REVIEW OF EFFECTIVENESS OF INVESTMENTS IN RENEWABLE ENERGY FOR SOCIAL AND AFFORDABLE HOUSING

Final Report

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Prepared for:

Evergreen

Prepared by:

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Sustainable Technologies Evaluation Program

NOTICE

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THE SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

The Sustainable Technologies Evaluation Program (STEP) is a multi-agency program, led by the Toronto and Region Conservation Authority (TRCA). The program helps to provide the data and analytical tools necessary to support broader implementation of sustainable technologies and practices within a Canadian context. The main program objectives are to:

- monitor and evaluate clean water, air and energy technologies;
- assess barriers and opportunities to implementing technologies;
- develop tools, guidelines and policies; and
- promote broader use of effective technologies through research, education and advocacy.

Technologies evaluated under STEP are not limited to physical products or devices; they may also include preventative measures, alternative urban site designs, and other innovative practices that help create more sustainable and livable communities.

ACKNOWLEDGEMENTS

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- Canada Mortgage and Housing Corporation
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LIST OF ACRONYMS

AHP	Affordable Housing Program
ASHRAE	American Society of Heating, Refrigeration and Air-conditioning Engineers
ASHPWH	air-source heat pump water heater
BAS	building automation system
CBA	cost-benefit analysis
CCAP	Climate Change Action Plan
CDFI	community development financial institutions
CGB	Connecticut Green Bank
CIC	community investment corporation
CMVP	Certified Measurement and Verification Professional
COP	coefficient of performance
CSI	California Solar Initiative
DG	distributed generation
DHA	Denver Housing Authority
DOE	U.S. Department of Energy
ECM	energy conservation measure
EF	emission factor
EER	energy efficiency ratio
EPBD	Energy Performance of Buildings Directive
EPC	energy performance contracting
ESCO	energy service companies
EU	European Union
EVO	Efficiency Valuation Organization
FIT	Feed-In Tariff

FHP	Fair Hydro Plan
FRESH	Financing Energy Refurbishment in Social Housing program
FTE	full-time equivalent
GDP	gross domestic product
GHG	greenhouse gas
GHX	ground heat exchanger
HHV	higher heating value
IEA	International Energy Agency
IESO	Independent Electricity System Operator
IPCC	International Panel on Climate Change
IPMVP	International Performance Measurement and Verification Protocol
ITC	investment tax credits
kWh	kilowatt hour
kW_p	peak power rating
LCA	lifecycle analysis
LDC	local distribution company
LED	light emitting diode
LIC	local improvement charge
M&V	measurement and verification
MASH	Multi-Family Affordable Homes program
MH	Manitoba Hydro
MHO	Ministry of Housing, Ontario
NAICS	North American Industry Classification System
NEMVP	North American Energy Measurement & Verification Protocols
NGO	non-governmental organization
NIR	National Inventory Report

NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
OBF	on-bill financing
OCC	Ontario Climate Consortium
OESP	Ontario Electricity Support Program
OPA	Ontario Power Authority (OPA merged with Independent Electricity System Operator (IESO) on Jan. 1, 2015)
PACE	Property Assessed Clean Energy
PIF	project information form
PV	photovoltaic
RE	renewable energy
REI	Renewable Energy Initiative
RESHAPE	Retrofitting Social Housing and Active Preparation for EPBD
RESOP	Renewable Energy Standard Offer Program
ROI	return on investment
ROSH	Retrofitting of Social Housing Program
SAM	System Advisor Model
SASH	Single Family Affordable Homes Program
SEED	STEM, Energy and Economic Development Program
SEER	seasonal energy efficiency ratio
SHRRP	Social Housing Renovation and Retrofit Program
STEP	Sustainable Technology Evaluation Program
TRCA	Toronto and Region Conservation Authority
TREES	Training for Renovated Energy Efficient Social Housing Program
UK	United Kingdom
UNFCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

Background and objectives

With the government of Ontario looking to rapidly scale-up low carbon investment in the social and affordable housing sector as part of the Climate Change Action Plan, the question of how to structure investment programs to deliver the most impact in terms of greenhouse gas (GHG) reductions and operating cost savings for housing providers is paramount. In order to develop insights on sector capacity for implementing low carbon investments, an evaluation of the Renewable Energy Initiative (REI) was sponsored by the Ontario Ministry of Municipal Affairs (MMA) and Ministry of Housing (MHO), Canada Mortgage and Housing Corporation (CMHC), and Natural Resources Canada's Program for Energy Research and Development. Launched in 2010 as part of a comprehensive economic stimulus program targeting Ontario's social and affordable housing sector, the REI disbursed approximately 57M$ in provincial and federal funding to 161 different social and affordable housing providers for the installation renewable energy (RE) systems, including: solar photovoltaics (PV), solar domestic hot water (SDHW), solar air heating, geothermal and wind turbines[1]. Housing providers from all service *regions* across the province participated in the REI, but providers from 14 of 47 service *areas* did not participate.

This report, prepared by the Toronto and Region Conservation Authority (TRCA) and Ontario Climate Consortium (OCC) in partnership with Evergreen, evaluates the social, economic and environmental outcomes of investments in the REI program and provides insights on preferred investment strategies to scale-up investment supporting the transition to net-zero communities in line with provincial and federal government GHG reduction commitments to the global community. The research incorporated a cross-jurisdictional review, 31 formal interviews and 27 informal conversations with key REI stakeholders (including housing providers, service managers, vendors and administrators), 19 completed surveys from housing providers that received REI funding, 17 site visits to REI funded RE systems, 10 case studies as well as a technical, financial, GHG and economic analyses. Benefits of the REI program were evaluated based on its effectiveness in achieving social, economic and environmental outcomes for social and affordable housing providers. Implementation challenges and lessons learned were also documented.

Findings

Overall provider experience of the REI program

During interviews and surveys, the majority of housing providers responded positively when asked about their experience with the REI program and felt that the installed systems were a success. Most reported minimal barriers to participation or program administration issues, aside from tight application timelines and issues connecting projects to the electricity grid. Though Local Distribution Companies are generally required to help customers connect to their network in a timely and efficient manner, connection of projects is subject to technical and safety limits. At times, a new connection

[1] The total amount of funding allocated under REI was 75M$ – with 65M$ to SHRRP funded projects and 6.9M$ to AHP projects. The final amount spent on SHRPP-funded REI projects was approximately 57M$. This report focuses on the final amount spent on SHRRP funded projects only.

can require an upgrade of the network, delaying connections. It may be uneconomic for projects to connect to the grid in certain areas. Solar domestic hot water (SDHW) systems were highlighted by some providers as having poor returns when offsetting natural gas.

Energy, cost and carbon savings

Key impacts of the REI are quantified in Table 1. The majority of funded systems were PV because it had the strongest financial performance due to the Feed-In Tariff (FIT) program, which paid a guaranteed, fixed-term price designed to recover costs plus a reasonable rate of return for grid-connected PV electricity. The financial performance of the remaining systems depended on the fuel that the systems were offsetting. Financial performance of solar air or geothermal was strong when compared with electric resistance heating, with net lifetime benefits outweighing system costs by a factor of three, approximately. However, estimated lifetime benefits were less then system costs when the systems are offsetting natural gas, due to low gas costs. SDHW was estimated to produce net lifetime benefits much lower than total system first costs regardless of the fuel being offset. GHG savings were much higher for systems that offset gas.

Table 1. Results from technical, financial, GHG and socio-economic analyses.

	Funding [M$]	# of systems funded	Energy generated or saved [GWh]	Net lifetime benefits for housing providers [M$][2]	GHG savings [kt CO_2e]	Full-time equivalent job creation
PV	39.1	255	132	62.2	6.6	411
SDHW	12.1	80	40	2.4 –3.3	6.9	128
Solar Air	3.7	17	65	3.9 –5.2	11.1	39
Geothermal	2.5	9	34	1.3 –2.3	7.2	26
Wind[3]	0.0	1	0	0.0	0.0	0
Totals	**57.4**	**362**	**271**	**69.8 – 73.0**	**31.8**	**604**

Economic returns within Ontario

Based on input-output analysis, the REI program was estimated to have generated as much as 62M$ of additional Gross Domestic Production (GDP) in Ontario. This additional production would have required as many as 604 Full-Time-Equivalent (FTE) jobs in Ontario, earning up to nearly 37M$ in labour income. An additional 3.2M$ in indirect tax revenue was likely earned in Ontario.

Program administration and guidelines

All stakeholders groups highlighted the REI's program timelines as a barrier. This likely limited participation to parts of the sector with higher human resource capacity at the service manager and

[2] Note that these values assume that systems are offsetting a mix of 20% electricity and 80% natural gas. Furthermore, these values are estimates that pertain *to the REI program*. Great care should be taken when drawing conclusions about system performance outside of the REI. For example, PV system financial performance is based on FIT/microFIT rates that are no longer available; a performance de-rate was applied to SDHW energy generation based on site visit observations, and some system costs may have been higher in the REI than in the private sector.

[3] Note that a small amount of funding was disbursed to one provider for engineering and feasibility studies concerning a wind turbine installation but the provider did not proceed on to the actual installation of the wind turbine.

housing provider level, as is the case in more urban areas. Lack of knowledge about potential benefits was a barrier to participation and resulted in low uptake in some service areas. Evaluation of program participation data showed that providers in more rural and remote areas used less of their total allocated funding than their urban counterparts.

Renewable Energy Technology (RET) Vendor list

The REI program required housing providers to select from a list of vendors that met certain eligibility criteria. The Renewable Energy Technology Supplier (RET) Vendor List was administered by the Ontario Power Authority (OPA). Any vendor who met a set of eligibility criteria and who applied through a dedicated website was included on the RET Vendor List. In some service manager areas outside of the Greater Toronto Area (GTA), there were very few vendors who met the eligibility criteria and applied to be included on the RET Vendor List. This may have limited the pool of available vendors that could respond to the REI procurement process.

Feasibility studies and business cases

The REI program did not place any limitations or criterion on the format and content of feasibility studies or business cases used to inform technology selection and suitability for REI program participants. Feasibility studies and business cases provided by the MHO to review for this evaluation differed in terms of format, evaluation tools, breadth and content.

System cost and design

Proposed system costs did not appear to be benchmarked against industry norms, potentially creating incentives to overpay for systems. Some housing providers noted that they were concerned about unanticipated future costs. There were some reports, specifically with SDHW, that systems and/or certain components were oversized or otherwise not optimally designed.

Utility connections

Several providers encountered issues connecting their projects to the grid. In some cases, local utilities could not connect PV systems (sometimes after the system had been installed) because of technical grid capacity constraints and the systems either did not go ahead or were moved to another site.

Operation and maintenance

PV and solar air were reported to require minimal operation and maintenance (O&M) effort. Geothermal systems typically require less O&M effort than conventional systems although some providers still opted for a maintenance contract. SDHW systems were identified by providers as requiring the most O&M, and failures or sub-optimal operation related to design or insufficient O&M were identified in several instances. Many providers paid up-front for a maintenance contract. In several cases, this had poor results with vendors going out of business or providing poor service.

Measurement and verification

PV systems were often installed with an online monitoring gateway. The REI program did not require measurement and verification (M&V) and the large majority of non-PV systems did not incorporate M&V. The lack of M&V and an M&V plan meant that some systems could fail with minimal indications of failure and ultimately, fall short of expectations.

Impact on tenants

Interviewees reported that income generated from FIT contracts was used to supplement capital or operating budgets. This was stated to have indirect positive benefits for tenants.

Program evaluation

The evaluation of the program was initiated several years after the program roll out and was not integrated into the program design itself. This contributed to difficulties collecting important data and information needed to conduct a comprehensive evaluation of program effectiveness.

Future program considerations

- **Administration, documentation and record keeping.** Longer timelines would be beneficial for promoting program uptake in certain service manager areas with capacity issues. Additional program requirements for record keeping on key information would improve accountability and facilitate accurate evaluation of program benefits.
- **Feasibility studies and business cases.** Guidance or a template for feasibility studies would help ensure consistency across studies performed by different consultants. It would aid service managers and housing providers, and help inform the program evaluation.
- **Measurement and verification**. M&V should be mandated in future programs. Widely used protocols exist and it should performed by a qualified professional according to an M&V plan.
- **Technology selection.** Up-front vetting of systems would identify systems at a risk of providing poor savings and additional guidance would help ensure that providers are well matched to chosen technologies. RE technologies should be considered alongside other retrofit options to achieve maximum GHG and financial impact. Additional RE emerging technologies, like air-source heat pumps, warrant consideration as well.
- **Funding.** For 100% capital cost subsidies, it is advisable to compare proposed system costs against industry benchmarks to ensure efficient use of funds. Additional administration and follow-up after systems have been installed would help improve accountability.
- **Vendors.** In rural areas, greater flexibility in selecting vendors would help promote uptake.
- **Operation and maintenance.** Additional guidance and training would help housing providers operate and maintain their retrofits effectively. This would need to address the challenge of staff turnover. Maintenance contracts that are 100% paid up-front should be avoided.
- **Program evaluation.** A program evaluation could be improved by incorporating it into the program itself, collecting important data as the program is rolled out. During program design, it is advisable to formulate clear metrics for program success.
- **Sector-wide capacity building.** A more comprehensive and concerted effort to address the full suite of barriers facing service managers and housing providers is needed. This research has developed a generic energy portfolio management framework, summarized in Figure 1, modeled after the MHO's Strategic Asset Management Framework[4]. It is a long-term strategic approach to encourage adoption of energy efficiency and RE measures by reducing barriers at

[4] Ontario Ministry of Housing. (2014). *Revitalizing and refinancing social housing: how do you get there?* Retrieved from: http://www.mah.gov.on.ca/AssetFactory.aspx?did=10648

each stage of the retrofit journey through targeted and systematic intervention.

- **Preferred investment strategies.** Eight strategies were evaluated for scaling-up low carbon investment strategies in the social and affordable housing sector, aside from the one-time capital-cost subsidies used in the REI. The results indicate that energy performance contracting (EPC), where a third party provides the capital and receives some of the savings for a retrofit, merits deeper consideration. EPC markets are relatively mature for the commercial, industrial and large building sector in Ontario, and expanding their reach to social and affordable housing may be key to unlocking massive energy savings and GHG reductions in the sector.

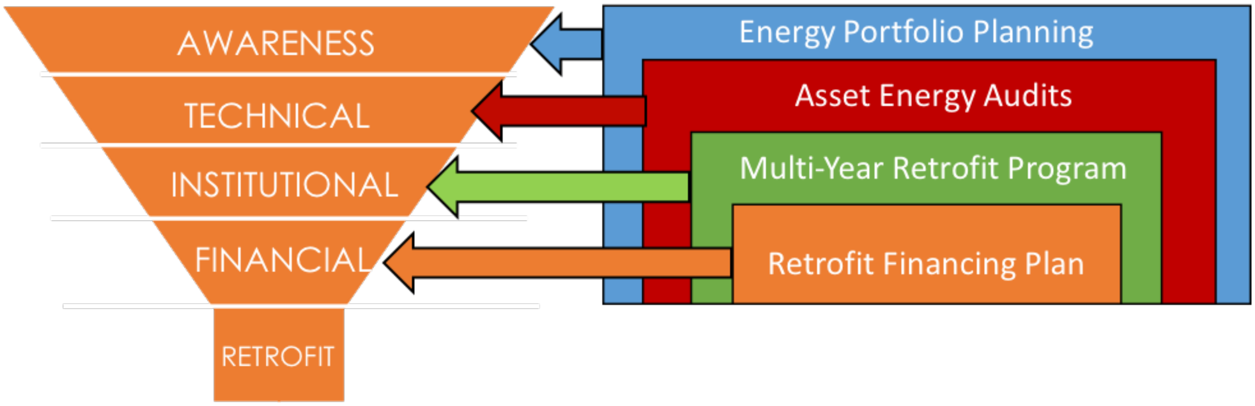

Figure 1. Comprehensive program approach to addressing social and affordable housing sector barriers.

Future work

Framework for management of emissions and energy in service manager housing portfolios

To take advantage of new funding opportunities, there is a strategic need for a practical guidance document and/or framework for service managers on how to (i) develop energy and emissions performance inventories for their building portfolios, (ii) identify and prioritize their efforts on a portfolio-wide basis, and (iii) develop energy conservation and GHG emissions reduction targets, and integrate those into the development of 10-year Local Housing and Homelessness Plans that reflect certain principles or "interests" that the government of Ontario has prescribed in addition to considering and responding to local needs.

Pre-built M&V hardware packages and centralized online monitoring portal

To encourage and facilitate M&V, an ideal solution may be to develop and incorporate pre-built, web-enabled hardware packages to be deployed with every retrofit that would communicate to a single online monitoring portal, accessible to both housing providers and program evaluators. This would reduce costs, simplify data collection and address the capacity gap that currently exists in the sector surrounding M&V activities.

Online training materials to support O&M of RE and energy efficiency retrofits

There is a capacity gap in terms of the O&M of energy retrofits in the sector and future programs should incorporate guidance and training for program participants. A cost-effective option is to create online training materials that housing providers can review at their own convenience.

Decision-making support tool for providers and service managers considering energy retrofits

While social and affordable housing providers often have a general desire to increase the environmental sustainability and energy efficiency of their housing portfolio, they are often unsure of their options and the steps necessary to evaluate those options. A decision-making support tool that helps prioritize the benefits and suitability of a wide range of options based on user inputs would help housing providers move toward an energy retrofit.

TABLE OF CONTENTS

1 INTRODUCTION, OBJECTIVES AND METHODOLOGY

1.1 Renewable Energy Initiative – an overview

As a part of the 2009 *Canada's Economic Action Plan,* the federal government allocated $352 million to the Province of Ontario to renovate and retrofit the existing social and affordable housing stock in the province. The Province matched federal funding, creating a total funding pool of approximately $700 million and forming the *Social Housing Renovation and Retrofit Program* (SHRRP). The aim of the SHRRP was to improve the quality of the housing stock, while helping low-income Canadians and creating opportunities for jobs in construction and related industries.

The Province signed administration agreements with each of the 47 service managers in Ontario, comprised of 37 Consolidated Municipal Service Managers and 10 District Social Services Administration Boards, which set the framework for the administration of SHRRP. Distribution of SHRRP funding was governed by provincial funding agreements on a project-by-project basis between the service manager and the Ministry of Housing (MHO), and in turn, by municipal funding agreements between the service manager and the housing providers. The municipal funding agreement identified the terms and conditions upon which funding were provided, including that the housing provider will remain a social and affordable housing provider for at least 20 years.

The Renewable Energy Initiative (REI) was created as a $70 million sub-component of the SHRRP program and the Canada-Ontario Affordable Housing Program (AHP)[5] to target investment in renewable energy (RE) technologies in Ontario's social and affordable sector. It generally operated in accordance with the overall program guidelines for SHRRP described above. As a one-time, 100% capital cost subsidy, the REI program assisted SHRRP-funded work by further improving energy efficiency in social and affordable housing projects through funding for one of five approved technologies:

1. solar photovoltaics (PV);
2. solar domestic hot water (SDHW) heating;
3. solar air heating;
4. geothermal; and
5. wind turbines.

The REI Program required that vendors for REI funded systems be selected from an approved vendor list administered by the Ontario Power Authority (OPA)[6] for facilitating the REI program. Any vendor who met a set of eligibility criteria and who applied through a dedicated website was included on the RET Vendor List. According to program documents and interviews with service managers and

[5] The total amount of funded allocated under REI was 75M$ – with 65M$ to SHRRP-funded projects and 6.9M$ to AHP projects. The final amount spent on SHRPP-funded REI projects was approximately 57M$. This report focuses on the final amount spent on SHRRP funded projects only. AHP funded projects were not included in this analysis.

[6] Note that the OPA merged with Independent Electricity System Operator (IESO) on Jan. 1, 2015.

program administrators, allocation of funding to service managers was based on a first-come first-served basis, with consideration of regional fairness across the province on the basis of a notional "fair allocation" to each service manager in relation to the number of social and affordable units within a given regional portfolio.

Eligible costs associated with the REI project included:

- purchase and installation of RE products from the RET Vendor List;
- professional services to provide building condition assessments and energy efficiency audits to guide the purchase of the most appropriate technology;
- project design fees (e.g. architect, engineers), preparation of tender documents, charges and fees required for municipal approvals (e.g. building permit fees);
- fees paid to installers of the approved technologies;
- operation and maintenance contracts; and
- additional service warranties if available.

Individual housing providers were required to submit business cases, or feasibility studies, to the service manager in their region. Service managers were responsible for evaluating business cases received, and preparing a recommended priority list of projects for funding within their region. Service managers were to use 'normal criteria' when reviewing and approving the individual projects, as was used in the SHRPP funded projects[7]. These criteria included:

- project scope and technology chosen based on the recommendation of a qualified consultant;
- estimated project costs;
- impact on operating costs, and where available, expected financial criteria (payback, ROI);
- modifications required to existing building; and
- a plan to mitigate impact on tenants.

Service managers were also directed that it was important that the "effectiveness and efficiency of RE projects are based on the circumstances of individual sites…" and based on recommendations from qualified consultants that have conducted a thorough feasibility study based on a building energy audit of the subject building. The MHO did not place limitations on service managers as to what criteria they should use to prioritize projects within their regional portfolio.

The program started allocating funding in 2010, and the final projects were completed by the end of 2012. There were 362 unique projects across the province that received funding under the REI. The vast majority of approved projects were for PV installations. This was largely due to the concurrent delivery of the Feed-In-Tariff (FIT) and microFIT Programs. Administered by the OPA, these programs allowed eligible RE generators to sell electrical power back to the grid over a 20-year contract period.

[7] Renewable Energy Initiative – SHRRP and AHP New Rental Housing Extension 2009 Information Package. February 2010. Ministry of Municipal Affairs and Housing.

The guaranteed, fixed-term FIT price was designed to recover costs plus a reasonable rate of return, providing an annual revenue stream.

REI projects that applied for a FIT or microFIT contract were subject to the same standardized processes, timelines and requirements as any other FIT or microFIT developer. These requirements included obtaining connection agreements, as well as constructing and maintaining the project. An overview of the administrative process is depicted in Figure 1-1.

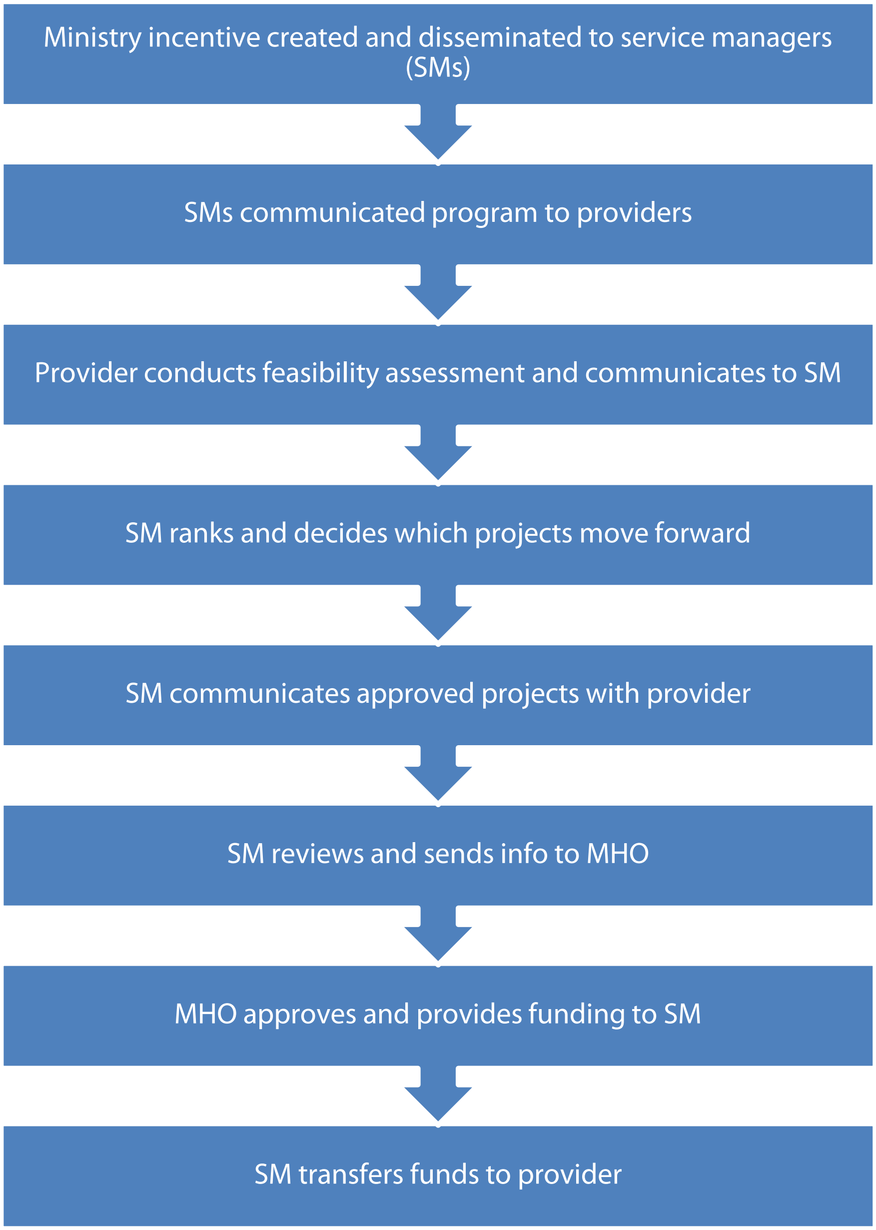

Figure 1-1. Overview of REI administrative process.

1.2 Research objectives

The project team in consultation with the project sponsors, the Ontario Ministry of Municipal Affairs (MMA) and MHO, determined the scope of the evaluation, and identified research objectives and questions to be answered through a quantitative and qualitative analysis of existing data and data collected through the course of the evaluation. For each component of the study, specific inputs or data sources, analyses of collected data, and anticipated results or outputs from the analyses were identified. Methodologies were outlined and developed for each component of the evaluation: technical, environmental impact (GHG), financial, socio-economic, and qualitative.

The overall objective of this research project was to quantify the benefit of investments in the REI program by evaluating their effectiveness in achieving social, economic and environmental outcomes for social and affordable housing projects and the Province of Ontario, while documenting insights on project implementation and provider experience. Specific research objectives include:

- evaluating the impact of REI program investments on greenhouse gas (GHG) emissions, building energy consumption, operating costs and the economy;
- assessing
    a. the technical strengths and weaknesses of the different technologies;
    b. challenges related to operation and maintenance and longer term lifecycle costs; and
    c. benefits in relation to the particular contexts of social and affordable housing projects;
- identifying the factors that contribute to project success and how these successes may be fostered through project planning and implementation;
- assessing challenges experienced in project procurement, implementation and operation of the facilities, and identifying strategies for addressing these challenges on future RE projects; and
- identifying preferred investment strategies and policy responses in relation to different social and affordable housing providers – public, private non-profit and community.

This research provides insights on the structure of future programs and informs ongoing and future initiatives aimed at reducing GHG emissions, energy consumption and energy costs in the social and affordable housing sector, as well as other residential stakeholders, for example private rental owners or condominiums.

1.3 Methodology

This report is based on research undertaken by the project team from May 2016 to February 2017. The research for this project was carried out through:

- detailed review of REI program documents, and program data provided by the MHO;
- review of Ontario's social and affordable housing, municipal, and climate change policy frameworks;
- a literature review and inter-jurisdictional scan;

- an online survey of housing providers;
- in-depth interviews and informal conversations with service managers and social and affordable housing providers;
- site visits to REI-funded installations;
- economic input-output analysis;
- technical analysis of estimated energy generation or savings, including the collection of performance data from REI-funded systems owners where possible;
- financial analysis of estimated revenues generated, and costs avoided;
- estimated GHG reductions; and
- case studies (consisting of data compiled from surveys, interviews and site visits).

Methodologies are summarized below with more detail provided in the corresponding sections of this report.

1.4 Detailed review of REI program documents, and program data provided by the MHO

Relevant program documents relating to the SHRRP and REI program were reviewed. The list of documents reviewed includes:

- REI Program Guidelines, distributed to service managers and housing providers (dated February 2010),
- OPA Renewable Energy Technology (RET) Vendor List; and
- Project Information Forms (PIF) submitted by housing providers given conditional approval for REI investment.

A detailed review of REI project data provided by the MHO was also conducted. This data served as the basis for contacting service managers and housing providers via survey and interviews.

1.5 Review of Ontario's social and affordable, municipal, and climate change policy frameworks

A review of Ontario's policy framework governing social and affordable housing, as well as the municipal and climate change policy frameworks was conducted. The team reviewed the following key pieces of provincial policy:

- Ontario Long-Term Affordable Housing Strategy (both current and proposed update);
- Ontario Housing Policy Statement;
- Ontario Housing Services Act, 2011;
- Ontario Municipal Act, 2011 and City of Toronto Act, 2006;
- Ontario Climate Mitigation and Low Carbon Economy Act, 2016; and
- Ontario Climate Change Action Plan (2016-2020).

1.6 Literature review and inter-jurisdictional scan

Through a desktop study of documents and literature from academic and non-academic sources (e.g. academic journals, industry reports, conference presentations, economic outlook information, grey literature, etc.) the team comprehensively examined the current state of knowledge relating to social and affordable housing and low carbon energy transitions (inclusive of energy efficiency and renewable energy). The focus of this review was to explore experiences in other jurisdictions with energy policy and programs focused on the social and affordable housing sector to identify transferable lessons for the Ontario context. The team looked at a wide range of literature, media articles, research reports and government policies and programs – with a focus on jurisdictions in the United States (US), and European Union (EU) countries.

1.7 Overview of data collection from housing providers

The approach to collecting provider feedback started with initial e-mail blasts to (i) determine which provider e-mails in the list supplied by MHO were current and (ii) gauge interest in participation in the study. In roughly equal parts, provider e-mails were either missing, bounced back, did not respond or responded with interest to participate. Starting with those that responded to the initial e-mail blast, providers were then contacted via phone where they were engaged in a short informal conversation about their RE system and their experience with the REI. These informal conversations provided initial data collection and the opportunity to gauge the interest level for participation in a survey, full formal interview or site visit. Depending on their interest, providers were then sent a survey or were scheduled for an interview.

Many providers were non-committal about further participation after the first interaction or did not end up participating in a survey or interview despite an initial interest. Most providers also did not opt to do both a survey and an interview. Once the initial list of confirmed contacts was exhausted, the team began reaching out to other providers using generic contact information from the provider webpages. The general process was the same but it was more challenging without the contact of a specific individual that was involved with the system or the REI. In total, the team reached out to 121 of 161 providers and 65 participated via survey, interview or an informal conversation.

1.8 Online survey of housing providers

Through the process listed above, a survey was designed in SurveyMonkey and distributed to approximately 69 housing providers by e-mail. Most of these were to providers that indicated that they were interested in a survey based on the informal conversations. Surveys were not distributed to those that indicated that they were not interested in a survey or those that stated they would prefer an interview. Nineteen survey responses were received. The survey was distributed in July 2016 and remained live until January 2017.

1.9 Formal interviews with service managers and housing providers

Thirty-one formal interviews were conducted with a range of REI program stakeholders, including service managers, housing providers, vendors and MHO program staff. The interviewees were from across Ontario and represented a mix of urban and rural locations. They also included service managers representing both small and large social and affordable housing portfolios, and represented a full range of property types including multi-unit residential buildings, townhouses and detached homes. There was also diversity in terms of technology implemented through the REI program. Interviews took place from July 2016 to January 2017. Interviews were semi-structured, lasting around an hour each. Interviews were transcribed for later analysis.

1.10 Site visits

In-person site visits were conducted on 17 sites from the REI portfolio. As with the interviews, the project team strived for a representative mix of urban and rural locations, as well as a mix of housing type and technology type.

1.11 Housing provider case studies

Based on the surveys, interviews and site visits, ten housing provider case studies were compiled. Case studies documented reported system performance and provider experience with the REI administration and implementation of their renewable energy retrofit. These case studies are provided in full in Appendix A. The basic criteria in selecting case study sites was that the provider participated in a survey, interview or site visit, and were interested in participating in a case study. Further than that, case studies were selected to ensure that across all case studies there was:

- geographic diversity;
- diversity in the type of ownership (public/private);
- diversity in technology type;
- high quality of feedback; and
- diversity in provider experience (case studies were intended to highlight both successes and lessons learned).

1.12 Technical, financial and GHG analysis

Using project data provided by MHO, along with additional data collected from housing providers, the project team developed estimated energy generation figures for each project in the REI portfolio. Estimates were generated based on system capacity coupled with proxy figures for generation based on technology specific factors developed by the project team. From the estimated energy generation figures, the project team developed estimates for financial returns to social and affordable housing providers (either revenue generated, or costs avoided), as well as estimated GHG reductions associated with reduced fossil fuel and electricity demand.

1.13 Economic input-output analysis

Using feasibility study data provided by MHO, along with data gathered from vendors and subject matter experts, the project team evaluated total expenditures and categorized them according to industry classification codes used by Statistics Canada to measure economic activity (North American Industry Classification System, or NAICS codes). The project team then used to Statistics Canada's economic input-out model for Ontario, and input estimated expenditures in order to generate estimated economic impacts in terms of GDP growth and job creation resulting from the REI program.

1.14 Notes on study limitations

Given data gaps, many estimates, assumptions and relatively high margin of error for some of the calculations, certain study limitations should be noted explicitly. These are dealt with in detail in their respective sections and an overview is provided here.

- Performing the surveys and interviews several years after the program rollout is likely to have affected the feedback on the REI administration, due to both staff turnover and the ability of providers to recall their impressions of the program.
- The qualitative analysis examined the results of surveys and interviews but it should be understood that these perceptions might be subject to bias, either good or bad. In the case of PV, which was the largest component of the REI, these perceptions are often based on actual performance data in the form of income provided by the systems. However, for other system types, system performance data was typically not collected. Provider impressions may therefore be based on what the system was anticipated to have saved as calculated in the feasibility assessments or on simple observations on monthly utility costs; but it remains that anticipated performance may not always be the same as actual performance and utility costs can fluctuate for a variety of reasons. A more thorough analysis would need to be done to separate the utility savings from the RE systems from the other fluctuations and this was typically not done by the providers.
- The study gathered perspectives of housing providers that participated in the REI but not from housing providers that did not participate in the REI. Many of those that participated were well positioned to do so and may have reported minimal barriers as a result, but it was clear from service managers that not all providers were well positioned. The barriers facing these providers were therefore reported on within this study based on comments from service managers rather than on comments made directly from the providers that were not able to participate.
- In the technical, financial, GHG and socio-economic analyses, a key limitation was data availability. There was minimal data available (i) on the performance of systems, (ii) on system specifications and (iii) on RE system performance in previous available studies. System costs were typically available and system sizes could often be estimated from satellite imagery. However, with a few exceptions, these were the only system-specific data upon which to estimate performance. It followed that a number of other sources were needed to formulate appropriate parameter values to be used in the estimation procedures. In the case of PV, the estimation procedure could be compared and calibrated against a small subset of real-world REI performance data but this was not possible with the other technology types. It follows that all results from these analyses are based on estimates – with the quality of the PV estimate being higher than that for the other technologies. Where appropriate, sensitivity analyses have been provided to demonstrate the effects of parameter estimations.

1.15 Overview of document

Via an interjurisdictional scan with supporting case studies, Section 2 introduces barriers and opportunities concerning renewable energy and energy efficiency retrofits within the social and affordable housing sector as a whole. Section 3 presents the analysis of the REI. Insights gained in both the literature review and in the REI analysis are combined in Section 4 to formulate future program considerations. Section 5 presents the knowledge mobilization plan. Section 6 presents conclusions. Future work is outlined in Section 7.

2 LITERATURE REVIEW AND INTER-JURISDICTIONAL SCAN

This section presents a comprehensive review of literature relevant to energy efficiency and renewable energy retrofits in social and affordable housing. The scope of review spans roughly 40 academic journal papers, 55 program reports from nearly 30 different jurisdictions, and more than 45 reports and analysis from grey literature.

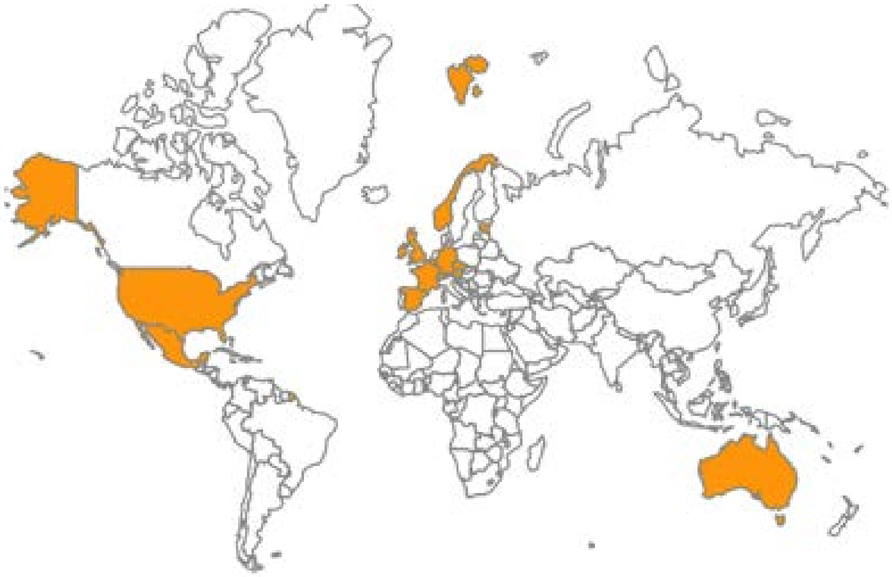

Figure 2-1. International jurisdictions scanned.

The goals of the literature review were to:

- evaluate current and prior practices on energy retrofits in social and affordable housing in multiple jurisdictions;
- limit jurisdictions to locations of geographic, weather, or policy relevance to Ontario;
- consolidate knowledge from a large number of studies;
- examine common themes in barriers and drivers for energy retrofits in social and affordable housing;
- express themes in a conceptual model that contrasts with REI program implementation;
- describe best and emerging practices;
- identify representative case studies;
- synthesize knowledge into a roadmap for future program considerations; and
- develop an energy portfolio management framework that is synergistic with existing strategic building asset management framework.

2.1 Drivers for building energy retrofits in social and affordable housing

Potential for massive retrofits

Social and affordable housing is regarded as an important sector to mobilize municipal, provincial and national efforts to reduce energy consumption and GHG emissions. Engaging with the social and affordable housing sector on energy sustainability provides many benefits, listed below.

- Social and affordable housing units are institutional players specialized in housing management, this is despite the fact that technical proficiency is generally low in the housing sector[8].
- Social and affordable housing units share similarities in governance, institutional assets, capacities and regulations[9]. Program activities and lessons learned with one provider can be replicated by another provider or scaled up in a different jurisdiction more easily than with private homeowners.
- Rental units occupied by energy poverty vulnerable households, many of whom live in social and affordable housing, may typically be a part of "older, less well-maintained buildings with poor insulation and electricity-intensive baseboard heating"[10], which presents significant "low-hanging fruit" opportunities for reducing energy use (margin) over a lot of social and affordable housing (volume).

Case Study
The Polish Renovation program[11], introduced in 1998, provided an 80% cost subsidy to applicants that were able to demonstrate a savings of 25% in heating demand over a 10-year period. Project qualifying conditions included certified energy audit and rigorous financial analysis. Over a 10-year period, the program supported nearly 11,000 projects in the social housing sector. A cost-benefit analysis demonstrated that an investment of 180 million euros (2.55M$ CAD) generated an energy efficiency refurbishment value of nearly 1 billion euros (141B$ CAD). In addition to generating value for government investments in the sector, an estimated 60,000 jobs were added to the construction sector because of this program.

Consolidated decision-making

Social and affordable housing organizations are institutional actors that specialize in housing management, and have better decision-making capacity. A single property manager of social and affordable housing has greater autonomy in decision-making over a large number of housing units

[8] Milin, C., & Bullier, A. (2011). Energy retrofitting of social housing through energy performance contracts a feedback from the FRESH project: France, Italy, United Kingdom. *Brussels: Intelligent Energy Europe (IEE) of the European Commission*.
[9] Energy Strategic Asset Management. (2008). *Methods and tools to optimize the energy strategy in social housing enterprises.*
[10] Rowlands, I. H., & Stephen, G. (2016). *Vulnerable Households and the Smart Grid in Ontario.*
[11] Innovative Financing of Social Housing Refurbishment in Enlarged Europe. (2008). *Guideline on Social Housing Energy Retrofitting Financing Schemes in EU New Member States*.

compared to individual private homeowners. They also have better technical expertise, project management, supervision and oversight - something that is essential for the effective adoption of relatively new technologies[12]. Through a few social and affordable housing providers, it is possible to reach a large number of dwellings and achieve significant GHG/energy savings. This presents a greater opportunity to concentrate large scale funding and investment of public monies.

Case Study

In 2011, Denver Housing Authority (DHA) launched a major solar installation project in an effort to secure fixed long-term utility costs for social housing, while also fulfilling their commitment to sustainable energy generation and meeting their 20% energy reduction targets. In order to finance such a large project with installations scattered over 380 locations in the city, DHA leveraged financing through an innovative public-private partnership where a private third-party finances, owns and operates the system while 'selling' electricity generated to the DHA at a fixed rate significantly lower than current utility rates, with rates secured over a 20-year contract period.

Over a 2-year period, the actions taken by a single housing authority led to the installation of more than 10,000 solar panels. In addition to securing cheaper energy costs for social housing, the project is expected to reduce carbon emissions by nearly 3,500 tons per year, the equivalent of taking 750 passenger vehicles off the road each year[13]. The project is also estimated to have created 40 new green jobs in the city of Denver.

Long term asset management

Average social and affordable housing ownership in North America is estimated to be 30-50 years while in contrast, the average private single-family home ownership occupancy is only 13 years[14]. While private housing is sometimes viewed as an equity investment with a future resale value, social and affordable housing buildings are built or purchased with the goals of providing affordable housing over the long lifespan of their assets. In order to extend the lifespan of their assets and to keep operational costs low, social and affordable housing providers have a natural incentive to implement policies for regular maintenance and rehabilitation of buildings. Social and affordable housing providers already develop strategic multi-year action plans for investment into building asset upgrades. With policy support, refurbishment operations that support comfort and tenant quality of life can be leveraged to help improve the overall building envelope and energy efficiency. With adequate planning, energy retrofit projects can be integrated into existing building renovation timelines and frameworks. For example, installing rooftop PV at the same time as upgrading a building's roof reduces fixed costs from engineering, design and installation.

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[12] Jenkins, D. P. (2010). The value of retrofitting carbon-saving measures into fuel poor social housing. *Energy Policy*, *38*(2), 832–839. http://doi.org/10.1016/j.enpol.2009.10.030.
[13] Calculated using Greenhouse Gas Equivalencies Calculator. (2017, January 24). Retrieved Feb. 2, 2017, from https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator%20.
[14] Emrath, P. (2013, Jan 3). Latest Study Shows Average Buyer Expected to Stay in a Home 13 Years [Article]. Retrieved Feb 2, 2017, from http://eyeonhousing.org/2013/01/latest-study-shows-average-buyer-expected-to-stay-in-a-home-13-years/.

Case Study

Social housing stock in the UK performs marginally better against energy efficiency standards than the UK housing stock as a whole. In a test conducted recently, the English Housing survey identified the average standard assessment procedure (SAP)[15] rating for housing stock as 53, while social housing stock was 60, evidence of a marginally better performance. One explanation is that social housing stock experiences a number of upgrade programs consistently. The UK social housing sector has managed to leverage programs focused on improving quality of tenant life in vulnerable households to make improvements to building fabric, heating improvements that may have led to an improved energy performance. For example, 1.5 million social housing units have been upgraded to meet the Decent Homes Standard[16] - a technical standard for social housing introduced in 2000 to ensure all social housing met statutory minimum standards for repair, facilities, services and thermal comfort.

Public investment for public good

The costs of distributed energy technologies like PV continue to fall across North America, creating new opportunities for energy consumers. The growth and adoption of local clean energy is supported by public incentive programs like the Investment Tax Credit (ITC) in the United States and the Ontario FIT and microFIT program. However, access to affordable and clean energy continues to remain out of reach for families that might benefit the most - residents of multi-family residential buildings and social and affordable housing units. As a result, there is a growing demand for using public investments to develop innovative business models to ensure that low-income families are not isolated from participating in sustainable energy transitions[17].

The social and affordable housing sector has the capacity for directing public investments towards generating public good for a significant segment of the population. Energy sustainability retrofits help social and affordable housing lower their energy use and energy bills, which reduces their long-term dependence on public funding. Lowering operational costs allows property managers to allocate resources towards preventative maintenance and regular property upkeep. This reduces vacancy rates (especially with market rate tenants) and helps improve their solvency.

Case Study

California Solar Initiative (CSI) provides incentives for utility customers to increase the adoption of solar energy. Out of a total program budget of 2.2B$ USD (2.93B$ CAD), CSI carved out 10% for investments in residential low-income and multi-family solar projects, commonly known as SASH (Single-family Affordable Housing) and MASH (Multi-family Affordable Housing) programs

[15] The Standard Assessment Procedure (SAP) is the methodology used by the Government to assess and compare the energy and environmental performance of buildings.
[16] Morrison, N. (2013). Meeting the decent homes standard: London housing associations' asset management strategies. Urban Studies, 50 (12), 2569{ 2587.
[17] Chan, C., Ernst, K., Newcomb, J., & Org, C. (2016). Breaking Ground – New models that deliver energy solutions to low-income customers (Tech. Rep.). Retrieved from http://www.rmi.org/elab leap resources.

respectively. SASH and MASH began offering incentives in 2009, delivered through up-front capacity rebates for households with lesser than 80% of the local median income. In 2015, using funds generated by its cap and trade program, California state utility regulator (CPUC) extended SASH and MASH. The extension set targets of 15MW and 35MW for SASH and MASH respectively, while allocating an additional 54M$ USD (72.7M$CAD) for each program. From 2009 to 2013, MASH installed 273 PV systems on multi-family residential units for a total installed capacity of approximately 21 MW. In the same period, SASH installed 3,164 PV systems amounting to 10.5 MW of installed solar. SASH also contributed to hands-on installation practice to 3,645 job trainees and more than 17,000 volunteers. Additionally, SASH required eligible participants to enroll in energy savings assistance program that helped increase awareness of energy use. Taken together, PV installed under SASH and MASH programs alone amount to nearly 12% of all PV installed in Ontario. Recent program reviews show[18] that SASH and MASH have succeeded in meeting program objectives of using public funding to:

- decrease energy use without increasing expenses for affordable housing buildings;
- stimulate clean energy adoption in social housing;
- improve overall quality of affordable housing; and
- Increase awareness of energy efficiency behaviors.

Serve as exemplars & stimulate economic activity

Developing markets for relatively new technologies has several challenges. Firstly, it is difficult to encourage the use of new technology retrofits in private sector when there are few locally working examples available for comparison[19]. Lack of information about system performance, proof of reliability and avoided energy costs makes it difficult to scale renewable and energy efficiency technology markets out of their niche. Large-scale retrofits in the social and affordable housing sector can provide evidence based data and case studies to improve market confidence in energy technologies. A large number of exemplar housing units can widen the market appeal of the technologies, encouraging technology adoption among local private homeowners. Public investments in the sector can drive down costs locally due to increased sales, stimulating further economic activity. In addition, such programs can have multiplier effects in local communities by boosting employment and GDP.

Case Study

Salus Ottawa is a not-for-profit housing corporation that provides community-based housing for vulnerable clients living with psychiatric illness. The organization owns and operates 13 buildings in Ottawa. In October 2016, Salus celebrated the opening of Salus Clementine, the first certified Passive House multi-residential affordable housing project in Canada. Clementine is a 4-storey, 42-unit

[18] Public, C., & Commission, U. (2015). California Solar Initiative | Biennial Evaluation Studies for the Single-Family Affordable Solar Homes (SASH) and Multifamily Affordable Solar Housing (MASH) Low-Income Programs Market and Program Administrator Assessment Program (Tech.Rep.).

[19] Jenkins, D. P. (2010). The value of retrofitting carbon-saving measures into fuel poor social housing. *Energy Policy*, *38*(2), 832–839. http://doi.org/10.1016/j.enpol.2009.10.030.

apartment building that is forecasted to use just as much energy as one typical single family home. The building has no furnace, resulting in total GHG emissions amounting to only 1/4th of comparable buildings[20]. Affordable housing projects similar to Salus are driving the demand for Passive House design in North America[21]. In Philadelphia, a housing development for low-income residents became the city's first certified Passive House project in 2012. By 2016, 27 of 94 new construction projects planned to pursue Passive House building standards. Project Managers at Salus report that the Clementine project construction has spurred renewed interest in Passive House standards from across all provinces in Canada[22].

2.2 Barriers and emerging practices

Barriers and drivers for energy sustainability retrofits are not discrete and independent events, but can instead be conceptualized as forces that propel a social and affordable housing provider towards adopting energy sustainability retrofits. The journey taken by a social and affordable housing provider in implementing an energy sustainability retrofit can be conceptualized in the form of a pipeline (Figure 2-2). Barriers[23] at each stage of the pipeline can be strong enough to cause some participants to 'bounce off' the pipeline. This systemic attrition is called 'bounce rate'. Similarly, drivers can be powerful enough to advance participants to the next stage of the pipeline. Most social and affordable housing providers in Ontario bounce off the energy retrofit pipeline without implementing energy retrofits. The total fraction of participants reaching the desired end goal is called the 'funnel conversion rate'. A well-designed overall retrofit program will have a high funnel conversion rate.

This section reviews common barriers to energy efficiency retrofits experienced by social and affordable housing providers at each stage of the retrofit journey. The section will also review emerging practices that act as drivers, moving social and affordable housing providers down the retrofit pipeline.

[20] HSC. (2016, Sep 26). Deep Energy Efficiency: Passive House in the Affordable Housing Sector [Article]. Retrieved Feb 2, 2017, from https://www.hscorp.ca/deep-energy-efficiency-passive-house-in-the-affordable-housing-sector/.
[21] Humphries, C. (2016, Sep 14). How Affordable Housing id Driving Passive Housing Design [Article]. Retrieved Feb 2, 2017, from https://www.hscorp.ca/deep-energy-efficiency-passive-house-in-the-affordable-housing-sector/.
[22] Kerr, Lisa. "Ottawa Salus Clementine Project Affordable Housing Built To International Passive House Standards". 2016. Presentation.
[23] Weber, L. (1997). Some reflections on barriers to the efficient use of energy. Energy Policy, 25 (10), 833{835.

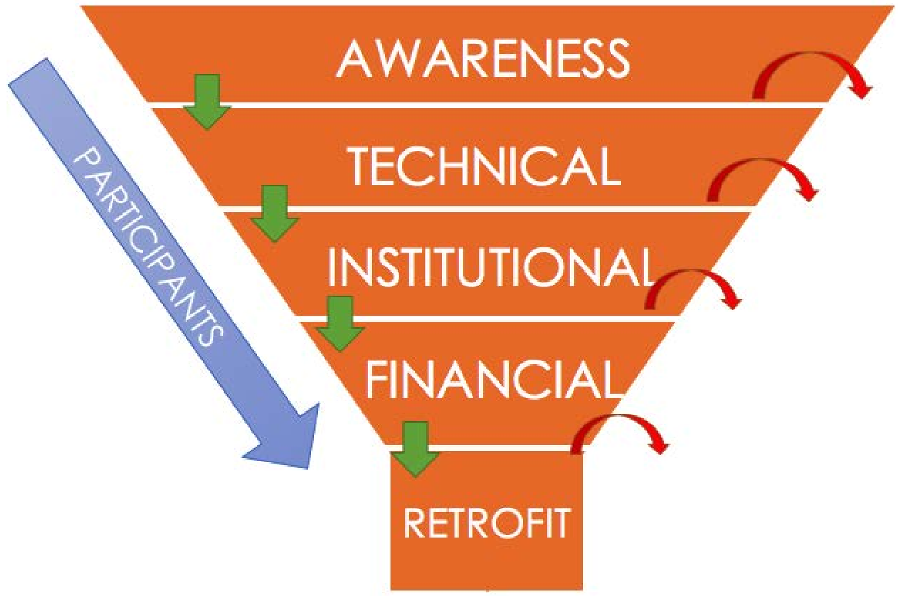

Figure 2-2: Conceptual model of barriers and drivers.

Stage 1- Awareness

Participants are aware of energy sustainability retrofits, but knowledge is rooted in broad statements; for example: *"I like energy efficiency"* or *"Social housing must also be sustainable"*. At this stage, participants have not yet demonstrated a desire to retrofit. Participants may experience the problem in the form of high-energy bills or low tenant comfort, but navigating towards a solution through actionable insights may prove challenging. Participants may be unaware of specifics of incentive programs available, and may lack knowledge of new technologies. Without proactive engagement, participants are likely to bounce off the pipeline.

Common Barriers

- Lack of knowledge about new technologies
- Complexity of navigating funding mechanisms
- Lack of awareness about available incentive programs

Emerging Practices

- Organized training programs for housing staff and property managers
- One-stop shop to address all program needs, developed by non-profits and other intermediaries and supported by provincial funding
- Helpline, accessible online webinars, and knowledge mobilization of best practices through case studies

Case Study
Retrofitting of Social Housing (ROSH) was a pilot program implemented in eight European Union (EU) nations from 2004-2008. ROSH hosted a telephone hotline and an interactive website - a one stop

reference and help-desk for all energy retrofit related questions. ROSH also provided training events led by experts, and coordinated group activities with peer-to-peer knowledge transfer to help raise awareness and technical expertise among social housing staff. Guidelines on developing information campaigns to increase awareness of energy sustainability for social housing providers is publicly available through the ROSH program report[24].

Stage 2- Technical

At this stage, participants consider implementing energy sustainability retrofits on their own building. They may have learned about details of programs available through participation in a workshop, or heard from another service provider about the benefits of energy sustainability. At this stage, participants are forming a 'choice set'[25] of retrofits they would like to implement but are limited by their technical capacity. For instance, participants in remote jurisdictions might not have adequate access to trained and qualified technicians and contractors. Smaller providers might lack in-house capacity and skills for regular maintenance post-retrofit, or the ability to gather information about building energy consumption.

Common Barriers

- Lack of historical energy consumption or building operation data
- Lack of skills within housing sector staff for regular maintenance post-retrofit
- Buildings might not have technical capacity to accommodate retrofit, e.g. adequate access to solar resource due to shading
- Lack of qualified and skilled technicians for retrofit installation

Emerging Practices

- Encourage development of building benchmarking tools and models to estimate energy use

Case Study

Netherlands building energy standards require residential constructions built after year 2000 to comply with building energy certifications. The City of Tilburg (Netherlands) maintained approximately 19,600 older social housing units that were exempt from this requirement. Anticipating changes to federal energy efficiency standards that would require assessment for all buildings, social housing organizations in the City of Tilburg hired a building energy assessment firm to estimate energy consumption across their entire building portfolio. The firm used a software developed using benchmarks provided by the Netherlands government. Prior to the assessment, building energy performance data was not available consistently across entire portfolio. Analysis of data collected from

[24] Battaglia, M., & Bolognani, O. (2007). *Guideline for the Training Materials*, 1–6.
[25] Tax, S. S., McCutcheon, D., & Wilkinson, I. F. (2013). The service delivery network (SDN) a customer-centric perspective of the customer journey. Journal of Service Research, 16 (4), 454{470. doi:10.1177/1094670513481108.

this initiative helped Tilburg public housing organizations use “new and effective strategies to improve overall energy performance” of their entire housing stock[26].

- Integrate new knowledge into continuing education of social and affordable housing managers

Case Study

Training for Renovated Energy Efficient Social Housing (TREES) was a 2-year project implemented in social housing organizations in six EU nations. TREES developed education and training materials for social housing managers structured in three main topics: techniques, tools and case studies covering technologies from heating to PV. Sets of slides, texts and other self-paced training material were made available at no cost to social housing managers[27].

- Encourage development of shared and community solar

Case Study

Community solar is a voluntary program that provides solar to multiple community members[28]. In 2015, Colorado Public Utilities Commission recognized that many low-income families lack the technical capacity to install PV on their rooftop owing to either home-ownership issues, lack of adequate solar windows, or living in multi-family residential units. In order to make solar energy more accessible to low-income households, Community Solar Gardens Act requires that community solar gardens allocate at least 5% capacity in each garden to low-income subscribers[29]. Non-profit and social housing providers sign up with solar provider or partner organization. With no initial costs, they begin receiving the benefits of solar energy in the form of credits on their utility bills. Participation in the program is free for income-eligible social and affordable housing providers.

[26] Energy Performance integrating in Social Housing. (2008). Dutch national pilot project (Tech. Rep. No. 50057/NG/080139).
[27]. Peuportier, B., Neumann, U., Dalenback, J.-O., Nesje, A., Csoknyai, T., & Boonstra, C. (2007). Training for renovated energy efficient social housing. CESB 2007 PRAGUE International Conference - Central Europe Towards Sustainable Building, 1.
[28] Coughlin, J., Grove, J., Irvine, L., Janet, F., Phillips, S. J., & Moynihan, L. (2010). A Guide to Community Solar: Utility, Private, and Non-Profit Development (Tech. Rep.). Retrieved from http://www.nrel.gov/docs/fy12osti/54570.pdf.
[29] Dobos, H. M. (2015). Analysis of the Fulfillment of the Low-Income Carve-out for Low-Income Communities (Tech. Rep. No. November).

- Improve opportunities for training and certification for technicians

Case Study
The US Department of Energy, US Housing and Urban Development, and US Department of Education collaborated to develop STEM, Energy and Economic Development (SEED) program. SEED initiative links existing federal investments to local place-based coalitions that encourage social housing residents to pursue careers in energy, providing them with skills training to prepare them for the green jobs workforce. The initiative is a concentrated effort to develop human capital needed to create improvements in residential building energy performance[30].

Stage 3- Institutional

At this stage, participants that have made the decision to proceed with energy upgrades might experience barriers associated with organizational constraints. Non-profit social and affordable housing volunteer boards may be unwilling to assume risks with untried and untested technologies. Providers might be unwilling to invest in upgrades without cooperative energy efficiency practices from tenants, for instance keeping windows closed to preserve indoor heat. Social and affordable housing providers may add energy retrofits to their "to-do" list but never prioritize upgrades due to staff workload. Institutional barriers contribute significantly to bounce-off rate for smaller social and affordable housing providers.

Common Barriers

- Split incentives for following efficient practices between property owners and tenants
- Low priority activity
- Tight timeframes and deadlines for implementing projects
- Lack of cross-sector coordination of services, actions and transfers among various programs

Emerging Practices

- Marketing, education, outreach and tenant awareness of energy sustainability

Case Study
Cardiff Council in the UK owns, manages and maintains nearly 14,000 social housing units. The council runs a quarterly tenant magazine that provides information regarding energy efficiency benefits. Tenant and resident groups are invited to participate and give input to planned energy upgrades. Council offers annual training for tenants on energy efficient behavior and best practices[31].

[30] STEM, Energy, Economic Development (SEED): Coalitions for Community Growth. (2017, January 10). Retrieved Feb. 2, 2017, from https://portal.hud.gov/hudportal/HUD?src=/program_offices/public_indian_housing/seed.

[31] Financial and Support Instruments for Fuel Poverty in Social Housing. (2010). Affordable Warmth for all: A guide to improving energy efficiency in the social housing stock, for social housing providers, residents and supporting organisations (Tech. Rep.).

- Leverage broader municipal goals and community energy plans

Case Study
Oxford City (UK) carbon management strategy mapped out a 5-year carbon reduction path, targeting a 25% reduction from a 2005 baseline. The city saw social housing as a market opportunity for low-carbon retrofits, leveraging provincial interest-free loans to fund, plan, implement and support an integrated GHG reduction asset management strategy. Similarly, the City of Berlin in Germany offered program management support to non-profit social housing sector, cutting carbon emissions in the sector by 60% in just a decade[32].

- Long term approach to funding schemes to enable proper planning, implementation and evaluation

Case Study
The "Solarize" project was first initiated by US Department of Energy's Sunshot Initiative in 2009. Since then, more than 250 campaigns in 26 US states in the U.S. have helped residents and housing authorities install PV. Solarize campaigns are locally organized community outreach efforts aimed at getting a critical mass of projects to qualify for a bulk installation at costs lower than the prevailing market. While consolidating projects for Solarize also happens over a short timeframe, all program administration is handled by a third party making it easier for social housing to participate in solar retrofits[33].

- Increase collaboration across sectors to increase effectiveness of program delivery

Case Study
The State of Maryland's Multi-family Energy Efficiency Improvement (emPOWER) program provides low cost loans and grants with flexible repayment terms for energy efficiency upgrades in affordable and social housing units. The program targets a package of energy conservation measures that collectively demonstrate a minimum savings ratio of 1:1. emPOWER consolidates multiple utility energy efficiency retrofit offerings into a single program. Project eligibility is determined by mandatory audit and quality control measures through a network of qualified technicians certified and approved by emPOWER[34].

[32] Financial and Support Instruments for Fuel Poverty in Social Housing. (2010). Affordable Warmth for all: A guide to improving energy efficiency in the social housing stock, for social housing providers, residents and supporting organisations (Tech. Rep.).
[33] Irvine, L., Sawyer, A., & Grove, J. (2011). Solarize guidebook: A community guide to collective purchasing of residential PV systems (Tech. Rep. No. DOE/GO-102011-3223).
[34] EmPOWER Maryland Low Income Energy Efficiency Program. (2016). Retrieved February 2, 2017, from http://dhcd.maryland.gov/Residents/Pages/lieep/default.aspx.

Stage 4- Financial

At this stage, participants are trying to raise capital and make a business case for energy retrofits. Some participants might find that the prevailing costs of fuel sources might not make a compelling business case for energy retrofits. Most participants might meet challenges in raising capital or attracting private investments. Lending institutions might be risk-averse to loan money due to lack of demonstrable operations and examples from existing buildings[35]. Financial barriers are the most significant bottleneck in achieving comprehensive energy upgrades for most social and affordable housing units, with significant bounce rates.

Common Barriers

- Structure of energy prices or fuel costs do not make a business case for retrofits
- Market risks due to uncertainty in technology and credibility of benefit claims
- Lack of demonstrable operation, case studies and examples from existing buildings
- Lack of access to capital

Emerging Practices

- Institute M&V protocol requirements for projects funded through public investments

Case Study
EU (RESHAPE) recommends making constant monitoring, evaluation and analysis a part of the organizational retrofitting strategy, where M&V is an integral part of every process throughout the design, implementation and post-installation assessments. EU funded Financing Energy Refurbishment in Social Housing (FRESH) recommends that private lending to a social housing provider be made contingent on reporting data according to the M&V protocol specified when the contract terms are being negotiated[36].

- Leverage technology to implement automated data gathering, warehousing and transmission; then use data to make evidence-based assessment of financial lending risks

Case Study
Supporting European Housing Tenants in optimizing Resource Consumption (SAVE@Work4Homes Project) instituted automatic monitoring and transmission of building consumption data across 2,100 social housing units. Simple interactive dashboards helped in program evaluation of retrofits across the entire program portfolio, while serving as exemplar projects. Visual data demonstrating actual energy consumption and avoided energy costs served as self-assessment tools, providing energy benchmarks for service managers across the sector[37].

- Mobilize third-party and private funding for energy retrofits

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[35] Geller, H., Harrington, P., Rosenfeld, A. H., Tanishima, S., & Unander, F. (2006). Polices for increasing energy efficiency: Thirty years of experience in OECD countries. Energy policy, 34 (5), 556{573}.

[36] RESHAPE. (2009). *Result Oriented Report : Energy Performance Certification and the Development of Renovation Strategies in Social Housing*,

[37] SAVE@Work4Homes. (2009). *Supporting European Housing Tenants in Optimizing Resource Consumption*.

- Alternative funding mechanisms are evaluated in detail in Section 4.3.

2.3 Summary

There are many drivers positioning social and affordable housing as an important sector in municipal, provincial and national efforts to reduce energy consumption and GHG emissions, such as the potential for massive retrofits, consolidated decision-making, long-term asset management and public investment for public good. However, the sector also faces many barriers to reaching this potential. These include:

- *Awareness* – Where housing providers are unaware of specifics of incentive programs available, may lack knowledge of new technologies, unaware of baseline energy consumption, etc.
- *Technical* – Where housing providers have limited access to trained and qualified technicians and contractors, lack of historical energy consumption data, etc.
- *Institutional* – Where housing providers experience split incentives, perceive energy upgrades to be a low priority activity, grapple with tight funding timeframes and deadlines for implementing projects, etc.
- *Financial* – Perhaps the largest barrier of them all, participants struggle to raise capital and make a business case for energy retrofits

These barriers are not discrete and independent events, but can be conceptualized as a pipeline (Figure 2-2) and barriers at each stage of the pipeline can be strong enough to cause some participants to 'bounce off' the pipeline. Around the world, best practices for tackling each category of barriers are emerging and it is clear that successful implementation of energy sustainability projects in social and affordable housing over the long term would require policy support to tackle barriers at *each level* of the energy retrofit pipeline. To tackle these barriers for the Ontario context, Section 4.2 illustrates a generic energy portfolio management framework that integrates planning and financing energy upgrades into strategic asset management frameworks.

This section summarized key findings from the literature and inter-jurisdictional scan in regards to the opportunities and barriers for renewable energy and energy efficiency retrofits in the social and affordable housing sector. The following section discusses analysis results for the REI. Insights from both the cross-jurisdictional scan and the REI analysis are synthesized in Section 4 to formulate future program considerations.

3 REI ANALYSIS

This section presents the analysis of the REI program. Section 3.1 provides detailed breakdowns about service area, proponent type, building type, technology type and similar. Section 3.2 provides an overview of the technical, financial and GHG analyses. Sections 3.3 to 3.6 provide results of those analyses for each technology type in the REI. Results from surveys, interviews and site visits are presented in Section 3.8. Lastly, the socio-economic analysis results are given in Section 3.9.

3.1 Breakdown of program participants and technologies

Across the province, 362 systems were funded under the REI program. A breakdown of total funding by service region and proponent type is provided in Figure 3-1 and Figure 3-2.

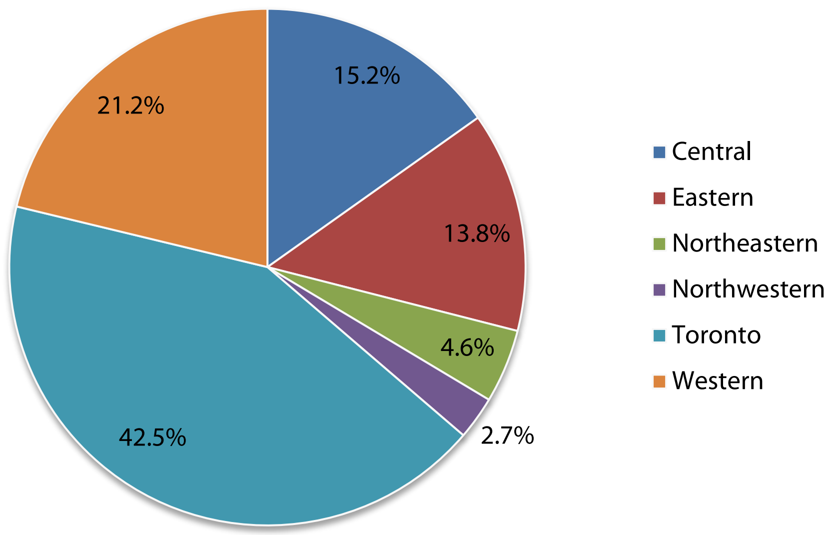

Figure 3-1. REI funding recipients by service region.

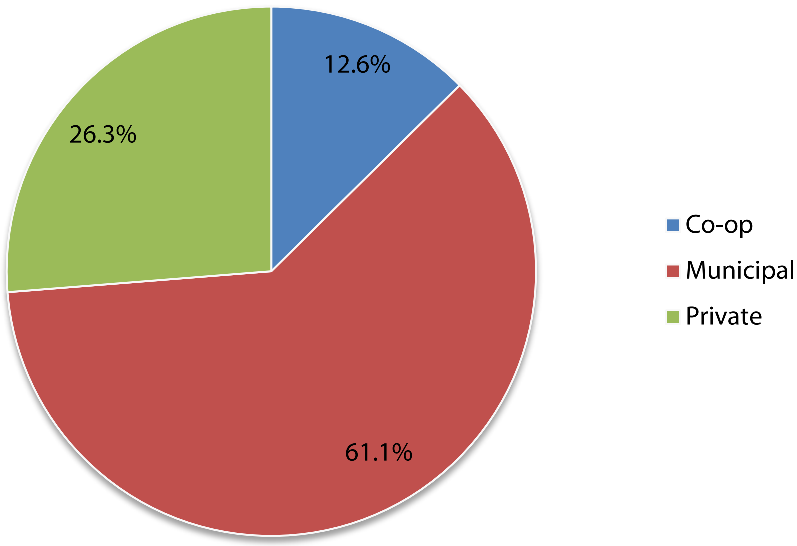

Figure 3-2. REI funding recipients by proponent type.

Funding predominately went to apartments, with row houses being receiving just less than a quarter of the total funding (Figure 3-3). Half of the funding went to buildings with between 50-150 units (Figure 3-4).

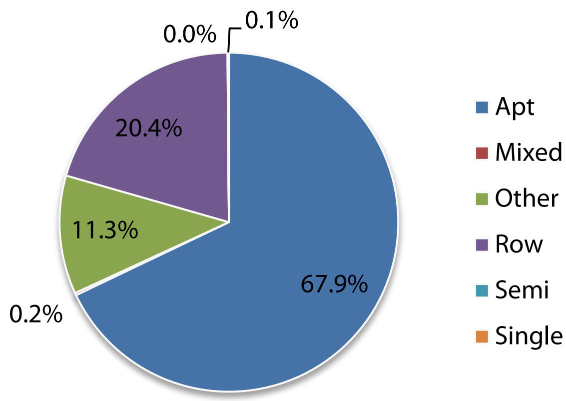

Figure 3-3. REI funding by building type.

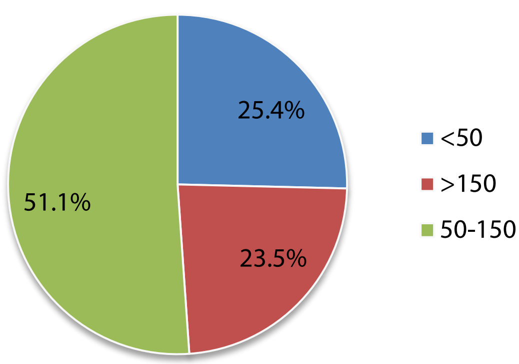

Figure 3-4. REI funding by number of units.

The majority of funding was provided for PV systems (Figure 3-5), and nearly two thirds of all RE funding went to systems with a capital cost between $100,000 and $200,000 (Figure 3-6). Breakdowns of system costs and number of systems are included in the technical analysis of each technology type (Sections 3.3.1, 3.4.1, 3.5.1, and 3.6.1).

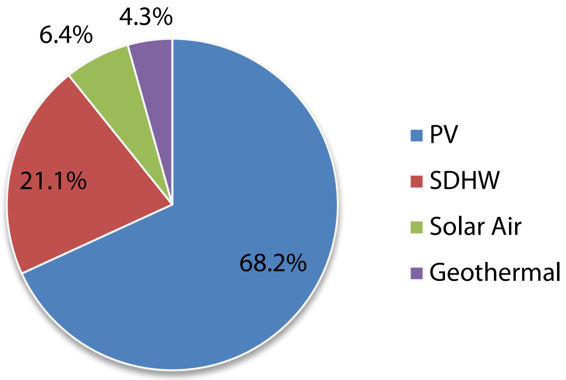

Figure 3-5. REI funding by technology type.

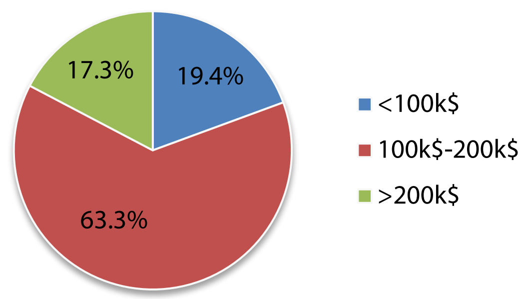

Figure 3-6. Breakdown of REI project capital costs.

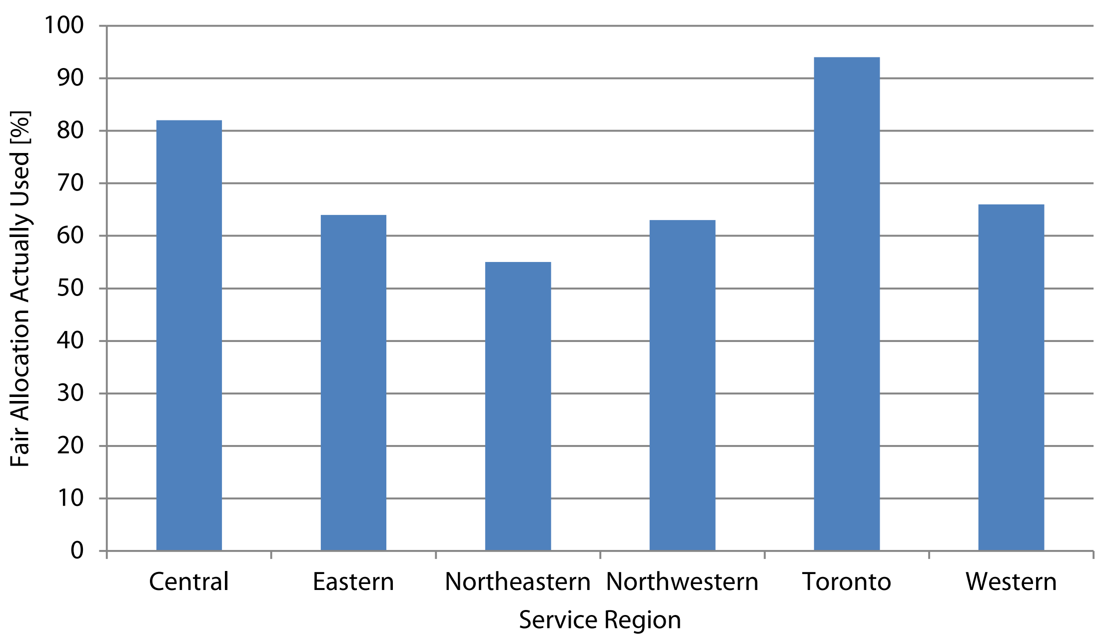

Figure 3-7. Fair allocation by service region.

Figures 3-8 and 3-9 show a geographical representation of the fair allocation per service area. The colours in the map, for each service area, depict the fair allocation value (the actual amount given divided by the amount allocated). Darker blue areas received less allocation, darker red areas received higher allocations, whereas paler regions (closer to white) received closer to the full allocation amount. Figure 3-9 shows a more detailed view of this representation for southern Ontario. These figures should be used as a visual representation and they may not reflect exact service area boundaries.

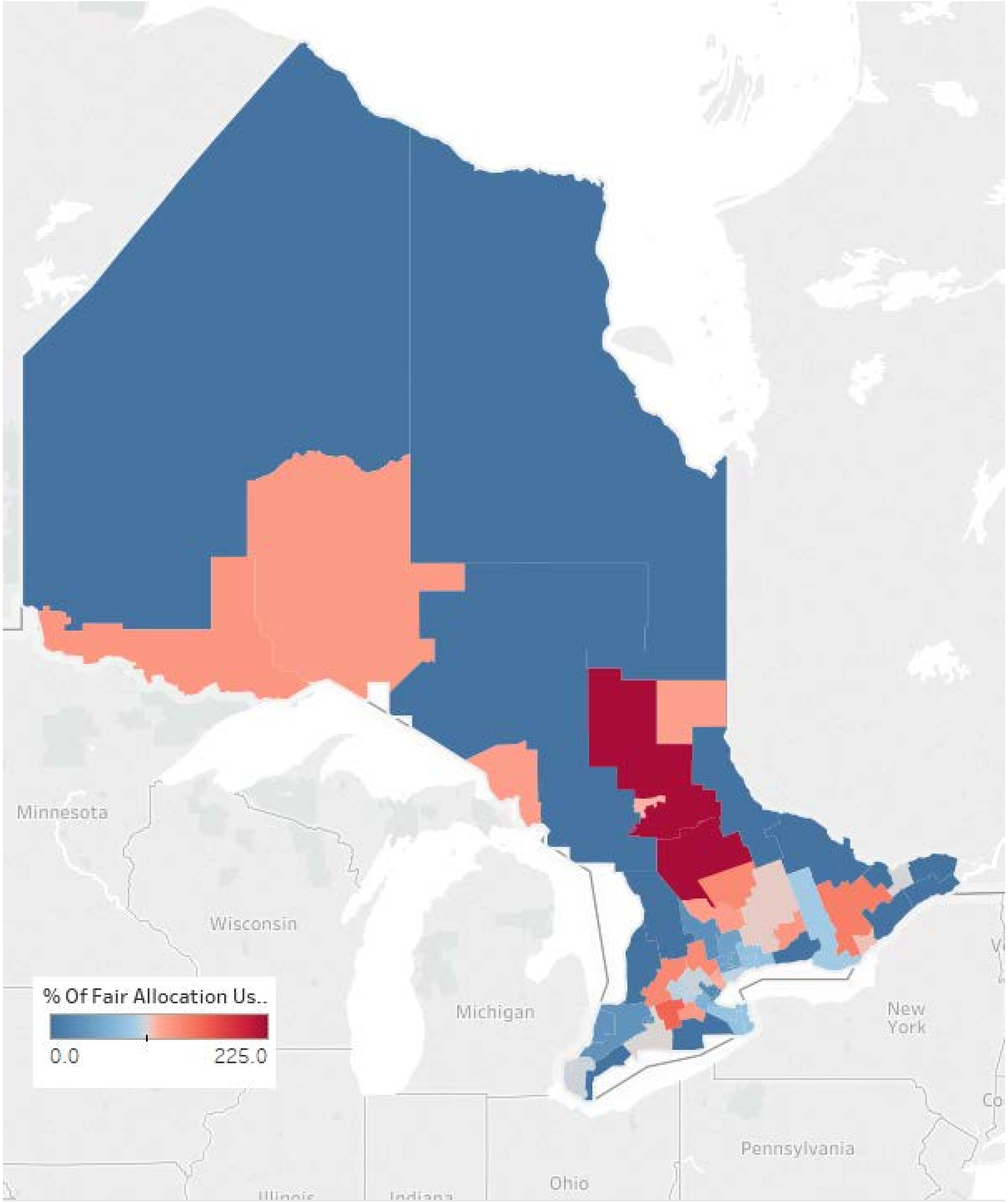

Figure 3-8. Fair allocation with respect to service area (all of Ontario).

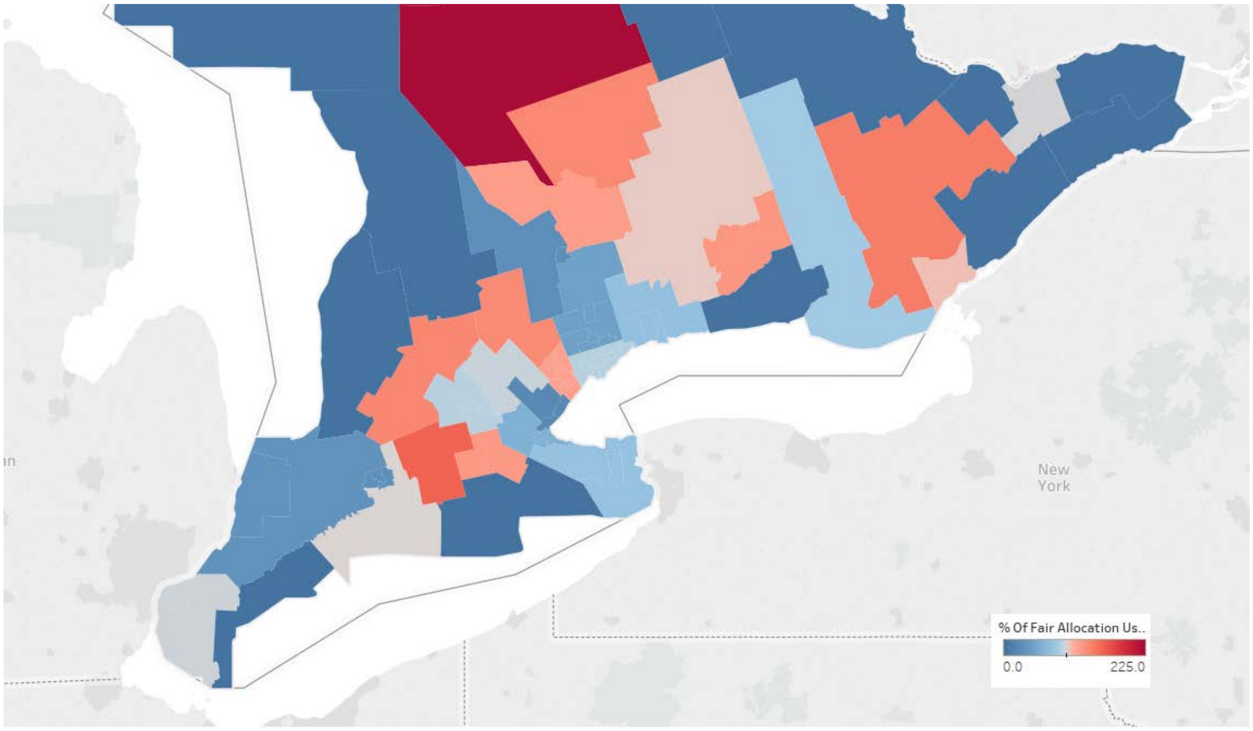

Figure 3-9. Fair allocation with respect to service area (Southern Ontario).

3.2 Technical, financial and GHG analyses

3.2.1 Overview

A logic model of the technical financial and GHG analyses is presented in Figure 3-10.

- The technical analysis estimated the energy savings of the REI-funded renewable energy installations.
- The financial analysis estimated the financial benefits.
- The GHG analysis estimated the emissions savings.

Analyses are summarized in Sections 3.2.2 to 3.2.4 with more technology-specific detail provided in the subsequent Sections 3.3 to 3.7 of this report.

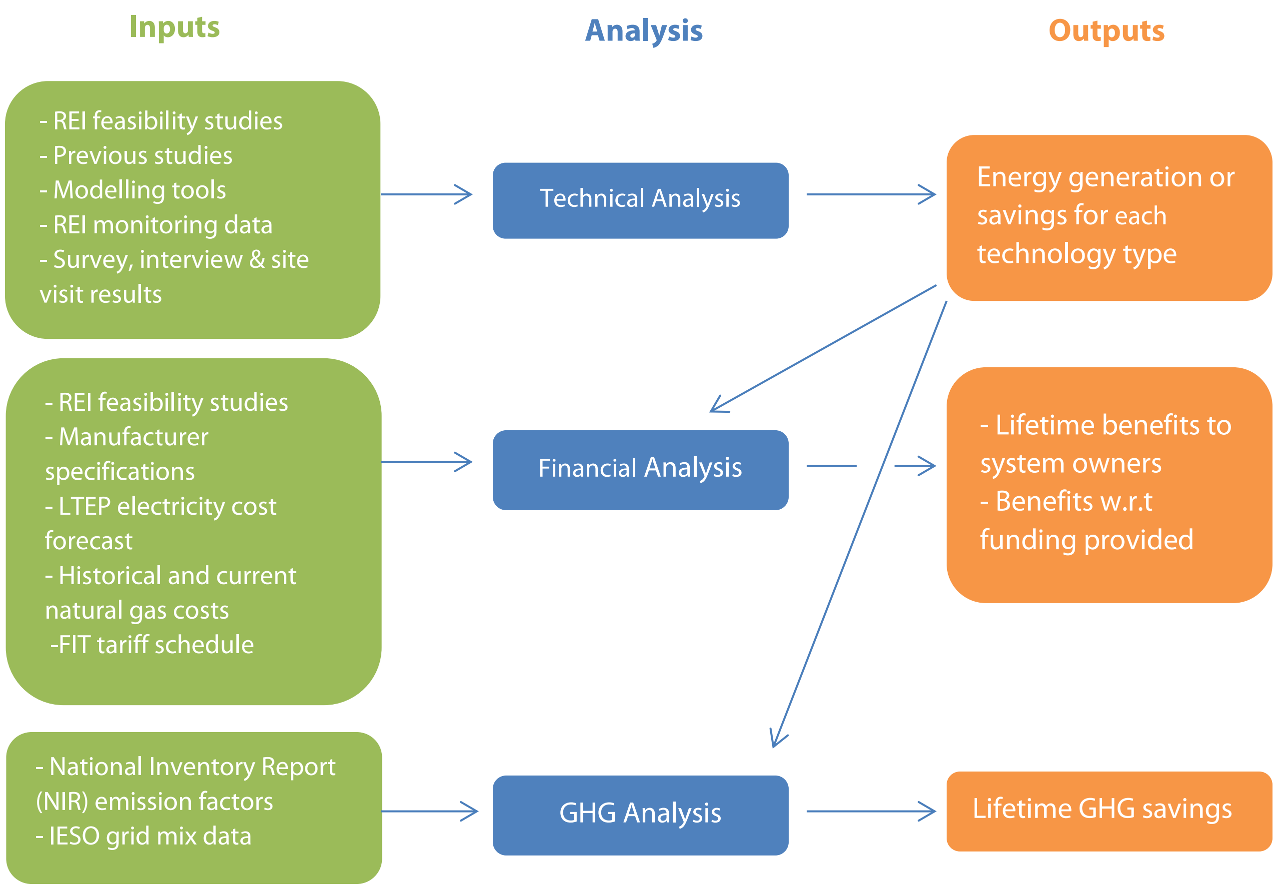

Figure 3-10. Logic diagram of technical, financial and GHG analyses.

3.2.2 Technical analysis

The goal of the technical analysis was to estimate program-wide renewable energy generation and energy savings for each technology type. The best option for determining energy generation and savings would be through performance monitoring of the systems. However, measurement and verification (M&V) was not a requirement of the REI program.

Some providers did monitor system performance and were able to share that information as part of this analysis. The best success was had with PV because it has a built-in performance monitoring in the form of the utility meter and the payments to the providers. For other system types, performance monitoring would have only been done through the initiative of the provider and the majority of providers did not install their own performance monitoring system.

Given the project's time-constraints and the logistics of conducting performance monitoring, it was not possible to conduct additional performance monitoring on the sites. The technical analysis therefore relied heavily on estimation. Energy performance estimates were based on the system size, system orientation (in some cases) as well as expected performance based on the REI feasibility studies and previous research.

System sizes were not recorded as part of REI record keeping. This data was also typically not available from the feasibility studies because the majority of systems did not have feasibility studies that were available for review, and of those that did, the system considered in the feasibility study was often not exactly the same as what was eventually was installed. With the exception of geothermal, system size data was obtained by analyzing each system using Google Earth satellite imagery. It was possible to count the total number of modules or collectors and, in most cases, estimate the total areas of collectors.

The ability to measure three-dimensionally oriented surfaces in a simple software package like Google Earth is new and the approach has its limitations, especially considering that the satellite images were not always clear. However, given the fact that actual system areas or system performance data was not available for the large majority of systems, this approach was the best option available. Area measurements were a key component of the SDHW and solar air analysis, but were not for PV, and it is acknowledged that the results for non-PV systems are a rough estimate because of the limited data available. It also worth noting that there were other, more significant, simplifications made in the estimation procedures for both SDHW and solar air. A more accurate analysis would require additional data on the performance of the systems and the system specifications.

With an estimate of the system size, it was possible to estimate the energy generation or savings based on expected performance. This was done individually for each system. Additional qualitative data collected through surveys, interviews and site visits was then used to de-rate the estimate if necessary. The process is summarized in Figure 3-11. It was slightly different for each of the technologies and is discussed in detail in each of their respective sections.

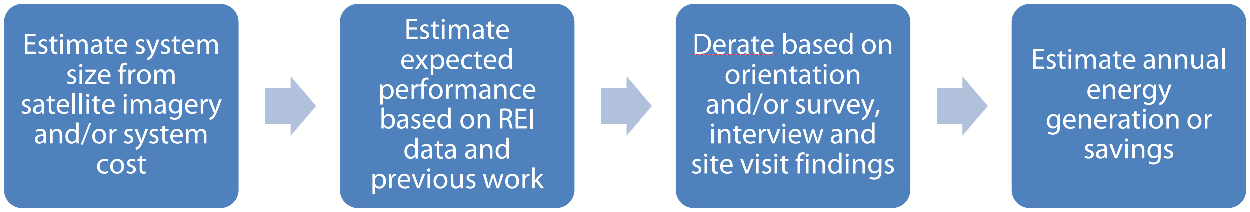

Figure 3-11. The process for determining an energy generation estimate starts with estimating a system size.

3.2.3 Financial analysis

Financial performance for each technology type was estimated by placing a value on the energy generation or savings that was determined in the technical analysis. This was more straightforward for PV, where system owners signed a 20-year contract to sell their electricity at a fixed rate. It was less straightforward for the other technologies.

Firstly, in most cases, no data was available that identified the fuel being offset for each of the installations. The 2011 Households and the Environment: Energy Use analysis from Statistics Canada[38] states that in Ontario 76% of the home household heating is accomplished with natural gas, 14% is from electricity, 5% is oil, 3% is wood or wood pellets and 2% is propane. Natural gas and electricity are the largest fuel sources and represent the full fuel cost spectrum, with natural gas being the cheapest option and electric resistance heating the most expensive. To determine program-wide savings, it was assumed that 80% of the energy savings was from natural gas and 20% was from electricity. Incorporating oil, wood and propane would have added complexity without significantly improving the accuracy of the results.

The second issue was that fuel costs are not fixed in time. The provincial government's 2013 Long Term Energy Plan (LTEP) estimated the increase in electricity prices looking outward to 2032. However, we note that recent legislative changes will impact the future cost of electricity. This is discussed in Appendix C. Natural gas is much more variable and it is not possible to forecast costs accurately over the lifetime of the systems. To deal with this uncertainty, the financial results for the natural gas component of savings was determined as a function of natural gas cost, spanning the lowest to approximately the highest estimated gas prices from the last 10 years (see Appendix B).

System lifetimes are long. Future cash flows were therefore discounted according to the rate of inflation. Since the focus of the analysis was on determining the impacts on providers, cash flows were not discounted to represent the lost opportunity from the MHO not investing that funding elsewhere. To analyze the financial performance, two metrics were calculated: (i) the net lifetime benefits to the social and affordable housing providers that installed the systems and (ii) a ratio of net benefits to the funding provided. The former represents the impact of the REI program for those that participated

[38] Statistics Canada. "Households and the Environment: Energy Use," Table 2, 2013. Retrieved Feb. 2, 2017 from: http://www.statcan.gc.ca/pub/11-526-s/11-526-s2013002-eng.pdf.

and the latter represents the cost-effectiveness with which the RE investments were made. These terms will be more formally defined in the corresponding sections for each technology.

3.2.4 GHG analysis

The GHG analysis used the energy generation/savings estimates from the technical analysis to estimate the GHG emissions savings. Information about the GHG emissions associated with a given activity, process or product is contained within its corresponding emissions factor (EF). In the GHG analysis, it was assumed that electrical consumption and natural gas consumption have an EF greater than zero but energy generated from renewable sources had an EF of zero. The emission factor of gas was assumed to be 1900 [g CO_2e/m^3]. The emission factor of electricity was assumed to be 50 [g CO_2e/kWh] [39].

The case of electricity was less straightforward than the case of gas because the electricity system is composed of a dynamic mix of many fuel sources, each with an associated EF. When electricity consumption is reduced in the case of a RE retrofit, not every fuel source in the mix is equally offset by the same amount; rather, the output is reduced for whatever source is the last to be dispatched at any given point in time. This is referred to as being "on the margin". However, marginal EFs are not currently available.

Within the "World Resource Institute's Guidelines for Quantifying GHG Reductions From Grid-Connected Electricity Projects", different methods for making assumptions about EF_{elec} are possible. The "Average Load Following" approach was used in this analysis. It was assumed that EF_{elec} could be calculated as a weighted average based on annual generation from each component of the electricity fuel mix that is not base-load or "must-run". The base-load in Ontario is met with nuclear. However, in the National Inventory Report (NIR), the grid emission factor is entirely due to non-base load fuel sources because all non-fossil fuel sources are assumed to have an emission factor of zero. Essentially for Ontario, the "Average Load Following" approach is equivalent to just using the NIR emission factor of 50 [g CO_2e/kWh] and this is what was done in the analysis.

[39] Both the gas and the electricity EFs came from Canada's "National Inventory Report, 1990-2014: Greenhouse Gas Sources and Sinks in Canada," 2016. Electricity EFs came from Table A13–7 (Part 3, p. 94). Natural gas EFs come from tables A6-1 to A6-2 (Part 2, p. 193). The combustion of gas emits carbon dioxide, nitrous oxide and methane. A total of 1.90 [kg CO_2e/m^3] is a weighted average determined using 20-year global warming potentials of 56 for methane and 280 for nitrous oxide, in accordance with UNFCC.

3.3 PV

3.3.1 Technical analysis

There were 255 sites that received REI funding for PV systems with an estimated[40] total funding of 39.1M$. A breakdown of system costs is presented in Figure 3-12. The aim of the technical analysis was to estimate the total annual energy generation over the lifetime of the systems. This required extensive use of estimation. Parameter estimates are defined in Table 3-1.

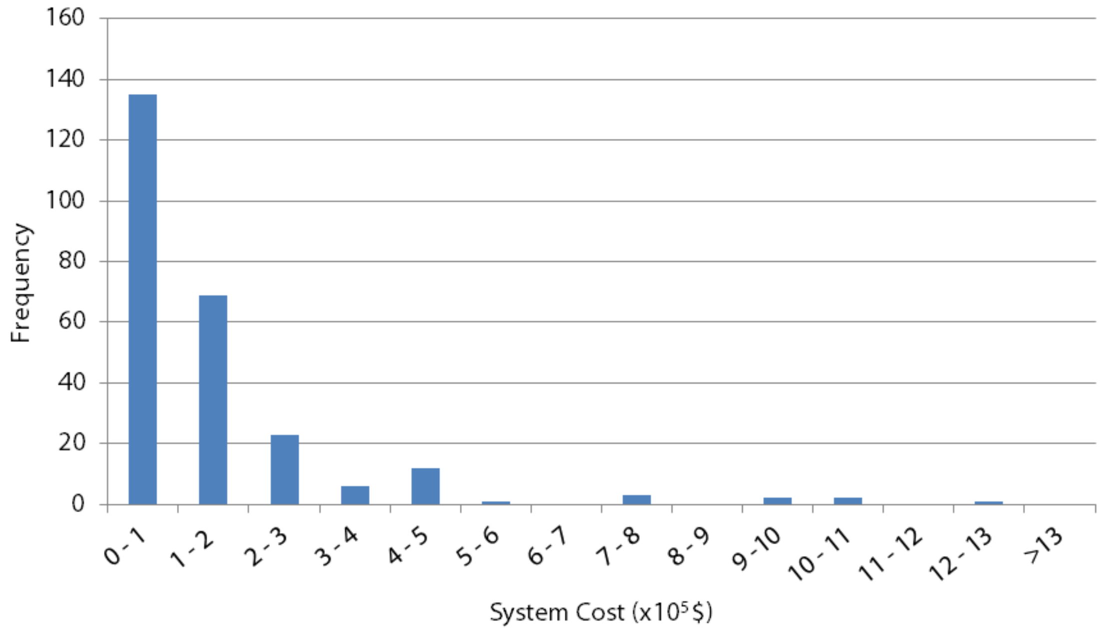

Figure 3-12. Most systems were below $100,000.

Table 3-1. Parameters used to estimate annual PV energy generation.

Parameter	Unit	Value	Description
Average module rating	[W_p]	210	Modules are rated according to the power they produce under a specific set of operating conditions, termed standard test conditions (STC). The rating is in units of peak-Watts [W_p]. There were 23 REI PV feasibility studies that provided information on the recommended module for a PV installation. There was additional module data from 6 sites evaluated under the Solar City Partnership[41] that were installed around the same time as the REI systems. The average module rating from the 29 different installations was 210 [W_p], with a range of 175 [W_p] to 245 [W_p]. Where necessary, an average module rating of 210 [W_p] was assumed.
Average system cost	[$/$W_p$]	9.6	Total system size and cost estimates were provided in 33 REI PV feasibility studies. The average value was 9.60 [$/$W_p$] for 23 roof mount

[40] This value is "estimated" because there were many cases in which multiple system types were installed at single location but only the *total* cost was recorded, not the cost per system. The estimate is the result of work done in the technical analysis.

[41] SolarCity Partnership, "Performance Review of Rooftop Solar Photovoltaic Projects in the Greater Toronto Area," 2012. Retrieved Feb. 2, 2017 from: http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2015/03/PVSiteComparison-finalreport.pdf.

			installations and cost estimates varied from 8.25 [$/W$_p$] to 11.64 [$/W$_p$]. For pole mounted installations, the average was 12.48 [$/W$_p$] across 6 installations and for 2-axis tracked, 11.63 [$/W$_p$] across 4 installations. The vast majority of installed systems were roof-mount and the estimated system costs used for estimates in the analysis was 9.6 [$/W$_p$].
Maximum specific yield	[kWh/kW$_p$]	1215	The specific yield is a ratio of the annual energy generation for a PV installation with respect to its total size. A simulation in National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM) predicted that the specific yield of a PV system in Toronto with optimal tilt and orientation was 1215 [kWh/kW$_p$]. Data from previous work in the Greater Toronto Area (GTA) conducted as part of the SolarCity Partnership is shown in Figure 3-13. Installations with a tilt angle near the optimal value, a tilt angle that is roughly matched with the latitude of the installation, had a specific yield between 1200 and 1250 [kWh/kW$_p$]. It is worth noting that the solar resource may vary on an annual basis and this would affect the specific yield. Regardless, good agreement is seen with the experimental data and the maximum specific yield prediction from SAM.
Corrections for system orientation	-	-	A parametric analysis was done in SAM to determine how specific yield was affected by module tilt and orientation. The results are shown in Figure 3-14 where the colour scale represents a percentage of the maximum value of 1215 [kWh/kW$_p$] (the darkest red being 95 to 100% of the maximum value). Based on this data the following was assumed when estimating system performance in this study: • maximum specific yield is 1215 [kW/kW$_p$]; • if an installation was within an azimuth of +/- 60° of S and not vertical then the output was assumed to be 95% of maximum (1154 [kWh/kW$_p$]); • if outside of that azimuthal range and not vertical then an output which was 85% of maximum (1033[kWh/kW$_p$]) was assumed; and • if vertical, specific yield was estimated on a case-by-case basis using Figure 3-14 as a guide. Variations in performance based on geography were not considered because this is a high-level estimate that would ultimately not be significantly improved by a more complex analysis.
Annual power output degradation	[%/year]	0.5	The median annual power degradation of crystalline silicon PV modules has been estimated by NREL to be 0.5%[42].
System lifetime	[years]	25 or 30	25 years is a standard warranty for PV modules. In practice, it is possible for modules to last 30 years. The inverter is anticipated to last 15 years. Inverter replacement costs were taken into account during the financial analysis.

[42] Jordan, Dirk C. and Sarah R. Kurtz, "Photovoltaic Degradation Rates - An Analytical Review," 2012. Retrieved Feb. 2, 2017 from: http://www.nrel.gov/docs/fy12osti/51664.pdf.

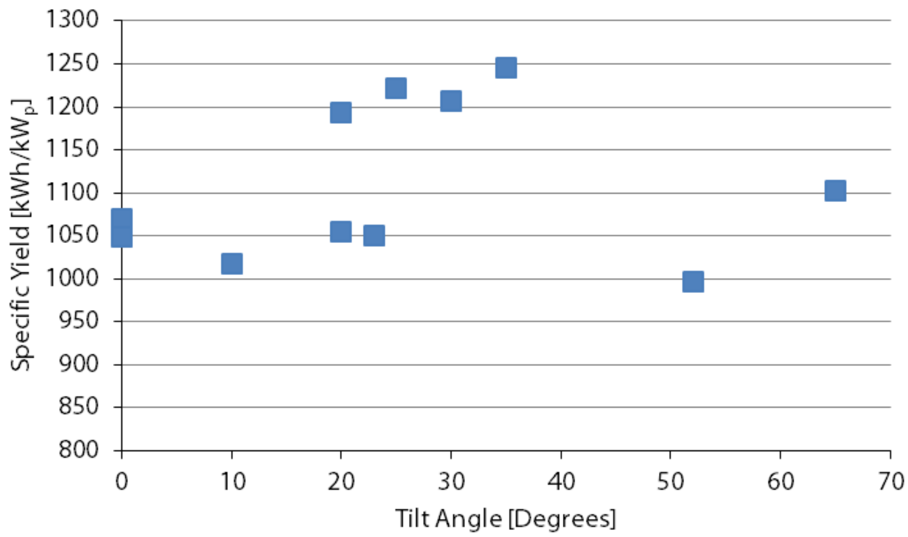

Figure 3-13. From previous work, the specific yield of systems within the GTA varies notably with the tilt angle of an installation. All installations in this figure were within ±20° of due south.

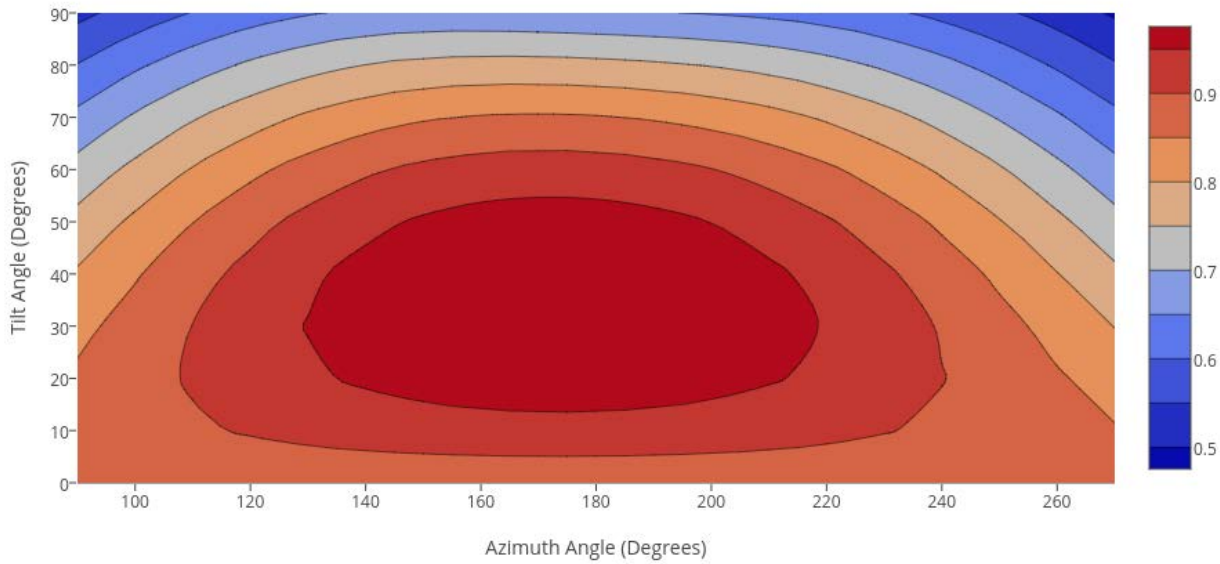

Figure 3-14. The specific yield of a PV installation is dependent on the orientation of the module. Note that the azimuth angle is the orientation in the compass plane with 180° being due south. The colour scale represents a percentage of the maximum value of 1215 [kWh/kW$_p$] with the darkest red being 95 to 100% of the maximum value.

3.3.1.1 *Procedure*

Annual yield estimates were generated *for each PV installation funded by the REI.* System energy yield estimates were then summed to estimate the total energy yield for all the PV systems in the REI. The procedure for estimating the annual yield of individual PV installations depended on whether satellite imagery was available and whether PV was the only technology present. These were considerations because (i) in all cases the system size needed to be estimated before the system energy yield, and (ii) where multiple technologies were funded, there was no data on how much funding was used for each technology. The procedure for estimating annual yield is described in Table 3-2.

Table 3-2. Procedure used for estimating the annual energy generation of REI PV installations.

	Case	Procedure
1	Satellite imagery available and PV was the only system type	a) System size was estimated based on the system cost using an estimated 9.6 [$/$W_p$]. b) System size estimate was checked by using the estimated size and the number of modules to determine the module rating. If the module rating was unrealistically large then the system size was re-estimated by multiplying the number of modules with an estimated module rating of 245[W_p] (the largest reasonable module size). c) Annual system energy yield was estimated by multiplying the system size with the estimated specific yield [kWh/kW_p]. The specific yield estimate was based on the system orientation.
2	Satellite imagery available and multiple system types	a) The number of modules was determined from satellite imagery. b) System size was estimated by multiplying the number of modules with an estimated module rating of 210 [W_p]. c) Annual system energy yield was estimated by multiplying the system size with the estimated specific yield [kWh/kW_p]. The specific yield estimate was based on the system orientation.
3	Satellite imagery not available and only PV	a) System size was estimated based on the system cost using an estimated 9.6 [$/$W_p$]. b) Annual system energy yield was estimated by multiplying the system size with a specific yield to be 1154 [kWh/kW_p].
4	Satellite imagery available and did not see PV in satellite imagery	a) If there was no PV system at the exact address given but there was a PV system in what appears to be the same housing complex. Then it was assumed that the PV system was the one funded under REI.

3.3.1.2 *PV Yield Estimate: Example 1*

A Non-Profit Apartment Corporation in Southern Ontario received $99,770 for a PV installation. The system was viewed using Google Earth satellite imagery. It was determined to have 52 modules oriented roughly 15° S of W. Assuming an average system cost of 9.6 [$/$W_p$], the system size was estimated to be 10.4 [kW_p]. This would lead to a module rating of 200 [W_p], a reasonable value given the estimate in Table 3-1. Since the system azimuth was greater than 60° from due south, the specific yield was estimated to be 1033 [kWh/kW_p], 85% of the estimated maximum value. Multiplying the system size with the specific yield led to annual energy yield estimate of 10,700 [kWh].

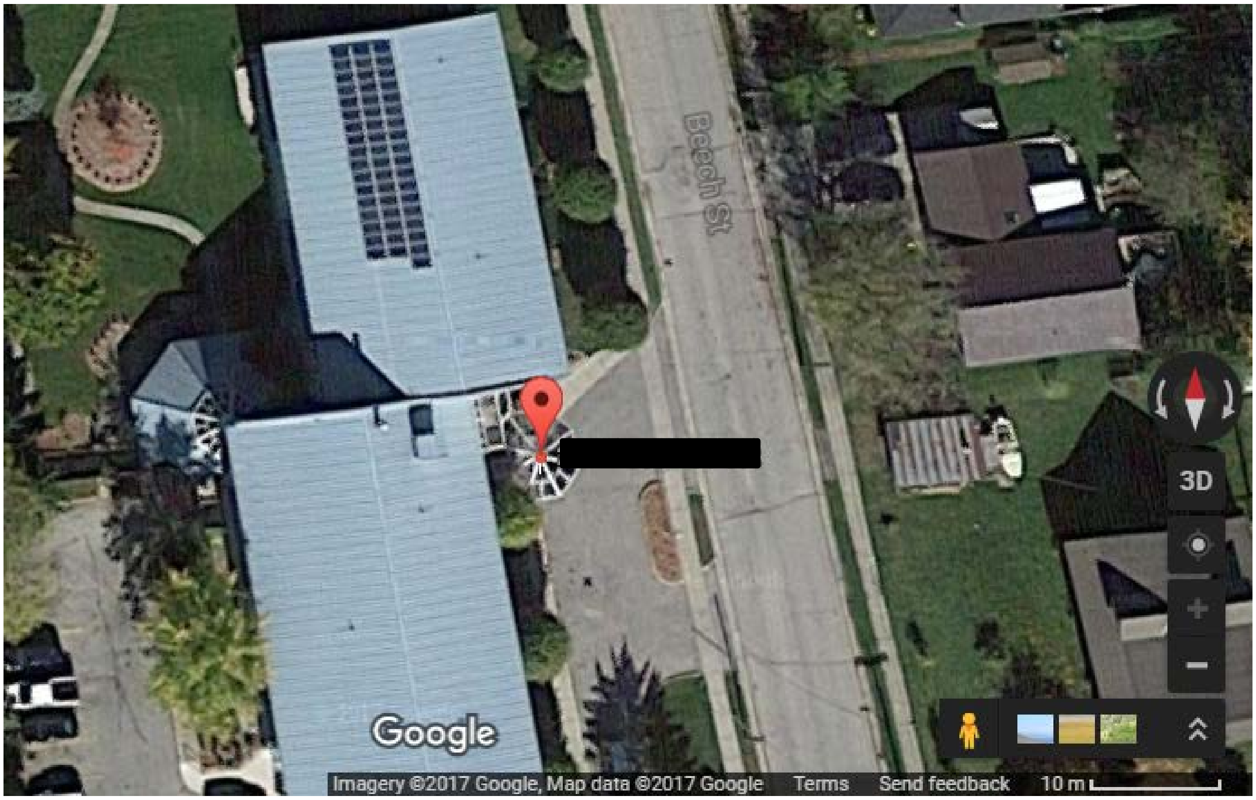

Figure 3-15. With the aid of satellite imagery, the annual energy yield of the PV system at a Southern Ontario Non-Profit Apartment Corporation was estimated to be 10,700 [kWh].

3.3.1.3 *PV Yield Estimate: Example 2*

Ahmadiyya Abode of Peace Inc. received $605,346 for PV, SDHW and solar air systems. The system was viewed using Google Earth satellite imagery. It was determined to have 45 modules mounted on a vertical wall (on top of solar air collectors) with an azimuthal orientation that is 20° E of S. The system size was estimated to be 9.5 [kW_p], based on an estimated module rating of 210 [W_p]. Using Figure 3-14 as a guide, the specific yield was estimated to be 67.5% of the maximum value based on the orientation of the system. The total annual energy yield was then estimated to be 7,800 [kWh].

Figure 3-16. With the aid of satellite imagery, the annual energy yield of the PV system at this building was estimated to be 7,800 [kWh].

3.3.1.4 *Comparison with real-world data*

Actual performance data was collected from some system owners. In total, there were nine different systems with at least a full year of performance data. Table 3-3 compares the actual data with results from the estimation procedure listed in Table 3-2. In total, across the nine sites, the estimation procedure underestimated the actual yield by 11%, suggesting that the estimation procedure is conservative. Note that there are many reasons why a single site might deviate from the estimated yield and the actual yield will fluctuate on an annual basis. Nonetheless, the estimation procedure used in this analysis appears to be reasonable. However, in the subsequent analysis, a calibration factor was used to account for the discrepancy between the estimation procedure and the actual data. Based on Table 3-3 the calibration factor is 1.12 (i.e. 202,000 [kWh] x1.12=226, 000 [kWh]).

Table 3-3. Comparison of PV estimation results with real-world data.

Index	Estimated System Size [kW_p]	Vertical (Yes or No)	Azimuthal Orientation	Estimated Specific Yield [kWh/kW_p]	Estimated Annual Yield [kWh]	Actual Annual Yield [kWh]	Difference b/w Estimated and Actual [%]	Year(s) of Data Collection
208	9.5	Yes	20° E of S	820	7,790	8,168	-4.6	2015
178	4.8	No	15° E of S	1154	5,539	4,560	21.5	2012 to 2016
315	8.9	No	50° E of S	1154	10,271	13,334	-23.0	2015
24	7.7	Yes	25° E of S	820	6,314	6,871	-8.1	2012 to 2015
307	10.1	No	25° E of S	1154	11,655	11,900	-2.1	2012 to 2013
305	10.1	No	30° E of S	1154	11,655	12,300	-5.2	2012 to 2013
305	10.1	No	55° E of S	1154	11,655	11,750	-0.8	2012 to 2013
424	71.5	No	5° W of S	1154	82,511	101,930	-19.1	2015
422	47.5	No	5° W of S	1154	54,815	55,276	-0.8	2015
				Total	**202,206**	**226,089**	**-10.6**	

3.3.1.5 *Lifetime Energy Generation*

Power degradation was taken into account when determining lifetime energy generation (Equation (3-1)). In this equation:

- $Y_{PV,i,j}$ is the PV energy yield in units [kWh] of the i^{th} installation in the j^{th} year;
- $Cap_{PV,i}$ is the estimated rated capacity of the i^{th} system in units [kW_p];
- $Y_{s,i}$ is the specific yield of the i^{th} installation based on the system orientation;
- d is the annual power degradation in decimal units; and
- CF is a calibration factor to account for the discrepancy between the estimation procedure and the real-world data.

$$Y_{PV,i,j} = Cap_{PV,i} \cdot Y_{s,i} \cdot (1 - d \cdot (j - 1)) \cdot CF \tag{3-1}$$

The total PV energy lifetime energy yield, Y_{PV}, is given in Equation (3-2). Note that the summation is over all 255 installations in the REI and over an estimated 25 years of operation.

$$Y_{PV} = \sum_{j=1}^{25} \sum_{i=1}^{255} Y_{PV,i,j} \tag{3-2}$$

3.3.1.6 *Challenges and Issues*

Several providers noted that they had grid connection issues. At least four installed a system that they were then unable to connect. Two of them moved the system (or planned to move the system). There was no further data for one, and another installed a battery bank. It was assumed that the system with the battery bank produced electricity at a value of 0.15 [$/kWh] (approximately the market rate). It was also assumed other systems were connected with a FIT contract at another location.

3.3.1.7 *Technical analysis results*

In total, funding was provided for 255 PV systems with a cumulative capacity of 3.7 [MW_p] and an estimated lifetime generation of 132 [GWh] for an average system lifetime of 30 years.

3.3.2 Financial analysis

The financial analysis built upon the results of the technical analysis by estimating the net benefits provided to the PV systems owners based on the energy generation. The result of the analysis depends on the accuracy of the input parameters, not all of which are known with accuracy. To account for this, different iterations of the calculation considered different input parameters. Table 3-4 outlines all parameter values that were considered.

Table 3-4. Parameters used in PV system financial analysis.

Parameter	Unit	Value	Description
Energy rate during FIT contract	[¢/kWh]	80.2 (<10 [kW_p]) 71.3 (>10 [kW_p])	At the time of the REI, the province's feed-in tariff (FIT) was in effect. This offered a guaranteed price for PV electricity sold to the grid that was above market rate, to cover costs plus a reasonable rate of return. Historical FIT prices are shown in Table 3-5[43]. Dates given are for when the price was instituted. The difference between 2009 and 2010 is for non-rooftop systems that are less than 10 [kW_p]). Very few REI systems fell into this category. Noting the fact that systems with an estimated capacity slightly over 10 kW_p are much more likely to be microFIT rather than FIT installations (due to the higher tariff) the analysis actually assumed anything below 15 [kW_p] was microFIT and anything above was FIT.
Energy rate after FIT contract	[¢/kWh]	0 or 0.20	FIT contracts last for 20 years. It is anticipated that systems will operate on a net-metering basis for the remainder of their useful life. Details of net-metering are not clearly laid out at this early stage. A value of 0.20 [$/kWh] was used in lieu of a better estimate. However, it is not known for sure that systems will continue into a net-metering arrangement. One iteration of the financial calculations assumes that the system do not continue to operate after the FIT term is over and another iteration assumes the systems do continue according to net metering.
Annual O&M costs	[% of total system first costs]	0, 0.2, or 1	O&M costs might include insurance, performance monitoring, a maintenance contract, snow removal, administration, etc. A value of 1% of the total system cost was typically estimated by consultants based on review of several REI feasibility analyses. In those cases where the provider purchased a maintenance contract, the cost of maintenance would be included in the funding provided by the REI and is not an additional expense to be considered in the financial case. However, it was reported that maintenance contracts were sometimes insufficient and the fraction of sites that procured a maintenance contract with REI funds is not accurately known. NREL estimates that the maintenance costs of PV systems that are less than 100 [kW] is between 19 and 21 [$/(kW year)][44]. Given system costs of the REI, this is approximately 0.2% of system first costs. The final analysis considered

[43] IESO, "FIT/microFIT Price Schedule (January 1, 2016)," 2016. Retrieved Feb. 2, 2017 from,http://fit.powerauthority.on.ca/sites/default/files/version4/FIT-Price-Schedule-2016-01-01.pdf

[44] NREL, "Distributed Generation Renewable Energy Estimate of Costs (Updated February 2017)," Retrieved Mar. 13,, 2017 from http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html

			annual O&M costs of 0%, 0.2% and 1%, with 0.2% anticipated to be the most accurate value.
Inverter replacement cost	[% of total system first costs]	5	Based on review of several REI feasibility analyses it was estimated that there is a one-time inverter replacement cost, equal to 5% of the total system cost that happens after 15 years.
System disposal cost	[$]	0	There may be additional expense to remove the system at the end of its useful life. As an estimate, removal costs are anticipated to be somewhat balanced by the end of life system value. Disposal costs were not considered in any of the REI feasibility analyses that were provided.
End of life system value	[$]	0	There is still value in the system at the end of its useful life particularly in the salvage value of components. However, the end of life system value is anticipated to be somewhat balanced by the removal costs. End of life system value is not considered in any of the REI feasibility analyses. PV Value is a software package developed in partnership with Sandia National Labs that can be used to appraise the value of a PV system. It states the following in regards to salvage value[45]: *"The value of the components at the end of 20, 25 or 30 years (the standard module warranty period) is similar to other rapidly advancing technologies which have reached the end of their warranty period, and although the PV system may continue to produce energy at a reduced rate for 40+ years (a bonus for the system owner at that time), electrical codes, efficiencies and manufacturing practices will have changed over the years. These factors combined with an expired warranty could render the technology obsolete. Currently there is no existing, reliable secondary market in place that can assign a value to mass-produced 25+ year old modules and inverters. In its absence, a scrap value of the components (metals) could be used. Since a present value calculation over 20, 25 or 30 years must also be used against the scrap value, the end result adds very little to the valuation and therefore is not included in the model."* Given that this data was not available in the feasibility analyses and that other reputable PV organizations omit end-of-life system value from their calculation tools, end-of-life system value was assumed to be zero.

[45] PV Value User Manual v. 1.1, 2012. Retrieved Mar. 13,2017 from http://energy.sandia.gov/wp-content/gallery/uploads/PV_Value_v1_1_user_manual.pdf

Inflation rate	%	1.5	Future cash flows were discounted according to the inflation rate as determined from the Bank of Canada inflation rate calculator[46].
Calibration factor (CF)	-	1 or 1.12	Equation (3-1) includes a calibration factor that can be used to correct discrepancies between the estimation procedure and the limited real-world data that was available. Table 3-3 suggests that the value of the calibration factor should be 1.12. However, the dataset is small (9 of 255 sites) and this is likely not sufficient to determine a calibration factor accurately. Different iterations of the financial analysis considered both a calibrated and an uncalibrated calculation.

Table 3-5. Historical PV Feed-In Tariff schedule around the time of the REI.

Category	Size	Sept. 24th, 2009	Aug. 13th, 2010	April 5th, 2012
PV Rooftop	<10 [kW_p]	80.2	80.2	54.9
	>10 [kW_p]<100 [kW_p]	71.3	71.3	54.8
	>100 [kW_p]<500 [kW_p]	63.5	63.5	53.9
PV Non-Rooftop	<10 [kW_p]	80.2	64.2	44.5
	>10 [kW_p]<500 [kW_p]	44.3	44.3	38.8

3.3.2.1 *Equations for Financial Analysis*

Two financial metrics were calculated. The net lifetime benefits to the system owners are given in Equation (3-3). This represents the impact for providers that participated in the program. The second financial metric is a ratio of net lifetime benefits to the total first costs. It is defined in Equation (3-4)[47]. This represents the cost-effectiveness of the investment from the province. Annual cash flows include power degradation and O&M costs, and are discounted to 2010 dollars according to the rate of inflation. In these equations:

- B_{PV} is the net lifetime benefits for system owners;
- $T_{i,j}$ is the feed-in tariff rate for the jth PV installation in the ith year;
- $C_{PV,i}$ is the total first costs of the ith PV system;
- r is the rate of inflation in a decimal unit;
- f_{inv} is the fraction of the total system cost required for the inverter;
- $f_{O\&M}$ is the fraction of total system cost required for O&M expressed as a decimal unit; and
- R_{PV} is a ratio of the total lifetime benefits to the first cost.

[46] Bank of Canada, "Inflation Calculator," 2016. Retrieved Feb. 2, 2017 from http://www.bankofcanada.ca/rates/related/inflation-calculator/.

[47] The term benefit-cost ratio was avoided here to avoid confusion. It is normally understood that a benefit-cost ratio would discount cash flows taking into account to a lost opportunity for other investment. This would allow one evaluate an investment in a RE retrofit against another investment. This was not done here. The purpose of expressing the net lifetime benefits as a ratio with respect to first costs is to be able to evaluate the level of benefits for each REI technology with respect to how much funding was provided.

$$B_{PV} = \left(\sum_{j=1}^{25} \sum_{i=1}^{255} \frac{Y_{PV,i,j} \cdot T_{i,j} - f_{O\&M} \cdot C_{tot,i}}{(1+r)^{(j-1)}} \right) - \left(\sum_{i=1}^{255} \frac{C_{tot,i} \cdot f_{inv}}{(1+r)^{15}} \right) \quad (3\text{-}3)$$

`

$$\boldsymbol{R_{PV}} = \frac{\boldsymbol{B_{PV}}}{\sum_{i=1}^{255} \boldsymbol{C_{PV.i}}} \quad (3\text{-}4)$$

3.3.2.2 *Results*

The total cost for PV in the REI was estimated to be 39.1M$. Total net lifetime benefits to the housing providers (shown in Table 3-6) was calculated using different iterations of the parameters provided in Table 3-4. Given the range of parameters considered, the total net lifetime benefits was estimated to be between 46.4M$ and 64.1M$. The most likely scenario is highlighted. It assumes that: (i) system owners pay 0.2% of total first cost for annual maintenance over and above any up-front maintenance contracts; (ii) system lifetime is 30 years but after the 20 year FIT term is over the system will be connected to the grid selling power at 0.20 [$/kWh]; and (iii) a calibration factor of 1.12 is used to align the estimation procedure with the real-world dataset. Using these assumptions, the total net lifetime benefits for PV system owners were estimated to be 62.2M$.

For every dollar spent by the province on PV installations for social and affordable housing providers, it was estimated that those providers received 1.59$ in 2010 dollars over the lifetime of the system. It is important to note that PV electricity was subsidized under the FIT program in addition to the REI. The good financial performance is dependent on the price paid for PV electricity. In this analysis, PV was not "penalized" for drawing from more than one subsidy.

Table 3-6. Lifetime benefits to PV system owners calculated using different input parameters

#	Lifetime	$f_{O\&M}$	CF	Electricity value after FIT [$/kWh]	B_{PV}	Net lifetime benefits/ First costs
1	25	0	1	0.2	$54,606,679.60	1.40
2	30	0	1	0.2	$57,067,296.83	1.46
3	25	0.002	1	0.2	$52,971,874.22	1.35
4	30	0.002	1	0.2	$55,172,414.68	1.41
5	25	0.01	1	0.2	$46,432,652.67	1.19
6	30	0.01	1	0.2	$47,592,886.10	1.22
7	25	0	1.12	0.2	$61,346,011.30	1.57
8	30	0	1.12	0.2	$64,101,902.59	1.64
9	25	0.002	1.12	0.2	$59,711,205.92	1.53
10	30	0.002	1.12	0.2	$62,207,020.45	1.59
11	25	0.01	1.12	0.2	$53,171,984.37	1.36
12	30	0.01	1.12	0.2	$54,627,491.86	1.40
13	20	0	1	0	$51,879,296.97	1.33
14	20	0.002	1	0	$50,524,668.12	1.29
15	20	0.01	1	0	$45,106,152.70	1.15
16	20	0	1.12	0	$58,291,342.76	1.49

17	20	0.002	1.12	0	$56,936,713.90	1.45
18	20	0.01	1.12	0	$51,518,198.49	1.32

3.3.2.3 *Limitations of the analysis*

The estimation procedure could only be compared against performance results from a small fraction of systems. This system performance data was used to calibrate the estimation procedure but, given that it is only a small amount of data, the calibration is imperfect. A sensitivity analysis (Table 3-6) was provided to show how the results vary with different input parameters. Ultimately, these are only best estimates and the accuracy of the analysis could be improved in future programs with M&V and additional record keeping.

3.3.3 GHG analysis

The technical analysis estimated that the lifetime energy generation of the PV installations was 132 [GWh]. If PV is replacing grid electricity with an EF of 50 [g CO_2e/kWh], it is estimated that the emissions savings is 6.6 [kt CO_2e].

3.3.4 PV analysis summary

In total, 39.1M$ was provided by the MHO to install an estimated 3.7 [MW_p] of PV across 255 locations. Over the lifetime of the systems, this was estimated to have generated:

- a total of 132 [GWh] of renewable electricity;
- a total of 62.2M$ in benefits for system owners; and
- an emissions savings of 6.6 [kt of CO_2e].

3.4 Solar domestic hot water

3.4.1 Technical analysis

There were 80 sites that were provided funding for SDHW systems under the REI, with an estimated total funding of 12.1M$. A breakdown of system costs is presented in Figure 3-17. The aim of the technical analysis was to estimate the total annual energy generation over the lifetime of the SDHW systems. This required extensive use of estimation. Parameter estimates are defined in Table 3-7.

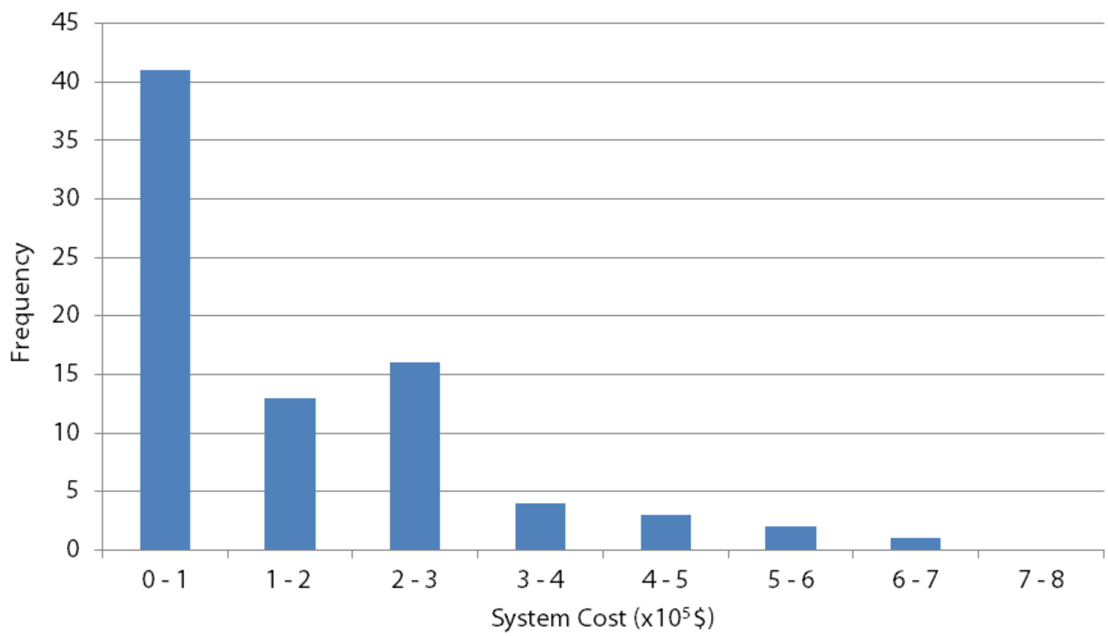

Figure 3-17. Most SDHW systems were less than $100,000.

Table 3-7. Parameters values used in the SDHW technical analysis.

Parameter	Unit	Value	Description
Average SDHW collector performance	[kWh/m^2]	500	Table 3-3 showed that using an estimated specific yield for a PV installation, on average, allowed for a reasonably good estimate of actual performance. There are a few notable factors that allowed for this level of accuracy: (i) every kWh produced by PV is exported to the electricity grid to provide useful income, (ii) PV installations tend to operate with minimal O&M and, (iii) if they fail catastrophically, it will be evident in the payments provided from the utility. SDHW systems are more maintenance intensive. They will sometimes produce heat that is not useful depending on how the system was sized and they may fail without obvious signs of failure. It follows that an estimated performance metric [kWh/m^2] per year may *only produce an approximate estimate – actual performance may vary greatly*. In this analysis, a minimum amount

			of data was provided about systems, typically only the cost. The collector area was estimated from satellite imagery. Performance results from previous studies in the GTA are shown in Table 3-8. They showed an average energy generation of approximately 500 [kWh/m^2], where m^2 refers to gross collector area. This was used as the expected system performance in this analysis. It is acknowledged that this approach is approximate but is necessary given the limited availability of any system specifications or performance data. No corrections were made from system orientation because this is a high-level estimate. There were a small number of feasibility studies that gave information on both the total system area and expected energy generation. These estimated energy production to be between 600 and 650 [kWh/m^2], suggesting that 500 [kWh/m^2] may be conservative. The approach used in this analysis was to base assumptions on actual real-world data as much as possible.
Average system cost	[$/$m^2$]	$2,760	It was sometimes necessary to estimate system size using only the system cost. Table 3-9 shows system cost results from previous work and REI feasibility studies where the average cost was 1,723 [$/$m^2$]. Based on areas estimated using satellite imagery, the median SDHW system cost in the REI was estimated to be 2,443 [$/$m^2$] and the mean cost was estimated to be 2,760 [$/$m^2$]. It would seem that within the REI actual system costs were higher than anticipated from feasibility studies and the small subset of previous work. Note that some of this may be due to some SDHW incorporating maintenance contracts into the total system first costs. The amount of funding for maintenance contracts was not included in centralized record keeping.
Performance degradation	[%/year]	0.5	A short literature review was conducted to evaluate performance degradation of SDHW collectors but it was not exhaustive. One study analyzed the performance of solar collectors after 15 years of operation and found performance degradation between 1% and 11% depending on the fluid temperature[48]. As an estimate, 0.5% per year was assumed.
Collector lifetime	[years]	25	A default value of 25 years was chosen[49]. NREL suggests lifetimes between 10 and 25 years[50].

[48] Fan, J. and Z. Chen, S. Furbo, B Perers, B. Karlsson. Efficiency and lifetime of solar collectors for solar heating plants," Proceedings of the ISES Solar World Congress, p. 331to 340, 2009. Retrieved Feb. 3 2017 from: http://orbit.dtu.dk/files/4035765/16%20Fan%20J.pdf

[49] This value is used in life cycle analyses. For example, see: Stucki, Matthias and Niels Jungbluth. "Update of the Life Cycle Inventories of Solar Collectors," ESU-services, 2012. Accessed online 02/02/2017: http://www.esu-services.ch/fileadmin/download/publicLCI/stucki-2010-Solar-Collector.pdf.

Performance de-rate	-	0.75	Site visit observations suggested that the actual system energy output would often be less than anticipated due to systems operating sub-optimally. It was necessary to incorporate this into the analysis and 0.75 was a best estimate – this means that on average, systems are estimated to be producing 75% of the expected energy.

Table 3-8. Results from previous SDHW studies used to form performance estimate in this analysis.

Source	Type	Total Gross Area [m²]	Annual Energy [kWh]	Energy per gross area [kWh/m²]
SolarCity Partnership[51]	Flat Plate	17.9	6,600	369
SolarCity Partnership[52]	Flat Plate	17.9	7,100	397
SolarCity Partnership[53]	Evacuated Tube	73.1	33,406	457
Master's Thesis[54]	Evacuated Tube	2.88	1,383	480
Master's Thesis[55]	Flat Plate	2.51	2,038	812
			Average:	**503**

[50] NREL, "Distributed Generation Renewable Energy Estimate of Costs (Updated February 2017)," Retrieved Mar. 13, 2017 from: http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
[51] SolarCity Partnership, "Toronto Fire Station #212 12.5 kWt Solar Water Heating Installation Final Report," 2012. Retrieved Feb. 3, 2017 from: http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2016/06/FH212-finalreport.pdf.
[52] SolarCity Partnership, "Toronto Fire Station #231 12.5 kWt Solar Water Heating Installation Final Report," 2012. Retrieved Feb. 3, 2017 from: http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2016/06/FH231-finalreport.pdf.
[53] SolarCity Partnership, "Wilmar Court 37 kWt Solar DHW Installation Final Report," 2013. Retrieved Feb. 3, 2017 from: http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2016/06/wilmar-court-final-report_final.pdf.
[54] K. Tanha, "Evaluating the Performance of Two Solar Domestic Hot Water Systems of the Archetype Sustainable Houses," *Ryerson University Masters Thesis,* 2012.
[55] Tanha (2012).

Table 3-9. Previous work and feasibility studies used to estimate the SDHW system cost.

Source	Type	Cost [$]	Total Gross Area [m²]	Cost [$/m²]
SolarCity Partnership[56]	Flat Plate	29,339	17.9	1,639
SolarCity Partnership[57]	Flat Plate	40,631	17.9	2,270
SolarCity Partnership[58]	Evacuated Tube	141,147	73.10	1,931
REI Feasibility Analysis 1	Flat Plate	16,000	10.9	1,468
REI Feasibility Analysis 2	Flat Plate	9,900	6.54	1,514
REI Feasibility Analysis 3	Flat Plate	9,900	6.54	1,514
			Average:	**1,723**

3.4.1.1 *Procedure*

As with PV, there were different cases of how annual energy yield was estimated based on the data that was available. These are listed in Table 3-10.

Table 3-10. Procedure for estimating the annual energy generation of REI SDHW installations.

	Case	Procedure
1	Satellite imagery available and SDHW only system type	a) System area was estimated using Google Earth satellite imagery. b) System energy production was estimated assuming 500 [kWh/m²].
2	Satellite imagery available and both PV and SDHW present	a) System area was estimated using Google Earth satellite imagery. b) System energy production was estimated assuming 500 [kWh/m²]. c) SDHW system cost was estimated by subtracting the PV system cost from the total system cost.[59]
3	Satellite imagery and PV, solar air and SDHW present	a) System area was estimated using Google Earth satellite imagery. b) System energy production was estimated assuming 500 [kWh/m²]. c) SDHW system cost was determined by multiplying the area with 2,760 [$/m²].
4	Satellite imagery not available and only SDHW	a) System area was determined by dividing the system cost by $2,760 [$/m²]. b) System energy production was estimated assuming

[56] SolarCity Partnership, FS #212 (2012).
[57] SolarCity Partnership, FS #231 (2012).
[58] SolarCity Partnership (2013).
[59] Ultimately, PV system costs vary much less than SDHW and the PV system cost estimates are more accurate, so PV costs were estimated first and the remainder was assigned to SDHW.

500 [kWh/m^2].

3.4.1.2 *Example 1*

A private housing provider in Southern Ontario was provided $169,805 by the REI program for a PV and a SDHW system (Figure 3-18). It was estimated in a previous step that $92,400 was provided for PV and therefore, it was estimated that $77,405 was provided for SDHW. By viewing the system in satellite imagery, it was determined that there were 12 SDHW collectors with a gross area of 4.10 [m^2] each, giving a total area of 44.5 [m^2]. It appears that they are evacuated tube collectors but they were not treated differently in this analysis. Based on the area and total cost, the cost per unit area of the installations was then estimated to be 1,739 [$/m^2], a reasonable value given Table 3-9. Assuming an average energy production of 500 [kWh/m^2], the annual energy production was estimated to be 22,250 [kWh].

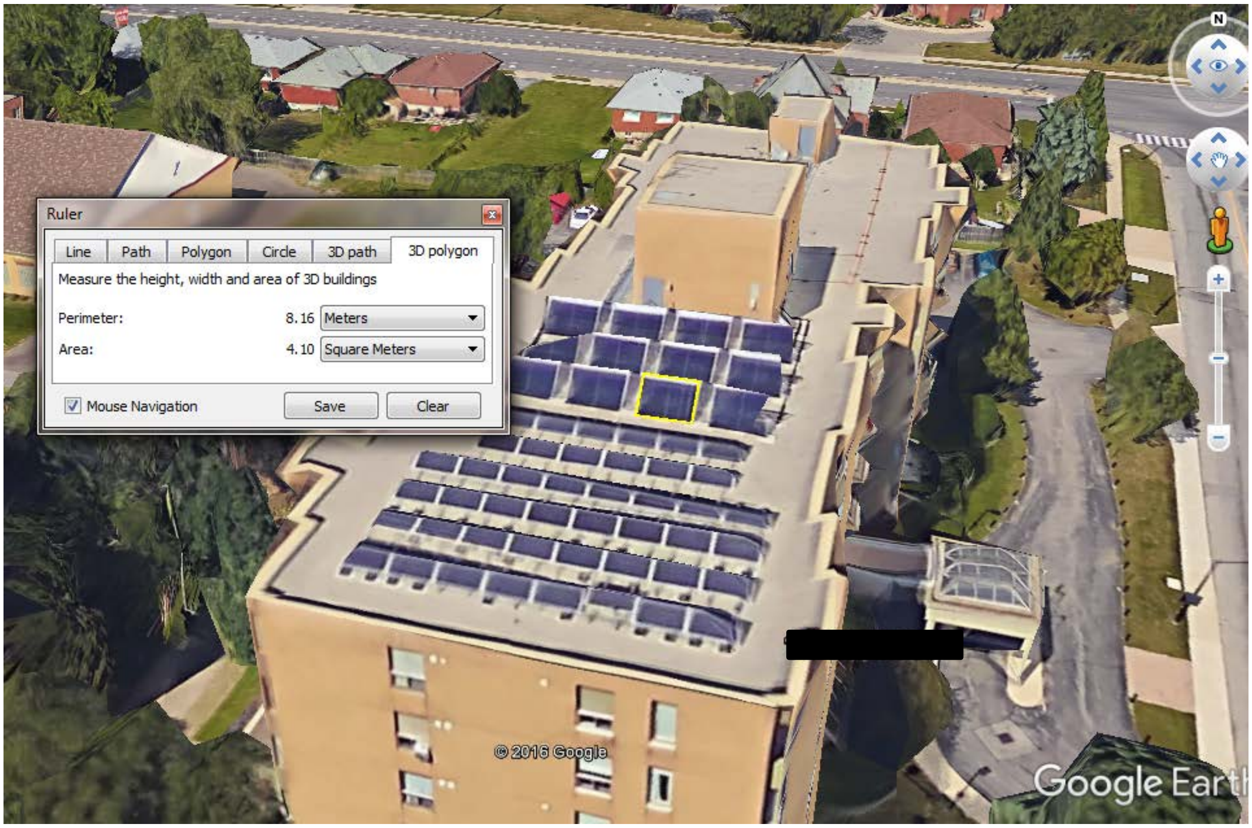

Figure 3-18. Using the estimation procedure outlined in this section, the annual energy produced by the SDHW system a private housing provider's building in Southern Ontario was estimated to be 22,250 [kWh].

3.4.1.3 *Lifetime Energy Generation*

The total lifetime energy generation from the REI SDHW systems is simply the sum for each year and for each individual system. Lifetime energy generation is shown Equation (3-5).

- Y_{SDHW} is the lifetime energy yield of all REI-funded SDHW systems in units [kWh];
- j is an index for the year;

- i is an index for the systems;
- δ is the performance de-rate for systems not working effectively;
- $Y_{SDHW.s}$ is the estimated SDHW specific yield of [kWh/m²] per year;
- $A_{SDHW,i}$ is the collector area of the i[th] SDHW system in units [m²]; and
- d_{SDHW} is the performance degradation factor in decimal units.

$$Y_{SDHW} = \sum_{j=1}^{25}\sum_{i=1}^{80} \delta \cdot Y_{SDHW,s} \cdot A_{SDHW,i} \cdot (1 - d_{SDHW} \cdot (j-1)) \tag{3-5}$$

3.4.1.4 *Results*

In total, funding was provided for 80 SDHW systems with a total estimated collector area of 4,560 [m²] and a lifetime estimated energy generation of 40.2 [GWh].

3.4.2 Financial analysis

The financial analysis built upon the results of the technical analysis by estimating the net benefits provided to the SDHW system owners based on the estimated energy generation. It is worth noting that analysis for SDHW is notably different than that for PV in that savings depends on the costs of natural gas and electricity, both of which are variable in time and difficult to forecast. This is discussed in Table 3-11.

Table 3-11. Parameter values estimates for financial analysis of SDHW systems.

Parameter	Unit	Value	Description
Total cost of gas	[$/m³]	0.32 – 0.62	See Appendix B.
Cost of electricity	[$/kWh]	-	See Appendix C.
Heating value of gas	[kWh/m³]	10.5	The higher heating value (HHV) of natural gas is between 950 and 1150 [Btu/ft³][60]. There is 0.010 [kWh/m³] for every [Btu/ft³]; it follows that the HHV could be estimated to be between 9.5 [kWh/m³] and 11.5 [kWh/m³]. Lower heating value is 850 to 1050 [Btu/ft³] (8.5 to 10.5 [kWh/m³]).
Annual fuel utilization efficiency (AFUE)	[%]	90	The financial performance of a SDHW improves when the efficiency of the gas-heating appliance decreases. A low efficiency boiler may be in the range of 70% and a higher efficiency version may be greater than 90%. Data was not available on the efficiency of boilers in the REI. Normally it would be a more attractive investment to upgrade an old

[60] Engineering Toolbox. "Fuel Gases Heating Values". Retrieved Feb. 3, 2017 from: http://www.engineeringtoolbox.com/heating-values-fuel-gases-d_823.html

			boiler than to add a SDHW system, so it was assumed that the primary heating AFUE was high.
Fuel being offset	-	80% Natural gas 20% Electric	See Section 3.2.3.
Annual O&M costs	[% of total system first costs]	0 and 1	NREL estimates that annual maintenance costs of SDHW to be between 0.5 and 1.0% of total first costs[61] and within the REI, SDHW was often reported to be maintenance intensive. Many SDHW owners reported purchasing maintenance contracts with REI funds. In these cases, O&M should not be considered as an additional cost; however, providers also noted that they were often not happy with the performance of the maintenance contractor or that they had gone out of business. The analysis for SDHW is very sensitive to this parameter. For example, if 1% is assumed then, on average, the systems in gas-heated buildings cost more to maintain then they provide in savings. To avoid this sensitivity, one iteration of the calculation neglected annual maintenance costs and another assumed them to be 1% of system first costs.
Inflation Rate	%	1.5	Future cash flows were discounted according to the inflation rate as determined from the Bank of Canada inflation rate calculator between 2010 and 2016[62].

3.4.2.1 *Equations*

For SDHW, benefits come in the form of avoided operating costs rather than direct income. The financial performance is different when a SDHW system is offsetting electricity rather than offsetting natural gas. The analysis therefore evaluated the net benefits to systems owners under different scenarios: (i) assuming all systems are offsetting electricity; (ii) assuming all systems are offsetting gas and (iii) assuming that the systems are offsetting 80% natural gas and 20% electricity. These options are shown in Equations (3-6) to (3-11), respectively, where in addition to the parameters defined in the technical analysis:

- $B_{SDHW,elec}$ is the net lifetime benefits [$] assuming the SDHW systems are all offsetting electricity;
- $e_{elec,j}$ is the [$/kWh] electricity rate in the jth year;

[61] NREL, "Distributed Generation Renewable Energy Estimate of Costs (Updated February 2017)," A Retrieved Mar. 13, 2017 from: http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html
[62] Bank of Canada (2016).

- $f_{O\&M}$ is the fraction of system first costs required for annual O&M;
- is the first costs of the i[th] SDHW system;
- r is the rate of inflation as a decimal unit;
- is a ratio of benefits to first costs when assuming all SDHW systems are offsetting electricity;
- is the net lifetime benefits [$] assuming the SDHW systems are offsetting gas;
- $AFUE$ is the fuel efficiency for natural gas as a decimal;
- HV is the heating value of natural gas in units [kWh/m^3];
- is the cost of gas in units [$/m^3];
- is a ratio of benefits to first costs when assuming all SDHW systems are offsetting natural gas;
- is the net lifetime benefits [$] assuming the SDHW systems are offsetting 20%/80% mix of electricity and gas; and
- $R_{SDHW,tot}(e_{gas})$ is a ratio of benefits to first costs when assuming SDHW systems are offsetting 20%/80% mix of electricity and gas.

Note the summations are performed over the 25-year system lifetimes and across all 80 SDHW systems.

$$B_{SDHW,elec} = \sum_{j=1}^{25}\sum_{i=1}^{80} \frac{\delta \cdot Y_{s,SDHW} \cdot A_{SDHW,i} \cdot (1 - d_{ST} \cdot (j-1)) \cdot e_{elec,j} - f_{O\&M} \cdot C_{ST,i}}{(1+r)^{(j-1)}} \quad (3\text{-}6)$$

$$R_{SDHW,elec} = \frac{B_{SDHW,elec}}{\sum_{i=1}^{80} C_{SDHW.i}} \quad (3\text{-}7)$$

$$B_{SDHW,gas}(e_{gas}) = \sum_{j=1}^{25}\sum_{i=1}^{80} \frac{\delta \cdot Y_{s,SDHW} \cdot A_{SDHW,i} \cdot (1 - d_{ST} \cdot (j-1)) \cdot \left(\frac{1}{AFUE}\right) \cdot \left(\frac{1}{HV}\right) \cdot e_{gas} - f_{O\&M} \cdot C_{SDHW,i}}{(1+r)^{(j-1)}} \quad (3\text{-}8)$$

$$R_{SDHW,gas} = \frac{B_{SDHW,gas}(e_{gas})}{\sum_{i=1}^{80} C_{SDHW.i}} \quad (3\text{-}9)$$

$$B_{SDHW,tot}(e_{gas}) = 0.2 \cdot B_{elec} + 0.8 \cdot B_{SDHW,gas}(e_{gas}) \quad (3\text{-}10)$$

$$R_{SDHW,tot}(e_{gas}) = \frac{B_{SDHW,tot}(e_{gas})}{\sum_{i=1}^{80} C_{SDHW,i}} \quad (3\text{-}11)$$

Note that the benefits in the gas scenario are given as a function of the gas price.

3.4.2.2 *Results*

Neglecting maintenance costs and assuming all systems were offsetting electricity, the net lifetime benefits to system owners are estimated to be 7.5M$. In other words, for every 1$ invested by the

MHO in funding SDHW systems, 0.62$ in lifetime benefits is estimated to be received by social and affordable housing providers.

Figure 3-19 shows the net lifetime benefits if maintenance costs are neglected and it is assumed that all systems are offsetting natural gas. At a gas rate of 0.32 [$/m^3] (Jan. 2017 rate), the net lifetime benefits are estimated to be 1.1M$; at 0.62 [$/m^3] (roughly the highest historical gas cost in the past 10 years), the net lifetime benefits are estimated to be 2.2M$. In this scenario, for every 1$ invested by the MHO in SDHW systems, between 0.09$ and 0.18$ in lifetime benefits are estimated to be received by social and affordable housing providers.

The total lifetime benefits assuming a split of 20% for electricity and 80% for natural gas, and neglecting annual maintenance costs, are estimated to be between 2.4M$ and 3.3M$. In this scenario, for every 1$ invested by the MHO towards installing SDHW systems, it is estimated that social and affordable housing provides receive between 0.20$ and 0.27$ over the lifetime of the system.

The above results neglected maintenance costs. If annual maintenance costs are equivalent to 1% of the total first costs, then SDHW systems that are offsetting gas are estimated to collectively *cost more to operate than is provided in savings* regardless of whether the gas rate is 0.32 or 0.62 [$/m^3].

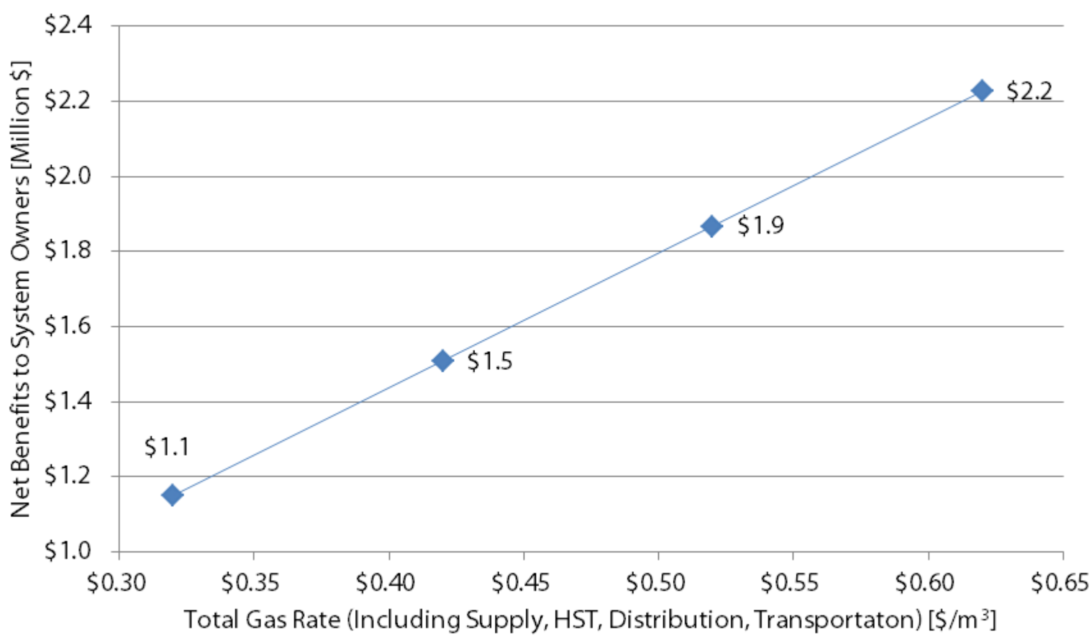

Figure 3-19. The net lifetime benefits, assuming all SDHW systems are offsetting natural gas, improves as the gas rate increases, but ultimately does not surpass, or even approach, the total costs to install the systems (12.1M$). This plot neglects maintenance costs.

3.4.2.3 *Limitations of the analysis*

This analysis was based on the limited data that was available. In most cases, system cost was known but this is the only data that was provided. Collector area was estimated through satellite imagery and the annual expected system performance was based on results from a limited amount of previous work. Many factors may affect system performance that could not be taken into account due to limitations of data availability. The results should be taken as a rough estimate.

3.4.3 GHG analysis

The technical analysis estimated a lifetime energy generation of 40.2 [GWh]. Assuming: (i) 20% of that is offsetting heating from electricity and 80% from natural gas; (ii) a gas heating value of 10.5 [kWh/m^3]; (iii) a gas heating efficiency of 90%; (iv) a grid emission factor of 50 [g CO_2e/kWh] and (v) a natural gas emission factor of 1900 [g CO_2e/m^3]; the total estimated emissions savings is 6.9 [kt CO_2e] according to Equation (3-12). Where,

- ΔGHG_{SDHW} is the greenhouse savings of all SDHW systems in units of [g CO_2e];
- EF_{elec} is the emission factor for electricity in units of [g CO_2e/kWh]; and
- EF_{gas} is the emission factor for gas in units of [g CO_2e/m^3].

$$\Delta GHG_{SDHW} = Y_{SDHW} \cdot \left[0.2 \cdot EF_{elec} + 0.8 \cdot EF_{gas} \cdot \left(\frac{1}{HV}\right) \cdot \left(\frac{1}{AFUE}\right)\right] \tag{3-12}$$

3.4.3.1 *SDHW Summary*

In total, 12.1M$ was provided by the MHO to install an estimated 4,560 [m^2] of SDHW collectors across 80 locations. Over the lifetime of the systems, this is estimated to have generated:

- a total of 40.2 [GWh] of renewable heat energy;
- between a total of 2.4M$ and 3.3M$ in lifetime benefits for system owners[63]; and
- an emissions savings of 6.9 [kt of CO_2e].

[63] However, as explained in Section 3.4.2.2 if additional annual maintenance costs are included, *the systems offsetting natural gas may collectively cost more to operate* than are provided in savings.

3.5 Solar air heating

3.5.1 Technical analysis

There were 17 sites that were provided funding for solar air heating systems under the REI, with an estimated total funding of 3.7M$. Individual system costs are presented in Figure 3-20. The aim of the technical analysis was to estimate the total annual energy generation over the lifetime of the systems. This required extensive use of estimation. Parameter estimates are defined in Table 3-12 and the procedure is defined in Section 3.5.1.1.

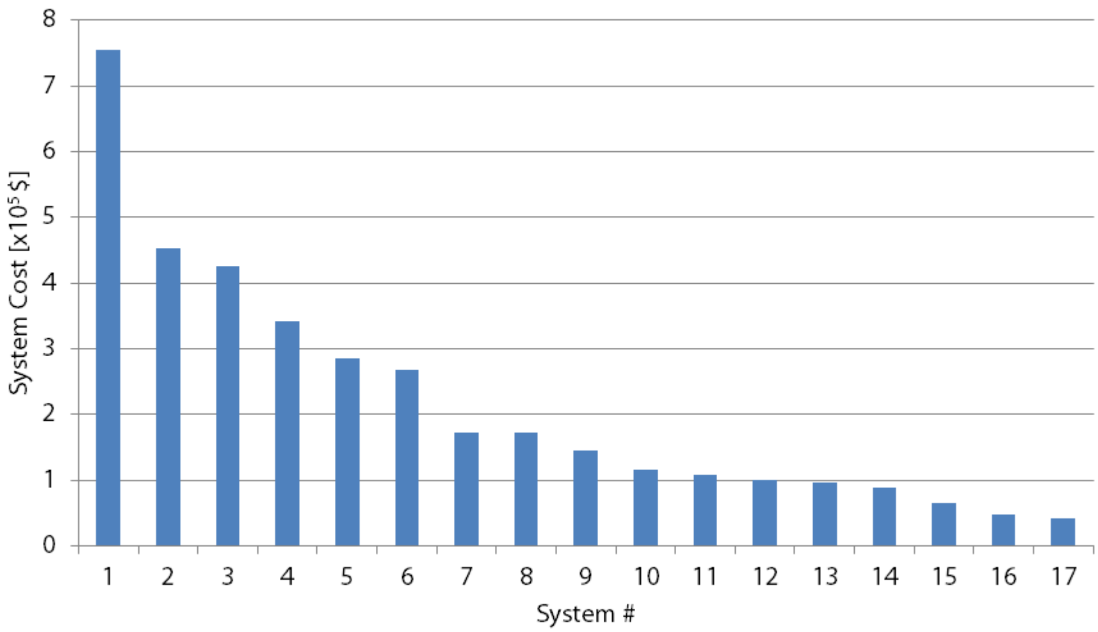

Figure 3-20. Individual solar air system costs.

Table 3-12. Summary of parameters required for solar air technical analysis.

Parameter	Unit	Value	Description
Annual energy generation	[kWh/m^2]	570	The expected performance [kWh/m^2] per year was required for the analysis. There is minimal performance monitoring data available from real-world installations. However, there was some minimal level of data available in the REI feasibility studies and in SolarWall case studies. Results from these sources are summarized in Table 3-13. For certain sources, only the modelled natural gas savings was given; the energy savings were calculated from this assuming a 90% efficiency and 10.5 [kWh/m^3] heating value of natural gas. The average system performance is 570 [kWh/m^2]. In practice, this will be affected by many factors: shading, orientation, make-up air scheduling, and state-of-repair of components and similar. Because not all of these factors can adequately be taken into account, this analysis did not further refine the 570 [kWh/m^2] estimate. This is therefore

			an approximate estimate.
Annual performance degradation	-	-	This was assumed to be zero since there is no data available to support an estimate.
System lifetime	[years]	30	SolarWall website claims 30+ year system lifetime.[64] NREL suggests 30 to 40 years.[65]

Table 3-13. Literature used to estimate annual performance of a solar air installation.

Building	Type of Information	Year of Study	Reported Natural Gas Savings [m^3]	Annual Energy Production [kWh/m^2]
NREL Waste Handling Facility Retrofit[66]	Monitoring data	2005		513
Ouelette Manor, Windsor[67]	Not clear	1994		584
Solar Air Site 1	REI Feasibility – Modelling Estimate	2010	8,223	627
Solar Air Site 2	REI Feasibility – Modelling Estimate	2010	2,397	113
Solar Air Site 3	REI Feasibility – Modelling Estimate	2010	6,006	405
Fred Douglas Place, Winnipeg[68]	SolarWall Case Study – Modelling Estimate	2009		690
Greater Sudbury Housing Corp[69]	SolarWall Case Study – Modelling Estimate	2007		1055
			Average:	**570**

[64] SolarWall, "SolarWall® Solar Air Heating and Ventilation Systems," Website. Retrieved Feb. 3, 2017 from: http://solarwall.com/en/products/solarwall-air-heating.php.
[65] NREL, "Distributed Generation Renewable Energy Estimate of Costs (Updated February 2017)," Retrieved Feb. 3, 2017 from: http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
[66] NREL, "Transpired solar collector at NREL's wastr handling facility uses solar energy to heat ventilation air," 2005. Retrieved Feb. 3, 2017 from: http://www.nrel.gov/docs/fy10osti/48453.pdf.
[67] CMHC, "Innovative Buildings: Solar Collector Lowers Highrise Heating". Retrieved Feb. 3, 2017 from: https://www.cmhc-schl.gc.ca/en/inpr/su/hirimu/inbu/upload/innovative-buildings-solar-collector-lowers-highrise-heating-costs.pdf.
[68] SolarWall, "Fred Douglas Place Case Study". Retrieved Feb. 3, 2017 from: http://solarwall.com/media/download_gallery/cases/FredDouglas_SolarWallCaseStudy_Y09.pdf.
[69] SolarWall, "Greater Sudbury Housing Corporation Case Study". Retrieved Feb. 3, 2017 from: http://solarwall.com/media/download_gallery/GreaterSudburyHousing-SolarWallCase.pdf.

3.5.1.1 *Procedure*

The only data provided about the systems was the first costs. System area was determined through Google Earth satellite imagery. The energy estimation procedure for an individual system was slightly different for two cases (Table 3-14).

Table 3-14. Procedure for energy estimates of solar air systems.

	Case	Procedure
1	Satellite imagery was available and funding was provided only for solar air	a. Estimate system area using satellite imagery. b. Estimate system annual energy production assuming 570 [kWh/m^2].
2	Satellite imagery was available and funding was provided for more than solar air	a. Estimate system area using satellite imagery. b. Estimate system annual energy production assuming 570 [kWh/m^2]. c. Estimate system cost by subtracting the estimated costs of all other systems from the total cost.

3.5.1.2 *Example*

A Southern Ontario municipal housing provider received $341,156 for a solar air installation. Satellite imagery showed the total system area was 386 [m^2]. Based on an expected performance of 570 [kWh/m^2], the annual energy generation from the installation was estimated at 220 [MWh].

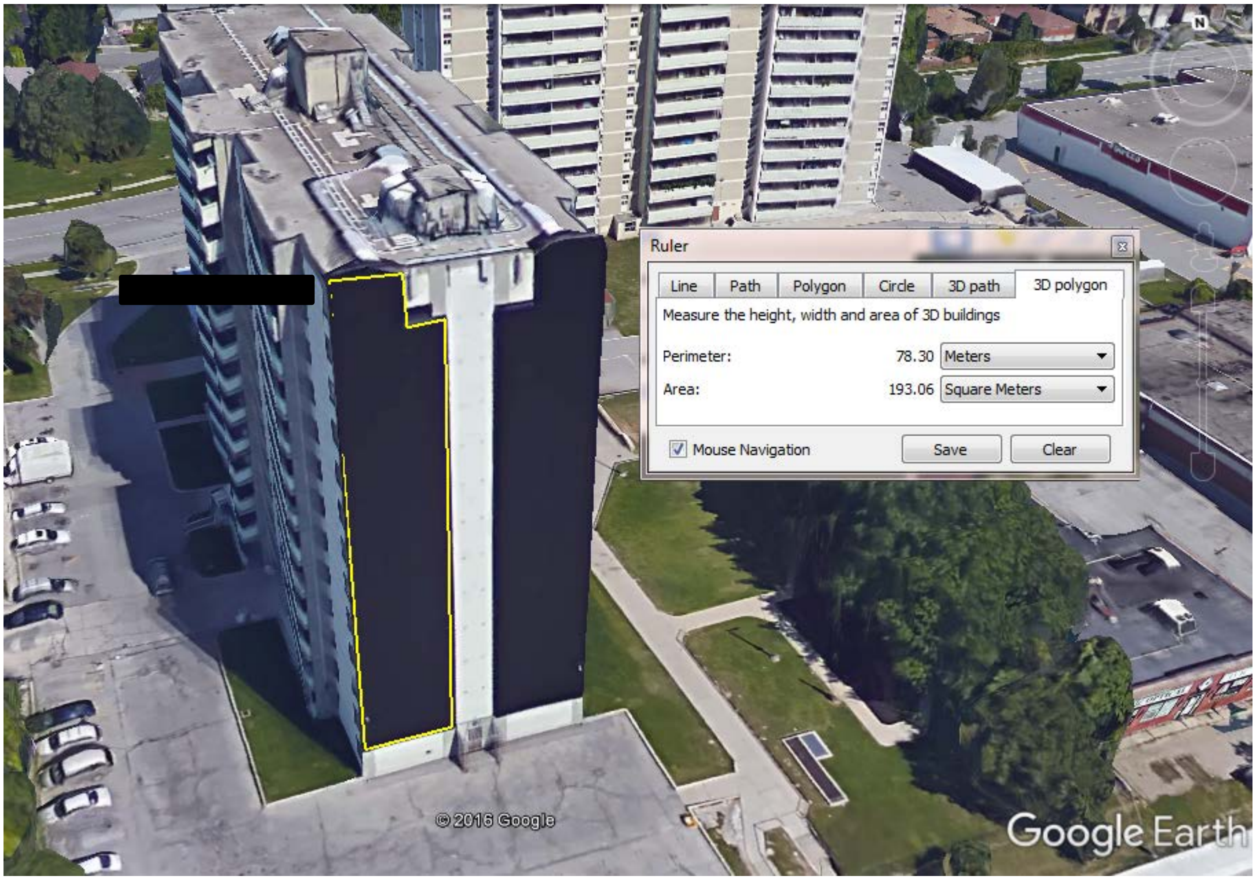

Figure 3-21. The annual energy generation at a Southern Ontario municipally owned building was estimated to be 220 [MWh].

3.5.1.3 *Lifetime Energy Generation*

Lifetime energy generation for all solar air installations in the REI is shown in Equation (3-13), where:

- Y_{SA} is the lifetime energy generation in units [kWh];
- $Y_{SA,s}$ is the specific yield for solar air installations in units [kWh/m^2] per year;
- l is the system lifetime; and
- $A_{SA,i}$ is the area of the ith solar air installation.

$$Y_{SA} = Y_{SA,s} \cdot l \cdot \sum_{i=1}^{17} A_{SA.i} \qquad (3\text{-}13)$$

3.5.1.4 *Results*

In total, there were 17 solar air installations funded by the REI and all were viewable using Google Earth satellite imagery. The total cost of all systems was 3.7M$ and the total installed area was estimated at 3,790 [m^2]. Total lifetime energy generation was estimated at 64.8 [GWh].

3.5.2 Financial analysis

The financial analysis built upon the results of the technical analysis by estimating the net benefits provided to the solar air system owners based on the energy generation.

Table 3-15. Parameters used in the solar air technical analysis.

Parameter	Unit	Value	Description
Cost of Gas	[$/m^3]	0.32 – 0.62	See Appendix B.
Cost of Electricity	[$/kWh]	-	See Appendix C.
Heating value of gas	[kWh/m^3]	10.5	Explained in Table 3-11.
Efficiency of make-up air unit	[%]	90	The financial performance of a solar air system improves when the efficiency of the make-up air unit decreases. Normally it would be a much more attractive investment to upgrade an inefficient make-up air unit then to add a solar air system, so it was assumed that the efficiency was high.
Fraction of buildings with electric heating	-	80% Natural gas 20% Electric	See Section 3.2.3.
Annual O&M costs	[% of total system first costs]	0	The system has no active components except a damper. It was assumed that operation and maintenance costs are negligible.
Inflation rate	%	1.5	Future cash flows were discounted according to the inflation ratio as determined from the Bank of Canada inflation rate calculator between 2010 and 2016[70].

Cost of individual solar installation is shown in Figure 3-22. There is a large variance in cost, from 310 [$/m^2] to 2,300 [$/m^2].

[70] Bank of Canada (2016).

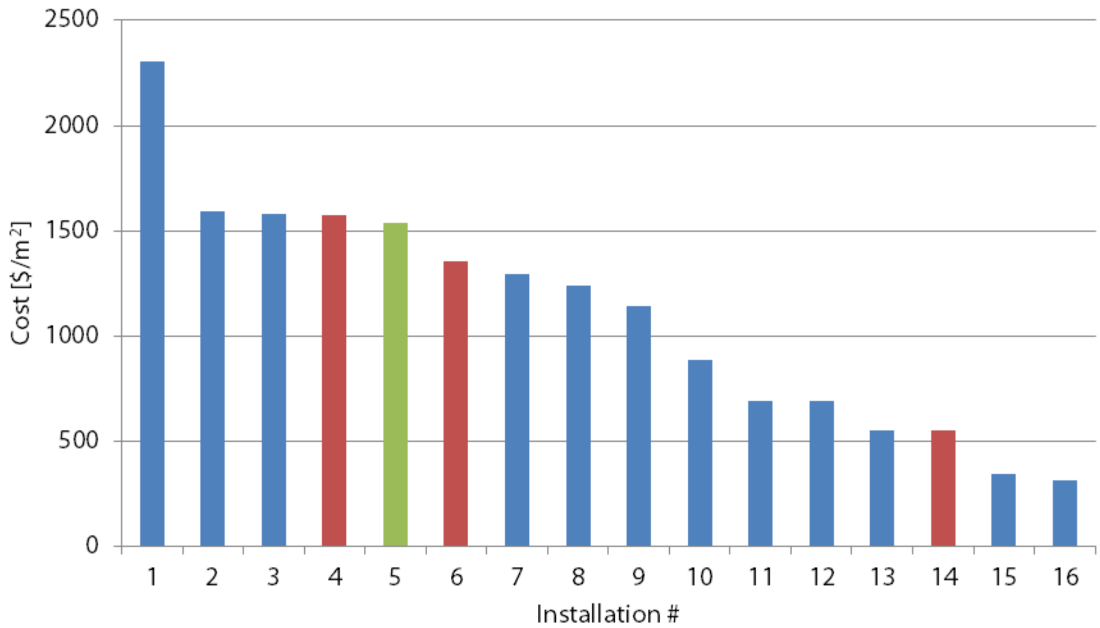

Figure 3-22. Cost of individual solar air installations. Blue columns represent large area solar air collectors like SolarWall. Red columns represent small area collectors attached to individual units. Green represents SolarDuct. There is a large variation in cost per unit area, which can partially be explained due to certain fixed costs related system installation that do not scale up proportionally to system size.

3.5.2.1 *Equations*

For solar air, benefits come in the form of avoided costs rather than direct income. The financial performance is very different when a solar air system is offsetting electricity rather than offsetting natural gas. The analysis therefore evaluated the net benefits to systems owners under different scenarios: (i) assuming all systems are offsetting electricity; (ii) assuming all systems are offsetting gas and (iii) assuming that the systems are offsetting a mix of 80% natural gas and 20% electricity. These options are evaluated in Equations (3-14) to (3-19); where, in addition to the parameters defined in Section 3.5.1:

- $B_{SA,elec}$ is the net lifetime benefits [$] assuming the solar air systems are all offsetting electricity;
- $e_{elec,j}$ is the [$/kWh] rate in the jth year;
- r is the rate of inflation as a decimal unit;
- $R_{SA,elec}$ is the net lifetime benefits with respect to the total first costs assuming the solar air systems are all offsetting electricity;
- $C_{SA,i}$ is the total system cost of the ith solar air system;
- $B_{SA,gas}$ is the net lifetime benefits [$] assuming the SDHW systems are all offsetting natural gas;
- η is the fuel efficiency for natural gas;
- HV is the heating value of natural gas in units [kWh/m^3];
- e_{gas} is the total cost of gas per m^3 including all fees and taxes;

- $R_{SA,gas}$ is the net lifetime benefits with respect to the total first costs assuming the solar air systems are all offsetting natural gas;
- $B_{SA,tot}$ is the net lifetime benefits [$] assuming the solar air systems are all offsetting a mixture of 20% electricity and 80% natural gas; and
- $R_{SA,tot}(e_{gas})$ is the net lifetime benefit with respect to the total first costs assuming the solar air systems are offsetting a mixture of 20% electricity and 80% natural gas.

$$B_{SA,elec} = \sum_{j=1}^{25} \sum_{i=1}^{80} \frac{Y_{SA,s} \cdot A_{SA,i} \cdot e_{elec,j}}{(1+r)^{(j-1)}} \quad (3\text{-}14)$$

$$R_{SA,elec} = \frac{B_{SA,elec}}{\sum_{i=1}^{17} C_{SA,i}} \quad (3\text{-}15)$$

$$B_{SA,gas}(e_{gas}) = \sum_{j=1}^{25} \sum_{i=1}^{80} \frac{Y_{ST,s} \cdot A_{SA,i} \cdot \left(\frac{1}{\eta}\right) \cdot \left(\frac{1}{HV}\right) \cdot e_{gas}}{(1+r)^{(j-1)}} \quad (3\text{-}16)$$

$$R_{SA,gas}(e_{gas}) = \frac{B_{SA.gas}(e_{gas})}{\sum_{i=1}^{17} C_{SA,i}} \quad (3\text{-}17)$$

$$B_{SA,tot}(e_{gas}) = 0.2 \cdot B_{elec} + 0.8 \cdot B_{gas}(e_{gas}) \quad (3\text{-}18)$$

$$R_{SA,tot}(e_{gas}) = \frac{B_{SA,tot}(e_{gas})}{\sum_{i=1}^{17} C_{SA,i}} \quad (3\text{-}19)$$

Note that the benefits in the gas scenario are given as a function of the gas price.

3.5.2.2 *Results*

If it is assumed that solar air installations are offsetting electricity in all cases then the net benefits to system owners is estimated to be 12.1M$. For every 1$ invested by the MHO in funding solar air systems that offset electricity it is estimated that 3.3$ in lifetime benefits is received by social and affordable housing providers.

The net lifetime benefits assuming all systems were offsetting natural gas is shown as a function of the total gas rate in Figure 3-23. At a gas rate of 0.32 [$/m^3] (Jan 2017 rate), the net lifetime benefits is estimated to be 1.8M$; at 0.62 [$/m^3] (roughly the highest historical gas cost in the past 10 years), the net lifetime benefits are estimates to be 3.5M$. In this scenario, for every 1$ invested in solar air installations by the MHO, it is estimated that between 0.49$ and 0.95$ in lifetime benefits is received by the social and affordable housing providers over the lifetime of the systems.

The total benefits assuming a split of 20% for electricity and 80% for natural gas are estimated to be between 3.9M$ and 5.2M$. In this scenario, for every 1$ invested by the MHO towards installing solar air systems, it is estimated that social and affordable housing providers receive between 1.0$ and 1.4$ over the lifetime of the system.

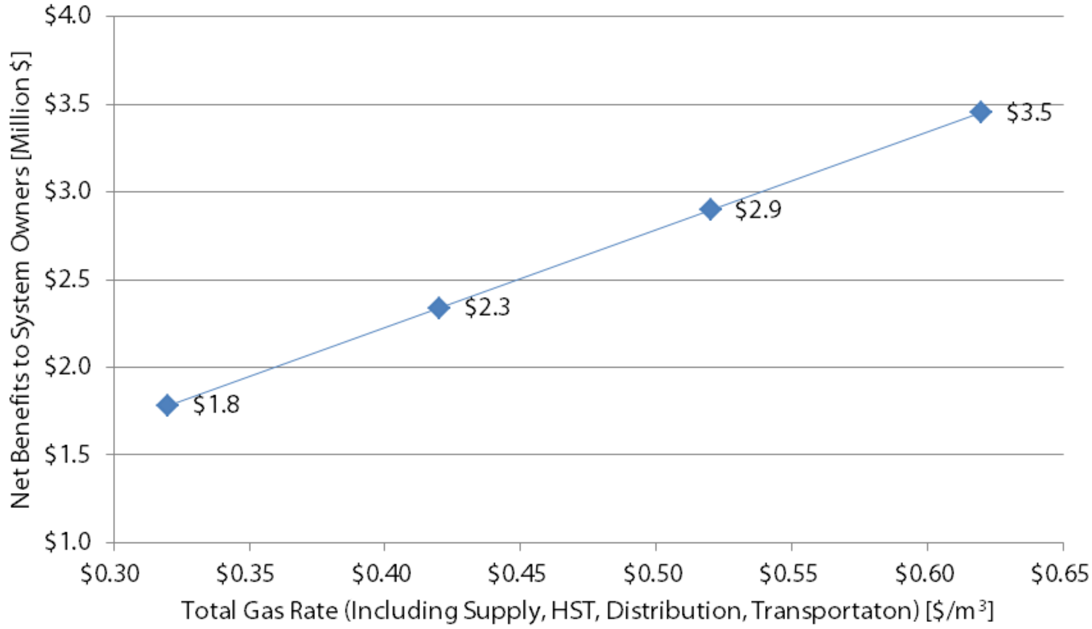

Figure 3-23. The net lifetime benefits, assuming all systems are offsetting natural gas, improves as the gas rate increases. The total costs to install the systems were 3.7M$.

3.5.2.3 *Limitations of the analysis*

The best financial performance from a solar air installation is obtained when cladding on a building needs to be replaced anyway. The financial analysis would then consider only the incremental cost of the solar air installation over conventional cladding rather than the full first costs of the systems. This scenario was not considered in the analysis because there was no stipulation in the REI that solar air installations should replace cladding that is in need of replacement. This scenario is likely to achieve very good financial performance regardless of the fuel costs or the fuel being offset.

A common issue amongst RE technologies is that while there are many studies in which performance is modelled, there is very little real-world performance data. Solar air is no exception. The analysis in this report used the limited experimental and modelling results that were available.

3.5.3 GHG analysis

The technical analysis estimated a lifetime energy generation of 64.8 [GWh]. Assuming: (i) 20% of that is offsetting heating from electricity and 80% from natural gas; (ii) a gas heating value of 10.5 [kWh/m^3]; (iii) a gas heating efficiency of 90%; (iv) a grid emission factor of 50 [g CO_2e/kWh] and (v) a natural gas emission factor of 1900 [g CO_2e/m^3]; the total estimated emissions savings is 11.1 [kt CO_2e] according to Equation (3-20), where:

- ΔGHG_{SA} is the greenhouse savings in units of [g CO_2e];
- EF_{elec} is the emission factor for electricity in units of [g CO_2e/kWh]; and

- EF_{gas} is the emission factor for gas in units of [g CO_2e/m^3].

$$\Delta GHG_{SA} = Y_{SA} \cdot \left[0.2 \cdot EF_{elec} + 0.8 \cdot EF_{gas} \cdot \left(\frac{1}{HV}\right) \cdot \left(\frac{1}{\eta}\right)\right] \quad (3\text{-}20)$$

3.5.4 Solar air summary

In total, 3.7M$ was provided by the MHO to install an estimated 3,790 [m^2] of solar air collector across 17 locations. Over the lifetime of the systems, this is estimated to have generated:

- a total of 64.8 [GWh] of renewable heat energy;
- between a total of 3.9M$ and 5.2M$ in lifetime benefits for system owners, and
- an emissions savings of 11.1 [kt of CO_2e].

3.6 Geothermal

3.6.1 Technical analysis

Nine sites were provided funding for geothermal systems under the REI, totalling 2.5M$. Individual system costs are presented in Figure 3-24. The aim of the technical analysis was to estimate the total annual energy generation over the lifetime of the systems. This required extensive use of estimation. Parameter estimates are defined in Table 3-16 and the procedure is defined in Section 3.6.1.1.

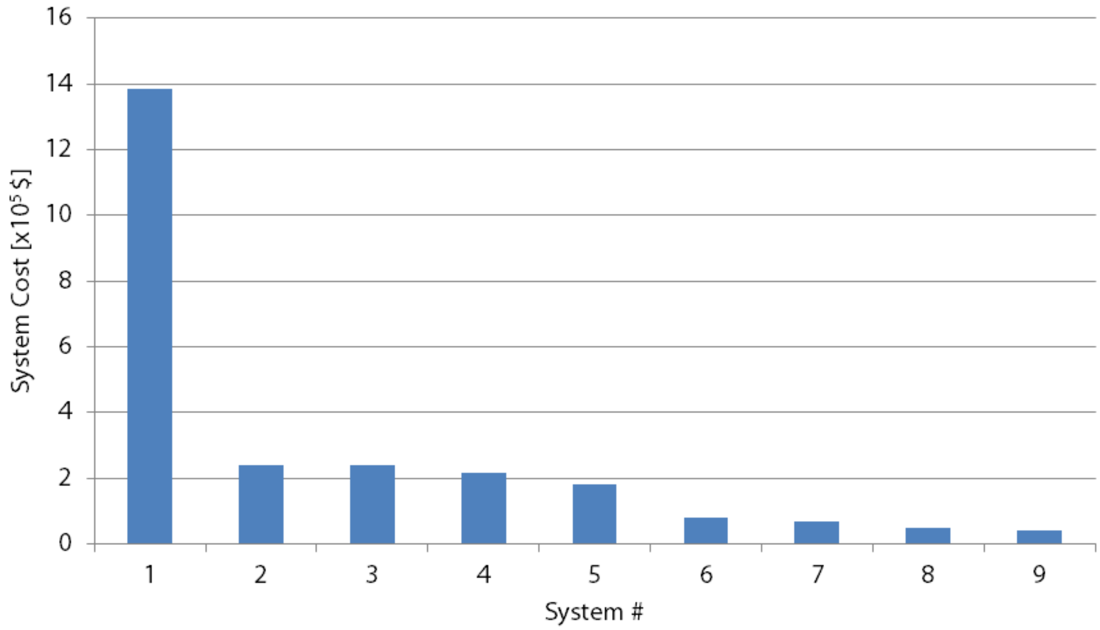

Figure 3-24 .Geothermal system costs in the REI.

Table 3-16. Parameters used to estimate geothermal system performance in the technical analysis.

Parameter	Unit	Value	Description
Cost	[$/ton]	13,800	Heat pump sizes can be expressed in units of tons. A refrigeration ton is equal to 12,000 [Btu/hr] or 3.5 kW. Unless otherwise specified, "tons" is reported in this document as the AHRI-rated full-load heating capacity for the ground-loop configuration. Note that this may be different from nominal ratings in the heat pump model number, or the capacity for other ground-loop configurations. An estimate for the average system cost per ton was determined from feasibility assessments in which the specific system cost and heat pump sizes were provided. There were five studies that provided this information, all vertical ground heat exchangers (GHX). This is shown in Table 3-17. The average value was 13,800[$/ton]. Market survey results reported in the Canadian

			Geoexchange Coalition (CGC) document "The State of the Canadian Geothermal Heat Pump Industry 2011," state that the average price for a residential vertical GHX geothermal system in Ontario in 2010 was 8,132 [$/ton][71]. This suggests that the installations in the REI were, on average, more expensive than other installs in the private sector.
Heat pump heating COP and cooling EER	[COP] [EER]	4.0 21.8	Based on rated COP (coefficient of performance) and EER (energy efficiency ratio) values provided in Table 3-17, a heating COP of 4.0 and a cooling EER/COP of 21.8/6.4 was assumed.
Base case air conditioner efficiency	[SEER]	13.0	A SEER (seasonal energy efficiency ratio) of 13.0 is the minimum requirement for EnergyStar certification[72] so this value was assumed as the base case air conditioner efficiency when calculating energy savings.
Annual Heating and Cooling Load w.r.t heat pump capacity	[kWh/ton]	11,100 (Heating) 980 (Cooling)	Ground source heat pumps are a more complicated estimate than other technologies considered in this analysis because it involves switching fuels and the system also functions to meet an entire load rather than just offset one. The savings then depends on what the load is – which is not known and was not measured as a requirement of funding. This analysis made assumptions about the annual heating and cooling loads based on the size of the heat pump. However, the heat pump may be sized first to meet a peak load (or some fraction of a peak load) and the relationship between peak load and annual load may vary. The estimate is therefore approximate due to constraints of data availability. This estimate was based on one detailed feasibility study that was chosen as representative of residential loads. The design heating load (minus gains) was 77.5 [kBtu/hr] and the design cooling load was 72 [kBtu/hr]. The annual heating load was 239,590 [kBtu] (70,200 [kWh]) and the annual cooling load was 21,051 [kBtu] (6,170 [kWh]). To meet these

[71] Canadian Geoexchange Coalition. "The State of the Canadian Geothermal Heat Pump Industry 2011," 2012. Retrieved Feb. 3, 2017 from: http://www.geo-exchange.ca/en/UserAttachments/article81_Final%20Stats%20Report%202011%20-%20February%206,%202012_E.pdf. Note that this report doesn't clarify what is meant by "ton" in its [$/ton] figure. However, previous reports in the same series indicate that "ton" is in reference to the design heat loss for the heat pump application (i.e. the load being met by the heat pump). It is therefore reasonable to use this value as a comparison for those calculated in this report.

[72] Natural Resources Canada, "Air Conditioning Your Home," Retrieved Feb. 3, 2017 from: http://www.nrcan.gc.ca/energy/publications/efficiency/residential/air-conditioning/6051

			loads a pair of heat pumps with a combined capacity of 76,000 [kBtu/hr] (6.3 [ton]) was chosen. Based on this it was then assumed that the annual heat load divided by the heat pump size is 11,100 [kWh/ton]. Similarly, the annual cooling load divided by the heat pump size is estimated to be 980 [kWh/ton].
System lifetime	[years]	25	U.S. Department of Energy (DOE) estimates indoor component lifetimes at 25 years and ground loop lifetimes at 50+ years[73].

Table 3-17. Data from REI feasibility studies was used to estimate an average [$/ton].

#	Total Cost	Equipment	System Size [full-load heating ton]*	Heating COP**	Cooling EER/COP**	Cost per unit size ($/ton)	GHX Type
1	$1,386,422.00	4 x McQuay WRA 1300	79.7	4.0[74]	21.8/6.4	$17,401	Vertical
2	$240,000.00	2 x HTR120R18A Geo Smart Heat Pump	15.8	3.4[75]	21.5/6.3	$15,158	Vertical
3	$181,092.00	4 x Climate Master TTS064	15.3	4.0[76]	22.1/6.48	$11,862	Vertical
4	$46,388.95	1 x Climate Master TTS064	3.8	4.0[77]	22.1/6.48	$12,154	Vertical
5	$78,818.00	2 x Florida Heat Pump EnviroSaver ES049	6.3	4.0[78]	21.8/6.39	$12,445	Not given
					Average:	$13,804.02	

*Full-load heating capacity for ground-loop configuration

[73] U.S. Department of Energy. "Geothermal Heat Pumps," Retrieved Feb. 3, 2017 from: https://energy.gov/energysaver/geothermal-heat-pumps.

[74] McQuay, "McQuay Water to Water Source Heat Pumps: Model WRA, WHA, WCA; Catalogue 1107," *May no longer be accessible online.*

[75] Geosmart Energy, " Premium hydronic system H series specification catalogue," Retrieved Feb. 2, 2017 from: https://geosmartenergy.com/wp-content/uploads/2016/01/PremiumHTInstallManual.pdf.

[76] Climate Master, "Tranquility Split (TTS/TTP/TAC/TAH) Series," Retrieved Feb. 2, 2017 from: http://www.climatemaster.com/commercial/wp-content/uploads/sites/2/climatemaster-residential-tranquility-split-tts-ttp-tac-tah-product-catalog.pdf.

[77] Climate Master.

[78] Envirosaver, *Envirosaver Heat Pumps ES Series Specification Sheet*.

**Shows part load efficiencies, which are higher due to cooler entering source temperatures in cooling mode and warmer entering source temperatures in heating mode. This is closer to real-world operation with a vertical GHX.

3.6.1.1 *Procedure*

The procedure for estimating energy savings is outlined below.

1. Determine/estimate system size.
    a. If feasibility study is available, use the size from the feasibility study.
    b. If feasibility study is not available estimate the system size based on the capital cost assuming 13,800 [$/ton].
2. Estimate the system loads.
    a. Estimate heating load as 11,100 [kWh/ton] of nominal heat pump capacity.
    b. Estimate cooling load as 980 [kWh/ton] of nominal heat pump capacity.
3. Estimate electrical energy used by heat pumps to meet the loads.
4. Estimate energy savings.
    a. Heating mode energy savings is the energy taken out of the ground in heating mode.
    b. Cooling mode energy savings is the electricity savings from using the higher efficiency heat pump over a conventional air conditioner.

3.6.1.2 *Example*

A Southern Ontario housing provider was provided 217,000$ for a geothermal system. No further information about the system was available. Using an estimated 13,800 [$/ton], the system heating mode capacity was estimated as 15.7 ton. Assuming that there is on average 11,100 [kWh] of annual heating load for every ton of heat pump capacity, the annual heating load was estimated to be 174,000 [kWh]. The annual cooling load was estimated at 15,400 [kWh], assuming 980 [kWh/ton]. Assuming a COP of 4.0, the total renewable energy taken from the ground annually in heating mode was estimated at 131,000 [kWh]. The geothermal EER was estimated at 21.8 versus a base case EnergyStar air conditioner with a SEER of 13.0. The difference in cooling efficiency resulted in an estimated annual cooling mode savings of 1,650 [kWh].

3.6.1.3 *Lifetime Energy Generation*

Lifetime energy generation for all geothermal installations in the REI is shown in Equations (3-21) to (3-23), where:

- Y_G is the total lifetime energy savings in units [kWh];
- Y_H is the total lifetime heating mode energy savings in units [kWh];
- Y_C is the total lifetime cooling mode energy savings in units [kWh];
- l is the system lifetime;
- $Cap_{G,i}$ is the nominal heating capacity of the i^{th} heat pump;
- L_H is the estimated annual heating load per nominal heating ton in units [kWh/ton];
- COP_H is the heating mode COP;
- L_C is the estimated heat pump cooling load per nominal heating ton in units [kWh/ton];
- $COP_{C,AC}$ is the cooling COP of the base case air conditioner; and
- $COP_{C,HP}$ is the cooling COP of the heat pump.

$$Y_G = Y_H + Y_C \tag{3-21}$$

$$Y_H = l \cdot \sum_{i=1}^{9} Cap_{G,i} \cdot L_H \cdot \left(1 - \frac{1}{COP_H}\right) \tag{3-22}$$

$$Y_C = l \cdot \sum_{i=1}^{9} Cap_{G,i} \cdot L_C \cdot \left(\frac{1}{COP_{C,AC}} - \frac{1}{COP_{C,HP}}\right) \tag{3-23}$$

3.6.1.4 *Results*

There were nine geothermal systems funded in total, with a cumulative capacity of an estimated 162 ton of nominal heating capacity and a total cost of 2.5M$. Total renewable energy removed from the ground to heat the buildings in heating mode was 33.6 [GWh]. Total energy saved due efficiency improvements in cooling mode operation was estimated at 419 [MWh].

3.6.2 Financial analysis

The financial analysis built upon the results of the technical analysis by estimating the net benefits provided to the geothermal system's owners based on the energy generation.

Table 3-18. Parameters used in geothermal system financial analysis

Parameter	Unit	Value	Description
Cost of Gas	[$/m^3]	0.32 – 0.62	See Appendix B.
Cost of Electricity	[$/kWh]	-	See Appendix C.
Heating value of gas	[kWh/m^3]	10.5	Explained in Table 3-11.
Annual fuel utilization efficiency (AFUE)	[%]	90	A geothermal system is normally used as the primary heating system. In this analysis, a geothermal system was compared against the base case of a high-efficiency natural gas heating appliance like a furnace or boiler.
Fraction of buildings with electric heating	-	80% Natural gas 20% Electric	Explained in Section 3.2.3.
Annual O&M costs	[% of Total System Cost]	0	Anecdotally, geothermal systems are often reported to need less maintenance than a conventional system. No additional O&M costs were considered.
Inflation rate	%	1.5	Future cash flows were discounted according to the inflation ratio as determined from the Bank of Canada

			inflation rate calculator between 2010 and 2016[79].
First costs of base case	[% of geothermal first costs]	25	Since a geothermal system is normally used to meet the whole building's heating and cooling requirements, it provides a benefit in the form of both avoided capital cost expenditures on a conventional system and potentially avoided operating costs. Geothermal is a more expensive heating and cooling option then a conventional. For example, in the REI, a 4-ton residential system suitable for a small-to-medium single family home would have cost 55,000$ according to average system costs. A high-efficiency furnace and air-conditioner would may be on the scale 10,000$ or possibly less. It was assumed that the first costs of a conventional alternative were 25% that of a geothermal system. This avoided cost was considered as a benefit in the financial analysis. Note that in the REI, there was actually no requirement for geothermal to replace a conventional system that is near end-of-life.

3.6.2.1 *Equations*

For geothermal, benefits come in the form of avoided operational costs and avoided capital costs rather than direct income. The financial performance is very different when a geothermal system is offsetting electricity rather than offsetting natural gas. The analysis therefore evaluated the net benefits to system owners under different scenarios: (i) assuming all systems are offsetting electricity; (ii) assuming all systems are offsetting gas and (iii) assuming that the systems are offsetting a mix of 80% natural gas and 20% electricity. These options are evaluated in Equations (3-24) to (3-33) respectively, where in addition to the parameters defined in the Section 3.6.1:

- $B_{G,elec}$ is the net lifetime benefits [$] assuming the geothermal systems are all offsetting electricity;
- $B_{G,elec,H}$ is the net lifetime operating benefits in heating mode [$] assuming the geothermal systems are all offsetting electricity;
- $B_{G,C}$ is the net lifetime operating benefits in cooling mode [$];
- $B_{G,avoided}$ is the avoided capital cost expenditure of having to replace the existing heating and cooling systems with another conventional system;
- $e_{elec,j}$ is the [$/kWh] rate in the jth year;
- r is the rate of inflation as a decimal unit;

[79] Bank of Canada (2016).

- $R_{G,elec}$ is the net lifetime benefits with respect to total first costs assuming all geothermal systems are offsetting electricity;
- $C_{G,i}$ is the first cost of the i[th] geothermal system;
- $B_{G,gas}$ is the net lifetime benefits [$] when the geothermal system is replacing gas;
- $B_{G,gas,H}$ is the net lifetime benefits [$] from heating mode operation when the geothermal system is replacing all gas;
- e_{gas} is the cost of gas in units [$/m^3] including all taxes and fees;
- $AFUE$ is the fuel efficiency for natural gas as a decimal unit;
- HV is the heating value of natural gas in units [kWh/m^3];
- $R_{G,gas}(e_{gas})$ is the net lifetime benefits with respect to total first costs assuming all geothermal systems are offsetting gas;
- $B_{G,tot}(e_{gas})$ is the net lifetime benefits assuming 20% electricity and 80% gas; and
- $R_{G,tot}(e_{gas})$ is the net lifetime benefit with respect to total first costs assuming 20% electricity and 80% gas.

Case (i):

$$B_{G,elec} = B_{G,elec,H} + B_{G,C} + B_{G,avoided} \tag{3-24}$$

$$B_{G,elec,H} = \sum_{j=1}^{25}\sum_{i=1}^{9} \frac{Cap_{G,i} \cdot L_H \cdot \left(1 - \frac{1}{COP_H}\right) \cdot e_{elec,j}}{(1+r)^{(j-1)}} \tag{3-25}$$

$$B_{elec,C} = \sum_{j=1}^{25}\sum_{i=1}^{9} \frac{Cap_{G,i} \cdot L_C \cdot \left(\frac{1}{COP_{C,AC}} - \frac{1}{COP_{C,HP}}\right) \cdot e_{elec,j}}{(1+r)^{(j-1)}} \tag{3-26}$$

$$B_{G,avoided} = 0.25 \cdot \sum_{i=1}^{9} C_{G,i} \tag{3-27}$$

$$R_{G,elec} = \frac{B_{G,elec}}{\sum_{i=1}^{9} C_{G,i}} \tag{3-28}$$

Case (ii):

$$B_{G,gas} = B_{G,gas,H} + B_{G,C} + B_{G,avoided} \tag{3-29}$$

$$B_{G,gas,H}(e_{gas}) = \sum_{j=1}^{25}\sum_{i=1}^{9} \frac{Cap_{G,i} \cdot L_H \cdot \left(\left(\frac{1}{AFUE}\right) \cdot \left(\frac{1}{HV}\right) \cdot e_{gas} - \frac{e_{elec,j}}{COP_H}\right)}{(1+r)^{(j-1)}} \tag{3-30}$$

$$R_{G,gas}(e_{gas}) = \frac{B_{G,gas}(e_{gas})}{\sum_{i=1}^{9} C_{G,i}} \tag{3-31}$$

Case (iii):

$$B_{G,tot}(e_{gas}) = 0.2 \cdot B_{G,elec} + 0.8 \cdot B_{G,gas}(e_{gas}) \tag{3-32}$$

$$R_{G,tot}(e_{gas}) = \frac{B_{G,tot}(e_{gas})}{\sum_{i=1}^{9} C_{G,i}} \tag{3-33}$$

3.6.2.2 *Results*

Assuming that geothermal installations are offsetting electricity in all cases, then the net lifetime benefits to system owners is estimated to be 7.0M$. For every 1$ invested by the MHO in funding geothermal systems to offset electric resistance heating, 2.8$ in lifetime benefits is estimated to be received by social and affordable housing providers.

The net lifetime benefits assuming all systems were offsetting natural gas is shown, as a function of the total gas and electricity rates, in Figure 3-25. Assuming the geothermal systems are all replacing gas, the net lifetime benefits are estimated to be -0.11M$ when the gas rate is 0.32 [$/m^3]; at 0.62 [$/m^3] (roughly the highest historical gas cost in the past 10 years), the net lifetime benefits are estimated to be 1.1M$. For the scenario of offsetting gas, this analysis estimated that for every 1$ invested in geothermal systems by the MHO, between -0.04$ and 0.44$ is received in lifetime benefits by social and affordable housing providers.

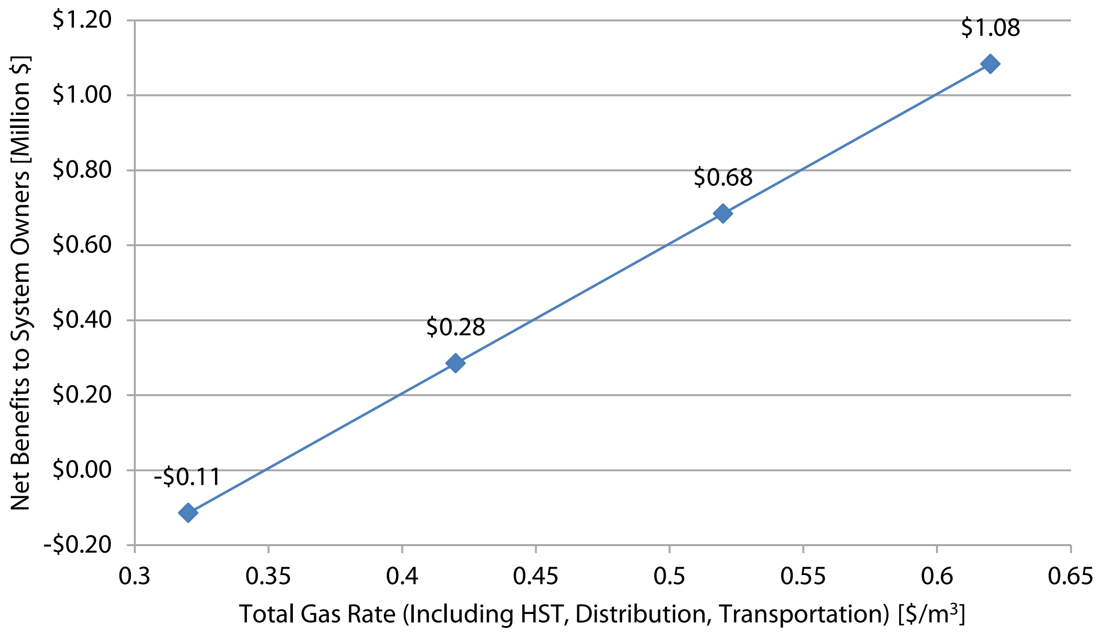

Figure 3-25. The net lifetime benefits, assuming all systems are offsetting natural gas, improves as the gas rate increases. Total costs to install the systems were 2.5M$ – however, it is worth noting that system costs within the REI may have been higher than geothermal system costs outside of the REI.

The total lifetime benefits assuming a split of 20% for electricity and 80% for natural gas were estimated to be between 1.3M$ and 2.3M$. For every 1$ invested in geothermal systems by the MHO, between 0.52$ and 0.91$ in lifetime benefits were estimated to be received by social and affordable housing providers. The financial performance in electrically heated buildings was estimated to be very strong while that in natural gas heated buildings was not strong.

3.6.2.3 Limitations of the analysis

- This analysis considered a residential load where the cooling load is much lower than the heating load. When the cooling load is higher, a greater amount of electricity will be saved and savings would be improved.

- Performance benefits are often had when geothermal is used to heat adjacent buildings with different load profiles (for example, an office building and a multi-unit residential building) but this was not explored.

- Geothermal systems may have other sources of savings that were not considered, for example, savings from operating a cooling tower in terms of chemical treatment and water usage. However, the geothermal systems in the REI are mostly small-scale and not likely to have replaced a cooling tower.

- The first costs of geothermal system within the REI appear to have been more expensive than systems outside of the REI.

- The GHX is extremely long-lived. To continue using geothermal at the end of the heat pump lifetime only requires a replacement of the heat pump, which is much cheaper than the GHX. The GHX has value at the end of 25 years if the provider decides to continue heating with geothermal. If they chose not to then it would not be a benefit. The GHX was not considered as an end-of-life system value in this analysis.

3.6.3 GHG analysis

The total GHG savings from geothermal is shown in Equation (3-34). It assumes that 20% of the total heating load is for electrical heat and 80% is for natural gas. EF_{elec} and EF_{gas} are 50 g [CO_2e/kWh] and 1900 g [CO_2e/m^3]. $L_{H,tot}$ and $L_{C,tot}$ is the total lifetime heating and cooling loads for all systems. Other parameters are as defined in Table 3-18. The total lifetime carbon savings is estimated at 7.2 [kt CO_2e].

$$\Delta GHG_{geo} = \left[0.2 \cdot L_{H,tot} \cdot EF_{elec} \cdot \left(1 - \frac{1}{COP_{H,HP}}\right)\right] + \left[0.8 \cdot L_{H,tot} \cdot \left(\frac{EF_{gas}}{HV \cdot AFUE} - \frac{EF_{elec}}{COP_H}\right)\right] + \left[L_{C,tot} \cdot EF_{elec} \cdot \left(\frac{1}{COP_{C,AC}} - \frac{1}{COP_H}\right)\right] \quad (3\text{-}34)$$

3.6.4 Summary of geothermal

In total, 2.5M$ was provided by the MHO to install an estimated 162 tons of geothermal heat pump capacity across nine locations. Over the lifetime of the systems, this is estimated to have generated:

- a total heating energy savings of 33.6 [GWh]and a cooling energy savings of 423 [MWh];
- between a total of 1.3 and 2.3M$ in lifetime benefits for system owners; and
- an emissions savings of 7.2 [kt of CO_2e].

3.7 Summary of technical, financial and GHG analysis

The results from the technical, financial and GHG analyses for each of the technologies are summarized in Table 3-19. Note that no provider opted to *install* a wind energy system within the REI, despite it being an option. A small amount of funding was disbursed to one provider for engineering and feasibility studies concerning a wind turbine installation but the provider did not proceed on to the actual installation of the wind turbine.

Table 3-19. Summary of technical, financial and GHG analyses

Technology type	# of systems	Total installed capacity	Total Cost [M $]	Estimated lifetime energy generation or savings [GWh]	Lifetime benefits to system owners [M $]	Ratio of lifetime benefits w.r.t. funding provided[80]	Lifetime GHG savings [kt CO_2e]	Lifetime GHG savings [$/ton]	Quality of estimate[81]
PV	255	3.7 MW_p	39.1	132	62.2	1.59	6.6	5900	**Medium**
SDHW	80	4,560 m^2	12.1	40	2.4 - 3.3	0.20 - 0.27	6.9	1800	**Low**
Solar Air	17	3,790 m^2	3.7	65	3.9 - 5.2	1.04 - 1.41	11.1	330	**Low**
Geothermal	9	162 ton	2.5	34	1.3 - 2.3	0.52- 0.91	7.2	350	**Low**
Totals			**57.4**	**271**	**69.8 - 73.0**	**1.22 -1.27**	**31.8**		

[80] This assumes that non-PV systems are offsetting a mix of 20% electricity and 80% natural gas. Furthermore, these values are estimates that pertain *to the REI program*. Great care should be taken when drawing conclusions about system performance outside of the REI. For example, PV system financial performance is based on FIT/microFIT rates that are no longer available; a performance de-rate was applied to SDHW energy generation based on site visit observations, and some system costs may have been higher in the REI than in the private sector.

[81] A formal uncertainty assessment was not done. There is not sufficient data to estimate the uncertainty of these calculations. As much as was possible, performance estimates were based on real-world experimental data. PV quality is estimated as medium because the estimation procedure was checked and calibrated against a small subset of systems and shown to be reasonable. This was not possible for the other technologies, and the quality is therefore listed as low.

In total, over the lifetime of the systems, the program is estimated to generate:

- between 69.8 and 73.0 M$ in lifetime benefits to social and affordable housing providers;
- 271 [GWh] in renewable electrical and heat energy (see Figure 3-27 for a full breakdown); and
- 31.8 [kt CO_2e] of GHG savings.

For every 1$ provided by the MHO towards renewable energy retrofits, it was estimated the social and affordable housing providers received between 1.22$ and 1.27$ in lifetime benefits. However, benefits were not equal across all technology types. The strongest financial performance came from PV due to the guaranteed price paid for PV electricity within the FIT program, which was designed to cover project costs plus a reasonable rate of return. While PV projects were responsible for 68% of the funding, they provided 90% of the estimated program benefits. On the other hand, PV was responsible for only 21% of the GHG savings.

The financial performance of the technologies was heavily dependent on many factors that were difficult to estimate. Firstly, there was limited experimental data on how these systems actually perform once installed and performance data was typically not collected within the REI. It follows that the performance estimates are approximate.

Data on the fuel source being offset was not collected either. Most technologies are estimated to perform better financially when they are offsetting electricity but less so when offsetting natural gas. In the analysis, it was assumed that 20% of buildings were heated with electricity and 80% with natural gas. It follows that the financial performance was mostly dominated by the assumption of inexpensive natural gas as the competing fuel and this is why results were not always strong.

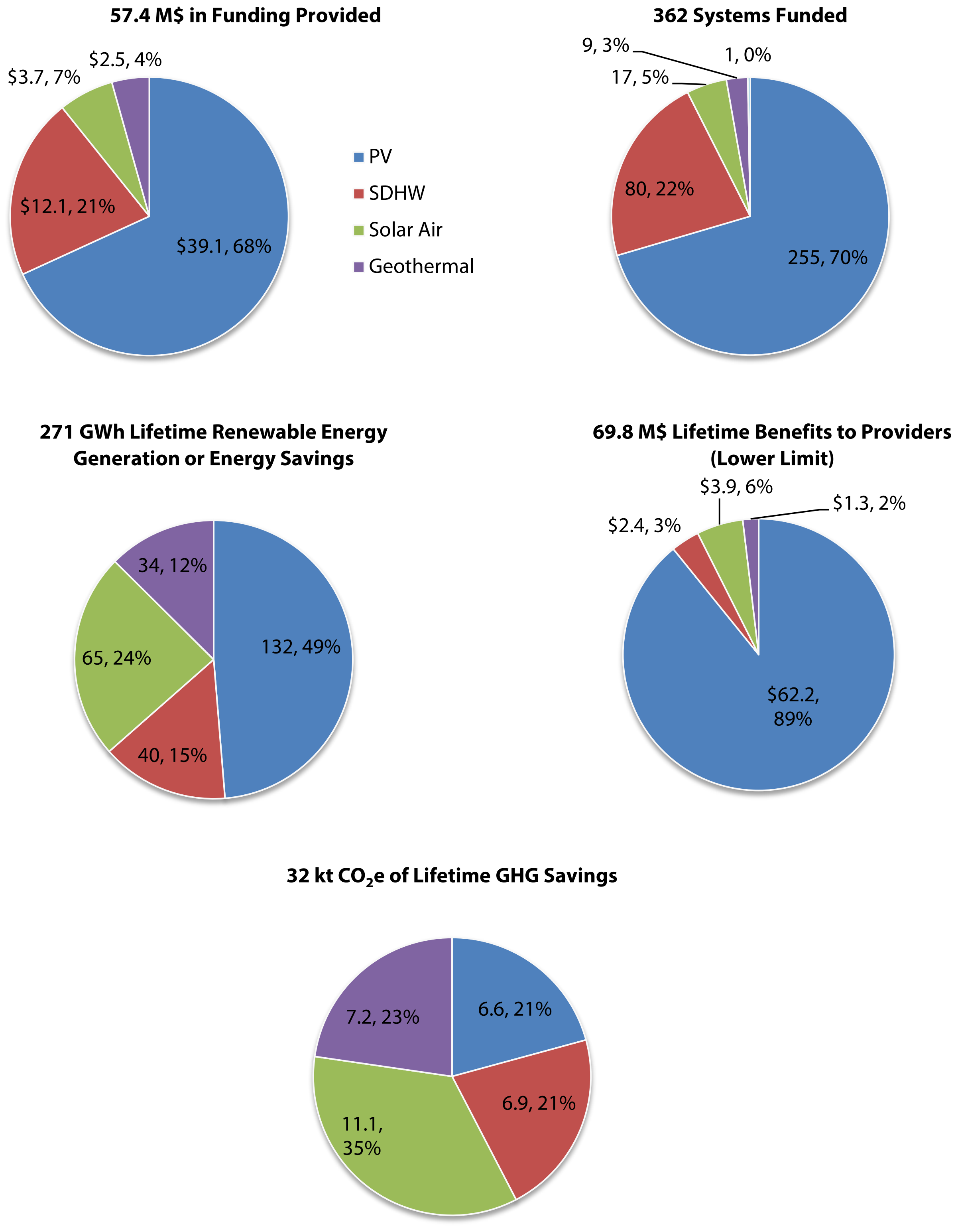

Figure 3-26. Summary of results from technical, financial and GHG analyses. Note that the lifetime benefits are presented with respect to 2010 dollars. Also, note that <u>the legend shown at top left applies to all pie charts</u>.

A third issue was that the future escalation in the cost of natural gas is challenging to forecast. With this is mind, financial performance was calculated both at the current rate (which is near a historical low) and at the highest rate within the last 10 years. At current gas rates, it was estimated that a small-scale geothermal system with a residential load would cost more to operate than a high-efficiency natural gas furnace or boiler. If some of these geothermal systems were offsetting natural gas then it is likely that they may be costing more to operate and not generating savings – but on the scale of the whole program, this may be balanced by those systems that are offsetting *electricity* (or oil, propane or wood). Maintenance costs were not considered for one iteration of the SDHW calculation and it may be the case that once these costs are taken into account these systems also cost more to operate than is provided in benefits from gas savings – this was commented on anecdotally within the interviews and surveys.

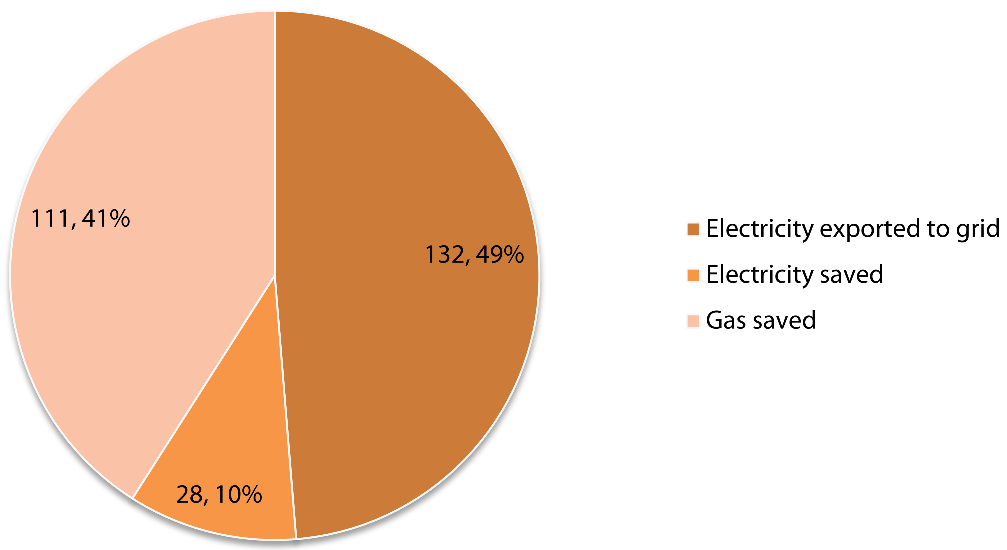

Figure 3-27. Breakdown of estimated lifetime energy generation and savings resulting from the REI. Units are in [GWh].

In general, from a financial perspective, it may not be cost-effective to use an RE retrofit to conserve gas when gas is inexpensive. However, it is also the case that GHG savings are dominated by the amount of gas that is saved. This is a notable barrier: *greenhouse gas savings and financial performance are at odds*. Financial performance comes from saving electricity but strong GHG savings comes from saving gas. By using a mix of technologies and by offsetting both gas and electricity it may be possible to achieve a reasonable overall balance between financial performance and GHG savings – but this may also mean that *not every participant in the incentive program receives comparable benefits from having participated*.

It is also worth noting that system costs may have been higher within the REI. For example, the average geothermal system cost was 13,800 [$/ton] as determined from feasibility assessments. As already described in Table 3-15, the CGC estimated average residential system cost at 8,132 [$/ton] in 2010 for Ontario. Similarly, the average installed cost of SDHW systems within the REI was 2,760 [$/m^2] while the average from previous work and REI feasibility studies was 1,723 [$/m^2] (although this was a small sample). Systems were selected at the discretion of the service managers but it did not seem that were checks to ensure that costs were reasonable compared with installations in the private sector. With this in mind, it is advisable to exercise caution when drawing broader conclusions about the technologies in the private section based on this analysis. This is because system costs, applications and level of O&M, may all be different when systems are completely funded through an incentive program.

3.7.1 New developments in renewable energy systems for residential or multi-residential buildings

There are several important things to note looking forward to future renewable energy incentive programs. Firstly, the cost of PV has lowered drastically and the FIT price schedule has changed as well. NREL reports on the cost of solar in the U.S. They report that small-scale solar has lowered in price from 7.06 [$/W$_p$] in Q4 2009 to 2.93 [$/W$_p$] in Q1 2016 (a change of 58%)[82]. A comparable drop could also be assumed for Canadian prices. The FIT 5.0 price schedule is shown in Table 3-20[83]. Ontario is currently transitioning the FIT/microFIT programs to net metering. It is still feasible that PV could be part of future incentive program to help bolster overall financial performance but, again, it should be noted that PV is not a high-impact emissions reduction technology because Ontario's overall electricity supply mix already comes from mostly non-emitting fuel sources, and also that application requirements are now more stringent.

Table 3-20. FIT prices for PV as of January 1st 2017.

Renewable Fuel	Project Size Tranche	Price (¢/kWh)
Solar (PV) (Rooftop)	≤ 6 kW	31.1
	>6kW; ≤ 10 kW	28.8
	> 10 kW; ≤ 100 kW	22.3
	> 100 kW; ≤ 500 kW	20.7
Solar (PV) (Non-Rooftop)	≤ 10 kW	21.0
	> 10 kW ≤ 500 kW	19.2

Geothermal heat pump technology has improved since the beginning of the REI, notably by incorporating variable capacity compressors and variable speed ground circulator pumps. However, perhaps more notable is the developments that have occurred in other heat pump technologies.

Cold climate air-source heat pump (ASHP) technologies have advanced considerably. Air-source heat pumps operating on the same principle as geothermal systems (also called ground-source heat pump

[82] Fu, Ran and Donald Chung, Travis Lowder, David Feldman, Kristen Ardani, and Robert Margolis. "S. Solar Photovoltaic System Cost Benchmark: Q1 2016," (2016). Retrieved Feb. 7, 2017 from: http://www.nrel.gov/docs/fy16osti/66532.pdf

[83]IESO, "FIT/microFIT PRICE SCHEDULE (January 1, 2017)." Retrieved Feb. 2, 2017 from: http://fit.powerauthority.on.ca/sites/default/files/2017-FIT-Price-Schedule.pdf

systems (GSHPs)) but use the air, rather than the ground, as a source and sink for heat energy. Air has greater fluctuations in temperature when compared with the ground and this means that the COP of an ASHP will not reach that of a GSHP (as high as 5.0) but it still very high with a seasonal average of that may reach 3.0. It also has the significant benefit that a GHX is not required, reducing costs considerably. ASHPs have been experimentally evaluated in previous work by the Sustainable Technologies Evaluation Program (STEP) with very positive results[84]. They can continue to function with a COP greater than 1.0 at outside air temperatures approaching -25°C. ASHPs come in many different packages and sizes, including mini-splits, central and building wide variable refrigerant flow (VRF) systems, and are often amenable to retrofit applications.

Conventional GSHPs or ASHPs both face the issue of high operating costs when using electricity as a fuel. However, gas powered heat pumps have recently entered into the North American market place. Gas powered heat pumps, either gas-absorption or gas-engine, do not boast the impressive COPs of their electric counterparts but they do have efficiencies that are on the scale of 50% better than conventional gas furnaces or boilers. The extra efficiency is gained by supplementing the heat of combustion with extra heat energy from the ground or air. Gas powered heat pumps may be cost effective in improving the energy efficiency of buildings heated by natural gas. There is currently a STEP project evaluating the performance of gas heat pumps in a Canadian climate.

Another relatively new technology is air-source heat pump water heaters (ASHPWHs). They use heat energy from the ambient indoor space to heat domestic hot water. In the cooling season, an ASHPWH can provide roughly enough cooling for a small apartment unit and provide all the domestic water needs, all while consuming roughly half the energy of a conventional hot water heater. This results in a large reduction in electricity usage and enhanced well-being of social and affordable housing tenants though a more comfortable indoor environment. In the heating season, they can function as a conventional electric water heater.

Note that this list is not exhaustive; there may be other notable options for RE retrofits in social and affordable housing.

[84] STEP. "Performance Assessment of Heat Pump Systems," 2012. Retrieved Feb. 2, 2017 from: http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2015/02/ASHPvsGSHP_TechBrief_Feb2015.pdf

3.8 Qualitative analysis

3.8.1 Approach

Qualitative data was collected via online survey, formal interviews, informal conversations[85] and site visits. The aim of the qualitative analysis was to synthesize this data to identify common themes and insights related to stakeholder experience with the REI, and further identify key success factors that promoted the uptake of participation in the REI and successful operation of an RE system. The online survey was developed using SurveyMonkey. It was distributed to housing providers beginning in July 2016 and remained live until January 2017. Results were collected on an ongoing basis. Survey questions are provided in Appendix D.

A set of interview questions was developed for each targeted stakeholder group: MHO staff, service managers, providers, Vendors, housing associations, and third party service providers (Appendix E). Both the survey and interview questions were developed based on the data requirements to carry out the program evaluation and questions used for evaluations of similar programs from other jurisdictions. Site visits provided the opportunity to speak directly with on-site operations staff and view the operations of the renewable energy systems. Site visits allowed the project team to identify qualitatively whether systems appeared to be operating well and in a good state of repair. Aside from the gathering of system and building specifications, site visits offered additional data on the nature of any maintenance done on the system; any obvious signs of disrepair; how the system is controlled and whether controls are believed by the system operator to be working effectively. Seventeen site visits were conducted at sites across the province representing the different renewable energy system types funded by the REI program (Figure 3-28). A summary of the site visit observations can be found in Appendix F.

[85] An informal conversation consisted of a short phone conversation, roughly 5 to 30 minutes in length, where the housing providers experience with their RE system and with the REI program were discussed in a relatively unstructured way. Notes were taken but audio was not recorded and transcribed.

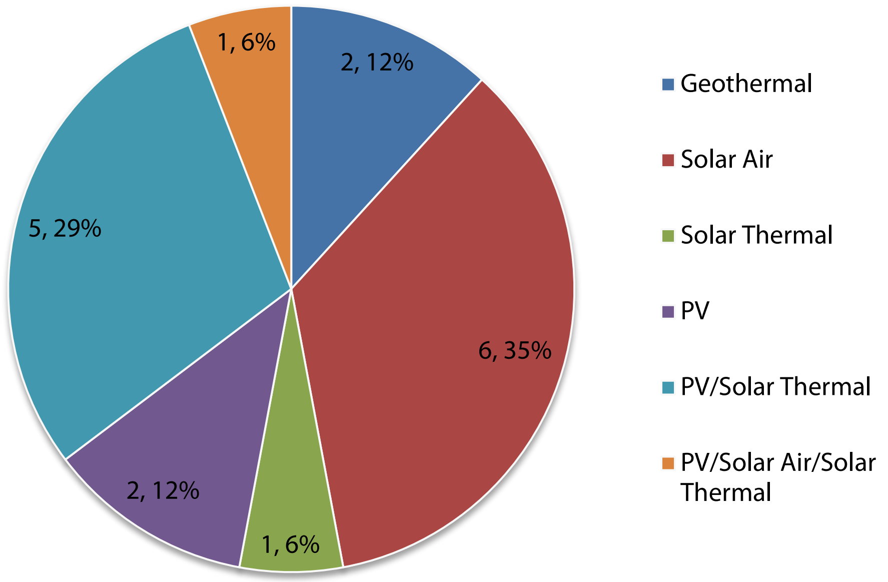

Figure 3-28. Renewable energy system types at sites visited.

Figure 3-29 and Figure 3-30 show the geographical distribution of data collected for the analyses. Data was collected from a range of providers, building, and system types across the province.

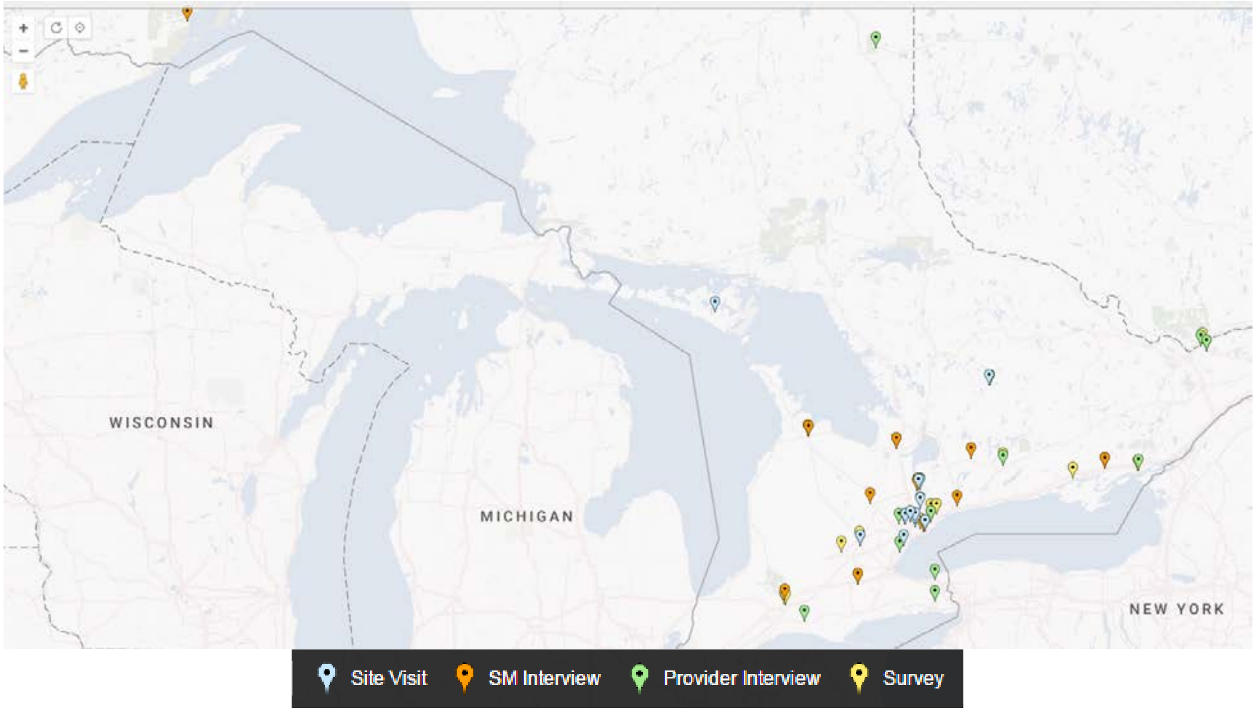

Figure 3-29. Geographical distribution of REI data collection.

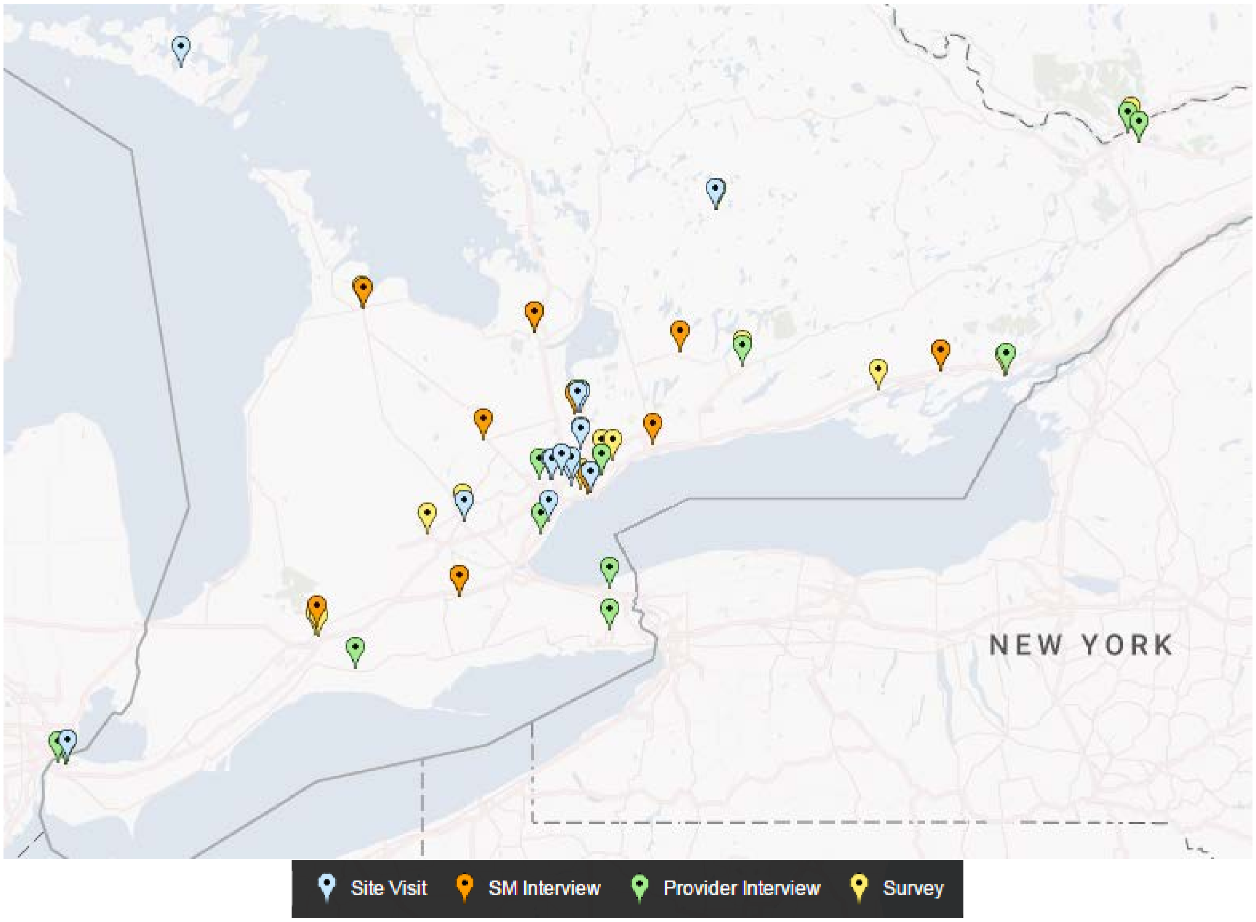

Figure 3-30. Geographical distribution of REI data collection – Southern Ontario focus.

3.8.2 Overview of methodology

Data was collected through informal conversations, a series of online surveys with housing providers for projects that received REI funding and through interviews with MHO staff, service managers, housing providers that received REI funding, and vendors involved with the installation of REI funded systems. Housing associations and third party service provider interviews were not conducted as part of the qualitative data collection. Additional qualitative data was also collected during site visits through visual inspections and informal conversations.

Informal conversations were summarized and recorded in a database for housing providers that received REI funding. Online survey responses were collected and collated by respondent for each survey question (survey questions are listed in Appendix D). Interviews were recorded and transcribed for analysis.

Results were analysed using the 'Framework' analysis method[86]. This qualitative research method is commonly used in applied policy research. A five-step process is involved[87]:

[86] Ritchie, J. & Spencer, L. 1994. "Qualitative data analysis for applied policy research" by Jane Ritchie and Liz Spencer in A. Bryman and R.G. Burgess [eds.] "*Analyzing qualitative data*", 1994, pp. 173-194.

1. Familiarization;
2. Identification of a thematic framework;
3. Indexing;
4. Charting; and
5. Mapping and interpretation.

The familiarization process involved the review of (i) all housing provider survey results, (ii) MHO staff, housing provider and service manager interview transcripts, and (iii) data collected through informal telephone conversations and site visits. Key insights and recurrent themes were noted during this process. A thematic framework was then developed, taking into consideration the original research questions to ensure they were being addressed[88]. Portions or sections of the data corresponding to an identified theme were then indexed (phase 3). This data was then organized in a chart (phase 4) of the themes identified in phase 2. Interpretation of the key findings laid out in the charts occurred in the final phase (Section 3.8.4).

3.8.3 Qualitative data collection summary

Of the 161 housing providers that participated in the REI, e-mail contact information was provided for 114 providers. Early in the project, an initial e-mail blast was sent out to all 114 addresses. E-mails outlined the project and its goals, verified contact information and gauged interest in participation. Of these e-mails, 48 addresses bounced back and 44 housing providers replied, with 43 replying that they were willing to participate. The willing housing providers were then contacted via phone where they were engaged in a short informal conversation about their RE system and their experience with the REI.

Key pieces of information gathered during an informal conversation included (i) whether they were satisfied with their system, (ii) whether it was operational and what they were doing to confirm the system's operation, and (iii) overall satisfaction with the REI, among other things. These informal conversations also provided the opportunity to gauge interest for participation in a survey, full formal interview or site visit. Depending on their interest, providers were then sent a survey and/or were scheduled for an interview. Formal interviews were scheduled at a later date and were recorded and transcribed for future analysis. Many providers were non-committal about further participation after the first interaction or did not end up participating in a survey or interview despite an initial interest. Most providers also did not opt to do both a survey and an interview.

Once the initial list of 43 confirmed contacts was completed, the team began reaching out to other providers using generic contact information from provider webpages. A similar process was followed - start with a phone call and follow-up with e-mail if necessary, find the right contact person, engage them in an informal conversation to collect some level of data at that first interaction, gauge interest in a survey interview or site visit, and then follow-up accordingly using either e-mail or phone. This typically involved a few rounds of follow-up to encourage participation. In total, the project team reached out to 121 of 161 providers (75%) that received REI funding and 65 (40%) participated in the

[87] (Ritchie & Spencer, 1994).
[88] (Ritchie & Spencer, 1994).

study via informal conversation, survey or formal interview. Many could not be reached after e-mail and phone follow-up.

The data collection approach was strategic. Early observations from interactions with providers suggested that they would often be willing to have a short conversation on the initial interaction but were then reluctant to spend additional time. The initial phone call then provided an opportunity to collect data but also to build a rapport that would encourage deeper participation in the form of survey, interview or site. Figure 3-31 shows the breakdown of housing providers by type that provided some level of qualitative data.

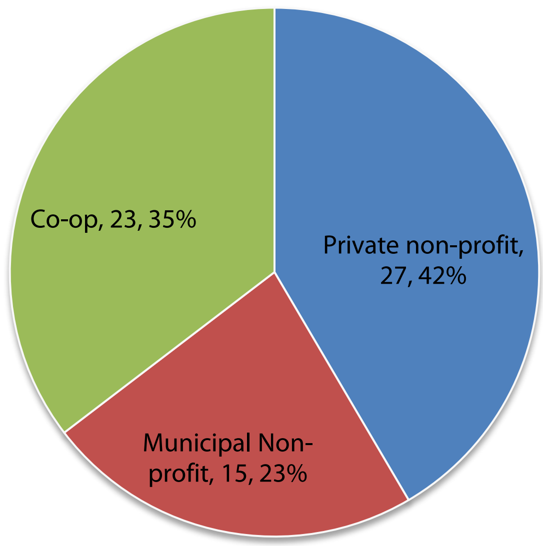

Figure 3-31. Qualitative data collection by provider type.

Figure 3-32 summarizes the data collection by data type. Note that some providers participated through multiple methods. Surveys, interviews, informal conversations and site visits with housing providers represented 232 sites (64%) that received REI funding. Eleven service manager interviews were conducted, representing 193 sites (53%) that received program funding.

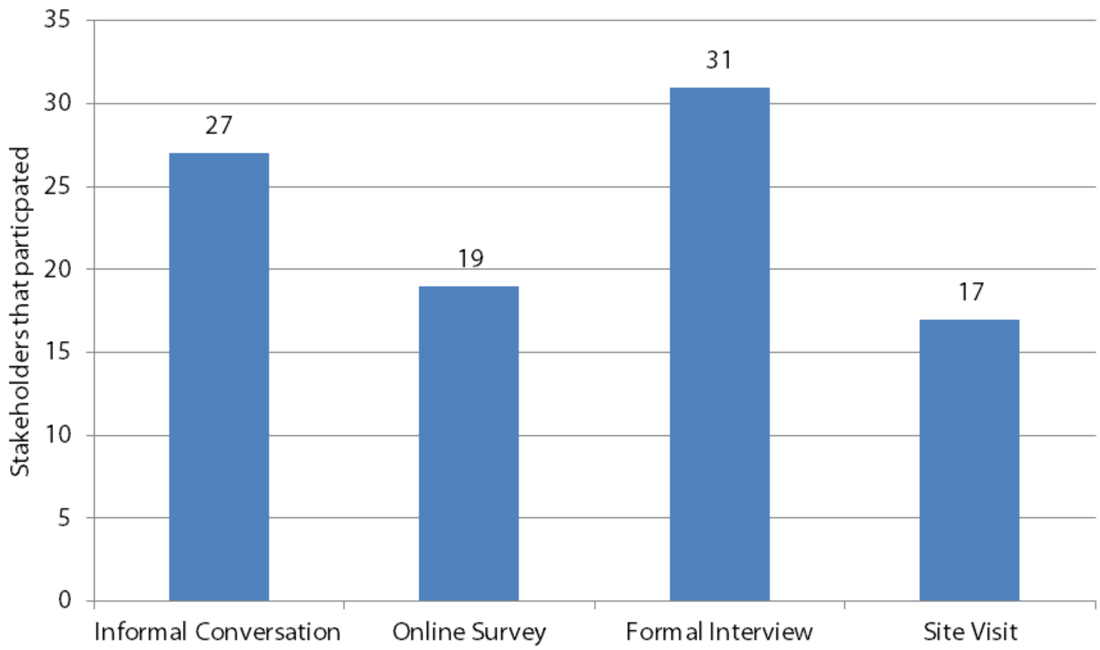

Figure 3-32. Summary of qualitative data collection.

3.8.4 Insights from the data collection

Insights observed from the qualitative data collection related to the areas listed below:

- Program Participation
- Program Goals and Structure
- System Design, Procurement, and Cost
- Installation, Operation and Maintenance
- Measurement and Verification

3.8.4.1 *Program Participation*

The majority of housing providers responded positively when asked about their experience participating in the REI program and felt that the installed RE systems were a success. The majority of housing providers also reported minimal barriers or program administration issues. However, it is worth noting that this study did not incorporate housing providers that did not participate in the program. Two significant barriers were noted: tight application timelines and grid connection affecting a small number of systems. Grid connection issues were due to technical grid capacity and safety limits and were not a shortcoming of the REI. Local Distribution Companies are generally required to help customers connect to their network in a timely and efficient manner, but connection of projects is subject to technical and safety limits. At times, a new connection can require an upgrade of the network, delaying connections[89]. It may be uneconomic for projects to connect to the grid in

[89] MHO Staff, telephone interview with Gil Amdurski, August 15, 2016.

certain areas. Of those providers asked, most felt they were better off for participating in the program[90] (Figure 3-33):

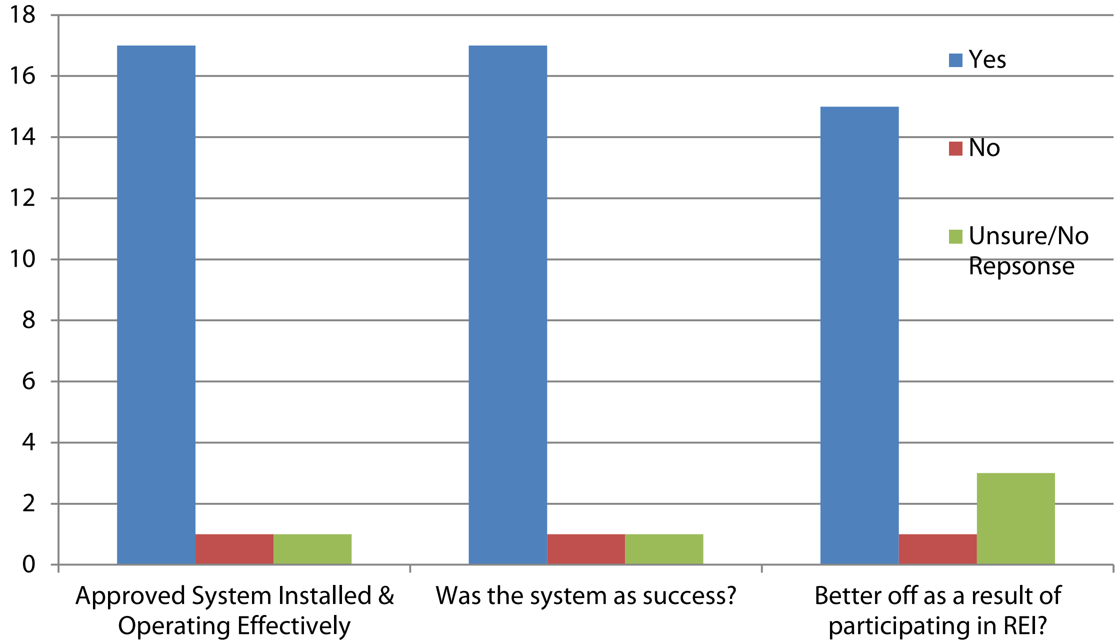

Figure 3-33. Provider feedback on systems and program participation.

Nearly all survey respondents reported that their systems were installed and operating effectively and that their systems were a success. Reasons for success included additional income and added funds to capital reserves, systems generating more energy than expected (PV), systems being low maintenance (PV), and decreased natural gas consumption (SDHW).

Most survey respondents also reported being better off because of their participation in the REI program (one respondent reported being neither better nor worse off). One respondent, who reported being 'unsure' if they were better off, felt that they are better off in the short term as they are receiving income from their FIT contract, but that in the long run (once the maintenance contract runs out) repair costs will be the same or higher for their SDHW system than a conventional domestic hot water system.

Of the survey respondents who knew the details of the project costs, half reported that REI covered all, or nearly all of the system costs (Figure 3-34).

[90] Data from online survey and informal conversations. Interview participants were not specifically asked this question.

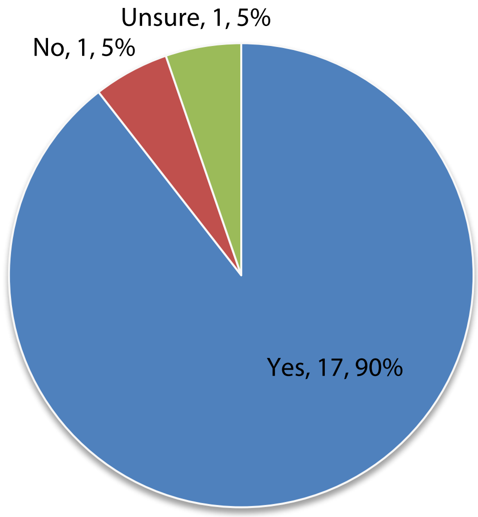

Figure 3-34. Survey responses: Did REI cover all, or nearly all, of system costs?

3.8.4.2 *Program goals and structure*

Program timelines were highlighted as an administrative issue by three stakeholders groups: housing providers, service managers, and MHO representatives. However, it was noted that as this was a joint provincial-federally funded program, flexibility in timelines was restricted. One service manager did state that because they were already engaged with housing providers due to the SHRRP program being in progress, it was easy to get the REI program out to providers[91]. Typically, some timeline flexibility was available for remote or Northern communities to work around weather and seasonal constrictions[92] - this may have affected some sites in those areas that did not have suitable vendors for systems, possibly preventing some providers from participating in the program.

Service managers noted that government-funding programs generally have fast turnaround times; however, the timeframe added additional constraints for the REI program due to the prescriptiveness of the program and types of systems funded. The program time constraints were not conducive to a proper site assessment to ensure that the proposed renewable energy system type was best suited to the property[93]. Generally, tight timelines are difficult for municipal housing providers who may also encounter delays due to municipal procurement policies and bureaucracy[94]. Providers that had already conducted energy audits and feasibility studies on the buildings in their portfolio were much better positioned to respond quickly to the program[95].

[91] Service manager ID 5, telephone interview with Gil Amdurski, September 15, 2016.
[92] MHO staff, telephone interview with Gil Amdurski, August 3, 2016.
[93] Service manager ID 29, telephone interview with Gil Amdurski, October 3, 2016; Service manager ID 10, telephone interview with Gil Amdurski, November 30, 2016.
[94] Service manager ID 29, telephone interview with Gil Amdurski, October 3, 2016.
[95] Sanjay Mishra, telephone interview with Gil Amdurski, August 22, 2016.

It was noted that a flaw of the program was a lack of performance metrics and goals built into the program, which made it difficult to evaluate the program[96], and MHO has since built metrics into other funding programs.

One service manager also stated that some providers did not feel there was anything in the program for them. This demonstrates a lack of knowledge about renewable energy system and their potential benefits, acting as a barrier to their participation and resulted in low uptake in some service areas[97]. There was also a perception from some providers whose portfolio consisted of smaller buildings (such as townhomes or single family homes) that renewable energy systems were not applicable to their buildings. One provider had stated that they did not see how a FIT/microFIT would work for a non-profit. As an example, PV was a relatively simple retrofit that would have been a good option on most buildings provided there was grid capacity and no significant shading issues, but providers were not always aware of the opportunity.

3.8.4.3 *System Design, Procurement, and Cost*

System Design

Within the different technology categories (PV, SDHW, solar air, geothermal and wind energy), different system types/designs are also possible and best practices for preferred system types were not always firmly established at the time of the REI due to the infancy of the renewable technology industries. Some providers saw an opportunity to build sector knowledge by purposely piloting different system types, yielding very useful case studies.

Several providers reported systems with design issues, and TRCA observed some design issues on site visits, of which the provider had not noted or been aware. One provider noted that their SDHW system "was way oversized" for the building[98], and modifications were necessary after the system was installed (at no additional cost to the provider; the system is working better but still not optimally). As a result, cost savings were reported to be lower than expected as the system is using additional electricity, partly diminishing the cost savings from reduced natural gas consumption. Another provider had the design of his or her system change because of additional engineering that was conducted[99]. The original design of the system required additional structural reinforcement to the building. This was done at the cost of the vendor. Other issues related to design in SDHW included a system where the piping froze and cracked and collectors mounted at non-optimal tilt angles that resulted in much lower savings for the provider. Some systems seemed to be encountering issues to sizing issues[100].

For the seven sites visits with SDHW onsite, there were notable issues with three systems (related to operation), two were inconclusive and two appeared operational (Appendix F). Because many of these systems are not monitored, it may be that system issues are not easily detectable. One of the

[96] MHO staff, telephone interview with Gil Amdurski, August 3, 2016..
[97] Service manager ID 5, telephone interview with Gil Amdurski, September 12, 2016; Service manager ID 13, telephone interview with Gil Amdurski, January 25, 2017.
[98] Anonymous, telephone interview with Gil Amdurski, August 17, 2016.
[99] Site contact ID 4, telephone interview with Gil Amdurski, August 12, 2016.
[100] Anonymous, telephone interview with Gil Amdurski, August 17, 2016.

geothermal systems had an unresolved O&M issue that limited performance. One vendor also reported that the designers of some REI funded PV systems did not design the system to the full potential of the roof, and there was capacity for the building to accommodate larger photovoltaic systems[101].

Other design issues noted were that the service life of existing roofs was not considered. Two sites indicated that additional costs would be incurred at the time of roof replacement due having to remove roof mounted PV systems to facilitate the repair. Some sites experienced minor technical or equipment issues, such as inverter failure on PV systems, which were either covered under warranty (with provider covering labour costs) or by the installing vendor[102].

Vendors

In some service areas outside the GTA, a lack of approved vendors was noted by survey and interview respondents. In the opinion of survey and interview respondents, the requirement for approved vendors worked well around the GTA but in more rural or remote areas, it may have limited the number of vendors that were eligible for REI funded projects. One service manager noted an issue finding vendors that were registered on the RET Vendor list –in a service area that was already experiencing low response to project bids[103]. Some interested vendors were not eligible under the REI rules, either because they did not apply to be on the RET Vendor List or did not meet the criteria to be included as an approved vendor. One municipal housing provider[104] suggested that many of the companies on the RET Vendor List may have been inexperienced installing renewable energy systems, potentially due to the infancy of the industry in Ontario at the time of the REI program roll out.

3.8.4.4 *Installation, Operation and Maintenance*

Utility connections

Many housing providers and service managers commented on the time required to obtain FIT/microFIT contracts or encountered issues connecting their projects to the grid. In other cases, housing providers suggested that initial issues in obtaining connection agreements with local distribution companies resulted in delays in them obtaining FIT contracts. One provider required four years to obtain the necessary connection agreements and FIT contract105. One site was not able to connect to the grid at the time of installation, and the vendor installed batteries to offset some loads in the interim[106,107]. This site was not yet connected to the grid at the time of this study[108]. A service manager from an area outside the GTA suggested that it was often the first time local distribution companies were dealing with these types of contracts, given the infancy of the Green Energy Act and

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[101] Vendor ID 1, telephone interview with Gil Amdurski, September 1, 2016.
[102] Vendor ID 1, telephone interview with Gil Amdurski, September 1, 2016; Site Contact ID 3, telephone interview with Gil Amdurski, January 26, 2017.
[103] Service manager ID 10, telephone interview with Gil Amdurski, November 30, 2016.
[104] Site contact ID 32, telephone interview with Gil Amdurski, January 19, 2017.
[105] Site contact ID 30, telephone interview with Gil Amdurski, August 22, 2016.
[106] Site contact ID 43, telephone interview with Gil Amdurski, September 1, 2016; Vendor ID 1, telephone interview with Gil Amdurski, September 1, 2016.
[107] It is not clear how the decision to install batteries was arrived at. The project team notes that this was not a cost-effective solution.
[108] Vendor ID 1, telephone interview with Gil Amdurski, September 1, 2016.

FIT/microFIT program at the time of the REI program rollout[109]. That service manager suggested that this caused delays for some REI projects and may have been the cause for some REI projects not going ahead or needing to be relocated, and it may have prevented some housing providers from applying to the REI program.

The authors of the report note that there may have been some confusion among service managers and housing providers as to what processes needed to be followed to contract and connect a RE project, what their responsibilities were for key elements of that process, and what expectations were reasonable for the development process.

Operations and Maintenance

The different technologies varied in terms of operations and maintenance (O&M) requirements. PV and solar air were reported to require minimal O&M. Previous work in this area found that geothermal systems typically require equal or less maintenance when compared to conventional systems[110]. Many providers noted that O&M of SDHW was more of a challenge. A number of providers reported that that there is no preventative maintenance done and no onsite method or procedure to monitor systems. During interviews and surveys, ten housing providers and one service manager reported having maintenance contracts with vendors. Nine of these contracts were stated to be long-term, ranging in length from 10 to 30 years, and all but two were paid up front with REI funding. Six providers reported that the original vendor with whom they had the contract either was sold to another company or had gone out of business. Two providers also reported that their vendor cancelled the contract. One provider indicated that it was looking to hire a contractor to perform annual maintenance as they do not have the proper in-house expertise to maintain the system properly and the initial vendor looking after the system went out of business[111]. One provider reported having difficulty getting the vendor to explain the maintenance requirements of the system[112].

The additional O&M challenge for SDHW technology resulted in some systems not operating optimally. For the seven sites visits with SDHW, there were issues related to O&M with three systems (Appendix F). Because many of these systems are not monitored, part of the issue is that system issues are not easily detectable. SDHW system owners with proactive internal maintenance personnel and building automation systems (BAS) to monitor system performance reported better results with their systems. This shows that SDHW systems are not intrinsically prone to failure but rather require a certain level of internal operational support infrastructure to ensure proper functioning. Furthermore, STEP's experience with SDHW is that systems with pre-assembled pumping/control/heat transfer stations tend to work more reliably than custom designed systems. This is an important consideration for applications where minimal O&M is desirable.

Six survey respondents reported performing regular maintenance to ensure systems were operating well, four also reported performing routine inspections of the systems (Appendix D). It should be

[109] Site contact ID 3, telephone interview with Gil Amdurski, January 26, 2017.
[110] Meanwell, C., T. Van Seters, and E. Janssen, 2015. Closing the Loop: A survey of Owners, Operators and Suppliers of Geoexchange Systems in the Greater Toronto Area, Toronto and Region Conservation Authority, Toronto.
[111] Site contact ID 34, telephone interview with Gil Amdurski, September 1, 2016.
[112] Site contact ID 84, informal conservation with Gil Amdurski, n.d.

noted that this does not mean that providers are not doing sufficient O&M in all cases –PV specifically requires very little O&M. One municipally owned housing provider reported having the capacity to send maintenance teams to check building systems, including arrays[113].

Costs - Net Revenue/Savings

Provider experience regarding expected net revenue/savings versus actual was varied among survey respondents (Figure 3-35). Those that reported net revenue or savings as less than was expected stated issues with FIT contracts (FIT1 vs. FIT2), assumptions regarding natural gas costs, and SDHW system maintenance issues as causes. Respondents who were unsure about expectations were not involved in the initial REI program application process.

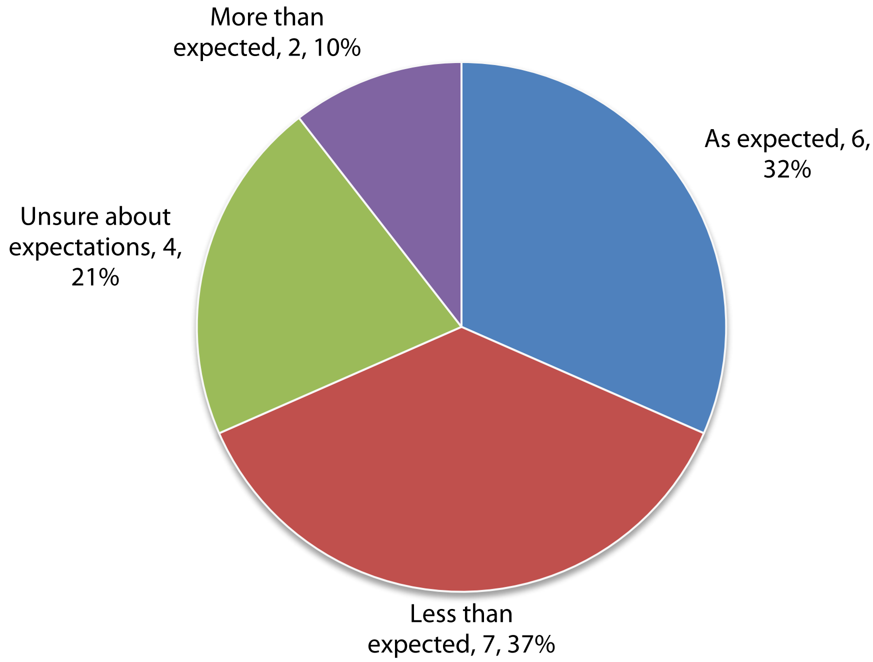

Figure 3-35. Survey responses: Were the net revenue or savings as expected?

Income and Savings

Half of survey respondents reported decreases in day-to-day operational costs for the building (Figure 3-36). Two providers that reported costs remained the same did state that they do receive revenue from their PV system that is put towards capital expenses, indicating that the question may not have been phrased appropriately. Another who reported costs remained the same did not see an appreciable reduction in gas consumption from their SDHW system, but stated there were other factors that may have contributed, such as occupant's water consumption habits. Two others reported there is some savings from gas usage but the amount is not monitored and savings are unknown. One provider reported that the installation of their PV system offset forthcoming roof replacement costs. The provider who reported an increase in day-to-day operational costs stated that their PV installation does earn them money, but the money was spent on roof repairs for a leak that was suspected to be caused by the PV installation. Several housing providers interviewed with SDHW systems reported

[113] Service manager ID 3, interview with Gil Amdurski, September 7, 2016.

seeing minimal or no cost savings. One provider reported that this was due to added maintenance costs[114], while others reported that it was difficult to determine savings as natural gas usage for water heating is combined with other uses[115].

In a small number of cases, PV system owners interviewed reported additional costs, at their expense, for rodent proofing[116] and snow removal (for systems installed at lower angles)[117]. There were also PV systems that have had to replace inverters; however, these were still under warranty and replaced at no cost to the providers. One site had to replace their SDHW system due to a cold winter that caused the system components to crack[118].

Some providers noted that the service life of existing roofs was not considered. Two sites indicated that additional costs would be incurred at the time of roof replacement due to having to remove roof mounted PV systems to facilitate the repair.

Operational Costs Savings and Impact on Tenants

Interviewees reported that income generated from FIT contracts was either kept by providers and used towards capital expenses or operating budgets, or a portion went towards offsetting operational subsidies received by the area service manager. Two providers are looking into having the income go into a separate fund for special sustainability or energy efficiency related projects[119]. Survey respondents reported operational costs savings were being passed down to tenants by directing funds towards building maintenance and upkeep.

[114] Site contact ID 27, telephone interview with Gil Amdurski, August 11, 2016.
[115] Site contact 1D 87, telephone interview with Gil Amdurski, September 8, 2016.
[116] Site contact ID 27, telephone interview with Gil Amdurski, August 11, 2016; Site Contact ID 34, telephone interview with Gil Amdurski, September 1, 2016.
[117] Site contact 1D 87, telephone interview with Gil Amdurski, September 8, 2016.
[118] Site contact ID 49, informal conversation with Erik Janssen, July 12, 2016.
[119] Site contact ID 34, telephone interview with Gil Amdurski, September 1, 2016; Site Contact ID 75, telephone interview with Gil Amdurski, August 22, 2016.

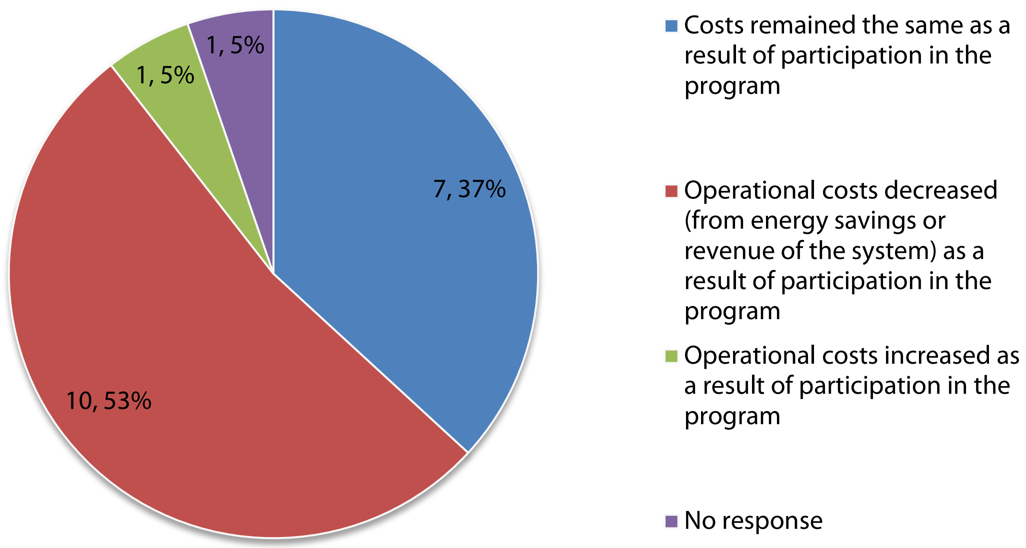

Figure 3-36. Survey responses: Impacts on the day-to-day operational costs [120].

Operations and Maintenance Guidance and Training

Operation and maintenance guidance and training was not included in the REI program. While there were some housing providers who had an onsite employee or dedicated maintenance person who was knowledgeable in the systems, generally many did not seem to have a strong understanding of how their systems worked. Capacity building to help providers effectively operate systems was highlighted as an issue in discussions with some service managers and providers. Only six providers surveyed reported receiving some training on their systems at the time of installation (Appendix D)[121]. However, one municipal housing provider interviewed did report spending time training on-site staff on the systems[122].

Sites often do not have a dedicated maintenance person. They also sometimes reported being understaffed and that inspecting mechanical systems may not be part of a building superintendent or building operator's duties[123]. Some commented that they do not have the in-house expertise to maintain the system[124], though did express willingness to learn if some training materials or tools were available (Appendix F). Providers did not always seem to be aware off the additional O&M requirements of the systems and while they acknowledge staff training was important, there was not

[120] It should be noted that this question may not have been framed effectively. Some providers noted that PV system income went to capital reserve rather than an operational budget and therefore they reported that operational costs remained the same.
[121] Site Contact ID 27, telephone interview with Gil Amdurski, August 11, 2016; Site Contact 1D 87, telephone interview with Gil Amdurski, September 8, 2016.
[122] Site Contact ID 3, telephone interview with Gil Amdurski, January 26, 2017.
[123] Service manager ID 33, telephone interview with Gil Amdurski, November 21, 2016; Site Contact ID 75, telephone interview with Gil Amdurski, August 22, 2016.
[124] Site Contact ID 34, telephone interview with Gil Amdurski, September 1, 2016.

always the capacity to do it[125]. A further challenge is that maintenance and building superintendent positions typically have a high turnover and any system knowledge acquired by staff may not be transferred.

One vendor commented that many property managers do not have much knowledge about the renewable energy system or electricity usage, and that there should be some education or training available to ensure they are better informed[126]. One service manager area office does offer resources and training to providers within their jurisdiction and have added components to RFP's for these types of programs to try to include capacity building and training of providers, but noted that they cannot force providers to use those resources[127]. They also noted that they tried to get vendors for REI funded system to provide training or an owner's operation and maintenance log and handbook to provide to providers[128]. On-site O&M log books or handbooks were not observed during the site visits.

3.8.4.5 *Measurement and Verification*

Operational supports

Survey respondents were asked if any supports were put in place after installation to ensure the system was operating well (Figure 3-37). The majority of respondents reported having installed one or more support to encourage system operations (Figure 3-38).

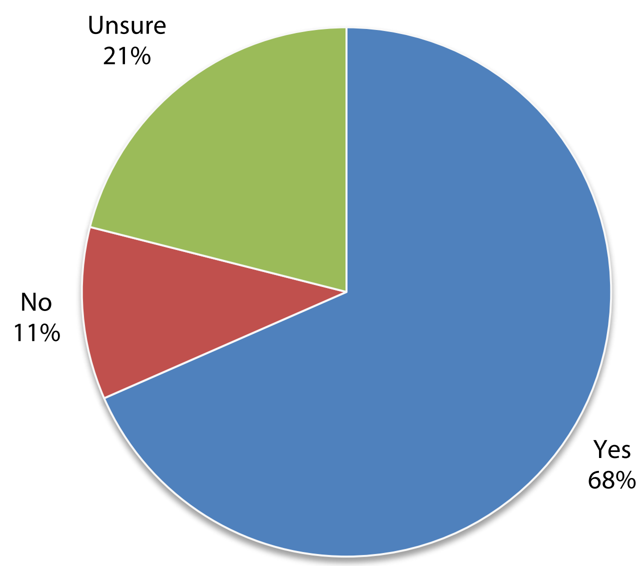

Figure 3-37. Survey responses: Were there supports in place to encourage effective system operations?

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[125] Service manager ID 29, telephone interview with Gil Amdurski, October 3, 2016.
[126] Vendor ID 1, telephone interview with Gil Amdurski, September 1, 2016.
[127] Service manager ID 29, telephone interview with Gil Amdurski, October 3, 2016.
[128] Service manager ID 29, telephone interview with Gil Amdurski, October 3, 2016.

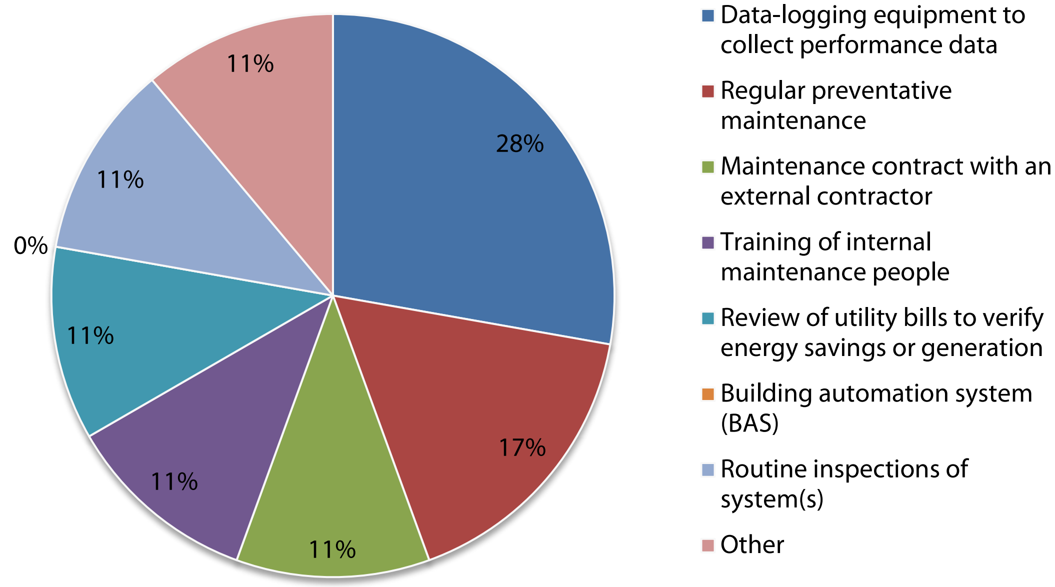

Figure 3-38. Survey responses: types of supports to monitor system operations used by housing providers.

In addition to those surveyed, three providers interviewed indicated that they had data loggers on-site or an online monitoring system[129]; 16 of the 17 site visits also had a type of monitoring system, though some were not operating (Appendix D). However, for sites with building automation systems (BAS) monitoring their systems, there was no screen visible on site and the information could only be accessed remotely. In some cases, this was part of an overall strategy to separate responsibilities of building operators and superintendents from system maintenance, but in other cases, it may have been a barrier for on-site staff to do basic checks on the system. Some providers noted that regular inspections were included as part of the systems O&M procedure. However, the occurrence and frequency of these inspections were not confirmed.

Several sites interviewed reported that there is no ongoing monitoring of system operations, outside of receiving income from a FIT contract. One site realized they were having problems with their PV system due to changes in their FIT payments[130], although it was not clear what was meant by that. Several sites with SDHW systems reported not reviewing and comparing historical usage to determine savings and general speaking, it did not seem like this type of analysis was formally done by many providers.

[129] Site contact ID 4, telephone interview with Gil Amdurski, August 10, 2016; Site Contact ID 27, telephone interview with Gil Amdurski, August 11, 2016; Site Contact ID 47, telephone interview with Gil Amdurski, August 11, 2016.
[130] Site contact ID 83, telephone interview with Gil Amdurski, August 12, 2016.

3.8.5 Summary of qualitative analysis: Key success factors

Through analysis of the survey, interview and site visit data, numerous factors were identified that contributed to the success of RE systems. Key success factors could be broken down into (i) those that promoted provider participation in the REI and (ii) those that promoted successful operation of an RE system once installed. Key factors promoting participation of providers in the REI program included:

- awareness of the opportunity presented by RE retrofits;
- existing knowledge of the RE system types;
- existing energy audits or feasibility studies;
- geographic availability of approved vendors;
- capacity to allocate resources to meet program deadlines;
- capacity to take on retrofit given other requirements of the building and the tenants;
- individual staff within organizations acting as champion for sustainability initiatives;
- organization sustainability targets to set priorities and guide decision-making;
- previous participation in SHRRP; and
- external project management support (service managers, Housing Services Corporation).

Key factors promoting successful system operation included:

- technology simplicity and minimal O&M requirements;
- design simplicity;
- effective system sizing and design;
- performance monitoring;
- on-site accessible performance indicators (gauges, control displays, etc.);
- strong system savings or income;
- maintenance contracts with large long-established companies;
- on-site knowledgeable/trained staff maintenance or dedicated off-site BAS building operators;
- maintenance checklists or other operational supports that incorporated RE systems alongside other mechanical system maintenance; and
- organizational follow-up between on-site maintenance staff and higher-level managers.

Many of the key factors promoting program participation were present in larger urban service areas and this is where program uptake was strongest. Issues surrounding capacity, awareness and readiness had the greatest affect in smaller rural service areas and limited uptake. The most important factor governing system success once installed was the simplicity of the technology, the system design and its O&M requirements. Systems that had notable O&M requirements were a challenge for providers and this affected system performance. However, it should be noted that such systems are not intrinsically prone to failure but rather, that they need to be placed in an environment with operation supports to ensure proper functioning. PV, solar air and geothermal were relatively simple in terms of O&M and these technologies were generally reported to be a success in terms of effective operation within the REI. SDHW was more of a challenge for providers to operate and maintain, and this was compounded by the fact that utility savings were perceived to be low due to the low-cost of natural gas.

The primary challenges encountered by REI program stakeholders were tight timelines and minimal renewable energy systems knowledge. More lenient timelines and additional guidance on the RE systems could have helped:

- increase program participation, particularly in service areas with smaller portfolios, limited staffing, and/or smaller vendor pools;
- led to improved system designs, resulting in systems that are within the provider's capacity to operate effectively and optimizing the amount of renewable energy generated or energy savings achieved; and
- mitigated some of the encountered O&M issues, ensuring that providers have the capacity and knowledge to properly and cost-effectively operate and maintain their systems for the duration of their service life.

3.9 Socio-economic impact analysis

This section analyzes the socio-economic impacts from installing renewable energy financed by the REI program. "Socio-economic" is understood to mean the consideration of economic impacts from a societal perspective. The REI program increased expenditures and income in Ontario. These are called *market impacts* because their effects were transmitted through the marketplace. The REI program also generated *social impacts* that affected wellbeing in ways that were not monetized as income or expenditures. Market and social impacts were analyzed by detailing the changes that resulted from the REI program, and how those changes were transmitted to others in Ontario.

Market impacts include the income earned by various sectors in the economy as they installed solar and geothermal technologies financed by the REI program[131]. The REI program *directly* paid companies that employed or subcontracted renewable energy installers, producers of equipment and materials, and designers that include architects, engineers, and other specialized professionals that played a role in planning for the projects. These direct payments ended up *indirectly* affecting other sectors of the economy that supplied other goods and services, as part of the broader supply chain.

Households employed in one of the impacted sectors would have *induced* additional market impacts when the household spent its additional income on other goods and services in the economy. Altogether, the *direct*, *indirect*, and *induced* effects were considered as the full market impacts in Ontario. These impacts were attributed to an estimate of full-time-equivalent jobs in Ontario that would have earned the income that was generated from REI program expenditures. Effects were also attributed to tax revenues generated in Ontario, and gross profits.

Social impacts of the REI program include the effects upon people seeing the installed renewable capacity on the buildings. Some people gained experiences and knowledge by being involved in planning for the systems and installing them. The team working on this report also gained experiences and knowledge analysing the projects, and engaging with industry personnel. These social impacts are important to consider, but the data to fully quantify them and assess their economic implications is not available and outside the current scope of work. In its place, similar research from other jurisdictions was reported in Section 2.

3.9.1 Allocation of program expenditures to NAICS sectors

To assess socio-economic impacts across the wider supply chain, REI program expenditures needed to be allocated to specific industries and sectors that were directly impacted. Existing information from Statistics Canada about the economy's entire supply chain was used, which helps to estimate economy-wide impacts. Statistics Canada's 2010 public list of 234 "industries" to account for the input-output relationships within the entire Ontario economy was used[132]. Industries encompass the entire business sector and were defined according to the 2007 version of the North American

[131] Expenditures on micro-wind projects were insignificant and were not included.
[132] Statistics Canada. 2014. Provincial Input-Output Multipliers, 2010. Industry Accounts Division / Statistics Canada. [Catalogue no. 15F0046XDB].

Industrial Classification System (NAICS)[133]. Industries also include the activities of non-profit institutions serving households, and functions of government.

The 2007 version of NAICS used by Statistics Canada in 2010 to account for the entire economy did not distinguish between solar and geothermal industries. There was no distinction of a "renewable energy" industry. Therefore, the project team needed to allocate expenditures to other industries that encompass a much broader scope of production. This allocation involved a detailed examination of REI program expenditures together with a detailed examination of Statistics Canada's presentation of NAICS[134] [135].

A collection of REI program feasibility studies was analyzed to disaggregate their expenditures. Detailed feasibility studies for seven solar photovoltaic projects, one solar air project, and one geothermal project were found. No REI SDHW feasibility studies provided by MHO included detailed cost breakdowns that could be used for this analysis. The nine feasibility studies analysed served as a convenience sample of all projects. A statistically random sample could not be determined because feasibility studies were not provided for all projects. However, since a categorization of all REI program expenditures was needed, the convenience sample was treated as if it were a random sample. This introduced an error of unknown significance. Table 3-21 presents results of this sampling.

Table 3-21. Sampling approach used to break down technology-specific spending.

	PV	SDHW	Solar Air	Geothermal	Wind[136]	All
Number of funded projects	255	80	17	9	1	362
Number of sampled projects	7	0	1	1	0	9

Feasibility studies from the convenience sample were supplemented by interviews with renewable energy companies. Some of these companies participated in the REI program, and some did not, but all had been involved in projects in Ontario. A complete list of interview questions can be found in Interview Methodology and Interview Guides (Appendix E). These interviews helped to generate a technology-specific breakdown of costs for installations of new PV, SDHW, solar air, and geothermal technologies.

The resulting breakdowns of costs were categorized into five mutually exclusive categories of: feasibility analysis, development, engineering, equipment and materials, and installation. Appendix G details this breakdown. The proportion of expenditures within each category was averaged for each

[133] Statistics Canada. 2015. North American Industry Classification System (NAICS) 2007. Retrieved from http://www.statcan.gc.ca/eng/subjects/standard/naics/2007/list.
[134] Statistics Canada. 2014. Provincial Input-Output Multipliers, 2010. Industry Accounts Division / Statistics Canada. [Catalogue no. 15F0046XDB].
[135] Statistics Canada. 2015. North American Industry Classification System (NAICS) 2007. Retrieved from http://www.statcan.gc.ca/eng/subjects/standard/naics/2007/list.
[136] Note that a small amount of funding was disbursed to one provider for engineering and feasibility studies concerning a wind turbine installation but the provider did not proceed on to the actual installation of the wind turbine.

technology type, and then applied to all expenditures of the same technology type. Therefore, as an example, the expenditures on feasibility analysis for all PV projects are assumed to be the average proportion that was spent within the seven sampled PV projects. The results from the PV projects were applied to SDHW since no feasibility study was found.

Table 3-22. Allocation of project cost categories to NAICS industries with NAICS codes.

Categories of Project Costs	Corresponding NAICS Industry (NAICS Code)*
Installation	Residential building construction (2361)
Equipment & materials	Building material and supplies wholesaler-distributors (416)
Engineering Feasibility study Development	Architectural, engineering and related services (5413)
(*) NAICS is the North American Industrial Classification System, which defines the activities carried out by the enterprises defined within each industry. The 2007 version of NAICS was used because this was consistent with the same industries recorded by Statistics Canada in its 2010 input-output tables.	

Table 3-23 allocates all five of the REI project cost categories from the convenience sample with three NAICS-defined industries. These industries are the smallest level of NAICS disaggregation that was represented in the 2010 input-output tables of Ontario from Statistics Canada[137]. Total REI project expenditures were allocated, by four technology types, to three industries as detailed in Table 3-23.

Table 3-23. REI expenditures allocated to industries, by technology (millions 2010 $).

Industry directly impacted	PV	SDHW	Solar Air	Geothermal	All
Residential building construction	4.2	4.1	0.4	1.4	10.1
Building material and supplies wholesale distributors	32.2	3.7	3.0	1.0	39.9
Architectural, engineering and related services	2.9	4.0	0.3	0.1	7.3
Total	**39.3***	**11.8***	**3.7**	**2.5**	**57.3**
*The totals are based on a previous iteration of the technical analysis. The totals for PV and SDHW are actually 39.1 and 12.1 (see Table 3-19), and total program expenditure is 57.4M$. These minor changes are inconsequential to the analysis.					

[137] Statistics Canada. 2014. Provincial Input-Output Multipliers, 2010. Industry Accounts Division / Statistics Canada. [Catalogue no. 15F0046XDB].

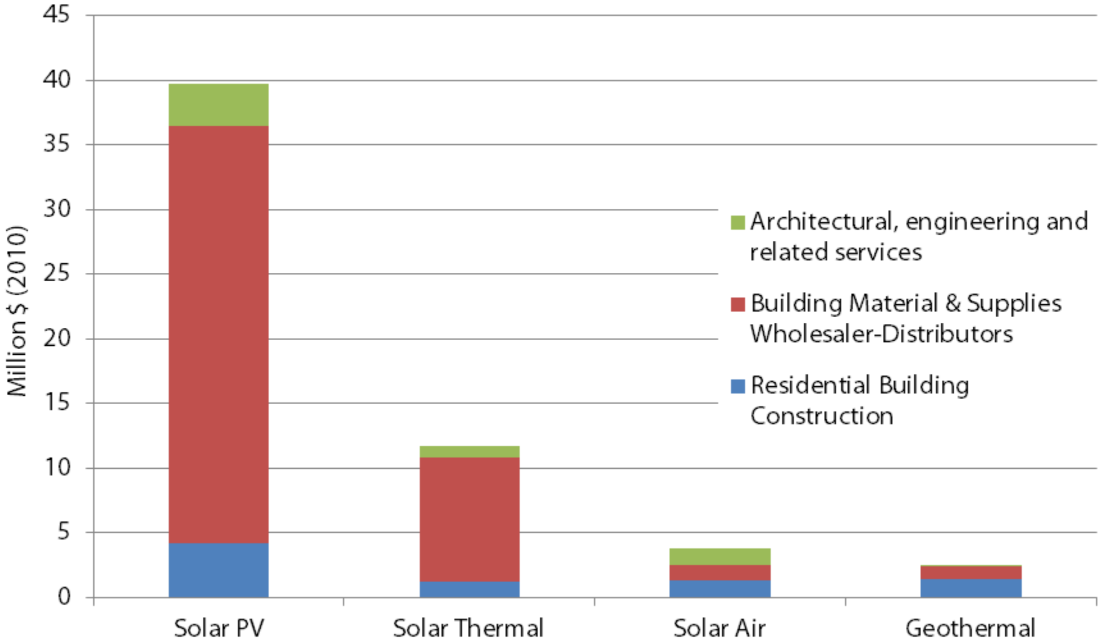

Figure 3-39. REI expenditures allocated to industries, by technology (millions 2010$).

3.9.2 Estimation of market impacts in Ontario

Statistics Canada accounts for inter-relationships between all industries that span business, government, and non-profit institutions serving households. These relationships inform an economy-wide supply chain, with an understanding of how each industry relates to each other in its supplies of outputs or use of inputs. These relationships are detailed by input-output tables from Statistics Canada, which are offered on a national and provincial scale[138].

Statistics Canada uses its input-output tables to derive multipliers that assess how a change in demand for one industry's output would affect that industry's production in a jurisdiction, in our case for Ontario. Multipliers are also derived for how a change in demand for one industry's output would affect all other industries, through the economy-wide supply chain. These multipliers from Statistics Canada for Ontario[139] in 2010 were used to estimate the market impacts in Ontario from REI program expenditures. Multipliers exist for all 234 industries, though the multipliers for the three aforementioned industries that supplied all the goods and services demanded by the REI program were used.

Input-Output tables represent economy-wide relationships at a certain point in time. Therefore, the multipliers generated from this data embed an assumption that relationships do not change when one or more are impacted. For this reason, economists urge caution when using these multipliers for estimating the impacts of significant changes in expenditures, which are more likely to change economy-wide relationships significantly. Fortunately, REI program expenditures of 57.4M$ were

[138] Statistics Canada. 2009. User's Guide to the Canadian Input-Output Model. Draft June 2009.
[139] Statistics Canada. 2014. Provincial Input-Output Multipliers, 2010. Industry Accounts Division / Statistics Canada. [Catalogue no. 15F0046XDB].

relatively small within Ontario's $600 billion economy in 2010[140]. Input-output tables and their derived multipliers represent an aggregation of all enterprises within an industry; they are not able to account for any variability of how industries might use inputs, or produce outputs. For this reason, actual impacts will differ from estimated impacts if the impacted enterprises are not the statistical average of all enterprises in their industry. This limitation is therefore embedded in all of our estimation of impacts.

Production in Ontario requires labour and capital, which both earn income. Some of the income from production is earned by government as indirect taxes, while at the same time governments may subsidize enterprises. Therefore the generation of additional Gross Domestic Production (GDP) results in the same amount of income being earned by either labour, capital (as gross profits), or by government as indirect taxes less subsidies. This is represented by the accounting identity:

GDP = Labour Income + Capital Income (profits) + Indirect Taxes Less Subsidies

Statistics Canada offers multipliers for each term within this identity. These multipliers were used to estimate each term, and to compare them as an indication of how the additional earned income was distributed between labour, capital, and government.

3.9.3 Impacts to GDP in Ontario across the wider supply chain

As detailed earlier, REI expenditures of 57.4M$ created new demand for the outputs of three industries that supplied and installed the four renewable technologies. These expenditures were estimated to **directly** generate 37.7M$ of Gross Domestic Production (GDP) in Ontario from the three industries that supplied the goods and services for the REI program. This is presented in Table 3-24 along with estimates of GDP that were indirectly generated and induced.

Table 3-24. Impacts on Gross Domestic Product (GDP) in Ontario (millions 2010 $).

	PV	SDHW	Solar Air	Geothermal	All
GDP directly generated in Ontario	26.8	7.0	2.5	1.4	37.7
GDP indirectly generated in Ontario	7.7	2.6	0.7	0.6	11.6
GDP induced in Ontario	8.7	2.6	0.8	0.5	12.6
Total GDP generated in Ontario	**43.2**	**12.2**	**4.0**	**2.5**	**61.9**
Total GDP Directly & Indirectly generated	**34.5**	**9.6**	**3.2**	**2.0**	**49.3**

GDP that was directly generated by REI program expenditures also **indirectly** generated GDP from other industries that supplied the three directly affected industries. This indirect effect captures impacts that rippled through the economy-wide supply chain, such that an additional 11.6M$ in GDP in Ontario was indirectly generated by REI program expenditures. This includes, for example,

[140] Statistics Canada. 2017. Gross domestic product, expenditure-based, provincial and territorial. CANSIM Table 384-0038.

production in industries that supplied materials for the engineers and designers who worked on installing the technologies under the REI program.

GDP that was generated directly and indirectly would have resulted in additional income to households who were employed in the impacted industries. When households spent this additional income on various goods and services, additional GDP would have been **induced**. This induced effect is estimated to have increased GDP by 12.6M$. When added to the other effects, the total of direct and indirect and induced effects in Ontario amount to generating 61.9M$ of GDP.

The correct way to interpret the total results from Table 3-24 is that the REI program likely generated between 49.4M$ and 61.9M$ of additional GDP in Ontario. The inclusion of induced GDP in the total is generally considered to overestimate the economic impacts, while its exclusion from the total would lead to an underestimate[141]. The exclusion of induced effects would omit the consequences of households spending their additional labour income and capital income. The inclusion of induced effects tends to overstate the impact of household spending because its composition is more dynamic (responsive to prices) than is captured by the static (once-in-time) input-output tables. Therefore the totals with and without induced effects should be considered upper and lower bounds of impacts, respectively. The timing of these effects cannot be specified, so one can only say that the additional GDP would have been realized in Ontario once all effects had finished rippling through the economy. Likely, this took place within a few years.

3.9.4 Impacts on jobs and labour income in Ontario

Statistics Canada multipliers were used to estimate the jobs that could have been created in order to generate the additional GDP attributable to the REI program. Jobs were estimated as if they were all Full-Time-Equivalent (FTE) jobs, based upon industry-level average statistics of labour productivity and full-time hours.

Table 3-25 presents the estimate that 365 FTE jobs could have been directly created in Ontario in the three sectors that worked to install the REI capacity. It is estimated that 122 additional FTE jobs could have been indirectly created in other sectors that supplied goods and services to the three sectors that were directly impacted. A further 117 FTE jobs could have been induced in Ontario when the households with the additional jobs would have spent their additional income. Altogether, the REI program is likely to have created between 487 and 604 FTE jobs in Ontario while the additional GDP was being generated. These results are presented in Figure 3-40.

Table 3-25. Impacts on Full-Time-Equivalent (FTE) jobs in Ontario.

	PV	SDHW	Solar Air	Geothermal	Total
FTE Jobs directly created in Ontario	251	75	24	15	365
FTE Jobs indirectly created in Ontario	80	29	7	6	122

[141] Statistics Canada. 2014. Provincial Input-Output Multipliers, 2010. Industry Accounts Division / Statistics Canada. [Catalogue no. 15F0046XDB].

FTE Jobs induced in Ontario	80	24	8	5	117
Total Jobs created in Ontario	**411**	**128**	**39**	**26**	**604**
Total Jobs directly & indirectly created	**331**	**104**	**31**	**21**	**487**

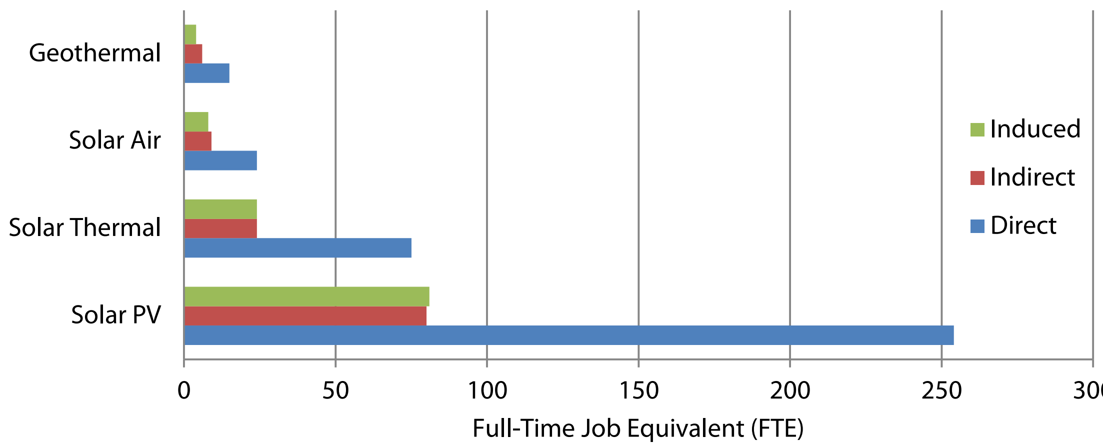

Figure 3-40. Full-time-equivalent (FTE) jobs generated in Ontario as a result of REI investments.

Table 3-26. Impacts on Labour Income in Ontario (millions 2010 $).

	PV	SDHW	Solar Air	Geothermal	All
Labour Income directly earned	16.2	4.8	1.5	0.9	23.4
Labour Income indirectly earned	4.9	1.7	0.5	0.4	7.5
Labour Income induced in Ontario	4.1	1.2	0.4	0.2	5.9
Total Labour Income earned in Ontario	**25.2**	**7.7**	**2.4**	**1.5**	**36.8**
Total Directly & Indirectly earned	**21.1**	**6.5**	**2.0**	**1.3**	**30.9**

Each job that was created resulted in additional labour income. This income was estimated in Table 3-26 using Ontario-level multipliers from Statistics Canada. The jobs that could have been directly created in Ontario from the REI program would have earned about 23.5M$ in additional labour income. Divided by the 365 directly created FTE jobs, this income works out to about $64,400 per job, which is inclusive of employer contributions to voluntary and mandated labour benefits such as Employment Insurance and the Canada Pension Plan. In total, between 30.9M$ and 36.8M$ in labour income was earned in Ontario from REI program expenditures.

3.9.5 Impacts on government revenue of indirect taxes less subsidies

Governments in Ontario earned additional indirect tax revenue, and provided additional subsidies to enterprises, because of REI program expenditures. Statistics Canada accounts for indirect taxes on products (such as sales taxes), and production (such as fees and capital taxes), subsidies on products (including energy), and subsidies on production (such as payments for workforce training)[142]. These subsidies on products were found to be just slightly higher than taxes on products. Subsidies on production were found to be negligible, while taxes on production generated net revenues to government.

Table 3-27. Impacts on Net (Indirect) Taxes (less Subsidies) in Ontario (millions 2010 $).

	PV	SDHW	Solar Air	Geothermal	All
Net Tax Revenue directly earned	1.06	0.04	0.10	0.10	1.30
Net Tax Revenue indirectly earned	0.48	0.12	0.04	0.03	0.67
Net Tax Revenue induced (in Ontario)	0.86	0.25	0.08	0.05	1.24
Total Net Tax Revenue earned	**2.40**	**0.41**	**0.22**	**0.18**	**3.21**
Total Net Tax directly & indirectly earned	**1.54**	**0.16**	**0.14**	**0.13**	**1.97**

Table 3-27 presents the analysis of the net effects of the sum of taxes on products and production less the effects of subsidies on products and production. On a net basis, governments in Ontario earned between 1.97M$ and 3.21M$ in additional revenue because of REI program expenditures as their impacts rippled throughout the economy. Most of this net revenue was generated from taxes on production. Statistics defined these taxes to include regulatory fees, taxes on payrolls and capital, local real property taxes, and fees earned from selling business licences, permits, and other authorizations[143].

3.9.6 Distribution of increased income in Ontario

As stated earlier, all production of GDP results in the same amount of income being earned by labour, capital, and government through indirect taxes less subsidies. Therefore, the REI program's generation of between 49.4M$ and 61.9M$ in additional GDP in Ontario resulted in the same amount of income being distributed between labour, capital, and indirect taxes less subsidies. Capital earns income after payments to labour and government are deducted from gross earnings. Capital income represents gross profits to business enterprises. This amount was calculated directly using Statistics Canada multipliers, though it could also have been determined as the residual after subtracting labour income and indirect taxes less subsidies from the income generated by increased GDP in Ontario.

Table 3-28. Distribution of the total additional income generated in Ontario by the REI program after all direct, indirect, and induced effects were realized.

Share of additional income earned as	PV	SDHW	Solar Air	Geothermal	All
Labour income	58%	58%	63%	62%	59%
Capital income (gross profits)	36%	36%	33%	30%	36%

[142] Statistics Canada. 2009. User's Guide to the Canadian Input-Output Model. Draft June 2009.
[143] Statistics Canada. 2009. User's Guide to the Canadian Input-Output Model. Draft June 2009.

Government indirect taxes less subsidies	5%	5%	3%	7%	5%

The percentage share of these distributions is provided in Table 3-28. The percent shares were calculated for the maximum impacts (from direct, indirect, and induced effects). These shares are within a few percentage points of the same calculated from the minimum of only direct and induced effects (not shown). Shares vary slightly by technology since the expenditure on each technology involved a different composition of expenditure among the three industries that supplied the goods and services of purchasing and installing the technologies. The technology of solar air generated the highest relative returns to labour, while PV generated the highest relative returns to capital (as gross profits). Among all installed technologies, geothermal installations generated the highest relative share of revenue to government through indirect taxes less subsidies. A summary of all REI program impacts is provided in Figure 3-41.

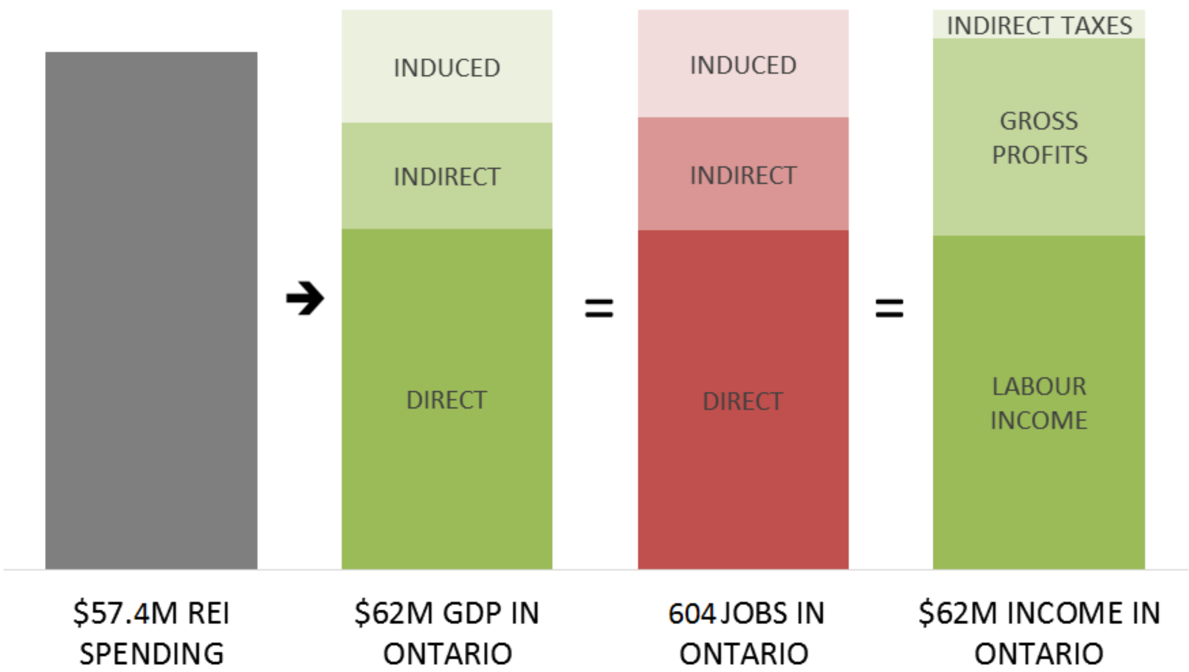

Figure 3-41. Summary of direct, indirect and induced socio-economic impacts of the REI program

3.9.7 Social impacts in Ontario

The REI program generated social impacts that affect individual and societal wellbeing, but which were not monetized as a change in income or expenditures. According to the International Energy Agency (IEA), programs like the REI, if analyzed through the energy-saving benefits alone, show modest returns on investment and might suggest an ineffective use of government spending. However, the multitudes of co-benefits of such programs, which are not often considered in program evaluations, have long-lasting benefits for low-income communities that surpass simple government policies, such as fiscal or monetary initiatives, which can often be unsustainable[144].

Many social impacts would flow from renewable energy installations. A Corporate Social Responsibility report completed by Deutsche Bank in 2012 outlines the multiple benefits of energy efficiency and retrofits in affordable housing. This is reproduced in Figure 3-42 an easy-to-follow and logical timeline of the systemic economic, social and environmental benefits.

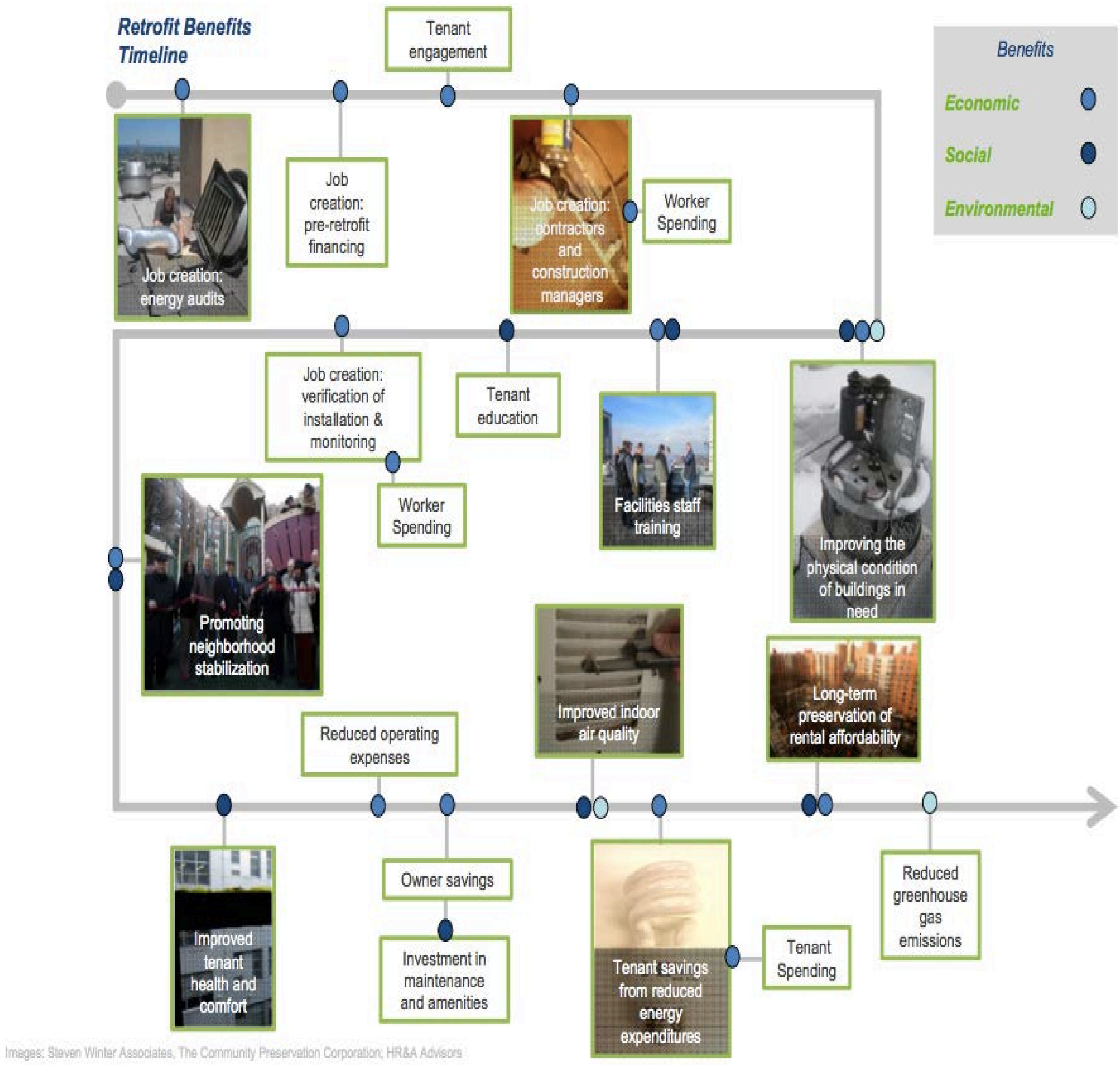

Figure 3-42. Multiple benefits of energy efficiency and retrofits in affordable housing.[145]

[144] Heffner, G., & Campbell, N. (2011, June). Evaluating the co-benefits of low-income energy-efficiency programmes. In Workshop Report, OECD/IEA, Paris.

Additional co-benefits could be **directly** felt by governments, energy providers, property owners, and residents. These might come in the form of avoided energy assistance spending/subsidies, disconnection fees, or collection calls[146]. Co-benefits may also be **indirectly** felt by program participants, the broader community, taxpayers and building owners as renewable energy retrofits provide energy-security thereby improving the health and safety of residents[147]. This leads to reduced emissions and fewer sick days and hospital visits. It also drives up the value of property, decreases the strain on LDCs and, if properly introduced, generates key understanding and knowledge of renewable energy within the community. These social impacts are important to consider, but the data was not available to fully quantify them and assess their economic implications. Additionally, analysis of this kind was outside the scope of work for this project.

Understanding the socio-economic impacts as well as the co-benefits of renewable energy retrofits in social and affordable housing in Ontario is an important starting block in developing programs that address current inequality in the province's energy systems. Moreover, while the results gained in REI program provide insight into the economic impacts and effectiveness of this project, the data available to conduct a comprehensive analysis of social effects was quite limited. For example, to what extent did tenant consultation take place in housing where retrofits occurred? Were they engaged in the installations as they were carried out? Were they made aware of the objectives of the REI and how they, personally, might be impacted? Were they given an opportunity to participate to some extent in the installation or to see its ongoing progress? Unfortunately, the REI program was not set up in a way that required consultation with, or participation of, affected communities. While this may have happened in some instances, data was not available to the project team to determine the qualitative social impact.

Similarly, the amount of money saved because of the REI retrofits is an important quantitative measurement; however, understanding more clearly what was done with that money would go a long way towards understanding the social benefits to local communities. For example, was the money saved reinvested into the community, the social and affordable housing sector, the renewable energy industry? Was tenant rent affected – did it remain the same, did it rise or decrease? Understanding and measuring these factors may have led to a broader awareness of the social benefits and could lead to the quantitative and qualitative measurements of factors such as those listed in Figure 3-42.

Analyzing the implementation of the REI program facilitates the ministry's goal of mitigating energy poverty and driving a low-carbon energy transition by providing guidelines and recommendations that aim to increase the success of future projects progressively. In order to do this, it is recommended that additional parameters be included in program application requirements. Specifically, feasibility

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[145] Image Source: Deutche Bank (2012). Retrieved from http://energyefficiencyforall.org/sites/default/files/DBLC_Recognizing_the_Benefits_of_Efficiency_Part_B_1.10%20%281%29.pdf.

[146] Heffner, G., & Campbell, N. (2011, June). Evaluating the co-benefits of low-income energy-efficiency programmes. In Workshop Report, OECD/IEA, Paris.

[147] Heffner, G., & Campbell, N. (2011, June). Evaluating the co-benefits of low-income energy-efficiency programmes. In Workshop Report, OECD/IEA, Paris.

studies could also include an examination of social and economic barriers in the community prior to REI installations and the expected social and economic benefits to the local community and to society. To complete the application requirements, sites could then provide a post-project report that details to what extent those social impacts were achieved and how.

Recognizing the merits and drawbacks of such investments raises awareness about renewable energy among government, service providers, local residents and the public. With this knowledge, decision-makers and community members can mobilize in an effort to support renewable energy technologies, energy conservation and efficiency measures, and provides energy access that recognizes existing geographic and climate limitations. Being Canada's most populated province[148], Ontario also stands to be a leader in the transition to a low-carbon future. With the social and affordable housing sector at the helm, the province can show where and how investments in renewable energy can instigate the greatest impacts.

More specifically, determining the impacts are important for building energy literate planners, service providers and other decision makers who understand the functionality of different renewable energy technologies for different geographic locations. This is an important step to building understanding for:

- how communities are directly and indirectly impacted by renewable energy and on-site generation,
- how this differs from traditional forms of generation and distribution,
- what types of renewable energy technologies are suitable for different geographic locations, and
- understanding the socio-economic impacts generates discourse around renewable energy projects and provides a platform to both learn and grow in our transition to a low-carbon future.

3.9.8 Cost-effectiveness of technologies

Key outcomes from the REI program include (i) provincial energy savings, (ii) energy-cost-savings to housing providers, (iii) reductions of greenhouse gas emissions, and (iv) FTE jobs created in Ontario from the full GDP impacts of installations. Results reported earlier in this section were integrated to assess the cost-effectiveness of the four renewable energy technologies that were installed. Table 3-29 reports these results. Per million dollars of REI expenditures, solar air generated the highest lifetime energy savings. This technology was therefore estimated to be the most cost-effective at saving energy of all the installed technologies. PV generated the highest lifetime energy-cost savings to housing providers, per dollar of REI expenditure, but the lowest lifetime GHG reductions. All technologies generated at most about 10 to11 Full-Time-Equivalent (FTE) Jobs in Ontario from the full (direct, indirect, and induced) GDP impacts.

[148] Statistics Canada. 2016. Population by year, province and territory. Retrieved from http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo02a-eng.htm.

Table 3-29: Outcomes per million dollars of REI expenditures on each technology.

	Outcome per million dollars of REI expenditure				
Outcomes	**PV**	**SDHW**	**Solar Air**	**Geothermal**	**All**
Lifetime energy savings or generation (GWh)	3.4	3.3	17.6	13.6	4.7
Lifetime benefits to housing providers ($M)[149]	1.59	0.20 - 0.27	1.04 – 1.41	0.52 - 0.91	1.22 – 1.27
Lifetime GHG reductions (kt CO_2e)	0.17	0.57	3.00	2.88	0.55
FTE Jobs created in Ontario from full GDP impacts of installations	11	11	11	10	11

Table 3-30 presents the same basic data as Table 3-29, except that the data is expressed as a ratio to compare the different technologies more easily. The numerator of the ratio is simply the corresponding value in Table 3-29 and the denominator is the smallest value in the corresponding row in Table 3-29. As an example, the lifetime energy generation of PV, SDHW, solar air and geothermal is 3.4, 3.3, 17.6 and 13.6 GWh per million dollars of REI expenditure. Table 3-30 reports a cost-effectiveness ratio where these values are all divided by the lowest value in the group (which is SDHW at 3.3). SDHW is therefore assigned a cost-effectiveness ratio of one for energy generation. On the other hand, the cost-effectiveness ratio of solar air for energy generation is five, illustrating that solar air generates five times more energy over the system lifetimes when the same amount of funding is provided for each technology. It is clear from Table 3-30 that no single technology was the most cost-effective across all categories.

For lifetime energy savings in Ontario, solar air was estimated to be the most cost-effective technology, generating five times more energy savings than SDHW, per dollar of REI expenditure. PV was the most cost-effective in terms of net benefits to housing providers through the FIT program price[150], while it was the least cost-effective in terms of GHG reductions. Solar air is estimated to have generated 18 times more lifetime GHG reductions than PV, per dollar of REI expenditures. This is based on the assumptions that 80% of systems are offsetting natural gas. All technologies generated about the same FTE Jobs per dollar of REI expenditures, and therefore had the same relative cost-effectiveness ratio.

[149] For non-PV systems, these values assume that systems are offsetting a mix of 20% electricity and 80% natural gas. Furthermore, these values are estimates that pertain *to the REI program*. Great care should be taken when drawing conclusions about system performance outside of the REI. For example, PV system financial performance is based on FIT/microFIT rates that are no longer available; a performance de-rate was applied to SDHW energy generation based on site visit observations, and SDHW/geothermal system costs may have been higher in the REI than in the private sector.

[150] There will be no further FIT application windows, however, and the microFIT program will finish at the end of 2017.

Table 3-30: Relative cost-effectiveness ratios of installed technologies, by outcome. [151]

	Relative Cost-Effectiveness Ratio			
Outcomes	**PV**	**SDHW**	**Solar Air**	**Geo-thermal**
Lifetime energy savings	1	1	5	4
Lifetime net benefits to housing providers	8	1	5	3
Lifetime GHG reductions	1	3	18	17
FTE Jobs created in Ontario from full GDP impacts of installations	1	1	1	1

[151] These outcomes are based on the assumption that non-PV systems are offsetting 20% electricity and 80% natural gas. The results vary widely based on the assumptions about the fuel being offset.

4 FUTURE PROGRAM CONSIDERATIONS

Future program considerations based on analysis results from the previous section are presented in Section 4. Section 4.1 present considerations more directly related to the REI and future programs of similar nature. Section 4.2 discusses insights related to sector-wide capacity building.

4.1 Observations from the REI program and how it impacted REI

4.1.1 Administration documentation and record keeping

Table 4-1. Future program considerations for administration, documentation and record keeping.

	Observation	How it impacted REI	Cross-jurisdictional insights	Future consideration
1	System size data was not recorded.	System size data is needed to estimate energy generation, financial performance and carbon savings. Collecting system size data also allows for the benchmarking of system costs in the REI in comparison to the private sector. System sizes needed to be estimated in this evaluation because it was not recorded. This was time consuming and less accurate.	N/A	Collect system size data alongside system cost and other data.
2	Where multiple systems were installed, only the overall cost was recorded not the per-system cost.	The evaluation looked at the different technologies both separately and as a whole. However, the total costs spent on a certain technology were not precisely known because of those cases where multiple systems were installed and there was no cost-breakdown. This then required a greater degree of estimation within the analysis.	N/A	Collect data on the cost of each individual system installed in those cases where multiple systems were installed.
3	Centralization of record keeping.	Items (1) and (2) may have actually been recorded within the different service manager offices – just not centrally. If it is not centrally recorded, then it is less conducive for a program evaluation.	N/A	Record data centrally when it is important for a program evaluation.
4	Missing a proper address on a small number of sites.	In the records provided, a small number of sites did not have the physical street address where the system was installed. In other cases, it seemed that the system was installed on an adjacent building in the complex but not at the specific address given. In other cases, systems may have moved without being updated within the central records. This	N/A	Ensure that the address provided for the system is a complete address and is the actual location of the install (rather than a mailing address for example).

		made the evaluation more challenging.		
5	Complete contact information was not provided across all stakeholders service managers, housing providers, and vendors.	Contact information is very helpful when doing a program evaluation; for example, it is useful when generating an e-mail list for mass e-mails or online surveys. Without the contact information, it is necessary to call or e-mail stakeholders using generic contact information, navigate the organizations, perform repeated rounds of follow-up, etc.	N/A	Collect and centrally record REI stakeholder contact information (including e-mail) for the specific individuals that were associated with the retrofits (SMs, providers, vendors).
6	Requiring and recording commissioning reports would be beneficial.	A formal commissioning procedure would ensure that a given systems meets its design objectives before handing the system off to a housing provider. Commissioning procedures are typically summarized in a commissioning report and this document would be useful to record centrally alongside other program document like feasibility studies. If nothing else, it is evidence to service managers, governments and other third parties that the given system was installed properly and operating as designed.	N/A	Consider requiring a formal commissioning procedure with a commissioning report centrally recorded.
7	Data was not kept on person-hours spent administering program from any of the stakeholder groups.	It was not possible to quantitatively analyze the effort required to administrate the program.	N/A	Consider collecting data on the person-hours spent to administer the program.
8	Criteria used by service managers to rank or approve systems were not known.	This may not have impacted the program. However, it would be useful to have this piece of information for a program evaluation.	N/A	Provide guidance to SMs on how to rank systems or record the criteria they used to rank systems.

4.1.2 Feasibility studies and business cases

Table 4-2. Future program considerations for feasibility studies and business cases.

	Observation	How it impacted REI	Cross-jurisdictional insights	Future consideration
1	Feasibility studies varied widely in terms of what sort of data was presented and what was considered.	When feasibility studies are presented in different formats it makes an evaluation of them more onerous. The larger issue was that there often was not a lot of information in the business cases or feasibility study. This meant that there was limited data with which to evaluate their quality or utilize their information in the evaluation. It also meant the SMs might have had more difficulty in ranking projects.	Best Case Practices: Technical and financial analysis of a retrofit project supported through standardized methods (RetScreen, etc.) can elevate the acceptance of retrofit measures. Comparing analysis against standardized building benchmarks can help identify and prioritize retrofit investments. Case Study from Wiltshire (England) - Housing Board provides benchmark criterion as guidelines or reasonable payback period. Individual housing units can check against the established standard to see if they are making a financially viable decision.	Provide a feasibility study template or list requirements for feasibility studies.
2	Feasibility studies for the majority of systems were not provided.	Feasibility studies contain a wealth of useful information about expected system performance, cost and cost-breakdowns, and are very helpful for a program evaluation. With most feasibility studies not provided, the data was more limited.	N/A	Centrally collect all feasibility studies.
3	What was actually installed often differed from what was proposed in the feasibility study.	It would be beneficial for a program evaluation if data on the actual install were recorded as well as what was initially proposed in the feasibility study.	N/A	In addition to feasibility studies, collect data on what was actually installed.
4	Cost breakdowns were not normally provided within the feasibility study – only total cost.	Cost-breakdowns that are more detailed would have been beneficial for evaluating the socio-economic benefits of the program.	N/A	Require a cost-breakdown in feasibility assessments and for the actual installed system.

4.1.3 Measurement and verification

Table 4-3. Future program considerations for measurement and verification.

	Observation	How it impacted REI	Cross-jurisdictional insights	Future consideration
1	M&V was not included	It would be ideal if the program	North American and international energy M&V	Incorporate M&V.

	as part of the REI.	evaluation could be based on actual performance data. Requiring some level of monitoring would also be beneficial for the providers by providing feedback on system performance.	protocols are used by funding agencies and lenders to develop verified measures of energy savings. Consider adopting one such standard, North American Energy Measurement & Verification Protocol (NEMVP) Options B, as a requirement. NEMVP Option B provides recommendations for verifying actual energy savings post-installation and over the long term of the retrofit.	
2	Requiring performance monitoring is not enough.	Simply installing monitoring equipment is not likely to be enough. To ensure successful data collection, there needs to be an M&V plan that incorporates appropriate checks to ensure data quality. There also needs to be some mechanism to ensure that the M&V plan is followed. For one provider, there was evidence of monitoring equipment that had been installed but never utilized.	Consider requiring NEMVP Option A, which provides recommendations for verifying that equipment and systems that were contracted to be installed were actually installed.	Incorporate M&V in such a way that involves a formalized M&V plan with some mechanism to ensure that the plan is followed.
3	Where M&V was done independently by consultants hired by the providers, the reporting was sometimes not sufficiently detailed to have confidence in the results upon review.	An M&V report should provide monitoring results but also provide sufficient detail about the monitoring such that a reader can be confident that the results are reliable. Data is ultimately not that useful unless there is confidence in its accuracy. In this evaluation, providers did share some M&V reports that did not have enough detail to have confidence in the results.	Consider adopting International Performance Measurement and Verification Protocol (IPMVP) Option A standard, which provides recommendations for selecting parameters of reported data on individual retrofit projects	Where external consultants do M&V, provide clear guidance on what needs to be included in the final reporting to ensure the quality of the results.

4.1.4 Technology selection, installation, operation and maintenance

Table 4-4. Future program considerations for technology selection, installation, operation and maintenance.

	Observation	How it impacted REI	Cross-jurisdictional insights	Future consideration
1	No operation and maintenance training or	Some of the non-PV systems were not operated effectively and	Retrofitting of Social Housing (ROSH) was a pilot program by implemented in 8 European Union	Incorporate O&M guidance or training.

	guidance was provided as part of the program.	some operators expressed that they did not know how to operate or maintain their systems.	nations from 2004-2008. In addition to supporting energy sustainability retrofits, the ROSH initiative provided training, seminars, workshops and conferences for building managers, housing boards and service managers during the retrofit installation and decision-making process.	
2	Providers may or may not have trained their own staff internally.	Some of the non-PV systems are not operated and maintained effectively.	ROSH provided training and consultation events led not just by experts, but peers in the housing sector. Such peer-to-peer knowledge transfer activities helped raise awareness and technical knowhow among the housing staff.	Incorporate O&M guidance or training.
3	Staff turnover creates an additional challenge for providers in terms of O&M.	Superintendents might have high turnover and if the system knowledge is not transferred appropriately then the incoming staff might not be able to operate and maintain it effectively.	ROSH hosted a telephone hotline and an interactive website - a one stop reference and help-desk for all energy retrofit related questions. This helped provide long-term technical support for staff, boards and managers (old and new).	Incorporation of O&M guidance or training should address the challenge of staff turnover.
4	Providers may not have had a clear idea of what system maintenance entailed prior to system ownership.	Some providers were overwhelmed when they began encountering O&M challenges. There may be a tendency to take a system because it is free even though an organization is not truly ready to operate and maintain it effectively.	Energy Performance Integration in Social Housing (EPI-SoHo) is a European project for developing a strategic approach for portfolio management. In a case study of 30,000 social housing units in Netherlands, EPI-SoHo recommends providing orientation on energy improvement technologies, methods and practices to housing sector personnel. This basic training was achieved through checklists, brochures, and webinars, and helped support "implementation of energy performance into the daily practice of public housing organizations".	Provide guidance to providers that helps ensure that their O&M capabilities are well-matched with O&M requirements of the technology they may be considering.
5	Some systems had limited gauges or displays and relied on a BAS that was not accessible on the site. This made it difficult for on-site personnel to actually see if/how the system is operating.	When the system is a "black-box" with no or minimal indication about whether it is working, on-site personnel will not be able to troubleshoot, or even identify, whether there is a problem or not. Without some sort of indicator about the system and its performance, providers become	Can be addressed by adopting a M&V protocol like IPMVP Option A.	The benefit of on-site performance indicators should be made clear to both vendors and providers.

		skeptical about whether it is doing anything at all – and potentially even skeptical about renewable energy systems in general.		
6	Some providers paid up front for a long-term maintenance contract using REI funding. In general, paying 100% up front results in poor service.	The REI was a one-time payment. This meant that O&M contracts needed to be paid for up-front. However, because it was paid for 100% up-front, the service was sometimes poor or the company went out of business without providing the services.	Two municipalities in Germany (Frankfurt and Potsdam) have an innovative approach to financing energy consultation services. First, the city sponsors training energy consultants and technicians, paid for through city budgets and federal job-training funds. The portion of training costs borne by the city is recovered through energy savings in social housing operated by the municipality. Subsequently, the energy consultants offer consulting packages free of charge to local social housing units. The costs for these services are sponsored by a partnership of manufacturers, utilities, youth employment center and workforce training organizations. Initiatives like this can make long-term maintenance cost neutral for social housing, while also providing employment opportunities for locals.	Incorporate O&M contracts in such a way that does not require 100% up-front payment to the vendor.
7	There was sometimes insufficient follow-up from higher level staff in larger organizations	Some superintendents responsible for general building maintenance reported that there was no follow-up from any other staff higher up in the organization and furthermore, that they were never trained on the system or officially given responsibility over it. If there is no follow-up within the organization than a lower-level employee like a superintendent or maintenance person can easily turn the system off or not address any problems that arise.	Can be addressed by adopting a M&V protocol like IPMVP Option A or C.	There should be some mechanism to ensure that higher level staff is communicating with on-site staff to ensure effective system operation. This might be solved through M&V requirements.

9	Some FIT systems never got connected	This was an issue with the initial versions of the FIT and microFIT program. Later versions included a connection capacity assessment that determined up front whether a system could be connected to the grid.	N/A	
10	In some cases, savings may be not enough to justify O&M effort.	The technical analysis identified that for SDHW, in some cases, it may be that systems cost more to operate or maintain then is provided in gas savings or that savings are entirely offset by costs. This sentiment was echoed in the interviews.	N/A	More thorough up-front vetting of systems may identify systems that are at risk of providing poor savings. O&M costs should be considered in feasibility analyses.
11	O&M may have been represented as being more complicated than it needs to be.	There was one geothermal installation that required a seasonal switch over of the heat pumps. This was not always done in timely manner and the system was sometimes operating in cooling mode during heating months. The provider seemed engaged and willing to take part in O&M and it is feasible that seasonal switch over could have been accomplished by the provider rather than an O&M contract.	N/A	Provide guidance to providers on the type of O&M work that requires specialized knowledge and the type that can be done by maintenance staff of the building.

4.1.5 System design and cost

Table 4-5. Future program considerations for system design and cost.

	Observation	How it impacted REI	Cross-jurisdictional insights	Future consideration
1	Costs of systems could vary greatly and there is some evidence to suggest that system costs within the REI were higher than private	Both the SDHW and geothermal system costs may have been higher in the REI than in the private sector. Solar air system costs varied greatly, as much as an	Best Case Practices: Technical and financial analysis of a retrofit project supported through standardized methods (RetScreen, etc.) can elevate the acceptance of retrofit measures. Comparing analysis against standardized	In the case of a 100% capital cost subsidies, costs should be compared against industry benchmarks costs prior to

	sector costs.	order of magnitude. If costs are artificially higher in the REI then it is feasible that a greater number of retrofits could have been performed with the same level of funding.	building benchmarks can help identify and prioritize retrofit investments. Case Study from Wiltshire (England) - Housing Board provides benchmark criterion as guidelines or reasonable payback period. Individual housing units can check against the established standard to see if they are making a financially viable decision. A rule-of-thumb benchmark for maximum payback periods as criteria for project approval may help rein in extreme variance and outliers in project costs.	approval to help reduce artificially inflated prices. Providers themselves could be given some motivation to install cost-competitive systems.
2	100% capital cost subsidy might encourage system oversizing or poor system design.	There might be a temptation to build a system that is larger than it needs to be (or should be) when it is fully funded, both on the side of the providers and on the side of the vendor. There was one case of an SDHW system that was notably oversized.	N/A	Design-bid-build contract structures might help alleviate this issue.

4.1.6 Program evaluation

Table 4-6. Future program considerations for program evaluation.

	Observation	How it impacted REI	Cross-jurisdictional insights	Future consideration
1	This evaluation of the REI was performed several years after the program was administered. Due to staff turnover, it was often difficult to get quality feedback from Service managers.	It was common that the program staff that worked with the REI were no longer at the service manager office. Even when we got in touch, the quality of the feedback was lower because this is several years later and they have not thought about the program in a long time.	Consider combining formal M&V protocol with automated quantitative data gathering and warehousing to assist with future project evaluation. Case study from EU (SAVE@Work4Homes Project) - Automatic monitoring and transmission of building consumption data across 2100 social housing units. Through simple interactive dashboards, this initiative provides self-assessment tools for service managers, property managers and even building tenants. The evaluation process demonstrated that in many cases feedback from visual data on actual energy consumption and costs helped achieve energy savings close to 10%. Furthermore, it helped evaluate post-installation performance of retrofits across the entire program portfolio. Another case study from the EU (RESHAPE) recommends making constant monitoring, evaluation and analysis a part of the organizational process throughout the design, implementation and post-installation process.	Some level of evaluation should be conducted shortly after each system has been commissioned.
2	Due to the constraints of the evaluation, there was a heavy reliance on surveys and interviews with housing providers rather than on quantitative performance data.	It may be the case that staff representing the systems is not always intimately aware with their function. It is sometimes difficult to rely on the perceptions of providers in terms of system performance - they may be biased from pre-existing viewpoints (good or bad) At least in the case of PV, which comprised the majority of systems in the REI, it is more likely that their view of the technology is based on actual performance data in the form of payments from their utility.		Incorporating M&V as well as surveys and interviews would allow for a balanced evaluation based on real data.
3	In general, the program evaluation was not built into the program design.	Ultimately, the evaluation is less effective because it was not incorporated into the program design and key data are missing.		Program design should build in the program evaluation such that all necessary data are collected as the program is implemented.
4	In general, providers are busy and have limited time to participate in an evaluation if they are not specifically required to.	The response from providers is lower than it otherwise could have been. They may have been keener to participate if it was a requirement of the funding or they were engaged in the evaluation shortly after they		Participation in the program evaluation could be a requirement of the providers receiving funding.

	received their funding.

4.1.7 Program goals and structure

Table 4-7. Future program considerations for program goals and structure.

	Observation	How it impacted REI	Cross-jurisdictional insights	Future consideration
1	There was no program-wide performance metrics formulated up front against which the success of the program could be evaluated.	The program evaluation was not part of the initial program design. It may have been ideal if the program was designed to achieve a certain performance metric and then an evaluation could measure the extent that that was achieved.	N/A	Consider formulating clear performance metrics when designing an RE incentive.
2	Providers naturally gravitated to the system type with the best financial performance.	Providers overwhelming opted to install the most lucrative system type, PV, but PV is not a strong carbon saving technology because Ontario's overall electricity supply mix already comes from mostly non-emitting fuel sources. There is likely an optimal balance of system types to promote both overall cost-effectiveness and GHG savings.	N/A	An incentive program might incorporate mechanisms to actively encourage a diversity of system types to achieve different goals.
3	Some providers reported that timelines were unnecessarily tight between the announcement of the program and due dates for applications.	This was more stressful on smaller providers with more limited resources.	At energy sustainability workshops focused on energy sustainability in Ontario's social and affordable housing sector, organized by Housing Services Corporation (HSC), Clean Air Partnership, ONPHA and others, a common recommendation emerges - be prepared. Utility program managers, energy contractors, building managers and professions familiar with the sector suggest routine building assessments and planning for retrofit funding opportunities. Other recommendations include assessing building' energy profiles cross entire service	There are various strategies to promote sector readiness for incentive programs.

			area portfolio, identifying worst performers, prioritizing projects, building relationships with utilities and energy professionals to target opportunities for retrofits.	
4	Renewable energy systems were sometimes deployed in buildings that may have benefitted more strongly from other upgrades (for example, high efficiency boilers).	Where the goal is to optimize payback to the provider and GHG savings, in many cases it may be more appropriate to first upgrade current building systems rather than installing an entirely new additional renewable energy system.	N/A	Renewable energy systems could be considered for a building after higher impact financial and carbon-saving opportunities have been explored.

4.2 Insights on sector wide capacity building

Low carbon energy finance initiatives like the REI program rely on improving the business-case for retrofits by offering 100 percent up-front capital cost subsidies. In doing so, they directly tackle the biggest and final barrier in the energy retrofit pipeline – the barrier of lack of access to capital. However, when funding is limited and competitive, program eligibility is restricted to a small percentage of housing providers. Moreover, an even smaller segment actually receives the full benefits of such programs. There is also evidence that the periodic availability of full capital cost subsidy programs like REI creates a culture of dependence within the sector that inhibits proactive and innovative financing approaches by service managers and housing providers. The decision to defer capital energy investments until the availability of a new pot of provincial subsidies is a rational one from the perspective of service managers and housing providers: why risk capital with a third-party financing scheme when a full capital cost subsidy program is expected to be on the way from the provincial government? While rational, this perspective potentially limits total investment in low carbon energy retrofits, and hence presents a barrier to achieving sector-wide and provincial GHG reduction objectives.

Successful implementation of energy sustainability projects in social housing over the long-term would require policy support to tackle barriers at each level of the energy retrofit pipeline. Incentive programs like REI however can eliminate only financial barriers, and only for a limited pool of applicants that have already successfully navigated through other barriers. Without support at other stages of the retrofit pipeline, a majority of housing providers will continue to experience awareness, technical and institutional barriers. By concentrating funding at only one barrier, programs like REI risk negatively disrupting the entire retrofit pipeline (Figure 4-1).

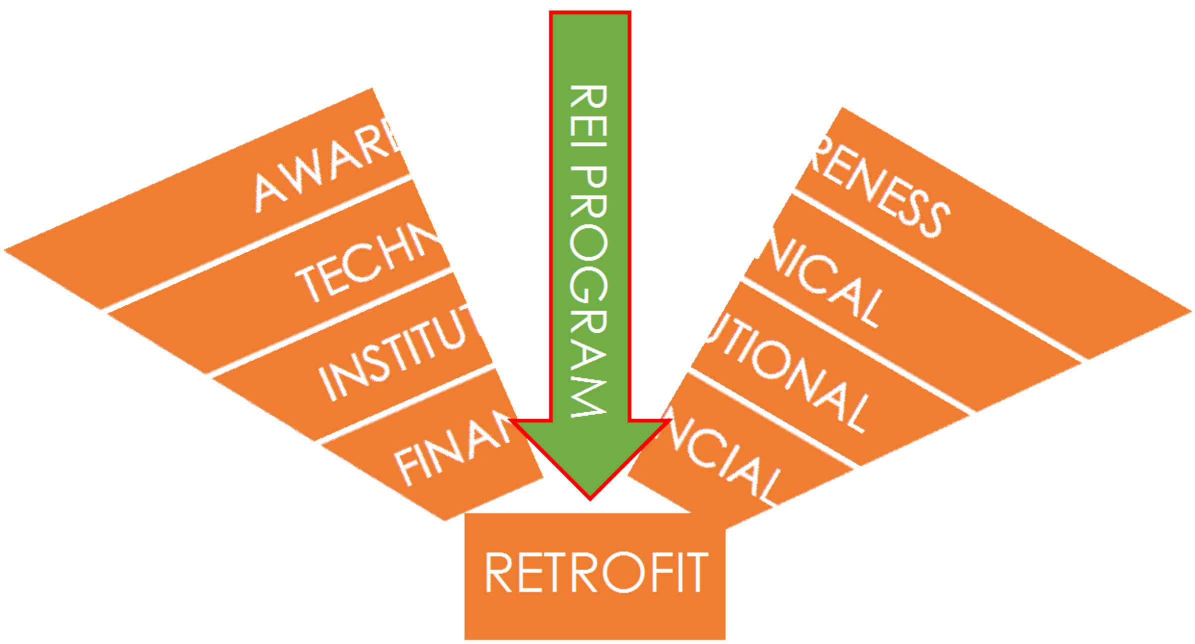


Figure 4-1. REI Program conceptual diagram

With an overall stock of more than 260,000 homes, social and affordable housing represents 5% of Ontario's housing supply, and nearly 20% of all rental supply. Given the lack of investment in new social and affordable housing buildings, and historically limited investment in energy retrofits, current dynamics indicate that the vast majority of Ontario's 260,000 social and affordable housing units will remain energy inefficient unless comprehensive action is taken to increase sector-wide capacity for low carbon energy investment (Figure 4-2)[152].

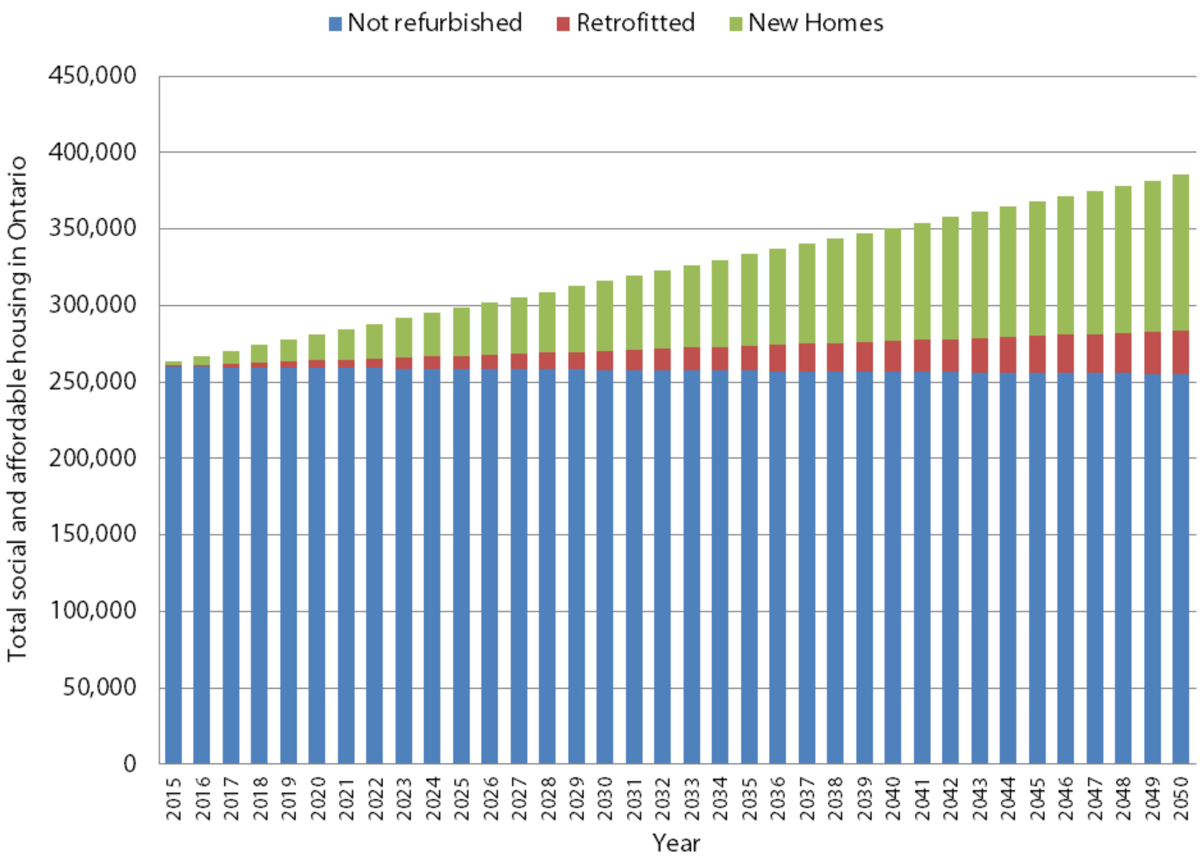


Figure 4-2. Ontario social and affordable housing future projections[153]

Even under the ambitious assumption that all new social and affordable buildings built in Ontario from 2016 onwards will be net-zero constructions, the overall stock in 2050 will still consume a substantial amount of energy (Figure 4-2).

[152] Milin, C., Conseil, I., F-, V., Immobili, A. B., & F-, P. (2011). Energy retrofitting of social housing through energy performance contracts a feedback from the FRESH project : France, Italy, United Kingdom and Bulgaria. *Energy*.
[153] In the European Union, the annual new building replacement rate is slightly lesser than 1%. Each year, new buildings being built account for roughly 1.1% of all building stock. Close to 0.15% stock is destroyed or lost each year. United Nations Economic Commission for Europe estimates that in the business as usual case, only 0.3% of social housing building stock undergoes a comprehensive energy refurbishment every year.
Assuming these trends hold true for Ontario, current dynamics indicate that nearly 80% of all buildings currently existing will still be operational by 2050. At this rate, on average, nearly 90% of building stock in 2050 will still be energy inefficient

The scale and pace of necessary low carbon investment will not be met through traditional public incentive mechanisms like up-front cost subsidies or fully funded projects. Indeed, unlocking the full potential of energy savings in social and affordable housing will require mobilization of massive amounts of private investment. In addition, rapid development of energy sustainability retrofits necessitates additional support like raising awareness, improving technical and program assistance, training a skilled workforce, and building confidence in technology through demonstration projects. A well-designed holistic retrofit program will seek to improve the overall rate of energy retrofit program participation by building readiness within the sector to serve as a host for low carbon capital investment by public and private sector institutions. Maintaining energy sustainability projects over the long term would require policy support to tackle barriers at each level of the energy retrofit pipeline. Strategic and systematic interventions at each stage of the pipeline can accrue exponential gains in the overall retrofit rate (Figure 4-3).

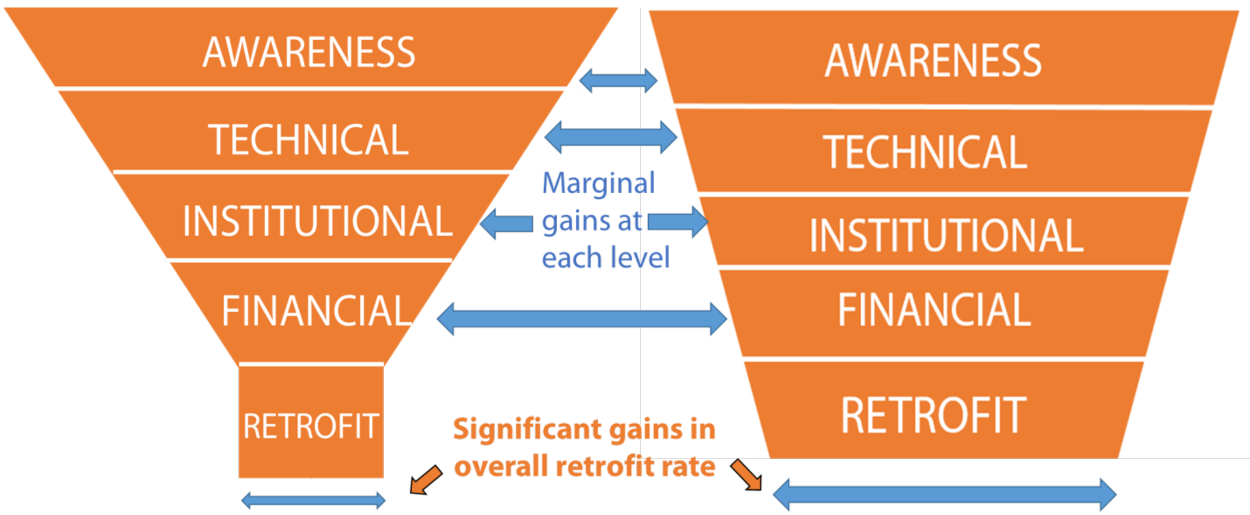


Figure 4-3. Conceptual diagram of how interventions at each stage of pipeline can lead to significant gains in overall retrofit rate.

In order to increase the social and affordable housing sector's capacity and readiness to serve as a host for low carbon investment, an effort to integrate energy management into existing asset management strategies is needed. To illustrate this at a high-level, a generic energy portfolio management framework explicitly modeled after MHO's Strategic Asset Management Framework is presented below (Figure 4-4)[154].

[154] Ontario Ministry of Housing. (2014). *Revitalizing and refinancing social housing: how do you get there?* Retrieved from: http://www.mah.gov.on.ca/AssetFactory.aspx?did=10648.

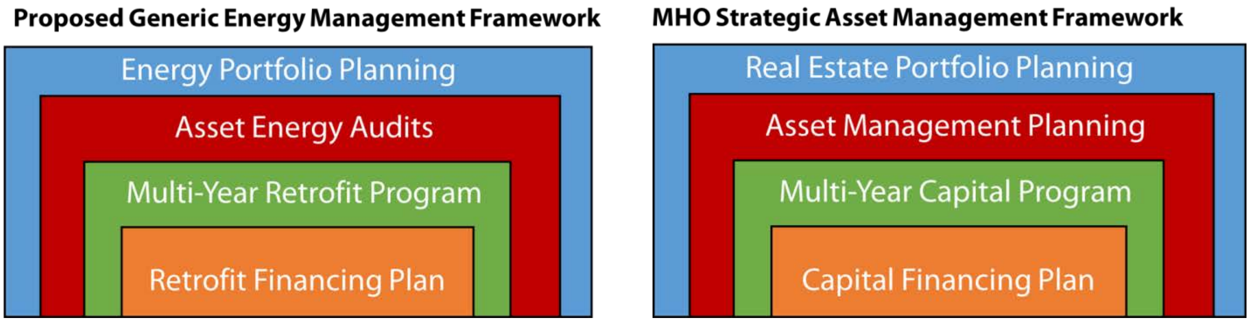


Figure 4-4. Proposed generic energy management framework compared to MHO's strategic Asset management framework.

4.2.1 *Energy portfolio planning*

An evidence-based assessment of energy use across an area service manager's building portfolio is the first step in the comprehensive energy management strategy. A big picture overview of baseline energy consumption helps area service managers identify opportunities and limitations to energy retrofits within their portfolio. A comprehensive database of building level energy consumption helps them identify the most energy intensive assets, and prioritize them for upgrades.

4.2.1.1 *Barriers addressed*

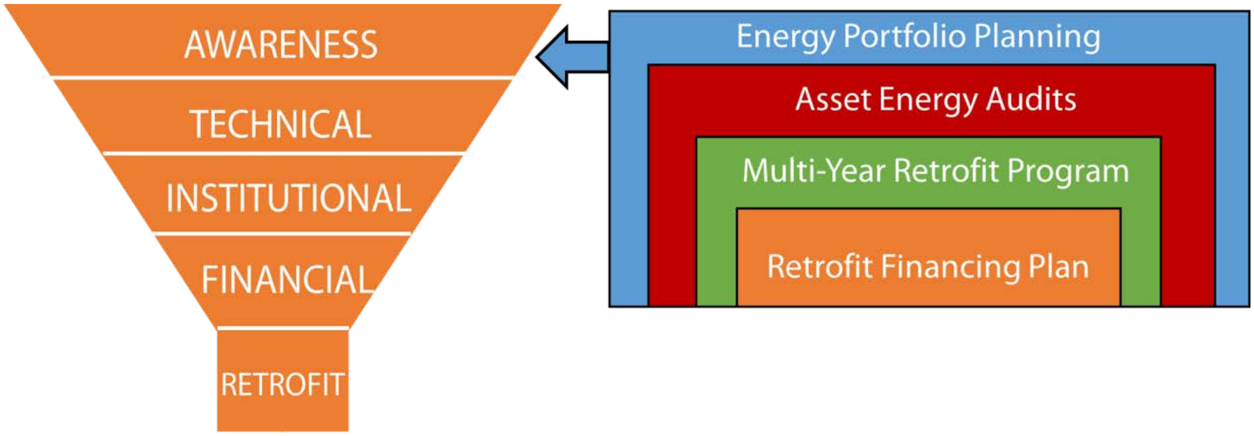


Figure 4-5. Addresses barriers regarding lack of awareness of baseline energy consumption and building level information

4.2.1.2 *Establish vision and goals*

Strategic alignment of energy performance goals in the social and affordable housing sector with overarching provincial and federal sustainability goals may provide long-term financial, policy and planning support. Service managers can leverage broader municipal energy goals and community energy plans in support of retrofit programs. Adopting quantitative goals about increasing renewable energy adoption, decreasing energy use or reducing GHG emissions[155] provides guidance for directing investments and developing strategies while measuring program success and outcomes.

4.2.1.3 *Analyze energy portfolio*

Prepare an inventory of assets and baseline energy use across the portfolio. Collected information may include:

- current and past utility energy bills[156];
- fuel type for heating;
- building age, typology. climatic zone, building material;
- building management and operations (municipal, non-profit or co-op); and
- history of past energy audits or retrofits in building.

The exercise aims at developing a statistical overview of overall energy demand and general characteristics of energy use across a service manager's portfolio. Data will be used to estimate the potential for energy and GHG reductions across the portfolio.

4.2.1.4 *Develop an energy management plan*

Based on analysis of baseline energy use data, area service managers can develop a long-term energy upgrade plan in consultation with social and affordable housing providers. Long-term plans will quantify the magnitude of investments and technology adoption necessary to meet energy goals. An integrated plan will identify timelines for making updates, beginning with most inefficient assets. Plans will review policy, technical and financial resources available to support energy upgrades and develop a roadmap streamlining all available and proposed programs.

4.2.1.5 *Housing provider engagement*

Service manager can lend their expertise and assist social and affordable housing providers to meet their energy sustainability goals by:

- building capacity and sharing strategies for energy management planning;
- encouraging housing providers to review energy use data and retrofit existing stock;
- reviewing community energy plans and promote social and affordable housing sector as a market opportunity to direct investments towards meeting local energy goals;
- providing financial incentives to encourage collection of building level energy use data;
- promoting blending energy planning into prevailing asset management planning;
- sharing knowledge, best practices, case studies and success stories of energy retrofits from other social and affordable providers; and

[155] Natural Resources Canada. (2014). Improve your Building's Energy Performance: Energy Benchmark Primer (Cat. No. M144-250/2013E-PDF). Retrieved from: http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/BenchmarkPrimer_en.pdf.

[156] Initiatives like Ontario's Green Button make it easier for utility consumers to access energy usage information. Currently 60% of Ontario's electric customers have access to Green Button 'Download my Data' program. See https://news.ontario.ca/mei/en/2014/02/ontarios-green-button-initiative-1.html.

- qualitatively assessing the barriers faced by housing providers - understanding how housing providers experience barriers (awareness, technical, institutional or financial) can help service managers identify opportunities for providing support.

4.2.2 Asset energy audits

Once baseline energy use has been determined and energy inefficient buildings have been identified, energy audits provide specific insights into measures that can be taken to improve building energy use. Audits help service managers and housing providers make informed decisions about how to prioritize retrofits across their portfolio.

4.2.2.1 Barriers addressed

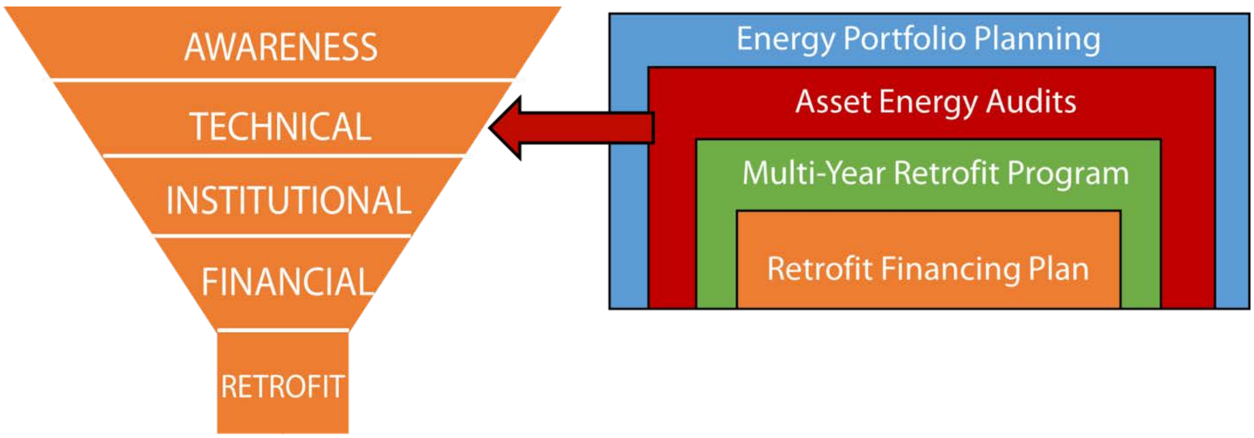


Figure 4-6. Asset energy audits address barriers associated with lack of technical capacity in social and affordable housing providers.

4.2.2.2 Perform energy audits

An energy audit[157] is a comprehensive examination of how a building uses energy, how much the energy costs and a recommended program for changes in practices or technology that will reduce energy usage and lower energy bills.

Audits usually begin with a walkthrough inspection of buildings to compile equipment inventory, age and operation characteristics. Expert energy auditors will identify defective equipment issues and perform metering/testing to identify energy losses. Investment grade energy audits[158] will include cost-benefit analysis, calculation of payback periods and return on investments (ROI).

A complete and comprehensive energy audit[159] will also identify possible sources of financing, implementation strategy and a detailed post-installation M&V plans.

[157] Note that MHO Strategic Asset Management Framework Guide already recommends combining an energy audit along with BCA.
[158] U.S Department of Energy. (2011). Energy Savings Performance Contracting: The Investment Grade Audit [Powerpoint Slides] (July). Retrieved from: https://energy.gov/sites/prod/files/2014/05/f15/espcinvestmentgradeaudit.pdf.
[159] For each building specific energy audit, identify appropriate energy conservation measures. For each option, a further breakdown usually includes - characteristics of equipment, location, make and model, recommendation for new equipment and update timeframe, estimated costs of update, including equipment,

4.2.2.3 *Prioritize Retrofit Initiatives*

From the audits, service manager or housing providers can begin prioritizing specific energy upgrades. Retrofits that have the highest potential for energy savings may be implemented first. Upgrades with unreasonably long payback periods may be completely disregarded. MHO's Strategic Asset Management Framework[160] provides guidelines for ranking capital initiatives that can also be applied to prioritizing energy retrofit programs[161]:

1. Priority 1 – Imperative, must do
2. Priority 2 – Essential, should do
3. Priority 3 – Important, could do

By the end of this stage, service managers should understand their portfolio-wide baseline energy consumption, know what buildings need upgrades, know what those upgrades are, and understand the order in which they should ideally be implemented.

4.2.3 Multi-year retrofit program

A multi-year retrofit program adds specifics to energy retrofit projects to be implemented, including associated project costs, and a roadmap for installations. A well-designed retrofit plan gives service managers and housing providers' time to collect necessary data, raise capital and prepare for upgrades in advance.

4.2.3.1 *Barriers Addressed*

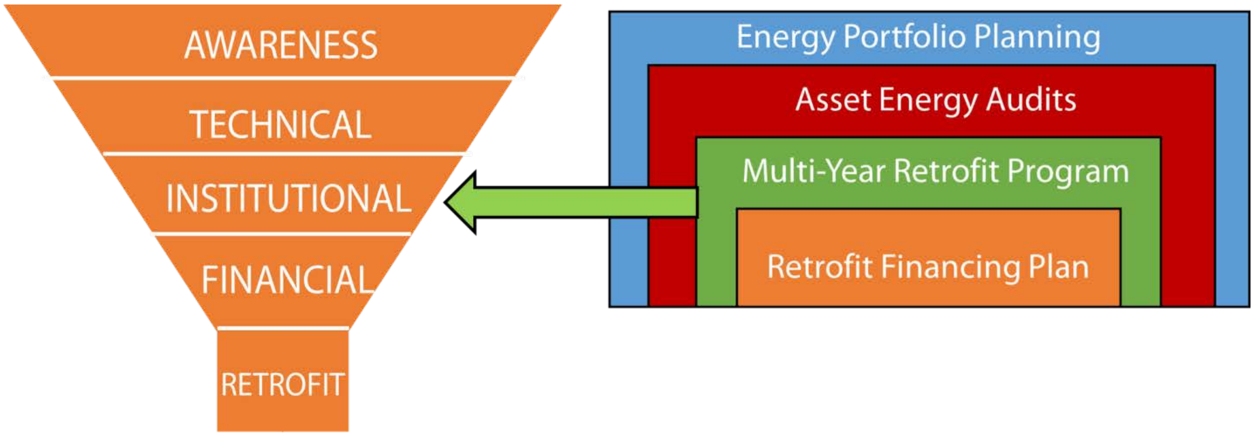


Figure 4-7. Multi-year retrofit programs can help overcome institutional barriers to energy sustainability by integrating energy management with asset management strategies.

labor and insurance, estimated annual savings, including energy usage and dollar value, information on available rebates, warranty and replacement, basic training on unit maintenance and operation, comments and best-practice recommendations.

[160] Ontario Ministry of Housing. (2014). *Revitalizing and refinancing social housing: how do you get there?* Retrieved from: http://www.mah.gov.on.ca/AssetFactory.aspx?did=10648.

[161] Alternative criteria for prioritizing capital incentives is available in the framework, and includes prioritizing projects that address urgent safety needs, prevents irreparable damage, reduces deferred maintenance costs, reduces future operation costs, improves tenant quality of life, and leverages existing government programs and funding.

When an energy portfolio management framework is fully integrated into the asset management framework, additional synergies for scheduling retrofits are likely to emerge. For instance, a scheduled window replacement presents an opportunity for upgrading to energy efficient windows. A roof replacement might be a good time to install PV by consolidating fixed costs of engineering and labor.

4.2.4 Retrofit financing plan

The final element of energy portfolio management framework is a plan that aligns energy upgrades with funding opportunities. A retrofit financing plan identifies sources of funding, cash flows and incurred debts. Equipped with energy use data and a comprehensive multi-year retrofit plan, service managers and housing providers can pursue capital to pay for their energy upgrades.

4.2.4.1 Barriers Addressed

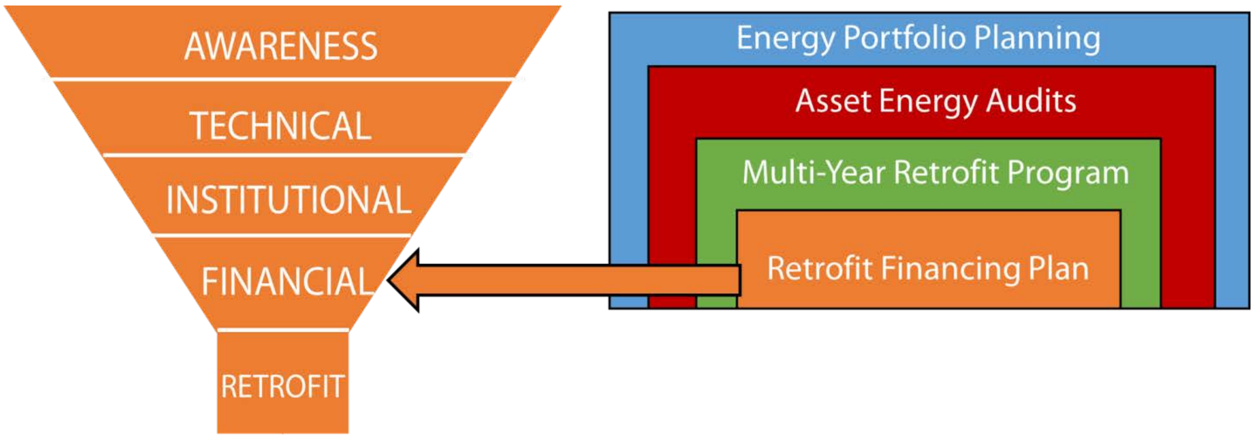


Figure 4-8. Retrofit financing plan aligns energy upgrades with sustainable long-term funding opportunities.

4.2.5 Measurement and verification

The first step in pursuing stable private market financing and capital investments for energy retrofits is a robust M&V protocol. M&V is a tool for "defining, controlling and allocating risks associated with energy project financing"[162]. Standardized protocols for M&V for energy saving projects were first developed in 1990 to assist project managers, developers and funders develop measures of verified energy savings.

[162] IPMVP Committee. (2001). International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings, Volume I (No. DOE/GO-102001-1187; NREL/TP-810-29564). National Renewable Energy Lab., Golden, CO (US). Retrieved from: http://www.nrel.gov/docs/fy02osti/31505.pdf.

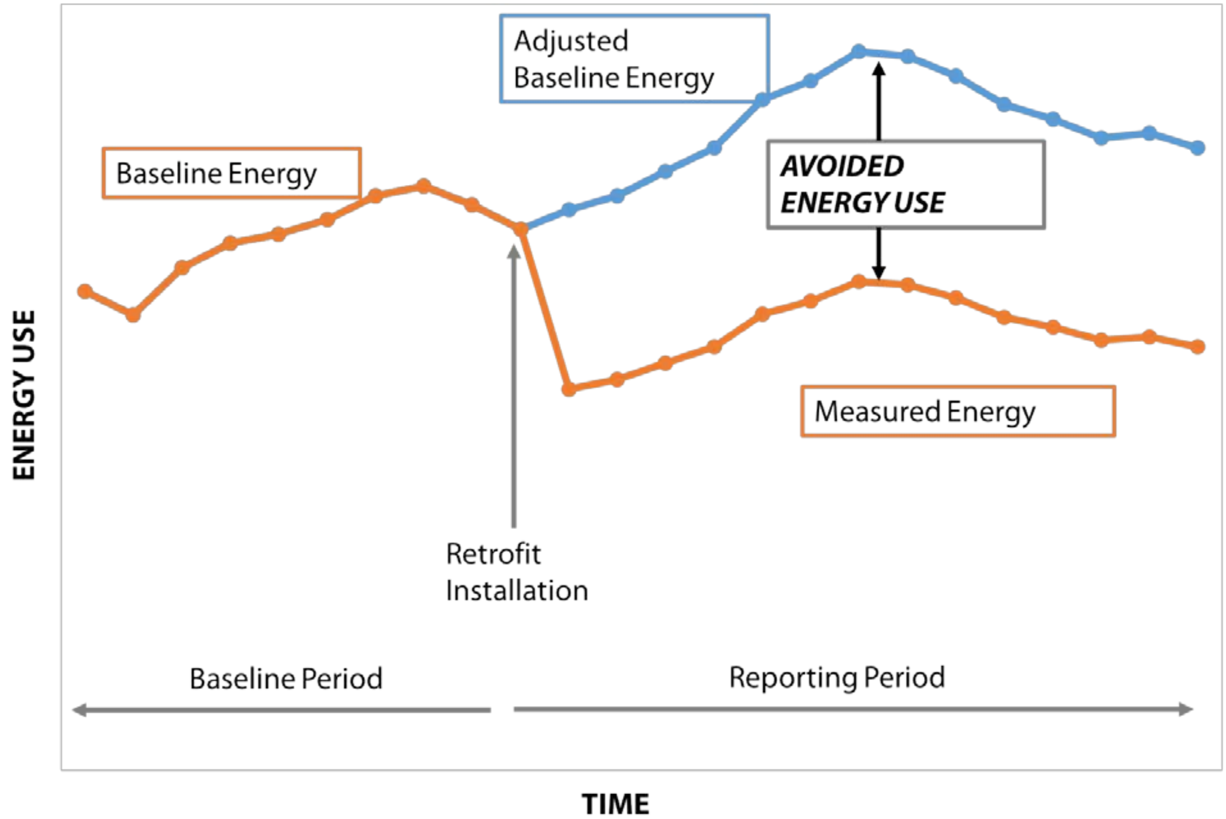


Figure 4-9. M&V calculating energy savings from estimating avoided energy use[163].

Over the years, many protocols[164] have been developed to meet the changing needs of the industry. A theme common to all protocols is the understanding that *actual energy savings cannot be directly measured*[165] but can be estimated using the following general approach:

1. Establish baseline energy use projections.
2. Make energy use measurements after retrofit.
3. Adjust baseline to account for changing operating conditions.
4. Calculate savings by subtracting post-installation consumption from baseline and then normalizing for weather, wear and tear or other independent factors.

Robust M&V protocols are essential for scaling energy sustainability upgrades in social and affordable housing. Studies [166] [167] show that developing standardized tracking metrics and frameworks for

[163] Ontario Power Authority. (2008). Measurement and Verification : Getting the Most From Energy Saving Projects.
[164] Natural Resources Canada. (2008). Overview of Different Measurement and Verification (M&V) Protocols.
[165] Kromer, J. S., Berkeley, L., Schiller, S. R., & Associates, S. (1996). National Measurement and Verification Protocols, 141–146.
[166] Gilleo, A., & Stickles, B. (2016). Green Bank Accounting : Examining the Current Landscape and Tallying Progress on Energy Efficiency, (September).

reporting energy savings are necessary[168] to drive investments for sustainability initiatives in the sector.

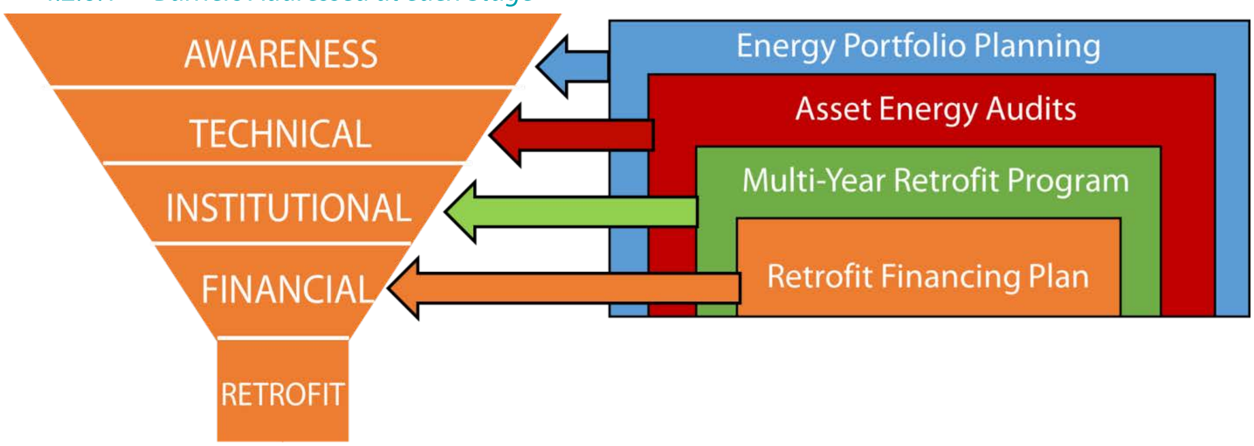
4.2.6 Summary

Unlocking the full potential of energy savings in social and affordable housing will require a long-term program that will seek to improve overall program participation by reducing barriers at each stage of the retrofit journey through strategic and systematic intervention. This section developed a generic energy portfolio management framework explicitly modeled after MHO's Strategic Asset Management Framework[169], providing synergies for housing providers and area service managers to embed energy performance management into existing asset management strategies.

In summary, a generic energy portfolio management framework has the following stages:

1. Energy Portfolio Planning – service managers develop portfolio wide energy needs assessment to identify buildings that need upgrades.
2. Asset Energy Audits – Service managers in consultation with housing providers perform energy audits to determine what energy upgrades to make.
3. Multi-year Retrofit Program – Service managers or housing providers develop a long-term plan to make energy performance upgrades.
4. Retrofit Financing Plan – Equipped with a retrofit plan and an M&V protocol, housing providers can solicit funding investments to pay for energy retrofit plans.

4.2.6.1 Barriers Addressed at each Stage



[167] IPMVP Committee. (2001). International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings, Volume I (No. DOE/GO-102001-1187; NREL/TP-810-29564). National Renewable Energy Lab., Golden, CO (US). Retrieved from: http://www.nrel.gov/docs/fy02osti/31505.pdf.
[168] In addition to bringing more investments, NREL notes that M&V also helps reduce the cost of financing energy retrofits, encouraging better component design and engineering, demonstrates the value of investments to private and public lenders, increases public understanding and support for investments in the sector, helps track progress towards sustainability goals and enables continuous corrective measured to be taken in response to performance feedback.
[169] Ontario Ministry of Housing. (2014). *Revitalizing and refinancing social housing: how do you get there?* Retrieved from: http://www.mah.gov.on.ca/AssetFactory.aspx?did=10648.

4.3 Preferred investment strategies

Access to stable, long-term and sustained capital is the single biggest barrier towards unlocking the enormous potential of energy savings in social and affordable housing. Periodically available, full capital cost subsidy initiatives like the REI program rely on improving the business-case for retrofits by offering 100 per cent cost subsidies. While helpful in the short-term, evidence has been found that programs of this nature might create a dependence on public subsidies and thereby inadvertently limit overall total investment in energy retrofits by sector stakeholders and the private sector. The scale and pace of necessary low carbon investment will not be met through traditional public incentive mechanisms like up-front cost subsidies or fully funded projects. Indeed, unlocking the full potential of energy savings in social and affordable housing will require mobilization of massive amounts of private investment.

This section will survey common investment strategies from other comparable jurisdictions, illustrate examples using case studies, and review their effectiveness as a preferred investment strategy for Ontario's social and affordable housing sector based on the following criteria:

- no to low up-front costs for housing providers and service managers;
- positive cash flow after installation;
- turnkey retrofit solutions, providing all services from financing to retrofit design to implementation;
- sustainable business model that delivers long-term investments;
- program accessible to social and affordable housing providers of all types (municipal, co-op and non-profit) of all capacities in all locations;
- guaranteed performance and energy savings; and
- program currently available in some capacity in Ontario.

4.3.1 Capital reserve funds

Capital reserve funds are used for making repairs and upgrades to buildings. Energy upgrades that have no or low up-front capital costs, have fast payback periods, higher ROIs and guaranteed system performance through contractor replacement warranties may qualify for being funded through capital reserve funds. For instance, building LED retrofits in common areas may be funded through capital reserve funds.

Review

Table 4-8. Review of capital reserve funds as a preferred investment strategy.

Program	Low up-front costs	Positive Cash Flow	Turnkey Solution	Sustainable business model	Program Accessible	Performance Guarantee	Available in Ontario
Capital reserve funds	X	X	X	X	✓	X	✓

4.3.2 On-bill financing

On-bill financing (OBF) allows customers and financial institutions to leverage a utility's existing relationship with the customer to provide convenient and easy access to funding for energy sustainability upgrades[170]. Qualifying customers with a certified energy audit can apply to their utility for a loan to pay for an energy retrofit. With up-front capital provided by a third party lender, the utility incurs the cost of the upgrade. The customer subsequently repays the investment through a charge on their monthly energy bill.

The goal of OBF programs is to provide an energy financing repayment that is equal to or lower than energy bills prior to energy upgrades. For customers, this means a cash-positive and no up-front cost loan with baked-in performance guarantees. OBF is accessible, simple to understand, and in most cases, the loan is transferrable with the property.

OBF programs are designed to remove barriers to accessible financial loans while leveraging existing billing infrastructure by the utility. Utility bills have better payment rates than any other type of bill. For financial institutions, this reduces overhead costs of loan program operations and reduces the risk and costs of recovering delinquent payments[171]. As a financing mechanism, OBF is uniquely positioned to reduce "first-cost barriers" to residential building markets, including affordable, social and multi-family units and other markets that have previously been underserved by other lending programs[172]. The Ontario Energy Board recognized OBF as a key priority for natural gas utilities in its 2015-2020 Demand Side Management framework[173].

Case Study
OBF has been used to support PV and energy efficiency since 1993 across many jurisdictions in America. Currently, at least 23 US states have implemented or are about to implement on-bill financing. In 2011, South Carolina electrically heated co-ops leveraged OBF to mobilize energy efficiency investment in residential markets in an effort to mitigate rising energy costs, reducing delinquent payments, reducing peak loads and reducing new generation capacity investments[174]. The OBF program uses low-interest loans from the US Department of Agriculture as the third party financial lending mechanism. South Carolina's OBF goals are expected to impact 225,000 homes across the entire residential building stock by 2020. Estimated savings from the program are expected to exceed 2.5 million MWh of electricity, resulting in a reduction of up to 2.4 million metric tons of CO_2 each year.

[170] Bell, Catherine J., Steven Nadel, and Sara Hayes. "On-Bill Financing for Energy Efficiency Improvements." *Washington, DC: American Council for an Energy-Efficient Economy* (2011).
[171] American Council for an Energy-Efficient Economy. (2012). On-Bill Financing for Energy Efficiency Improvements. (April). Retrieved from: http://aceee.org/files/pdf/toolkit/OBF_toolkit.pdf.
[172] Bell, Catherine J., Steven Nadel, and Sara Hayes. "On-Bill Financing for Energy Efficiency Improvements." Washington, DC: American Council for an Energy-Efficient Economy (2011).
[173] Government of Ontario. (2015, March 6). Regulatory proposal to clarify that electricity utilities may undertake on-bill financing for electricity conservation and demand management measures under the Ontario Energy Board Act, 1998 and the Electricity Act, 1998. Retrieved from: http://www.ontariocanada.com/registry/view.do?postingId=17942.
[174] Bell, Catherine J., Steven Nadel, and Sara Hayes. "On-Bill Financing for Energy Efficiency Improvements." Washington, DC: American Council for an Energy-Efficient Economy (2011).

Manitoba Hydro's (MH) Power Smart Residential Program[175], one of North America's most successful OBF programs, has served nearly 5000 customers per year since its inception in 2001. The programs annual total loan amounts to approximately 29M$, with total loan volume reaching nearly 300M$. MH reports very low start-up-costs for OBF program development. MH was able to leverage existing billing infrastructure to provide low-interest OBF loans to its customers with a loan default rate of less than 1%.

Challenges

- OBF programs are simply a mechanism for delivering loans to eligible customers. They rely on third party financial lenders to provide capital to fund energy upgrades. Seeding initial capital funding might prove challenging[176].
- When energy savings are not guaranteed, social and affordable housing providers may end up bearing the risk and costs of investing in upgrades[177].
- Repayment liability may be transferred to the balance sheet and be classified as debt[178].
- Delinquent payment may risk service shutoffs[179].
- OBF may not be uniformly implemented across all Ontario utility jurisdictions.

Review

Table 4-9. Review of on-bill financing as a preferred investment strategy.

Program	Low up-front costs	Positive Cash Flow	Turnkey Solution	Sustainable business model	Program Accessible	Performance Guarantee	Available in Ontario
OBF	✓	✓	X	✓	X	✓	X

4.3.3 Loan guarantees and credit enhancements

Some jurisdictions offer a mechanism where the funding entity offers subsidies to a conventional lending agency to reduce the market rates of loans, or to achieve more generous conditions for loan repayment. This mechanism is similar to international development loans granted to developing economies with lower risk premiums, in addition to longer default grace periods. Public funding may

[175] Seref Efe, Inam ur Raheem, T. W. & C. W. (2015). *Cheaper Power Bills, More Jobs, Less CO2 : How On-Bill Financing Done Right can be a Quick Win for British Columbia*. Retrieved from https://pics.uvic.ca/sites/default/files/uploads/publications/On-Bill Financing FINAL.pdf.
[176] Environmental Defense Fund. (n.d). On-bill repayment programs. Retrieved from: https://www.edf.org/energy/obr.
[177] Fredette, J. (2015, December 16). Consumer Considerations for On-Bill Finance Programs [Blog post]. Retrieved from: http://efc.web.unc.edu/2015/12/16/consumer-considerations-for-on-bill-finance-programs/.
[178] American Council for an Energy-Efficient Economy. (2012). On-Bill Financing for Energy Efficiency Improvements. (April). Retrieved from: http://aceee.org/files/pdf/toolkit/OBF_toolkit.pdf.
[179] EnergyCut. (n.d.) On-bill financing. Retrieved from: http://energycut.com.au/vets/step-18/on-bill-financing/

also be used to set up a loan-loss reserve mechanism[180] – a fund that may cover losses incurred through the life of a loan. The loan loss reserves mitigate the risk that loans might not be paid back, allowing housing providers to access credit at a rate lower than market rates.

Case Study
PANEL program offered by Czech state budget, offers direct subsidies on interest rates. Customers can obtain loans for energy retrofits that are around 3 percentage points lower than prevailing market rates. The program is funded through a mix of loans and bank guarantees. Massachusetts offers low-interest loan programs to income-eligible state residents supported through a loan loss reserve mechanism, offering loans from $3,000-$35,000 to income eligible households[181].

Review

Table 4-10. Review of loan guarantees and credit enhancements as a preferred investment strategy.

Program	Low up-front costs	Positive Cash Flow	Turnkey Solution	Sustainable business model	Program Accessible	Performance Guarantee	Available in Ontario
Loans and Credit Enhancements	✓	X	X	-	✓	X	X

4.3.4 Community development financial institutions (CDFI)

CDFIs are lending institutions that leverage public sector funding and match it with private capital to provide financing for community development. CDFIs have the experience and expertise in developing social and affordable housing, in working with government grants and programs, and in raising capital for energy conservation and clean energy generation[182]. With that history and mission-driven values[183], they may be ideally positioned to mobilize funding for energy retrofits in the social and affordable housing sector.

Case Study
Community Investment Corporation (CIC) was a Chicago based CDFI that made energy efficiency retrofits available to multi-family apartments though an accessible "one-stop shop". From 2008 to 2014, CIC in partnered with Elevate Energy to offer free energy audits to more than 1,000 multi-family

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[180] Interstate Renewable Energy Council. (2013). Shared Renewable Energy for Low to Moderate Income Customers : Policy Guidelines and Model Provisions. http://doi.org/10.1017/CBO9781107415324.004.
[181] Massachusetts Department of Energy Resources. (2015). Massachusetts Residential Solar Loan Program. (January). Retrieved from: http://www.mass.gov/eea/docs/doer/renewables/solar/mass-solar-loan-program-final-design.pdf.
[182] Ross, L., Jarrett, M., & York, D. (2016). Reaching More Residents: Opportunities for Increasing Participation in Multifamily Energy Efficiency Programs, (May), 43.
[183] GRID Alternatives. (2016). *Low-Income Solar Policy Guide*.

apartment buildings and more than 42,000 units. Nearly 50% of those audited qualified for a retrofit. Through their streamlined application process and empowered community engagement, CIC was able to translate an approximately 14M$ loan into more than 12 million kWh saved and nearly 35,000 metric tons of CO_2 from avoided energy use[184].

Review

Table 4-11. Review of CDFI's as a preferred investment strategy.

Program	Low up-front costs	Positive Cash Flow	Turnkey Solution	Sustainable business model	Program Accessible	Performance Guarantee	Available in Ontario
CDFI	✓	✓	X	✓	X	X	X

4.3.5 Green Bank

While CDFIs are intermediaries that operate in general public interest, Green Banks are publicly chartered financing institutions created by state/provincial and local governments specifically to improve access to financing energy sustainability initiatives. Like CDFIs, green banks leverage public funds to attract private capital investment towards greater energy savings in public interest. A comprehensive survey of green bank initiatives in North America found that “green bank operations are limited in multi-family and low-income markets”[185] but are committed to increasing and improving their service to all customer classes when driven by policy directives.

Case Study

Connecticut Green Bank (CGB) began developing initiatives for the low-income sector, when directed by its board in 2014. By 2015, nearly 31% of CGB loan funded projects were delivered to the low-income residential sector. In addition, CGB also explicitly targets communities classified as ‘distressed’[186] (communities with low per-capita income, high unemployment, etc.). In 2015, nearly 22% of total projects were deployed in ‘distressed’ communities.

Review

Table 4-12. Review of green banks as a preferred investment strategy.

Program	Low up-front	Positive Cash	Turnkey Solution	Sustainable business	Program Accessible	Performance Guarantee	Available in Ontario

[184] Foundation, E., Energy, E., With, P., Assistance, T. H. E., & Icf, O. F. (2015). Program Design Guide : Energy Efficiency Programs in Multi-family Affordable Housing, (January).
[185] Gilleo, A., & Stickles, B. (2016). Green Bank Accounting : Examining the Current Landscape and Tallying Progress on Energy Efficiency, (September).
[186] Connecticut Green Bank. (2015). Comprehensive Annual Financial Report. Retrieved from: http://spark2.cronindev.com/wp-content/uploads/2015/11/Connecticut-Green-Bank-2015-CAFR.pdf.

	costs	Flow		model			
Green Bank	✓	X	X	✓	✓	X	X

4.3.6 PACE and LIC

Property Assessed Clean Energy Financing (PACE) and Local Improvement Charges (LIC) are municipal financing mechanisms that allow a local government to recover costs of capital investments made in public benefit to be recovered from property owners that benefit from the improvements. PACE projects are exclusively used for energy efficiency and renewable energy upgrades in jurisdictions in USA[187]. LICs on the other hand have been employed for public projects ranging from water infrastructure to speed bumps in Ontario[188]. While regulations "do not currently list energy retrofits as a sample type of work" [189], any local infrastructure including energy retrofits may qualify as a project that can secure LIC financing. Both PACE and LICs allow permanent structural improvements to be added off balance sheets and the low-interest loan paid off through local property taxes.

Case Study
Phyllis Wheatly YMCA is an affordable housing complex in Washington DC. Originally constructed in 1920 as a safe place for migrant African-American women, the facility offers 84 affordable rental units to low-income and vulnerable women[190]. As part of a redevelopment project, the housing provider secured PACE financing to make upgrades to meet the building code, as well as install 30kW of solar, LED lighting, Energy Star appliances and low-flow water fixtures. With total project costs of $700,000, the annual electric and water savings are estimated to exceed $73,000 while reducing annual emissions by 114 metric tons of CO_2. The project is the first time PACE financing was used in an assisted mixed social housing property in the US.

Challenges

A report released by the Ottawa City Council[191] summarizes some of the challenges of using LICs to finance residential energy retrofits in Ontario:

- Securing initial program seed funding may prove challenging;
- Banks and private lenders may offer loans at lower interest rates than municipalities can offer;
- Lower natural gas rates may lead to low program uptake; and

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[187] United States Department of Energy. (2016). Best Practice Guidelines for Residential PACE Financing Programs. Retrieved from: https://energy.gov/sites/prod/files/2016/11/f34/best-practice-guidelines-RPACE.pdf.
[188] Ontario Ministry of Municipal Affairs., & Ministry of Housing. (2015). Local Improvement Charges. Retrieved from: http://www.mah.gov.on.ca/Page10226.aspx.
[189] Persram, S. (2011). Property-Assessed Payments for Energy Retrofits: Recommendations for Regulatory Change and Optimal Program Features. The David Suzuki Foundation. Retrieved from: http://www.sustainable-alternatives.ca/PAPER_Persram_for_DSF.pdf.
[190] U.S Department of Energy. (n.d). Project Profile: Phyllis Wheatley YMCA. Retrieved from: http://www.thesolarfoundation.org/wp-content/uploads/2015/11/CivicPACE-Fact-Sheet-YWCA.pdf.
[191] Assessment of the Use of Local Improvement Charges to Finance Home Energy Retrofits in Ottawa. (2016, Feb 9). Retrieved Feb.2, 2017, from http://ottwatch.ca/meetings/file/366137.

- Fixed costs of program administration may be higher, especially in the event of low program participation.

In addition,

- PACE and LIC might not be available in all Ontario jurisdictions.

Review

Table 4-13. Review of PACE and LIC as a preferred investment strategy.

Program	Low up-front costs	Positive Cash Flow	Turnkey Solution	Sustainable business model	Program Accessible	Performance Guarantee	Available in Ontario
PACE & LIC	✓	✓	✓	✓	X	✓	X

4.3.7 Energy performance contracting

Energy Performance Contracting (EPC) is a contractual agreement between an energy service company (ESCO) and a housing provider, wherein the ESCO designs and implements energy retrofits with a guaranteed level of energy performance[192]. Typically, the service comes at a no or low-upfront capital cost to the housing provider. The cost of the installation is borne by the contractor who guarantees that the monthly payments for services rendered will not be higher than monthly energy bills prior to the installation. This allows housing providers to have a net positive cash flow without incurring debt for energy upgrades[193].

Case Study
Financing Energy Refurbishment for Social Housing (FRESH) is a European cooperation project for developing EPC in for comprehensive energy retrofits in Europe's social housing. Their final report[194] presented outcomes of EPC pilot programs in a few candidate EU countries. EPCs were funded through grants, low-interest loans, capital reserve funds and private equity, and were able to demonstrate a net energy and cost savings of 10%-35% for residents in affordable and social housing.

Challenges

- Savings measurement is often difficult; energy savings are not tangible but calculated as series of assumptions negotiated over contracts[195].
- M&V may be cost prohibitive, finding a balance between accuracy and costs may prove challenging[196].
- Unreasonable expectations – energy savings may not be enough to pay for comprehensive and deep energy retrofits.
- High transaction costs – EPC implementation may require a minimum building size because each EPC is customized for a particular location[197].

[192] Hoicka, C. E., Parker, P., & Andrey, J. (2014). Residential energy efficiency retrofits: How program design affects participation and outcomes. *Energy Policy*, *65*, 594–607. http://doi.org/10.1016/j.enpol.2013.10.053.
[193] FRESH (Financing Energy Efficiency in Social Housing). (n.d.). *Energy Performance Contract in Social Housing*.
[194] International Consulting on Energy. (n.d.). FRESH - Financing energy Refurbishment for Social Housing Final Publishable Report.
[195] Commission, E., & Engineers, C. C. (2009). ECOLISH : Energy Exploitation and Performance Contracting for Low Income and Social Housing, (December), 1–133.
[196] Milin, C., & Bullier, A. (2011). Energy retrofitting of social housing through energy performance contracts a feedback from the FRESH project: France, Italy, United Kingdom. Brussels: Intelligent Energy Europe (IEE) of the European Commission.

- Performance guarantee can prove costly, with high risk of participation for contractors in untested markets.
- Smaller housing providers may lack the volume to attract quality EPC contractors.

Review

Table 4-14. Review of EPC as a preferred investment strategy

Program	Low up-front costs	Positive Cash Flow	Turnkey Solution	Sustainable business model	Program Accessible	Performance Guarantee	Available in Ontario
EPC	✓	✓	✓	✓	X	✓	✓

[197] Sunikka-Blank, M., Chen, J., Britnell, J., & Dantsiou, D. (2012). Improving Energy Efficiency of Social Housing Areas: A Case Study of a Retrofit Achieving an "A" Energy Performance Rating in the UK. *European Planning Studies*, *20*(1), 131-145.

4.3.8 Summary of preferred investment strategies

Table 4-15 presents a summary of the preferred investment strategies covered in Section 4.3.

Table 4-15. Summary of Preferred Investment Strategies

Program	Low up-front costs	Positive Cash Flow	Turnkey Solution	Sustainable business model	Program Accessible	Performance Guarantee	Available in Ontario
REI Program	✓	✓	X	X	X	X	✓
Capital reserve funds	X	X	X	X	✓	X	✓
OBF	✓	✓	X	✓	X	✓	X
Loans & Credit	✓	X	X	-	✓	X	X
CDFI	✓	✓	X	✓	X	X	X
Green Bank	✓	X	X	✓	✓	X	X
PACE & LIC	✓	✓	✓	✓	X	✓	X
EPC	✓	✓	✓	✓	X	✓	✓

This section surveyed common investment strategies, illustrated examples using case studies, and reviewed their effectiveness. Based on the criteria selected for review, Energy Performance Contracting (EPC) emerged as a strong contender for a preferred investment strategy for Ontario's social and affordable housing sector. EPC markets are relatively mature for commercial, industrial and large building sector in Ontario, and expanding their reach to social and affordable housing may be the key to unlocking massive energy savings in the sector.

Comprehensive reviews[198] and guidelines[199] on setting up[200], expanding[201] and sustaining[202] EPCs for retrofitting[203] in social and affordable housing with best practices[204], challenges[205] and case studies[206] are widely available in literature.

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[198] Milin, C., & Bullier, A. (2011). Energy Retrofitting of Social Housing through Energy Performance Contracts, 26.
[199] IEE. (2008). Guideline on Social Housing Energy Retrofitting Financing Schemes in EU New Member States, (December), 71. Research, Reports and Documents/Economics, Procurement and Funding/InoFin - Financing Schemes for Social Housing Refurbishment in Europe - GOOD!.pdf.
[200] DECC, & Local Partnerships. (2012). A guide to financing energy efficiency in the public sector, (November).
[201] Darmstadt, B. A. G. (2009). EPI-SoHo " Energy Performance Integration in Social Housing - a strategic approach for portfolio management", (February), 1–3.. Research, Reports and Documents/Tools and Modelling/IEE - Energy Performance Integration in Social Housing - 1 of 2.pdf.
[202] Europe, I. E. (n.d.). Retrofitting Social Housing and Active Preparation for EPBD.
[203] Milin, C., & Bullier, A. (2011). Energy retrofitting of social housing through energy performance contracts a feedback from the FRESH project: France, Italy, United Kingdom. Brussels: Intelligent Energy Europe (IEE) of the European Commission.
[204] Costanzo, E., & Pfister, V. (2012). *Best Practices on Quality Schemes and EPC in Renovation*.
[205] FRESH (Financing Energy Efficiency in Social Housing). (n.d.). *Energy Performance Contract in Social Housing*.
[206] RESHAPE. (2009). Result Oriented Report : Energy Performance Certification and the Development of Renovation Strategies in Social Housing, (March).

5 KNOWLEDGE MOBILIZATION

The project team has identified two priority next steps to help mobilize the knowledge generated through this research to inform current and future program development targeting low carbon energy retrofits in the social and affordable housing sector:

1. Provide policy and program recommendations to senior levels of government (provincial and federal) that builds capacity to develop and implement effective programs aimed at stimulating energy efficiency and renewable energy in the social and affordable housing sector.
2. Raise awareness within the municipal and private non-profit social and affordable housing sector of steps they can take to be prepared to effectively respond to and evaluate the potential benefits of future government programs offering investment in energy efficiency and renewable energy.

In order to meet the objectives established above, the project team is developing partnerships with think tanks, civil society groups and industry associations with established networks in the social and affordable housing sector in Ontario:

- **Evergreen – GTA Housing Action Lab**: The GTA Housing Action Lab (HAL) is a collaborative working group that has come together to build programs and policies that support the affordability of housing to ensure residents of all incomes have the best chance to live in a suitable home and have a choice in their housing. The collaborative advocates for a more sustainable housing system by increasing policy and public support for intensification and complete communities.
- **Community Energy Knowledge Action Partnership** (CEKAP): This is a collaborative partnership of Canadian academic institutions, municipal governments, and other stakeholders, that have come together to collaborate on research to support implementation of community energy initiatives.
- **Ontario Low Income Energy Network** (LIEN): A network of advocacy organizations focused on ensuring universal access to adequate, affordable energy as a basic necessity, while minimizing the impacts on health and on the local and global environment of meeting the essential energy and conservation needs of all Ontarians. LIEN promotes programs and policies that tackle the problems of energy poverty and homelessness, reduce Ontario's contribution to smog and climate change, and promote a healthy economy through the more efficient use of energy, a transition to renewable sources of energy, education, and consumer protection.
- **Ontario Municipal Social Services Association** (OMSSA): an association of Municipal Service Managers and District Social Services Administration Boards (DSSABs) across Ontario. OMSSA supports its members with policy advocacy, education and professional development as well as knowledge and information dissemination.
- **Northern Ontario Service Deliverer's Association** (NOSDA): NOSDA is similar to OMSSA, but focuses on the Northern Ontario region.

- **Ontario Non-Profit Housing Association** (ONPHA): Is an association of more than 700 non-profit housing providers across Ontario. ONPHA's mission is to build capacity within the non-profit housing sector through networking events, policy advocacy, research, knowledge dissemination, and professional development.
- **Co-operative Housing Federation of Canada** – Ontario region (CHFC): CHFC has a similar mandate to ONPHA (above), but is focused on the cooperatively owned sub-sector of the social and affordable housing sector.
- **Ontario Chapter of the Association of Energy Services Professionals** - dedicated to professional development and networking of energy services professionals in Ontario.

Working collaboratively with these partners, the project team proposes to implement the following next steps:

Table 5-1. Proposed near-term knowledge mobilization activities

Audience	Activity	Timing
Provincial and federal government policy makers	Publish final report and case studies; distribute to key stakeholders identified by MHO	March-April 2017
	Briefing presentation to Government of Ontario inter-ministerial working group, e.g.: Planning Environment Resources and Lands (PERL) ADM or director's committee	TBD
	Presentation to National Housing Research Committee - Sustainable Housing Working group	Committee typically meets in the Fall
	Article for CMHC Housing Research e-newsletter	Spring 2017
Service managers	Presentation to OMSSA Service manager Housing Network	Spring 2017
Co-operative and Non-Profit Housing Providers	Presentation delivered at ONPHA annual conference	November 2017
	Article for ONPHA focusON research series	TBD
Energy Services Companies	Presentation to Ontario Chapter - Association of Energy Services Professionals (AESP) Fall Summit	October 2017

6 CONCLUSIONS

6.1 Background and objectives

With the government of Ontario looking to rapidly scale-up low carbon investment in the social and affordable housing sector as part of the Climate Change Action Plan, the question of how to structure investment programs to deliver the most impact in terms of greenhouse gas (GHG) reductions, and operating cost savings for housing providers is paramount. In order to develop insights on sector capacity for implementation low carbon investment, this study evaluated of the social, economic and environmental outcomes of investments in the REI. Launched in 2010 as part of a comprehensive economic stimulus program targeting Ontario's social and affordable housing sector, the REI disbursed approximately 57M$ in provincial and federal funding to 161 different social and affordable housing providers for the installation renewable energy (RE) systems, including: solar photovoltaics (PV), solar domestic hot water (SDHW), solar air heating, geothermal and wind turbines[207].

This report, prepared by the Toronto and Region Conservation Authority (TRCA) and Ontario Climate Consortium (OCC) in partnership with Evergreen, evaluated the REI to provide insights on preferred investment strategies to scale-up investment supporting the transition to net-zero communities in line with provincial and federal government GHG reduction commitments to the global community. The research incorporated a cross-jurisdictional review, 31 formal interviews and 27 informal conversations with key REI stakeholders, 19 completed surveys from housing providers that received REI funding, 17 site visits to REI funded installations, 10 case studies as well as a technical, financial, GHG and economic analyses. Benefits of the REI program were evaluated based on its effectiveness in achieving social, economic and environmental outcomes for social and affordable housing providers. Implementation challenges and lessons learned were also documented.

6.2 Findings

Overall provider experience of the REI program

During interviews and surveys, the majority of housing providers responded positively when asked about their experience with the REI program and felt that the installed systems were a success. Most reported minimal barriers to participation or program administration issues, aside from tight application timelines and issues connecting projects. Though Local Distribution Companies are required to help customers connect to their network in a timely and efficient manner, at times a new connection can require an upgrade of the network, delaying connections. SDHW systems were highlighted by some providers as having poor returns when offsetting natural gas.

Energy, cost and carbon savings

Key impacts of the REI are quantified in Table 6-1. The majority of funded systems were photovoltaic (PV) as it had the strongest financial performance due to the Feed-In Tariff (FIT) program, which paid a guaranteed price for grid-connected PV electricity over a fixed-term contract that was designed to

[207] The total amount of funded allocated under REI was 75M$ – with 65M$ to SHRRP funded projects and 6.9M$ to AHP projects. The final amount spent on SHRPP-funded REI projects was approximately 57M$. This report focuses on the final amount spent on SHRRP funded projects only.

cover project costs plus a reasonable rate of return. The financial performance of the remaining systems depended on the fuel that the systems were offsetting. Financial performance of solar air or geothermal is very strong when compared with electric resistance heating, with net lifetime benefits outweighing system costs by greater than a factor of two. However, estimated lifetime benefits were less than system costs when the systems are offsetting natural gas, due to low gas costs. SDHW was estimated to produce net lifetime benefits much lower than total system costs regardless of the fuel being offset. GHG savings were much higher for systems that offset gas.

Table 6-1. Results from technical, financial, GHG and socio economic analyses.

	Funding [M$]	# of systems funded	Energy generated or saved [GWh]	Net lifetime benefits for housing providers [M$][208]	GHG savings [kt CO_2e]	Full-time equivalent job creation
PV	39.1	255	132	62.2	6.6	411
SDHW	12.1	80	40	2.4 – 3.3	6.9	128
Solar Air	3.7	17	65	3.9 – 5.2	11.1	39
Geothermal	2.5	9	34	1.3 – 2.3	7.2	26
Wind[209]	0.0	1	0	0.0	0.0	0
Totals	**57.4**	**362**	**271**	**69.8 – 73.0**	**31.8**	**604**

Economic returns within Ontario

Based on input-output analysis, the REI program was estimated to have generated as much as 62M$ of additional Gross Domestic Production (GDP) in Ontario. This additional production would have required as many as 604 Full-Time-Equivalent (FTE) jobs in Ontario, earning up to nearly 37M$ in labour income. An additional 3.2M$ in indirect tax revenue was likely earned in Ontario.

Program administration and guidelines

All stakeholders groups highlighted the REI's program timelines as a barrier. This likely limited participation to parts of the sector, with higher human resource capacity at the service manager and housing provider level, as is the case in more urban areas. Lack of knowledge about potential benefits was a barrier to participation and resulted in low uptake in some service areas. Evaluation of program participation data showed that providers in more rural and remote areas used less of their total allocated funding than their urban counterparts.

Renewable Energy Technology (RET) Vendor list

The REI program required housing providers to select from a list of vendors that met certain eligibility criteria. The Renewable Energy Technology Supplier (RET) Vendor List was administered by the Ontario Power Authority (OPA). In some service manager areas outside of the Greater Toronto Area

[208] Note that these values assume that systems are offsetting a mix of 20% electricity and 80% natural gas. Furthermore, these values are estimates that pertain *to the REI program*. Great care should be taken when drawing conclusions about system performance outside of the REI. For example, PV system financial performance is based on FIT/microFIT rates that are no longer available; a performance de-rate was applied to SDHW energy generation based on site visit observations, and some system costs may have been higher in the REI than in the private sector.

[209] Note that a small amount of funding was disbursed to one provider for engineering and feasibility studies concerning a wind turbine installation but the provider did not proceed on to the actual installation of the wind turbine.

(GTA), there were very few vendors who met the eligibility criteria and applied to be included on the RET Vendor List. This may have limited the pool of available vendors that could respond to the REI procurement process.

Feasibility studies and business cases

The REI program did not place any limitations or criterion on the format and content of feasibility studies or business cases used to inform technology selection and suitability for REI program participants. Feasibility studies and business cases provided by MHO to review for this evaluation differed in terms of format, evaluation tools, breadth and content.

System cost and design

Proposed system costs did not appear to be benchmarked against industry norms, potentially creating incentives to overpay for systems. Some housing providers noted that they were concerned about unanticipated future costs. There were some reports, specifically with SDHW, that systems and/or certain components were oversized or otherwise not optimally designed.

Utility connections

Several providers encountered issues connecting their projects to the grid. In some cases, local utilities could not connect PV systems (sometimes after the system had been installed) because of technical grid capacity constraints and the systems either did not go ahead or were moved to another site.

Operation and maintenance

PV and solar air were reported to require minimal operation and maintenance (O&M) effort. Geothermal systems typically require less O&M effort than conventional systems although some providers still opted for a maintenance contract. SDHW systems were identified by providers as requiring the most O&M, and failures or sub-optimal operation related to design or insufficient O&M were identified in several instances. Many providers paid upfront for a maintenance contract. In several cases, this had poor results with vendors going out of business or providing poor service.

Measurement and verification

PV systems were often installed with an online monitoring gateway. The REI program did not require measurement and verification (M&V) and the large majority of non-PV systems did not incorporate M&V. The lack of M&V, and an M&V plan, meant that some systems could fail with minimal indications of failure and ultimately, fall short of expectations.

Impact on tenants

Interviewees reported that income generated from FIT contracts was used to supplement capital or operating budgets. This was stated to have indirect positive benefits for tenants.

Program evaluation

The evaluation of the program was initiated several years after the program roll out and was not integrated into the program design itself. This contributed to difficulties collecting important data and information needed to conduct a comprehensive evaluation of program effectiveness.

6.3 Future program considerations

In order to scale-up the investment necessary to transition Ontario's social and affordable housing sector to net zero carbon with affordable energy services, future programs should take into account the lessons learned from service manager and housing provider experience with the REI program. Key lessons learned include:

- **Administration, documentation and record keeping.** Longer timelines would be beneficial for promoting program uptake in certain service manager areas with capacity issues. Additional program requirements for record keeping on key information would improve accountability and facilitate accurate evaluation of program benefits.
- **Feasibility studies and business cases.** Guidance or a template for feasibility studies would help ensure consistency across studies performed by different consultants. It would aid service managers and housing providers, and help inform the program evaluation.
- **Measurement and verification**. M&V should be mandated in future programs. Widely used protocols exist and it should performed by a qualified professional according to an M&V plan.
- **Technology selection.** Up-front vetting of systems would identify systems at a risk of providing poor savings and additional guidance would help ensure that providers are well matched to chosen technologies. RE technologies should be considered alongside other retrofit options to achieve maximum GHG and financial impact. Additional RE emerging technologies, like air-source heat pumps, warrant consideration as well.
- **Funding.** For 100% capital cost subsidies, it is advisable to compare proposed system costs against industry benchmarks to ensure efficient use of funds. Additional administration and follow-up after systems have been installed would help improve accountability.
- **Vendors.** In rural areas, greater flexibility in selecting vendors would help promote uptake.
- **Operation and maintenance.** Additional guidance and training would help housing providers operate and maintain their retrofits effectively. This would need to address the challenge of staff turnover. Maintenance contracts that are 100% paid up-front should be avoided.
- **Program evaluation.** A program evaluation could be improved by incorporating it into the program itself, collecting important data as the program is rolled out. During program design, it is advisable to formulate clear metrics for program success.

6.4 Enabling the low carbon transition in Ontario's social and affordable housing sector

Ontario's social and affordable housing sector faces challenges in finding the investment necessary for capital replacement programs, including low carbon energy retrofits. With rising energy prices, the lack of investment capacity threatens the long-term viability of the sector in terms of meeting its mandate to provide affordable housing to Ontario's neediest citizens. While traditional energy retrofit strategies have been supported by direct 100% capital cost subsidies, such as was the case with the REI program, this project's analysis shows that service managers and housing providers face additional non-financial barriers that limit the uptake of low carbon technologies.

As a full capital cost subsidy program, REI was effective at tackling one of the biggest barriers to low carbon energy investment: the lack of financial capital within the sector. However, a more comprehensive and concerted effort to address the full suite of barriers facing service managers and housing providers is needed. This research has developed a generic energy portfolio management framework, summarized in Figure 6-1, explicitly modeled after MHO's Strategic Asset Management Framework[210]. This is a long-term strategic approach to encourage adoption of energy efficiency and RE measures by reducing barriers at each stage of the retrofit journey through targeted and systematic intervention.

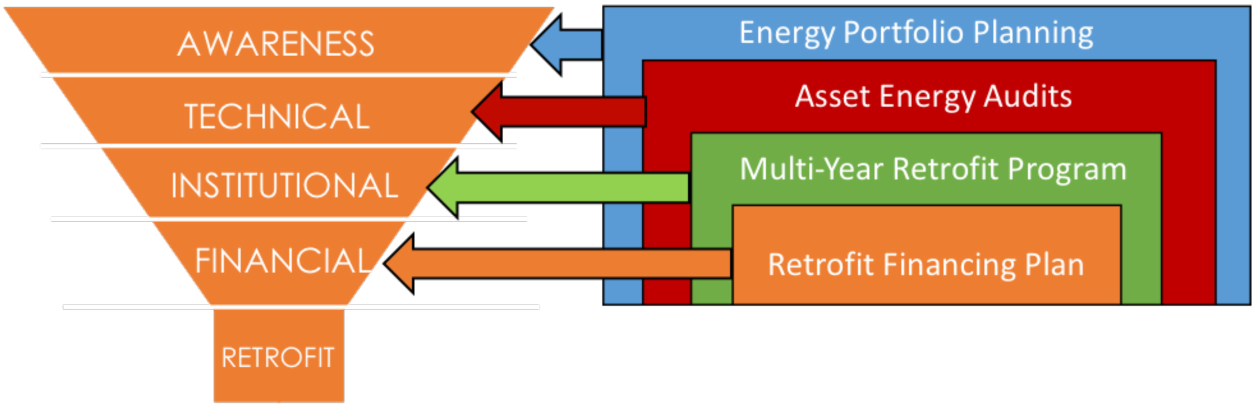


Figure 6-1. Comprehensive program approach to addressing social and affordable housing sector barriers.

In terms of preferred investment strategies, the analysis suggests that 100% capital cost subsidy programs such as REI miss important opportunities to leverage private sector capital to scale up investment. The report analyzes a range of investment strategies, and finds that energy performance contracting (EPC) merits deeper consideration. EPC markets are relatively mature for the commercial, industrial and large building sector in Ontario, and expanding their reach to social and affordable housing may be the key to unlocking massive energy savings and GHG reductions in the sector.

[210] Ontario Ministry of Housing. (2014). *Revitalizing and refinancing social housing: how do you get there?* Retrieved from: http://www.mah.gov.on.ca/AssetFactory.aspx?did=10648

7 FUTURE WORK

This research identified key considerations for future programs across several categories, and future work that could address these considerations. This section presents options for future research that could build upon the knowledge and experience gained thus far:

1. Framework for management of emissions and energy efficiency in service manager housing portfolios.
2. Pre-built M&V hardware package and centralized online monitoring portal.
3. Online training materials/courses to support operations and maintenance of RE and energy efficiency retrofits.
4. Decision-making support tool for housing providers and service managers considering RE or energy efficiency retrofit.

7.1 Framework for management of emissions and energy efficiency in service manager and housing provider portfolios

Based on the REI program evaluation, and exploration of sustainable energy issues facing the broader Ontario social and affordable housing sector, it is understood that there is significant interest within the broader sector to plan for and implement low carbon energy strategies at an individual building and portfolio-scale. It is known that service managers are now required to develop 10-year Local Housing and Homelessness plans that address environmental sustainability and energy conservation, and report publicly on progress annually. As highlighted in this report, knowledge and capacity within the sector to develop comprehensive long-term energy transition plans is limited, which creates challenges for taking advantage of provincial and federal funding opportunities.

There is a critical window of opportunity in 2017-2018 to support service managers and housing providers with the development and implementation of low carbon energy plans as part of comprehensive Local Housing and Homelessness plans, as well as with the development of public reporting frameworks. Through service manager capacity-building for low carbon energy planning, the sector will be much better prepared to put forward high-quality low carbon retrofit projects to take advantage of new funding opportunities available through the Ontario Green Investment Fund, the Ontario Climate Change Action Plan (CCAP, 2016), and Federal investment through the social infrastructure fund.

There is a strategic need for a high-quality, practical and flexible guidance document/framework for service managers on (i) how to develop energy and emissions performance inventories for their building portfolios, (ii) how to identify priority actions to reduce energy consumption and emissions on a portfolio-wide basis, and (iii) develop energy conservation and GHG emissions reduction targets, and integrate those into Local Housing and Homelessness plans. This guidance document could cover the following key elements of low carbon sustainable energy planning at a building portfolio scale in the multi-unit residential sector:

1. how to develop a comprehensive portfolio-wide energy and emissions performance inventory, including best practices, case studies and success stories as well as an overview of implementation challenges and barriers and direction on how to address these barriers;

2. setting portfolio-wide GHG emission reduction targets, including:
    a. stakeholder engagement approaches (e.g. building managers and residents);
    b. achieving support/ endorsement from boards and other decision-makers;
3. developing portfolio-wide energy and emissions reduction plans that support achievement of established targets; and
4. implementing portfolio-wide energy and emissions reduction plans, including various financial tools and approaches available to social and affordable housing portfolio managers.

7.2 Pre-built M&V hardware package and centralized online monitoring portal

M&V has numerous benefits and the MHO understands the need to incorporate M&V into future programs. M&V (i) helps safeguard investments made into renewable energy and energy efficiency, (ii) provides additional tools to help system owners operate and maintain their retrofits and (iii) supports evidence-based decision making for future program design.

However, M&V requires specialized knowledge. It is not as simple as installing performance monitoring hardware. Widely recognized M&V protocols like the International Performance Measurement & Verifications Protocol (IPMVP) make it clear that each M&V exercise needs an M&V plan and the Efficiency Valuation Organization (EVO), which created IPMVP, certifies and trains individuals capable of creating and administering an M&V plan. It is not enough to install monitoring hardware – there needs to be a measurement plan created and implemented by a trained individual or consultant; but further than that, incentive programs also need to be structured in such a way that ensures that the plan is actually followed.

The research conducted for this report suggests that in most cases, social and affordable housing providers just do not have the capacity to take on M&V themselves[211]. This is for a few reasons, mainly that they do not have the specialized expertise or time to focus on M&V of an RE system or energy efficiency retrofit amongst a wide-range of other responsibilities central to their duties as housing provider. Through this work, this was seen in some challenges observed with O &M where providers often did not have a good understanding of how their systems functioned and often did not have the capacity for effective O&M. Service managers may face similar obstacles. Another option is to require either service managers or housing providers to hire consultants to perform the M&V and then report back to MHO. This may be a better option but there are still significant drawbacks: (i) it does not take advantage of "economies-of-scale," (ii) it requires greater reporting and administrative infrastructure and (iii) data is less accessible to program evaluators. It is also worth noting that the majority of O&M contracts paid up-front within the REI resulted in poor service – therefore, if M&V were to be done by separate individual consultants, this payment structure should be avoided.

[211] It should be noted that PV was an exception in this regard because it is simple to perform M&V on a PV installation. This is mainly because ready-made measurement hardware packages and online monitoring gateways come as a standard option with many inverters, but also because the energy generated by PV is something that can be directly measured – whereas energy "savings" is not something that can be measured. It must be estimated from pre- and post-retrofit energy usage data.

A potential solution to this issue is to centralize M&V activities for programs of a similar nature to REI. Pre-built web-enabled hardware packages could be deployed with every retrofit and communicate to a single online monitoring portal, accessible both to housing providers and program evaluators. The costs of hardware and software design would be incurred once rather than individually for every installation. It would also significantly simplify data collection - rather than manual periodic submission to the MHO, service managers or housing providers could automatically submit data. Notably, this approach places fewer requirements on service managers or housing providers and addresses the capacity gap that may currently exist in the sector.

7.3 Online training materials/courses to support operations and maintenance of RE and energy efficiency retrofits

As has been identified in this research, there is a sector-wide capacity gap in terms general knowledge and competence with regard to the O&M of RE and energy efficiency retrofits. It is advisable that future programs incorporate guidance and training for program participants. In-person training events are logistically challenging for maintenance staff (for example, building superintendents are typically restricted with regard to when they can leave the premises of their building) and generally onerous for housing providers to attend. One of the most cost-effective options is to create online training materials that housing providers can review at their own convenience. An example of what online PV system commissioning and O&M training could look like can be seen here: http://www.sustainabletechnologies.ca/wp/events/ (available under the Renewable Energy tab). Online training courses delivered in future programs would build capacity in the sector and help to ensure that energy efficiency and RE retrofits are operated and maintained effectively.

7.4 Decision-making support tool for providers and service managers considering RE or energy efficiency retrofits

While social and affordable housing providers often have a general desire to increase the environmental sustainability and energy efficiency of their housing portfolio, they are often unsure of their options and the steps necessary to evaluate those options. A decision-making support tool at this crucial stage could help housing providers move toward a retrofit. The tool should be developed with input from service managers and housing providers to ensure their needs are directly met. In general, it could allow housing providers to input certain key inputs about a building and their needs as a provider and would then provide a list of options. Options could be categorized according to criteria that is relevant to the providers, including financial metrics, capital cost, energy savings, tenant impacts, thermal comfort, O&M requirements, and similar. Once they select an option, the tool would outline the next steps.

APPENDICES

A. CASE STUDIES

Case Study:
Ahmadiyya Abode of Peace Inc.

Since its conception in 1990, Ahmadiyya Abode of Peace Inc. (AAP) has been an award-winning leader in energy conservation and efficiency. Numerous energy retrofits have been conducted over the years that have resulted in notable reductions in their environmental footprint and lower operating expenses.

The capital funding provided by the REI allowed them to further their conservation goals by installing three renewable energy systems, which as a non-profit housing provider, they would not have been otherwise able to install. AAP installed a PV system, a solar air heating system and a solar domestic hot water (SDHW) system. With limited roof space, they were able to reduce the physical footprint of the systems by installing the PV system on top of the solar air collector on the south facing wall of the building.

"We do it as a social obligation. We are in the forefront of showcasing [energy conservation and efficiency technologies] so that other people can understand that it works." –Karim Tahir, Property Manager Ahmadiyya Abode of Peace Inc.

They entered into a 10-year maintenance contract with a local firm that also provides them with monitoring data that is closely reviewed by their property manager. Uniquely, both the solar air and SDHW are monitored as well. The savings seen at the gas meter is reported by AAP to be approximately 40% over 2010 levels.

The AAP property manager was the on-site coordinator for the installation of the renewable energy system with Housing Services Corporation acting as the project manager. The AAP reported no issues with the administration of the REI program or the flow of funding. The AAP property manager's advice for prospective renewable energy system owners in the social and affordable housing sector is to stay current on the available funding opportunities. In their case, in addition to the REI, they were able to connect their PV system to the grid via a microFIT contract and the gas savings on their make-up air unit from their SolarWall allowed them to receive a grant from Enbridge.

Case Study:
Toronto Area Private Social and Affordable Housing Provider

This provider opted to install a small PV system and a much larger solar thermal system using funding from the REI. Both systems were installed with modules and collectors nearly horizontal, likely due to wind-loading concerns. It is most often the case that solar modules or collectors are tilted at an angle to maximize solar energy capture.

The provider hired a consultant to evaluate the performance of the systems because they felt the energy savings was poor given the cost of the system to install. Aside from the non-optimal tilt angle, the consultant found that the systems had generally been sized and designed appropriately and that incurring costs for structural changes to the mounting to improve the tilt angle would not be financially justified by the resulting increases in savings and income.

"I feel the payback(s) between the PV & Solar system are not high enough to offset the costs associated with the installation and maintenance of the system. In addition I was informed that when it is time to replace the roof I have significantly increased the cost due to the panels having to be removed and then replaced." -Executive Director for the housing provider

In general, the provider reports that they are unsure if they are better off for having installed the systems because the savings are low and they are concerned about maintenance costs once the current maintenance contract runs out. Furthermore, they note that the systems will introduce costs when it comes time to replace the roof and that this was not brought to their attention when they were deciding whether to move forward with the system.

Case Study:
Cole Road Co-operative Community

The Cole Road Co-operative Community (CCC) used funding available from the Renewable Energy Initiative (REI) to install both a photovoltaic (PV) system on the roof of townhome units and a solar domestic hot water (SDHW) on the roof of their community room. The 10 kW_p PV system was connected to the grid via a microFIT contract and the SDHW system comprised a single 2.5 m^2 collector were that was used to supplement a natural-gas powered heating system in a common-use community room.

CCC reports that the PV system works well, evidenced by regular microFIT payments averaging from $10,000-$12,000 each year. They noted that there was an initial cost for a local pest control company to provide rodent proofing for the installations after the CCC had heard this might be an issue with other installs, but aside from that, maintenance on PV has been minimal.

"We get regular reports on trees saved from installing solar from Enphase [solar inverter company], and I enjoy providing this information to our board of directors"- Judith Sainsbury, Community Coordinator

CCC experienced problems with SDHW system shortly after installation when the system began leaking glycol. The original installer could not be reached for warranty support, so CCC hired a maintenance contractor referred by their insurance company. Problems with the system continued to persist over the years. At the time of writing for this case study, the SDHW system was not operational. Performance monitoring was not required in the REI and no monitoring system installed with the SDHW system. CCS reports that they did not notice a significant reduction in heating costs post-installation but without sufficient data, it is not possible to judge how much gas the system is saving.

Case Study:
Northern Social and Affordable Housing Provider

A social and affordable housing provider in a Northern service region was committed to saving energy and the reduction of greenhouse gas emissions and towards this end, the provider utilized funds available from the Renewable Energy Initiative (REI) to install a geothermal system with a vertical ground heat exchanger (GHX) in their 24-housing unit apartment building.

Prior to the geothermal installation, the provider relied upon electricity to meet building heating and cooling needs because the site does not have access to natural gas. An old make up air unit serviced common areas, hallways and community rooms. Radiant electric heaters provide heating in tenant units and some tenants used personal air-conditioners for cooling during warm summer months.

The geothermal system was designed to provide make-up air and recirculation capabilities for the building, replacing the old make-up air unit. The provider has a contract with an external geothermal technician that switches the system to 'heating' mode at the beginning of the winter season, and into 'cooling' mode at the onset of the summer season. However, during the December site inspection (5 years after installation), it became apparent that the unit was supplying cold air.

"We are very thankful for REI programs and funding, and really want the systems to work, but we lack expertise in-house and are thus unable to troubleshoot technical issues. Due to a 'one-time funding' model for grant programs, the burden of maintenance and capital repairs over the lifetime of the system comes directly from the Municipally funded social housing operating and maintenance budgets"- Supervisor of Infrastructure and Asset Management for housing provider

The housing provider reports that they are unsure about how well the installation is performing because monitoring equipment, like a Btu-meter, was not provided for the system. In the absence of a rigorous measurement and verification (M&V) protocol, savings can only be very roughly estimated by comparing post-installation building energy consumption against a pre-installation baseline. A simple analysis of historical utility consumption data from the site indicates no significant change in total building energy use after the system was installed, but this is likely inconclusive because the load of the make-up air unit may not be large enough to be distinguishable from the other electrical loads in the building and from the natural annual fluctuations in electricity consumption.

The REI program funding was a one-time opportunity and thus the provider must fund repairs, maintenance and capital replacement from current capital and maintenance budgets. Staff report experiencing challenges with system operation and maintenance, and barriers to measuring actual energy and cost savings. Essentially, they feel they do not have the tools or training to understand how their system is operating. Overall, the provider remains supportive of the REI program goals as well as subsequent energy retrofit programs.

Case Study:
The Corporation of the County of Simcoe

The Corporation of the County of Simcoe (CCS) used funds available from the Renewable Energy Initiative (REI) to install both a photovoltaic (PV) system and a solar domestic hot water (SDHW) on three of their social and affordable housing low-rise apartment buildings. The 10 kW PV systems were connected to the grid via a microFIT contract and the SDHW system were used to preheat mains water prior to a condensing gas boiler.

Aside from some initial PV components failures that were replaced under warranty, maintenance of the PV systems have consisted of little more than a review of the on-line monitoring data that is provided through the vendor. CCS notes that the SDHW are all operating well but maintenance of the systems is more intensive. To help, they created preventative maintenance sheets and they also credit a good maintenance team that conducts daily checks to ensure the performance and health of the system. It is estimated that the SDHW system result in a 15 – 20% savings in gas usage for DHW but this did not translate into large financial savings because gas is inexpensive and maintenance costs can notably diminish the savings. For prospective owners, the facilities manager recommends keeping systems as simple as possible to keep operation and maintenance costs low.

"SDHW system savings [were] $500-800 per year. In years [that] we lost a circ[ulator] pump that is say, $500, so annual savings can be cancelled out by maintenance costs." Bradley Spiewak, Facilities Manager

There were no barriers reported in terms of the administration of the REI program or the flow of funding from the service manager. However, they did note that interfacing with the LDC to get contracts in place was time-consuming. Overall, CCS reports that they are better off from having participating in the REI program and that their operational costs have decreased. Savings in operations go to additional capital repairs and other building upgrades.

Case Study:
Southern Ontario Social and Affordable Housing Provider

Through the Renewable Energy Initiative (REI), this provider obtained renewable energy systems on many of their properties including: solar photovoltaics (PV), solar domestic hot water (SDHW), solar air heating and geothermal, ranging across different sizes and capacities. Most of the systems are PV and these are connected to the grid through Ontario's Feed-In Tariff (FIT) allows the power to be sold back to the utility at a fixed above-market rate. PV system performance data is available through a single online monitoring gateway that is closely inspected by the provider's staff. Systems are reported to be performing slightly better than anticipated and any issues are quickly dealt with under an operations and maintenance (O&M) contract with a large reputable company in the PV industry.

The provider monitors non-PV systems using a pre-existing portfolio-wide building automation system (BAS). A building operator is able to efficiently analyze data from a number of buildings from a single location and then notify a superintendent or maintenance team if any issues arise. This ensures the functioning of systems while also helping to take the strain off building superintendents. The provider also hired consultants to perform measurement and verification post-commissioning to evaluate system performance against expectations.

For the provider, it was important that tenants had the opportunity to provide feedback on the renewable energy systems that were being considered and they report to have held meetings in each building to discuss the potential systems with tenants. Seniors buildings often had a strong turnout to the meetings, partly due to tenants that were retired engineers and were eager to learn about the renewable energy systems.

Case Study:
Housing York Inc.

The Regional Municipality of York's non-profit housing corporation, Housing York Inc., is the seventh largest social and affordable housing provider in Ontario and offers housing and support to 4,000 tenants across 36 housing properties. Their sustainability efforts are guided by York Region Vision 2051 with a key aspirational directive to "encourage initiatives that move toward zero greenhouse gas emissions by 2051".

Housing York installed both solar domestic hot water (SDHW) and solar air systems with funding from the REI. They noted that application timelines were tight, but they had performed building energy audits a year prior to the REI roll out and already had a strong interest in solar air heating technology from previous experience. This left them well positioned to participate in the REI. They noted that the fact that it was a 100% capital cost subsidy was important to them because it can be hard to find the capital for these types of retrofits that can have very long paybacks.

"So [for] solar air as far as I know, the maintenance is really simple, there's no regular maintenance requirement because we have a building maintenance system to also monitor the duct damper position…. I would say [a solar air system] is a pretty reliable system as far as my experience because there's no moving parts on the panel." Richard Zhang, Sustainable Building Engineer, Infrastructure Asset Management, Housing Services York Region

Housing York's solar air heating installations are integrated into a building automation system (BAS) that allows them to remotely change the position of dampers on a seasonal basic, drawing preheated fresh air from the collector in winter and directly from the ambient outside air in summer. They report that this is really the only operations and maintenance (O&M) effort that the systems require. In general, they are very pleased with the technology because the technology itself is simple, it has minimal moving parts, it requires minimal O&M and there are different colour options to allow the solar air collector to more seamlessly integrate into the building façade.

Case Study:
Grachanica Non-profit Housing Corporation

The Grachanica Non-Profit Housing Corporation (GNPHC) used funding available from the Renewable Energy Initiative (REI) to install a photovoltaic (PV) system on the roof of their non-profit social housing building in Windsor. In 2009, GNPHC secured SHRRP funding to undergo a "much needed" roof replacement. While the capital upgrades were underway, GNPHC was able to leverage the engineering, and labor already involved in the roof replacement to also install roof anchors for a proposed PV project. The additional cost of the anchors ($21,000) was covered by SHRRP program. In the subsequent year, GNPHC was able to turn in a competitive proposal for a PV installation funded through the REI program. The 10.5 kW_p PV system is connected to the grid via a microFIT contract.

This project is a case study on how integrating energy portfolio planning with strategic asset management plans can provide benefits to both housing providers and project administrators. For GNPHC, getting a new roof right before PV locks in long-term savings through the lifetime of the roof and panels. For REI administrators, using the engineering and labor from roof replacement to set the stage for the solar installation helped save "several thousand" dollars in project costs [GNPHC estimate].

"We are very proud of our solar panels on our roof; our building may be the Taj Mahal of social housing. Solar is just the beginning, we want to continue to be as efficient as possible. Large projects are sometimes challenging for non-profit social housing providers, so we aim to lead by example." - Snjezana Gacea, Property manager

GNPHC directed a small portion ($3,465) of their REI funding towards an energy audit. The comprehensive audit and subsequent caulking and sealing upgrades helped secure a well-insulated thermal envelope for the approximately 40-year-old building. GNPHC also carried out a whole building LED retrofit at a later date, and reports good feedback on lighting quality from the tenants. GNPHC reports that the PV system works well, evidenced by regular microFIT payments averaging between $9,500-$12,000 each year.

There were no strong barriers reported in terms of the administration of the REI program or the subsequent flow of funding from the service manager. However, GNPHC suggests that additional training and support may be necessary for private non-profit social housing providers to remain competitive with provincial funding programs and achieve long-term deep retrofits. Overall, GNPHC reports that they are better off from having participated in the REI program, and are eager to participate in future programs. Their integrated energy and asset management framework includes plans for securing more efficient bathrooms, improving tenant heating and comfort, and implementing preventative maintenance of asset exterior.

Case Study:
Haliburton Community Housing Corporation

Starting in 2004, Haliburton Community Housing Corporation (HCHC) has made reducing the carbon footprint of their buildings a key priority. Through their efforts, and partially with the aid of programs like the Social Housing Renovation and Retrofit Program (SHRRP), they report saving approximately 350,000 kWh per year over 2004 levels between two of their locations. HCHC decided to install a solar photovoltaic (PV) system at one of their locations using REI funding. However, the East-West orientation of the gable roof was not ideal for PV. The issue was resolved by mounting the 10 kW PV array vertically on the south-facing end wall. The system was connected to the grid via microFIT contract at $0.802/kWh.

"REI helped us continue our work to reduce our carbon footprint and has allowed us, through the generation of extra income, to keep our buildings in excellent condition thereby making the lives of our tenants that much more enjoyable." Barbara Fawcett, HCHC Manager

A monitoring system was installed as well. It can be accessed via a user-friendly online gateway and HCHC receives monthly energy generation reports that are closely examined by the property manager. There have been no reported problems with the system but this level of monitoring would allow them to act quickly on any performance-related issues that may arise. The data shows that the system is performing better than anticipated.

The funds from the PV system are being used to maintain the buildings and this reduces the need to draw from the capital replacement reserve. As an example, the income from the PV system allows new carpets to be installed in units as needed when they are vacated. In addition, rents have been kept as low as possible with the extra income. HCHC notes that a broader impact of their efforts is the discussion surrounding energy conservation that is occurring within their community, and other projects that have been inspired or influenced by their actions.

Case Study:
Peel Living

The Region of Peel's non-profit housing company, Peel Living (also known as Peel Housing Corporation), offers homes in 70 sites to 7,100 residents. Their sustainability vision is guided by the Region of Peel's Energy and Environment Sustainability Strategy (EESS), which has a key goal of reducing greenhouse gas emissions to 80% below 1990 levels by 2050. Through the Renewable Energy Initiative (REI), Peel Living received funding for both PV and solar domestic hot water heating (SDHW) systems. Specifically, they were interested in evaluating the benefits of different SDHW system types and they installed both drain-back and closed-loop SDHW systems.

In general, it was their experience that SDHW systems were complex to design, install, maintain and operate, and through the process of implementing their own systems they've gained much experience worth sharing:

- Drain-back systems are preferred over closed-loop systems because they are simpler to operate and maintain.
- Design and installation of SDHW systems in retrofit applications is complex, invasive and impacts both tenant experience and operations.
- SDHW system equipment impacts roof systems, and requires space that may be better suited or reserved for other purposes, such as future retrofit of other existing equipment and systems (i.e. central heating boiler, DHW systems).
- SDHW systems must be right sized, and their proposed best approach is to size SDHW capacity to meet minimum hot water capacity.
- Retrofits for enhancing performance of existing base systems is preferred over allocating resources (funds, staff) for SDHW projects.

The Region continues to assess the actual operational benefit of their REI-funded SDHW systems and in general, they recommend measurement and reporting as an important part of a renewable energy retrofit. They note that training is also important for end-users and operations staffs, especially where the technology can be perceived as complex. As owners/operators, they rely on the market to provide best practices for design and installation of systems. This can be a challenge for new technologies that are not firmly established, which has important implications on the ability of owners to effectively install, operate and maintain their systems. Lastly, Peel Living highlighted an issue echoed by many other social and affordable housing providers: timelines. They recommend that funding programs provide sufficient time to complete structural, shading, and design studies required to enhance the opportunity for an overall successful installation of any retrofit initiative.

B. NATURAL GAS COST ESTIMATE

Figure B-1 shows the historical natural gas commodity price in Ontario[212]. Note that this is *not* the total cost of buying gas, but rather, the [$/m³] value charged before additional fees and taxes are applied. The current price is near a historic low.

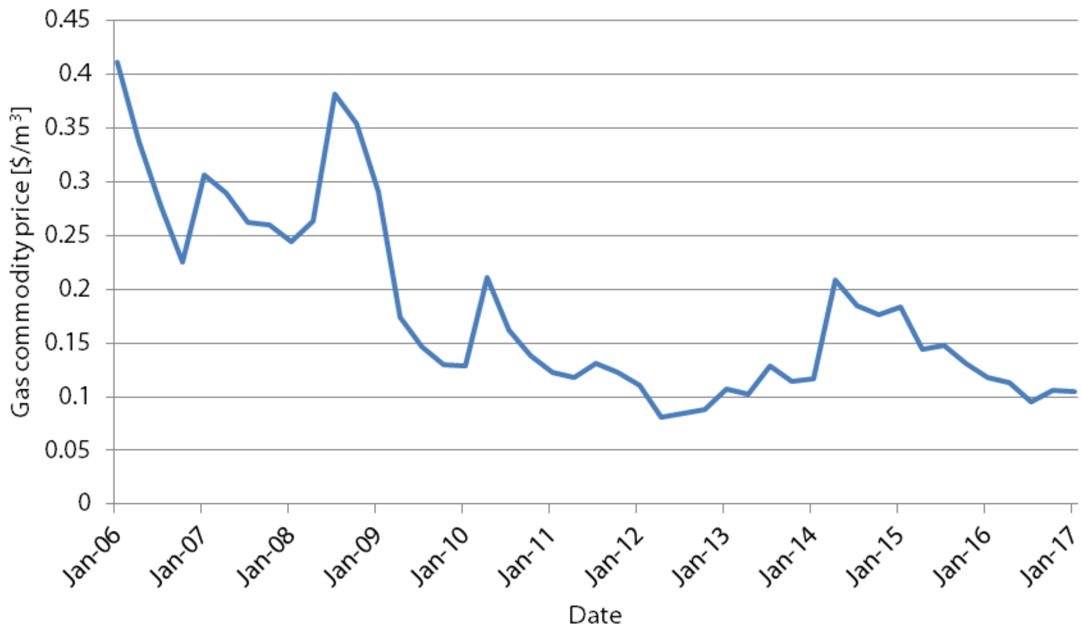
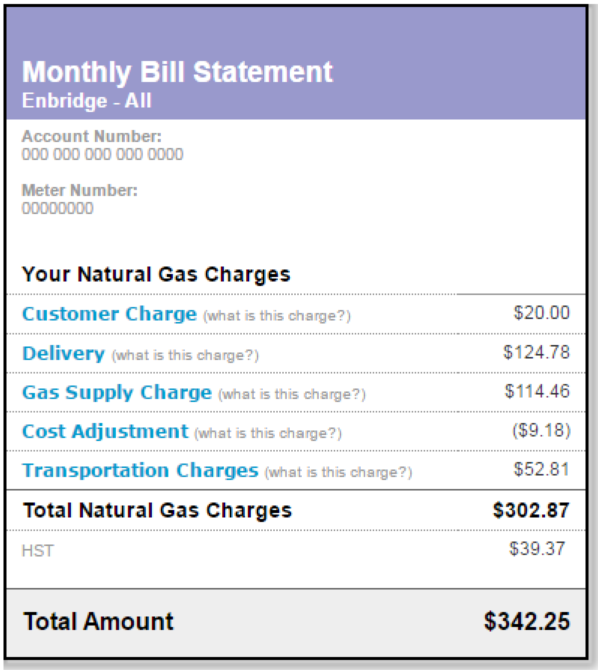


Figure B-1. Historical natural gas commodity price in Ontario.

An actual natural gas bill includes costs for maintaining an account, delivery, gas supply, transportation and HST. Below is an example bill from Enbridge for 1000 [m³] of natural gas delivered in Mississauga, calculated using the Ontario Energy Board's gas bill calculator[213]. Neglecting the customer charge, it works out to 0.32 [$/m³] while the gas supply charge, depicted in Figure B-1 above is only 0.11 [$/m³].

Table B- 1 recalculates the bill assuming a commodity price of 0.38 [$/m³] but leaving all other fees (except for HST) constant. Neglecting the customer charge, it estimates the total cost of gas as 0.62 [$/m³]. This is in rough agreement with historical gas price cost trends provided by Union Gas, where the 2008 average annual residential gas bill is reported to be roughly $1,100 for a consumption 2,200 [m³], 0.50 [$/m³] (Figure B-2)[214]. In this report, the analysis considers gas prices between 0.32 and 0.62 [$/m³].

[212] Ontario Energy Board. "Natural gas rate – Historical." Retrieved Feb. 7, 2017 from: http://www.ontarioenergyboard.ca/OEB/Consumers/Natural+Gas/Natural+Gas+Rates/Natural+Gas+Rates+-+Historical.
[213]Ontario Energy Board. "Your natural gas utility." Retrieved Feb. 7, 2017 from: http://www.ontarioenergyboard.ca/OEB/Consumers/Natural+Gas/Your+Natural+Gas+Utility.
[214] Union Gas. "Why choose natural gas?" Retrieved Feb. 8, 2017 from: https://www.uniongas.com/residential/products-services/why-choose-natural-gas.



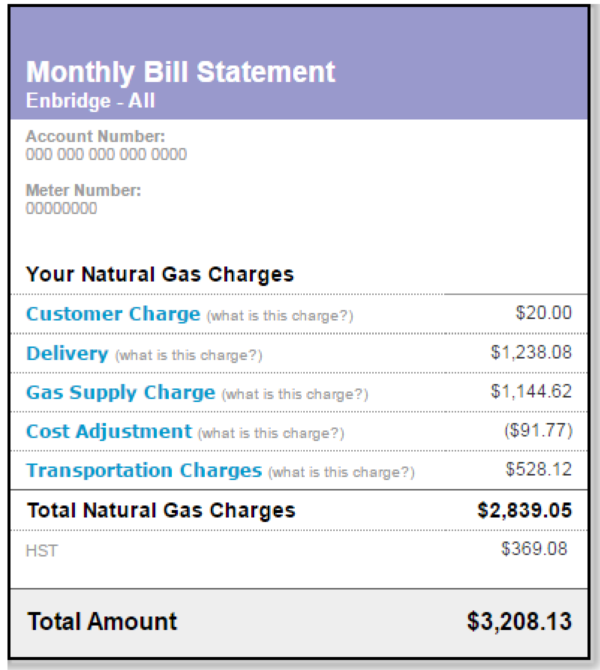
Monthly Bill Statement
Enbridge - All

Account Number:
000 000 000 000 0000

Meter Number:
00000000

Your Natural Gas Charges

Customer Charge (what is this charge?)	$20.00
Delivery (what is this charge?)	$124.78
Gas Supply Charge (what is this charge?)	$114.46
Cost Adjustment (what is this charge?)	($9.18)
Transportation Charges (what is this charge?)	$52.81
Total Natural Gas Charges	**$302.87**
HST	$39.37
Total Amount	**$342.25**



Monthly Bill Statement
Enbridge - All

Account Number:
000 000 000 000 0000

Meter Number:
00000000

Your Natural Gas Charges

Customer Charge (what is this charge?)	$20.00
Delivery (what is this charge?)	$1,238.08
Gas Supply Charge (what is this charge?)	$1,144.62
Cost Adjustment (what is this charge?)	($91.77)
Transportation Charges (what is this charge?)	$528.12
Total Natural Gas Charges	**$2,839.05**
HST	$369.08
Total Amount	**$3,208.13**

Figure B- 2. Example gas bills calculated using the Ontario Energy Board's gas bill calculator. On the left, the gas consumption is 1000 [m³] and on the right 10,000 [m³].

Table B- 1. Total gas cost estimate using 10-year historical high gas commodity price.

Gas commodity price (Supply Charge) [$/m³]	0.11	0.38
Customer Charge [$]	20	20
Delivery [$]	124.78	124.78
Gas Supply[$]	114.46	380
Cost Adjustment [$]	-9.18	-9.18
Transportation [$]	52.81	52.81
HST [$]	39.37	73.89
Total [$]	342.24	642.30
Total gas cost [$/m³]*	0.32	0.62

*Neglecting customer charge

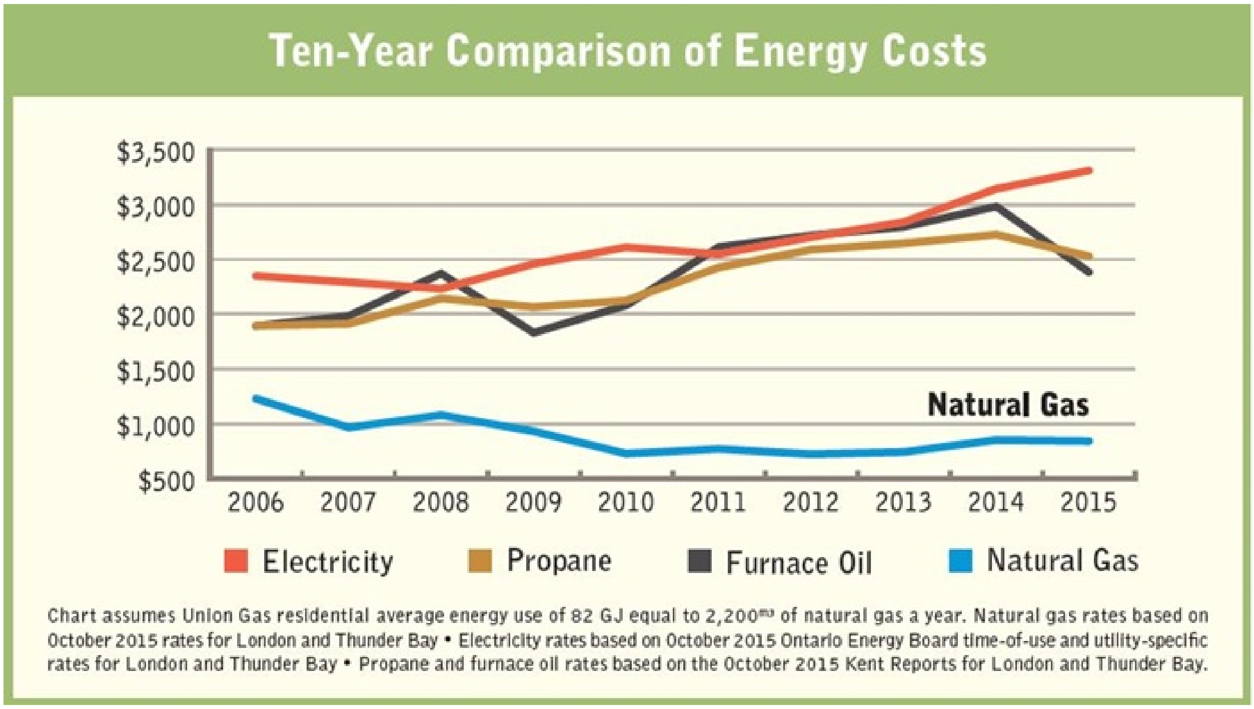


Figure B- 3. Historical average annual residential gas bill according to Union Gas assuming 2,200 m^3 of consumption.

C. ELECTRICITY COST ESTIMATE

The RE technologies evaluated in this report reduced the consumption of electricity and natural gas in the social and affordable housing buildings. To evaluate the lifetime financial impacts of reduced energy consumption, it was necessary to forecast the future value of energy. The most recent Long Term Energy Plan (LTEP), from 2013, provides a forecast for the future cost of electricity.[215] This was converted to a value in units [$/kWh] in the analysis. However, significant changes to electricity costs implemented in 2017 were not included in the 2013 LTEP projections.

As of January 1st 2017, electricity consumers are provided a full rebate equal to the provincial portion of the HST (8%) on their electricity bills. On March 2nd 2017, the Province announced Ontario's Fair Hydro Plan (OFHP) under which the average household electricity bill will be reduced by 25%, starting in summer 2017. This reduction includes the 8% rebate introduced in January. The OFHP will reduce electricity bills through:

- refinancing a portion of the Global Adjustment (GA);
- an Affordability Fund to help customers undertake energy efficiency improvements;
- a reduction in distribution charges for consumers in low- and medium-density areas;
- an On-Reserve First Nations Delivery Credit;
- enhancements to the Ontario Electricity Support Program (OESP), and
- funding electricity support programs (Rural or Remote Rate Protection and Ontario Electricity Support Program) through provincial revenues instead of electricity bills.

The OFHP will also ensure that the electricity bills will not increase beyond the rate of inflation for four years. While 25% is being reported by the Province as the average electricity bill savings, a different level of savings will be experienced by different types of consumers depending on their consumption and their electricity distributor. Low-income consumers may receive an even greater savings on their electricity bills but this may be due a credit provided by the OESP that is a constant amount on their monthly bill. While many social and affordable housing residents may qualify for the program, it should be noted that electricity bill savings from the OESP are not relevant when trying to valuate avoided costs from the reduced energy consumption associated with the use of RE technologies. This is because a fixed credit is applied based on household income and size, and not electricity consumption.

Within this report, the cost of electricity forecasted using the 2013 LTEP was *not* adjusted to take into account the provincial HST rebate and the OFHP because a long-term forecast will not be available until the next LTEP is released in late 2017. However, it is not anticipated that these changes will significantly affect the overall conclusions of the analysis because:

[215] Government of Ontario. "Achieving Balance: Ontario's Long Term Energy Plan," Figure 7, 2013. Retrieved Feb. 2, 2017 from: http://www.energy.gov.on.ca/en/files/2014/10/LTEP_2013_English_WEB.pdf. Note that the forecast is for 20 years from 2013 to 2032; to evaluate RE systems starting in 2010, and possibly with a longer lifetime than 2032, the 2013 LTEP electricity costs were extrapolated.

- PV is unaffected by electricity rate changes and the large majority of REI Funding was provided for PV (PV also was estimated to produce 90% of the program financial benefits);
- only 20% of non-PV systems were estimated to be offsetting electricity; and
- the systems have already been operating for several years.

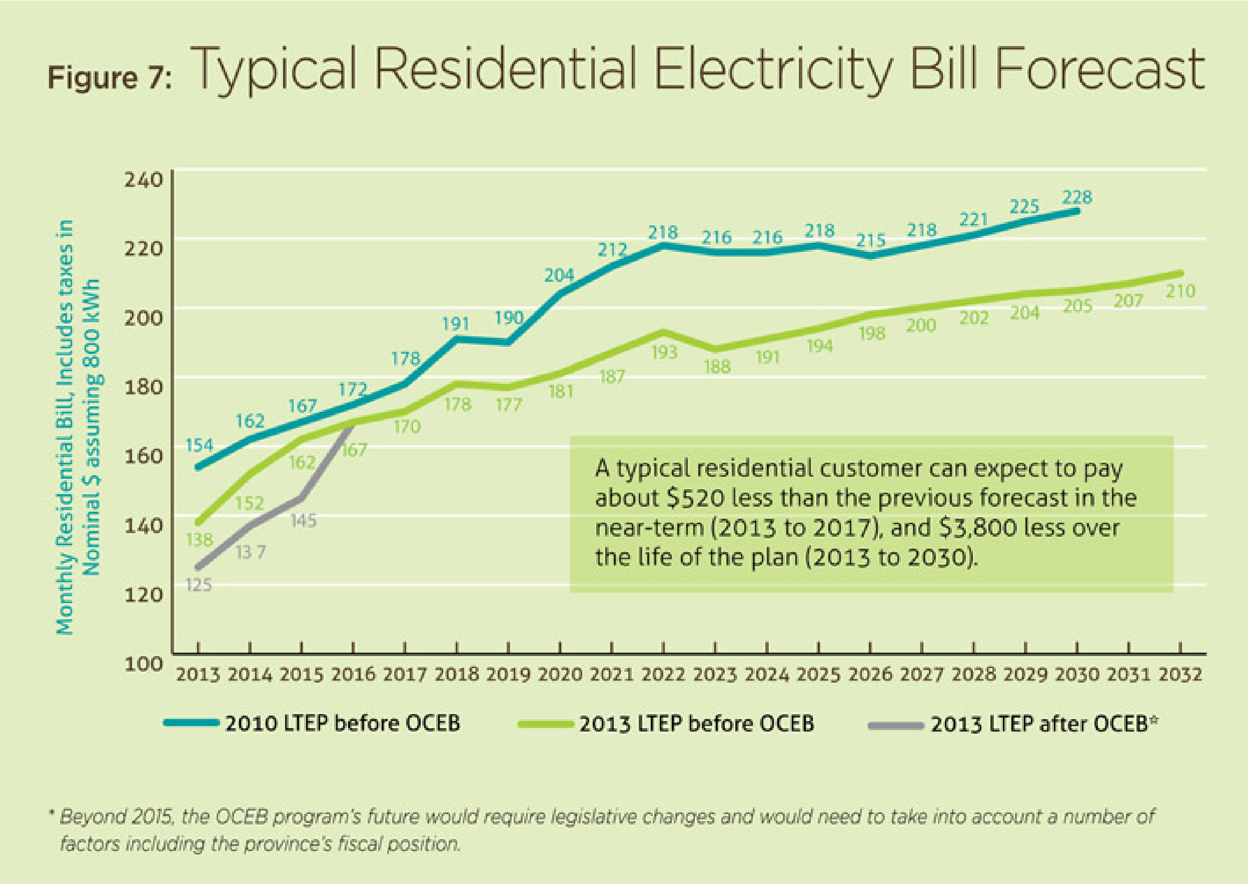


Figure C-1. Estimated increase in monthly electricity costs for residential consumers according to the LTEP.

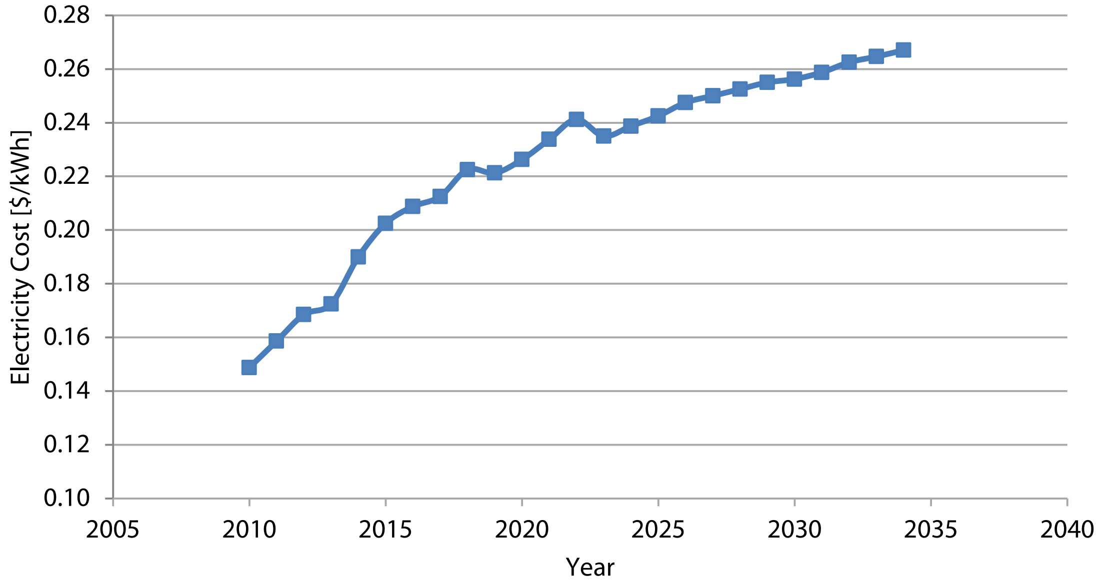


Figure C-2. 2013 LTEP forecast converted to a [$/kWh] electricity rate incorporating all charges and fees.

D. SURVEY QUESTIONS

PROJECT SPONSOR

Renewable Energy Initiative (REI) Program Evaluation

1. Personal and Organization Information

Under the sponsorship of the Ontario Ministry of Housing (MHO), Evergreen and the Toronto & Region Conservation Authority (TRCA) are partnering to evaluate the Renewable Energy Initiative (REI) incentive program, a sub-initiative of the Social Housing Renovation and Retrofit Program (SHRRP). Between 2009 and 2012, the REI provided funding to social and affordable housing providers for the installation of approved renewable energy technologies, including: solar panels, small-scale wind turbines, solar hot water heating, solar air heating and geothermal. *Please note that the REI was a different incentive program from the Green Energy and Economy Act's Feed-In Tariff (FIT) program, which allowed renewable energy producers to sell electricity back to the grid at a premium price, although in many cases both were used for the same system.*

The purpose of this survey is to collect feedback from social and affordable housing providers that received REI funding. We would like to know if your needs were met and if your renewable energy system(s) is (are) helping to reduce your operating costs. We would also like to capture any technology-specific lessons-learned in terms of planning, installation, operation and maintenance. This information is being collected so that your experience can aid prospective system owners and also, inform the development of future renewable energy incentive programs.

The survey is intended to be filled out by individuals employed by social and affordable care providers that were involved in the implementation of the renewable energy system or, alternatively, are involved with its ongoing operation. It may take between 15 to 30 minutes. Please feel free to leave any questions blank if you do not have an answer. Please use the text boxes to provide additional comments where applicable. Survey results may or may not be made publicly available. If made publicly available, results will be reported at the aggregate level with no indicators of who provided what feedback unless your express consent is given otherwise. We greatly value your feedback and thank you for participating.

1 Full Name

2 Email

3 Phone Number

4 Which social and affordable housing provider do you work for?

5 What is your current role?

6 What was your role during the implementation of the renewable energy system(s) (2009 - 2012)?

7 How many individual **REI-funded** renewable energy system(s) were installed by your organization? Please identify a number next to each technology type below. For example, 0, 1, 2, 3, 4, 5 or >5. If your organization has additional renewable energy systems that were not funded by the REI, please provide further details below.

Solar panel installation (electricity-producing)

Solar hot water heating systems

Solar air heating systems

Geothermal systems

Small-scale wind turbines

Additional renewable energy installations **not funded by REI** (please indicate type and number)

PROJECT SPONSOR

Renewable Energy Initiative (REI) Program Evaluation

2. Site and Installation Information

8 If possible, please provide any information on the size/capacity of the renewable energy system(s) that was (were) installed. For example, the # of solar thermal collectors, the area of solar air systems, the rated power of PV systems, etc. Please feel free to leave blank if this information isn't available to you. Also, please feel free to offer any additional information on the type of equipment used if that information is available to you. If it is more straightforward for you, it is also possible to simply indicate that you have documentation to share and we can follow up.

9 Did the REI fund all or nearly all of the installed cost for your renewable energy system(s)? If not, please provide an approximate percentage of the installed system(s) cost **covered by the affordable and social housing provider.**

- REI covered all, or nearly all, of the system cost
- Unsure

Or, enter a percentage covered by social and affordable housing provider

10 What external factors affected renewable technology choices made by you as the provider?

- [ ] FIT or Micro-FIT programs
- [ ] Costs
- [ ] Building limitations
- [ ] Technology limitations
- [ ] Guidance from external organizations

Additional information

11 Were the approved projects installed and operating effectively?

- ( ) Yes
- ( ) No
- ( ) Unsure

12 If you answered "no" above, what was the nature of the issues associated with installation and operation?

- [ ] Inability to connect to the grid
- [ ] Internal challenges
- [ ] Maintenance issues
- [ ] Unsure

If other, please specify

13 Were there impacts on the day-to-day operational costs for the building in which the system was installed as a result of having participated in the REI program?

- ◯ Operational costs increased as a result of participation in the program
- ◯ Operational costs decreased (from energy savings or revenue of the system) as a result of participation in the program
- ◯ Costs remained the same as a result of participation in the program

Please feel free to provide further information on how operational costs were affected

14 After the installation, were any supports put in place to ensure that the system(s) was (were) operating well?

- ◯ Yes
- ◯ No
- ◯ Unsure

15 If you answered "yes" above, please choose from the following supports put in place.

- ☐ Data-logging equipment to collect performance data
- ☐ Regular preventative maintenance
- ☐ Maintenance contract with an external contractor
- ☐ Training of internal maintenance people
- ☐ Review of utility bills to verify energy savings or generation
- ☐ Building automation system (BAS)
- ☐ Routine inspections of system(s)

If other, please specify, or feel free to use this space to elaborate on whether these supports were effective

16 Was the net revenue or savings (after accounting for any maintenance or operational costs) provided by the renewable energy system(s) approximately what was expected?

- Less than expected
- As expected
- More than expected
- Unsure about expectations

Please feel free to comment further on how/why the system deviated from expectations

17 Are there any monitoring data or historical utility bills/payment information associated with the renewable energy system(s) that could be shared for this study? This data will be used to help us estimate program-wide energy savings (or generation) and carbon emissions savings.

- Yes
- No
- Unsure

Additional Information

18 For PV and wind systems: Is (are) the PV system(s) connected to the utility via a FIT or micro-FIT contract?

- Yes
- No
- Unsure

Additional Information

19 For solar hot water heating, geothermal and solar air heating: Is the heat produced by your system(s) offsetting natural gas, electricity or another fuel type?

- [ ] Electricity
- [ ] Gas
- [ ] Oil
- [ ] Propane

If other, please specify

20 Was a feasibility analysis or business case prepared for the system(s) prior to installation?

- ○ Yes
- ○ No
- ○ Unsure

If yes, could it be shared for this study?

21 If you feel your system(s) was (were) a success, could you identify the key success factors in terms of project planning, implementation, operation and maintenance? Alternatively, if the system was not a success, please use the blank space provided below to briefly describe why.

- ○ System(s) was (were) a success
- ○ System(s) was (were) not a success

Why? (please specify)

PROJECT SPONSOR

Renewable Energy Initiative (REI) Program Evaluation

3. Experience with REI

22 Were there any issues with the flow of funding from the service manager?

- Yes (Please elaborate below)
- No
- Unsure

If yes, what were the issues?

23 Did you experience any barriers to participating in the program?

- Yes (Please elaborate below)
- No
- Unsure

If yes, what were the barriers?

24 As the social housing provider, were you better off as a result of having participated in this program?

- ◯ Better off
- ◯ Worse off
- ◯ Neither better nor worse off
- ◯ Unsure

Additional information

[ ]

25 Were any savings in operational costs passed down to social housing tenants?

- ◯ Yes (Please elaborate below)
- ◯ No
- ◯ Unsure

If yes, in what way did tenants benefit?

[ ]

26 Did the renewable energy system(s) implementation involve tenant or community engagement in any way (i.e. education about renewable energy, tenant input on location of system(s), etc.)?

- ◯ Yes (Please elaborate below)
- ◯ No
- ◯ Unsure

If yes, how were tenants engaged?

[ ]

27 Did you receive SHRRP funding in addition to REI funding?

- ◯ Yes
- ◯ No
- ◯ Unsure

28 If you answered "yes" above, was the funding focused on conserving or enhancing energy efficiency?

- ◯ Focused on energy efficiency
- ◯ Not focused on energy efficiency

Additional information

PROJECT SPONSOR

Renewable Energy Initiative (REI) Program Evaluation

4. Closing Questions

29 May we contact you for follow-up questions?

- ◯ Yes
- ◯ No
- ◯ Unsure

Additional information

30 Would we be able to feature your system(s) as a case study?

- ◯ Yes
- ◯ No
- ◯ Unsure

Additional information

31 Would one of our technology experts be able to visit and assess the state of your system(s)? This could possibly involve installing short-term monitoring equipment, at no cost, to help estimate system performance.

- Yes
- No
- Unsure

Additional information

32 Is there anything else you would like to add? Please feel free to add any final thoughts. For example, did the REI help to meet your needs as a social or affordable housing provider? How could the REI program have been changed to better meet your needs?

We greatly appreciate your feedback. Thanks for taking part of this survey.

E. INTERVIEW METHODOLOGY AND INTERVIEW GUIDES

The project team conducted interviews with MHO staff and program stakeholders. Table E-1 outlines the categories of interview groupings that were proposed to use for analysis. A series of five interview guides were development for the evaluation, each of which was tailored to specific sets of interview groups. Interview Groupings are outlined in Table E-1. A master list of interview questions is outlined in Table E-2. Interview Guides for the following groupings are included in this document: MHO senior management and program staff, area service managers, program vendors, and housing providers (Tables E-3 to E-5). Interview guides for energy and housing associations, third party service providers, and other groups were not created and no interviews from these stakeholder groups took place.

Questions listed in the interview guide have not been arranged in the sequence they will be asked. Sequencing of questions occurred organically during the interviews.

Table E- 1. Interview groupings

Grouping	Description	Proposed number of Interviewees	Actual Number of Interviews
MHO senior management and program staff	MHO staff	4	2
Area service managers	Staff at municipal and district social services administration boards responsible for REI program management and implementation	5-10	10
Program vendors	Approved vendors from the OPA's Renewable Energy Vendor List	2-4	2
Housing Providers	Recipients of REI program funding	5-10	18
Energy associations	Renewable energy associations: • Ontario Sustainable Energy Association • Low Income Energy Network	2	0
Housing associations	• Co-op housing federation • Housing Services Corporation • Ontario Non-Profit Housing Association	3	0
Third party service providers	• Homestarts (Co-op housing management agency) • Greensaver (energy program delivery agency) • Toronto Atmospheric Fund (financing agency for social housing retrofit projects)	3	0
Other	Representative from groups that are not directly involved in REI but knowledgeable on renewable energy	1	0

Total	25-37	32

The primary goal of the interviews was to collect data to add context to the technical, financial and GHG portions of the quantitative analysis

Interview Introduction

The script below was used prior to interviews commencing:

"The Sustainable Technologies Evaluation Program (STEP) and the Ontario Climate Consortium (OCC), in partnership with Evergreen, has undertaken an evaluation of Renewable Energy Initiative (REI) program. This evaluation is sponsored by the Ministry of Municipal Affairs (MMA) and Ministry of Housing (MHO) with support from Canada Mortgage and Housing Corporation (CMHC).

The goal of the evaluation is to identify if (i) there is a continued need for program(s) of this nature, (ii) the program was effective in achieving its outcomes, and (iii) was efficient in achieving its outcomes. These objectives will be addressed using both qualitative and quantitative evaluation process.
This interview is part of the qualitative evaluation process and will be used to (i) assess the relevance and performance (effectiveness and efficiency) of the REI program in meeting its objectives; and (ii) make recommendations for potential future programs of a similar nature.

Because of your experience and interaction with the REI program, you have been identified as a valuable resource to provide input to this process. The following questions will serve as a guide for our interview. Your responses will be managed in accordance with the *Access to Information Act* and the *Privacy Act* and other applicable privacy laws. Information gathered from these interviews will be reported at the aggregate level. Individual responses will not be attributed to you in the final report.

The interview will take approximately 60 to 90 minutes to complete."

Table E- 2 Master list of interview questions

No.	Questions	Type of Information						MHO Information Type			
		Program	Technical	Environmental Impact	Financial	Socio-economic	Other	Introduction	Program Administration	Implementation	Provider Experience
1	How would you describe your organization's goals or needs in relation to the REI program? Do you think it was successful in meeting those goals?	x									
2	How did your organization determine success in meeting REI program goals? Were there defined program performance metrics? (How) was performance against these metrics monitored during and after the REI program?	x									
3	In your opinion, who were the REI program stakeholders? Were their needs effectively addressed by the REI program?	x									
4	How was your organization organized in terms of the managers and staff who worked on the REI program? How well do you think this structure worked towards meeting your goals? Are there any aspects that could be improved for future programs of a similar nature?	x									
5	What coordination was required between MHO and area service managers? How did this coordination work?	x									
6	Are there any issues that your organization experienced with respect to REI program implementation and administration? If so, what was done to address these issues?	x									

7	What does your organization believe were the most significant barriers to program participation? Related to above, what were the program guidelines that caused the most difficulty for program participants?	x			x
8	In general, what are your organization's thoughts on how the area service managers could have improved program marketing or delivery to increase housing providers interests in the program?	x			
9	Have there been changes in the operating environment that have impacted on the needs of yourselves and/or the stakeholders? What has changed since the REI program was implemented?	x	x		
10	In your opinion, has the program contributed to an increase in energy efficiency, and more specifically renewable energy generation and capacity, beyond the projects it directly supported? What has supported, or hindered, this growth?	x	x		
11	We compared the list of eligible social and affordable housing providers against those that actually received funding. It appears that the funding went disproportionately to (i) buildings with >50 units; (ii) buildings that were municipally owned (and/or (iii) buildings in urban areas). What do you think may have contributed to this?	x	x		
12	What changes would your organization recommend making to a future program with similar objectives to REI, to improve its overall effectiveness?	x			
13	Have area service managers or housing providers reported any positive or negative outcomes resulting from their participation in the program?	x			x
14	What problems did you experience as a service manager participating in the REI program in regards to application submittals and funding disbursement? Were there any other administrative issues encountered? What changes would you recommend for future programs of a similar nature?	x			
15	How did you determine which project(s) would receive funding in your service area? (Based on size of project and number of tenants, On a "first-come, first-served" basis, Based on likelihood of success, Other?)	x		x	

16	Did you encounter any issues with the flow of actual funding from the Province?	x			x	
17	If Yes, what was the nature of the challenges that you encountered with the funding? (Delays in the transfer of funding, Administrative errors, Other?)	x			x	
18	Did you encounter any issues with implementation of the technology? If yes, what was the nature of the issues associated with implementation? (Technical issues, Administrative issues, Financial issues, Operational issues, other?)					x
19	Were the approved projects installed and operating effectively? If not, what was the nature of the issues associated with installation and operation? (Inability to connect to the grid, Internal challenges , Maintenance issues, Other)					x
20	Was their clear guidance and communication from MHO to service managers and from service managers to REI funding recipients?	x		x		
21	Did the funding recipients express any dissatisfaction with the administration of the program? If so, please elaborate.	x				
22	Did you feel that the needs of the funding recipients were adequately addressed in MHO's administration of the REI funding?	x				
23	Could your administration of the REI been made more efficient through changes to the program design or administrative structure? What type of changes?	x				
24	Could you point us towards any particular projects that may have worked well (or not so well) for use within a case study that outlines lessons-learned?			x		
25	As a result of the REI, were there new hires in your company? If so, how many and what type of jobs (approximate wage level)? Were there new training opportunities for staff?		x			
26	How could future programs of a similar nature encourage recruiting and job training efforts for participating vendors?	x	x			

27	Could you list any barriers that were experienced when applying to be an approved vendor under the REI? How might changes to the program address those barriers?	x				
28	What financial impacts did you experience as a participant in the REI program? Did you offer volume discounts for REI-funded projects? What recommendations, if any, do you feel would have improved the overall effectiveness of REI in promoting positive financial impacts to vendors?	x	x			
29	Do you have any recommendations for how the Provincial government can better meet the needs of the social and affordable housing market while installing more renewable energy projects?	x	x			
30	From your organization's perspective, are low-income tenants benefitting (monetarily or non-monetarily) from REI projects? If so, how?		x			
31	Have you noticed any other benefits resulting from the REI program and the installation of renewable energy on social and affordable housing dwellings? What about negative impacts?	x	x	x		
32	What is your role/title within your organization?					
33	May we contact you for follow-up questions?					
34	Would you be interested in providing additional information to make one of your installations a case study?					
35	What services did you provide? (Design, installation, O &M)					
36	In your opinion, were the renewable energy projects installed and operated effectively? If not, could you elaborate?				x	
37	In your opinion, did the renewable energy installation help to reduce operating costs? If so, were the savings in-line with what was expected? How were the savings used?	x				x

38	Have you noticed any other positive impacts/benefits resulting from the installation of a renewable energy system on your property? If yes, please elaborate with specifics.			x	x			
39	Could you list any barriers that were experienced in relation to the administration of the REI program?		x	x	x			
40	In your opinion, how might the administration of the program been changed to make it more effective?							
41	Were tenants (or the community) engaged during the renewable energy retrofit? Did they benefit from the renewable energy installation? If so, how?	x		x	x			x
42	Were there any unintended / unplanned outcomes, either positive or negative, encountered as a result of the renewable energy installation?	x	x	x	x			
43	Would you have considered installing a renewable energy system if the REI was not available? Why or why not?							
44	Could you list any barriers or challenges associated with the implementation or operation your renewable energy installation?		x	x	x			
45	What general advice might you offer prospective system owners based on your experience with this renewable energy installation?							
46	In what capacity were you / your organization involved in a REI funded project between the years 2009-2012?			x				
47	Which renewable energy technology did you choose for your housing project?					x		
48	Would we be able to feature your project as a case study?	x					x	
49	Were you able to benefit from other programs (ex. microFIT, FIT) as well as the REI program?			x	x			

50	Finally, is there anything that you would like to add before we end our discussion today?	x

Table E- 3. Interview questions for MHO senior management and program staff

No.	Questions	Type of Information						MHO Information Type			
		Program	Technical	Environmental Impact	Financial	Socio-economic	Other	Introduction	Program Administration	Implementation	Provider Experience
1	How would you describe your organization's goals or needs in relation to the REI program? Do you think it was successful in meeting those goals?	x									
2	How did your organization determine success in meeting REI program goals? Were there defined program performance metrics? (How) was performance against these metrics monitored during and after the REI program?	x									
3	In your opinion, who were the REI program stakeholders? Were their needs effectively addressed by the REI program?	x									
4	How was your organization organized in terms of the managers and staff who worked on the REI program? How well do you think this structure worked towards meeting your goals? Are there any aspects that could be improved for future programs of a similar nature?	x									
5	What coordination was required between MHO and area service managers? How did this coordination work?	x									
6	Are there any issues that your organization experienced with respect to REI program implementation and administration? If so, what was done to address these issues?	x									

7	What does your organization believe were the most significant barriers to program participation? Related to above, what were the program guidelines that caused the most difficulty for program participants?	x		x
8	In general, what are your organization's thoughts on how the area service managers could have improved program marketing or delivery to increase housing provider interests in the program?	x		
9	Have there been changes in the operating environment that have impacted on the needs of yourselves and/or the stakeholders? What has changed since the REI program was implemented?	x	x	
10	In your opinion, has the program contributed to an increase in energy efficiency, and more specifically renewable energy generation and capacity, beyond the projects it directly supported? What has supported, or hindered, this growth?	x	x	
11	We compared the list of eligible social and affordable housing providers against those that actually received funding. It appears that the funding went disproportionately to (i) buildings with >50 units; (ii) buildings that were municipally owned (and/or (iii) buildings in urban areas). What do you think may have contributed to this?	x	x	
12	What changes would your organization recommend making to a future program with similar objectives to REI, to improve its overall effectiveness?	x		
13	Have area service managers or housing providers reported any positive or negative outcomes resulting from their participation in the program?	x		x
53	Finally, is there anything that you would like to add before we end our discussion today?	x		

Table E- 4. Interview questions for service managers

		Type of Information						MHO Information Type			
No.	**Questions**	Program	Technical	Environmental Impact	Financial	Socio-economic	Other	Introduction	Program Administration	Implementation	Provider Experience
14	What problems did you experience as a service manager participating in the REI program in regards to application submittals and funding disbursement? Were there any other administrative issues encountered? What changes would you recommend for future programs of a similar nature?	x									
15	How did you determine which project(s) would receive funding in your service area? (Based on size of project and number of tenants, On a "first-come, first-served" basis, Based on likelihood of success, Other?)	x							x		
16	Did you encounter any issues with the flow of actual funding from the Province?	x							x		
17	If Yes, what was the nature of the challenges that you encountered with the funding? (Delays in the transfer of funding, Administrative errors, Other?)	x							x		
18	Did you encounter any issues with implementation of the technology? If yes, what was the nature of the issues associated with implementation? (Technical issues, Administrative issues, Financial issues, Operational issues, other?)									x	
19	Were the approved projects installed and operating effectively? If not, what was the nature of the issues associated with installation and operation? (Inability to connect to the grid, Internal challenges , Maintenance issues, Other)									x	
20	Was their clear guidance and communication from MHO to service managers and	x					x				

	from service managers to REI funding recipients?			
21	Did the funding recipients express any dissatisfaction with the administration of the program? If so, please elaborate.			
22	Did you feel that the needs of the funding recipients were adequately addressed in MHO's administration of the REI funding?			
23	Could your administration of the REI been made more efficient through changes to the program design or administrative structure? What type of changes?			
24	Could you point us towards any particular projects that may have worked well (or not so well) for use within a case study that outlines lessons-learned?			
11	We compared the list of eligible social and affordable housing providers against those that actually received funding. It appears that the funding went disproportionately to (i) buildings with >50 units; (ii) buildings that were municipally owned (and/or (iii) buildings in urban areas). What do you think may have contributed to this?	x		x
30	What financial impacts did you experience as a participant in the REI program? Did you offer volume discounts for REI-funded projects? What recommendations, if any, do you feel would have improved the overall effectiveness of REI in promoting positive financial impacts to vendors?	x	x	

Table E- 5. Interview questions for program vendors

		Type of Information					MHO Information Type				
Categories	**Questions**	Program	Technical	Environmental Impact	Financial	Socio-economic	Other	Introduction	Program Administration	Implementation	Provider Experience
General	Could you please state your current name, title/role and company name?						x				
	What was your role during the implementation of the REI program (2009-2012)?						x				
	Could you please describe the size of your company, the range of services it provides and the primary customer base (residential, multi-residential, commercial, etc.)?					x					
	Could you please estimate the number of renewable energy installs your company has completed? How many would you estimate were funded through the REI, and also through other incentive programs?	x				x				x	
Economic Impact	How do system costs compare?					x					
	How much of the total project cost was spent on different steps i.e.: actual manufactured products (panels) installation, equipment etc.?					x				x	
	For larger vs. smaller systems, say 10KW vs. 100kW, is there much difference in the proportions/ratios of costs or is it generally consistent?					x					

Program Feedback	As a result of the REI, were there new hires in your company? If so, how many and what type of jobs (approximate wage level)? Were there new training opportunities for staff?	x		
	How could a program like this be modified to ensure that there was more opportunity for job recruitment or job training for participating vendors?	x	x	
	What financial impacts did you experience as a participant in the REI program?	x	x	
	What recommendations, if any, do you feel would have improved the overall effectiveness of REI in promoting positive financial impacts to vendors?	x	x	
	Are operation and maintenance costs included in the installation?	x	x	
	Do you have any recommendations for how the Provincial government can better meet the needs of the social and affordable housing market while installing more renewable energy projects?	x		x
	In your opinion, has the program contributed to an increase in energy efficiency beyond the projects it directly supported? What has supported, or hindered, this growth?	x		
	Have you noticed any other benefits resulting from the REI program and the installation of renewable energy on social and affordable housing dwellings? What about negative impacts?	x		x
	Do have any general feedback regarding energy efficiency or renewable energy incentive programs? It could be regarding challenges for vendors or providers, needs for improvement, successes stories or similar.			x
	Could you speak to any challenges facing your industry that might affect the performance of systems that get installed? For example, is there a lack of training opportunities, guidelines or standards, is the	x		x

	behaviour/attitude of housing providers a barrier or challenge, etc.?	
	Do you have any recommendations for how the Provincial Government can better meet the needs of the social and affordable housing market while installing more renewable energy projects?	x
O&M / M&V	For the MHO who is investing money into renewable energy incentive program on social and affordable housing, what is the best way to ensure these installations continue to work once they are installed?	
	Did you enter into any ongoing or long term O&M contracts as a result of the program? How can the structure of an incentive program encourage effective operation and maintenance?	
Wrap up	May we contact you for further questions or clarifications?	

F. SITE VISIT SUMMARY

Table F-1. Site visit summary

Site Visit No.	Provider Type	System Type	System Operation? (Yes/No/Yes but not fully)	Supports to Monitor System Operations ? (Yes/No)	Support Type	Comments
1	Private Non-profit	PV/Solar Air/SDHW	PV - Yes SDHW - Yes but not fully Solar Air - Unconfirmed	Yes	PV: SOLRENVIEW direct inverter communications Solar Air: Solarwall Monitoring System SDHW: BTU Meter	PV: Observed inverter generating a reasonable amount of power given low lighting conditions. Solar Air: SolarWall damper was closed and outside air damper was open. An air temperature rise was observed from the SolarWall, compared against ambient temperature. System appeared to be operation but not verified during the visit. SDHW: 1 of 2 loops potentially not operating properly due to air in system, suggested to owner to flush system.
2	Co-op	PV/SDHW	PV - Yes SDHW - No	Yes	Utility bill monitoring (hydro)	SDHW: Solar hot water tank had sprung a leak a few years ago and had flooded the room. Insurance company replaced water tank and rewired system. At visit, sensor wires were noted to be plugged properly and valves were set at correct level. SDHW panel was not functioning during visit, did not appear to be any water flowing through system. PV: PV system is functioning - monthly credits are received from Hydro company.
3	Private Non-profit	PV	Yes	Yes	Tigo monitoring system w/ online gateway.	PV: Property manager examines monthly energy generation reports. Performance verified with energy production data. Provider is very happy

						for having participated in the program.
4	Municipal Non-profit	Geothermal	Yes but not fully	Yes	Manual temperature recordings by site custodian	Geothermal: System provides heating and cooling to common areas. Units are heated with electric radiant heaters. System was sized for a second phase of project where all radiant heating units would be replaced with make-up heating and cooling from the geothermal system. During the visit, an unresolved operational issue prevented the system from functioning. System could not be confirmed to produce heat during winter on site visit as technician hadn't be able to check the system this year and adjust to winter settings. Custodian and Property Manager are tentatively pessimistic about system. System has resulted in added costs (technician, recording of temperatures). Not confident system is working as intended - system feels needlessly complex, and they feel unnecessarily burdened with maintaining a legacy stranded asset. Did not receive any training on system.
5	Municipal Non-profit	PV/SDHW	PV - No SDHW - Yes	Yes	SDHW - "DeltaSol BS Solex US" re-branded controller (re-sol), Badger BTU Meter, with temperature sensors, however, not hooked up. (see pics) PV - none	SDHW: 12 SDHW collectors, system seems to be running with little maintenance needed. All of the necessary parts of the system were present, this helped to ensure that the system would run trouble free. There was a BTU meter present however, it was not connected to anything and was not on. PV: 10 kW system, not connected to grid. Seems like system was never working due to grid connection issues.
6	Municipal Non-profit	PV/SDHW	PV - Yes SDHW - Unconfirmed	Yes	PV had a monitoring system that was once installed. May be possible to get it back online.	SDHW: Was unable to confirm operation due to low light levels during visit. Vendor has been doing maintenance every 3 months, but not clear what they are doing as system should not need maintenance that often. Building super

						had not received any training on system, if given some guidance he said he would be able to incorporate into his normal inspections. PV appears to be fine.
7	Municipal Non-profit	PV/SDHW	PV - Yes but not fully SDHW – Yes but not fully	Yes	Remote monitoring system, BTU meter, pressure transducer, and other temperature sensors.	SDHW: Monitoring instrumentation was installed but there was nothing to record the data. Would be easy to get it back online. Superintendent did not receive training on system. No level of O&M. It was turned off seasonally (during the winter) but this was not actually necessary. PV: Some issues with install of system, one string dead. Some sensors, but were not connected to a logger. Other sensors not installed properly.
8	Municipal Non-profit	Geothermal	Yes but not fully	Yes	BAS (offsite)	Geothermal: There was not access to the BAS on-site. The heat pumps did not have an LCD display (just an indicator light to say if it was on or off). The ground loop had a pressure gauge but no flow or temperature gauge. In general, it would be hard for someone to look at this system on-site and try to figure out if everything was OK. Residents excited about system as it provides in suite cooling, which they did not have previously. There is a PowerPoint to train incoming building personal, however turnover is high. System is primarily monitored offsite so onsite training is less important. System seems to only provide cooling to the building and only operates in shoulder seasons (above 0 degrees). Seem to be sized for cooling load and only operates in heating in shoulder seasons to balance the system.
9	Municipal Non-profit	PV/SDHW	PV - Yes SDHW - Unconfirmed	Yes	Resol Controller, remotely monitored by BAS	SDHW: There was not much seen at the site that could confirm proper operation of system. There was a lack of gauges to identify system operation and BAS system was not available

						onsite. Performance could not be verified. PV: Individual strings on the PV array were measured and observed to be performing as expected.
10	Municipal Non-profit	SDHW	Yes	Yes	BAS, Johnson Controls	SDHW: 24 flat plate collectors, 2 loops, 2 packaged pump stations, with separate expansion tanks, both with pressure and flow. System seemed to be working fine (even under very low irradiance), without any operation or maintenance.
11	Municipal Non-profit	Solar Air	Yes	Yes	BAS, Johnson Controls	Solar Air: The summer bypass damper (that should be fully closed in winter operation) was slightly ajar; this may be due to mechanical failure of the device. This may affect performance of the system. Appeared to be in good state of repair and likely to be working but operation could not be verified due to the make-up air unit not operating at the time of visit.
12	Municipal Non-profit	Solar Air	Yes	Yes	BAS, but does not record data, only live display	Solar Air: At roughly 200-400 w/m^2, we observed an 8.4°C temperature rise over ambient. The system seemed to be installed and operating effectively. A single temperature measurement was taken from inside the filter cabinet of the make-up air unit (4.3°C, Solar Air tempered air) and a single measurement was taken in ambient air (-4.1°C).
13	Municipal Non-profit	Solar Air	Yes	Yes	BAS, but does not record data, only live display	Solar Air: $89m^2$ transpired solar air collector. We observed a 7.6°C temp rise over ambient temperatures. The system seemed to be installed and operating effectively. A single temperature measurement was taken from inside the filter cabinet of the make-up air unit (4.1°C, Solar Air tempered air) and a single measurement was taken in ambient air (-3.5°C). There was a small amount of missing insulation along the ducting; this will have a minor affect the performance of the system.

14	Municipal Non-profit	Solar Air	Unconfirmed	Yes	BAS, Johnson Controls	Solar Air: Could not identify the exact operation of the system, building super had no knowledge and no access to BAS. Provider did have building operator(s) dedicated to the system's operation, however these operators are not on site and it is not clear how often they appear on site.
15	Municipal Non-profit	Solar Air	Yes but not fully	Yes	BAS, Johnson Controls	Solar Air: Ducted transpired solar air collector, 2 separate systems both providing preheat, then mixed into HRV. One system had damper in off position (not working).
16	Municipal Non-profit	Solar Air	Unconfirmed	Yes	BAS, Johnson Controls	Solar Air: Could not identify the exact operation of the system, building super had no knowledge and no access to BAS. Provider did have building operator(s) dedicated to the system's operation, however these operators are not on site and it is not clear how often they appear on site.
17	Non-Profit	PV	Yes	Yes	Inverter and microFIT payments	Solar Air: System fully working and operational, no problems reported or observed.

G. SOCIO-ECONOMIC IMPACT ANALYSIS – COST BREAKDOWNS

Table G- 1. Renewable energy initiative breakdown of project costs (PV)

	Project							
Project Costs	**PV System 1**	**PV System 2**	**PV System 3**	**PV System 4**	**PV System 5**	**PV System 6**	**PV System 7**	**% Average**
Total project cost	$98,074	$151,351	$170,720	$415,005	$1,013,498	$707,681	$80,352	
- contingencies + insurance	$3,929	$6,064	$4,441	$69,167	-	$0	$2,162	
Total Adjusted Project Cost	$94,145	$145,287	$166,279	$345,838	$1,013,498	$707,681	$78,190	
Feasibility								1.1
Analysis	$1,150	$1,150	$1,150		$3,000	$3,000	$1,150	
Total Cost	$1,150	$1,150	$1,150	$3,000	$3,000	$3,000	$1,150	
Percent of total project cost	1.2%	<1%	<1%	<1%	<1%	<1%	1.50%	
Development								2.1
permits & approvals	$800	$800	$800	$330			$800	
legal & accounting	$600	$600	$600				$800	
Total Cost	$1,400	$1,400	$1,400	$330	$39,000	$31,000	$1,600	
Percent of total project cost	1.4%	<1%	<1%	<1%	3.80%	4.30%	2%	
Engineering								4.9
electrical design	$700	$700	$700				$700	
civil design	$1,800	$1,800	$1,800				$1,800	
tenders & contracting	$250	$250	$250	$5,000*				
construction supervision	$1,125	$1,350	$1,350				$675	
architectural design				$2,100				
electrical BOS							$9,933	
Total Cost	$3,875	$4,100	$4,100	$7,100	$29,000	$22,000	$13,108	
Percent of total project cost	4.1%	2.8%	2.5%	2.1%	2.9%	3.1%	16.8%	

Equipment/materials								82
Inverter	$9,288	$14,792	$18,060				$7,224	
collector support structure	$9,505	$15,138	$18,482				$1,680	
spare parts	$232	$370	$452					
power system	$53,854	$85,768	$99,750		$92,2625***	$62,7750***	$38,648	
Transportation	$1,500	$1,500	$1,500					
Total Cost	$74,379	$117,568	$138,244	$295,260**	$942,498	$651,681	$47,552	
Percent of total project cost	79%	80.9%	83.1%	85.40%	92.90%	92.10%	60.80%	
Installation fees								10.6******
Installation Labour	$11,340	$18,060	$18,375				$880	
Building & Yard Construction		$2,160	$2,160					
Crane & Boom Lift Fees	$2,000	$850	$850					
Roof Renovation				$35,148				
Total Cost	$13,340	$21,070	$21,385				$880	
Percent of total project cost	14.20%	14.50%	12.90%	10.10%	unknown	unknown	1.10%	
MAINTENANCE & OPERATIONS								
Insurance Premium	$464	$740	$903		$9,200	$6,300	$361	
Parts & labour							$700	
GHG monitoring & verification	$164	$162	$162				$168	
bi-annual inspection & cleaning	$800	$800	$800				$800	
periodic costs (inverter)	$5,000	$5,000	$10,000		$3,000	$2,000		
Contingencies							$1,015	
Total Cost	$6,428	$6,702	$11,865		$12,200	$8,300		
Percent of total project cost	6.80%	4.60%	7.10%	****	1.20%	1.20%		
* feasibility study states "Tenders, Review etc."								
** feasibility study allocates entire system cost as one complete number. We assume, but cannot be sure, that installation labour is included.								

*** Base of System (BOS) costs were added to this section as the detailed breakdown was not specified. Five of our other convenience samples consistently showed "materials and equipment" to be the largest component of BOS costs and that is why it has been allocated there
**** undisclosed in feasibility study
***** vendor stated "electrical costs"
****** Because PV Systems 5 and 6 have unknown installation labour fees, the average of the other 5 projects in the convenience sample were used.

Table G- 2. Renewable energy initiative breakdown of project costs (Solar Air)

Project	
Project Costs	**Solar Air System 1**
Total project cost	$211,500
- contingencies + insurance	
Total Adjusted Project Cost	$211,500
Feasibility	
Total Cost	
Percent of total project cost	UNKNOWN
Development	
Total Cost	
Percent of total project cost	UNKNOWN
Engineering	
Engineering	$3,500
Electrical contractor	$3,000
Mechanical Sheet Metal Contractor	$65,000
Total Cost	$71,500
Percent of total project cost	34%
Equipment/materials	
Solar Wall Materials	$65,000
Total Cost	$65,000
Percent of total project cost	31%
Installation fees	
Metal Wall Siding Installer	$75,000
Total Cost	$75,000
Percent of total project cost	35%

Table G- 3. Renewable energy initiative breakdown of project costs (Geothermal)

Project	
Project Costs	**Geothermal System 1**
Total project cost	$198,440

- contingencies + insurance	$0
Total Adjusted Project Cost	$198,440*
Feasibility	
Total Cost	
Percent of total project cost	UNKNOWN
Development	
Total Cost	
Percent of total project cost	UNKNOWN
Engineering	
Required Electrical	$10,000
Total Cost	$10,000
Percent of total project cost	5%
Equipment/materials	
Geo Heat Pump	$26,258
Geo Storage Tank	$5,643
Pump Package	$20,000
Heat Transfer Fluid	$4,010
Hydronic Hot Water Coil	$2,565
Associated Geo Hardware	$16,644
Associated Hardware	$6,020
Total Cost	$81,140
Percent of total project cost	41%
Installation fees	
Installation of Ground Loop	$75,000
Installation of Geo Equipment	$14,000
Retrofit Existing Duct Work	$8,500
Commission Geo Equipment	$3,800
Interface Geo Unit to Duct Work	$6,000
Total Cost	$107,300
Percent of total project cost	54%

Table G- 4. Average percentage of total project costs of convenience sample.

Title	Associated Project Categories	Average Percentage of Total Project Costs of Convenience Sample			
		Solar Photovoltaic	Solar Air	SDHW	Geothermal
Residential Building Construction	installation	10.60%	35%	10.60%	54%
Building Material & Supplies Wholesaler/Distributor	equipment, materials	82.00%	31%	82.00%	41%
Architectural, Engineering & Related Services	engineering, feasibility studies, development	8%	34%	8%	5%