 3.3 HOW IS ENERGY POVERTY ALLEVIATED?

There are three broad types of policy response to alleviate energy poverty, each focused on one of the key determinants of whether a household is energy poor—i.e., incomes, energy prices, and home energy consumption. The generalized impacts of each of these policy levers on energy poverty, as defined by the LIHC, are outlined below (Hills, 2012):

- Income-based policy (e.g., general increase in benefit levels for all low-income households):

| | |
|---|---|
| Effect on energy cost threshold | Remain unchanged |
| Effect on income threshold | Remain unchanged, so long as no middle income households benefitted |
| Effect on extent of energy poverty | The number of energy poor households could fall |
| Effect on depth of energy poverty | The aggregate energy poverty gap could fall |

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[6] Besides a lack of capital, there are several other factors that limit the access of low-income households to energy efficiency, including: split incentives, language and cultural barriers, literacy, awareness, illness and disability.

- Income-based policy (e.g., non-means tested winter fuel payment for all households):

| | |
|---|---|
| Effect on energy cost threshold | Remain unchanged |
| Effect on income threshold | Would tend to increase |
| Effect on extent of energy poverty | The number of households could fall |
| Effect on depth of energy poverty | The aggregate energy poverty gap could fall |

- Price-based policy (e.g., bill rebates targeted at low-income households):

| | |
|---|---|
| Effect on energy cost threshold | Tend to fall slightly |
| Effect on income threshold | Remain unchanged, though it would intersect the cost threshold at a lower point |
| Effect on extent of energy poverty | The number of households would tend to fall |
| Effect on depth of energy poverty | The aggregate energy poverty gap would tend to fall |

- Energy use-based policy (e.g., energy efficiency program targeting all energy inefficient homes):

| | |
|---|---|
| Effect on energy cost threshold | Tend to fall |
| Effect on income threshold | Remain unchanged, though it would intersect the cost threshold at a lower point |
| Effect on extent of energy poverty | Ambiguous, depends on the number of middle- and high income households that participate in the program |
| Effect on depth of energy poverty | As above regarding the aggregate gap, though households with the largest energy poverty gaps would see them reduced |

- Energy use-based policy (e.g., energy efficiency program targeting low-income, inefficient homes):

| | |
|---|---|
| Effect on energy cost threshold | Tend to fall slightly |
| Effect on income threshold | Remain unchanged, though it would intersect the cost threshold at a lower point |
| Effect on extent of energy poverty | The number of households would fall |
| Effect on depth of energy poverty | The aggregate energy poverty gap would fall |

An empirical analysis of options to alleviate energy poverty found that improving the energy efficiency of homes and helping occupants reduce energy use are more cost-effective in achieving sustained reductions in energy burdens than income-based and price-based approaches (Hills, 2011 and 2012).

Finally, it should be noted that how a particular policy is funded will affect its outcomes. There are two main sources of funding: (1) general (direct and indirect) tax revenues and (2) charges or levies on consumer energy bills. Funding policies through tax revenues does not generally affect their outcomes. In contrast, funding policies from money collected from energy consumers can increase the energy poverty gap of those households who do not benefit from them—e.g., non-participants in utility energy efficiency programs.

# 4 DEVELOPING A REPLICABLE MODEL

A key objective of the project is to develop a replicable analytical process for 'whole building' energy efficiency improvements of public and private affordable housing buildings in Calgary, using a CHC building as a case study. To facilitate replication of the analytical approach at other sites a further key objective of the project is to develop tools to:

- Support the definition of an integrated portfolio of energy saving measures that best balance costs, benefits, and GHG emission reductions—the **Financial Decision Support Tool**; and
- Help public and private providers of affordable housing meaningfully engage their residents on behavioral change for energy conservation—the **Tenant Engagement Guide**.

The replicable analytical process developed from the case study is outlined briefly below; the Financial Decision Support Tool and the Tenant Engagement Guide are provided separately.

## 4.1 ANALYTICAL PROCESS

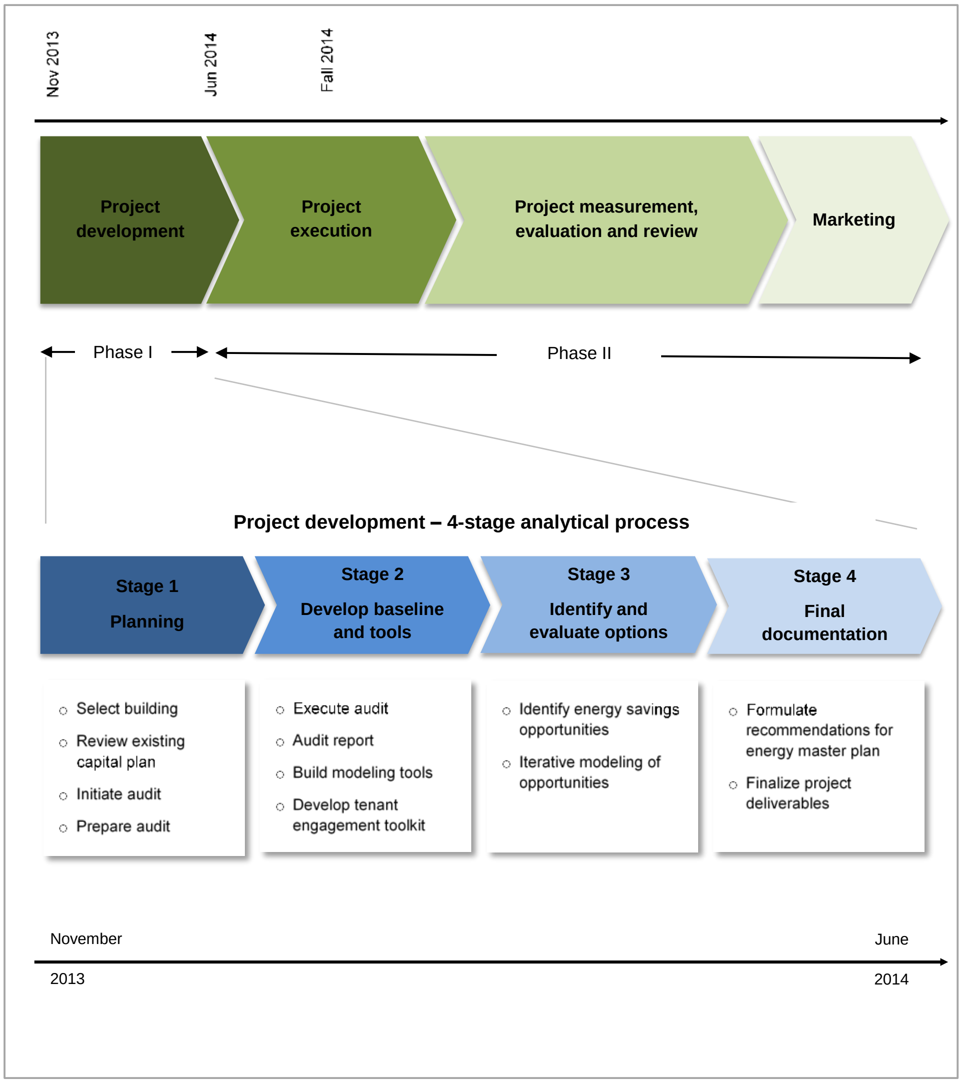
The full analytical process followed in the project comprises four stages, with each stage consisting of a number of tasks (as shown in Figure 3). The process shown in Figure 3 is necessarily more complicated than what needs to be employed to replicate the analysis of energy saving measures and practices at other sites—the supporting tools have already been developed and lessons learned. Hence, a replicable analytical process distills down to the following seven tasks:

1. Select the building(s);
2. Review the existing capital refurbishment program for the selected building(s);
3. Undertake energy (audit) assessment;
4. Build and calibrate energy model;
5. Identify energy saving opportunities;
6. Iteratively appraise identified opportunities; and
7. Formulate recommendations.

### 4.1.1 Task 1: Select the Building(s)

The reality is that most owners and managers of low-income housing will have limited financial resources. When choosing how to use those resources they will likely want to maximize outcomes for a given level of spend. In the context of undertaking building refurbishments as part of a capital renewal program, a number of factors should be considered when selecting sites to help maximize the contribution of energy efficiency improvements to energy poverty alleviation. Key factors to guide building selection are listed in Table 2. Bearing these factors in mind a CHC property scheduled for refurbishment in 2014 was selected as a case study. The property is located in Bankview and is described in Box 3.

Figure 3: Four-stage replicable analytical process for project development



### 4.1.2 Task 2: Review the Existing Capital Refurbishment Plan

For deep energy efficiency upgrades to be most cost-effective, the upgrades need to be aligned and integrated with planned building refurbishments and equipment replacement. Clearly, if a building's skin or windows, etc. are scheduled for replacement as part of a capital renewal plan, the cost of adding 1-3 inches of insulation or buying more efficient windows will be less than it otherwise would be, since (less efficient) materials and equipment, as well as labor costs, are being incurred in any event. What matters is the incremental cost of the energy efficiency improvements over and above business-as-usual (BAU). Likewise, what matters are the incremental energy savings relative to the BAU case. For this project, the BAU case is defined by the planned capital refurbishment plan for the building. Hence, a key task in the analytical process is to review the existing plan, and in particular, identify planned upgrades that will have implications for energy use in the building.

### Table 2: Factors to Consider when Selecting Buildings for Refurbishment to Maximize Energy Poverty Reduction Outcomes

| Factor | Consideration |
|---|---|
| Age of building | The proportion of households living in energy poverty increases with the age of the building. |
| Energy efficiency of building (related to age) | The energy efficiency of a building strongly determines the likelihood that low-income households will be energy poor (older buildings tend to be relatively energy inefficient). |
| Past refurbishments or upgrades | The energy efficiency of the building will have been affected by past envelope or equipment upgrades – look for buildings that have not been refurbished since they were originally constructed. |
| Home size (unit size) | The likelihood of a low-income household being energy poor increases with the size of the home or unit. |
| Tenant population | Energy poverty is more prevalent among lone-parents with dependent child(ren) and among unattached individuals under 65. The elderly, very young children, and the ill or disabled are most vulnerable to the adverse health effects of energy poverty. |
| On-site tenant support | An important consideration for the effectiveness of tenant engagement initiatives. |
| Common space for tenant activities | An important consideration for the effectiveness of tenant engagement initiatives. |
| Tenant pays utility bills | Tenants who pay their own natural gas, electricity, and water bills will benefit more from energy efficiency projects and conservation behaviors than if utility costs are embedded in rents. |
| Tenant participation in existing programs | An important consideration for tenant engagement initiatives - higher tenant participation tends to result in increased energy conservation. |
| Tenant turnover | An important consideration for tenant engagement initiatives – lower tenant turnover will tend to result in increased energy conservation. |
| Alternative energy potential | Does the building offer the opportunity to install some form of alternative energy source (e.g., solar PV or solar hot water)? Buildings with larger, unshaded flat or south pitched roof areas will offer the largest potential. |
| Nature of existing capital renewal plan for building | Does it involve window replacement, door replacement, flooring, re-roofing, lighting, other electrical, interior modernization, mechanical systems, hot water system, insulation, landscaping? The scope for incremental cost-effective energy saving improvements will tend to be greater the more extensive the planned upgrades. |

## Box 3: Case Study Building – Bankview 1

Bankview 1 building is a low-rise apartment block constructed in 1982. It has a gross conditioned area of 28,312 ft$^2$ (2,630 m$^2$), including the underground parkade with 18 vehicle stalls. There are 26 separate apartments, including 3 in the basement level, each with street-level entry, and 23 units in the three above-ground storeys.

Residential suites are individually metered for electricity, but not for natural gas. Residents are obliged to have private contracts for electricity supply, and the CHC divides the natural gas bill based on the floor area of each suite.

Space heating is provided by perimeter hot-water baseboards along the perimeter of each suite. The parkade is heated by two hot-water unit heaters. Hot water for space heating is generated by two Lochinvar natural gas fired boilers each rated at 81% steady-state efficiency with 645,000 BTU/hr (188 kW) gas input. These boilers were installed five years ago and are in good condition.

Ventilation is provided by one roof-top unit (RTU) equipped with a gas-fired heating section. The ventilation rate is continuous at 1350 cfm (637.1 l/s) of 100% outdoor air, and the heating maximum input is 180,000 BTU/hr (52.7 kW) with 136,800 BTU/hr (40.0 kW) output. The RTU supplies fresh air to the common hallways, and the pressurized air in the hallways is transferred to the suites under the doors. This method of fresh air distribution is very common to buildings of this vintage. Ventilation in the parkade is provided through a gas-fired make-up air unit that is controlled with a carbon monoxide detector. The MUA supplies 4500 cfm (2123.7 l/s) of fresh air, and the heating section has 500,000 BTU/hr (146.4 kW) maximum gas input. The carbon monoxide sensor also controls an exhaust fan in the parkade.

Domestic hot water is provided by two natural-draft natural gas-fired water heaters. One is 82 US gallons and the other is 80 US gallons storage capacity. The 80 gallon tank has a gas input of 180,000 BTU/hr (52.7 kW) while the 82 gallon tank has an input of 179,100 BTU/hr (52.4 kW).

Lighting was originally designed for incandescent lamps throughout the suites and common hallways, with T12 fluorescent tubes throughout the parkade, mechanical rooms, and laundry room. The common hallways have been converted to two-pin PL-type compact fluorescent lamps, and the lighting in suites is being converted to CFL bulbs as the existing incandescent bulbs burn out.

The north and south walls are metal stud construction with 6-inch deep studs. The cavity is filled with R20 fiberglass batts. The east and west walls are wooden stud construction with 6-inch deep studs, also filled with R20 fiberglass batt insulation.

Windows are original to the building and generally consist of single glazing with either wooden frame or aluminum slider frames. Patio doors are either metal swinging door with a fixed glass panel, or a full glass sliding door.

The flat roof was re-done two years ago, and consists of wooden truss structure with R30 batt insulation. The exterior of the roof is sealed asphalt sheeting.

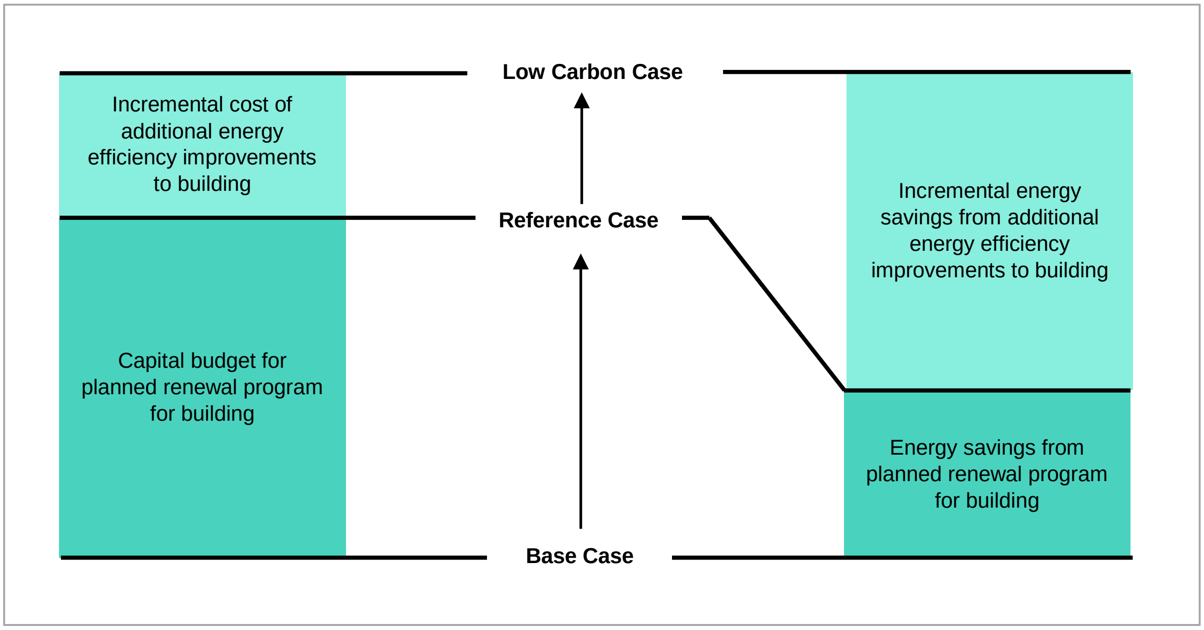
The building is in reasonably good condition for its age and the energy consumption is in the middle of the range for similar building types of this vintage.

The existing capital renewal plan for Bankview 1 includes re-skinning of the entire building for architectural modernization to improve aesthetics and to bring fire-egress up to current code. The plan includes the following upgrades with implications for energy use on the building:

- Exposing and removing the existing insulation in the north and south walls and replacing it with R25 Roxul batts;
- Replacing all the windows with units that meet R3.85 thermal resistance; and
- Replacing all exterior steel doors with steel doors of higher-insulation value.

These upgrades define the starting point—or project **Reference Case**—against which additional energy efficiency improvements to the building are appraised. Analytically, the situation that could exist following any additional improvements defines the **Low Carbon Case**, while the situation that exists prior to the originally planned upgrades defines the project **Base Case** (consider Figure 4).

Figure 4: Base Case, Reference Case, and Low Carbon Case for Analytical Process



## 4.1.3 Task 3: Energy (Audit) Assessment

The third task involves identifying where, and how much, energy is consumed in the building. This is typically accomplished through an energy (audit) assessment. Information collected during the audit is used (a) to characterize the project Base Case and (b) to identify and recommend potential economically justified energy and cost savings opportunities resulting from reductions in electricity, natural gas, and water use. Typically an energy audit costs about 5 per cent of a building's annual energy bill.

There are three types of energy audit:

- **Walk-through audit**—this is the least expensive form of audit. It involves a visual examination of the building and associated mechanical and electrical systems. Historic energy consumption data (usually covering 3 years) is reviewed to analyze patterns of energy use and to compare them with averages or benchmarks for similar buildings. The walk-through audit provides a preliminary estimate of potential savings and generates a list of inexpensive savings options, usually involving incremental improvements in operational and maintenance regimes. Information collected during a walk-through audit also serves as a basis for determining if a more detailed audit is needed.
- **Standard audit**—this involves a more comprehensive evaluation of the building and its systems. In addition to an examination of utility bills, on-site measurements and testing are conducted to allow for a careful quantification of energy use, including losses. The efficiency of the building's various systems are determined using accepted energy engineering computational techniques. Technical changes and improvements to each of the systems are individually analyzed to quantify potential energy and cost savings. The standard audit will also include a simplified financial economic analysis of the proposed technical changes and improvements.
- **Computer simulations**—this approach is the most expensive and often is recommended for more complicated electrical and mechanical systems, or buildings. It involves using computer simulation software for the purpose of predicting the performance of buildings and associated systems. In contrast to the standard audit, this form of audit considers the effects of external factors (e.g., changes in weather and other conditions) and, importantly, the interactions between building systems and individual energy saving opportunities. Typically, a business-as-usual scenario related to the building's actual energy use is established, against which effects of technical changes and improvements are compared.

An energy audit comprises several steps: initiate (define scope and objectives, select and appoint auditor); prepare (set audit date, collect billing and other data, preliminary data analysis, prepare audit plan and checklists); execute (audit building, analysis and evaluation of data, formulate recommendations); and report. A detailed explanation of each can be found in NRCAN (1993).

For the purpose of this project, ATCO Energy Sense was commissioned to perform a standard energy audit of Bankview 1 in May 2014. The project team separately took infra-red images of the building, which provide a visual indication of heat loss (shown in Figure 5). The audit report summarized energy use by different systems at the site and provided a list of recommended energy efficiency measures encompassing communal lighting, mechanical systems, building envelope, and communal laundry. The information contained in the audit report and illustrated by the infra-red images served as a basis for the development of an energy model for the building, which is used in subsequent steps to simulate the financial and environmental performance of different portfolios of energy saving measures.

## Box 4: Base Case Energy Use at Bankview 1

In 2013 energy consumption at Bankview 1 comprised 2,169 GJ of natural gas and 47,620 kWh of electricity (excluding electricity use in the rental units). This equates to a natural gas consumption rate of approximately 0.0766 GJ per $ft^2$ which is in the middle of the accepted range of 0.060 GJ per $ft^2$ to 0.085 GJ per $ft^2$ for buildings of this type. The combined energy use intensity (where natural gas is converted to equivalent kilowatt-hours and combined with electricity consumption) is 22.96 kWh per $ft^2$. Again, this is a reasonable value for this type of building.

The project team separately estimated potable water consumption at 6,505 liters per day. Electricity consumption by residents within the rental units was estimated at 282 kWh per day.

Figure 5: Infra-red Images of Bankview 1

### 4.1.4 Task 4: Build and Calibrate Energy Model

Buildings are like systems. They comprise many materials, components and systems, which work together to determine overall energy use. Simply improving one aspect of a building may be detrimental (or beneficial) to the performance of another part of the system. External factors (e.g., exposure to sunlight, humidity, external temperature) will also affect energy performance.

Energy efficiency measures when evaluated in isolation of each other, and without accounting for external factors, may appear to provide more (or less) savings than they actually would in-situ. Reducing energy consumption in one building component can often indirectly increase (or reduce) energy use by other end-uses due to interaction effects among building components. For example, an upgrade to more efficient lighting will decrease electricity consumption. However, lighting also contributes to heat gain in the building, which can be beneficial in winter and detrimental in summer. A decrease in electricity consumption for lighting will tend to increase natural gas consumption for heating in the winter, and decrease cooling energy consumption in the summer. In larger buildings, with multiple interacting components, evaluating energy saving measures in isolation, one-at-a-time may (over)understate potential savings and costs. When appraising deep energy efficiency upgrades in larger buildings it is necessary to use a computer simulation model.

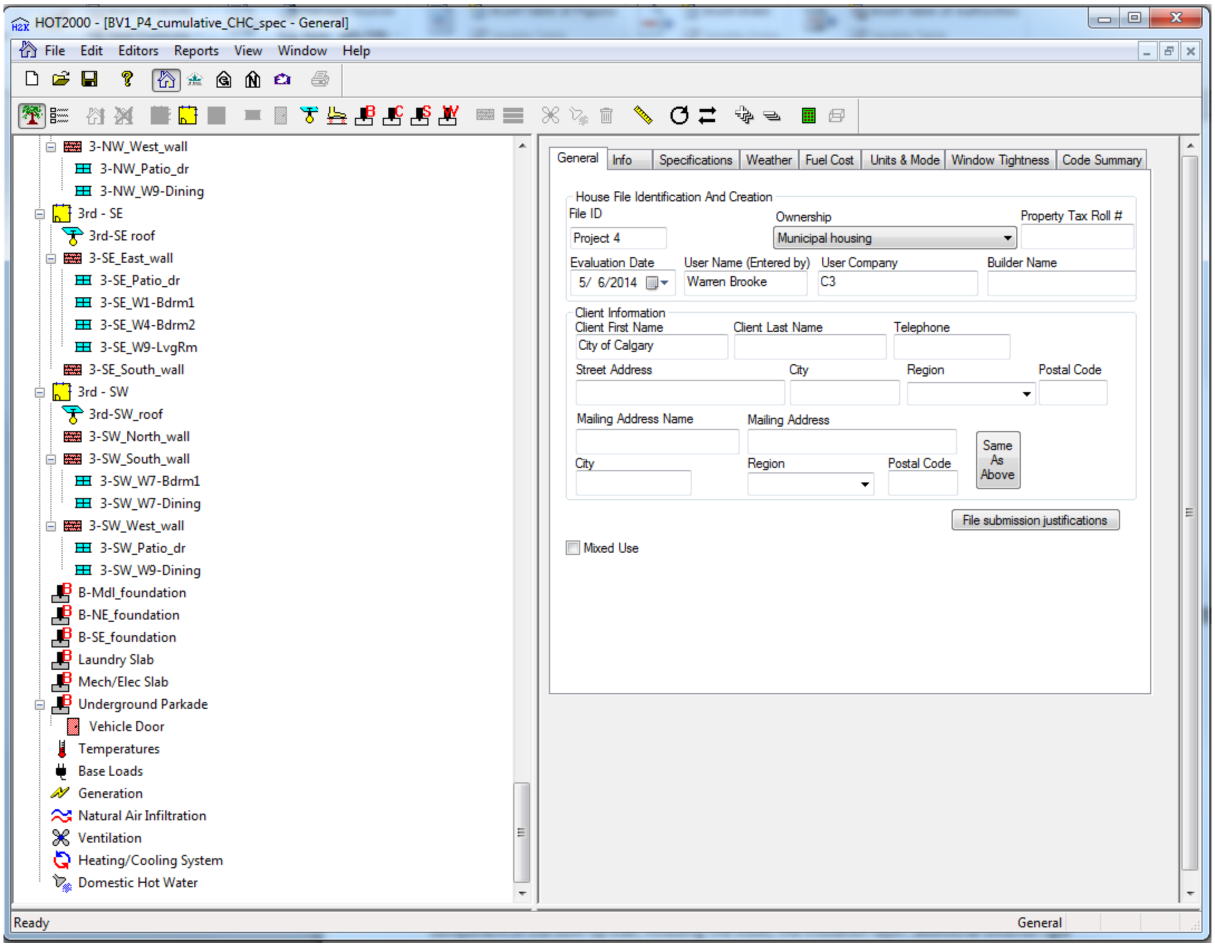
The project team developed an energy simulation model of Bankview 1 in the Hot2000 software. Hot2000 is a freely available software package developed by Natural Resources Canada's CanmetENERGY group, and has become the most trusted and widely used software for evaluating residential housing stock. The software has the capability of modeling energy consumption in many types of residential structures, including Multi-Unit Residential Buildings (MURBs), attached housing (townhouses), and stand-alone houses. Hot2000 has been extensively tested by third parties and refined throughout 23 years of service. An image of the tree of building components from the Bankview 1 model is shown in Figure 6.

The energy model of Bankview 1 was developed from architectural, mechanical, and electrical drawings provided by the CHC, so rental units were modeled with the correct geometry. Where adjacent units had similar geometry and exposure to the sun, these were grouped and modeled as a single unit.

Only exterior walls were modeled, since only heat transfer from the interior to the exterior of the building will affect space heating energy consumption. The software allows the user to input components of the built-up wall, including the studs, the insulation layer, additional exterior rigid insulation, sheathing, and interior and exterior finishes. The same is true of windows, where the user can model each of the glazing components such as the number of glass layers, the spacing distance and spacer material, any inert gas to fill the space, the frame type, and the solar films applied. These detailed user inputs allow for thermal bridging through the wall studs or the window frame to be evaluated, so that realistic thermal resistance (R-value) is modeled. Exposed ceilings and exposed floors are used for rental units that have a roof area exposed to the outside, or ground-floor units that have their floor on the foundation slab. These exposed areas allow heat to escape to the surroundings.

The model includes a variety of energy consuming devices such as space heating boilers, circulation pumps, domestic water heating, lighting, appliances, ventilation fans, and the heating load associated with natural infiltration. The user of the energy model is able to enter the specific characteristics of each piece of mechanical or electrical equipment, such as boiler efficiency and maximum heating output, or ventilation rates along with fan power consumption. Each of these parameters is important to the overall energy consumption profile, since there are often interactions between the different components.

Figure 6: Screen Capture of Hot2000 Model of Bankview 1 Building



House File Identification And Creation

File ID: Project 4
Ownership: Municipal housing
Property Tax Roll #:
Evaluation Date: 5/ 6/2014
User Name (Entered by): Warren Brooke
User Company: C3
Builder Name:

Client Information

Client First Name: City of Calgary
Client Last Name:
Telephone:
Street Address:
City:
Region:
Postal Code:
Mailing Address Name:
Mailing Address:
City:
Region:
Postal Code:

☐ Mixed Use

The energy model was constructed to reflect conditions prior to the planned capital renewal program, and calibrated to match an average of the monthly utility bills over the past three years. This defines the Base Case for the building. With the model calibrated to the actual utility billing data, the project team could proceed with modeling the Reference Case and Low Carbon Case with reasonable confidence.

The overall energy performance of the building under the Base Case is provided in Table 3, which shows how energy is consumed by different end-uses throughout the building. The corresponding GHG emissions are about 205 t $CO_2$-eq per year.

Table 3: Energy Consumption at Bankview 1 under the Base Case

| Domestic water heating | Space Heating | Interior Lighting | Appliances | Other Electrical (plug loads) | HVAC Fans |
|---|---|---|---|---|---|
| MJ | MJ | kWh | kWh | kWh | kWh |
| 464,719 | 1,590,574 | 44,019 | 76,540 | 18,542 | 11,530 |

As noted above in Section 4.1.2, the planned capital renewal program for Bankview 1 includes three improvements to the building envelope that will affect the energy performance of the building. These three upgrades are incorporated into the Base Case model to create the project Reference Case for the building, against which additional energy efficiency improvements are identified in Task 5 and appraised in Task 6. All three upgrades improve the thermal performance of the building envelope. Table 4 presents energy use at Bankview 1 under the project Reference Case, by end-use. The corresponding GHG emissions are about 195 t $CO_2$-eq per year. This represents about a 5 per cent reduction on the project Base Case.

Table 4: Energy Consumption at Bankview 1 under the Reference Case

| Domestic water heating | Space Heating | Interior Lighting | Appliances | Other Electrical (plug loads) | HVAC Fans |
|---|---|---|---|---|---|
| MJ | MJ | kWh | kWh | kWh | kWh |
| 464,719 | 1,394,515 | 44,019 | 76,540 | 18,542 | 11,530 |

### 4.1.5 Task 5: Identify Energy Saving Opportunities

The next task involves identifying additional energy savings opportunities. There are multiple upgrade options to reduce energy consumption in a residential building, which fall into one of two broad categories:

1. **Technological measures** – e.g.,
    - (Super)high performance (energy efficient) windows;
    - High performance (energy efficient) doors;
    - Window films;
    - Roof insulation;
    - Wall insulation;
    - Ceiling insulation;

  - Foundation insulation;
  - Air leakage and duct sealing;
  - Condensing furnaces and boilers;
  - Programmable thermostats;
  - High efficiency heat recovery ventilators;
  - (Ultra)low flow showerheads;
  - Faucet aerators;
  - Condensing water heaters;
  - Tankless water heaters;
  - Pipe insulation;
  - High efficiency appliances;
  - Natural gas dryers;
  - Solar hot water systems; and
  - Solar PV.

2. **Conservation behaviors** – e.g.,
   - Turning down the temperature at night or during the day;
   - Keeping windows closed;
   - Maintaining draft proofing;
   - Turning off lights when not in the room;
   - Turning down the temperature of the water heater when away;
   - Lowering the water temperature in general;
   - Air dry dishes and clothes;
   - Maintain proper temperature in refrigerator and freezer;
   - Regularly defrost freezer;
   - Activate power management features on computers and peripherals; and
   - Unplug TV and related equipment when not in use.

In total, 22 potential energy efficiency upgrades and two renewable energy projects were identified for Bankview 1. The chosen upgrades are based on recommendations contained in the energy audit and the project team's own examination of the building and the planned capital renewal plan. The 24 candidate upgrades are listed in Table 5. Specification of the two renewable energy projects is briefly explained in Appendix A. Some of the energy efficiency upgrades are mutually exclusive, in that only one of two opportunities can be implemented in practice. For example, windows can either be upgraded to achieve an R-value of 5 (Project 14) or an R-value of 7.7 (Project 15), but both projects cannot be pursued. Each mutually exclusive project was appraised in Task 6, with only the best performing option considered for inclusion in a package of deep upgrades for the building.

### 4.1.6 Task 6: Iteratively Appraise Identified Opportunities

Task 6 seeks to evaluate the financial and environmental performance of each candidate energy saving measure, and subsequently to evaluate packages of measures for Bankview 1. Measures are appraised on the basis of incremental discounted cash flows, where:

Energy savings = Discounted lifetime energy use at building under project Reference Case *less* discounted lifetime energy use at building with energy saving measure installed (i.e., under project Low Carbon Case); and

Costs = Discounted lifetime costs (capital and annual O&M costs, net of available financial incentives) of energy saving measure *less* discounted lifetime costs of Reference Case measure (if any). Costs are defined to reflect the full price paid by the property owner, including equipment costs, material costs, labor costs, and overhead and profit.

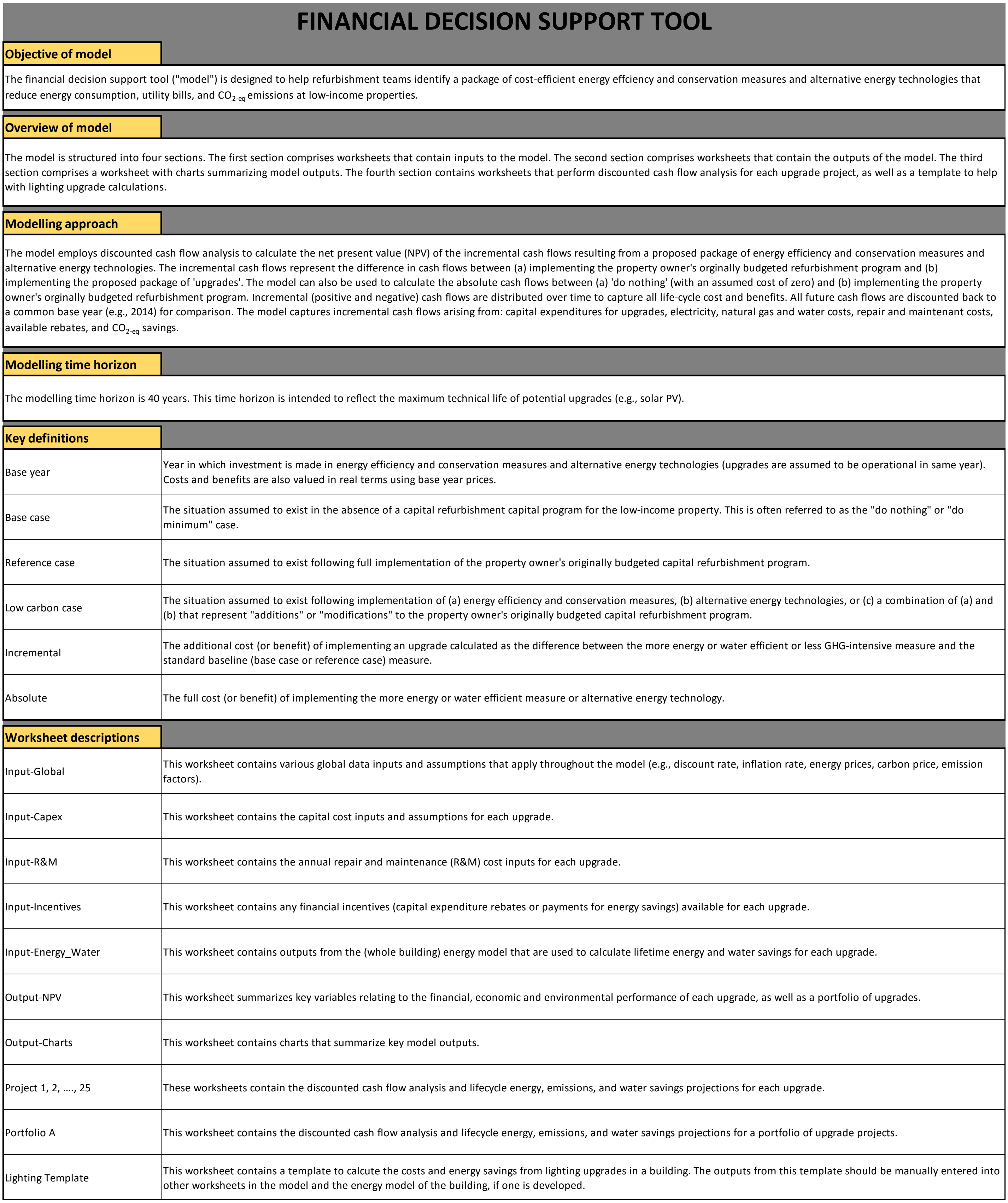
Water savings, reductions in GHG emissions, and reductions in Criteria Air Contaminants are similarly defined. Measures are appraised primarily on the basis of Net Present Value (NPV), though a number of other standard financial decision criteria are calculated to add value to the investment decision—discounted return on investment (ROI), benefit-cost ratio (BCR), and simple (undiscounted) payback (SPB). NPV is calculated from both a public policy perspective and the private perspective of the property owner or manager. The main difference between the two metrics is the inclusion of the discounted value of lifetime GHG emission reductions in the public measure of NPV. The analysis is performed using the Financial Decision Support Tool, developed as part of the project.

A screenshot of the tool, describing its overall structure and purpose, is provided in Table 6. A summary of modeled outcomes for each of the 24 candidate energy saving measures is provided in Table 7.

## Table 5: Full List of Energy Saving Measures Modeled at Bankview 1 under the Low Carbon Case

| | |
|---|---|
| 1 | Upgrade lighting in common areas (full LED: "Lighting-Comm B" package). Retrofit with building refurbishment |
| 2 | Upgrade lighting in apartments (full LED plus dimmer switches: "Lighting-Apart E" package). Retrofit with building refurbishment |
| 3 | Upgrade lighting in common areas (T12 to T8, plus CFL to LED: "Lighting-Comm A" package). Retrofit with building refurbishment |
| 4 | Upgrade lighting in apartments (full LED: "Lighting-Apart D" package). Retrofit with building refurbishment |
| 5 | Install low-flow faucet aerators in apartments as part of building refurbishment |
| 6 | Install low-flow showerheads in apartments as part of building refurbishment |
| 7 | Replace existing clothes washing machines with Energy Star qualified appliances as part of building refurbishment |
| 8 | Replace existing refrigerator in apartments with Energy Star qualified appliances as part of building refurbishment |
| 9 | Replace existing refrigerator in apartments with Energy Star qualified appliances as part of natural replacement |
| 10 | Install programmable thermostats in apartments as part of building refurbishment |
| 11 | Replace existing electric clothes dryers with natural gas dryers as part of building refurbishment |
| 12 | Upgrade all East and West exterior walls to R25. 6" cellulose blown insulation (R19) + 1-1/2" unfaced fiberglass (R6) |
| 13 | Upgrade all exterior walls to R25. 6" cellulose blown insulation (R19) + 3" unfaced fiberglass (R12) |
| 14 | Upgrade all windows to achieve R5. Increase window air tightness from CSA A1 to A2. |
| 15 | Upgrade all windows to achieve R7.7 as part of building refurbishment. Increase window air tightness from CSA A1 to A2. |
| 16 | Upgrade all patio doors with Energy Star in-swing French Doors to achieve R 3.85 as part of building refurbishment |
| 17 | Upgrade parkade roof to R50 as part of building refurbishment with 6" expanded polystyrene (R25) |
| 18 | Upgrade ceiling roofs to R50 as part of building refurbishment with 5" expanded polystyrene (R20) |
| 19 | Upgrade hot water heaters from existing tanks to condensing units (improvement in efficiency = 30%) as part of building refurbishment |
| 20 | Replace existing boilers to higher efficiency condensing boilers (improvement in efficiency = 10%) as part of building refurbishment |
| 21 | Weather stripping and air sealing to increase building air tightness from 'loose' to 'average' (4.5 ACH @ 50 Pa) as part of building refurbishment |
| 22 | Weather stripping and air sealing to increase building air tightness from 'loose' to 'tight' (1.5 ACH @ 50 Pa) as part of building refurbishment |
| 23 | Solar, closed loop, add-on hot water system, 3/4" tubing, 54 77" x 39" panels (maximum for available roof space) |
| 24 | Solar PV system, 72 panels (4 ROWS OF 18) with PTC ('real world') rating of 221 W (15.9 kW installed capacity) |

Table 6: Structure of the Financial Decision Support Tool (Screen Shot)



# FINANCIAL DECISION SUPPORT TOOL

## Objective of model

The financial decision support tool ("model") is designed to help refurbishment teams identify a package of cost-efficient energy effciency and conservation measures and alternative energy technologies that reduce energy consumption, utility bills, and $CO_{2\text{-eq}}$ emissions at low-income properties.

## Overview of model

The model is structured into four sections. The first section comprises worksheets that contain inputs to the model. The second section comprises worksheets that contain the outputs of the model. The third section comprises a worksheet with charts summarizing model outputs. The fourth section contains worksheets that perform discounted cash flow analysis for each upgrade project, as well as a template to help with lighting upgrade calculations.

## Modelling approach

The model employs discounted cash flow analysis to calculate the net present value (NPV) of the incremental cash flows resulting from a proposed package of energy efficiency and conservation measures and alternative energy technologies. The incremental cash flows represent the difference in cash flows between (a) implementing the property owner's orginally budgeted refurbishment program and (b) implementing the proposed package of 'upgrades'. The model can also be used to calculate the absolute cash flows between (a) 'do nothing' (with an assumed cost of zero) and (b) implementing the property owner's orginally budgeted refurbishment program. Incremental (positive and negative) cash flows are distributed over time to capture all life-cycle cost and benefits. All future cash flows are discounted back to a common base year (e.g., 2014) for comparison. The model captures incremental cash flows arising from: capital expenditures for upgrades, electricity, natural gas and water costs, repair and maintenant costs, available rebates, and $CO_{2\text{-eq}}$ savings.

## Modelling time horizon

The modelling time horizon is 40 years. This time horizon is intended to reflect the maximum technical life of potential upgrades (e.g., solar PV).

## Key definitions

| | |
|---|---|
| Base year | Year in which investment is made in energy efficiency and conservation measures and alternative energy technologies (upgrades are assumed to be operational in same year). Costs and benefits are also valued in real terms using base year prices. |
| Base case | The situation assumed to exist in the absence of a capital refurbishment capital program for the low-income property. This is often referred to as the "do nothing" or "do minimum" case. |
| Reference case | The situation assumed to exist following full implementation of the property owner's originally budgeted capital refurbishment program. |
| Low carbon case | The situation assumed to exist following implementation of (a) energy efficiency and conservation measures, (b) alternative energy technologies, or (c) a combination of (a) and (b) that represent "additions" or "modifications" to the property owner's originally budgeted capital refurbishment program. |
| Incremental | The additional cost (or benefit) of implementing an upgrade calculated as the difference between the more energy or water efficient or less GHG-intensive measure and the standard baseline (base case or reference case) measure. |
| Absolute | The full cost (or benefit) of implementing the more energy or water efficient measure or alternative energy technology. |

## Worksheet descriptions

| | |
|---|---|
| Input-Global | This worksheet contains various global data inputs and assumptions that apply throughout the model (e.g., discount rate, inflation rate, energy prices, carbon price, emission factors). |
| Input-Capex | This worksheet contains the capital cost inputs and assumptions for each upgrade. |
| Input-R&M | This worksheet contains the annual repair and maintenance (R&M) cost inputs for each upgrade. |
| Input-Incentives | This worksheet contains any financial incentives (capital expenditure rebates or payments for energy savings) available for each upgrade. |
| Input-Energy_Water | This worksheet contains outputs from the (whole building) energy model that are used to calculate lifetime energy and water savings for each upgrade. |
| Output-NPV | This worksheet summarizes key variables relating to the financial, economic and environmental performance of each upgrade, as well as a portfolio of upgrades. |
| Output-Charts | This worksheet contains charts that summarize key model outputs. |
| Project 1, 2, …., 25 | These worksheets contain the discounted cash flow analysis and lifecycle energy, emissions, and water savings projections for each upgrade. |
| Portfolio A | This worksheet contains the discounted cash flow analysis and lifecycle energy, emissions, and water savings projections for a portfolio of upgrade projects. |
| Lighting Template | This worksheet contains a template to calcute the costs and energy savings from lighting upgrades in a building. The outputs from this template should be manually entered into other worksheets in the model and the energy model of the building, if one is developed. |

## Table 7: Financial and Environmental Performance of Identified Energy Saving Measures

| | | Project 1 | Project 2 | Project 3 | Project 4 | Project 5 | Project 6 | Project 7 | Project 8 | Project 9 | Project 10 | Project 11 | Project 12 | Project 13 | Project 14 | Project 15 | Project 16 | Project 17 | Project 18 | Project 19 | Project 20 | Project 21 | Project 22 | Project 23 | Project 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Costs = Case outflows** | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total net capital expenditure on upgrade | $ in year 0 | 11,838 | 9,186 | 4,083 | 6,167 | 295 | 1,664 | 1,890 | 20,904 | 1,430 | 3,900 | 3,100 | 10,283 | 14,249 | 2,235 | 14,155 | 11,232 | 13,796 | 22,645 | 12,450 | 25,330 | 11,066 | 16,599 | 73,515 | 55,650 |
| Present value total costs | $ | 11,838 | 9,186 | 4,083 | 6,167 | 295 | 1,664 | 1,890 | 20,904 | 1,430 | 3,900 | 3,100 | 10,283 | 14,249 | 2,235 | 14,155 | 11,232 | 13,796 | 22,645 | 12,450 | 25,330 | 11,066 | 16,599 | 73,515 | 55,650 |
| **Benefits = Case inflows** | | | | | | | | | | | | | | | | | | | | | | | | | |
| Energy savings | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cumulative natural gas savings | GJ | -392 | -568 | -171 | -558 | 156 | 372 | 148 | -116 | -116 | 1,328 | -402 | 1,079 | 1,123 | 4,334 | 7,107 | 2,220 | 1,031 | 717 | 2,471 | 3,623 | 5,345 | 8,520 | 1,948 | - |
| Cumulative electricity savings | GJ | 425 | 621 | 187 | 610 | - | - | - | 127 | 127 | - | 400 | - | - | - | - | - | - | - | - | - | - | - | - | 2,958 |
| Cumulative total energy savings | GJ | 33 | 53 | 15 | 52 | 156 | 372 | 148 | 11 | 11 | 1,328 | -1 | 1,079 | 1,123 | 4,334 | 7,107 | 2,220 | 1,031 | 717 | 2,471 | 3,623 | 5,345 | 8,520 | 1,948 | 2,958 |
| Cumulative value of energy savings (undiscounted) | $ | 14,007 | 20,239 | 6,168 | 19,865 | 926 | 2,213 | 847 | 4,186 | 4,186 | 8,296 | 12,987 | 8,862 | 9,222 | 35,579 | 58,347 | 18,230 | 8,466 | 5,890 | 16,658 | 26,051 | 38,438 | 61,265 | 15,997 | 118,070 |
| Average annual value of total energy savings (undiscounted) | $ per year | 1,751 | 810 | 1,234 | 795 | 93 | 221 | 121 | 299 | 299 | 593 | 1,181 | 253 | 263 | 1,017 | 1,667 | 521 | 242 | 168 | 833 | 1,042 | 1,538 | 2,451 | 457 | 2,952 |
| Present value energy savings | $ | 12,038 | 13,383 | 5,570 | 13,136 | 765 | 1,828 | 737 | 3,267 | 3,267 | 6,386 | 10,633 | 4,664 | 4,853 | 18,724 | 30,707 | 9,594 | 4,455 | 3,100 | 11,522 | 16,465 | 24,293 | 38,721 | 8,419 | 62,337 |
| Water savings | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cumulative value of water savings (undiscounted) | $ | - | - | - | - | 3,379 | 7,164 | 2,915 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Average annual value of total water savings (undiscounted) | $ per year | - | - | - | - | 338 | 716 | 416 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Present value water savings | $ | - | - | - | - | 2,780 | 5,893 | 2,533 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Operating cost (utility bill) savings | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cumulative operating cost savings (undiscounted) | $ | 14,007 | 20,239 | 6,168 | 19,865 | 4,306 | 9,376 | 3,762 | 4,186 | 4,186 | 8,296 | 12,987 | 8,862 | 9,222 | 35,579 | 58,347 | 18,230 | 8,466 | 5,890 | 16,658 | 26,051 | 38,438 | 61,265 | 15,997 | 118,070 |
| Average annual operating cost savings (undiscounted) | $ per year | 1,751 | 810 | 1,234 | 795 | 431 | 938 | 537 | 299 | 299 | 593 | 1,181 | 253 | 263 | 1,017 | 1,667 | 521 | 242 | 168 | 833 | 1,042 | 1,538 | 2,451 | 457 | 2,952 |
| Present value operating cost savings | $ | 12,038 | 13,383 | 5,570 | 13,136 | 3,545 | 7,721 | 3,270 | 3,267 | 3,267 | 6,386 | 10,633 | 4,664 | 4,853 | 18,724 | 30,707 | 9,594 | 4,455 | 3,100 | 11,522 | 16,465 | 24,293 | 38,721 | 8,419 | 62,337 |
| Carbon savings | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cumulative total GHG emission savings | t CO2-eq | 50.2 | 58.6 | 23.0 | 57.5 | 8.0 | 19.0 | 7.6 | 13.9 | 13.9 | 68.0 | 43.8 | 55.2 | 57.5 | 221.8 | 363.8 | 113.6 | 52.8 | 36.7 | 126.5 | 185.4 | 273.6 | 436.1 | 99.7 | 366.1 |
| Cumulative value of GHG emission savings (undiscounted) | $ | 2,238 | 3,018 | 998 | 2,962 | 364 | 868 | 335 | 655 | 655 | 3,223 | 2,005 | 3,251 | 3,383 | 13,052 | 21,405 | 6,687 | 3,106 | 2,161 | 6,371 | 9,830 | 14,504 | 23,117 | 5,868 | 21,617 |
| Average annual value of total GHG emission savings (undiscounted) | $ per year | 280 | 121 | 200 | 118 | 36 | 87 | 48 | 47 | 47 | 230 | 182 | 93 | 97 | 373 | 612 | 191 | 89 | 62 | 319 | 393 | 580 | 925 | 168 | 540 |
| Present value GHG emission savings | $ | 1,926 | 2,027 | 901 | 1,990 | 301 | 718 | 292 | 514 | 514 | 2,487 | 1,647 | 1,739 | 1,810 | 6,981 | 11,449 | 3,577 | 1,661 | 1,156 | 4,430 | 6,265 | 9,243 | 14,732 | 3,139 | 11,573 |
| Criteria air contaminant savings | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cumulative nitrogen oxides (NOx) savings | kg NOx | 124.6 | 182.4 | 54.8 | 179.1 | 6.2 | 14.9 | 5.9 | 37.3 | 37.3 | 53.1 | 116.2 | 43.2 | 44.9 | 173.3 | 284.3 | 88.8 | 41.2 | 28.7 | 98.8 | 144.9 | 213.8 | 340.8 | 77.9 | 977.1 |
| Cumulative particulate matter (PM total) savings | kg PM | 9.7 | 14.2 | 4.3 | 14.0 | 0.5 | 1.2 | 0.5 | 2.9 | 2.9 | 4.2 | 9.1 | 3.5 | 3.6 | 13.9 | 22.7 | 7.1 | 3.3 | 2.3 | 7.9 | 11.6 | 17.1 | 27.3 | 6.2 | 76.4 |
| Cumulative sulphur dioxide (SO2) savings | kg SO2 | 191.0 | 279.4 | 83.9 | 274.2 | 0.0 | 0.1 | 0.0 | 57.2 | 57.2 | 0.4 | 180.0 | 0.3 | 0.3 | 1.3 | 2.1 | 0.7 | 0.3 | 0.2 | 0.7 | 1.1 | 1.6 | 2.6 | 0.6 | 1,331.3 |
| Cumulative volatile organic compounds (VOC) savings | kg VOC | 0.2 | 0.2 | 0.1 | 0.2 | 0.4 | 0.9 | 0.3 | 0.1 | 0.1 | 3.1 | 0.1 | 2.5 | 2.6 | 10.0 | 16.3 | 5.1 | 2.4 | 1.6 | 5.7 | 8.3 | 12.3 | 19.6 | 4.5 | 7.4 |
| **Economic evaluation criteria** | | | | | | | | | | | | | | | | | | | | | | | | | |
| Net Present Value (NPV) (private - excluding carbon value) | $ | 200 | 4,197 | 1,487 | 6,969 | 3,250 | 6,057 | 1,380 | -17,637 | 1,837 | 2,486 | 7,533 | -5,620 | -9,396 | 16,489 | 16,552 | -1,638 | -9,341 | -19,545 | -928 | -8,865 | 13,227 | 22,122 | -65,096 | 6,687 |
| Net Present Value (NPV) (public - including carbon value) | $ | 2,126 | 6,224 | 2,388 | 8,959 | 3,551 | 6,776 | 1,672 | -17,123 | 2,351 | 4,973 | 9,179 | -3,881 | -7,586 | 23,470 | 28,001 | 1,939 | -7,680 | -18,389 | 3,502 | -2,601 | 22,470 | 36,854 | -61,957 | 18,259 |
| Return on Investment (ROI) (private - excluding carbon value) | % | 2% | 46% | 36% | 113% | 1102% | 364% | 73% | -84% | 128% | 64% | 243% | -55% | -66% | 738% | 117% | -15% | -68% | -86% | -7% | -35% | 120% | 133% | -89% | 12% |
| Benefit-Cost Ratio (BCR) (private - excluding carbon value) | ratio | 1.0 | 1.5 | 1.4 | 2.1 | 12.0 | 4.6 | 1.7 | 0.2 | 2.3 | 1.6 | 3.4 | 0.5 | 0.3 | 8.4 | 2.2 | 0.9 | 0.3 | 0.1 | 0.9 | 0.7 | 2.2 | 2.3 | 0.1 | 1.1 |
| Simple Payback (SPB) | years | 6.8 | 11.3 | 3.3 | 7.8 | 0.7 | 1.8 | 3.5 | 69.9 | 4.8 | 6.6 | 2.6 | 40.6 | 54.1 | 2.2 | 8.5 | 21.6 | 57.0 | 134.6 | 14.9 | 24.3 | 7.2 | 6.8 | 160.8 | 18.9 |
| Cost of Energy Saved (CES) | $ per GJ | 416.02 | 263.65 | 295.09 | 180.10 | 2.28 | 5.38 | 14.64 | 2,380.48 | 162.84 | 3.77 | -2,818.21 | 16.67 | 22.20 | 0.90 | 3.49 | 8.85 | 23.41 | 55.24 | 7.09 | 10.61 | 3.14 | 2.96 | 66.03 | 35.24 |
| Marginal cost of abatement (including operating cost savings) | $ per t CO2-eq | -5 | -103 | -71 | -175 | -490 | -382 | -209 | 1,598 | -166 | -47 | -208 | 178 | 286 | -130 | -80 | 25 | 310 | 932 | 10 | 73 | -73 | -77 | 1,142 | -31 |

The first step involves eliminating mutually exclusive projects. In cases where more than one energy saving measure targets a particular source of energy use or heat loss at Bankview 1, the measure with largest NPV (on the basis of incremental cash flows) was retained for inclusion in a package of deep upgrades for the building. Once all mutually exclusive energy saving measures are eliminated, the remaining upgrades can be rank-ordered on the basis of a profitability metric. Table 8 contains the prioritized list of candidate energy saving measures, rank-ordered on the basis of their BCR (measures with the highest BCR are at the top of the table; measures with the lowest BCR at the bottom).

Faced with a budget constraint, the property owner or manager can maximize the value of their investment in energy saving measures by working down the list in Table 8, until either (a) the cumulated capital expenditure exhausts the available budget or (b) the BCR of the next best measure drops below 1.0. In the table, this point is marked with a thick red line. Note that this is also the point at which the NPV (private) turns from positive to negative.[7] (The BCR shown is defined on the basis of private incremental cash flows—i.e., it does not include the value of GHG emission reductions.) From a public policy perspective, the inclusion of a value for GHG emissions avoided, means investment in a further two energy savings measures can be justified (Project 19 and Project 16). The thick blue line marks the point at which the NPV (public) NPV of measures turns from positive to negative.

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[7] A negative NPV indicates that investing in the project will actually decrease the present value wealth of the investor, based on the investor's discount rate.

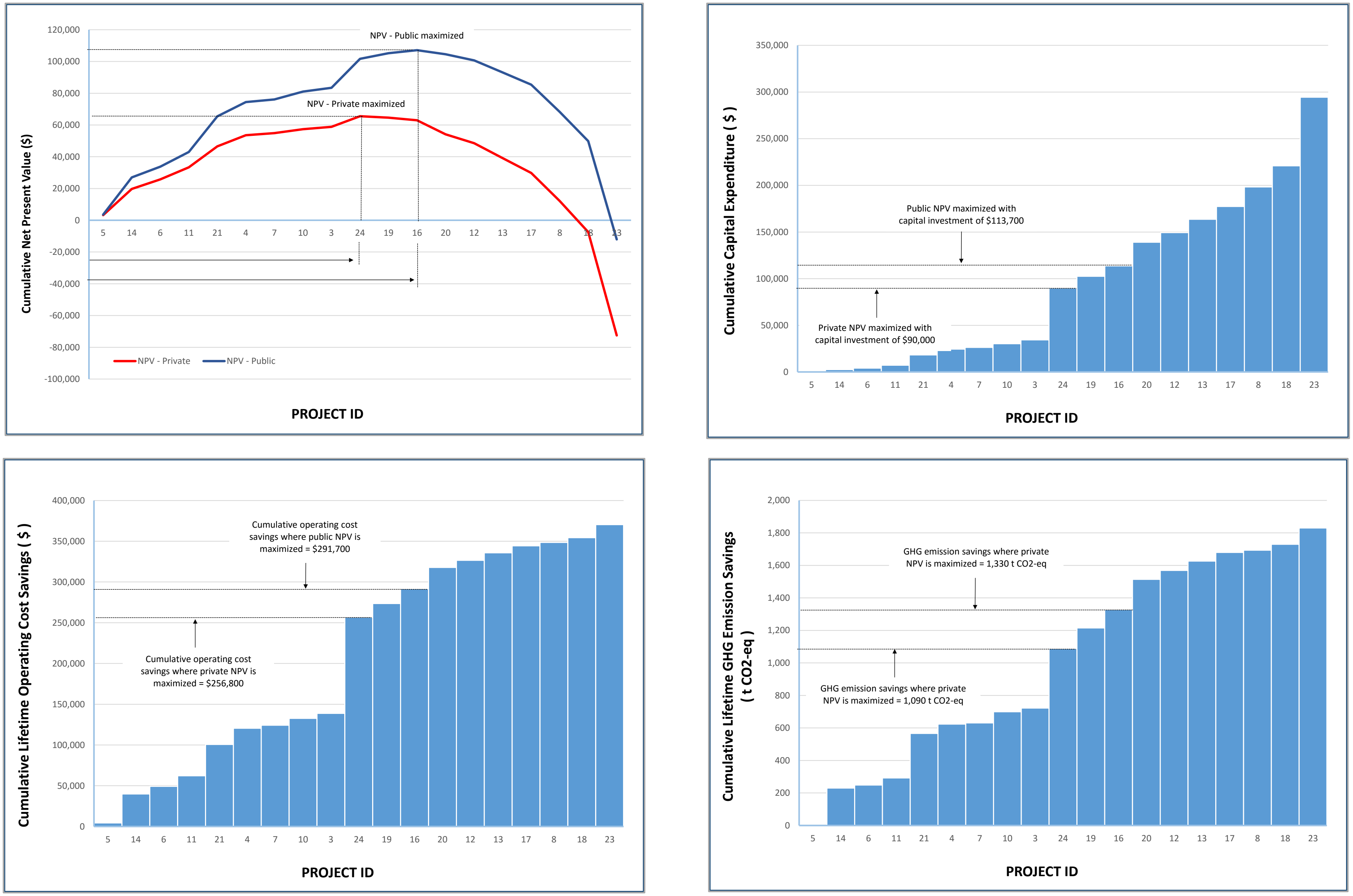
Low-income families and individuals face certain barriers in accessing energy saving opportunities that are unique to this group of energy users. In addition, the dollar value of utility bill savings does not capture all the social, health and well-being benefits that will accrue to low-income households from energy efficiency improvements (recall Section 3.2.2). Studies have broadly estimated these 'non-energy social benefits' to be worth as much as 50 per cent of annual household energy bill savings. Reflecting the wider social benefits of low-income energy assistance programs offered by utilities, regulators tend to relax the cost-effectiveness criteria employed to screen programs for other groups of energy consumers. For example, the Ontario Energy Board uses a threshold equivalent to a BCR of 0.7 as opposed to a value of 1.0 which is applied to residential, commercial, and industrial programs. On this basis one additional energy saving measure (Project 20) is justified from a public policy perspective. The thick gold line in Table 8 thus defines a cut-off point, below which investment in energy saving measures at Bankview 1 is not socially justified at present.

Using the information in Table 8 it is not possible to construct portfolios of energy saving measures for Bankview 1 that maximize NPV from different perspectives. Figure 7 shows the potential cumulative capital expenditure, lifetime operating cost savings (electricity, natural gas, and water), and lifetime GHG emission reductions from a portfolio of energy saving measures that maximizes either private NPV or public NPV.

## Table 8: Prioritizing Energy Saving Measures under the Low Carbon Case

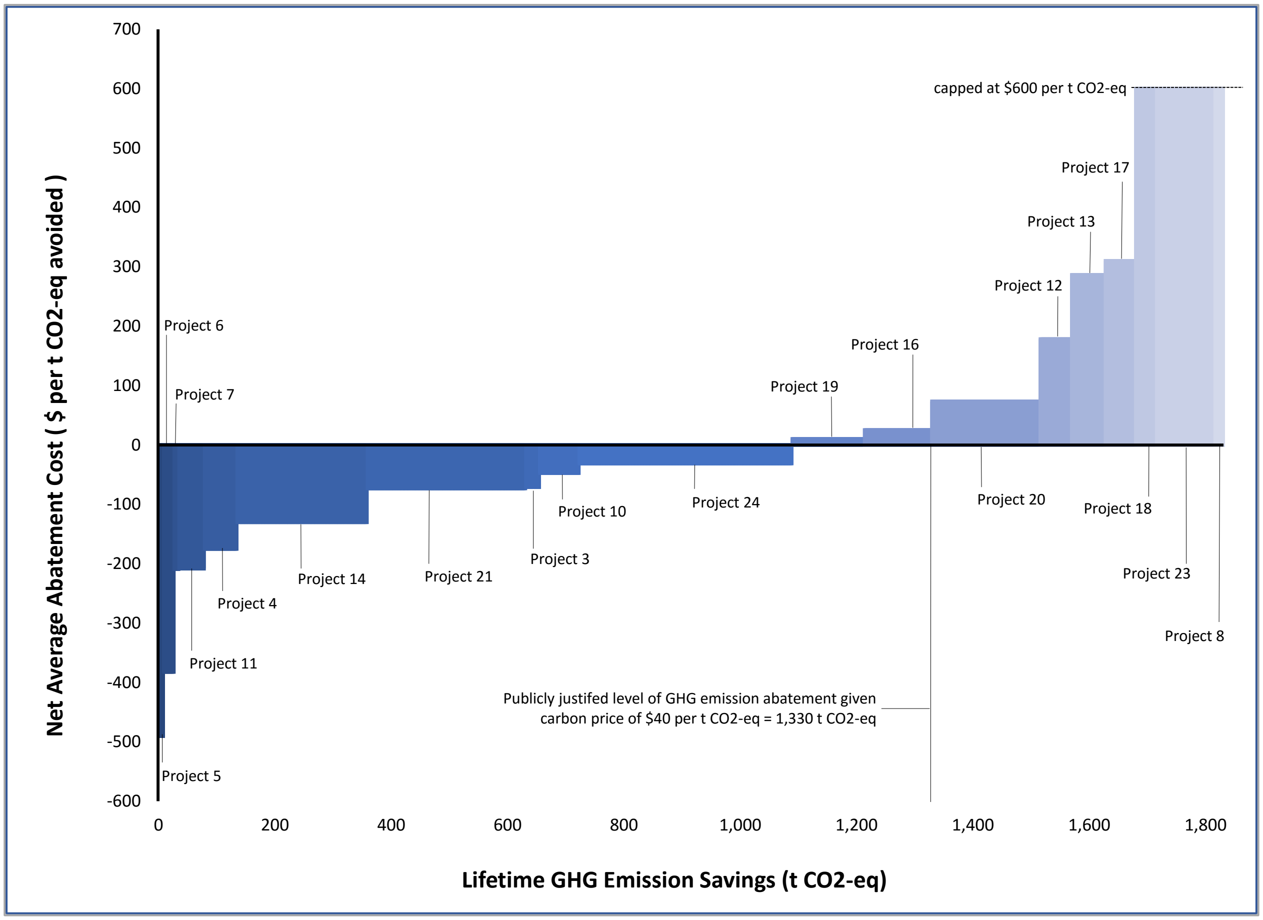
| Project ID | Description of energy efficiency and conservation measure | Benefit cost ratio | NPV Private ($) | NPV Public ($) | Operational cost savings | lifetime CO2-eq savings | Capital expenditure |
|---|---|---|---|---|---|---|---|
| 5 | Install low-flow faucet aerators in apartments as part of building refurbishment | 12.0 | 3,250.3 | 3,551.0 | 4,305.6 | 8.0 | 295.0 |
| 14 | Upgrade all windows to achieve R5. Increase window air tightness from CSA A1 to A2. | 8.4 | 16,489.2 | 23,470.4 | 35,578.8 | 221.8 | 2,235.0 |
| 6 | Install low-flow showerheads in apartments as part of building refurbishment | 4.6 | 6,057.3 | 6,775.6 | 9,376.3 | 19.0 | 1,664.0 |
| 11 | Replace existing electric clothes dryers with natural gas dryers as part of building refurbishment | 3.4 | 7,532.7 | 9,179.4 | 12,986.9 | 43.8 | 3,100.0 |
| 21 | Weather stripping and air sealing to increase building air tightness from 'loose' to 'average' (4.5 ACH @ 50 Pa) as part of building refurbishment | 2.2 | 13,227.3 | 22,470.3 | 38,437.5 | 273.6 | 11,066.0 |
| 4 | Upgrade lighting in apartments (full LED: "Lighting-Apart D" package). Retrofit with building refurbishment | 2.1 | 6,969.0 | 8,959.0 | 19,865.0 | 57.5 | 6,167.0 |
| 7 | Replace existing clothes washing machines with Energy Star qualified appliances as part of building refurbishment | 1.7 | 1,379.9 | 1,671.7 | 3,761.5 | 7.6 | 1,890.0 |
| 10 | Install programmable thermostats in apartments as part of building refurbishment | 1.6 | 2,485.9 | 4,973.2 | 8,295.7 | 68.0 | 3,900.0 |
| 3 | Upgrade lighting in common areas (T12 to T8, plus CFL to LED: "Lighting-Comm A" package). Retrofit with building refurbishment | 1.4 | 1,487.0 | 2,388.0 | 6,168.0 | 23.0 | 4,083.0 |
| 24 | Solar PV system, 72 panels with PTC rating of 221 W (15.9 kW installed capacity) | 1.1 | 6,686.7 | 18,259.4 | 118,069.7 | 366.1 | 55,650.0 |
| 19 | Upgrade hot water heaters from existing tanks to condensing units (improvement in efficiency = 30%) as part of building refurbishment | 0.9 | -928.0 | 3,502.1 | 16,658.3 | 126.5 | 12,450.0 |
| 16 | Upgrade all patio doors with Energy Star in-swing French Doors to achieve R 3.85 as part of building refurbishment | 0.9 | -1,638.3 | 1,938.7 | 18,229.6 | 113.6 | 11,232.0 |
| 20 | Replace existing boilers to higher efficiency condensing boilers (improvement in efficiency = 10%) as part of building refurbishment | 0.7 | -8,865.0 | -2,600.5 | 26,051.3 | 185.4 | 25,330.0 |
| 12 | Upgrade all East and West exterior walls to R25. 6" cellulose blown insulation (R19) + 1-1/2" unfaced fiberglass (R6) | 0.5 | -5,619.7 | -3,880.9 | 8,861.7 | 55.2 | 10,283.4 |
| 13 | Upgrade all exterior walls to R25. 6" cellulose blown insulation (R19) + 3" unfaced fiberglass (R12) | 0.3 | -9,395.7 | -7,586.1 | 9,222.1 | 57.5 | 14,249.1 |
| 17 | Upgrade parkade roof to R50 as part of building refurbishment with 6" expanded polystyrene (R25) | 0.3 | -9,341.0 | -7,679.8 | 8,465.7 | 52.8 | 13,796.3 |
| 8 | Replace existing refrigerator in apartments with Energy Star qualified appliances as part of building refurbishment | 0.2 | -17,637.1 | -17,123.5 | 4,185.5 | 13.9 | 20,904.0 |
| 18 | Upgrade ceiling roofs to R50 as part of building refurbishment with 5" expanded polystyrene (R20) | 0.1 | -19,545.0 | -18,389.4 | 5,889.7 | 36.7 | 22,644.6 |
| 23 | Solar, closed loop, add-on hot water system, 3/4" tubing, 54 77" x 39" panels (maximum for available roof space) | 0.1 | -65,096.2 | -61,957.3 | 15,996.9 | 99.7 | 73,515.0 |

## Figure 7: Defining a Portfolio of Energy Saving Measures that Maximizes NPV



A GHG abatement cost curve was constructed for Bankview 1 (depicted in Figure 8). This curve ranks (from lowest to highest) the candidate energy saving measures in terms of their average (net) costs in avoiding the emission of one t $CO_2$-eq. Net costs are defined as the present value (PV) lifetime costs less the present value (PV) lifetime utility bill savings. Hence, measures with a positive NPV (whereby PV lifetime utility bill savings > PV lifetime costs) will have a negative net abatement cost. An energy saving measure with a negative net abatement cost will produce a net resource saving for society for each t $CO_2$-eq avoided. Moving left-to-right along the curve, the cost-effectiveness of the measures in abating GHG emissions worsens. In the Financial Decision Support Tool energy saving measures with a net average abatement cost less than a carbon price of $40 per t $CO_2$-eq are judged to be cost-effective. Cost-effective lifetime GHG emission abatement at Bankview thus equates to about 1,330 t $CO_2$-eq. Note that this level of GHG emission reductions is delivered by the portfolio of energy saving measures that maximizes NPV from a public perspective (recall Figure 7).

Figure 8: Net Average GHG Abatement Cost for Bankview 1



The two portfolios of energy saving measures depicted in Figure 7 are constructed on the basis of modeling each measure one-at-a-time. The next step is therefore to iteratively model them as a collective portfolio of measures in the energy model and Financial Decision Support Tool. This provides a more accurate prediction of potential outcomes as interaction effects between measures are taken into account. Four portfolios of energy saving upgrades were constructed:

1. Low Carbon Case-Max (all measures listed in Table 8 regardless of the sign of their NPV);
2. Low Carbon Case-Private (all measures listed in Table 8 with a positive private-NPV);
3. Low Carbon Case-Public (all measures listed in Table 8 with a positive public-NPV); and
4. Low Carbon Case-Social (all measures listed in Table 8 with a BCR >= 0.7).

A summary of the modeled outcomes for each portfolio of measures is provided in Table 9. Although not shown in Table 9, it is worth noting that on an annual basis:

- GHG emissions under the Low Carbon Case-Max are 41 per cent below Reference Case levels and 44 per cent below Base Case levels;
- GHG emissions under the Low Carbon Case-Private are 26 per cent below Reference Case levels and 30 per cent below Base Case levels;
- GHG emissions under the Low Carbon Case-Public are 31 per cent below Reference Case levels and 34 per cent below Base Case levels; and
- GHG emissions under the Low Carbon Case-Social are 35 per cent below Reference Case levels and 38 per cent below Base Case levels.

### 4.1.7 Task 7: Make Recommendations

The final task is to formulate recommendations to reduce energy consumption and GHG emissions at the building on the basis of analysis performed during Task 6. The recommendations of the project team for Bankview 1 are outlined in Section 5.3.

# Table 9: Financial and Environmental Performance of Low Carbon Case Portfolios

| | | LCC-Max | LCC-Private | LCC-Public | LCC-Social |
|---|---|---|---|---|---|
| **Costs = Case outflows** | | | | | |
| Total net capital expenditure on upgrade | $ in year 0 | 434,899 | 159,493 | 197,229 | 237,757 |
| Present value total costs | $ | 434,899 | 159,493 | 197,229 | 237,757 |
| **Benefits = Case inflows** | | | | | |
| Energy savings | | | | | |
| Cumulative natural gas savings | GJ | 33,607 | 13,232 | 19,948 | 25,744 |
| Cumulative electricity savings | GJ | 7,978 | 7,531 | 7,531 | 7,531 |
| Cumulative total energy savings | GJ | 41,585 | 20,764 | 27,479 | 33,275 |
| Cumulative value of energy savings (undiscounted) | $ | 613,722 | 416,860 | 475,872 | 526,808 |
| Average annual value of total energy savings (undiscounted) | $ per year | 15,343 | 10,421 | 11,897 | 13,170 |
| Present value energy savings | $ | 309,736 | 214,462 | 242,764 | 267,192 |
| Water savings | | | | | |
| Cumulative value of water savings (undiscounted) | $ | 116,234 | 116,234 | 116,234 | 116,234 |
| Average annual value of total water savings (undiscounted) | $ per year | 2,906 | 2,906 | 2,906 | 2,906 |
| Present value water savings | $ | 52,232 | 52,232 | 52,232 | 52,232 |
| Operating cost (utility bill) savings | | | | | |
| Cumulative operating cost savings (undiscounted) | $ | 729,956 | 533,094 | 592,107 | 643,042 |
| Average annual operating cost savings (undiscounted) | $ per year | 18,249 | 13,327 | 14,803 | 16,076 |
| Present value operating cost savings | $ | 361,968 | 266,694 | 294,995 | 319,423 |
| Carbon savings | | | | | |
| Cumulative total GHG emission savings | t CO2-eq | 2,707.3 | 1,609.2 | 1,952.9 | 2,249.6 |
| Cumulative value of GHG emission savings (undiscounted) | $ | 165,054 | 97,067 | 118,400 | 136,813 |
| Average annual value of total GHG emission savings (undiscounted) | $ per year | 4,126 | 2,427 | 2,960 | 3,420 |
| Present value GHG emission savings | $ | 83,502 | 50,052 | 60,501 | 69,521 |
| Criteria air contaminant savings | | | | | |
| Cumulative nitrogen oxides (NOx) savings | kg NOx | 3,979.2 | 3,016.7 | 3,285.4 | 3,517.2 |
| Cumulative particulate matter (PM total) savings | kg PM | 313.6 | 236.9 | 258.4 | 276.9 |
| Cumulative sulphur dioxide (SO2) savings | kg SO2 | 3,600.1 | 3,393.1 | 3,395.1 | 3,396.8 |
| Cumulative volatile organic compounds (VOC) savings | kg VOC | 97.2 | 49.3 | 64.7 | 78.0 |
| **Economic evaluation criteria** | | | | | |
| Net Present Value (NPV) (private - excluding carbon value) | $ | - 72,931 | 107,201 | 97,766 | 81,666 |
| Net Present Value (NPV) (public - including carbon value) | $ | 10,571 | 157,253 | 158,267 | 151,187 |
| Return on Investment (ROI) (private - excluding carbon value) | % | -17% | 67% | 50% | 34% |
| Benefit-Cost Ratio (BCR) (private - excluding carbon value) | ratio | 0.8 | 1.7 | 1.5 | 1.3 |
| Simple Payback (SPB) | years | 23.8 | 12.0 | 13.3 | 14.8 |
| Cost of Energy Saved (CES) | $ per GJ | 19.59 | 14.39 | 13.44 | 13.38 |
| Marginal cost of abatement (including operating cost savings) | $ per t CO2-eq | 49 | - 119 | - 90 | - 66 |

# 5 RECOMMENDATIONS

## 5.1 IDENTIFYING A BALANCED PORTFOLIO

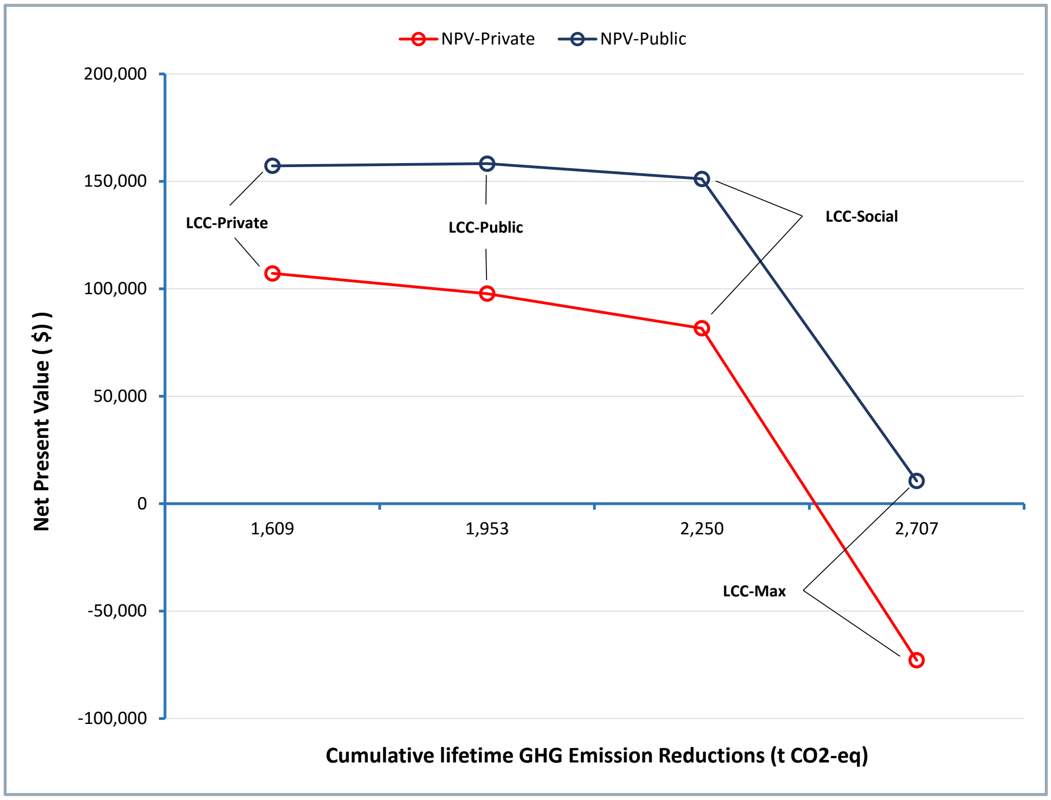
Working through the replicable analytical process outlined in the preceding section suggests that a significant amount of energy, water, GHG emissions, and emissions of Criteria Air Contaminants can be cost-effectively saved through energy efficiency improvements at Bankview 1. Four portfolios of energy saving measures were developed—the modeled financial and environmental outcomes of each portfolio are displayed in Table 9.

At one extreme, maximum lifetime GHG emission reductions amount to 2,710 t $CO_2$-eq (corresponding to lifetime energy savings of 41,590 GJ). This level of GHG emission abatement is achieved at a positive NPV for the public (at \$10,600), at a net average cost of \$49 per t $CO_2$-eq. However, from the perspective of the property owner, who does not directly benefit financially from reducing GHG emissions, the NPV associated with the required \$434,900 capital spend to realize this level of emission savings, is negative. Specifically, the property owner is worse off by \$72,950 in present value terms. At the other extreme, the NPV to the property owner is maximized under a portfolio of measures resulting in lifetime GHG emission reductions of 1,610 t $CO_2$-eq (corresponding to lifetime energy savings of 20,760 GJ). The same portfolio of measures generates a net public benefit of \$157,250 in present value terms. The other two portfolios of energy saving measures modeled lie between these two extremes.

To help identify a recommended set of energy saving measures for Bankview 1, the private and public NPV of each portfolio can be plotted against the corresponding level of lifetime GHG emission reductions (as shown in Figure 9). It is evident from the figure that moving from LLC-Social to LCC-Max offers diminishing (and costly) returns for greater GHG emission savings and levels of energy efficiency—both from a public and private perspective. Furthermore, in moving from LCC-Private to LCC-Public to LCC-Social, the public NPV changes only marginally; increasing ever so slightly from LCC-Private to LCC-Public, and falling by 4 per cent from LCC-Public to LCC-Social. In contrast, changes in the private NPV are more pronounced—falling by 8 per cent when moving from LCC-Private to LCC-Public and by 16 per cent when moving from LCC-Public to LCC-Social. **This suggests that the best portfolio—in terms of balancing NPV with lifetime GHG emission savings—is LCC-Public**.

Implementing the portfolio of measures contained in LCC-Public as opposed to LCC-Private will make the property owner worse off by \$9,435 in present value terms. However, an additional 344 t $CO_2$-eq are saved over the lifetime of the measures. At \$40 per t $CO_2$-eq the value of these additional GHG emission savings is \$13,750. A public policy-maker could therefore compensate the property owner for the loss in NPV (i.e., pay for the additional GHG emission savings), while leaving society better off overall.

Figure 9: Balancing NPV and GHG Emission Reductions



## 5.2 SENSITIVITY ANALYSIS OF RECOMMENDED PORTFOLIO

To highlight the effect of uncertainty around key input variables and assumptions included in the evaluation, sensitivity analysis is performed on the outcomes of each of the four portfolios of energy saving measures. Specifically, one-way sensitivity analysis is used to test the responsiveness of estimated NPVs (from a public perspective) to changes in each of the following key input variables:

- Variable electricity charges;
- The electricity charge (real) escalator;
- Variable natural gas charges;
- The natural gas charge (real) escalator;
- Variable water charges;
- The water charge (real) escalator;
- The shadow price of carbon (value attached to GHG emissions avoided);
- Capital expenditures on energy saving measures;

- The real annual discount rate;
- The GHG intensity of the Alberta grid by 2050; and
- Energy and water consumption under the LCC (note that the higher these values the lower the overall level of energy and water savings).

Ideally, a range of values is specified for each variable, which reflects realistic maximum or minimum values (usually derived from confidence intervals of the variable). However, in the absence of realistic maximum or minimum values, each variable is instead varied a uniform 30 per cent either side of the assumed 'central' value. With one-way sensitivity analysis, each variable is altered one at a time, and the resulting NPV recorded. For example, the total net capital expenditure for the LCC-Public portfolio of measures is first increased by 30 per cent (from a central estimate of $197,230 to $256,400) and subsequently decreased by 30 per cent (from $197,230 to $138,060). With each change in the value of the variable the re-estimated NPV is recorded so it may be compared with the initially estimated NPV (i.e., $158,265 shown in Table 9).

In reality, multiple variables will likely move simultaneously and not necessarily in the same direction. A weakness of one-way sensitivity analysis is that it does not examine the implications of two or more different variables changing simultaneously. Consequently, one-way sensitivity analysis may understate the true range of uncertainty in the NPVs reported in Table 9. To partially address this concern, the sensitivity of the estimated NPVs of each portfolio in Table 9 is also tested to simultaneous changes in the following groups of variables:

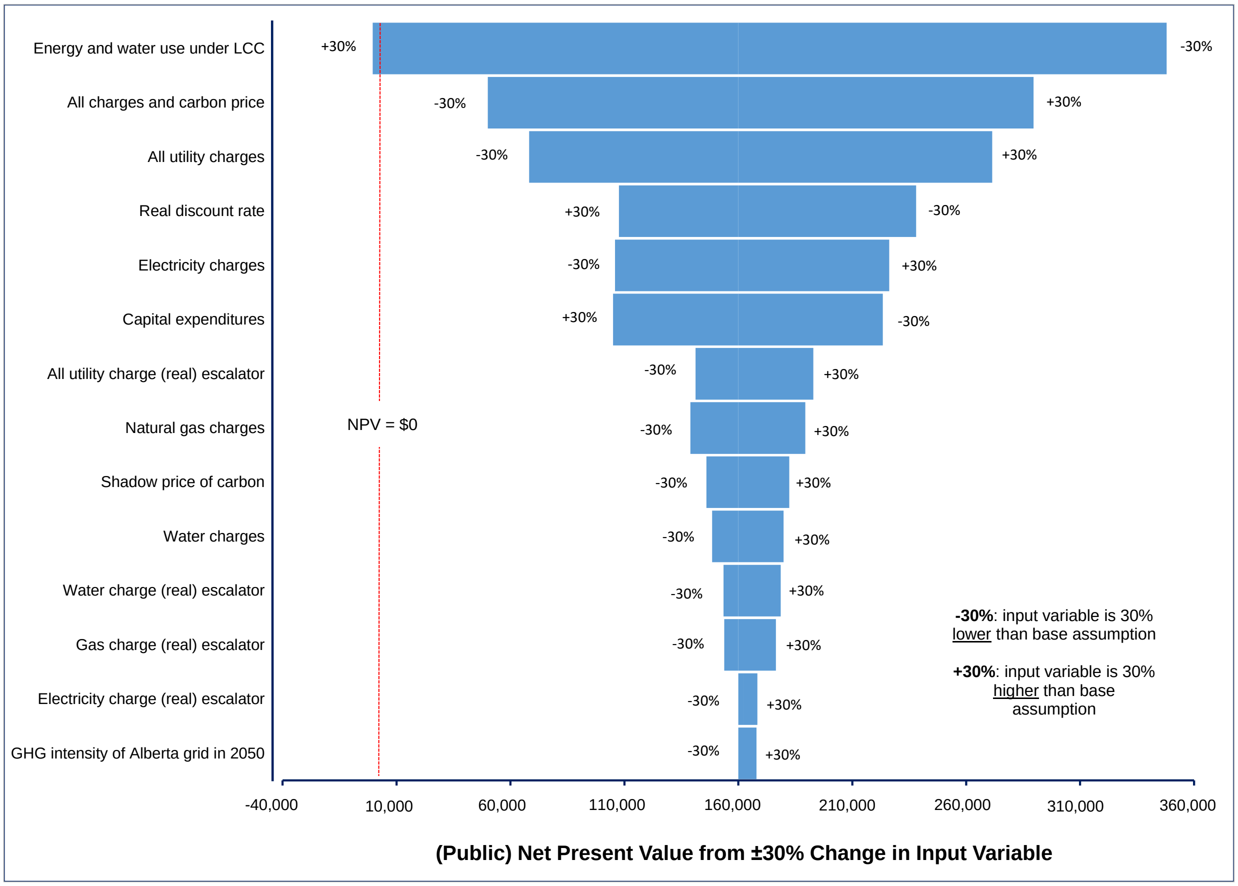
- All variable utility charges (i.e., natural gas, electricity and water);
- All utility charge (real) escalators; and
- All variable utility charges and the shadow price of carbon.

As it turned out, the sensitivity analysis did not affect the initial choice of LCC-Public as the recommended portfolio of energy saving measures. Hence, only the results for the LCC-Public portfolio are presented below, for the purpose of illustration.

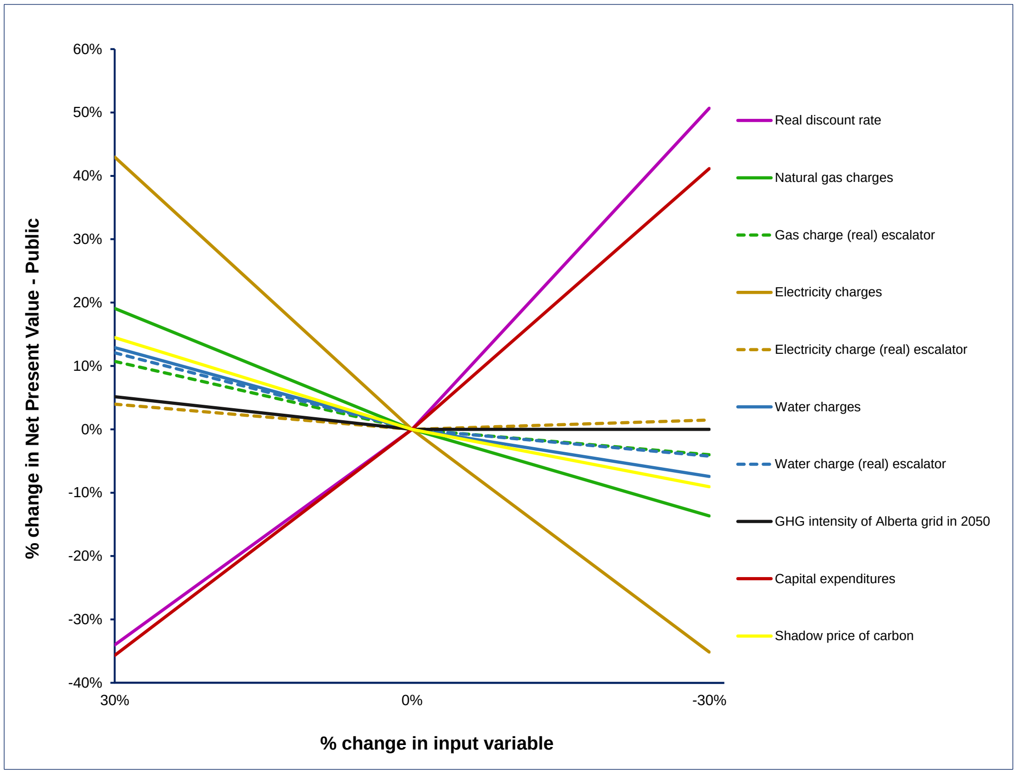
An established way of displaying the results of one-way sensitivity analysis is by using a tornado diagram. Tornado diagrams are a type of bar chart that displays how much impact varying an input assumption has on estimated NPVs. Figure 10 shows the tornado diagram constructed from the above sensitivity tests applied to the NPV of the LCC-Public portfolio. Each bar in the chart indicates the absolute variation of the NPV when each input assumption is changed (one at a time) by ±30 per cent from its central value. The variables are ranked so that the input assumption that causes the greatest absolute variation in the NPV is shown at the top; the input assumption that causes the second largest absolute variation in the NPV is ranked second; and so on. With all the variables arranged in descending order of impact on the NPV from top to bottom, it is clear why the chart is called a tornado diagram. Reading the tornado diagram is simple—big bars indicate input variables that have the greatest impact on the estimated NPV and thus need more attention; small bars indicate less crucial input variables. The results shown in Figure 10 suggest the most significant driver of the NPV is modeled energy and water use at Bankview 1 under the low carbon case. If actual energy and water use is 30 per cent higher than modeled for the low carbon case, the NPV will turn negative. It is therefore crucial that we are confident with the outputs of the energy model of Bankview 1. The next most noteworthy determinant of the NPV is simultaneous movements in all charges and the carbon price. The real discount rate, electricity charges and capital expenditures have a moderate impact on the NPV. Nonetheless, even estimation errors of 30 per cent for each of these variables do not result in a negative NPV. The least important assumptions relate to the assumed value for the GHG intensity of the electricity grid in Alberta and the escalators applied to energy and water charges.

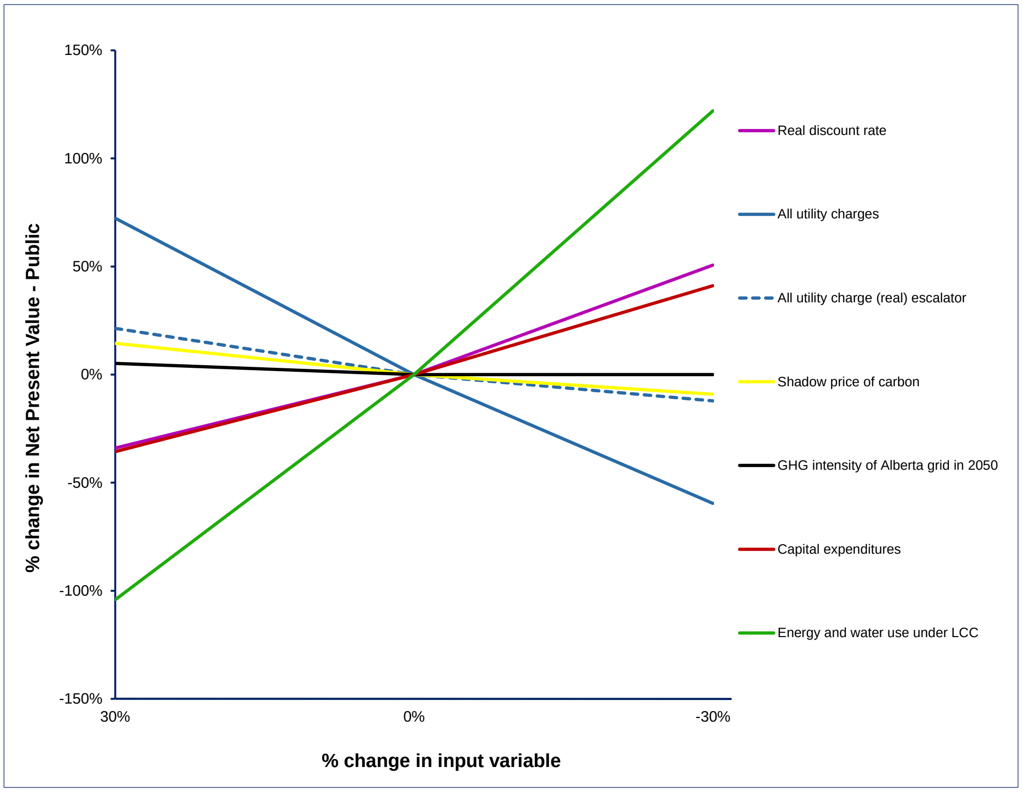
Another useful way to display the results of a one-way sensitivity analysis is by using a spider plot. Figure 11 contains spider plots constructed from the same sensitivity tests applied to the NPV of the LCC-Public portfolio. Each line shows the variation of the NPV to one input assumption. All lines cross at the central NPV value of $158,265 shown in Table 9. The lines are predominantly straight, suggesting that the relationship between each variable and the NPV is linear over the range of variation considered – i.e., ±30 per cent from central values. The direction of a line indicates whether the relationship between a variable and the NPV is positive or negative. For example, the solid purple line in the upper plot in Figure 11, which rises from left to right, indicates that the NPV decreases (increases) as the real discount rate increases (decreases) from its central value. In contrast, the solid brown line, which falls from left to right, indicates that the NPV decreases (increases) as electricity charges decrease (increase) from central values. The slope of a line indicates the sensitivity of the NPV to changes in an input assumption—the steeper the slope, the more sensitive the NPV is to variation in that variable. For instance, the green line in the lower plot representing energy and water use under the low carbon case has the greatest slope, so the NPV is most sensitive to outputs from the energy model of Bankview 1. It is least sensitive to changes in the assumed value for the GHG intensity of the electricity grid and the escalators applied to energy and water charges. These are the same conclusions drawn from the tornado diagram in Figure 10.

**Figure 10: Deterministic Tornado Diagram of Sensitivity Analysis for LCC-Public Portfolio**



## Figure 11: Spider Plots of Sensitivity Analysis for LCC-Public Portfolio





## 5.3 ENERGY SAVING MEASURES IN RECOMMENDED PORTFOLIO

The recommended portfolio of energy saving measures for Bankview 1 includes:

- Installing low-flow faucet aerators in in all apartments;
- Upgrading all windows to achieve R5 and increase window air tightness from CSA A1 to A2;
- Installing low-flow showerheads in all apartments;
- Replacing existing electric clothes dryers with natural gas dryers;
- Weather stripping and air sealing to increase building air tightness from 'loose' to 'average' (4.5 ACH @ 50 Pa);
- Upgrading lighting in apartments (full LED package);
- Replacing existing communal clothes washing machines with Energy Star qualified appliances;
- Installing programmable thermostats in all apartments;
- Upgrading lighting in common areas (T12 to T8, plus CFL to LED);
- Installing a solar PV system, 72 panels with PTC rating of 221 W (15.9 kW installed capacity);
- Upgrading hot water heaters from existing tanks to condensing units (seeking improvement in efficiency = 30%); and
- Upgrading all patio doors with Energy Star in-swing French Doors to achieve R 3.85.

The estimated incremental capital expenditure to implement all the above measures is $197,230. However, this expenditure will produce multiple benefits:

- Lifetime energy savings of 27,480 GJ (a reduction of about 28 per cent on the Reference Case);
- Average energy bill savings of about $11,900 per year;
- Average water bill savings of about $2,900 per year;
- Average total operating cost savings of about $14,800 per year;
- Lifetime GHG emission savings of 1,955 t $CO_2$-eq (a reduction of about 31 per cent on the Reference Case); and
- Lifetime reductions in emissions of $NO_x$, PM, and $SO_2$ of 3.3 t, 0.3t, and 3.4t, respectively.

The modeling was based on an assumed occupancy at Bankview 1 of 42 adults. Annual operating cost savings therefore amount to about $350 per resident, or $700 per household residing in one of the 16 2-bedroom rental units. To put these bill savings into context, some of which would directly accrue to residents[8], the poorest 20% of households in Alberta spend, on average:

- $1,470 per year on health care (the bill savings would thus pay for health care for 12 weeks);

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[8] In this case, about 30 per cent of the bill savings accrue directly to residents, with the remaining 70 per cent accruing to the CHC.

- $910 per year on education (the bill savings would thus pay for education for 20 weeks);
- $700 per year on public transport (the bill savings would thus pay for public transport for 26 weeks);
- $5,020 per year on food (the bill savings would thus pay for food for four weeks).

Looking at the bigger picture, Bankview 1 comprises 26 non-market rental units and is currently "of average efficiency" for its age. According to City of Calgary (2012) there are about 11,760 non-market rental units for low-income families and individuals in the city. About 72 per cent (about 8,470) of these units are roughly the same vintage as Bankview 1. If all buildings housing these units underwent a similar energy efficiency upgrade as part of a planned capital refurbishment program, the outcomes would be very significant:

- Lifetime energy savings of 8.9 PJ;
- Lifetime net benefits for low-income households of $51.6 million in present value terms;
- Average energy bill savings of about $3.9 million per year;
- Average water bill savings of about $0.9 million per year;
- Average total operating cost savings of about $4.8 million per year; and
- Lifetime GHG emission savings of 0.6 Mt $CO_2$-eq.

Clearly, a program of energy efficiency upgrades in low-income buildings at this scale would put a huge dent in energy poverty in Calgary, and generate significant 'win-win-wins' for poverty alleviation, health and well-being, and climate change mitigation.

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# 7 APPENDIX A: SOLAR PV AND WATER HEATING

The large, flat roof on the Bankview building lends itself to the installation of solar panels to provide either electricity (solar photovoltaic), or hot water (solar thermal). The number of panels that can be installed on the roof is limited by the geometry of the roof, and the need to avoid (or at least minimize) the panels shading each other.

It is desirable to have the panels face due south if they are fixed and do not rotate to track the sun. The panels are typically tilted to maximize exposure to the sun, and a good angle to choose is equal to the latitude of the city, which in Calgary is 51° N.

The separation distance between rows of panels can be determined by analyzing the sun path across the sky on the winter solstice (December 21st) which is the shortest day of the year. Shading is the enemy of solar projects. To get a good four hours of non-shading on each row of panels even on the shortest day of the year, the sun altitude and azimuthal angle (the angle measured from due north) must be determined from sun path charts such as the one for Calgary shown in Figure 12, with data from www.sunearthtools.com.

Figure 12 shows that at 10:00 am on the winter solstice in Calgary, the sun has an elevation of 8.12° and an azimuthal angle of 144.65°. The most common dimensions for both solar PV and solar hot water panels are 77-inches by 39-inches (very close to 2 m by 1 m). The roof on the Bankview building is roughly rectangular with dimensions of 31.8 m by 18.4 m. The width of the roof would allow a maximum of 18 panels in a row. The calculation of the minimum spacing between rows is explained below.

Figure 13 shows the rough size of the flat roof at Bankview 1—indicating the dimensions of the roof and the maximum number of solar panels that will fit in one row. Given that the flat roof width is 18.4 meters, and given the common area of both solar PV and solar thermal panels, a maximum of 18 panels will fit in one row.

To avoid rows of panels shading each other, the spacing between the rows of panels must be considered for the shortest day of the year. The position of the sun is used to determine the minimum spacing required as shown in Figure 14 and Figure 15.

The two equations that determine the minimum spacing, D, between rows of panels are:

$D' = h / \tan \alpha$, where $h = 2\text{meters} * \sin(51°)$, and

$D = D' \cos(180 - \psi)$.

In this case, at 10:00am on December 21st, the azimuthal angle is $\psi = 144.65°$ and the sun elevation is $\alpha = 8.12°$. The spacing between rows is rounded to D = 8 meters, which means that a maximum of 4 rows of solar panels can fit on the roof, giving a total of 72 individual panels.

Figure 12: Solar Disk Showing Summer Solstice Path (black), Winter Solstice Path (orange), and Analemma for Calgary

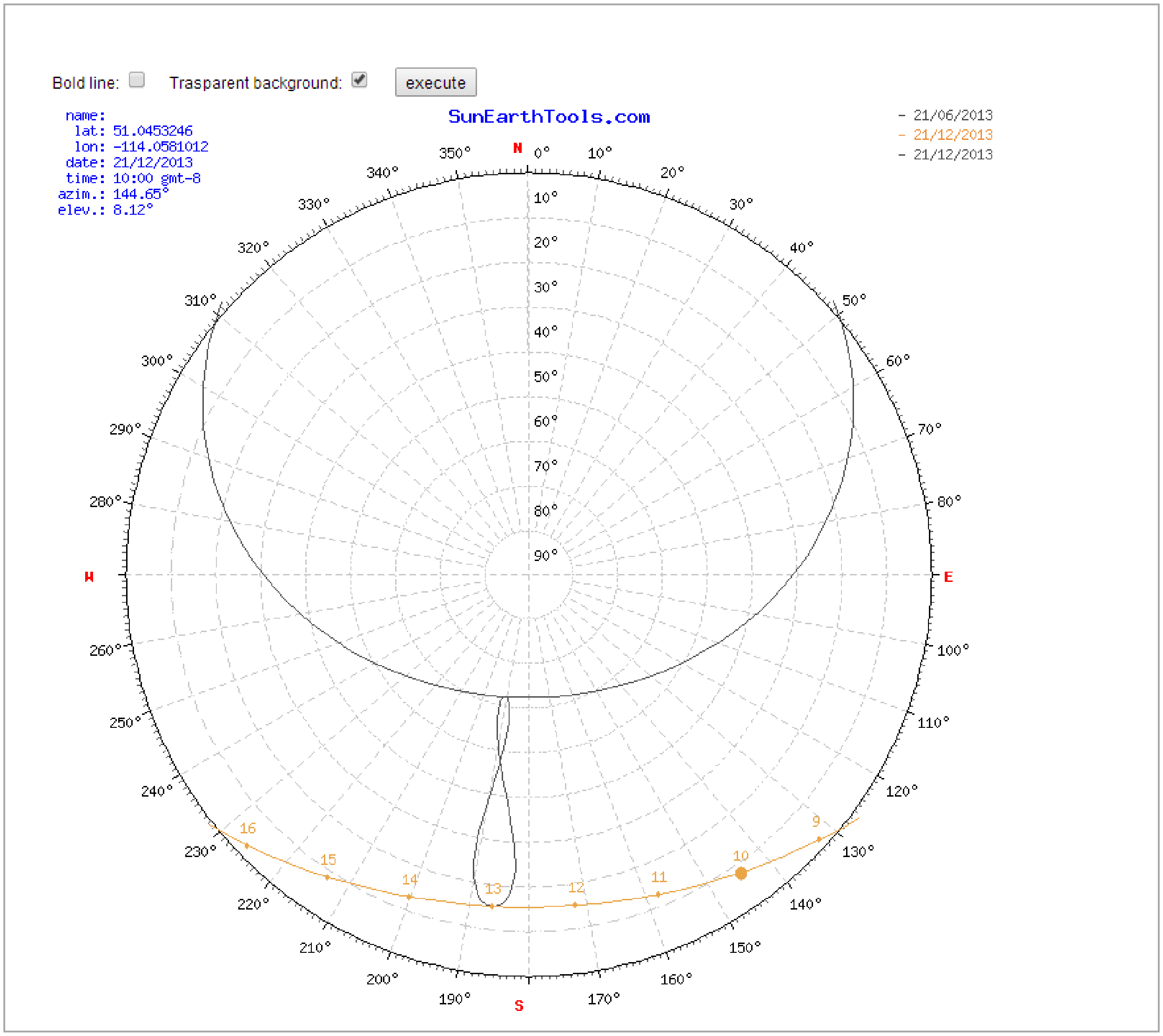

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Figure 13: Schematic of the Roof at Bankview 1

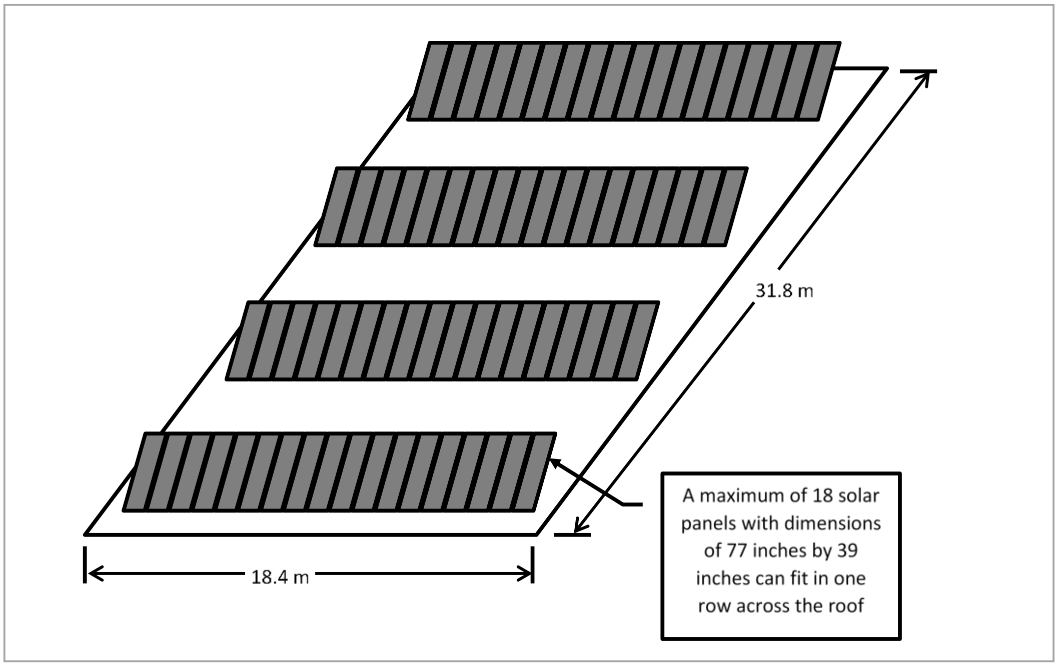


Figure 14: Side View of Two Rows of Solar Panels

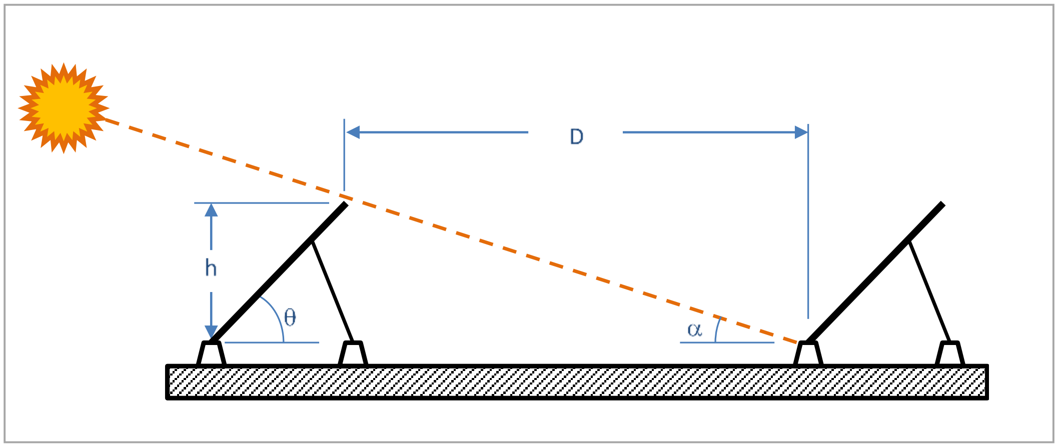
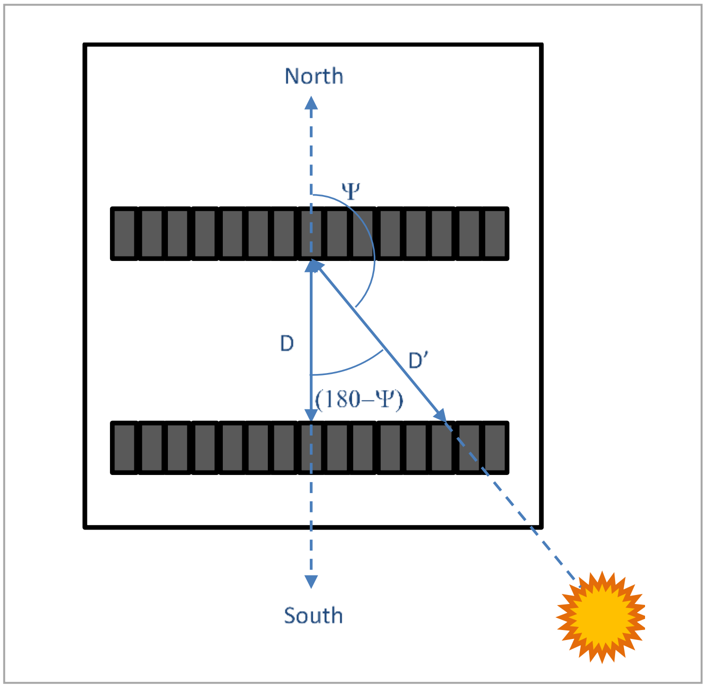


Figure 15: Side View of Two Rows of Solar Panels



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