The Business Case for Alternative Energy Technologies in Ontario

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This report is comprised of work and excerpts from
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Executive Summary

Currently alternative energy is receiving much attention in Canada because of its potential to replace polluting forms of energy. This attention thus far has mostly driven installations of utility scale renewable energy plants, such as large wind farms. There is, however, a large benefit to be realized in using alternative energy in a distributed fashion, such as incorporated into buildings, and indeed some systems are specifically meant for this purpose. There are many resources available from governments, industry groups, not for profits and companies describing these various distributable alternative energy options, their benefits, and their designs. This work reports on a key piece missing from this collection of resources – the economics. This report provides a comprehensive and up-to-date explanation of the business case for these energy systems.

As the policies and market conditions for distributable alternative energy vary across Canada this report focuses on the Ontario case. Five technologies are considered: photovoltaic (PV) and wind electricity generation, solar air (SAH) and water (SWH) heating, and ground source heat pumps (GSHP) for space conditioning. The business case is applied to five audience types: homeowners, large corporations and institutions (treated as one throughout the study), small to medium businesses and investors. The report determines the internal rates of returns and payback periods for the audience technology pairs, tests sensitivity to key variables and quantifies the risk associated with the investment opportunities in order to draw comparisons to more conventional investment opportunities.

The internal rates of return (IRR) and payback periods (PBP) for all but the investor case are shown in the Figures I and II below. The only audience type with positive returns for all technologies is the commercial / institutional. This result is consistent with positive returns to scale, as the system sizes are biggest for the commercial / institutional audiences. The only exception is for ground source heat pumps, where the best returns are for small to medium businesses. This anomaly is explained by the intricacies of the Ontario natural gas billing system, which currently charges less per metre cubed of monthly usage the more that is used. As GSHP systems reduce the use of natural gas, the billing intricacies result in smaller economic

benefit for the larger commercial and institution system since these audience types use much more natural gas than the small to medium businesses in general.

The economies of scale for PV and wind are a result of the available cost reductions per unit of capacity for larger systems. The economies of scale for SAH and SWH are a result of capital grants available from the government to the commercial, institution and small business audience types.

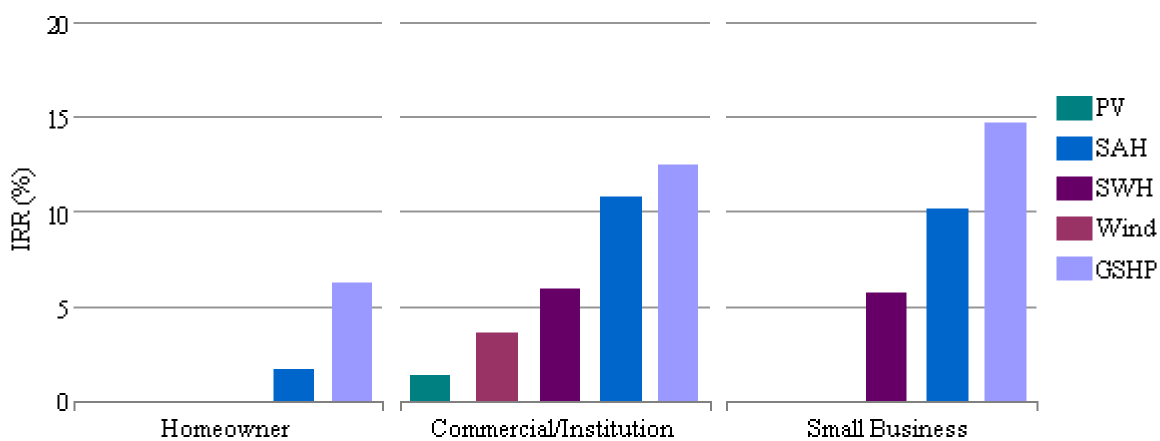

Figure I Internal Rates of Return for Non-Investor Audience Technology Pairs (Reference Case)

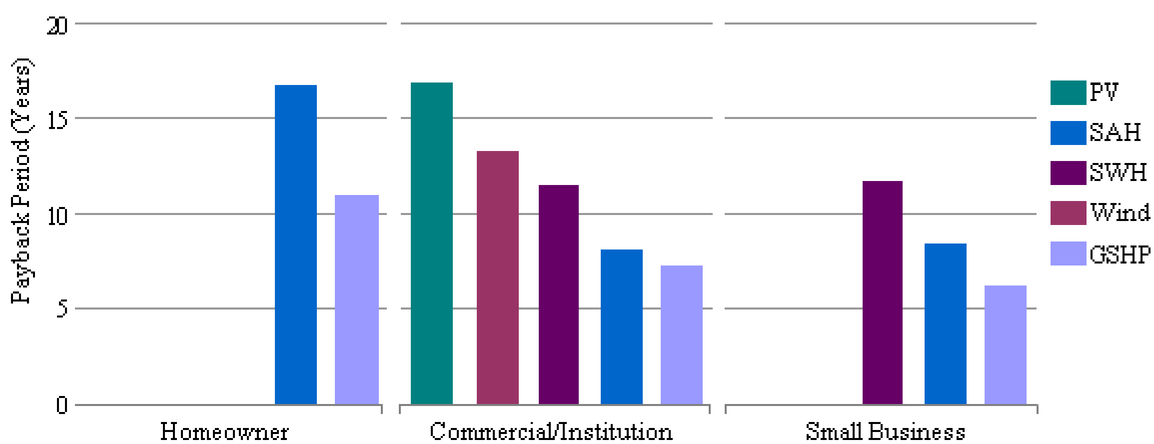

Figure II Payback Periods for Non-Investor Audience Technology Pairs (Reference Case)

For the investor case the risk is quantified for the investments with positive returns in order to determine the best audience technology pairs around which to invest or construct a business. Figure III illustrates the outcomes of this analysis and compares the alternative energy cases to other common investments. All of the alternative energy investments included in the figure have less risk than the common investments. The alternative energy investments that did not, were excluded from the graph since their risk was much higher and could not accurately be calculated.

This work shows the array of opportunities available for investors and the various other audience types that they could work with.

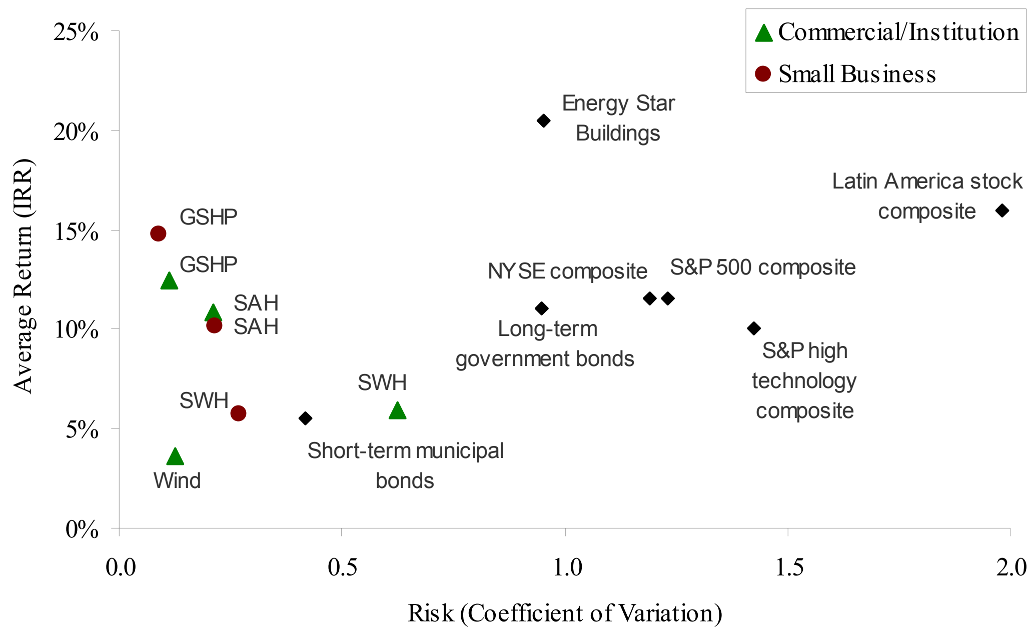

Figure III Risk based analysis of alternative energy investments in comparison to other opportunities

The results presented in this report provide a base case for further analysis. The focus of the study was to provide a broad sweeping pre-feasibility level of analysis and does not include rigorous designs of specific projects. For this reason this work can be used to encourage others to perform economic studies for their own possible alternative energy projects. It is recommended that this report be used to guide such efforts and that those considering their own projects consider details specific to their projects that are not included in this base case. Such items could include a rigorous energy system definition including specific attention to project lifetime and or salvage value, and details relating to the marketing or real estate value of their alternative energy installation.

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Terms & Notation

BOS	Balance of System
CCA	Capital Cost Allowance
CCTF	Capital Cost Tax Factor
CO_2-eq	GHG emissions, measured in terms of carbon dioxide
COP	Coefficient of Performance
GHG	Green House Gas, generally measured in CO_2 equivalent tonnes [CO_2-eq t]
GTA	Greater Toronto Area
GSHP	Ground Source Heat Pump
IRR	Internal Rate of Return
O&M	Operation and Maintenance
OEB	Ontario Energy Board
OPA	Ontario Power Authority
PBP	Payback Period
PV	Photovoltaic
REDI	Renewable Energy Deployment Initiative
SAH	Solar Air Heating
SWH	Solar Water Heating
ŋ	Efficiency (in %)

SI Prefixes

P	Peta (10^{15})
T	Tera (10^{12})
G	Giga (10^{9})
M	Mega (10^{6})
k	Kilo (10^{3})

Units

ºC	Degrees Celsius	Temperature
g	Gram	Mass
K	Kelvin	Temperature
L	Litre	Volume
J	Joule	Energy
M	Metre	Length
t	Tonne (= 1000kg)	Mass
W	Watt	Power
Wh	Watt-Hour	Energy

Chapter 1
Introduction

1.1 Overview

Historically one of the most significant barriers to market adoption of renewable or alternative energy is the lack of a good business case for its implementation. As a result the case for renewable energy has generally been dominated by the moral argument that "it's the right thing to do" as one of the ways to reduce green house gas emissions and combat climate change. Although the moral argument is compelling for many people, it does not have broad market appeal and as a result is not likely to have a significant impact on the market for renewable energy. In recent years the situation has changed, advancements in renewable technology, the rising costs of oil and gas, electricity, incentives, standard offer contracts for renewable electricity, emissions trading markets and the desire of corporations to attract consumers by associating with "green" is changing the business case for renewable energy.

Discussions with experts in the renewable energy sector have indicated that there is a significant amount of misinformation or misunderstanding of the business case for renewable energy. Often generalizations on the simple "pay-back-period" for renewable energy installations are passed around by word-of-mouth and are taken as fact. In many cases these generalizations are based on actual case studies, but the information has been used more broadly as a general rule-of-thumb.

These general rules are important tools, to generate interest and help us understand how and where best to apply our resources on more detailed feasibility studies or implementation. However, the context for these general rules is often lost and thus just how applicable the rule is to a specific audience or set of circumstances cannot be determined without undertaking a feasibility study. This lack of good general rules for a defined set of contexts is considered a significant barrier to the uptake of renewable energy technologies.

Described herein is the business case in Ontario for five building-scale renewable and alternative energy sources for a variety of audiences. This report explores the business case for building scale photovoltaic (PV), solar air heating (SAH), solar water heating (SWH), ground source heat pumps (GSHP) and wind power. The audience types considered are homeowner, commercial, small to medium business (small business from here on), institutional, and investor. The goal of the investigation is to define the context for investment in alternative energy projects in Ontario in order to encourage interested parties to start their own projects or at least undertake their own feasibility studies.

Table 1.1 summarizes the high level assumptions made about the audience types. For the bulk of the study the commercial and institution audiences are examined together as their characteristics do not differ greatly with respect to the details examined. Figure 1.1 shows the twenty-five audience and technology pairs that are examined.

Table 1.1 Audience Assumptions

Audience Type	Notes
Homeowner	• Ownership of domicile / Right to perform interior & exterior modifications • Building type: Detached & Semi-detached houses.
(Large) Commercial and Institutional	• Ownership of building(s) / Right to perform major interior & exterior modifications • Large Building
Small Business	• Ownership of building / Right to perform major interior & exterior modifications • Medium Size Building
Investor	• The investor is an individual or body (such as municipalities, governments, or investment firms). • Investing in renewable energy installations (rather than the manufacture of renewable energy technologies themselves)

	Photovoltaic (PV)	Solar Air Heating (SAH)	Solar Water Heating (SWH)	Ground Source Heat Pump (GSHP)	Wind
Homeowner					
Large Business (Commercial)					
Institution					
Small to Medium Business (Small Business)					
Investor					

Figure 1.1 Audience and Technology Matrix

The report progresses through the steps required to assess the business case for a given installation, or audience technology pair. This process is presented graphically in Figure 1.2. This process and hence this report begins by defining feasible ranges of energy production and savings for each audience technology pair. As the bulk of the energy and GHG analysis of each of the scenarios are completed with the help of RETScreen (NRCan, 2006a), several values provided by RETScreen are used in the analysis. The weather and environmental parameters used for each scenario (as shown in Appendix A) are from RETScreen Toronto data, except for the wind scenarios where more suitable locations are used (as described in the energy scenarios chapter). In this definition a summary of greenhouse gas (GHG) emission reductions is also included. The GHG values are not included in the reference case calculation but later in the extended analysis.

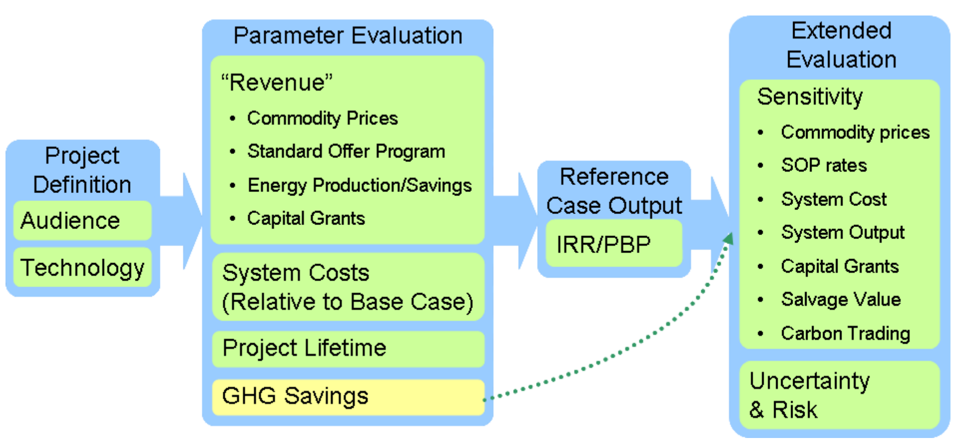


Figure 1.2 Overview of Business Case Definition Process

Following the energy and GHG analysis is a description of the cost data available for the energy sources considered. Next (Chapter 4) is a description of the future price scenarios for electricity and natural gas in the context of Ontario and the audience types considered. Following this is the reference case economic analysis which investigates payback periods (PBP) and internal rates of return (IRR). This analysis is extended to a discussion of risk and return for renewable and alternative energy in Ontario is provided in order to draw comparisons to other investment opportunities such as is shown in Figure 1.3, and an assessment of sensitive and uncertain variables. Finally the report ends with conclusions and recommendations. The primary conclusions being that the bulk of the audience technology pairs result in positive returns and low risk relative to other investments

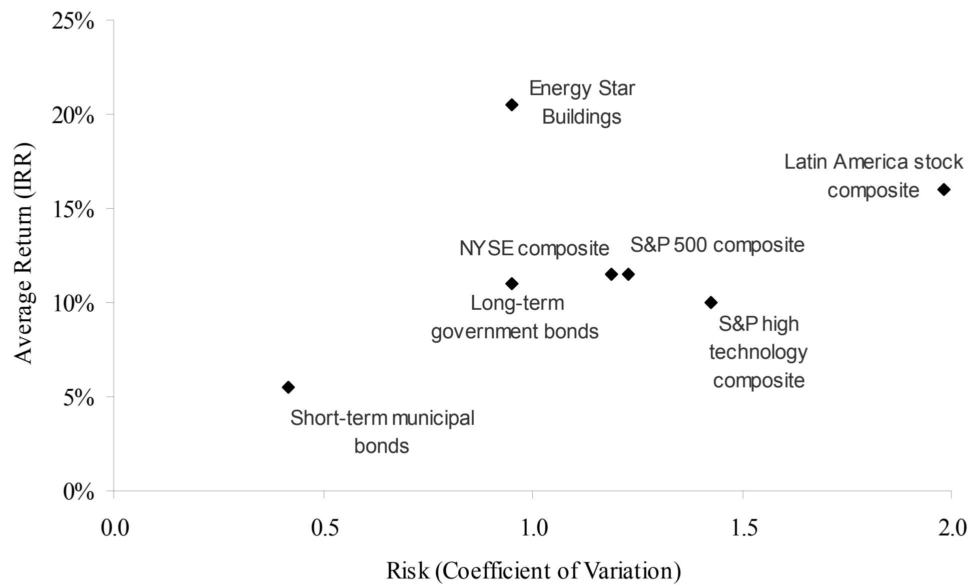


Figure 1.3: Risk versus Return of Various Investments
Adapted from Romm (1999)

Chapter 2
Energy Scenarios: Defining Typical Technology Installations

2.1 Introduction

This chapter provides the assumptions and parameters that specify typical building characteristics for each audience type, and the energy systems, the parameters used are in large part values that represent the best case scenario, e.g., buildings are oriented to maximize solar radiation. In other instances, typical average parameters are used, e.g., the reference residential building size is based on a national average. The chapter concludes with a summary of the energy systems for each audience type.

2.2 Building Definitions

The five audience types and their associated buildings are described here. These descriptions determine the required or possible sizing of the alternative energy systems. Where possible, building characteristics from Etcheverry (2004) are used in this study as they are generally based on national or provincial averages. For the purposes of analysis the buildings are located in the Greater Toronto Area (GTA), at latitude 43.7º and longitude -79.4º. The exception to this is the analysis of the wind energy scenarios as a more suitable location is required. This detail is discussed further in the Wind section of this chapter.

2.2.1 Homeowner

For the homeowner a single family home is used with floor space of 185m² over two full stories and a basement. The heat load of the building is 8.8kW and the cooling load is 9.9kW. The size and orientation of the roof allows for a 20m^2 photovoltaic array and a 6m^2 solar water collector – both south facing. Finally, the ventilation demand of the residence is 144m^3/h and the hot water demand is 240L/day, based on four individuals. All sizing values listed here are from Etcheverry (2004), except for the water and air demand which come from RETScreen.

2.2.2 Commercial and Institutional

The commercial and institution building has 9290m² of floor space over five full stories. The heat load of the building is 212.5kW and the cooling load is 599.5kW. The size and orientation of the roof allows for a 728m^2 photovoltaic array and a 45m^2 solar water collector – both south facing. Finally, the hot water demand of the building is 2685L/day and has a ventilation demand of 9222m^3/h. All sizing values listed here are again from Etcheverry (2004), except for the water and air demand which are from RETScreen.

2.2.3 Small Business

The commercial and institution building has 1460m^2 of floor space over three full stories. This size is based on an average size for Ontario from NRCan (2004). The heat load of the building is 39.3kW and the cooling load is 95.2kW. The size and orientation of the roof allows for a 144m^2 photovoltaic array and a 7m^2 solar water collector – both south facing. Finally, the hot water demand of the buildings are 422L/day and a ventilation demand of 1449m^3/h. The building parameters are a result of scaling down the commercial/institutional building parameters.

2.2.4 Investor

The investor model does not include a specific building type. This audience type is structured to look at the investment opportunities in using space on buildings from the other audience types.

2.3 Energy Systems

The five types of energy system are described below. The key design variables are specified and the expected annual energy output and greenhouse gas (GHG) emission savings are determined. Each system includes a specific energy value which describes how much energy it delivers and saves per unit, where the unit is a characteristic variable for the given type of system (e.g., per square metre of panel). This specific energy value is used in the business case analysis to scale the price and size of the unit for each of the audience types.

2.3.1 Photovoltaics

The photovoltaic system considered is grid connected with fixed array, south facing orientation and panel slope of 32.7º. This orientation and slope maximizes annual energy output of the system based on the latitude and longitude of the project. The cells considered are Mono-Si with efficiencies of η=16.1%. These parameters are the same as those used in the Toronto photovoltaic cooperative feasibility study performed by TREC (2007).

The remaining parameter values are inverter efficiency and miscellaneous losses. Inverter efficiency is assumed to be 94% and miscellaneous losses 11%. PV degradation is not explicitly included in the model as RETScreen does not provide this functionality. However this limitation is partly mitigated by using a slightly higher value for miscellaneous losses. A more explicit degradation model would include more degradation at the beginning of the project life and less at the end.

Based on the above parameters, as the system scales in size its electricity and power capacity scale linearly by a factor of 0.192 and 0.161 respectively as shown in Figure 2.1.

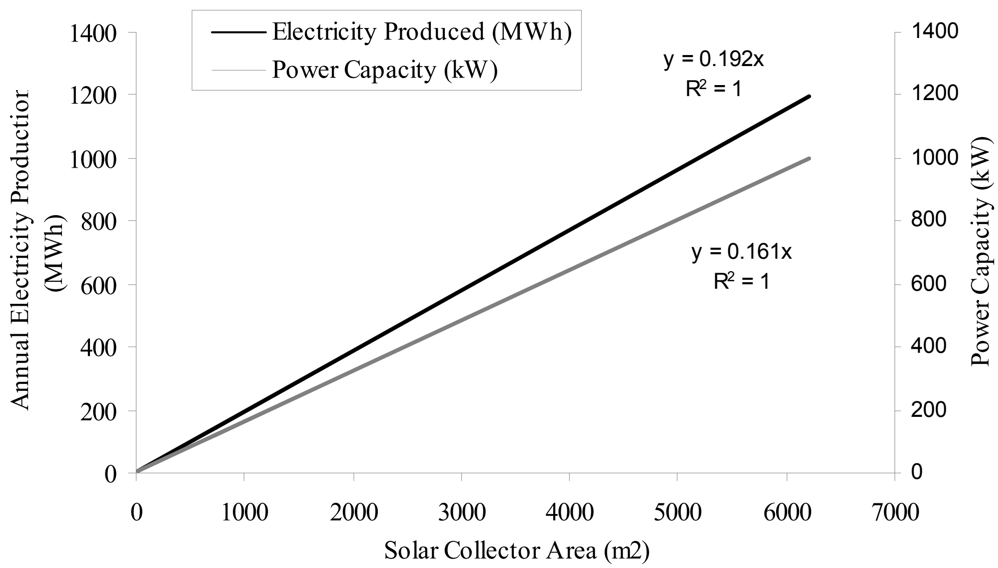


Figure 2.1 PV System Scaling With Respect to Collector Area
The annual output (MWh) and capacity (kW) of the PV systems can be calculated from the collector area using the values found in this regression.

Calculating the GHG emissions reductions associated with using a PV system in Ontario can be accomplished using several methods. For the purposes of this study, proposed guidelines form Alberta Government (2008), UNFCC (2006) and UNFCC (2008) are used. The use of these sources is relevant as the policies developed under the proposed Canadian GHG offset trading system are likely to incorporate them (Environment Canada, 2008a).

The guidelines suggest various methods for calculating GHG reductions from the use of renewable energy. For this study the average GHG emission rate from the Ontario electricity grid is used, this value being 0.23kgCO_2-eq/kWh based on data from OPA (2007) and including 9% losses from transmission and distribution. Although other methods suggested by the guidelines are more desirable this method is the simplest and provides a fair approximation. Ideally a marginal value would be used based on historical data from the electricity grid. In this context marginal refers to peak energy production, since it is the generally higher emitting and more expensive sources that are likely supplanted by the alternative energy source. Thus, the average value used here is likely a lower estimate of the GHGs offset or eligible for offset accounting.

2.3.2 Solar Air Heating

As the RETScreen solar air heating energy model is designed for a specific unglazed transpired plate solar wall collector (NRCan, 2004a) the SAH scenarios for this project are restricted to use of this technology only. To determine the size of the SAH systems for the audience types the suggested size generated by RETScreen from the building characteristics are used. Figure 2.2 shows how this value scales with the air flow rate of the building along with how the energy savings and production scale. The GHG emissions savings can be calculated from the energy delivery and savings using appropriate emissions factor and furnace efficiency. The emissions factor used in this study is 0.06 tCO_2-eq/GJ and the efficiency of the heating system being offset by SAH is 80%.

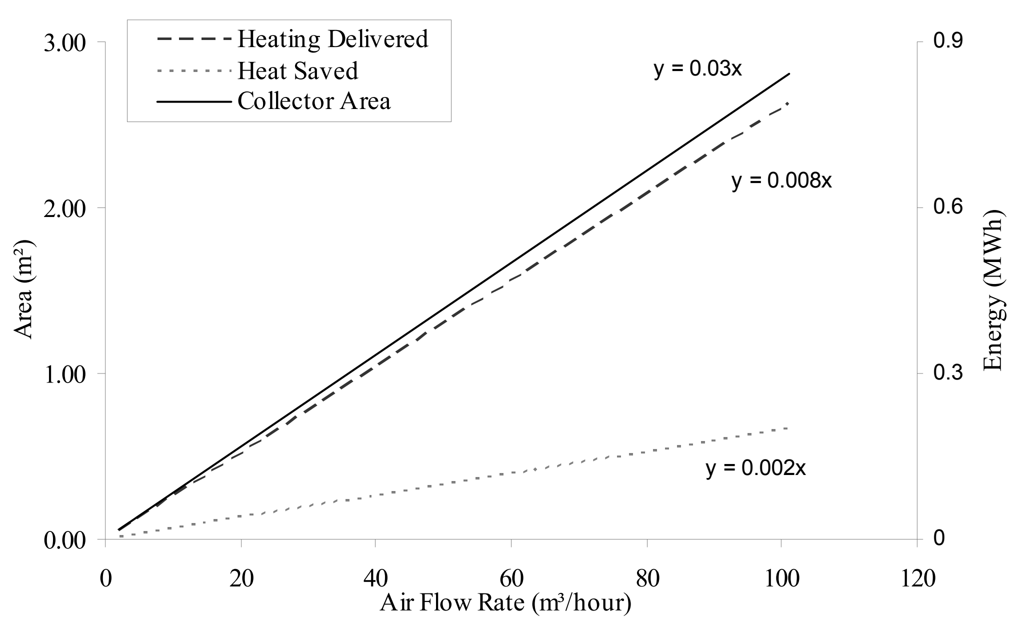


Figure 2.2: Scaling of SAH Systems

2.3.3 Solar Water Heating

The three system sizes of interest are shown in Table 2.1. The SWH scenario uses a pump power rating of 50W per metre squared of solar collector area and assumes an efficiency of 75% from a natural gas conventional system. The energy savings in Table 2.1 are from Hargreaves (2008) and are similar to values from Kapoor (2008).

Table 2.1: SWH System Characteristics

	Homeowner	Commercial/Institution	Small Business
Demand (L/day)	240	2685	422
Collector Area (m^2)	6	46	8
Energy Savings (MWh/a)	2.9	32.6	5.7

2.3.4 Wind

The wind scenarios consist of a single turbine for each audience type. The details of each system appear below in Table 2.2. The turbine sizes selected are roughly representative of the sizes that each audience type could be expected to afford.

Table 2.2 Summary of Energy Scenarios for Wind

	Power (kW)	Hub Height (m)
Homeowner	2.6	20
Commercial/Institution	50	25
Small Business	10	24

As mentioned previously, the location of the wind turbines scenarios differ from the other technology scenarios. A more rural area with a high wind speed is more suitable for the installation of a wind turbine. Thus, this study does not use the GTA to locate the wind scenario. Instead a best case location is chosen based on the average wind speeds in Ontario. Using data from the Canadian Wind Energy Atlas a distribution of wind speeds in Ontario was constructed (Figure 2.3). This study uses a wind speed of 5.9m/s which corresponds roughly to the highest peak in this distribution.

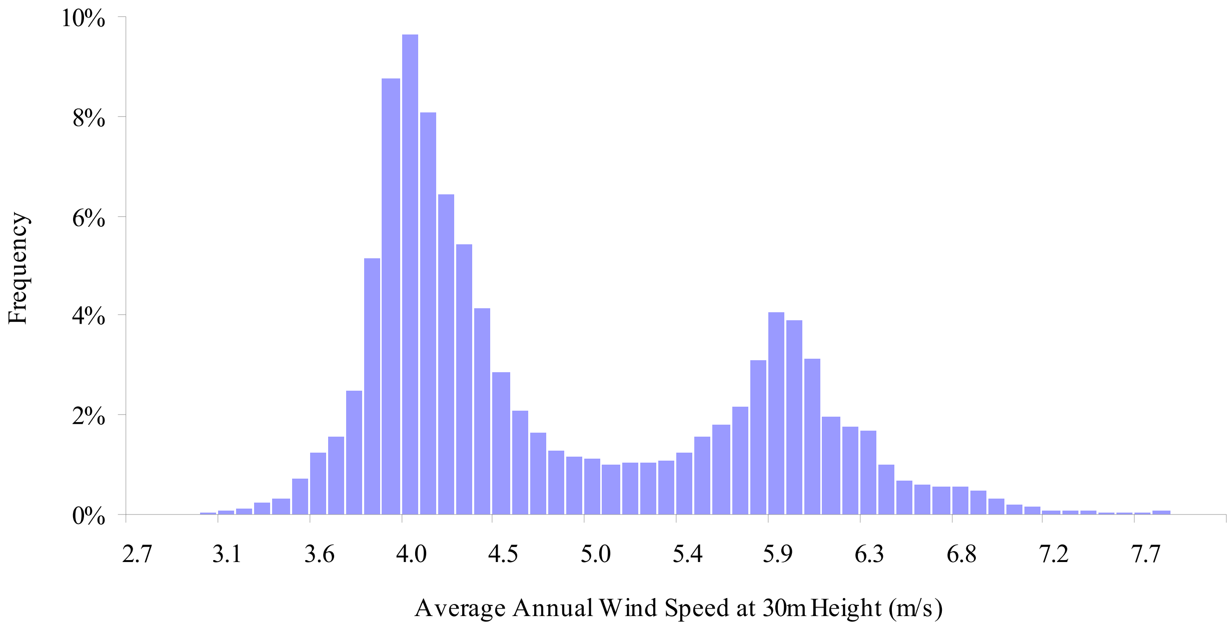


Figure 2.3: Ontario Wind Speed Distribution
The distribution is calculated from a set of over 45,000 data points provided by the Canadian Wind Energy Atlas Model (Environment Canada, 2003). The data set was filtered using GIS software to extract only those points of data over land as offshore wind turbines are not considered in this study.

Using the above data the annual energy output and GHG emission reductions are calculated and tabulated in Table 2.3. The emission factor of 0.23kgCO_2-eq/kWh from the PV case also applies to this case. Wind is also assumed to offset centralized grid electricity production.

Table 2.3 Wind Energy Output and GHG Emission Savings

	Annual Output (MWh)	Annual GHG Reductions (tCO_2-eq)
Homeowner	4.9	1.1
Commercial/Institution	129.4	29.8
Small Business	12.2	2.8

2.3.5 Ground Source Heat Pumps

The differences from conventional systems are important details for describing the business case for GSHP systems. The first difference, discussed here, is the annual energy savings and GHG emission reductions that these systems produce. The second important difference, system cost, is discussed in chapter 3.

The cooling and heating power ratings of the buildings discussed in the first section of this chapter are used to size the conventional and GSHP systems, and to determine the space conditioning profiles of the buildings. Also important for sizing GSHP systems are deciding what tradeoff to make between the capital costs of the system and the desired annual energy savings. This tradeoff exists because less capital is required if the GSHP system is supplemented with a backup conventional system that operates during stages of peak demand. For this study, the homeowner's system is approximately sized to 70% of peak demand (including hot water) while the other cases are sized to approximately 75% of peak cooling demand as recommended by NRCan (2000) and NRCan (2002) respectively. The details of the systems, with reference to the base case or common system are summarized in Table 2.4.

Table 2.4: GSHP Scenario Definition

	Homeowner	Commercial/Institution	Small Business
Base Case			
Heating System Fuel Type	Natural Gas	Natural Gas	Natural Gas
Heating System Efficiency (%)	80	80	80
Cooling System Fuel Type	Electricity	Electricity	Electricity
Cooling System COP	4	4	4
Annual Electricity Usage (MWh)	3.7	223.4	35.5
Annual Natural Gas Usage (m^3)	2628	55180	10205
Proposed Case			
GSHP Heating Efficiency (%)	330	300	300
GSHP Cooling COP	4.2	3.9	3.5
Peak Cooling System Fuel Type	--	Electricity	Electricity
Peak Heating System Fuel Type	Electricity	--	--
Peak Cooling COP	--	4.0	4.0
Peak Heating Efficiency (%)	80	--	--
Annual Electricity Use (MWh)	10.3	382.2	68.5

2.4 Summary

The building descriptions and energy system characteristics defined throughout this chapter result in the energy scenarios summarized in Table 2.5. The values in this table are combined with the system cost data defined in the next chapter and natural gas and electricity price projections described after that in order to define the business case for these technology audience pairs.

Table 2.5: Summary of Energy Scenarios

	System Characteristic	PV	SAH	SWH	Wind	GSHP
Homeowner	Collector Area (m^2)	20	4	6	--	--
	Power Capacity (kW)	3.2	--	--	2.6	Heat=8.8 Cool=9.9
	Annual Energy Output/Savings (MWh)	4.2	1.8	2.9	4.9	21.0
	Annual GHG Emission Savings (tCO_2-eq)	1.0	0.3	1.1	1.1	4.9
Commercial/Institution	Collector Area (m^2)	728	256	46	--	--
	Power Capacity (kW)	117	--	--	50	Heat=213 Cool=600
	Annual Energy Output/Savings (MWh)	150.7	112.2	32.6	129.4	420.5
	Annual GHG Emission Savings (tCO_2-eq)	34.7	20.1	12.5	29.8	103
Small Business	Collector Area (m^2)	117	40	8	--	--
	Power Capacity (kW)	18.4	--	--	10	Heat=39 Cool=95
	Annual Energy Output/Savings (MWh)	22.5	14.6	5.7	12.2	74.1
	Annual GHG Emission Savings (tCO_2-eq)	5.2	3.1	2.2	2.8	19

Chapter 3
Financial Data

3.1 Introduction

Part of building any business case includes defining cost estimates and their variations. For fairly new and diverse investments, as considered here, this necessitates using data from several sources. This chapter presents the available system costs for photovoltaic, solar air heating, solar water heating, ground source heat pump and wind systems. The pertinent cost categories for this study are total installed cost, annual operation and maintenance (O&M) costs where applicable, and sources of financial assistance. Total installed costs include the price of equipment, labour and any other necessary initial services. For technologies where O&M costs are not discussed it is assumed that they are negligible or negligible compared to the base case. Sources of financial assistance include capital grants available from the government, feed in tariff rates available through the Ontario Standard Offer Program and capital cost allowance regulations.

3.2 Cost Data

3.2.1 Photovoltaics

Although it is known that prices of photovoltaic modules have been steadily dropping by about 5% per year (CanSIA, 2005) there is difficulty in assessing the final total installed cost for grid connected PV systems including labour, balance of system and administrative costs. Data from 2006 shows that the total installed prices are decreasing (Table 3.1) and more recently in a study for Environment Canada (Bailie, et al., 2007) an installed price of $9.50 per watt was used to model the economics of PV in Canada. This latter number roughly agrees with the decreasing trend in cost shown in Table 3.1.

Table 3.1: Installed Prices of Solar PV in Canada
Adapted from Ayoub (2006)

$ / Watt	1999	2000	2001	2002	2003	2004	2005	2006
Grid-Connected (≤ 10 kW)	21	20	Insufficient data	Insufficient data	Insufficient data	14.5	10	10
Grid-Connected (>10 kW)	no data	no data	no data	no data	no data	no data	12.6	10

More recent data on the total installed cost of PV systems for residential installations in bulk purchase programs is shown in Table 3.2. This data comes from a community initiative in the city of Toronto that arranged bulk purchases and installation of PV systems for a group of homeowners. It shows that for systems greater than 1kW prices around the $9.50/W mark are achievable on these smaller scales for homeowners who purchase as a group. It is assumed that the installed price for individual homeowners is closer to $11/W.

Table 3.2: Installed Residential PV Costs
Adapted from Traynor (2008)

Capacity (kW)	Cost/Watt ($)
1	$12.5 – $15.5
2	$9.5 – $10.5
3	$9.0 – $10.2

In summary, the price of $9.50 per Watt installed is the most recent price available and agrees with historic decreasing trends and is used for this study as the PV reference price. However, this price is not reasonable for small individual residential installations. For the homeowner case a price of $11/W is more realistic.

3.2.2 Solar Air Heating

NRCan's Renewable Energy Deployment Initiative (REDI) program ended in 2007. It provided financial support for 25% of the (eligible) capital cost of renewable energy systems up to a maximum of $80,000 for non-residential installations (Kapoor, 2008). The average system costs (gross of REDI funding) and cost standard deviation by year from the program are shown in Figure 3.1 (further data from REDI is available in Appendix B). This study uses the data for the last year of the program for the SAH reference cost and the cost standard deviation, of \$373/m^2 and \$203/m^2 respectively. This choice was made as the final year of the program includes the largest sample population (number of systems installed) and since the data does not indicate a strong trend over the course of the program. Also, notice that this price is used for all audience types and that no data exists that illustrates there are economies of scale in the system cost.

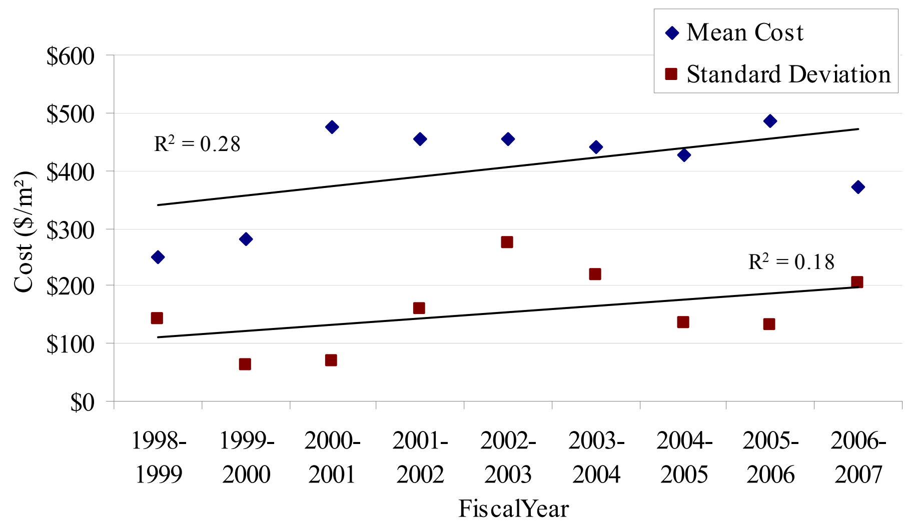


Figure 3.1: SAH Cost Trends from REDI

3.2.3 Solar Water Heating

Cost data for SWH systems also comes from the REDI program. The SWH installed system costs from the REDI program are shown in Table 3.3. Of note is the average cost of $1,032.73 and $1,374.80 per metre squared for glazed and evacuated tube systems respectively. The glazed prices are used in this study for all the audiences.

Table 3.3: Sample SWH REDI Installation Characteristics from 1998-2007 (Kapoor, 2008)

Technology	# of Systems	Average Collector Area (m^2)	Average Cost/m^2 ($)	Cost Fit (R^2)	Cost Standard Deviation ($/$m^2$)
Glazed	78	44.6	1,033	0.84	425
Unglazed	27	143.7	198	0.77	53.9
ETC	10	37.8	2165	Unavailable	1,118

3.2.4 Wind

As described in chapter 2, the wind installations considered in this study are for single turbine instillations ranging in size from 2.6kW to 50kW. Cost data specific to each class of turbine is required as costs are scale dependent. For these costs, a survey of the Canadian market in 2005 is used, as summarized in Table 3.4. For the 10kW and 50kW systems studied in this report, the installed cost and annual operation and maintenance (O&M) costs are taken directly from this table. For the 2.6kW case, the costs are interpolated between the 1kW and 10kW systems. The

1kW system is meant for battery charging and thus the interpolation may lead to slightly high estimates. The resulting costs for the 2.6kW system are $17,580 and $335/year for the capital and O&M costs respectively.

Table 3.4: Small Turbine Costs in 2008 Dollars
Adapted from Marabek (2005). Inflation adjusted to 2008 Dollars

	1kW	10kW	50kW
Application	battery charging	battery charging or on-grid	on-grid
Turbine Cost	$3,012	$34,964	$118,340
Installation & BOS Cost	$3,873	$27,003	$59,170
Total Installed Cost	$6,885	$61,967	$177,510
Total Cost per kW	$6,885	$6,197	$3,550
Annual O&M Cost	$140	$1,237	$3,550

3.2.5 Ground Source Heat Pumps

For the GSHP case, the cost data collected represents the differential over installing a conventional heating system. Several sources for this information have been consulted for this study. The following first examines sources that discuss differential operation and maintenance (O&M) costs compared to traditional space conditioning systems. The second discusses sources that look at the differential installed cost.

Differential Operation and Maintenance Costs

A Comprehensive survey of GSHP operation and maintenance costs for non residential installations is available in Cane and Garnet (2000). The paper provides a summary comparison of the annual O&M costs of GSHP and other space conditioning systems. The data is presented graphically in Figure 3.2 and shows the large annual savings (a factor of 10 to 20) that GSHP provides compared to conventional systems.

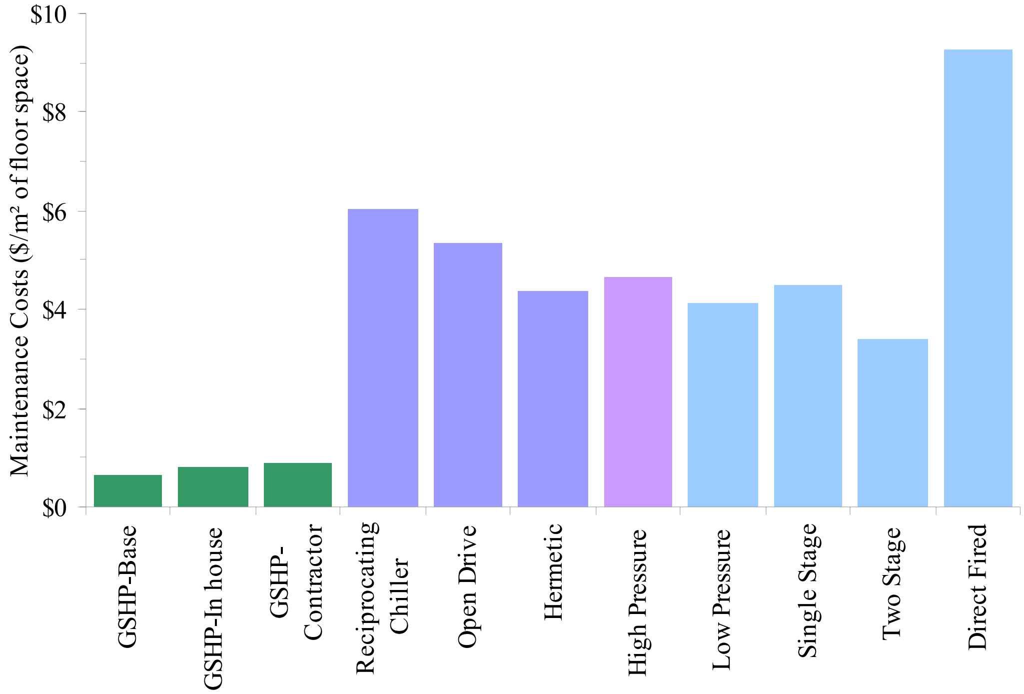


Figure 3.2: Space Conditioning Annual O&M Costs by Type for Commercial Buildings
Adapted from Cane (2000)

Figure 3.2 illustrates the absolute O&M costs, whereas for the economic analysis the differential is required. This differential is calculated by taking the average of the non-GSHP space conditioning systems and subtracting the average of the different GSHP maintenance methods. This result gives a differential annual savings of $4.43 per metre squared of floor space per year. This number is viewed as the average case and serves as the estimate for this study. When performing an economic assessment for a specific building installation, a more rigorous estimation will likely be required, especially in the case of an existing building. Note that this estimate may be low since the use of a GSHP system removes the need for both a heating and cooling system and only a comparison to the cooling systems is used in the calculation.

The estimate developed above is for non-residential audience types. It is assumed that the difference in O&M costs for residential circumstances is negligible.

Differential Total Installed Costs

RETScreen and the Ontario government provide data comparing the installed cost of various space conditioning systems for commercial and residential systems respectively. This data, combined with market experience, shows the cost differential is around 3:1 for homeowners and

2.4:1 for other audiences (Schafer, 2008). Hence, the GSHP costs are as shown in Table 3.5, for the building sizes considered.

Table 3.5: Differential GSHP Costs
† Total Installed Costs, Adapted from RETScreen and assuming 2.4:1 incremental cost
* Heat Pump Costs Adapted from Government of Ontario (2007) and assuming a 3:1 incremental cost

Audience	Differential Install Cost ($\$/m^2$ of floor space)	Notes
Homeowner	61.6*	Relative to 80% natural gas furnace
Commercial/Institution	39.7†	Relative to average cost of conventional systems
Small Business	40.4†	

The costs for GSHP in non-residential buildings can be further broken down by equipment components as shown in Table 3.6.

Table 3.6: Non-Homeowner GSHP equipment Costs
Adapted from RETScreen

	Average Unit Cost ($/Unit)	Unit
Circulating pump	550	kW of Pump Power
Circulating fluid	2950	m^3 of fluid
Drilling & grouting	56	m of drilling
Loop pipe	3	m of pipe
Fittings & valves	9	kW of cooling capacity
GSHP	450	kW of Power

3.3 Sources of Financial Assistance

3.3.1 Government Funding

There are two sources of government grants available for SAH and SWH systems for non-homeowner installations. The first is the federal government program that replaced REDI, ecoEnergy. The renewable heat arm of this program, as of April 2007 provided a grant of 25% for the capital cost of SAH and SWH systems up to a maximum of $80,000 (Government of Canada, 2008a). The rules of this program have been updated for September 2008. However these new rules, which include changes to the subsidies, have not been included in this study. Projects in Ontario that qualify for this program are also eligible for a grant from the provincial government under the OSTHI (Ontario Solar Thermal Heating Initiative). This program offers additional support of 25% for the capital cost of SAH and SWH systems up to a maximum of \$80,000 (Government of Canada, 2008b). These grant amounts are included in the analysis of non-homeowner SAH and SWH scenarios.

There are also grants available under ecoEnergy programs for wind and PV installations, but the minimum size of eligible installation is well beyond those considered in this study.

3.3.2 Standard Offer Program

Under the Standard Offer Program (SOP) in Ontario, PV and Wind projects can be guaranteed a feed in tariff rate of 0.42$/kWh and 0.11$/kWh respectively for twenty years. These rates, however, are the initial tariff rates of the program. At the time of this writing the program is undergoing a restructuring that may impact the rates. These rates are the source of income for PV and Wind projects in this study. Other techniques can be used, such as net metering of energy demand. However, as there is much uncertainty in the future price of electricity, the scenarios in this report were constructed using the SOP rates in order to mitigate this uncertainty.

3.3.3 Capital Cost Allowance

Under tax regulations the non-homeowner projects are eligible for capital cost allowance. The capital cost allowance is included in this study by use of the capital cost tax factor (CCTF) which is a mechanism that allows for the future benefit of tax savings from depreciation to be incorporated into an economic analysis. CCTF can be calculated in the following two ways (Fraser et al., 2000):

$$CCTF_{new} = 1 - \frac{td\left(1 + t/d\right)}{\left(i + d\right)\left(1 + i\right)} \tag{3.1}$$

$$CCTF_{old} = 1 - \frac{td}{i + d} \tag{3.2}$$

Where t is the income tax rate (16.5% for small business and 33.5% for commercial/institution), d the CCA rate (30% for Wind and PV and 4% for other technologies) and i the after-tax interest rate. For the after-tax interest rate a before tax value of 10% is used and adjusted by a factor of (1-t).

In equation (3.1), $CCTF_{new}$ is used to calculate the tax benefits for all time and accounts for the half year rule. $CCTF_{old}$, in equation (3.2) is necessary when the projects do not last for all time. $CCTF_{old}$ is thus used to account for this by adjusting for the salvage value. In this study the reference case, however, assumes a salvage value of zero.

3.4 Summary

In this chapter, the costs of alternative energy systems under examination in this study were presented along with sources of financial assistance. The cost data used in the economic analysis to follow is summarized in Table 3.7 and Table 3.8.

Table 3.7: Summary of Cost Data

	Reference (Mean) Installed Cost ($/unit)			Standard Deviation (% of Cost)	Standard Deviation ($/unit)
	Homeowner	Commercial/ Institution	Small Business		
PV	11.0/W	9.5/W	9.5/W	47.9	4.6/m^2
SAH	372.7/m^2	372.7/m^2	372.7/m^2	54.6	203.4/m^2
SWH	1032.7/m^2	1032.7/m^2	1032.7/m^2	41.2	425.0/m^2
Wind	6.8/W	3.6/W	6.2/W	47.9	Varies
GSHP	$50.3/m^2	46.6/m^2	48.4/m^2	47.9	Varies

Table 3.8 Incremental Annual O&M Costs ($)

	Homeowner	Commercial/Institution	Small Business
PV	Negligible	Negligible	Negligible
SAH	Negligible	Negligible	Negligible
SWH	Negligible	Negligible	Negligible
Wind	335	3550	1237
GSHP	Negligible	-41,149	-6,467

Chapter 4
Energy Price Forecasts

4.1 Introduction

As many of the energy systems considered in this study replace or divert demand for natural gas and centralized grid electricity, changes in price of these traditional sources will affect the business case for the new sources. To address this issue this chapter presents a summary of various future natural gas and electricity price scenarios and the structure of customer billing of these commodities in Ontario. The chapter also discusses the methodology used to select a meaningful price projection for this study as well as a range of possible prices that affect the risk of investment in alternative energies. Note that unless otherwise stated all prices are in 2008 dollars.

4.2 Billing Structure

The first step to understanding the affect of natural gas and electricity price on alternative energy investments is to understand how users of these commodities are impacted by price changes. The following describes the billing structure of these commodities in Ontario and offers a perspective on how these conditions may change during the project timeframe considered here.

The prices that natural gas and electricity customers in Ontario pay are comprised of several charges, most of which are controlled by a provincial governmental body called the Ontario Energy Board (OEB). This board dictates the prices that distribution companies are allowed to charge end customers in various parts of the province. This study focuses on these charges in the GTA context.

Firstly, end users are broken up into several categories or billing groups depending on their energy demand and their market segment (e.g. homeowner). For the energy scenarios in this study the audience types can be grouped into two natural gas and three electricity price brackets as shown in Table 4.1. Each of these customer types has a different billing structure and is charged different rates accordingly.

Table 4.1: Energy Customer Type Breakdown
The power ratings for the electricity types refer to monthly average peak demand.

	Homeowner	Commercial/Institution	Small Business
Natural Gas	Residential	General Service	General Service
Electricity	Residential	General Service 50 to 999kW	General Service < 50kW

This distinction of customer type is important as it breaks down the commodity charges from the other service charges. This allows for a proper evaluation of the savings realized through the reduction in demand of the commodity. This distinction is clearer seen when the customer fees are defined, as in Table 4.2 for Natural Gas. There are two important things to note in this table. The first is that the customers are billed differently and that they are charged twice for their energy demands, once for the commodity and once for the delivery of the commodity. The second point is that since the economic analysis deals with a difference in demand, the monthly charges can be ignored as they cancel out in the subtraction unless the use of a new alternative energy source entirely removes the demand for a commodity.

Table 4.2: Natural Gas Billing Structure Comparison for April 2008
Adapted from OEB (2008)

Residential		General Service	
Monthly Customer Charge ($)	14	Monthly Customer Charge ($)	50
Gas Charge ($/m³)	0.390	Gas Charge ($/m³)	0.391
Delivery Charge per m³:		Delivery Charge per m³:	
For the first 30 m³ ($/m³)	0.152	For the first 500 m³ ($/m³)	0.133
For the next 55 m³ ($/m³)	0.146	For the next 1050 m³ ($/m³)	0.116
For the next 85 m³ ($/m³)	0.142	For the next 4500 m³ ($/m³)	0.103
For all over 170 m³ ($/m³)	0.138	For the next 7000 m³ ($/m³)	0.095
		For the next 15250 m³ ($/m³)	0.092
		For all over 28300 m³ ($/m³)	0.091

4.3 Forecasts

Two pieces of information are needed to project what end customers will be paying for the use of these commodities over the project life. The first is the prices of the non-commodity fees, such as delivery charges, and the second is the prices of the commodities themselves.

4.3.1 Non-Commodity Fees Forecasts

The non-commodity fees for natural gas are assumed to remain constant for all customer types. This assumption is based on historical patterns, of which the residential pattern is shown as an example in Figure 4.1.

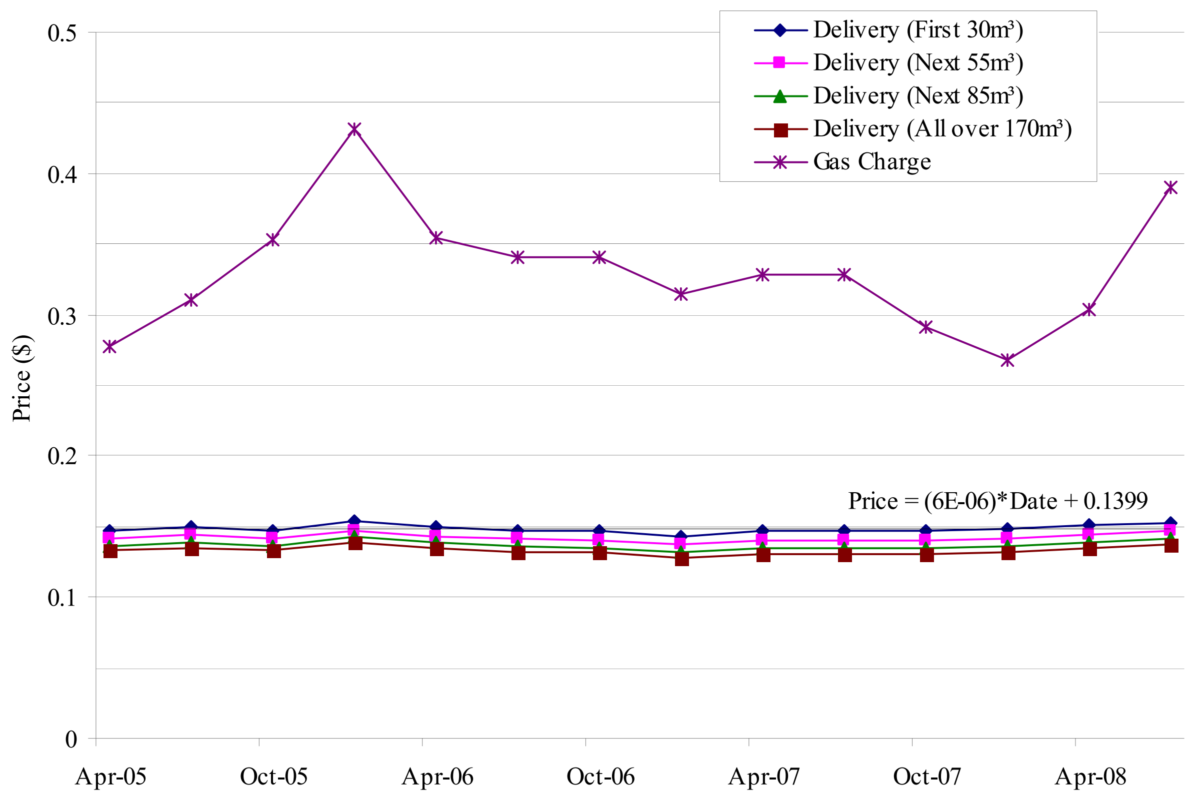


Figure 4.1: Historical Residential Natural Gas Fees vs. Commodity Price
The non-commodity fees remain nearly constant with respect to time. The equation illustrates the linear fit for the First $30m^3$ delivery fees. The slope of the line is nearly zero. Adapted from OEB (2008).

For the non-commodity fees associated with the use of electricity, a combination of OPA forecasts and linear interpolations are used to forecast the non-commodity fees. The linear interpolations are required as the OPA projections are in five year increments. The residential electricity fee projections are shown in Figure 4.2.

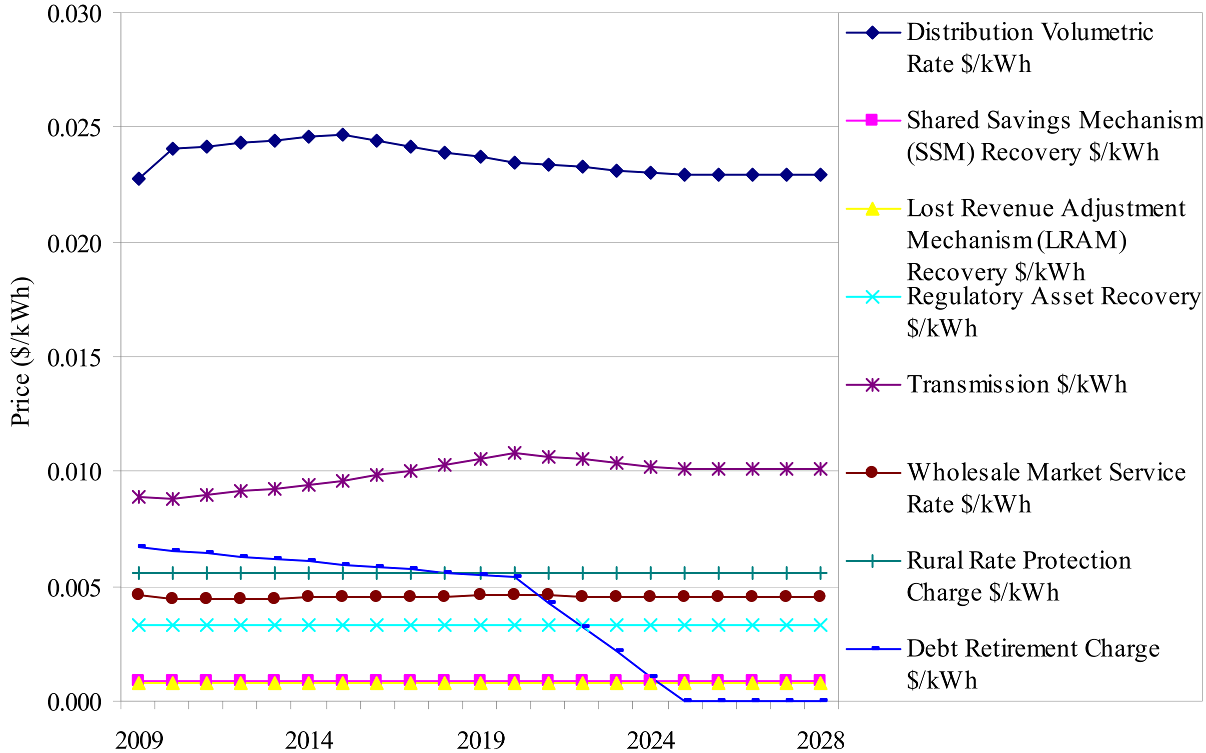


Figure 4.2: Residential Electricity Fee Projections
Adapted from OPA (2007)

4.3.2 Commodity Price Forecasts

Natural Gas

Two steps are required to forecast OEB natural gas prices. The first is the collection of natural gas price forecasts from the available literature, as modeling such forecasts is outside the scope of this study. The second step is to convert these forecasts into OEB prices. This second step is required as natural gas prices in North America can be referenced at several different places. The reference point used in this study is the Alberta provincial natural gas price. The transformation from the Alberta price to OEB prices is a shifted linear transformation as illustrated in Figure 4.3.

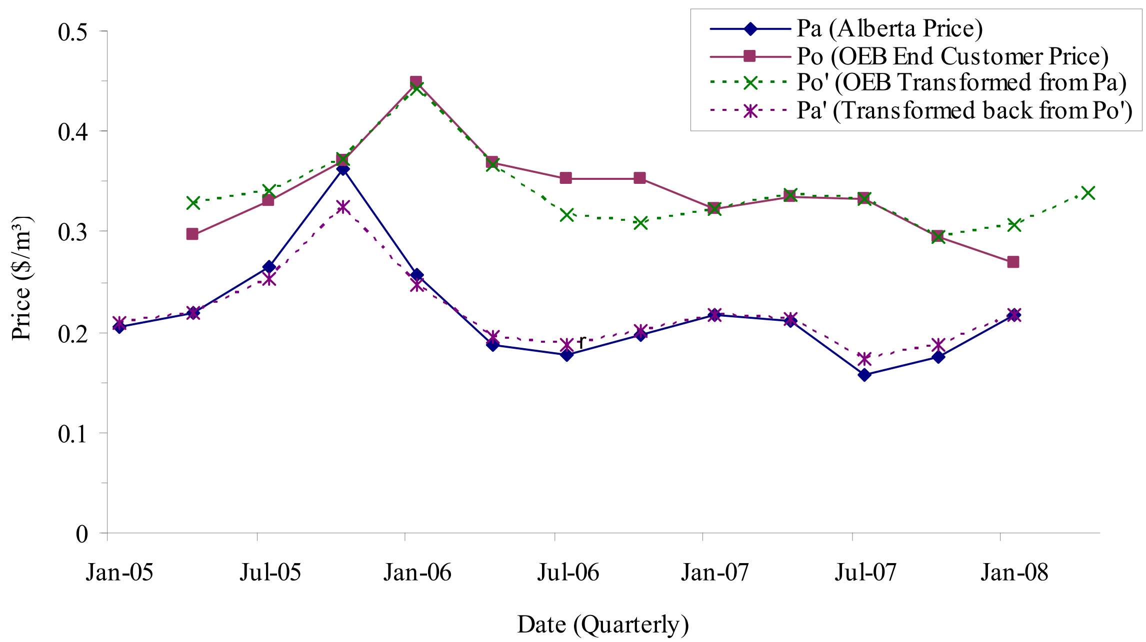


Figure 4.3: Alberta/OEB Natural Gas Price Transformation

The price forecasts for step 1 appear in Figure 4.4. The data in this figure have been converted to the Alberta reference. The original forecasts were for prices referenced at the Henry Hub and the United States Wellhead. To transform natural gas prices from Henry Hub prices to Wellhead prices the Henry Hub prices are reduced by the mean difference between historical Henry Hub and Wellhead prices (Budzik, 2003), a process used by the OPA in their long-term Integrated Power Systems Plan (IPSP). This process is also used to convert the Wellhead prices into the Alberta reference.

The price used in the reference case of this study is $0.388 per metre cubed (transformed to the OEB price) or $0.286 per metre cubed based on Alberta prices (Sproule, 2008). This value comes from the average Alberta price from 1995 to the present. As can be seen in Figure 4.4, this price roughly represents the average price of the forecasts. It also represents the approximate average OEB price since 2003 once transformed (Figure 4.3).

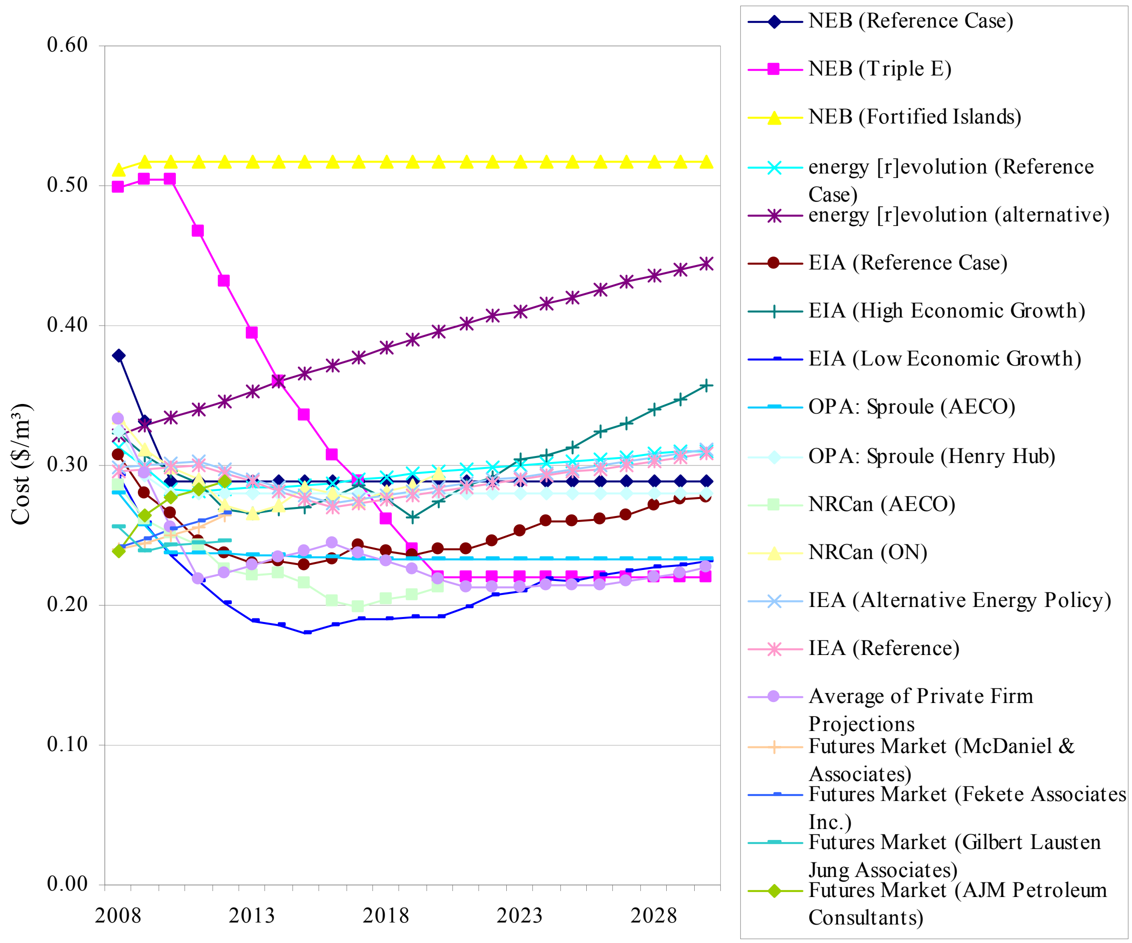


Figure 4.4: Natural Gas Price Forecasts - Adjusted to Alberta Price
Adapted from, NEB (2007), Greenpeace & EREC, 2007 (2007), EIA (2007), OPA (2007), NRCan (2007), IEA (2004), NPC (2007), Enbridge (2007).

Electricity

For forecasting the commodity price of electricity in Ontario for the project period the forecast from the OPA IPSP (OPA, 2007) is used. Again, interpolation between the five year points is required to complete the annual forecast (Figure 4.5). The OPA forecast includes a measure of variation in its maximum and minimum projections as indicated with the error bars in the figure.

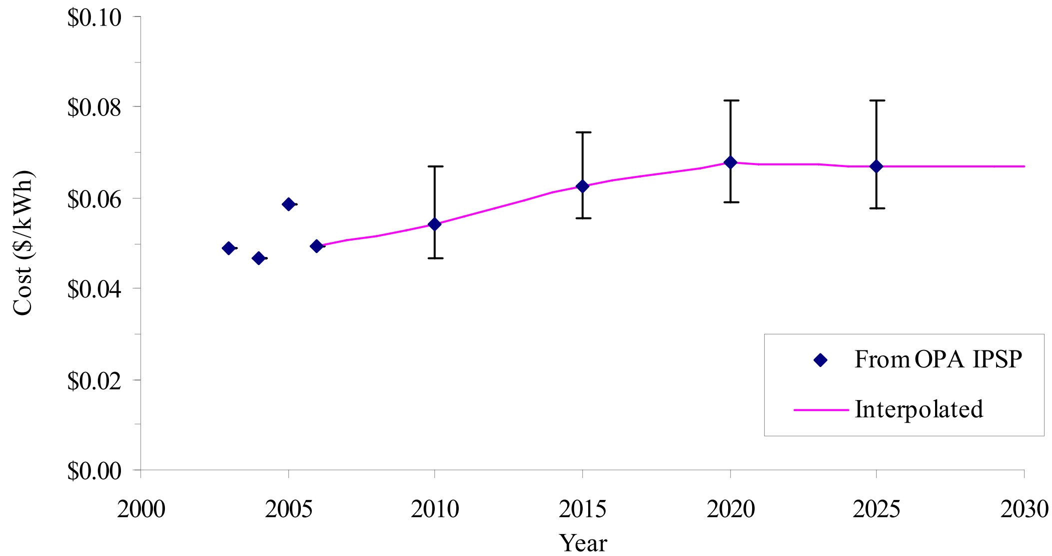


Figure 4.5: Electricity Commodity Price Forecast (OPA, 2007)

To use the commodity price in the analysis this price must be converted into the form used by the OEB to set end customer prices. The OEB sets two commodity prices, a price charged for an initial allotment of electricity use per month and another price for the amount used above this allotment. For this study it is assumed that this pricing scheme will continue for ease of calculation. In actuality, all customers will likely be changed to a peak power pricing model, however, this model was found not to substantially affect the outcome of this study, and is thus not used due to its computational intensity.

To convert the commodity price to these two values the following formulae are used

$$P_{high} = P_{commodity} + \Delta_{high-low} \cdot T \cdot n/d \qquad \textbf{(4.1)}$$

$$P_{low} = P_{high} - \Delta_{high-low} \qquad \textbf{(4.2)}$$

Where,
P_{high} is the price paid over the monthly threshold;
P_{low} is the price paid below the threshold;
$P_{commodity}$ is the commodity cost of electricity;
$\Delta_{high\text{-}low}$ is the difference between the two prices (OEB maintains this value at 9$/MWh);
n and d are the number of customers and their total demand respectively (residential values projected by OEB are used); and
T is the threshold (A static value of 750kWh is used, although OEB changes the value throughout the year for different customers.)

4.4 Commodity Price Uncertainty

Although sensitivity to commodity price changes can easily be tested by using the expected range of values, to test the uncertainty a probabilistic method is better equipped to quantify the possible outcomes.

This is performed by examining the stochastic nature of the historical commodity prices, and assuming that both the natural gas and electricity prices are random walks. Thus the first difference can be taken and tested statistically to determine which, if any, probability distribution the year to year price change exhibits. In doing this test it was determined that this distribution for both is a Laplace distribution. With this distribution specified, random projections can be generated for the project lifetime. These random projections are generated several times in the Monte Carlo analysis described in the following chapter, which quantifies the overall uncertainty of investing in each of the scenarios impacted by these commodities.

4.5 Summary

This chapter presented the billing structure for users of electricity and natural gas, projections of what will happen to these bills and the commodity prices and how these values can be tested in the economic, sensitivity and uncertainty analyses. The results appear in the following chapter.

Chapter 5
Business Case

5.1 Introduction

This chapter presents the results of the economic analysis. The analysis begins with a reference case, which provides the internal rates of return (IRR) and payback periods (PBP) of each of the audience technology pairs under the reference data and assumptions laid out in the previous chapters. This is followed by the sensitivity analyses and uncertainty analyses. Note that the project life is twenty years for all technologies; although some may have a slightly longer usable lifetime, it was assumed that the use of a shorter lifetime has a negligible impact due to the time value of money. This assumption is tested later in this chapter.

The results indicate that a wide range of IRRs and PBPs exist between the audience technology pairs. This is to say that some are quantitatively very good investments, while others are not. There are many other aspects that are not considered in the analysis such as the marketing value of investing in green technologies or the desire to invest in green technologies simply in a desire to reduce one's environmental footprint. In this later case all that may be important is that the returns are slightly positive. The methodology, data used and results presented in the remainder of the chapter serve as a baseline for understanding economic returns.

5.2 Reference Case

The reference case results (Table 5.1) consist of the IRRs and PBPs for the set of audience technology pairs, excluding the investor cases as these are defined after the uncertainty analysis. The cells of the table with no values are for those projects with a negative IRR.

Table 5.1: Reference Case Internal Rates of Return (%) and Payback Periods (Years)

	Homeowner	Commercial	Institutional	Small Business
PV	--	1.5%, 16.9	1.5%, 16.9	--
SAH	1.7%, 16.8	10.9%, 8.0	10.9%, 8.0	10.1%, 8.4
SWH	--	5.9%, 11.5	5.9%, 11.5	5.8%, 11.7
Wind	--	3.6%, 13.3	3.6%, 13.3	--
GSHP	6.4%, 11.0	12.4%, 7.2	12.4%, 7.2	14.7%, 6.3

Presented graphically in Figure 5.1, the results of the reference case clearly indicate that the largest returns, and thus shortest payback periods are available for GSHP installations. The second best opportunities are seen in the SAH and SWH non-homeowner cases due to the available federal and provincial grants. PV and Wind systems perform relatively poorly, and do so for all audience types as the pricing data available did not provide conclusive evidence of economies of scale. The results also tend to illustrate the available economies of scales in the systems. The commercial and institution audience has the best returns for all the technologies except for GSHP. The GSHP anomaly is a result of the natural gas pricing structure described in the previous chapter. The province charges less per unit of natural gas as demand increases, thus when natural gas demand is replaced by GSHP in the commercial and institution cases the marginal benefit is smaller than in the small business case. The degree to which the above outcomes remain under varying conditions and uncertainty are tested in the following sections.

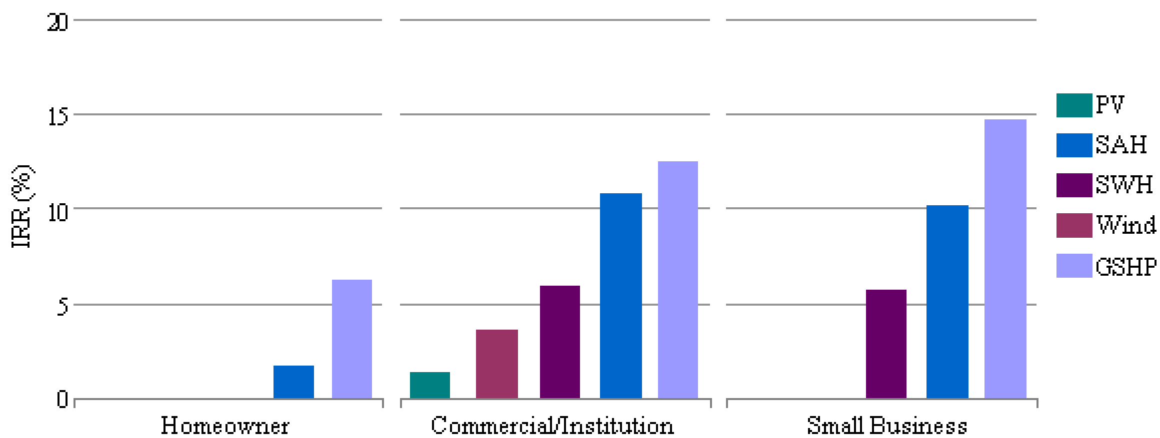


Figure 5.1: Reference Case Internal Rates of Return

5.3 Sensitivity Analysis

The sensitivity analysis consists of an examination of five key variables: commodity prices, tariff rates, system costs, capital grants and system output. Not all of these variables apply to each technology, as indicated throughout the following sections. The goal of the analysis is to gauge the affect of these variables on the suitability of investment for the audience technology pairs. The data produced by this examination are useful in assessing the viability of an individual project under varying circumstances or different expectations in future commodity prices.

5.3.1 Commodity Prices

As described in the previous chapter on commodity prices, the economics of SAH, SWH are impacted in the scenarios constructed here by the price of natural gas, while GSHP projects are impacted by both natural gas prices and electricity prices. The sensitivity of the investments to these commodity prices is tested with results shown below.

Figure 5.2 illustrates the natural gas price sensitivity for the homeowner cases while Figure 5.3 illustrates this test for commercial, institution and small business audience members. The curves illustrate the IRR resulting from a specified average annual increase of natural gas prices. Also shown are the IRRs resulting from the natural gas price forecasts described in Figure 4.4. These IRRs are fit to the average annual gas price increase curve in order to drawn comparisons.

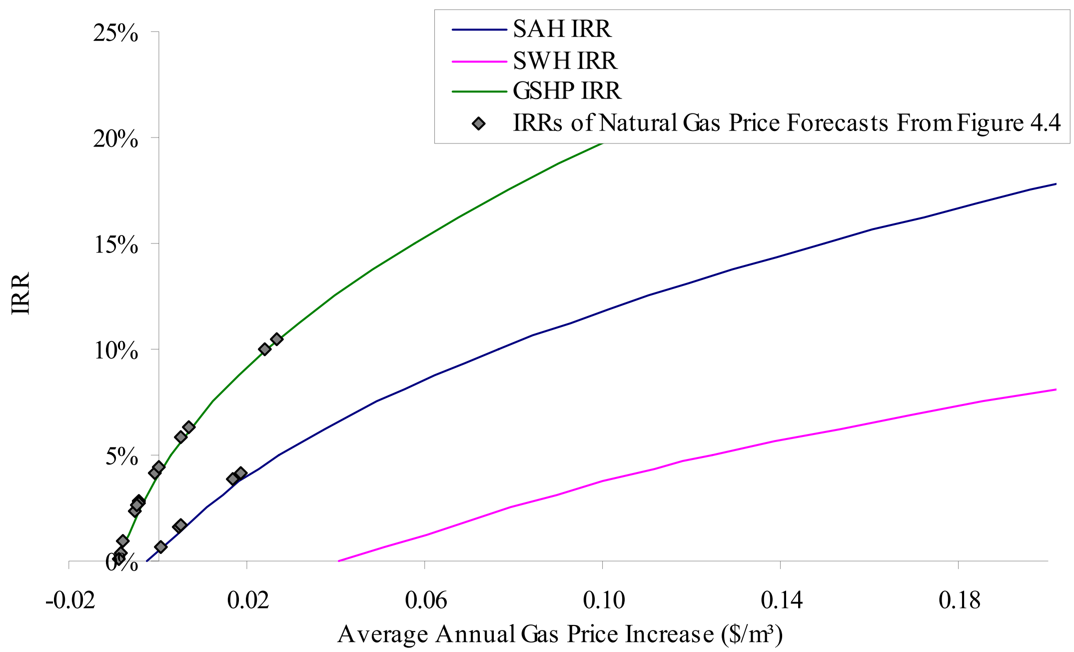
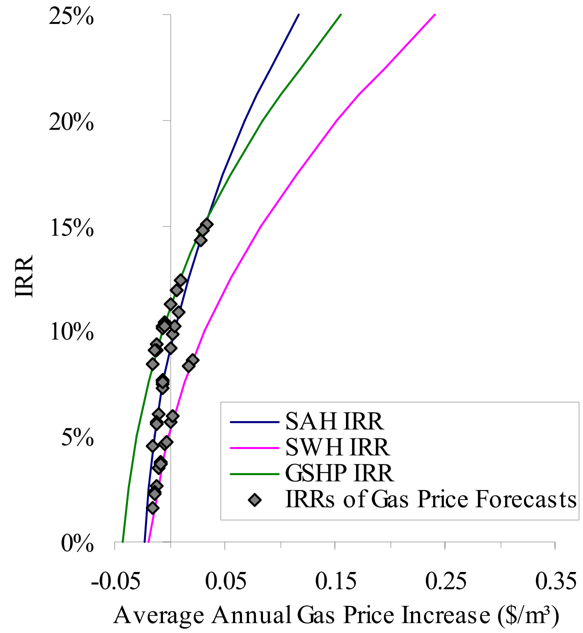
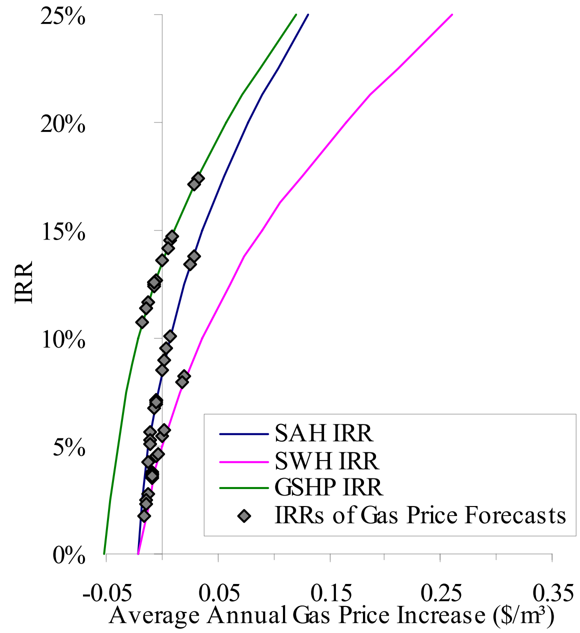


Figure 5.2: Affects of Natural Gas Price on SAH, SWH and GSHP (Homeowner)
The solid lines indicate the average annual natural gas price increase required to achieve a given IRR. The ♦ indicate the IRR and comparable natural gas price change realized from various natural gas price projections (as documented in Chapter 4). This graph illustrates that under the reference conditions it is likely that SAH, SWH & GSHP for these two audiences will see at least modest returns with respect to possible natural gas price changes.

The importance of including these fitted points on the curves is that they illustrate how realistic a given IRR may be. For example in the homeowner SWH case the required annual gas price increase for a positive IRR is so high (~ $0.04/m^3) that none of the projections fall on the curve. Or in other words, the gas price forecasts all produce a negative IRR in the SWH homeowner scenario. Similarly, it can be seen that some of the projections fall on the SAH and GSHP curves. As these price forecasts describe widely varying scenarios that can, but may not occur, the best investment choices are those audience technology pairs which produce acceptable IRRs for the most number of these forecasts – such as is the case with GSHP for all audience types.



(a) Commercial/Institution



(b) Small Business

Figure 5.3: Affects of Natural Gas Price on SAH & SWH (Commercial/Institution)
The solid lines indicate the average annual natural gas price increase required to achieve a given IRR. The ♦ indicate the IRR and comparable natural gas price change realized from various natural gas price projections (as documented in Chapter 4). This graph illustrates that under the reference conditions it is likely that SAH, SWH and GSHP for these two audiences will see at least modest returns with respect to possible natural gas price changes.

With an understanding of the dependence on natural gas prices for suitability of investment the next step is to establish such an understanding for electricity prices, with respect to the GSHP case. For this analysis the commodity price projections made by the OPA (2007) are used. The resulting changes in IRR are presented in Figure 5.4, with differences between high and low cases of about 1%. As the electricity prices used are from the OPAs plan to 2027, this outcome can only be realized if this plan is followed.

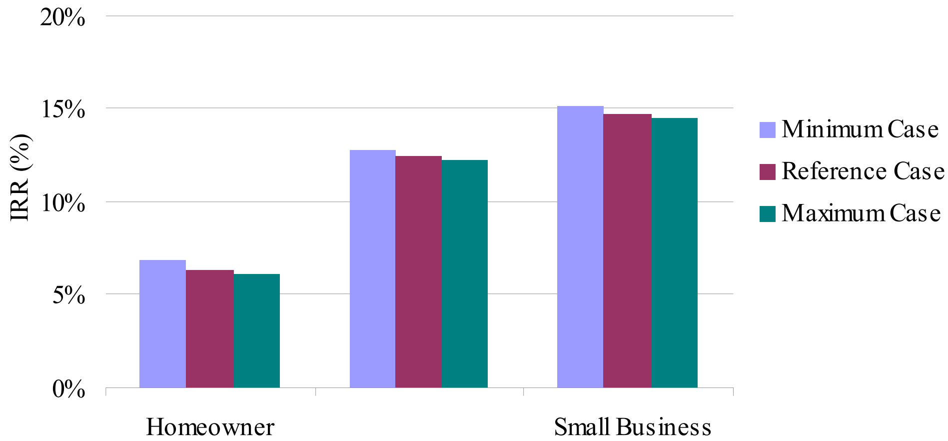


Figure 5.4: GSHP IRR Sensitivity to Electricity Prices
The three electricity price cases are those presented in Chapter 5 from the OPA IPSP (OPA, 2007).

5.3.2 Sensitivity to Tariff Rates

The PV and wind tariff rates produce the income for these systems. Since these rates are fixed by the provincial government, testing the sensitivity to them is not entirely relevant to the individual or entity already in the SOP. Results of the sensitivity study are still, however, meaningful since they provide a description of the economic returns in the event the rates are changed – a likely event at the time of this writing.

Figure 5.5 to Figure 5.7 illustrate how the affect a change in the SOP tariff rate would have on the IRR for PV or wind projects. The figure shows that thresholds for positive returns are a tariff rate of about $0.3/kWh for wind and $0.6/kWh for PV (compared to $0.11/kWh and $0.42/kWh for the reference case). Important to note is that a small change in the SOP rate can have a large impact on the IRR of wind projects while a similar change (in absolute terms) for the PV rate will have less of an affect. This difference is due to the nonlinearity of the time value of money in the IRR calculation.

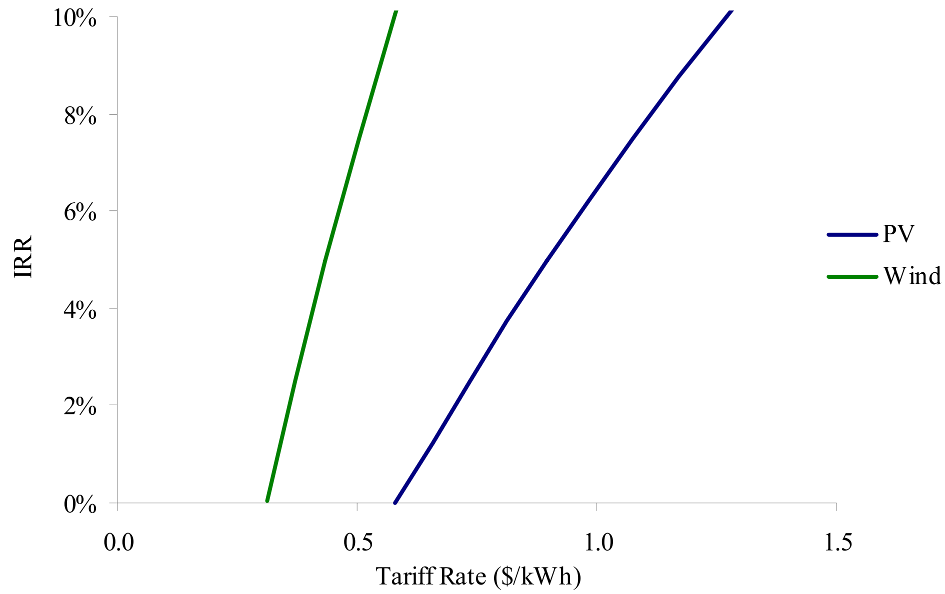


Figure 5.5: Affect of Tariff Rates on PV and Wind Homeowner IRRs

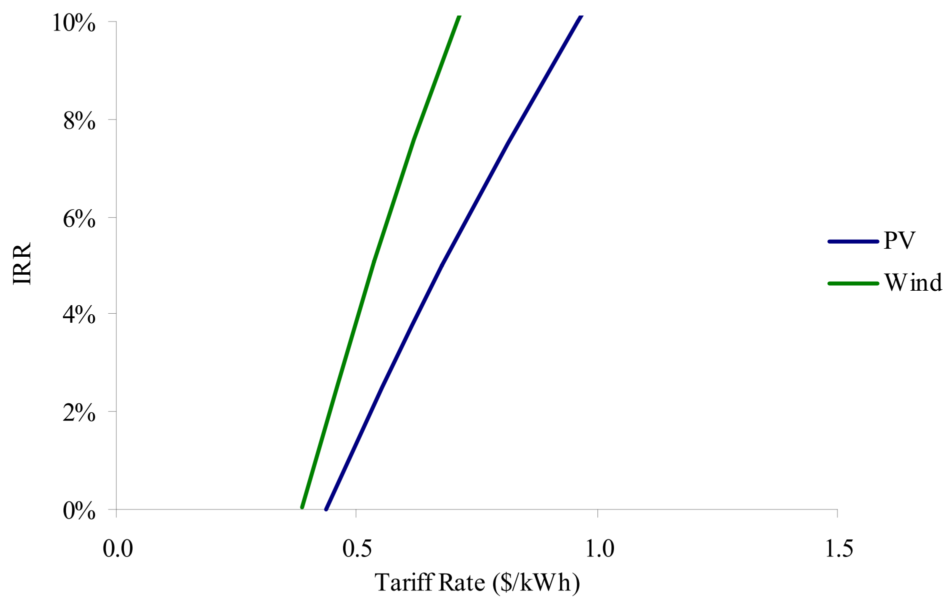


Figure 5.6: Affect of Tariff Rates on PV and Wind Small Business IRRs

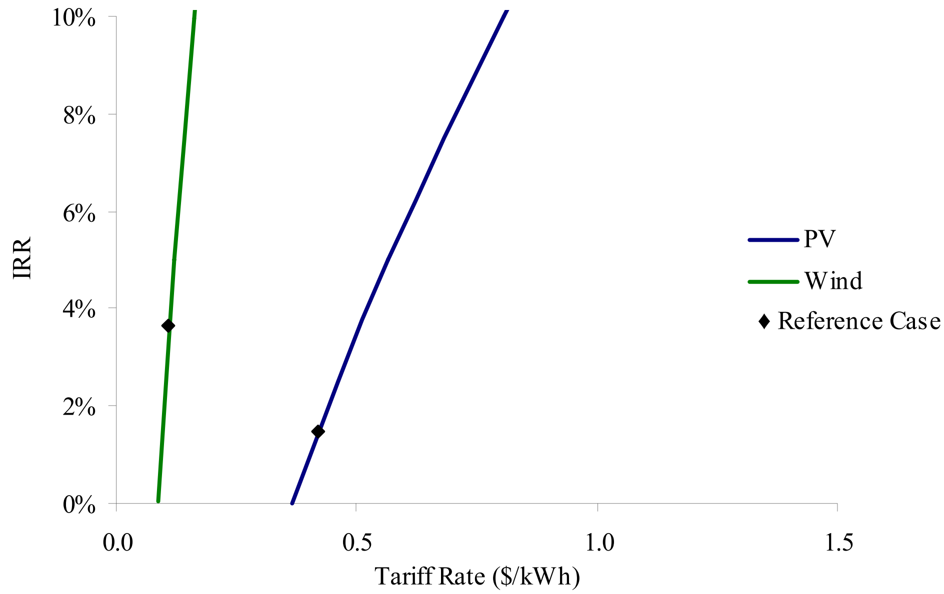


Figure 5.7: Affect of Tariff Rates on PV and Wind Commercial IRRs

5.3.3 Capital Grants

As was shown in the reference case, the non-homeowner SWH and SAH cases are made profitable by the available provincial and federal grants. Thus an assessment of the impact of grants on the twenty reference case scenarios is presented in Figure 5.8 to Figure 5.10 for the different audience types. In these figures the reference case is illustrated with a black diamond. These graphs are useful for understanding what returns can be expected if grant funding of a given amount becomes available.

A similar pattern to the other sensitivity analyses is shown by this examination. For example, a drastic change in grant amounts is required to achieve an increase in IRR for PV compared to Wind. Also, it is shown how the grant is somewhat unnecessary for GSHP scenarios as these already have a decent IRR. Finally, the impact of the grants on the SAH and SWH cases is illustrated and it is shown how a relatively small grant for the homeowners in these cases could produce a better IRR, similar to those seen for the commercial, institution and small business audience types.

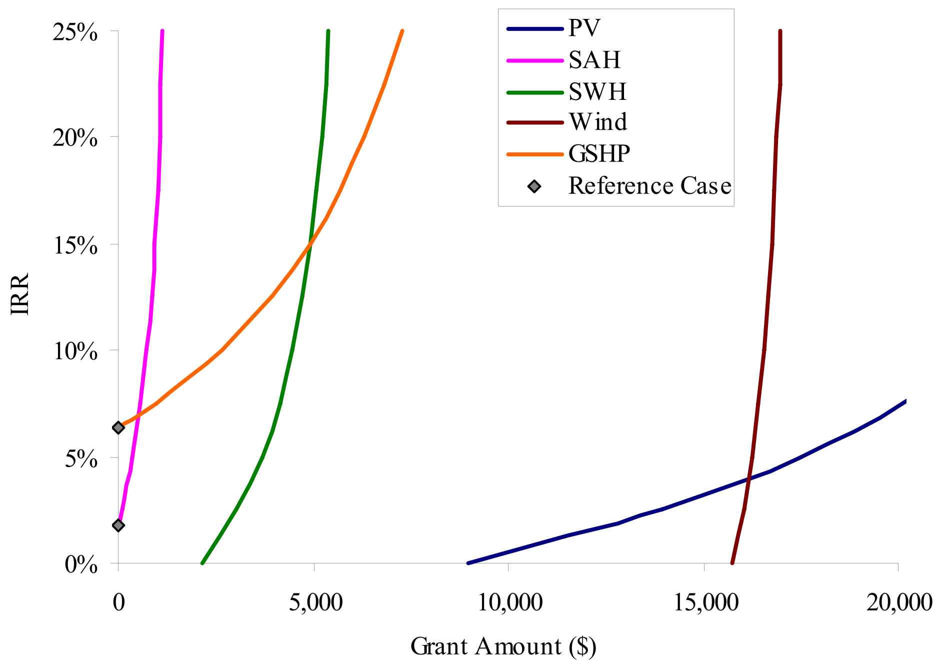


Figure 5.8: Affects of Capital Grants on Homeowner IRRs
The reference case is indicated by a ♦, except for the audience technology pairs with a negative cumulative cash flow.

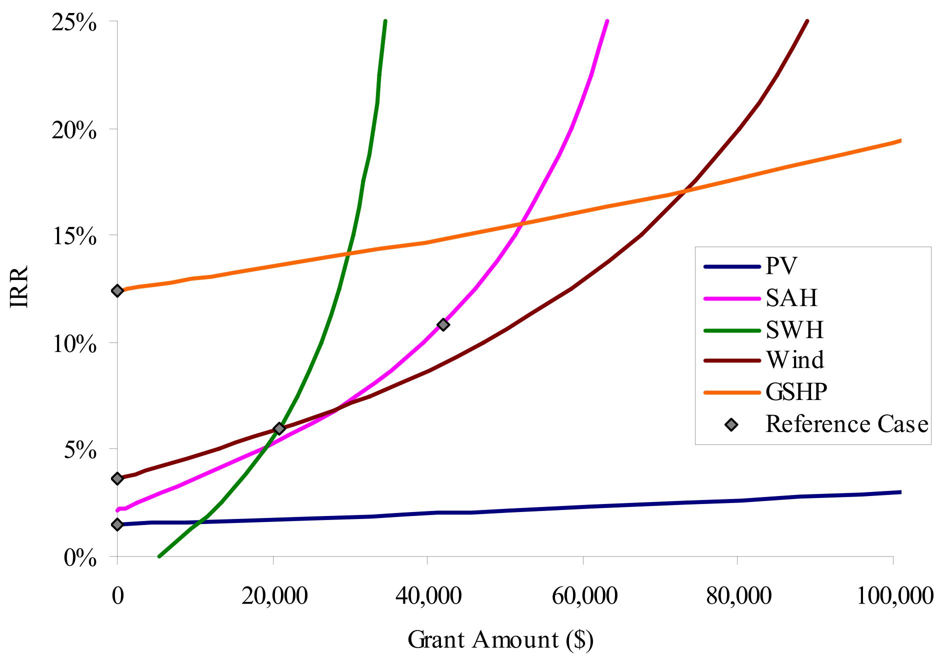


Figure 5.9: Affects of Capital Grants on Commercial/Institution IRRs
The reference case is indicated by a ♦, except for the audience technology pairs with a negative cumulative cash flow.

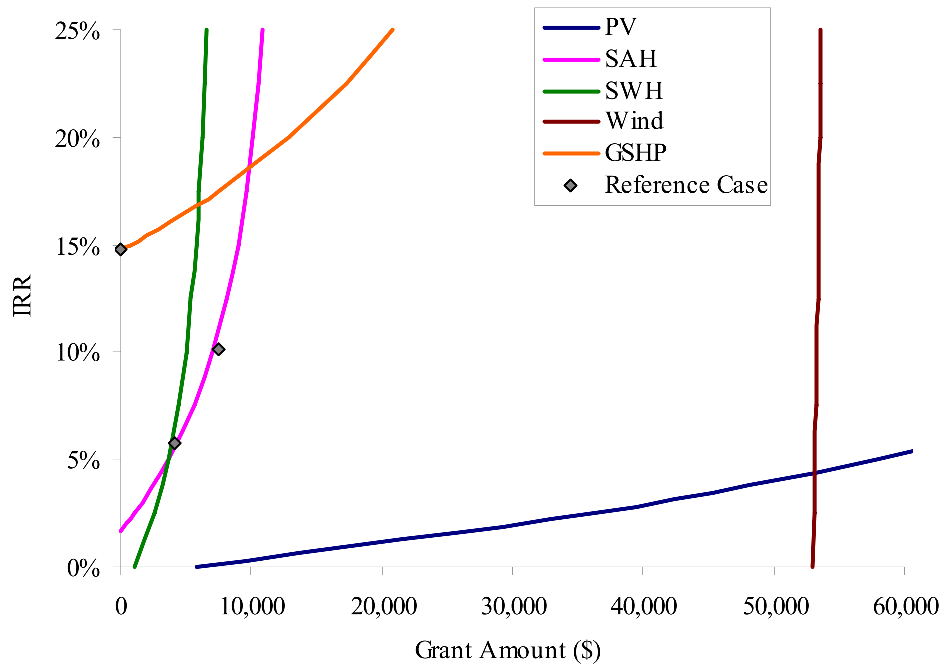


Figure 5.10: Affects of Capital Grants on Small Business IRRs
The reference case is indicated by a ♦, except for the audience technology pairs with a negative cumulative cash flow.

5.3.4 System Costs

To test the sensitivity to system cost the means and standard deviations described in Chapter 2 are used to randomly generate a set of log normally distributed costs and the resulting IRRs. As the standard deviations used were all in the area of 40% of the reference costs the resulting variation of IRRs is wide for most cases. Also, in the scenarios where the reference case IRR is low, many and sometimes all of the randomly generated costs produce a negative IRR. The results of this sensitivity study are presented for homeowners in Figure 5.11, for commercial and institutional bodies in Figure 5.12, and for small business in Figure 5.13. Each point in these graphs represents the percent of the time the given return could be expected based on system cost variation. The area under the graph represents the percent of the time a positive return could be expected based on system cost variation.

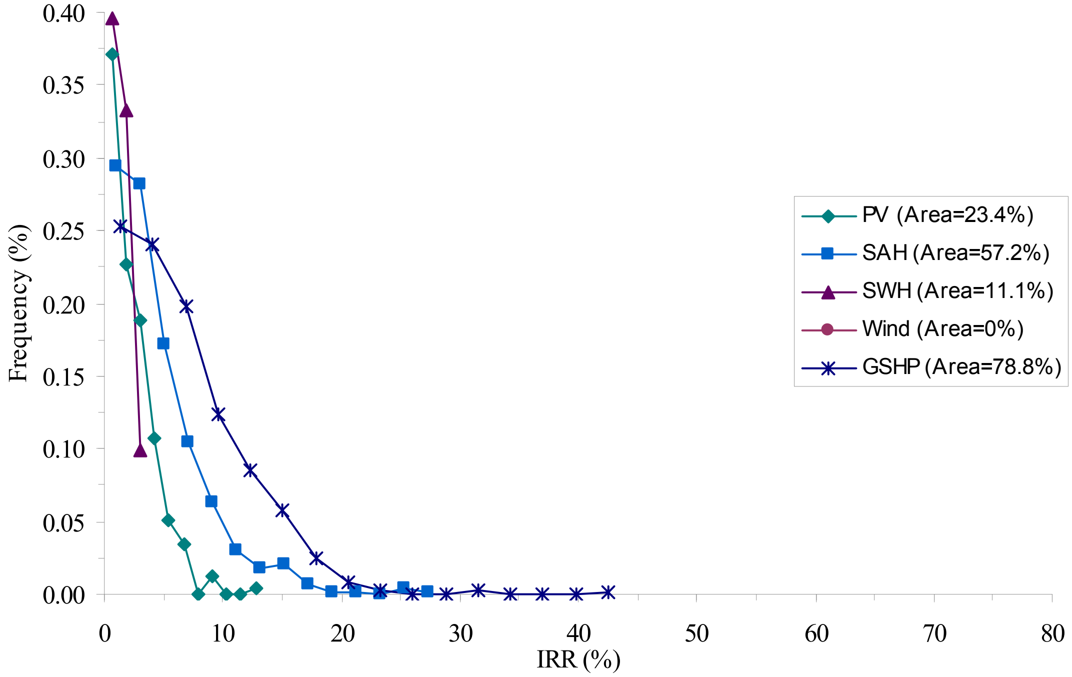


Figure 5.11: Homeowner Sensitivity to Installed System Cost

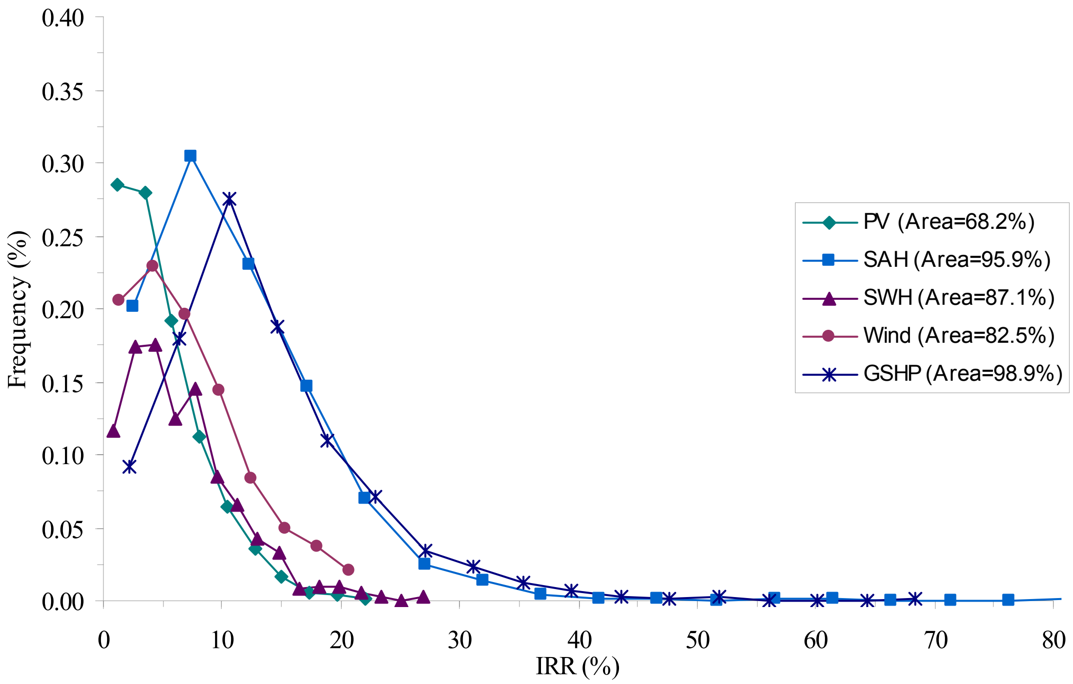


Figure 5.12: Commercial/Institution - Sensitivity to Installed System Cost

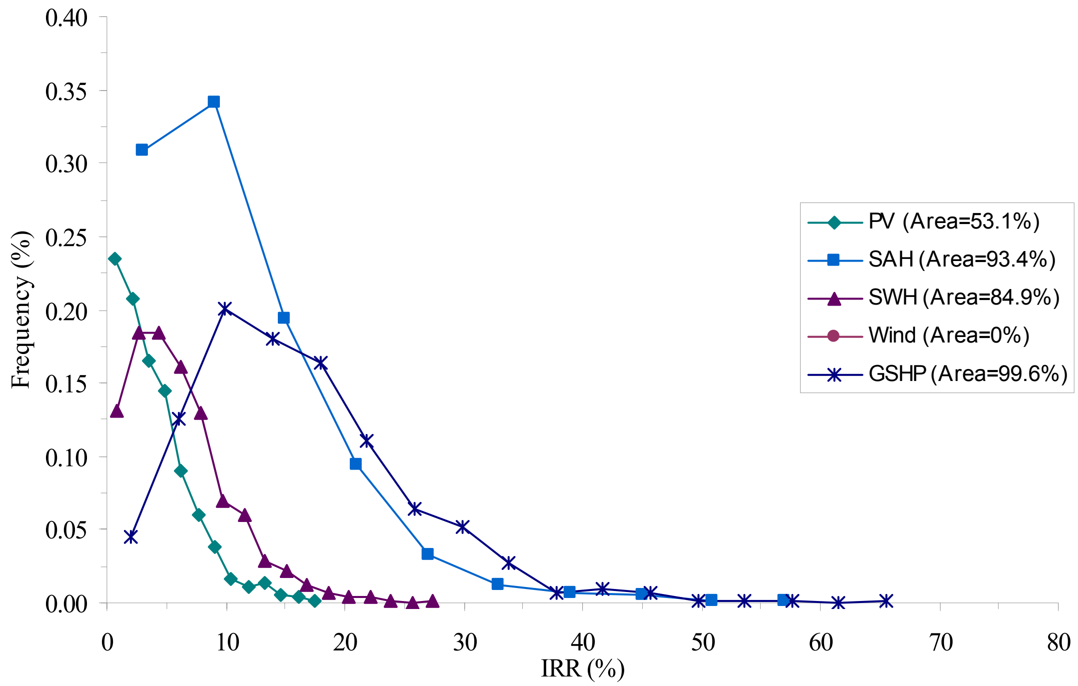


Figure 5.13: Small Business - Sensitivity to Installed System Cost

Bulk Purchase Plans

In section 3.2.1, the savings from neighbourhood organized bulk purchases of PV systems was described. The price under a bulk purchase was approximately $9.50/W while the reference case price was $11/W. The affect of these savings proves negligible as the IRR remains negative for the homeowner case under these reduced prices.

5.3.5 System Output

To test sensitivity to system output, i.e., performance, a similar method to that used for the cost sensitivity study is employed. In this case randomly generated output values are generated with a normal distribution whose mean is that of the reference case and whose standard deviation varies with technology type. The standard deviation for PV and SWH is 3.85%, 4.93% for SAH, and 3.00% for Wind and GSHP. These standard deviations are based on estimated model accuracy from RETScreen documentation (NRCan, 2006a). Figure 5.14 shows the result of the study for homeowners, Figure 5.15 for commercial and institution bodies and Figure 5.16 for small businesses. The output value varies with respect to technology and is indicated on the horizontal axis label of each graph. For homeowners, only GSHP offers positive returns over the whole range of performance variation, but for commercial/institutional all five technologies offer positive returns.

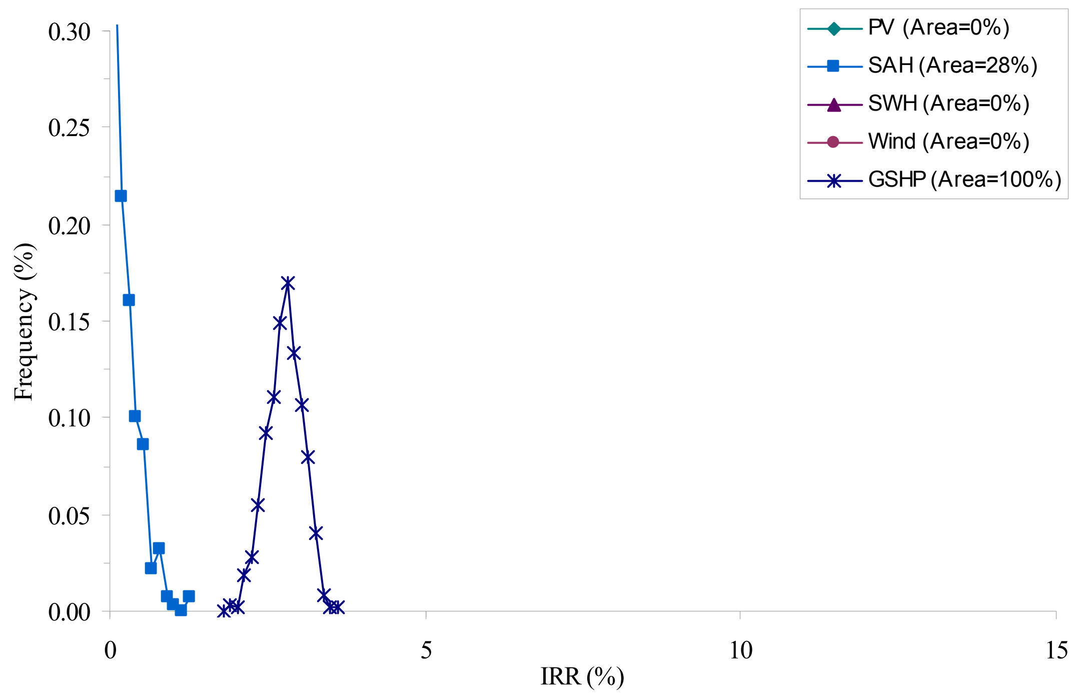


Figure 5.14: Homeowner Sensitivity to Output

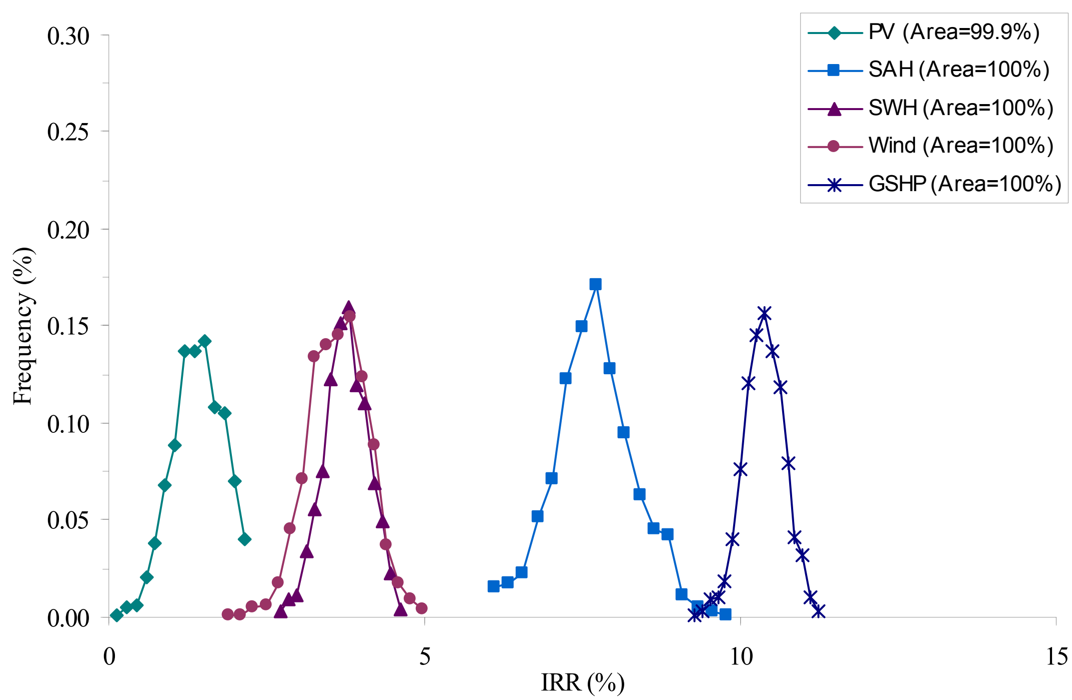


Figure 5.15: Commercial/Institution Sensitivity to Output

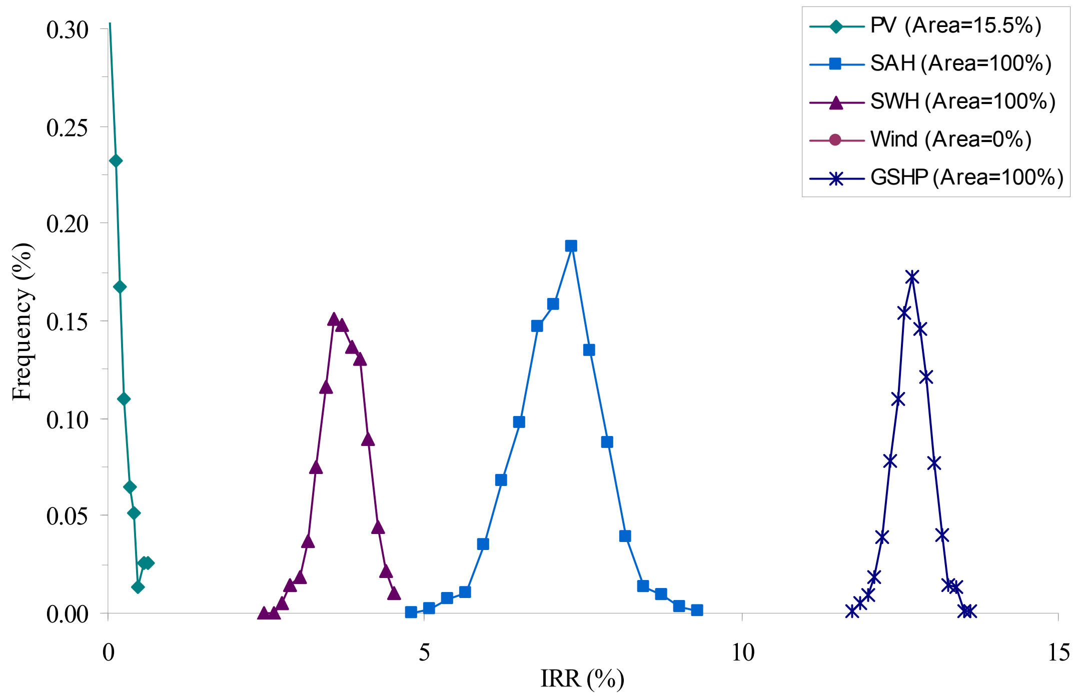


Figure 5.16: Small Business Sensitivity to Output

5.3.6 Salvage Value

As a final test of sensitivity, salvage value is examined. Figure 5.17 shows the result of this test for the homeowner PV case. The figure shows that if the salvage value were to increase to nearly 30% of the total installed cost, or roughly eight times the annual revenue, a positive return would result. This could occur if the lifetime of the project is about thirty years as opposed to twenty or if there is an added real estate or marketing value (for the other audience types) resulting from the installation of the PV system. Similar impacts to the IRR could be expected for all the audience-technology pairs. Thus, the impact of a non-zero salvage value should be considered in feasibility studies for specific projects.

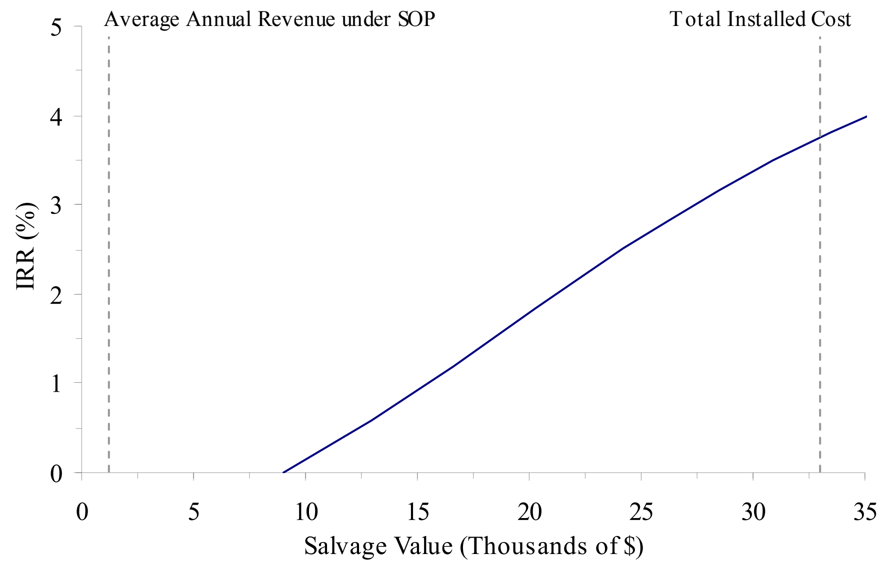


Figure 5.17: Homeowner Sensitivity to Salvage Value

5.4 Investor Case

To establish the business case for investors an uncertainty analysis is completed which allows for the quantification of risk. The investor case also includes an analysis of the impact of carbon trading as this could be a useful means of increasing the profitability of investing in alternative energy projects once Canada's cap and trade system is started.

5.4.1 Carbon Offset Trading

Under proposed federal regulations a carbon offset trading program may be available in the next year. Thus, using the preliminary information from the government on carbon prices and the structure of the offset market the affects of trading carbon offsets can be tested. The primary elements of the test include trading fees, price projection of carbon and the calculation of the tradable offset value. For this study the trading fees are ignored as these values are not yet available. A carbon price projection is shown in Figure 5.18 and is derived from data provided by Environment Canada (2008b). The offset value is awarded by multiplying the annual GHG emission reductions of the project by 8 years.

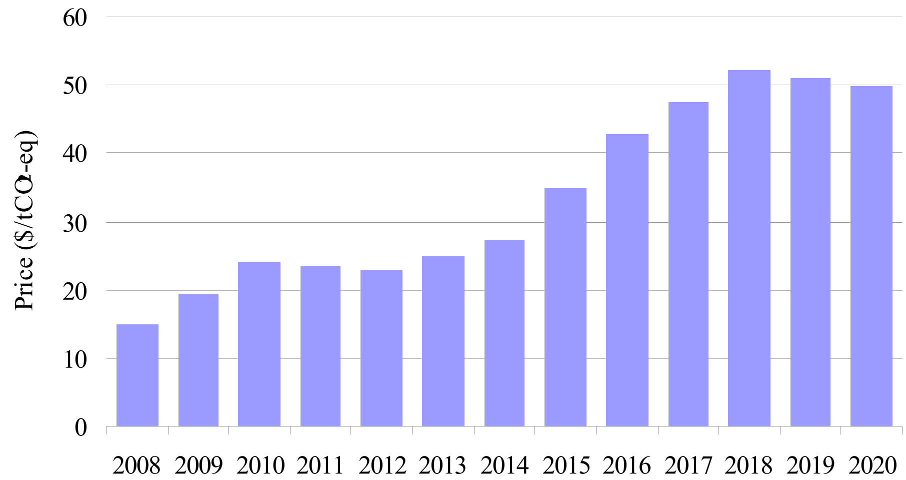


Figure 5.18: Carbon Price Projection
Adapted from Environment Canada (2008b).

The above data is used in the test to determine the best year to sell the offsets from a given project. This revenue is incorporated into the project cash flows, and then the IRR is recalculated. The test was performed against each technology audience pair. The results of this test are shown in Figure 5.19. Essentially, about a 1% increase in IRR is realized with the inclusion of offset trading.

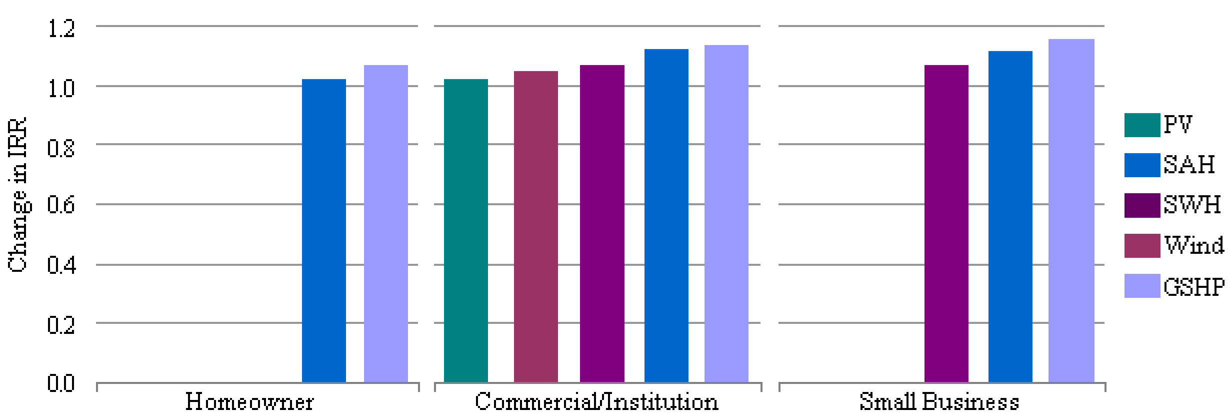


Figure 5.19: Affect of Carbon Offsetting on IRR

5.4.2 Risk & Uncertainty Analysis

The risk analysis consists of a Monte Carlo analysis involving the randomization of system cost, system output, and natural gas and electricity prices for these technologies whose business case is directly impacted by such commodities. The results are presented for all homeowners, commercial and institution buildings and small businesses in Figure 5.20, Figure 5.21, and

Figure 5.22 respectively. Here the commodity prices are generated using a random walk procedure.

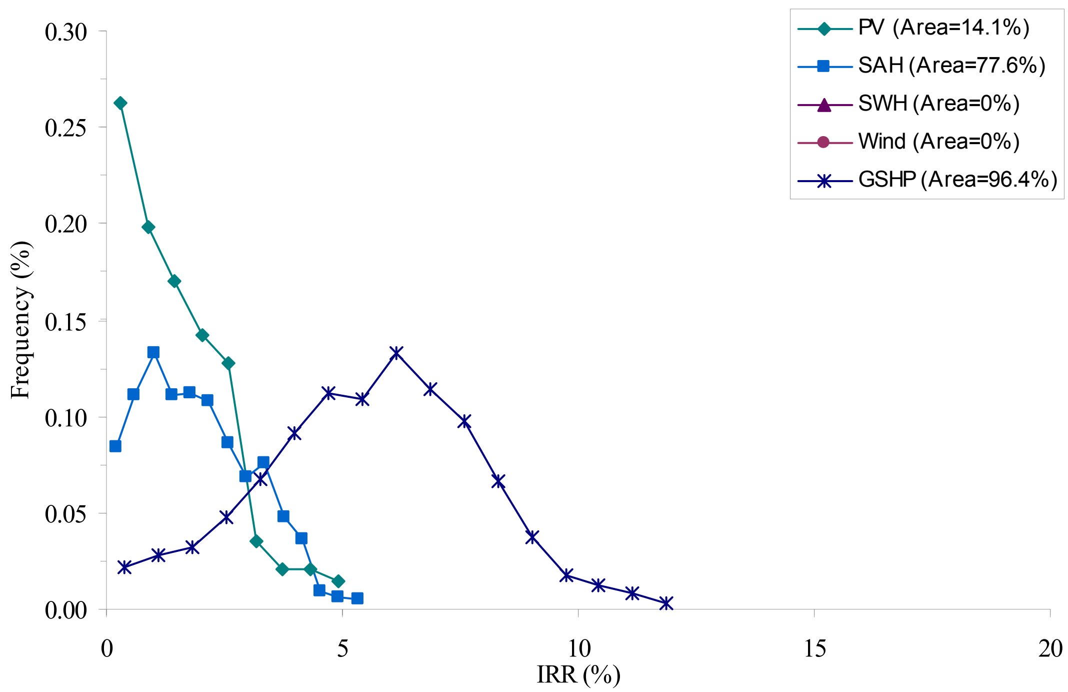


Figure 5.20: Homeowner Uncertainty Analysis Results

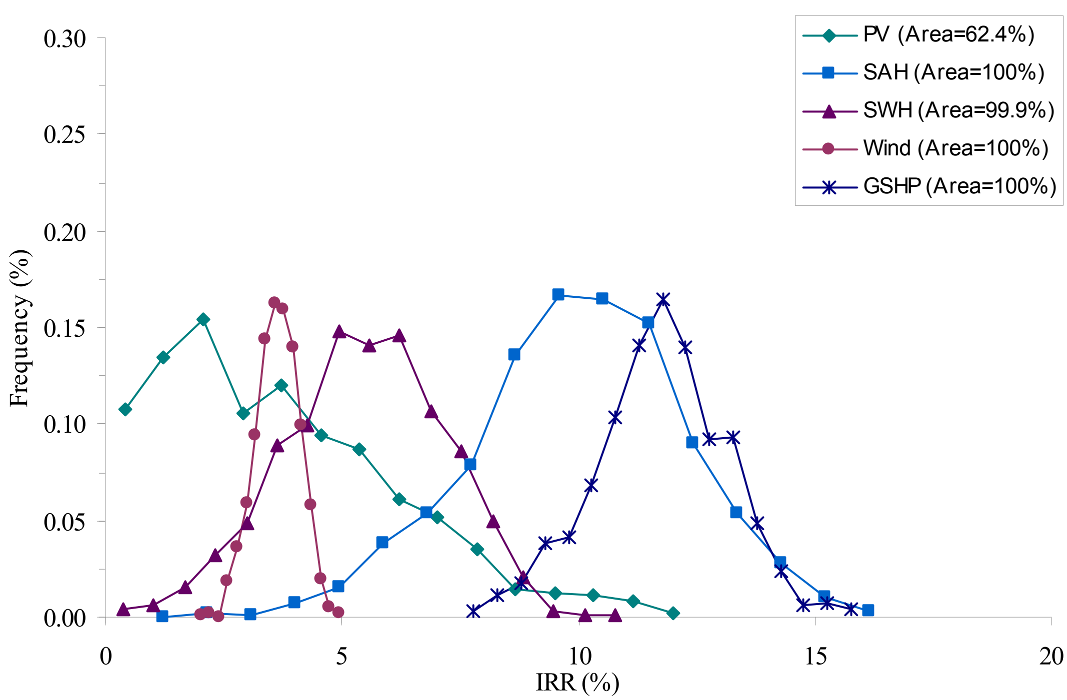


Figure 5.21: Commercial/Institution Uncertainty Analysis Results

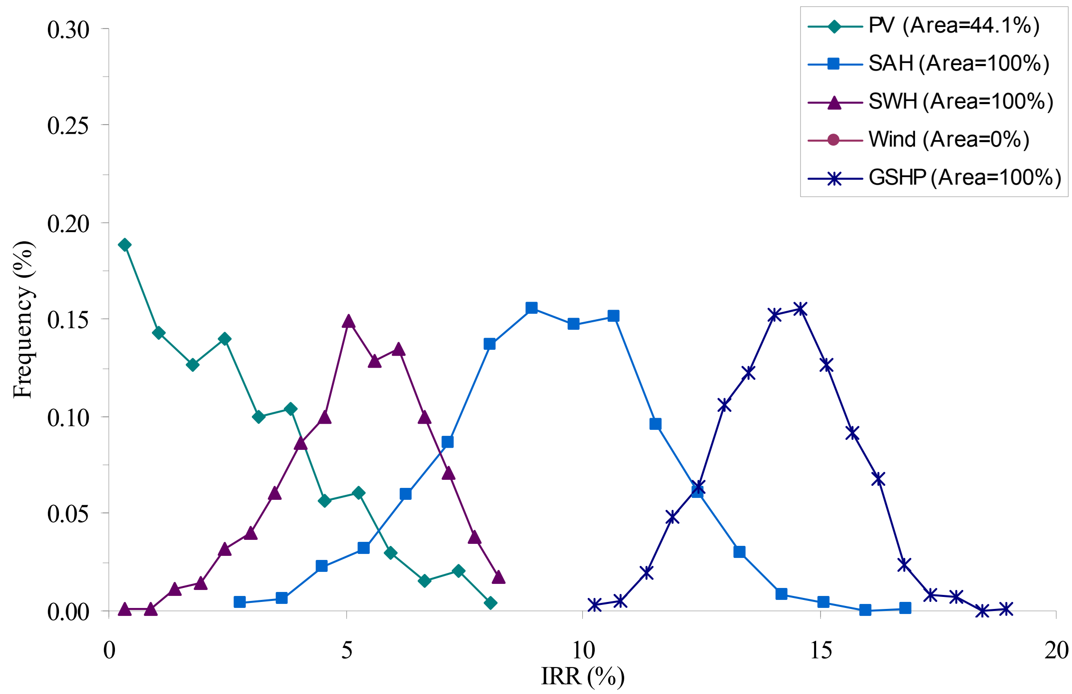


Figure 5.22: Small Business Uncertainty Analysis Results

5.4.3 Outcomes

Using the distributions resulting from the uncertainty analysis, coefficients of variation can be calculated (Table 5.2), plotted against average IRR (Figure 5.23), and compared to other common investments (Figure 5.24). Only those investments that show a probability of positive return around 100% are included in the calculation as the calculation breaks down when a large proportion of the returns are negative. For these cases the coefficient of variation would be much higher than those calculated for the 100% positive return cases. This comparison shows that the investments considered here are less risky than the more common investments and investments in energy star buildings. The alternative energy investments also offer larger returns in many cases. This indicates that there is a business case for investors to establish co-ops or similarly structured distributed means of installing alternative energy technologies.

Table 5.2: Coefficiant of Variation of Investment Pairs

	Homeowner	Commercial/Institution	Small Business
PV	--	--	--
SAH	--	0.21	0.22
SWH	--	0.63	0.26
Wind	--	0.13	--
GSHP	--	0.11	0.09

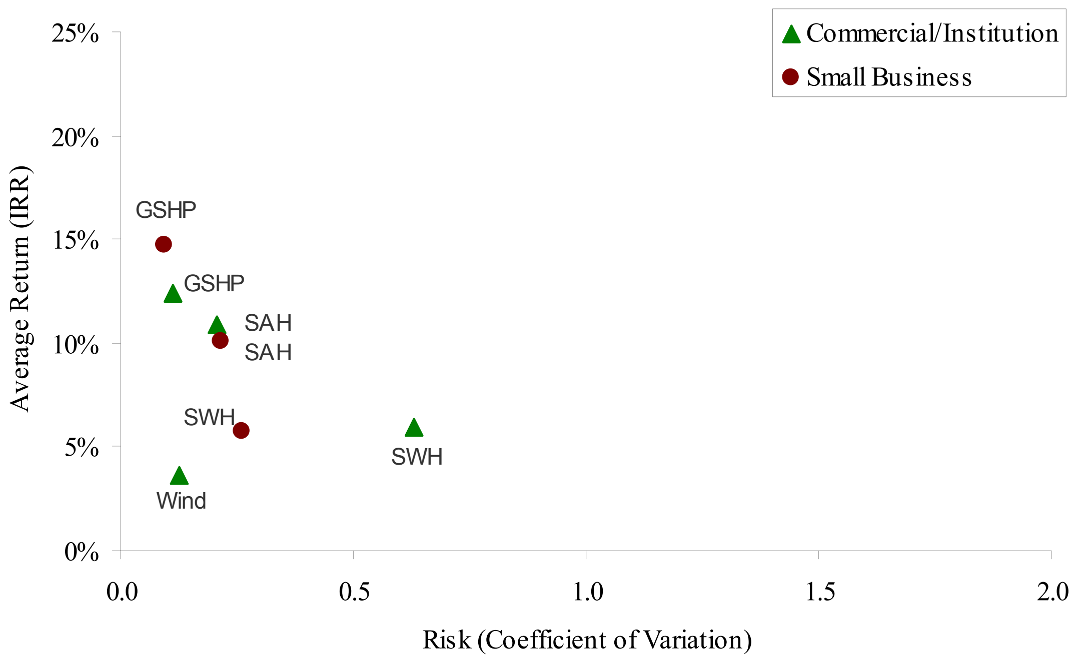


Figure 5.23: IRR vs Risk for Alternative Energy Investments

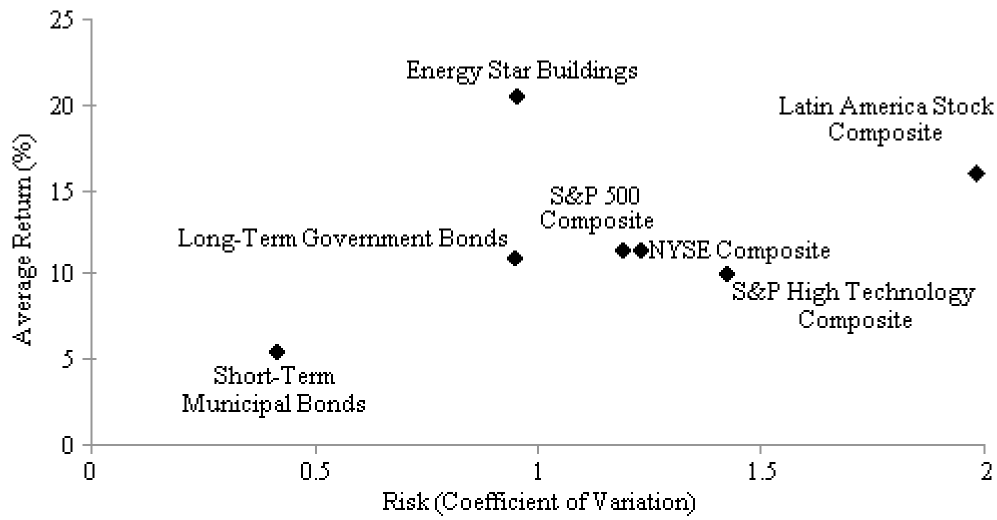


Figure 5.24: Return vs Risk for Common Investments
Adapted from Romm (1999)

5.5 Conclusions

This chapter has presented the primary findings resulting from the analysis of the data presented in the preceding chapters. Overall there is a wide variation in economic viability of the different audience technology pairs. GSHP systems offer the best returns and payback periods for all audience types while solar thermal technologies offer the next best returns and payback periods for non-homeowner audience types due to the available grants. These options also seem likely to provide positive returns in the face of several future natural gas price scenarios. The alternative energy investments perform better than the other common investment opportunities explored here. There are, however, instances where investment in the alternative energy sources considered do not make sense in the context of this baseline study, such as with PV, Wind in the non commercial and institution cases and homeowner SAH and SWH cases.

With the completion of this baseline, further studies could attempt to quantify and incorporate the other important factors relevant to these investment possibilities. These factors include: the marketing value from the use of alternative energy; the possible change in real estate value from the incorporating alternative energy; and the impact of different financing techniques. Finally, aspects of this analysis have shown how changes to government policies, such as with grants and tariff rates, could impact the viability of these projects. Although this report is not intended as a policy analysis these results could be useful for such work. This fact being especially relevant when issue of full life cycle costing, such as was performed here for alternative energies, are considered in planning for centralized grid electricity production.

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Appendices

A) Environmental Parameters

The below data describes the local details used for the study.[1]

	Unit	Climate Data	Project Location
Latitude	˚N		43.7
Longitude	˚E		-79.4
Elevation	m		107
Heating design temperature	°C	-17.1	
Cooling design temperature	°C	28.8	
Earth temperature amplitude	°C	21.3	

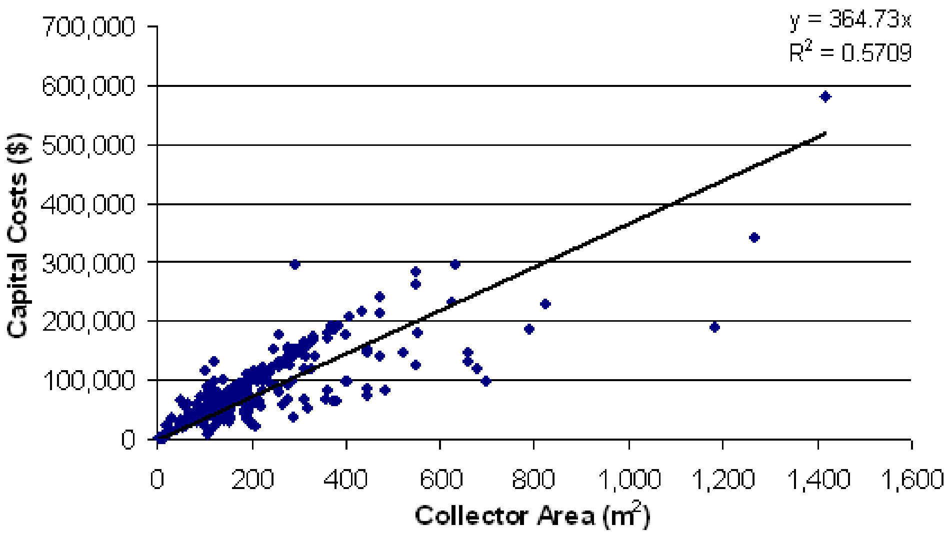
The following summarizes the environmental and weather conditions used for the study (data from measurements at ten metres).[1]

Month	Air temperature (°C)	Relative humidity (%)	Daily solar radiation – horizontal (kWh/m²/d)	Atmospheric pressure (kPa)	Wind speed (m/s)	Earth temperature (°C)	Heating degree-days (°C-d)	Cooling degree-days (°C-d)
Jan	-7.1	79%	1.44	99.5	4.7	-7.6	778	0
Feb	-6.2	77%	2.22	99.5	4.4	-5.9	678	0
Mar	-0.8	76%	3.36	99.5	4.5	-0.1	583	0
Apr	6.3	69%	4.5	99.3	4.4	7.4	351	0
May	12.4	68%	5.47	99.4	3.7	13.8	174	74
Jun	17.4	70%	6	99.3	3.4	18.7	18	222
Jul	20.5	70%	6.14	99.4	3.3	20.9	0	326
Aug	19.5	73%	5.14	99.5	3.3	19.5	0	295
Sep	15.2	75%	3.75	99.6	3.8	15.1	84	156
Oct	8.9	76%	2.47	99.6	4.3	8.8	282	0
Nov	3.1	80%	1.31	99.5	4.8	2.6	447	0
Dec	-3.2	81%	1	99.5	4.8	-4.3	657	0
Yearly	7.24	74%	3.57	99.5	4.1	7.5	4052	1073

[1]RETScreen (see www.retscreen.net for more information).

B) REDI Data

The data presented here is from the experience gained from the national Renewable Energy Deployment Initiative (REDI)[2] and is used in the study to price SAH and SWH systems.

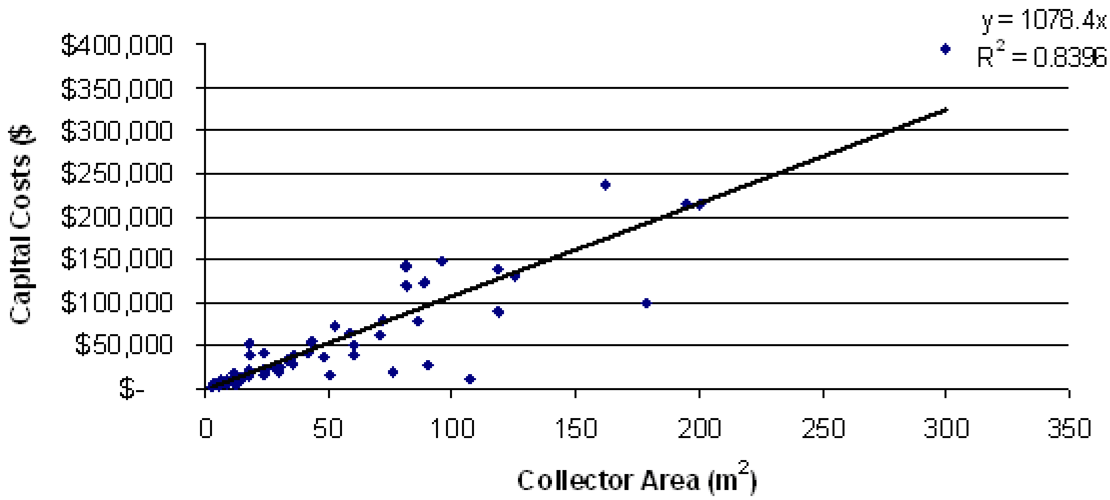


SAH Installed Costs from REDI Program 1998-2007

SAH Installed System Characteristics from REDI 1998-2007 (Kapoor, 2008)

Year	Fiscal Year	# of Systems	Collector Area (m^2)	System Costs ($)	($\$/m^2$)
1	1998-1999	5	2,180	$452,613	207.62
2	1999-2000	3	1,690	$403,190	238.57
3	2000-2001	6	1,127	$461,989	409.92
4	2001-2002	19	3,488	$1,396,633	400.41
5	2002-2003	26	4,319	$1,763,737	408.36
6	2003-2004	61	14,018	$5,671,247	404.56
7	2004-2005	33	7,462	$2,987,273	400.33
8	2005-2006	60	13,597	$6,302,702	463.53
9	2006-2007	69	17,675	$6,443,442	364.55
TOTAL	--	282	65,556	$25,882,826	394.82

[2] Kapoor, A. 2008. REDI System Costs, NRCan. Personal Communication.



SWH Sample of Solar Water Glazed Systems: Costs and Collector Area

Sample SWH REDI Installation Characteristics from 1998-2007

Technology	# of Systems	Average Collector Area per System (m2)	Average Cost per m2 ($)	R^2
Glazed	78	44.95	$1,032.73	0.84
Unglazed	27	143.71	$197.60	0.77
ETC	10	37.75	$1,374.80	Unavailable
Totals	115	67.51	$631.99	--