Community Solar Energy Initiatives in Toronto: Potential for City Involvement

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Cover Photo:
1-kW solar photovoltaic system on RISE participants' home,
Riverdale, Toronto, Ontario.
Photo from www.ourpower.ca

Executive Summary

In 2006, a new grassroots movement emerged in Toronto in the form of community solar energy initiatives. Neighbours are joining together to make bulk purchases of solar photovoltaic (PV) systems, using economies of scale to reduce costs and uncertainties for individual participants. These initiatives, though currently very small scale, help expand the local solar market and provide clean, distributed electricity to the grid, thereby benefiting the city at large. This is particularly important given Toronto's current energy situation of almost no local generation, constrained transmission capacity leading into the city, and high peak demand.

Despite discounts through group purchasing, the capital costs of PV remain very high compared to their electricity generating potential. At present, solar photovoltaic systems will not pay for themselves within their expected lifetime of 30 years, even with very low-interest financing and revenues from the Province's new renewable energy Standard Offer Program (SOP). As a result, potential participation in community solar initiatives is limited to "early adopters" – those who are willing to lose money on the project or see very small returns on the investment in order to achieve non-financial goals.

Given the environmental, health, and long-term economic benefits of solar energy, and in light of municipal energy goals and mandates, the City should consider providing support to these community solar initiatives. The City can use financial incentives to leverage private investment, expanding participation beyond early adopters, and making Toronto a world leader in renewable energy policy. Building the local solar market now will help bring the price of solar-based electricity down to current prices for fossil fuel-based generation within 20 years.

In my analysis, I calculate and compare the projected costs and benefits of solar photovoltaics and solar thermal under the community initiative model to two other potential strategies to improve Toronto's energy situation: energy efficiency measures under a government incentive model, and local electricity generation from natural gas-fired power plants. Ultimately, the City's energy goals and priorities will determine what policy strategies should be followed.

If the City is primarily interested in reducing energy demand at the lowest cost, a focus on conservation and demand-side management would be most appropriate, including support for solar thermal technologies. If the City is primarily interested in increasing local generation capacity, gas-fired generation is the most scaleable option, with lower costs than photovoltaics and lower greenhouse gas emissions than coal. If the City is really committed to supporting local renewable energy generation, despite higher costs, support for solar power would make sense.

In order to bring the financial payback of solar PV to within an expected system lifetime of 30 years, and thereby expand the potential scale of the community solar initiatives, the City would need to provide or help secure additional financial incentives for solar investors. Such incentives could include a combination of: low-interest financing through a not-for-profit organization such as the Toronto Atmospheric Fund; grants to reduce upfront capital costs; extension of SOP contract periods; and increasing SOP payment rates for solar in line with general economic inflation rates. Support for community solar today will help move Toronto down the path to a more sustainable energy future.

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1 Municipal Support for Community Solar?

In 2006, a new grassroots movement emerged in Toronto in the form of community solar energy initiatives. Led by a handful of committed community members, neighbours are joining together to make bulk purchases of solar photovoltaic (PV) panels. These initiatives not only use economies of scale to reduce costs and uncertainties for individual participants, but also help expand the local solar market and provide clean, distributed electricity to the grid, thereby benefiting the city at large.

The first such initiative started in Riverdale in early 2006, and has since been replicated in three other downtown neighbourhoods. Hundreds of Torontonians have attended informational meetings about local solar initiatives. While the Riverdale Initiative for Solar Energy (RISE) is the only project that has progressed to the installation stage, the others are recruiting participants and requesting proposals from solar energy companies to deliver and install solar energy systems (including both photovoltaics and solar thermal water heating systems).

Given Toronto's current energy situation – almost no local generation, constrained transmission corridors, and high demand – should the City support (with money, regulations, or public promotion) these community initiatives? If so, what are some appropriate actions that the City could take to increase participation in the initiatives and associated benefits to the city?

In order to answer these questions, I will analyze the potential financial, environmental, and health benefits and costs of the projects, using the RISE as a case study for solar photovoltaic systems. In addition, I will use preliminary information from the West-Toronto Initiative for Solar Energy (WISE) as a case study for solar thermal hot-water systems. I will also describe how these solar initiatives fit into existing and proposed municipal policies and mandates related to energy and the environment, and how municipal support of these initiatives could help achieve the City's energy goals.

In my financial analysis, I will provide projections for energy generation from the solar initiatives (on an individual and aggregate basis), and calculate the financial paybacks and returns on investment for participants under various financing and incentive scenarios. In the environmental analysis, I will estimate potential reductions in greenhouse gas emissions through the displacement of coal- and natural gas-fired electricity generation by solar-based generation, and the associated cost per tonne of emissions reduction (based on my financial analysis). I will also identify the health benefits of reduced air pollution that arise due to reduced coal-fired generation. Finally, I will evaluate the scalability of these initiatives and the potential for replication across the city, to determine the likely magnitude of the related costs and benefits.

In addition to analysing the initiatives using financial, environmental, and scalability criteria, I will discuss the political considerations that might come to play in any municipal decision to support these initiatives, including a desire to help build a local solar industry, meet climate change targets or commitments, or compete with other municipalities to become world leaders in sustainability. Though harder to quantify, these imperatives may outweigh purely financial considerations.

Given Toronto's limited resources, any decision by the City to support a particular type of project or program will have associated opportunity costs. Therefore, I will compare the projected costs and benefits of solar photovoltaics and solar thermal under the community initiative model to two other potential strategies to improve Toronto's energy situation: energy efficiency measures under a government incentive model, and local electricity generation from natural gas-fired power plants. In the end, any decision to support these initiatives will depend on the City's priorities. Different priorities call for different courses of action, within a broader municipal energy strategy. Suggested courses of action will be discussed further in my recommendations.

Before analyzing these community solar initiatives, I will outline the context in which they developed. I will begin with a brief history of the Ontario power sector and recent moves to include renewables in provincial energy plans, most notably the Ontario Power Authority's Supply Mix Report and the new Standard Offer Program. I will also describe the Toronto energy situation in terms of supply and demand, and key actors in the local energy sector.

2 The Ontario Power Sector: Past and Present

2.1 The Ontario Hydro Monopoly

For the greater part of the twentieth century, the Province followed the model of the vertically integrated monopoly with Ontario Hydro, a Crown corporation, controlling generation – originally hydro-electric, and then coal and nuclear – as well as transmission and distribution. But by the 1970s, concerns were being raised about the corporation's planning process and its level of accountability. A series of commissions between 1972 and 1988[1] found that there was a lack of public input and accountability in the organization, and that Ontario Hydro was over-building capacity, without providing any planning rationale.

Starting in 1989, Ontario Hydro was required to come up with an integrated system plan that would provide justifications for any plans for new supply. Plans and proposals had to be brought before the Province and the public, and third-party assessors were brought in to comment on the proposals. In 1992, Maurice Strong became the CEO of Ontario Hydro, and declared it "a corporation in crisis." He realized it had overbuilt supply, and as the economy fell into recession, would not be able to sell enough electricity to pay off its debt. Strong laid off about five thousand employees – nearly a third of the staff – in an attempt to streamline the corporation.[2]

2.2 Liberalization of the Electricity Market

Under the administration of Premier Mike Harris, the generation-transmission-distribution monopoly was dismantled. With the introduction of the new *Energy Competition Act of 1998*, Ontario Hydro was broken into five separate entities: Ontario Power Generation (OPG), Hydro One Inc., the Independent Market Operator (now known as the Independent Electricity System Operator), the Ontario Electricity Finance Corporation, and the Electrical Safety Authority.[3]

In May 2002, the Ontario electricity market was finally opened to wholesale competition, with the introduction of a spot market, and retail competition for all consumers. Attempts had been made to reduce Ontario Power Generation's dominance over generation, but it still retained considerable market power. Municipal distribution companies, including Toronto Hydro, were not restructured, but were converted to for-profit enterprises with the option to privatize. Transmission remained the exclusive domain of Hydro One Networks.[4]

The Independent Electricity System Operator (IESO), a not-for-profit Crown corporation, was put in charge of the electricity exchange, managing the sale and purchase of power from generators, and arranging the dispatch of electricity to distribution companies. The IESO runs a

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[1] These included the Solandt Commission (1972-1974), the Porter Commission (1975-1980), and the Hare Commission (1988).
[2] Swift and Stewart (2004).
[3] *Bill 100,* 2004. Swift and Stewart (2004).
[4] Thomas (2004), pp. 5-6.

real-time market, collecting bids and offers for electricity generation until two hours before the energy is needed, thereby matching supply with demand. The IESO then issues its instructions to power suppliers based on the winning bids, who then provide electricity into the power system for transmission and distribution to customers.

Under the open market, electricity prices became increasingly volatile. Retail rates nearly doubled during the summer months, leading to massive public outcry. By November 2002, a mere six months after its launch, the retail market was suspended. Electricity prices for retail consumers were capped at 4.3 cents per kWh.[5] The short-lived experiment with liberalization was over. The Province returned to a centrally planned model, though some aspects of the 1998 restructuring have been retained.

2.3 The Emergence of Renewable Energy Policy: RFPs

While renewable energy (other than hydro-electric) could not compete with traditional electricity generation in a fully liberalized market due to its higher costs, the return to the central planning model allowed for greater integration of renewable generation into the supply mix. In 2003, as part of its plan for balancing supply and demand the Ontario government, under then premier Dalton McGuinty, set targets for renewable generation of 1,350 MW (5 percent of capacity) by 2007 and an additional 1,350 MW (to total 10 percent of capacity) by 2010.

On June 24, 2003, the government issued a Request for Proposals (RFP) for 300 MW of new renewable generation, which garnered 41 responses totalling 1,100 MW of proposed capacity. Proposals that passed the technical and financial evaluation set out in the RFP were then ranked according to price. From the original 41, the government selected ten projects totalling 395 MW of capacity to enter into contracts to supply renewable electricity capacity for a period of twenty years, beginning no later than December 31, 2007.[6]

As the RFP targeted renewable energy sources that could provide energy at the lowest price, it is unsurprising that the winning bids were all hydroelectric, wind, or landfill gas projects. In addition to the market-based design of the RFP, the bidding process was criticized for being cumbersome, bureaucratic and costly.[7] Solar electricity, along with most other small-scale, distributed generators, was effectively excluded from the process.

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[5] Thomas (2004), p. 6.
[6] Ontario Ministry of Energy (2004a and 2004b).
[7] "Standard Offer Contracts - the Future for Renewable Generation?" (2006).

2.4 OPA and Integrated Power System Planning

In August 2003, a massive blackout hit Ontario, reinforcing concern over electricity system reliability and adequacy. Wary of leaving such an important public good to the market, the Provincial government passed *Bill 100, the Electricity Restructuring Act*, in December 2004. As a result of this restructuring, both public and privately owned companies control the energy supply and distribution systems, and the provincial government is able to shape the system through soliciting planning advice and issuing policy directives. *Bill 100* also created the Ontario Power Authority (OPA). Laden with a forecasting and supply mandate, the OPA is in charge of creating a twenty-year Integrated Power System Plan.[8]

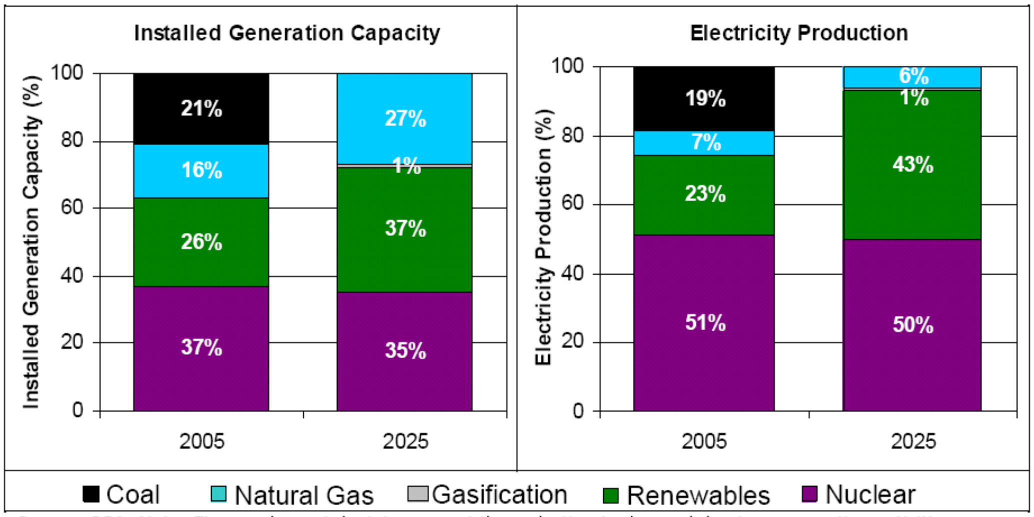
2.5 Renewables in the Current Supply Mix and Projections

According to the IESO, close to 13,000 MW of Ontario's forecasted electricity demand will need to be met with new supply or demand-side resources by 2014.[9] This compares to the 31,209 MW of installed capacity in Ontario as of February 2007,[10] of which up to 80 percent will become obsolete or require significant repair within the next fifteen years.

In December 2005 the OPA published its *Supply Mix Advice Report*, outlining the planning goals of Ontario energy provision. The proposed supply mix in 2025 consists predominantly of new nuclear generation, but will also include 1,800 MW to 6,700 MW (5 to 18 percent) of capacity from new renewable energy sources, and 1,800 to 4,300 MW (5 to 12 percent) of conservation and demand management [see Figure 1]. This is in line with current Provincial policies that establish three priorities related to electricity provision: creation of a conservation culture, preference for renewable energy sources, and replacement of coal-fired generation due to environmental and health concerns.[11]

[8] *Bill 100* (2004). Swift and Stewart (2004).
[9] Independent Electricity System Operator (2007b).
[10] IESO (2006).
[11] *Bill 100* (2004). Ontario Power Authority (2005), pp. 3-4.

Figure 1: OPA's Electricity Supply Development Plan[12]



Source: OPA; Note: Figures shown take into account the reduction in demand due to conservation activities

2.6 Standard Offer Program

In order to meet these renewable energy capacity goals, the Province announced the creation of the new Standard Offer Program (SOP) in March 2006, run by the Ontario Power Authority. The program is based on the Advanced Renewable Energy Tariff model widely used in European countries, most notably Germany.

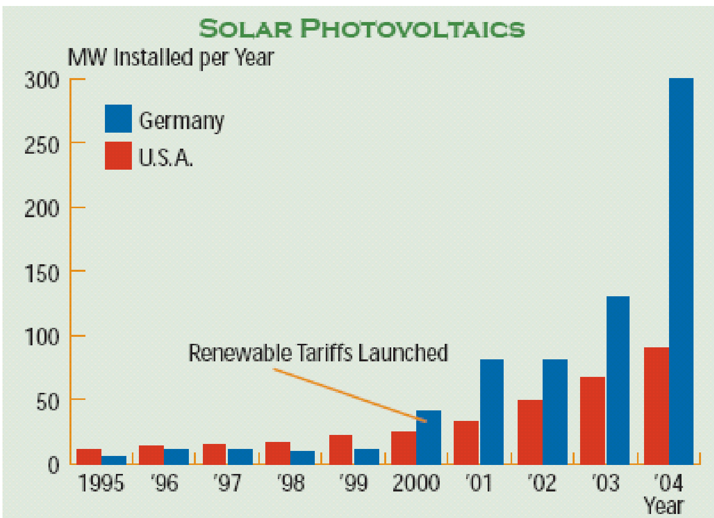
The SOP will pay a premium to small-scale (less than 10 MW) renewable electricity generators under 20-year contracts, thereby stimulating renewable energy investments in the province. Under the program, solar photovoltaic generation will receive $0.42 per kilowatt hour, the highest rate of any of the renewable energy sources due to its significantly higher cost.[13] This compares to the $0.09 per kilowatt hour currently paid by Ontario consumers for delivered electricity, but is actually lower than the peak prices paid to generators on the spot market during periods of extremely high energy use in the province.

Despite this high rate for solar-based electricity, the program is not expected to make solar photovoltaics commercially viable. Rather, the program was designed to encourage early adopters and thereby start to build the local solar industry. This is less ambitious than the European programs, which provide significantly higher payments, resulting in considerable investment in the industry.

[12] Ontario Power Authority (2005), p. 1.
[13] Under the SOP, wind, small-scale hydro, and biomass generators will receive $0.11/kWh, and 20 percent of this base rate will be indexed for inflation according to the year-over-year change in the Consumer Price Index.

Germany, for example, pays solar-based electricity generators $0.92/kWh, resulting in the installation of roughly 700 MW of new capacity in the four years following the introduction of their renewable tariff in 2000 [see Figure 2].[14] In comparison, Canada had less than 14 MW total of installed capacity in 2004.[15] Despite the fact that Germany receives even less sunlight than Ontario, 110,000 solar electric systems had been installed by the end of 2004, the majority owned by individuals and small businesses. In addition to the new, clean, generating capacity, the German ministry for the environment estimated that around 15,000 people would be working in the German solar industry by 2005.[16]

Figure 2: Growth of Solar Photovoltaics in Germany with Renewable Tariffs (compared to U.S., without)[17]



The OPA projected total installed solar photovoltaic (PV) capacity of 20-40 MW in Ontario by 2025 thanks to the SOP.[18] The Canadian Solar Industry Association (CanSIA) was more optimistic, projecting 40 MW of installation (on 15,000 homes) by early adopters within five to ten years of the program launch, assuming an "adequate" tariff level. After that, they predict the market could sustain growth rates of 30-35% annually, comparable to current international rates. This would result in 1,200 MW of installed capacity (on 400,000 homes) and 10,000 new jobs by 2025.[19] Both of these projections are quite modest compared to Germany's

[14] Gipe, Doncaster, and MacLeod (2005), pp. 16, 27.
[15] BP (2006).
[16] Gipe, Doncaster, and MacLeod (2005), p. 16.
[17] Gipe, Doncaster, and MacLeod (2005), p. 16.
[18] McMonagle (2006c), p. 1.
[19] McMonagle (2006b), p. 5.

program results, or Japan's official supply mix projection, which targets the installation of 100,000 MW of PV by 2030,[20] but are probably more realistic, given the lower tariff rate in Ontario.

2.7 Interval Meters and Net-Metering

Most Ontario consumers pay a steady electricity rate under the IESO's Regulated Price Plan, regardless of the price of electricity generation on the spot market. New "interval" or "smart" meters, though, track consumption in 15-minute blocks, allowing consumers to join a plan in which they pay different rates based on the time of day during which they use electricity. These rates reflect the different costs of wholesale electricity during periods of higher and lower electricity demand, and are expected to help motivate consumers to shift their electricity demand to periods when prices are lower. This would reduce peak demand in the province, and the amount of new generation capacity that would otherwise be required in the system. An initiative to install smart or interval meters in all homes and businesses across Ontario by 2010 is currently under consideration by the provincial government, and all commercial and residential consumers in Ontario's major urban centres are expected to switch to smart meters by the end of 2007.[21]

Two-way interval meters would also allow small-scale renewable energy generators, such as homeowners with solar PV panels, to take part in "net-metering" programs. With net-metering, owners are able to buy electricity from the grid when their renewable energy system is not producing enough electricity to meet their own demand, or sell excess electricity back to the grid when their production outweighs personal demand. With interval meters, these small-scale generators could be paid spot market prices for the electricity they deliver to the grid. This would be particularly beneficial to solar PV, which produces electricity during the time of day when demands for electricity also peak, along with wholesale prices.

3 Toronto's Electricity Situation

At the municipal level, the City of Toronto has its own targets for conservation and demand management, as well as electricity generation. Toronto also receives increased attention from the OPA, not only because it is the biggest economic and population centre in the province, and the region with the greatest electricity demand (consuming almost 20% of the electricity

[20] McMonagle, (2006b), p. 5. As of 2004, Japan had already installed 1,132 MW of PV. BP (2006).
[21] Ontario Energy Board (2007).

produced in Ontario – see Figure 3 for Toronto electricity demand statistics), but because of its particular situation in the electrical generation and transmission system.[22]

Figure 3: Toronto Electricity Demand at a Glance[23]
Population: **4.63 million**
Households: **1,634,755**
Toronto's Annual Electricity Consumption (2005): **26,372,169 MWh**; **$2.69 billion**
Toronto Peak Electricity Demand (2005): **5,005 MW**
Toronto Hydro Residential Customers: **597,469** Share of city-wide electricity use: **22%**
Toronto Hydro "General Service" Customers: **79,163** Share of city-wide electricity use: **10%**
Toronto Hydro "Large Users"[24] : **47** Share of city-wide electricity use: **68%**
City (Agencies, Boards, Commissions and Divisions) Electricity Consumption (2005): **2,043,519 MWh; $177 million** Share of city-wide electricity use: **8%**

3.1 Electricity Imports and Constrained Transmission

Toronto is one of the biggest cities in North America without significant power generation within its borders.[25] Only 1.2% of Toronto's electricity demand is met with local generation, while the remainder is met with electricity imports from elsewhere in the province (or beyond), delivered through only two transmission corridors, which often operate at close to their maximum capacity.[26]

Ontario's Independent Electricity System Operator (IESO) has warned that unless action is taken to address Toronto's increasing demand for electricity, the city may face rolling power blackouts by 2008. It advised that "250 megawatts of generation is needed within Toronto by 2008 and an additional 250 megawatts by 2010 to offset a growing risk of blackouts which could occur within 24 months."[27]

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[22] Average electricity demand in Toronto is 3,500 MW, distantly followed by Ottawa at 1,000 MW and Hamilton at 700 MW. IESO (2007),Ontario Clean Air Alliance (2006), p. 1.
[23] Statistics Canada (2001). IndEco (2006), p. 27.
[24] THESL defines large users as customers with monthly peak demands of 5,000 kilowatts or greater. IndEco (2006), p. 27.
[25] Cansfield (2006).
[26] Ontario Clean Air Alliance (2006), p. 1.
[27] Independent Electricity System Operator (2005a), pp. v-vi.

Toronto has already experienced a major blackout, in August 2003, triggered by a power disturbance hundreds of kilometres away in Ohio. The largest blackout in North American history, it affected 50 million people in the north eastern United States and Ontario, and raised many concerns about the reliability of the electrical grid system.[28] This precarious situation of constrained transmission and negligible local generation in which the city now finds itself has prompted calls for conservation and new local supply.

4 Community Solar Energy Initiatives in Toronto

4.1 Solar Pioneers

Inspired by Greenpeace's "Solar Pioneers" campaign [see Appendix A], a new movement has sprung up in Toronto: community solar energy initiatives. Led by a handful of committed community members, neighbours are joining together to make bulk purchases of solar photovoltaic (PV) panels, and helping expand the local solar market. By requesting bids from various solar energy companies through a Request for Proposals, organizers use economies of scale to reduce the unit costs for participants. They also reduce the legwork for participants by researching and choosing qualified companies, and providing complete packages (including grid-tied panels and invertors, installation, and all warranties[29]).

4.2 Riverdale Initiative for Solar Energy (RISE)

The first such initiative, the Riverdale Initiative for Solar Energy (RISE), took off in early 2006, and solar systems were being installed by mid-summer. Organizer Ron McKay, one of the original "Solar Pioneers," coordinated a grassroots informational campaign, using local media, store flyers, and word of mouth to advertise the program, resulting in a community meeting and informational session attended by 150 Riverdale residents in March 2006.[30] Solera Sustainable Energies Company, a local solar energy company and winner of the RISE Request for Proposals (RFP) bidding process, was on hand to show off the technology and answer questions. Seventy percent of attendees signed up for a site inspection to determine their house's potential for generating solar power, and about 90% of these had suitable locations for a photovoltaic panel.

[28] Hydro One (2003).
[29] WISE (2006).
[30] McKay (2006e).

Solera was able to offer a standard installation 1-kW grid-tied system with all warranties at $9,513 – about a 20% discount over retail prices. Larger systems resulted in even greater discounts for RISE participants, ranging from 25-30% (with 2-kW systems at $16,680, or $8,340/kW; 3-kW systems at $23,960, or $7,987/kW).[31] RISE was also able to arrange preferential financing for participants through TD Financial's green initiatives department.[32]

As of July 2006, 34 residents had decided to proceed with the project, purchasing systems from 1 to 3.8 kW in size. This means that over 20 percent of the attendees at the original informational session decided to make investments of $10,000 and more in solar technology, even before details of the OPA's Standard Offer Program were announced. An additional 37 RISE members are still considering purchasing a system, which could bring the participation rate up to nearly 50 percent.[33]

4.3 West-Toronto Initiative for Solar Energy (WISE)

A second group, the West-Toronto Initiative for Solar Energy (WISE), has come together in Toronto's St. Clair-Wychwood neighbourhood, modelled after the successful RISE initiative and organized by local resident Jed Goldberg.[34] Three community informational meetings have generated considerable interest, with a combined turnout of several hundred citizens, and preferable financing has been arranged through Royal Bank Canada. WISE's volunteer-based organizational committee is currently determining details of the initiative, and hopes to release an RFP this winter for quotes on both photovoltaic and solar thermal panels.[35]

Goldberg began organizing WISE shortly after hearing the March 2006 announcement of the Province's new Standard Offer Program (SOP), excited about the prospect that the incentive would allow more individuals to take part. Participants are counting on the program to make these solar investments economically viable, or at least to reduce costs to an acceptable level. Without the SOP, system payback periods would exceed the lifespan of the panels (generally quoted as 25-30 years, though CanSIA notes that early PV models are still generating electricity over 40 years later), while a standard offer contract could reduce that period to closer to two

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[31] McKay (2006e).
[32] Lane (2006). Ron McKay, phone interview with Danielle Murray, 18 August 2006.
[33] McKay (2006e).
Gregory Lane, "Solution's Sold and In Progress," Announcement on RISE homepage, 4 July 2006, viewed 18 January 2007 at Lane (2006).
[34] Goldberg is also president of Earth Day Canada.
[35] Interviews with Jed Goldberg and Chris Chopik (2006).

decades given very low financing rates. The payback on these investments is expected to be very long, in any case, and investors will make their money back only if they are able to secure very low financing (considerably lower than the financing offered through the community initiatives), and if they have an ideal site for their panels in order to maximize electricity generation.

4.4 Replication: Downtown-West Solar Initiative, GRASP

The RISE model has been replicated elsewhere in the city, as well as elsewhere in Ontario. Tim Grant and David Booz of the Harbord Village Residents Association have joined with Bathurst Quay Residents in creating the **Downtown-West Solar Energy Project**. The first public meeting, hosted by Councillor Martin Silva on September 26, 2006, attracted close to 200 community members, and organizers actually had to turn away people at the door. Solera representatives were again on hand to answer questions from attendees, and display system models. [36] A second meeting focused on opportunities for multi-unit residences, such as condominiums, co-operatives and apartment towers, to get involved.

The community solar initiative concept has even moved beyond the GTA, with the development of "GRASP" – Guelph Residents Advocating Solar Power. Organizers are currently gauging interest in the idea, and in November 2006, representatives from GRASP met with Guelph Hydro, who reportedly expressed encouragement and support for the initiative. To reduce the costs associated with metering, disconnection, and safety inspection of individual solar energy systems, the organization is considering centralizing the project, perhaps in partnership with a commercial landlord with roof space for a bigger project, rather than each participant installing a system on his or her own roof. This idea was also proposed at the Downtown-West informational meeting. While it would reduce costs, organizers are concerned that such a move would detract from the grassroots nature of the projects, and reduce the personal behavioural changes that often come with having a solar energy system installed on one's own home. [37]

4.5 Early Adopters

These community solar initiative participants are classic "early adopters," motivated to take part primarily for environmental and political reasons, rather than financial considerations. They tend to be long-time solar supporters. As RISE participant Nola McConnan noted, "It was

[36] The author attended the original Downtown-West informational meeting.
[37] GRASP (2006).

just a matter of time and money before the panels went on. I have been a solar supporter since the late '50s with the launch of the first weather and communication satellites with their tiny photo voltaic cells."[38] Similarly, participant Dave Ullrich wrote that, "We have been interested in solar power for years and the opportunity to join a buyers' group with RISE made the decision easy for us."[39]

McConnan also cited broader economic and environmental rationales for installing her solar photovoltaic system: "This is a silent partner that can employ a vast army of Canadians locally for installation, construction and maintenance, nationally for manufacture. It eliminates or at least reduces the need for environmentally and agriculturally unfriendly transmission corridors."[40]

Riverdale homeowners Susan and Bruce Crofts provided explicitly political intentions behind their decision to purchase PV panels through RISE: "We want to send a message to the federal and provincial governments and OPG that homeowners can and want to act to solve the problem of peak demand for electricity. We are trying to draw attention to the fact that there are options to the 550 MW power plant planned for the Portlands. We want to create a demand for government financial incentives for the capital costs of PV solar systems for homeowners."[41] This is echoed in RISE promotional materials, which critique gas-fired power plant "mega projects" and call on the government to develop a long-term strategy for sustainable energy for Ontario.[42]

In addition to helping shape the political and market situation for solar, participants are motivated by a sense of personal responsibility to future generations. As one resident concluded, "The best part of all is that you are doing the right thing for your family now and well into the future."[43] Solar installations are not seen as for-profit financial investments, but rather as investments in the value of their homes, or as a personal amenity.

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38 RISE (2006b).
39 RISE (2006a).
40 RISE (2006b).
41 RISE (2006c).
42 McKay (2006b).
43 RISE (2006a).

5 Economic and Environmental Analysis of Community Solar Initiatives

5.1 Economic Analysis of Solar Photovoltaics

Despite steeply decreasing prices since the 1970s,[44] solar photovoltaics (PV) remain quite expensive compared to conventional energy sources. That is why solar generators receive considerably higher payments under the Standard Offer Program than do other renewable electricity generators, such as wind and biomass. While this is a large incentive for early adopters to invest in solar power, it is still not be enough to make photovoltaics financially viable – that is, to reduce the payback period to within the system's lifespan – and it certainly will not produce a return on investment high enough to attract profit-oriented individuals or businesses.

The cost of the PV electricity depends on several factors, including: capital costs, operation and maintenance costs, interest rates, insurance, rated system size, average annual solar radiation on the panels, panel and balance-of-system efficiencies, lifespan of the panels, and levels of renewable energy production incentives, such as the SOP. In my analysis, I have used data from RISE and Toronto climate data to calculate anticipated electricity generation and costs. I then created several alternative scenarios by changing variables related to financing and incentives, while the underlying physical system attributes (and so electricity generation) were held steady. [45]

In my analysis, I examine the economics of a $24,000, 3-kilowatt system, as these larger systems provided the biggest cost reductions through the bulk-purchase agreement. The system price for RISE participants included all equipment, installation, and warranties, and I have assumed that the nominal system size refers to AC electricity delivered to the grid by the system (which would account for both panel and balance of system efficiencies). There may be additional costs of participating in the SOP, including obtaining an Ontario Energy Board generator licence, buying an interval meter, and maintaining a separate utility account for generation. [46] These have not been included in my calculations, as details have yet to be determined by the OPA and Toronto Hydro. While maintenance costs are very low with solar photovoltaics, I assume an average annual cost for operation and maintenance of one percent of the original capital cost starting after the warranties expire at the end of year twenty. Educational

[44] See the Solar Energy Industry Association for historic price data, www.seia.org.
[45] See Methods Appendix for details.
[46] "Standard Offer Contracts - the Future for Renewable Generation?" (2006).

materials from the community initiatives indicate a payback period of roughly 15 years.[47] The following analysis, though, shows that payback periods are likely to be considerably longer, and under currently available financing terms and government programs, the systems will not pay for themselves over the course of their life.

5.1.1 Base Case: RISE

In the base scenario, I examine the economics of the financing plan (through TD Financial) arranged by RISE: zero down, 60-month term, 120-month amortization, at 8.25%.[48] I also assume that the systems are grid-tied, and that owners take part in the Standard Offer Program, as the financial returns from the SOP far outweigh the savings of $0.09/kWh that would be achieved by using the system to reduce household electricity demand from the grid. Under the final rules of the SOP, these owners would receive $0.42 per kilowatt-hour produced for 20 years. Unlike the payments for other renewable energies under the SOP, or the renewable tariffs for solar in Europe, the SOP payments to solar generators are not tied to inflation rates.[49] Therefore, payments will actually have decreasing real values over the course of the contract.

When the SOP contract ends, owners are expected to take part in net-metering, selling their electricity to the grid at market prices. I assume in my analysis that the price of electricity does rise with inflation (in fact, it is expected to rise faster than general economic inflation due to increases in fuel costs, but to be conservative, I have calculated total inflation of net-metering rates at 2 percent per year, on par with anticipated general inflation). As such, the nominal value of income from net-metering rises each year, even though electricity generation from the PV system is assumed to stay constant.

In order for the solar panels to pay for themselves within the 20-year SOP contract period, the levelized cost of electricity[50] from the panels must drop below the $0.42 per kilowatt-

[47] Our Power (2007).
[48] Lane (2006). Normally, the amortization period is simply the length of time over which a loan is paid back. If the amortization period is longer than the loan term, as in this case, the size of the monthly payments is based on the amortization term, but at the end of the loan term, the debtor has to make one large payment to pay off the remaining value. This is also known as a "balloon payment." In my financial analysis below, I have assumed a more straightforward loan term of 120 months. As a result, the financial paybacks under the actual RISE financing would be even more onerous than what I have calculated.
[49] Under the SOP, wind, small-scale hydro, and biomass generators will receive $0.11/kWh, and 20 percent of this base rate will be indexed for inflation according to the year-over-year change in the Consumer Price Index.
[50] Also known as "levelized unit electricity cost" or LUEC, it is the present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments, levelized in real dollars (i.e. discounted to remove the impact of inflation).

hour paid under the SOP. Based on my analysis, the cost of solar PV electricity in Toronto never drops below this 42 cent horizon, even if the project is entirely self-financed by the homeowner at very preferable rates, similar to those of a home mortgage (5 percent over 20 years). The levelized cost in this base case ranges from $0.45/kWh if self-financed at 5% interest over 20 years, to $0.85/kWh if externally financed at 8.25% interest over 10 years . Only when government incentives are increased or the terms of the SOP are changed do the systems exhibit positive financial paybacks within their lifespan.

Under the financing plan promoted by RISE, the homeowner would actually lose money over the life of the system – over $20,000 by year 30 (giving an annualized return on investment of -2.8% over 30 years). If the system is fully self-financed by the homeowner at 5 percent interest per year (due to the opportunity costs), the payback is still negative over the life of the system, but much less daunting; owners could expect to lose roughly $3,000 on the investment by the end of year 30 (an annualized ROI of –0.5%; accounting for the interest the homeowner paid to his or herself, the ROI improves to 1.6%). This would be acceptable for early adopters, and perhaps a larger group of slightly more conservative green enthusiasts as well.

5.1.2 Alternative Scenarios: TAF Loan, SOP Changes, and Rebate

Given the very long or negative paybacks on these photovoltaic systems, I investigated the effect of changes to SOP contract terms, low-interest financing through the Toronto Atmospheric Fund (TAF),[51] and the addition of a municipal incentive in the form of a tax rebate or similar upfront grant for capital costs. The four new incentive scenarios examined are:

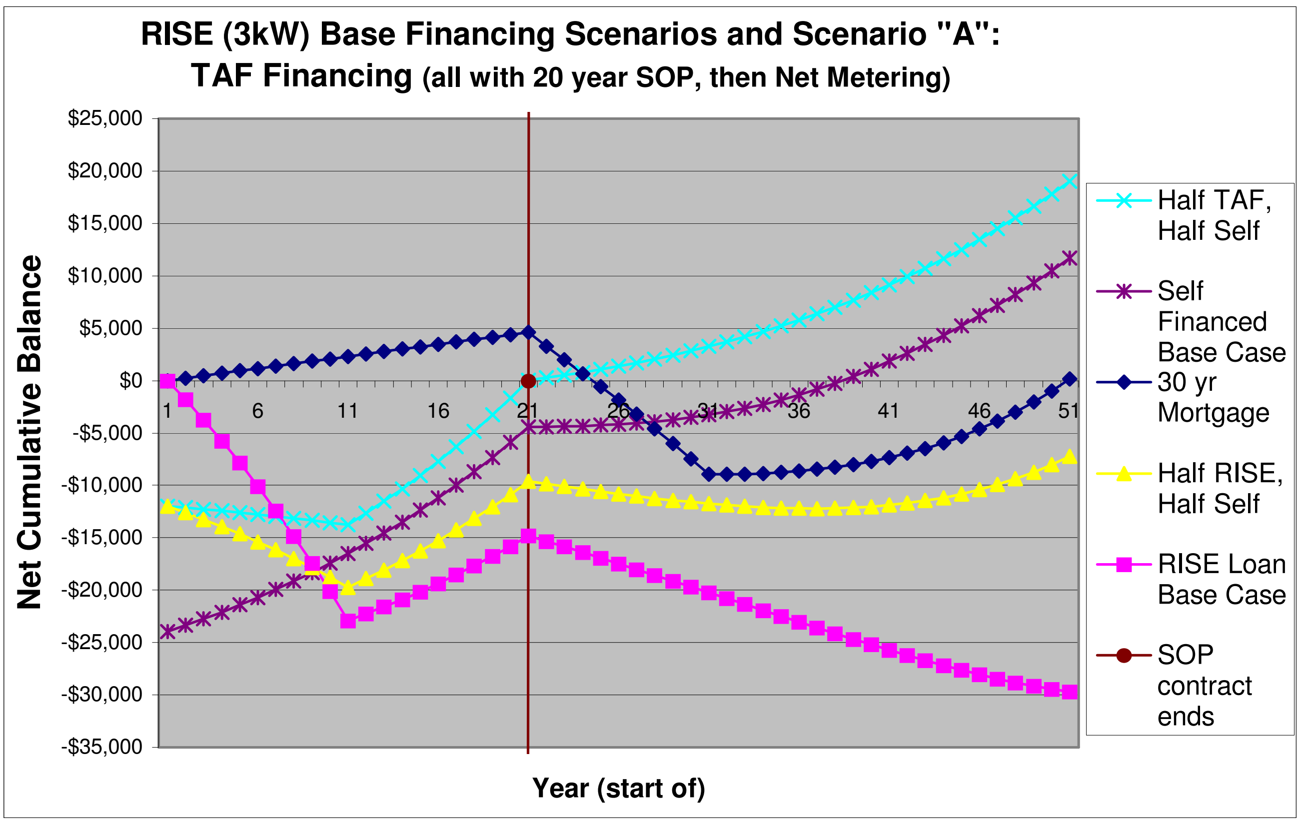
A. Provide TAF financing (2% nominal interest, 10 years) to cover half of capital costs;
B. Rebate of $2,000 from the municipality;
C. Index 20 percent of SOP solar payment rate economic inflation rates;
D. Extend SOP contract length to 30 years.

Under **Scenario A**, TAF would provide an essentially interest-free loan (2% nominal interest rate, but 2% expected economic inflation) to cover half of the system capital costs. The

[51] "The Toronto Atmospheric Fund (TAF), established by the Toronto City Council in 1991 with a $23 million endowment, offers support for projects with the potential to mitigate global climate change and improve Toronto's air quality. City of Toronto agencies and departments, non-profit organizations, registered charities, and public institutions and schools are eligible to apply for grants and loans in the areas of renewable energy, energy conservation and efficiency, and reduced fossil fuel content of energy sources." Fitzgerald et al. (2004), p. 8.

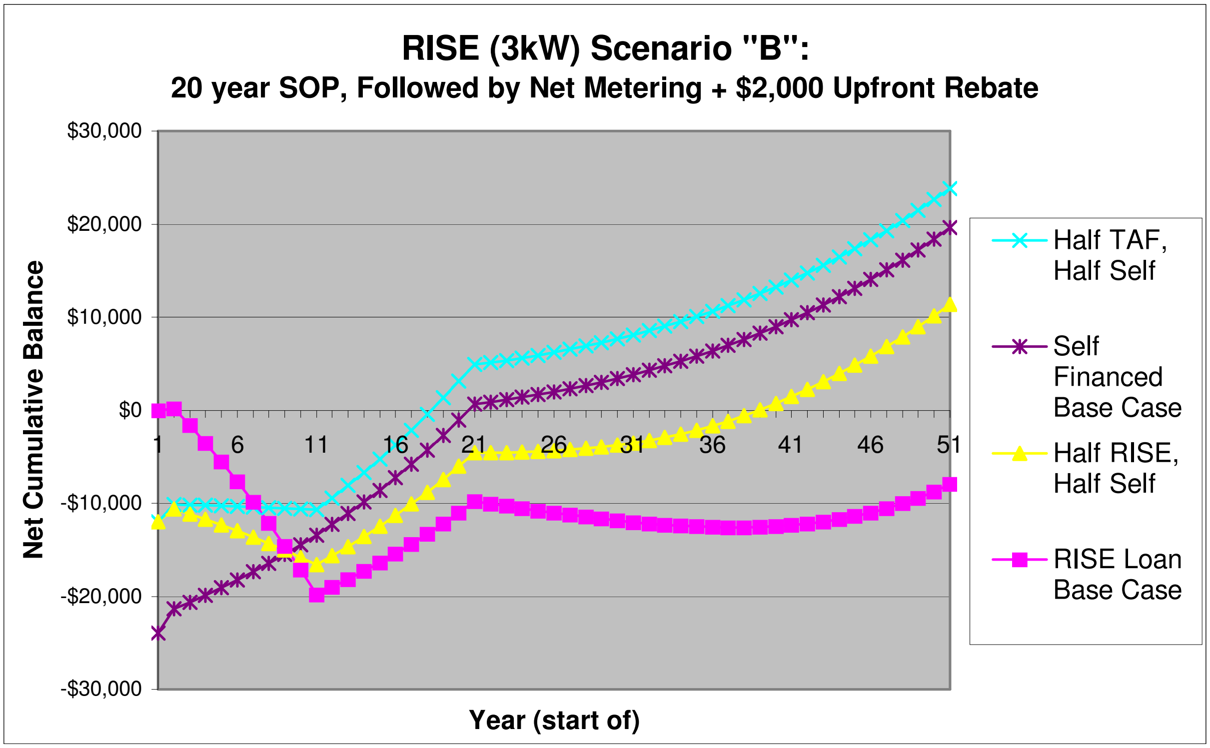
homeowner would self-finance the remainder of the costs (again, at 5% nominal interest). This is the only scenario in which the system pays for itself within the 20-year SOP contract term without changes to the SOP and without the addition of other financial incentives [see Figure 4]. After the system is paid off, it would turn a profit for the remainder of its operating life, as net-metering payments outweigh operating and maintenance costs. By year 30, the system would turn a profit of $3,250, providing an annualized ROI of 0.4%.

Figure 4: Financial Paybacks for RISE (3kW) Base Financing Scenarios and Scenario "A": TAF Financing
(All with 20-year SOP, followed by net metering)



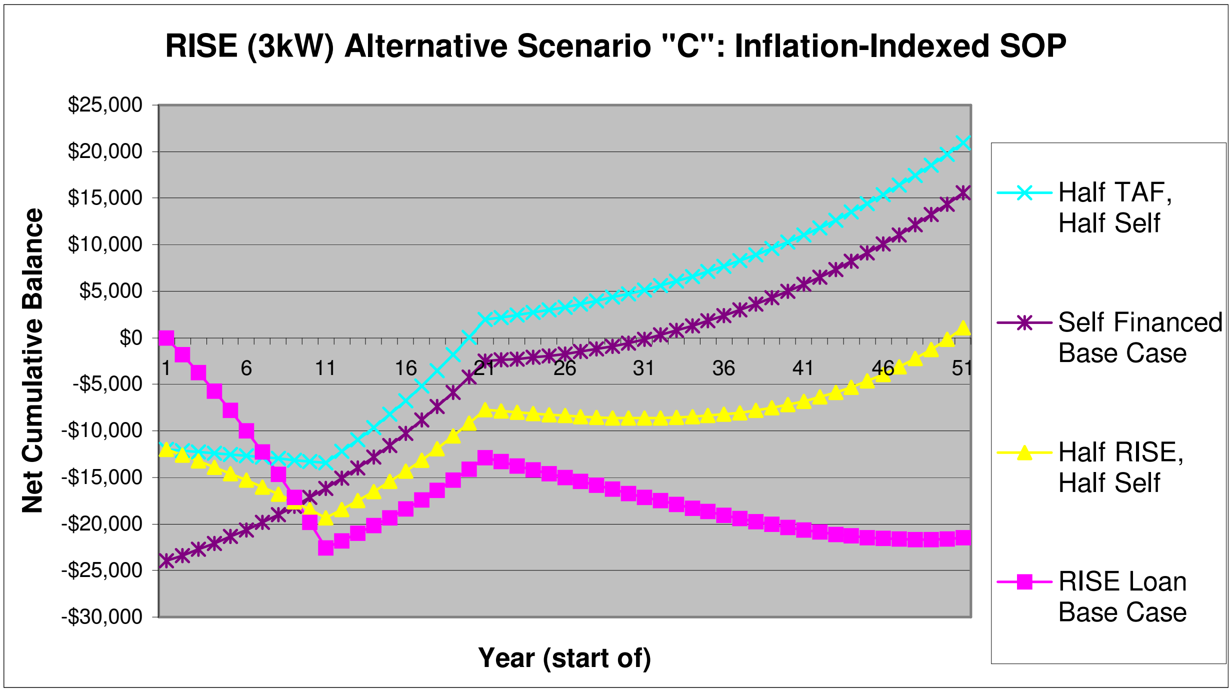
Under **Scenario B**, in which homeowners receive a $2,000 rebate on capital costs, the system payback length drops to exactly 20 years (that is, the levelized cost of the electricity from the system is equal to the SOP rate) for homeowners who fully self-finance the project. By year 30, the system would turn a profit of $3,850, providing an annualized ROI of 0.5% (or 1.8% if the interest paid to oneself is included). If the rebate is combined with a TAF loan, the profit jumps to $8,080 by the end of year 30, increasing the ROI to 1.0% (or 1.7% if the interest paid to oneself is included) [see Figure 5].

Figure 5: Financial Paybacks for RISE (3kW) Scenario "B": 20-year SOP, followed by net metering, with $2,000 upfront rebate



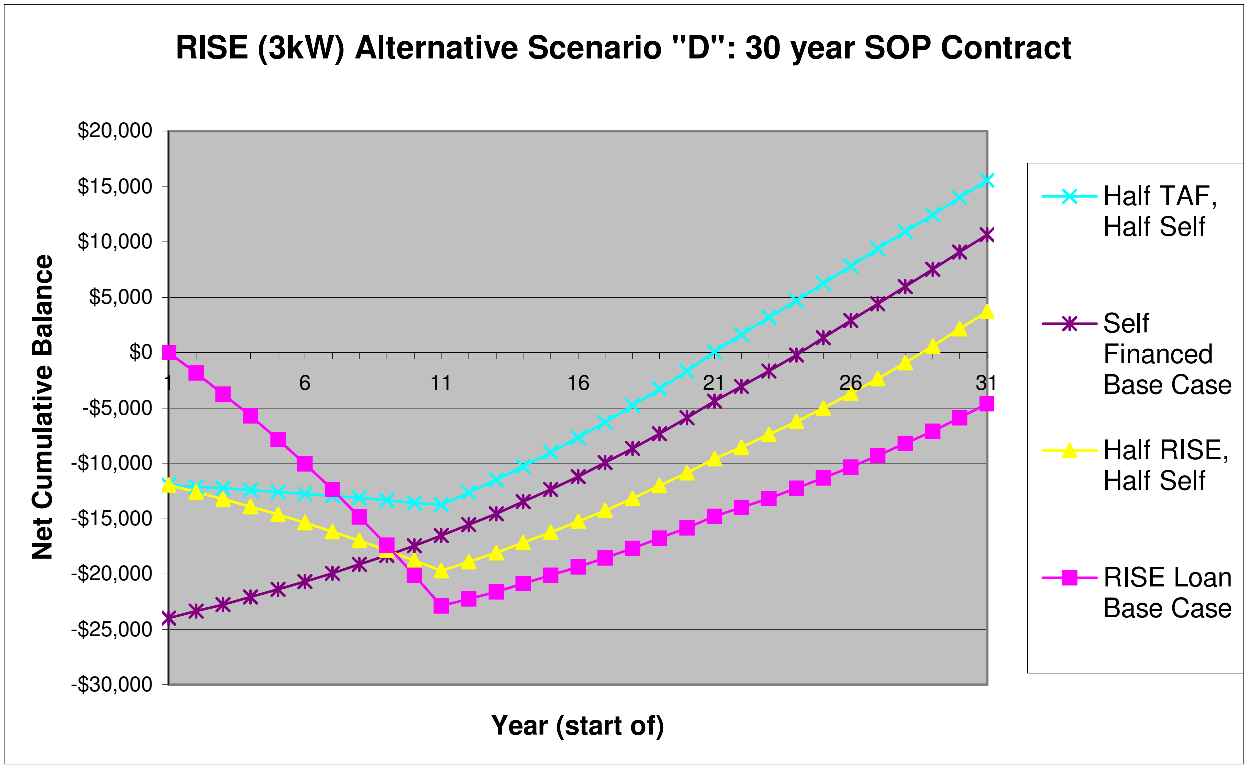
In **Scenario C**, I altered the SOP payments to increase in line with inflation (indexing 20% of the base rate to changes in the consumer price index, as will be done for other renewable energy generators under the SOP). While this does not bring the system payback to within the SOP contract term under any base financing scenarios, it significantly improves the balance-owed by the owner. For self-financed projects, it reduces the payback length to exactly 30 years (annualized ROI including interest paid to self of 1.8%). If the TAF financing scenario (A) is combined with inflation-indexed SOP payments, the payback drops to 19 years, giving an annualized ROI of 0.65% over 30 years (or 1.6% if interest to oneself is included) [see Figure 6].

Figure 6: Financial Paybacks for RISE (3kW) Alternative Scenario "C": Inflation-Indexed SOP



Under **Scenario D**, the SOP contract length is increased to 30 years from the current 20, at a constant payment rate of $0.42/kWh. This brings the payback period for all of the financing scenarios *except* fully-externally financed projects within the new 30 year contract length [see Figure 7]. Annualized ROIs range from 0.5% if half externally financed to 1.7% if half financed through TAF (if interest to self is accounted for, this improves to 2.1% and 2.5%, respectively).

Figure 7: Financial Paybacks for RISE (3kW) Alternative Scenario "D": 30-year SOP Contract



5.2 Environmental Benefits of Solar Photovoltaics

Regardless of the financial payback to the solar PV system owners, solar-based electricity produces environmental benefits to the city at large in terms of greenhouse gas emissions reductions from offset demand for fossil-fuel based electricity generation. These benefits depend on the form of generation that the solar energy displaces. While the majority of Ontario's electricity generating capacity is from nuclear and large hydro generating stations, coal still accounts for 19 percent of system capacity, and natural gas another 7 percent (and will grow under the OPA's supply plan) [see Figure 8]. It is these latter two that I will focus on, rather than the delivered electricity mix.

Figure 8: Ontario's Supply Mix, 2005 [52]							
Fuel type	**Fuel mix (%)**	**CO_2 emission factor (kg/MWh)**	**CH_4 emission factor (kg/MWh)**	**N_2O emission factor (kg/MWh)**	**Fuel conversion efficiency (%)**	**T & D losses (%)**	**GHG emission factor (t_{CO2}/MWh)**
Coal	19%	92.88	0.0036	0.00504	35%	8.0%	1.069
Large hydro	23%	0	0	0	100%	8.0%	0
Natural gas	7%	61.92	0.0036	0.00036	45%	8.0%	0.491
Nuclear	51%	0	0	0	100%	8.0%	0
Electricity mix	**100%**	**21.9816**	**0.000936**	**0.0009828**	**0.098**	**0.0208**	**0.23748**

In Ontario, coal power plants are the biggest stationary source of greenhouse gas emissions and smog precursors, such as sulphur dioxide and particulate matter. In 2003, the Liberal Provincial government promised to shut down all coal-based power plants in Ontario by 2007, but has since extended the deadline to 2014, under advice from the IESO, to provide more time to build generating capacity. In light of the political imperative to shut down the coal plants, and their overwhelming environmental costs, I have calculated the greenhouse gas emissions reductions that would be achieved by replacing coal-based power with solar-based generation [see Methods Appendix for details on calculations].

I have also calculated the emissions reductions that would be achieved from solar generation as compared to natural gas-based generation, as this is currently the least carbon-intensive form of fossil-fuel based generation, and a viable option for urban electricity generation in Toronto.[53] Construction has already started on a 350 MW natural gas-fired power plant in the city's Port Lands, despite considerable opposition from citizens groups and City officials, including Mayor David Miller, who called for greater conservation measures and the use of renewable energy, such as solar.

5.2.1 Greenhouse Gas Emissions Reductions and Costs

In my analysis, I found that when solar displaces coal generation, 1.51 tonnes of carbon dioxide equivalents are avoided annually for every kilowatt of installed solar capacity. This would result in 44.1 tonnes of carbon dioxide reductions over a conservative 30-year lifespan of a 3-kW system. Given a levelized cost of electricity of $0.45/kWh (if fully self-financed) to $0.85/kWh (if externally financed) for a 3kw system in the RISE base case, this gives a cost of

[52] OPA (2005). IPCC (1997).
[53] U.S. Department of Energy (2000), p. 5.

$390 to $763 per tonne of carbon dioxide equivalent reductions. This is well above the prices at which carbon dioxide emissions are currently being traded (below $10/tonne).

When solar displaces natural gas-based generation, 0.78 tonnes of carbon dioxide equivalents are avoided annually for every kilowatt of installed solar capacity. Because natural gas is less polluting than coal, fewer tonnes of emissions are avoided while the amount of money invested stays the same, and the price of emissions reductions rises to $680 to $1,402 per tonne of carbon dioxide equivalent. If achieving greenhouse gas emissions reductions at low cost is the key criteria for investing in or supporting renewable energy projects, solar photovoltaics are not the obvious choice.

Figure 9: GHG Reductions from Solera Solutions 1kW and 3kW PV Panels Due To Reduced Fossil Fuel Use

ELECTRICITY GENERATION & COSTS			**Unit**
1 kW Solar PV panel electricity generation		1420.09	kWh/yr
Levelized Cost of Electricity from 1 kW RISE system		0.54	$/kWh
	to	1.01	$/kWh
Levelized Cost of Electricity from 3 kW RISE system		0.45	$/kWh
	to	0.85	$/kWh
Cost of Electricity from coal:		0.04	$/kWh
Cost of Electricity from natural gas plant:		0.08	$/kWh
Efficiency of pulverized coal power plant:		0.35	
Efficiency of Natural Gas combined-cycle power plant:		0.45	
Transmission Efficiency:		0.92	
100-yr Global Warming Potential (GWP)			
CO_2		1	
CH_4		23	
N_2O		296	

(Figure continued next page)

IF SOLAR REPLACES COAL		Emission Factor	Unit
Coal CO_2 Emissions:		1.05763975	tonnes CO_2/MWh
Coal CH_4 Emissions:		1.118E-05	tonnes CH_4/MWh
Coal N2O Emissions:		1.5652E-05	tonnes N2O/MWh
Coal CO_2 Emissions Reductions from 1kW PV system:		**1.50195**	tonnes CO_2/yr
Coal CH_4 Emissions Reductions from 1kW PV system:		**1.59E-05**	tonnes CH_4/yr
Coal N_2O Emissions Reductions from 1kW PV system:		**2.22E-05**	tonnes N_2O /yr
Total Carbon Dioxide Equivalents Avoided per kWp PV:		**1.51**	**tonnes CO_2e/yr**
Cost of GHG Reductions		**471.08**	**\$/tonne CO_2e**
(from a 1kW RISE system):	**to**	**915.38**	**\$/tonne CO_2e**
Cost of GHG Reductions		**389.91**	**\$/tonne CO_2e**
(from a 3kW RISE system):	**to**	**762.92**	**\$/tonne CO_2e**

IF SOLAR REPLACES NATURAL GAS		Emission Factor	Unit
Natural Gas CO_2 Emissions:		0.5484058	tonnes CO_2/MWh
Natural Gas CH_4 Emissions:		8.70E-06	tonnes CH_4/MWh
Natural Gas N_2O Emissions:		8.6957E-07	tonnes N_2O /MWh
Natural Gas CO_2 Emissions Reductions from 1kW PV system:		**0.77879**	tonnes CO_2/yr
Natural Gas CH_4 Emissions Reductions from 1kW PV system:		**1.23E-05**	tonnes CH_4/yr
Natural Gas N_2O Emissions Reductions from 1kW PV system:		**1.23E-06**	tonnes N_2O /yr
Total Carbon Dioxide Equivalents Avoided per kWp PV:		**0.78**	**tonnes CO_2e/yr**
Cost of GHG Reductions		**837.25**	**\$/tonne CO_2e**
(from a 1kW RISE system):	**to**	**1697.35**	**\$/tonne CO_2e**
Cost of GHG Reductions		**680.11**	**\$/tonne CO_2e**
(from a 3kW RISE system):	**to**	**1402.22**	**\$/tonne CO_2e**

5.2.2 RISE Electricity Generation and Greenhouse Gas Reductions

As of July 4, 2006, 34 1-kW systems had been purchased through RISE, which will produce about 1,450 MWh of electricity over their 30-year lifetime (if optimally sited, with no shading). [54] Another 37 systems were still being considered by RISE participants, which would,

[54] Each 1-kWp system should deliver approximately 1,420 kWh to the grid each year, given an average insolation of 162 watts per square meter in Toronto (on a south-facing plane tilted at 45 degrees), and peak insolation of 1,000 watts per square meter. See methods appendix for details of energy generation calculations.

if adopted, produce an additional 1,580 MWh of electricity. Combined, this would prevent the emission of 3,200 tonnes of carbon dioxide equivalents and 78.6 tonnes of nitrogen oxide.[55]

5.2.3 Health Benefits

Emissions from combustion of fossil fuels are of concern not only because of their contribution to climate change, but also because of the negative health effects or air pollution. Toronto's location downwind from several Ontario and numerous mid-Western U.S. coal plants helped contribute to 48 smog alert days in 2005. Smog also contributes to 1,480 premature deaths and 14,740 hospitalizations in Toronto each year, raising $40 million in health care costs.[56] Solar initiatives, particularly if replicated on a large scale, will help reduce smog levels and associated health costs, and improve quality of life for Toronto residents. The European Commission estimates that the median external cost of coal-fired electricity in Europe is $0.12/kWh, primarily due to health impacts.[57] Reducing these externalities, which the City and its residents ultimately pay for, may justify a further incentive for renewable energy generators from the municipal government.

5.3 Economic and Environmental Analysis of Solar Thermal

WISE and the Downtown-West Solar Initiative are asking for RFPs for solar thermal hot water heating systems in addition to solar photovoltaics. These require much smaller capital investments, and are expected to have much faster paybacks than solar PV. Therefore, they are expected to increase the number of households that are able to participate in the community initiatives.[58]

Solar thermal produces energy in the form of useful heat, rather than electricity, as the sun's rays warm a working fluid inside dark-coloured solar thermal panels. The hot fluid is then piped into the house to heat water in normal hot water tank. Though the community solar initiatives have yet to receive bids for solar thermal systems, I have assumed a price of $4,000 for a 4kW system (based on current retail prices). This size system would meet about 50% of an average household's annual water heating demand. As with solar PV, the length of the loan and

[55] See Methods Appendix for calculations examples.
[56] Toronto Environmental Alliance (2006), p. 3.
[57] Rabl and Spadaro (1999).
[58] Like solar PV, solar thermal systems must be located on south-facing roofs, with minimal shading during the day.

the interest rate determine the pattern and size of cash flows and returns on investment for solar thermal.

Assuming solar thermal replaces energy that would otherwise cost $0.09/kWh (the current retail price of electricity in Toronto[59]), the financial payback period is less than 20 years in all financing scenarios considered. With longer term (25 year) external loans, homeowners may never face negative cash flows, but will have lower long-term gains. If homeowners self-finance the project, they will face negative cash flows for the first several years, but see higher cumulative returns in the long run (with an annualized ROI of 2.9% over 30 years, or 3.4% if interest to self is included). [For potential financial returns under various financing scenarios, see Figure 10.]

Government incentives, or low-interest loans (such as through TAF) would reduce the initial barrier to investment that often accompanies capital-intensive projects such as solar thermal, and increase long-term returns.[60] Even without government subsidies or incentives, solar thermal technologies are a financially attractive investment, competitive with the current cost of electricity in Ontario. Targeted educational campaigns about the technology and its financial benefits may be the key to increasing awareness and technology uptake, at little cost to the City.

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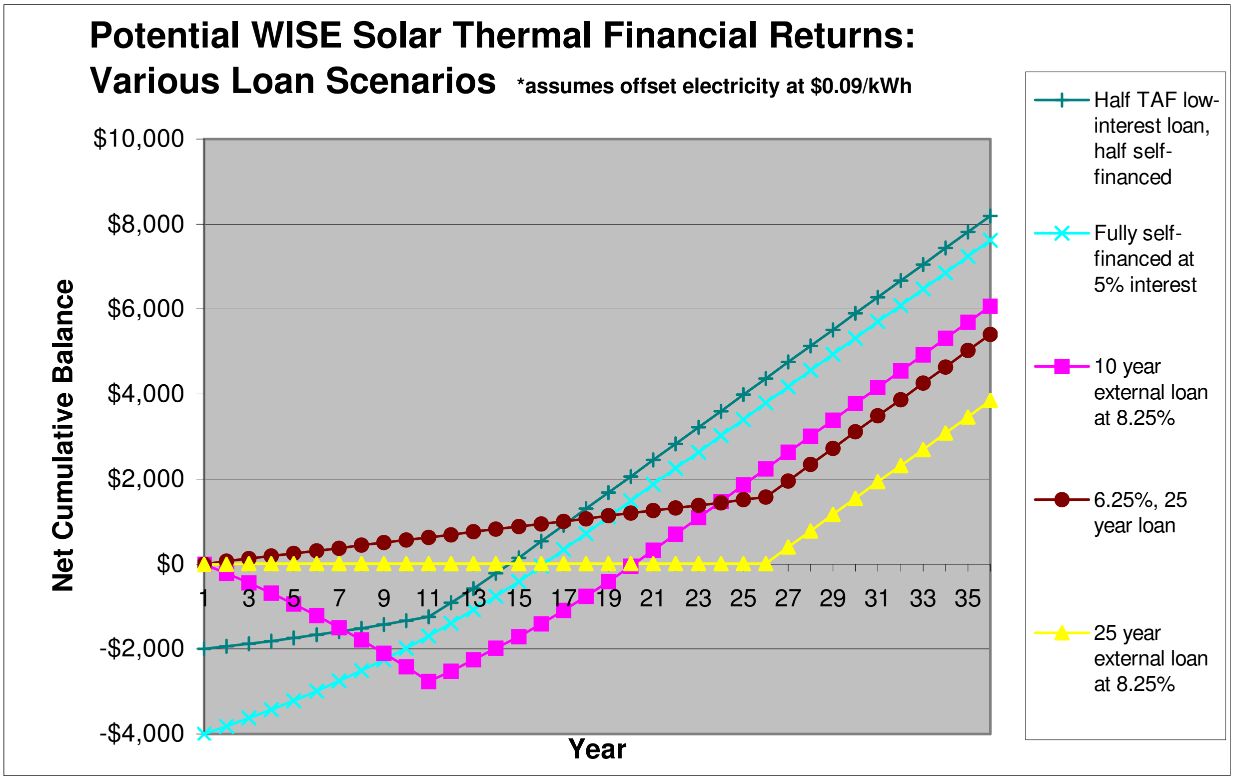
[59] This is only slightly higher than the cost of natural gas-based water heating, which comes to $0.08/kWh based on current delivered costs of $0.44/cubic meter natural gas, and a furnace efficiency of 60%. As such, I have only provided the financial payback graph for solar thermal replacing electricity at $0.09/kWh, as the paybacks would be very similar when replacing natural gas-based heating.

[60] NRCan has just such an incentive program for businesses only, called the Renewable Energy Deployment Initiative (REDI), which provides up to a 25% rebate on the purchase and installation cost of solar hot water systems. The program began in 1998, and ends March 2007. Fitzgerald et al. (2004), p. 9.

Figure 10: Potential WISE Solar Thermal Financial Returns - Various Loan Scenarios



As solar thermal water heaters often replace relatively efficient natural gas-fired water heaters, the benefit in terms of quantity of greenhouse gas reductions is less than that for equivalent energy production from solar PV that could replace coal-based electricity demand.[61] The cost per tonne of greenhouse gas emissions reductions, though, is much lower (even negative) for solar thermal projects compared to solar PV [see Figure 11].[62] A government initiative to install solar hot water heaters on homes would therefore be a more cost-effective option to reduce greenhouse gas emissions, even saving homeowners money in some cases.

[61] A number of households do still use electric hot water heaters, though. These should be targeted for replacement before natural gas water heaters, due to their lower efficiency.

[62] Emissions reductions are cheaper for solar thermal than solar PV primarily because of the lower capital costs. Solar thermal systems that replace natural gas-based water heaters can actually have a negative cost for emissions reductions when the levelized cost of energy from solar thermal heating is below the cost from natural gas-based heating. See Appendix B for more details on solar thermal emissions reductions calculations.

Figure 11: GHG Reductions from Solar Thermal 4kW System Due to Reduced Fossil Fuel Use

ENERGY COSTS FOR SOLAR THERMAL (10m^2, 4kW panel)			**Unit**
Energy generated (as useful heat)		5,148.00	kWh/yr
Levelized Cost of Energy		0.07	$/kWh
	to	0.13	$/kWh
Cost of Electricity from coal:		0.04	$/kWh
Cost of Heat from natural gas water heater:		0.08	$/kWh
Efficiency of pulverized coal power plant:		0.35	
Efficiency of Natural Gas water heater:		0.60	
Transmission Efficiency:		0.92	

IF SOLAR THERMAL REPLACES COAL-BASED ELECTRICITY		**Emission Factor**	**unit**
Coal CO_2 Emissions:		1.057639752	tonnes CO_2/MWh
Coal CH_4 Emissions:		1.11801E-05	tonnes CH_4/MWh
Coal N2O Emissions:		1.56522E-05	tonnes N_2O/MWh
Coal CO_2 Emissions Reductions per kW installed solar thermal capacity:		**1.361**	tonnes CO_2/yr
Coal CH_4 Emissions Reductions per kW installed solar thermal capacity:		**1.439E-05**	tonnes CH_4/yr
Coal N_2O Emissions Reductions per kW installed solar thermal capacity:		**2.014E-05**	tonnes N_2O /yr
Total Carbon Dioxide Equivalents Avoided per kW Solar Thermal:		**1.367**	**tonnes CO_2e/yr**
Cost of GHG Reductions		**$26.50**	**$/tonne CO_2e**
(from a 4kW system):	**to**	**$79.00**	**$/tonne CO_2e**

IF SOLAR THERMAL REPLACES NATURAL GAS WATER HEATER		**Emission Factor**	**unit**
Natural Gas CO_2 Emissions:		0.3784	tonnes CO_2/MWh
Natural Gas CH_4 Emissions:		6.00E-06	tonnes CH_4/MWh
Natural Gas N_2O Emissions:		0.0000006	tonnes N_2O /MWh
Natural Gas CO_2 Emissions Reductions per kW installed solar thermal capacity:		**0.487**	tonnes CO_2/yr
Natural Gas CH_4 Emissions Reductions per kW installed solar thermal capacity:		**7.722E-06**	tonnes CH_4/yr
Natural Gas N_2O Emissions Reductions per kW installed solar thermal capacity:		**7.722E-07**	tonnes N_2O /yr
Total Carbon Dioxide Equivalents Avoided per kW Solar Thermal:		**0.487**	**tonnes CO_2e/yr**
Cost of GHG Reductions		**-$33.91**	**$/tonne CO_2e**
(from a 4kW system):	**to**	**$113.37**	**$/tonne CO_2e**

5.4 Comparison to Natural Gas-Based Generation

Natural gas plants are another option for increasing electricity generation capacity in Toronto. While not emission-free, natural gas is the least carbon-intensive form of fossil fuel.[63] Natural gas combined-cycle generation is also more efficient than pulverized coal-based generation (45% and 35% efficiency, respectively). Together, these factors make natural gas nearly twice as clean as coal-based electricity generation. Greenhouse gas emissions reductions obtained by replacing coal with natural gas generation are also relatively low, close to $80/tonne [see Figure 12] – well below the cost of emissions reductions from solar PV [see Figure 15].[64]

Figure 12: GHG Reductions if Natural Gas Combined-Cycle Generation Replaces Coal-Fired Generation

IF NATURAL GAS REPLACES COAL		
Natural Gas CO2 Emissions Reductions vs. Coal	**0.50923**	tonnes CO2/MWh
Natural Gas CH4 Emissions Reductions vs. Coal	**2.48E-06**	tonnes CH4/MWh
Natural Gas N2O Emissions Reductions vs. Coal	**1.48E-05**	tonnes N2O/MWh
Total Carbon Dioxide Equivalents Avoided:	**0.51**	**tonnes CO2e/MWh**
Cost of GHG Reductions from switch to natural gas	**79.82**	**$/tonne CO2e**

5.5 Comparison to Building Energy Efficiency Retrofits

Energy planning in Ontario has traditionally focused on increasing supply to meet future demand. The most cost-effective way to reduce energy use and resultant greenhouse gas emissions, though, is to focus on reducing demand. Given Toronto's current housing stock and low building energy efficiencies, conservation and demand-side management could go a long way towards reducing energy demand and the need for new generation. Energy-efficient building retrofits (such as those promoted by the EEO's Better Buildings Partnership[65]) or stricter standards for new construction are expected to deliver the greatest electricity demand reductions at the lowest cost.

Natural Resources Canada's popular "EnerGuide for Houses" retrofit incentive program can be used as a model for building energy retrofit programs at the municipal level. From October 2003 to March 2006, 52,000 homeowners received grants for home energy retrofits. The

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[63] U.S. Department of Energy (2000), p. 5.

[64] U.S. Department of Energy (2000), p. 5.

[65] The Better Building Partnership has already retrofitted 39 million square feet in institutional, commercial and industrial building, reducing CO_2 emissions in Toronto by 172,000 tonnes. Toronto Environmental Alliance (2006), p. 5.

grant level varied from project to project based on the energy savings achieved, but on average recipients spent $5,680 on the retrofit, and received a $680 grant. Based on follow-up energy inspections, the average project achieved energy savings of 28%, reducing greenhouse gas emissions by 3.9 tonnes per year, and cutting household energy bills by $750 per year. Over 30 years, the 52,000 retrofits are expected to reduce carbon dioxide emissions by 6,084,000 tonnes. Given government program spending of $75 million and total homeowner investments of $260 million, this results in a total cost of $66/tonne of carbon dioxide emissions reductions [see Figure 13]. [66] This is less than the cost calculated for both natural gas- and solar-based electricity generation, but more expensive than reductions when solar thermal replaces electric or inefficient natural gas water heaters [see Figure 15 for summary of costs from solar PV, solar thermal, retrofits, and natural gas].

Figure 13: EnerGuide for Houses: Retrofit incentive participation and results[67]	
Number of retrofit incentive grant recipients, October 2003 to March 2006:	52,000
Average retrofit incentive grant per house to date:	$680
Average homeowner spending per house:	$5,000
Average bill savings under the retrofit incentive:	27.70%
Average annual energy bill savings under the retrofit incentive (at 2006 energy prices):	$750/yr
Levelized cost of energy reductions:	$0.04-0.09/kWh
CO_2 reductions per household:	3.9 tonnes/yr
Net program benefit (May 2006 energy prices)	
total government program spending	$75 Million
total homeowner investment	$260 Million
total lifetime (30 year) energy bill savings	$1,170 Million
Net benefit	$835 Million
CO_2 reductions over 30 years:	6,084,000 tonnes
Cost to government of CO_2 reductions:	$14.79/tonne
Cost to homeowner of CO_2 reductions:	$51.28/tonne

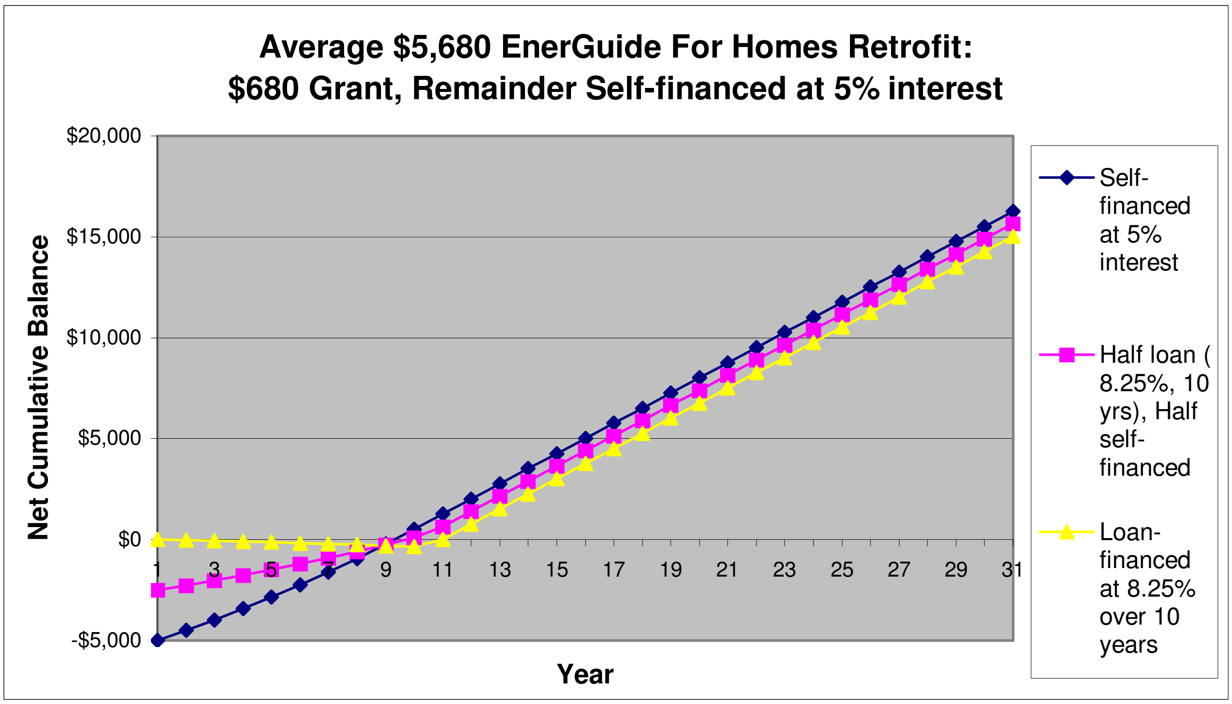
Figure 14 below shows the financial returns for the “average” EnerGuide for Homes project if financed with an external loan at 8.25% over 10 years, if half externally and half self-financed, and if fully self-financed at 5% interest. In each scenario, the project yields roughly $15,000 in savings, giving a very attractive ROI of 4.4% over 30 years. The levelized cost of

[66] Green Communities Canada (2006), pp. 4-5.
[67] Green Communities Canada (2006), pp. 4-5.

energy reductions range from $0.039/kWh for a self-financed project to $0.094/kWh for a loan-financed project.

Homeowners who are attracted to the community solar initiative model but wary of solar costs and financial losses could be encouraged to undertake household energy efficiency improvements and retrofits. The City should explore opportunities to cooperate with community solar initiative organizers to promote municipal energy initiatives, such as building retrofit incentives, among informational session attendees, as they would be a prime target audience.

Figure 14: Financial Returns for Average $5,680 EnerGuide for Homes Retrofit



6 Scalability: Building the Market

While these grassroots solar campaigns have been quite successful at building neighbourhood support, attracting the attention of several hundred Torontonians, they are small-scale compared to Toronto's population of 4.6 million. Given the current financial incentives and paybacks for solar photovoltaics, as outlined above, investment in PV will remain limited to ethically and politically motivated early adopters willing to risk losing money on the project.

6.1 How many potential "early adopters" are there?

According to the 2001 Canadian Census, there were 1.6 million households in Toronto in 2000. 376,000, or 23% of households, are in the highest income bracket (over $100,000 per year).[68] While participation in community solar initiatives is certainly not based on political affiliations, I have considered support for the Green Party as an indicator of the percentage of Torontonians with deep-seated environmental values, and therefore those who might be inclined to take part in these initiatives. The Green Party received roughly 4 percent of the Toronto vote in the 2004 and 2006 federal elections. Assuming that the percentage of citizens with "green" values holds steady across income levels, and that most households with incomes over $100,000 would own their own home, we can very roughly predict that 15,000 Toronto households might be interested in and able to take part in a community solar PV initiative.

While the RISE model has already been replicated in three Toronto neighbourhoods, reaching 15,000 potential early adopters will require considerable effort. The City may be able to provide promotional, logistical, or similar support to help organize additional community initiatives in neighbourhoods across the city, or to bring together interested but dispersed citizens to take part in a more centralized initiative.

If 15,000 households were to take part in community solar initiatives, each installing 3-kW systems, this would generate up to 63,900 MWh of clean, local electricity each year, offsetting over 22,000 tonnes of greenhouse gas emissions from coal-based generation, or reducing the need for 7 MW of new generating capacity. Still, this would only cover 2 percent of Toronto's 350 MW local generation mandate. Increasing the percent of generation from solar would require expanding the solar initiative participation beyond early adopters. Given current capital costs improving the financial payback of solar PV in order to bring the costs within reach of more households would require further government incentives, such as those outlined above.

6.1.1 Potential size of the solar PV market

According to the Canadian Solar Industry Association (CanSIA), almost half of all Ontario homes are physically suitable for installing a 3-kW solar PV array on their roofs. They estimate that it is technically feasible to install over 3,000 MW of PV on detached homes in Ontario now, including 1,300 MW in Toronto, and over 14,000 MW on all Ontario buildings by 2025. Based on projections of sustainable growth of the Canadian solar industry, CanSIA projects an "achievable" market potential for 2025 of 3,400 MW.[69]

[68] Statistics Canada (2001).
[69] McMonagle (2006c), p. 1.

In their 2005 recommendations to the OPA regarding the development of a Standard Offer Program, CanSIA noted that a properly designed SOP at $0.42/kWh of solar electricity could attract 15,000 early adopters, creating 40 MW of solar PV capacity within 5-10 years. With continued growth of the market, the SOP could stimulate the installation of 1,200 MW of PV on 400,000 homes by 2025, creating 10,000 new jobs in the local solar industry.[70]

The Ontario Sustainable Energy Association was less optimistic about the effects of a 42 cent SOP payment, calling for higher rates (from $0.67 to $0.83/kWh) in order to make solar investments marginally profitable, and thereby attract greater investment beyond the early adopter population.[71] This is more in line with the levelized cost of electricity I calculated in the RISE base case. Barring changes in the SOP details, the City could provide financial incentives (such as those in the alternative scenarios above) to close the gap between the SOP payments and the levelized cost of solar electricity. This would make solar investments more attractive today, and help bring down prices in the future.

6.1.2 Potential size of the solar thermal market

Almost any home that is suitable for solar photovoltaics is also suitable for solar thermal. Based on CanSIA's estimates in section 6.1.1, over 430,000 Toronto households are suitable for solar. If each of these households installed a 4kW solar water heating system, rather than PV, they would produce 2,200 GWh of thermal energy each year, offsetting 838,000 tonnes of carbon dioxide equivalent emissions if replacing natural gas water heaters (more if replacing electric water heaters).[72] Moreover, this would be achieved at one-sixth the price of installing the photovoltaic systems.

6.2 Looking Forward: Building the Solar Market

Like many other new technologies, solar photovoltaic prices decrease as cumulative, industry-wide experience increases. Solar PV has exhibited a progress ratio of 80 percent over the past 30 years, meaning that prices have decreased by 20 percent for every doubling of installed capacity.[73] The more solar PV that is installed, the faster prices will come down.

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[70] McMonagle (2006b), p. 5. Canadian Solar Industry Association (2005), pp. 5-6.
[71] Gipe, Doncaster, and MacLeod (2005), p. 41.
[72] This is assuming natural gas heater efficiency of 60%, as in the financial analysis in section 5.3.
[73] Ayoub, Dignard-Bailey, and Filion (2000), p. iv. CanREA (2006b), p. 2.

The average growth rate for global PV installed capacity was 32% from 1994 to 2004. Assuming sustained growth at this rate over the next 20 years and a steady progress ratio of 80%, PV prices could be expected to drop by half by 2014 (to roughly \$5,000/kW_p in Ontario), and by one-fourth by 2021.[74] This would make solar-based electricity competitive with the cost of natural gas-fired generation (at today's fuel prices) around 2025.[75]

Canada could wait for prices to decrease to this level, thanks to growing markets elsewhere in the world, but it may be prudent to build local manufacturing capacity, knowledge, and demand now in preparation for larger deployment in the future, while also contributing to the global market that ultimately drives the experience curve. As of 2004, Canada accounted for only one-half of one percent of total installed photovoltaic capacity in the world, with 13.9 MW out of the 1,195 MW global total.[76] While Canadian installations were up by 17 percent in 2004 over 2003, this pales in comparison to the global average of 44.5 percent – the highest growth rate witnessed in over a decade.[77]

Canada will need to take decisive action to catch up with other developed nations. This could include funding research and development, streamlining regulatory approvals for new solar technology, information dissemination to encourage early adopters, and providing financial incentives to help grow the market and accelerate the experience curve.[78]

Ontario has taken a large first step in this direction with the introduction of the Standard Offer Program, but its effect is far from certain. CanSIA forecasts that the SOP will start Canada onto a renewable energy growth path similar to that witnessed in Europe, though 30 years behind (with 290 MW of solar installed by 2025, a level Germany had achieved by 1996). The OPA's program expectations are lower. They project the SOP will spur 40 MW of solar installations over 20 years, equal only to the amount that was installed in Germany in just over 6 weeks in 2004, putting Canada's solar generating capacity on a much flatter growth trajectory.[79]

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74 Calculations based on data from BP (2006). This are in line with the projected price of \$2,000 USD/kW of PV in 2020, cited by: Ayoub, Dignard-Bailey, and Filion (2000), p. 27.

75 This corresponds with the later end of the timeframe projected by CanSIA in: McMonagle (2006b), p. 2. Advances in PV module efficiencies are projected to increase by 25 percent in this same timeframe, from 0.16 in 2006, to 0.19 in 2020 and 0.20 in 2030. Ayoub, Dignard-Bailey, and Filion (2000), p. 23.

76 BP (2006), citing data from the IEA Photovoltaic Power Systems Programme.

77 The average growth rate for solar photovoltaics over the decade leading up to 2004 was 32%. BP (2006).

78 Ayoub, Dignard-Bailey, and Filion (2000), p. 41.

79 McMonagle (2006c), p. 1.

6.2.1 Manufacturing Capacity

There is currently no solar manufacturing capacity in Ontario. Building demand for solar technology, through community initiatives and government incentives, could help attract manufacturing to the area, but further government support will be necessary to foster a significant industry. As the 2006 *BP Statistical Review of World Energy* points out, "Japan, Germany and the US are the countries that have the largest programmes in terms of government support to the PV industry. . . Not accidentally do the three countries with the largest government support programmes also house the biggest manufacturers." [80] If Ontario can attract manufacturers to the area, the region will reap further economic spin-off benefits through new jobs and reduced imports, in addition to the environmental and health benefits outlined above.

7 Municipal Energy Policy and Goals

7.1 How does community solar fit in with Toronto's energy policy and mandates?

Aside from the support of local city councillors, these community solar initiatives have developed without any funding from the municipality or involvement of City departments. While RISE has seen considerable initial success, and the community solar initiative model has been replicated in other neighbourhoods, there may be opportunities for the municipality to help increase participation in the initiatives and promote further replication across Toronto, thereby increasing associated benefits to the city in terms of energy security and pollution reduction. Before describing specific actions the City could take, I will outline Toronto's existing mandates and energy policy goals that relate to community solar and could be seen to support a decision to take such actions.

7.2 Energy and Greenhouse Gas Mandates

The City's Energy Efficiency Office (EEO)[81] is the municipal department responsible for developing and co-ordinating the implementation of an energy efficiency and conservation strategy for Toronto. This was originally in response to the City's commitments to reduce carbon dioxide emissions by 20 percent relative to 1988 levels by 2005.[82] Though this target was not achieved, the goal of reducing greenhouse gas emissions and smog remains. The EEO is now

[80] BP (2006).
[81] The EEO is part of the division of Facilities and Real Estate, Business and Strategic Innovation, of the City of Toronto.
[82] This resulted from recommendations from the City's Special Advisory Committee on the Environment.

also driven by the mandate to deliver 300 megawatts (MW) of energy conservation by 2010 in order to relieve strain on the electricity grid and to prevent brownouts.

The 300 MW conservation target was set in 2006 by Donna Cansfield, then Ontario's Minister of Energy, as part of a 1,000 MW province-wide conservation effort.[83] This is in addition to the 250 MW of existing and planned conservation initiatives that Toronto Hydro Electric Services Limited (THESL) has committed to through to September 2007, and is reportedly on track to achieve at a cost of only $40 million.[84]

A concurrent Minister's Directive to the Ontario Power Authority regarding reliable supply in Toronto also mandated that 550 MW of generation should be developed in Toronto. This is expected to be accomplished primarily through the construction of the Portlands Energy Centre, a natural gas-fired power plant in the city's former industrial port lands. [85] A number of citizens' groups and city councillors have opposed the plant, though, calling for greater use of renewable energy and denouncing continued reliance on polluting fossil fuels, particularly in the downtown area. While the Energy Efficiency Office does not have a specific mandate to support the development of renewable energy sources, such support could play a role in fulfilling the Minister's Directives, and implementing the OPA's recommended supply mix.

Support for renewable energy is also seen in several existing and planned municipal programs and policies, including the Energy Plan, the Environment Plan, the Renewable Energy Action Plan, and the City of Toronto Ten Point Plan to Reduce Peak Electricity Demand in the Southeast City Area, as detailed below.

7.3 Toronto's Energy Plan

In response to the warnings from Ontario's Independent Electricity System Operator, Toronto City Council directed Energy Efficiency Office staff to coordinate the creation of an energy plan for the city. As a first step towards developing an Energy Plan, the City commissioned IndEco Strategic Consulting to document the work that has been completed to date, and provide a framework for further development of the Energy Plan.

In its 2006 *Report on the Development of the Energy Plan for Toronto,* IndEco set out to identify energy-related requirements in existing policies, and conduct a situation analysis to

[83] Ontario Power Authority (2006a). IndEco (2006), pp. 36-37.
[84] IndEco (2006), p. 37. Toronto Environmental Alliance (2006), p, 5.
[85] IndEco (2006), p. 36.

identify the current and preferred states of energy supply and demand in Toronto under a vision of energy sustainability. From this, they developed a set of options to achieve the preferred state, setting priorities for the implementation of those preliminary options.[86] Several recommendations from the report relate to and could be interpreted to support community solar projects, as follows: [87]

a) To provide 550 MW of new generation capacity in Toronto by 2009 based on the Energy Minister's Directive. Community solar initiatives help contribute to new local generation capacity, but most household systems are only one to three kilowatts in size, and as such would need considerable support to increase participation enough to contribute noticeably to the 550 megawatt directive.[88]

b) To establish green industries including those that produce wind turbines, photovoltaic cells, soil remediation technologies, and recycling technologies. Community solar initiatives are playing an important role in building the solar industry in Toronto by increasing demand and building knowledge among the solar installers. At present, though, there is almost no local photovoltaic manufacturing capacity – the City could help attract these businesses to the area by building local demand for the technology, in part through support of community solar initiatives.

c) To provide access to appropriate space, favourable leases, and low cost financing to 'green industry entrepreneurs' consistent with the Renewable Energy Action Plan. This recommendation suggests City could provide low-cost financing to solar initiative participants, who are, as renewable energy generators, green industry entrepreneurs.

d) To develop a CO_2 Reduction Plan. As solar energy systems would offset greenhouse gas-emitting fossil fuel-based electricity generation, support for community solar initiatives could be included as part of a carbon dioxide reduction plan.

e) To strengthen EEO partnerships. The EEO could partner with community solar initiatives and solar companies in Toronto to provide technical or programmatic support, and to connect initiative participants to funding sources such as the Toronto Atmospheric Fund. This would improve EEO visibility in the communities where these projects are taking place, and would create opportunities to promote other EEO programs to a targeted group of citizens.

[86] IndEco (2006), pp. 1-2.
[87] IndEco (2006), p. 63.
[88] See discussion of potential market size and early adopters in section 6.1.

7.4 Environmental Plan

In 1998, Toronto City Council created an Environmental Task Force (whose mandate was subsequently transferred to the Sustainability Roundtable and then to the Roundtable on the Environment) to develop a comprehensive Environmental Plan for the City. In April 2000, Council adopted, in principle, the group's report, "Clean, Green and Healthy: A Plan for an Environmentally Sustainable Toronto." Commonly referred to as the Environmental Plan, it is a strategic document that contains recommendations about goals, targets, policies, strategies, structures and processes that will lead the city in the direction of environmental sustainability, if implemented.[89] As of 2004, half of the recommendations in the Environmental Plan had been implemented, and work was proceeding on most of the remaining items. [90]

Half of the outstanding recommendations, though, relate to renewable energy and conservation, including: "Support Green Power," "Encourage Improved Building Design," and "Promote the Development of Green Industry." In addition, in the Staff Report to Policy and Finance and City Council (28 September 2006), Deputy Mayor Joe Pantalone, Chair of the Roundtable on the Environment, recommended that "the City of Toronto consider renewable energy as one of the priorities of the new Environmental Plan including identifying funding opportunities to buy or generate renewable energy."[91] Municipal support for community solar initiatives, through funding to solar generators or encouragement of a local solar industry, would be one way of carrying out these recommendations.

7.5 Renewable Energy Action Plan

Work is currently underway to produce a renewable energy action plan to be implemented across City divisions and in partnership with partners such as Toronto and Region Conservation Authority and Toronto Hydro. The Renewable Energy Action Plan will offer support, encouragement, and incentives to participate in green power purchasing. The City has set a goal of 10% of all electricity to be provided from renewable sources by 2030. [92] While the Renewable Energy Action Plan pertains only to the Corporate City, efforts to build the renewable energy industry in Toronto, such as through support of community solar initiatives, would also make it cheaper and easier to achieve the Corporate renewable energy goal.

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[89] Toronto Interdepartmental Environment Team (2004), p. 1.
[90] Toronto Interdepartmental Environment Team (2004), p. 2.
[91] City of Toronto (2006), p. 2.
[92] IndEco (2006), p. 69.

7.6 Toronto Green Development Standard

In July 2006, City Council approved a new Green Development Strategy to help reduce the environmental and related health and economic impacts of urbanization in Toronto. The resultant Green Development Standard, updated in January 2007, includes mandatory building standards for City-owned properties, though the Standard is currently voluntary for private development.[93]

Among the standards related to Greenhouse Gas Emissions and Energy Efficiency are guidelines for "Green Energy" development features to "reduce demand for energy from the grid and encourage renewable energy production." The Standard directs developers, where feasible, "to provide onsite renewable energy to supply 5% -10% of a project's energy needs," and "purchase 25% of energy needs through grid source renewable energy." One of the possible strategies suggested is the use of photovoltaics, as well as solar-thermal technologies. [94] As such, the Green Development Standard directly supports projects such as the community solar initiatives. Further support from the City to these initiatives would help citizens implement the Green Development Standard in their own homes.

8 Different Goals Call for Different Strategies

The City of Toronto is currently outlining an energy plan that will guide energy policy and programs in the city over the coming years. Depending on the City's underlying energy goals, different strategy choices will be more or less appropriate. If the City is primarily interested in reducing energy demand at the lowest cost, a focus on conservation and demand-side management would be most appropriate, including support for solar thermal technologies. If the City is primarily interested in increasing local generation capacity, gas-fired power plants are the most scaleable option, with lower costs than photovoltaics and lower greenhouse gas emissions than coal. If the City is really committed to local renewable energy generation, despite higher costs, support for community solar initiatives would make sense. [See Figure 15 for a comparison of energy costs, payback lengths, returns, and emissions reductions from the various option studied.]

[93] City of Toronto (2007b).
[94] City of Toronto (2007b), pp. 9, 11.

Figure 15: Comparison of Options Studied

Option	LUEC ($/kWh)	Payback (Years)	Annualized ROI over 30 Years (%)	Cost of GHG Reduction vs. Coal ($/tonne)	Cost of GHG Reduction vs. Natural Gas ($/tonne)
Solar PV					
self	0.45	37[95]	1.6%	$390	$680
loan	0.85	(never)	-6.0%	$760	$1,400
Solar Thermal					
self	0.06	15	3.3%	$26	-$34
loan	0.13	19	2.4%	$79	$113
Energy Efficiency Retrofit					
self	0.04	8	4.4%	$65	n.a.
loan	0.09	10	4.4%		
Natural Gas Plant					
	0.08			$80	n.a.

8.1 Goal: Cost Effectiveness

8.1.1 Strategy: Support Building Energy Efficiency Improvements and Installation of Solar Thermal Hot Water Systems

The most cost-effective way to reduce energy use and resultant GHG emissions is still through conservation and demand side management. Focusing on energy-efficient building retrofits (as the Better Buildings Partnership does) or stricter standards for new construction would deliver the greatest electricity demand reductions at the lowest cost per unit of energy saved.

Energy conservation can also be achieved at roughly the same cost by promoting the installation of solar thermal hot water systems (though the absolute size of energy savings per household are not as large as from an energy efficiency retrofit). Like energy-efficiency improvements, solar thermal reduces fossil-fuel based energy demand (either as electricity from the grid, or delivered natural gas), improving energy security in the city. Greenhouse gas emissions reductions achieved through the installation of self-financed solar thermal systems are the most cost-effective of all the options studied in this report.

The City should continue to focus its energy and funding on building energy efficiency programs such as the BBP and the BBNCP, and consider instituting a program along the lines of the EnerGuide for Homes program targeted at single-family homes. They should also institute a campaign to increase awareness about the financial benefits of solar thermal, or even a introduce

[95] 37 year payback, with 5% guaranteed annual return due to interest payments to self.

a municipal by-law requiring solar thermal systems be installed on all new buildings, similar to Barcelona's solar thermal ordinance.[96]

8.2 Goal: Building Local Generation Capacity

8.2.1 Strategy: Support Natural Gas-Based Generation

Toronto is in the undesirable position of having almost no local electricity-generating capacity and limited transmission capacity to deliver imported electricity to the city. If the City's most pressing goal is to build sizable local generating capacity, it should support the construction of natural gas-fired power plants in Toronto. As shown in the analysis above, natural gas is the least carbon-intensive of the fossil fuels, and reductions in carbon dioxide emissions through a switch from coal to natural gas-based electricity generation are relatively cost effective (more expensive than energy efficiency improvements, but less expensive than solar PV).

A word of caution regarding fuel prices is necessary here. Costs for natural gas-based generation and emissions reductions are likely to increase significantly as global natural gas supply tightens and fuel prices rise. While natural gas is currently a cost-effective option for new generation, this may not be the case in coming decades.

8.3 Goal: New Local Renewable Generation

8.3.1 Strategy: Support Community Solar

If transmission constraints and local generation are primary concerns, but the City is disinclined to use fossil fuel-based generation (due to political commitments, sustainability targets, or long-term economic and energy goals), new local renewable energy generation should be the target of energy policy.

According to the *Report on the Development of the Energy Plan for Toronto*, the Standard Offer Program "is expected to change the cost-benefit ratio sufficiently to bring many participants into the market."[97] While this is true at the provincial level, there is little evidence that the SOP will spur new generation in Toronto. There is limited potential for siting new wind turbines within the city, and biogas resources are quite small due to the absence of landfills or sizable farms in Toronto. PV panels on the other hand can be placed on almost any roof or wall with southern exposure, making use of commonly underutilized spaces. As I have demonstrated

[96] Pujol (2005).
[97] IndEco (2006), p. 69.

in this report though, solar photovoltaics – a renewable energy technology well suited to urban settings – still will not have a positive payback under the SOP. As such, solar PV investments will be limited to a small group of early adopters. If Toronto is to see a large increase in renewable electricity generation in the near-term, the City will have to commit considerable resources to induce further investment in local solar generating capacity. This could be in the form of support for existing and future community solar initiatives, as outlined below.

9 Recommendations to City Regarding Support of Community Solar

Toronto's community solar energy initiatives have made considerable progress in a very short time. While the addition of solar thermal systems to the latest initiatives should increase participation, the potential for growth on the PV side is limited by the very slow, or negative, financial paybacks of solar photovoltaics at this time, even with the introduction of the provincial Standard Offer Program. The City may be able to provide support to solar initiatives, though, in order to increase their impact and expand participation beyond the realm of early adopters. This in turn would help fulfill the City's demand management and electricity generation mandates, and would fit well with existing and forthcoming energy-related policies.

9.1 Benefits to the City

These initiatives, while small-scale, provide environmental, economic, as well as social benefits to the city. Solar generation results in a reduction in carbon and sulphur dioxide emissions by displacing coal and natural gas-based electricity generation, although at great cost. On a large enough scale, this clean, distributed generation would help avoid the need to build new fossil-fuel or nuclear-based generation facilities and transmission lines into the downtown core. Building the solar market now will lower PV electricity generation prices in the future, thanks to economies of scale, greater module efficiencies, and local installation experience.

9.1.1 Peak Generation

An added benefit of solar-based electricity is that generation peaks are closely in line with the traditional afternoon peak in electricity demand. In Ontario, summer peak-demand is often met through electricity imports from coal power plants across the border or natural gas peaking plants, at significantly higher prices than baseload power.[98] These price peaks are then averaged into the retail price of electricity paid by customers. Encouraging investments in photovoltaics today could help reduce average electricity prices in the medium-term as solar electricity costs drop below the price paid for imports during peak hours.[99]

9.1.2 Alleviation of Transmission Strain

In Toronto, supplying electricity to meet peak demand is further complicated by transmission bottlenecks limiting the amount of electricity that can be delivered to the city. Encouraging the installation of solar generating capacity within the city would reduce demand for expensive imported electricity while also reducing strain on the transmission corridors.

9.1.3 Broad Economic Benefits

Support for solar would result in further economic benefits beyond future electricity cost reductions thanks to the development of a strong local or regional renewables industry. Germany, Spain, and Japan are prime examples of economic incentives for renewables spurring the growth of thriving local industries.[100] Finally, if enough solar generating capacity is installed to displace upwind coal-based generation, the city will benefit from reduced health costs and improvements in quality of life thanks to reduced smog levels.

9.1.4 Energy Awareness and Behaviour Change Among Participants

In addition to supplying electricity to the grid, community solar initiatives also motivates energy conservation among participants. Bringing electricity generation into their own backyard, literally, increases awareness about energy use and a greater understanding of the energy supply system. According to the Canadian Renewable Energy Alliance, "Through community power, DG [distributed generation] can help Canadians to better understand the value of renewable energy in reducing environmental impacts, stimulating community economic development, and forging stronger community ties… The smaller components and human-scale nature of DG can also help people relate to electricity generation better than with centralized generators which may be incomprehensible and difficult to interact with in a meaningful way due to their

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[98] These high peak prices are another reason for the high ($0.42/kWh) Standard Offer Program contract price for solar photovoltaic electricity generators.

[99] Historic data from the IESO show hourly electricity prices have risen above $0.40/kWh in Ontario on 17 days since June 2002, and above $0.20/kWh on 79 days in the same period.

[100] Ayoub, Dignard-Bailey, and Filion (2000), p. vi. Gipe, Doncaster, and MacLeod (2005), p. 41.

complexity."[101] Supporting community solar initiatives is one way to change energy behaviour and help realize the "culture of conservation" advocated by the Ministry of Energy.

9.2 Costs to the City

Community solar initiatives at present generate no costs for the City. If the City decides to provide support to the initiatives, the costs incurred by the municipality will vary depending on the form of assistance and size of the program. For example, aiding with promotion and organizational logistics would necessitate a much smaller budget than a large-scale incentive program to provide rebates to homeowners who install solar energy systems. Focusing on solar thermal rather than solar photovoltaics installation would entail smaller incentives to achieve comparable energy demand and greenhouse gas emissions reductions.

9.3 Possible Roles for the City

In light of the considerable benefits that these and similar initiatives create for the city, and the alignment of the projects' outcomes with the Energy Efficiency Office's mandate to reduce carbon emissions in Toronto, it is recommended that the City consider taking further action to promote such initiatives. This could take the form of:

- Providing community solar initiatives with an official "stamp of approval" from the City;
- Providing financial incentives, such as rebates or loans to participants to help cover upfront costs;[102]
- Coordinating with TAF to provide financial incentives or low-interest loans;
- Promoting and enabling project replication on wider scale through communications and logistical support;
- Instituting an educational and awareness campaign about solar technologies, particularly solar water heating (geared toward home owners and developers);
- Encouraging OPA and Toronto Hydro to develop enabling terms for micro-generators,[103] and extend the SOP to solar thermal applications;

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[101] Canadian Renewable Energy Alliance (2006a), p.8.

[102] For example, in other cities and states in North America, programs exist to cover 50% of upfront costs for solar panels.

[103] For example, lower connection and generators' fees for micro-generators, and combined generator and consumer accounts to reduce the amount of electricity generation billed as taxable income.

- Working with the Planning Department to reduce permitting obstacles to solar thermal installation.

9.4 Financial Incentives to make Community Solar Financially Viable

9.4.1 Solar Photovoltaics

Under the RISE scenario (8.25% financing on a 10-year loan; 20-year SOP contract at $0.42/kWh), residential PV systems are not attractive financial investments, as their payback periods are longer than their expected lifetimes. The City can use incentives to leverage private investment, and build the solar market. In order to bring the system payback to within an expected lifetime of 30 years, financial incentives could be provided as follows:

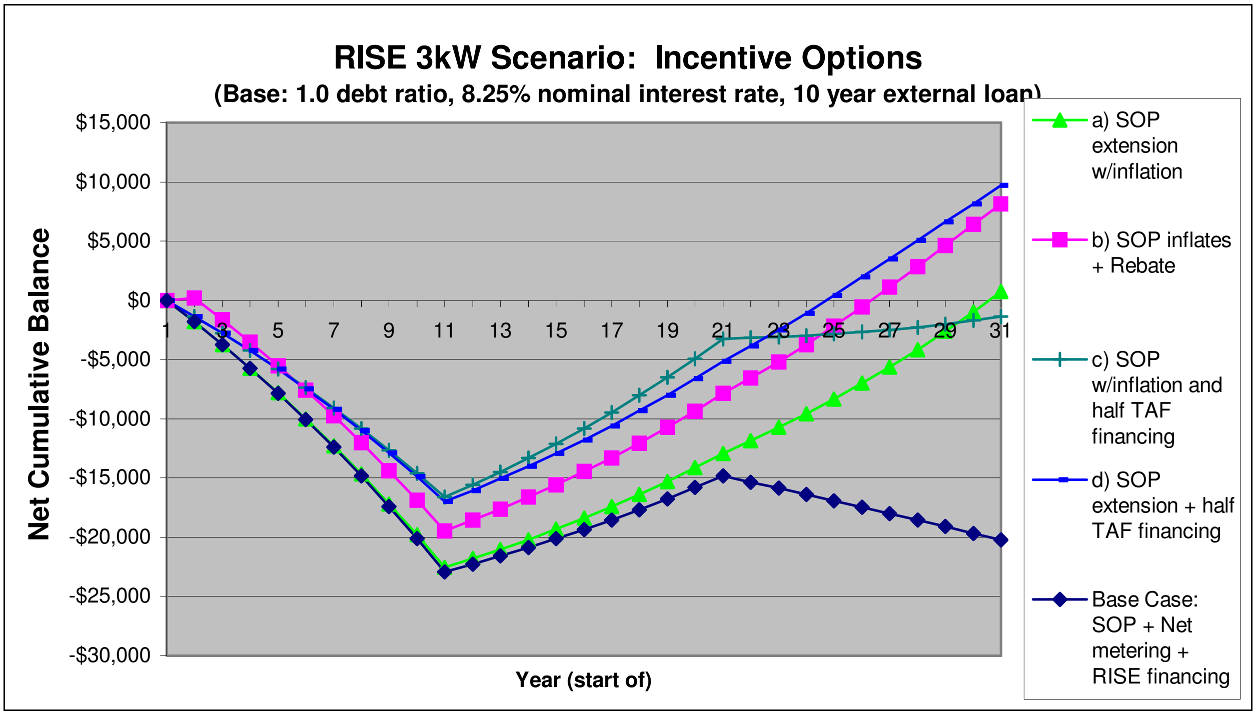
a) Extend SOP contract period to 30 years (either through changes to the SOP rules, or the City could provide equivalent support for years 21-30), *and*, make SOP payments for solar generation increase with inflation as they do for other technologies, and as is done in other countries.

b) Provide a $2000 upfront grant or tax rebate on the system *and* make SOP payments increase with inflation.

c) Provide an interest-free loan (e.g. through TAF) for half of capital costs *and* make SOP payments increase with inflation.

d) Provide an interest-free loan (e.g. through TAF) for half of capital costs *and* extend SOP contract period to 30 years.

Figure 16: Paybacks for Solar PV under Proposed Incentive Options



If the system is fully self-financed, smaller financial incentives would be needed to bring the system payback within 30 years, but this would limit the size of the potential pool of participants to those with the ability to secure very low financing (such as through a home mortgage).

9.4.2 Solar Thermal

Given the financial advantages of solar thermal, the City may prefer to focus on promoting solar thermal systems in coordination with community solar initiatives. The City could help secure low-interest loans, provide rebates, or pressure the OPA to include solar thermal systems in the Standard Offer Program in order to entice more homeowners to install solar thermal systems, but as shown above, the financial returns are already highly attractive. A less costly promotional and educational campaign could be pursued to increase awareness about the financial benefits of solar thermal, and thereby encourage private investment in the technology. A municipal by-law could also be established requiring solar thermal systems be installed on all new buildings, as has been done in other cities.[104] This could also be required

[104] Pujol (2005).

through Toronto's Green Development Standard, when and if it becomes compulsory for private developers.

9.5 Conclusions

Support for solar energy within a renewable energy strategy fits well with existing municipal energy policy and goals. Solar thermal technologies represent one of the most cost-effective options for reducing energy demand and greenhouse gas emissions in Toronto. Even with limited funding, the City can support community solar and achieve substantial energy demand reductions by focusing on promotion of installation of solar thermal water heaters.

If the City is more interested in clean, local electricity generation (rather than energy demand reductions), it will need to provide financial support for solar photovoltaics. Solar PV is currently the most expensive option for achieving municipal electricity generation and emissions reduction goals, but building the PV market today will bring down the price of solar-based electricity in the future. This in turn will allow for an affordable large-scale shift to renewable electricity supply mix down the line. Support for community solar will help move Toronto down the path to a more sustainable energy future.

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11 Appendix A: Greenpeace's Solar Pioneers, 1998-2000

- In 1998/9 Greenpeace organized a bulk purchase of 200W, grid-interactive solar rooftop systems. The program achieved savings of better than 15% for participants. (City of Toronto, 2000)
- Over 3,000 Canadians contacted Greenpeace about its "Solar Pioneers" program (Greenpeace 1999)
- <100 people committed to purchasing the panels, which cost $3,000 (Macdonell, 2000)
- The City of Toronto bought 8 100-W panels for Nathan Phillips Square (Macdonell, 2000)
- 37 Toronto households had systems installed (Greenpeace 1999)
- Also generated a database of more than 2,000 people who inquired about the campaign, and were sent information. (City of Toronto, 2000)
- Received $26,675 from TAF to establish Solar Pioneers program in 1998, and another $10,000 in 1999 (http://www.toronto.ca/taf/grantsapproved.htm)

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12 Appendix B: Methods and Calculations

12.1 RISE 3kW System Details

- 3 kW installed capacity, mono-crystalline silicone cells (16% efficiency)
- Fixed installation, 45 degree inclination, facing due south
- 43.7 degrees latitude (Toronto, ON)
- Average daily irradiance in plane of array: 3.89 kWh/m²/d
- Annual irradiance on array: 1.42 MWh/m²/yr = 162 W/m²
- Peak irradiance = 1000 W/m²

12.2 Calculating electricity production from solar PV

The quantity of electricity generated by photovoltaic panels and delivered to the grid depends on several key variables, including: module and balance of system efficiencies, angle and azimuth of module; and solar irradiance incident on the plane of the module (which depends on latitude and climate). In my calculations, peak irradiance is assumed to be 1,000 W/m^2, and average irradiance (162 W/m^2) was derived from Toronto-specific latitude and climate data (using NRCan's RETScreen software). In the RISE case, the system price includes the panels and balance of system equipment, and the system size is given in peak watts AC. As such, the formula for electricity delivered to the grid can be simplified to:

$$\mathbf{E}\ (\text{kWh/yr}) = (\textbf{Nominal System Size}\ (\text{kW}))(\mathbf{I_a / I_p})(\mathbf{8766})$$

12.3 Calculating financial paybacks for Solar PV

Given module costs initially specified in terms of \$ per square meter, the cost in terms of \$ per peak kiloWatt of DC electricity is given by:

$$\mathbf{C_m}(\$/\text{kW}_p) = \mathbf{C_m}\ (\$/\text{m}^2) \,/\, \eta_m \mathbf{I_p}$$

where η_m is the efficiency of the module, and I_p is peak insolation (in kW/m^2).

The Cost Recovery Factor (CRF), also known as the amortization rate, is calculated based on the interest rate (í) and the loan period (N):

$$\mathbf{CRF = i / [1- (1+i)^{(-N)}]}$$

In my scenarios, the interest rates and loan periods are varied, changing the CRF, and thereby the levelized cost of the electricity generated.

The levelized cost of producing photovoltaic AC electricity (that is, the selling price required per kWh produced in order to exactly pay off the system costs) is given by:

$$\mathbf{C}\ (\$/\text{kWh}) = \mathbf{[(CRF+INS)(1+ID)(C_m+ C_b+ C_p+ C_{inst})+OM]\ I_p / (8766 {*} I_a\ \eta_{BOS})}$$

where INS is insurance; ID is an indirect cost factor; C_m, C_b, C_p, and C_{inst} are the costs of the module, balance of system, power conditioning, and installation respectively (all in \$/kW_p DC); OM is a factor for annual operation and maintenance costs (given as a percentage of the initial system cost); I_p and I_a are peak and average insolation, and η_{BOS} is the efficiency of the balance of system.

In the RISE case, the system price includes the panels and balance of system equipment, all warranties, insurance, and installation. The module size is given in peak watts AC. As such, the formula can be simplified to:

$$C (\$/kWh) = [(CRF)(C_{system}) + OM] I_p / (8766 \cdot I_a)$$

The levelized cost of electricity from these projects changes dramatically depending on the financing terms. In my calculations, I looked at various ways of financing the solar systems, including different debt ratios (the ratio of the system cost financed through an outside loan to the total system cost). As such, I have identified in each case a range of levelized costs per kilowatt hour produced based on a debt ratio of 1, and a debt ratio of 0 (that is, a fully self-financed project, for which the interest is comparable to a home mortgage rate), using the appropriate cost recovery factor based on the interest rates and loan periods for the external and internal loans, respectively.

Comparing the levelized cost of electricity produced to the SOP rate paid to the producer gives us an initial indication whether the system will pay for itself within a 20 year lifespan and contract period. In order to get a fuller picture of the financial returns to system owners, I charted the external and loan internal interest payments, along with SOP and net-metering revenues, and operation and maintenance costs. Adding these costs and revenues for each year provided annual net revenues, from which the cumulative net balance of the project could be calculated.

Example 1: Financial analysis of **RISE 3-kW base scenario** (external financing through an 8.25%, 10 year loan, interest of 5% on personal debt; $0.42/kWh SOP payments for first 20 years, followed by net-metering)

Year (Start of)	**External Loan Remaining at start of Year**	Payment Made	Interest Paid	Principal Paid	Revenue	Funds payable to Self	O & M Costs	**Internal Loan Remaining at start of Year**	Interest on Personal Debt	**Cumulative Net Balance**
1	$23,960	$3,611	$1,977	$1,634	$1,789	-$1,822	$0	$0	$0	$0
2	$22,326	$3,611	$1,842	$1,769	$1,789	-$1,822	$0	$1,822	$91	-$1,822
3	$20,556	$3,611	$1,696	$1,915	$1,789	-$1,822	$0	$3,735	$187	-$3,735
4	$18,641	$3,611	$1,538	$2,073	$1,789	-$1,822	$0	$5,743	$287	-$5,743
5	$16,568	$3,611	$1,367	$2,244	$1,789	-$1,822	$0	$7,852	$393	-$7,852
6	$14,324	$3,611	$1,182	$2,429	$1,789	-$1,822	$0	$10,067	$503	-$10,067
7	$11,894	$3,611	$981	$2,630	$1,789	-$1,822	$0	$12,392	$620	-$12,392
8	$9,264	$3,611	$764	$2,847	$1,789	-$1,822	$0	$14,833	$742	-$14,833
9	$6,418	$3,611	$529	$3,082	$1,789	-$1,822	$0	$17,397	$870	-$17,397
10	$3,336	$3,611	$275	$3,336	$1,789	-$1,822	$0	$20,088	$1,004	-$20,088
11	$0	$0	$0	$0	$1,789	$1,789	$0	$22,914	$1,146	-$22,914
12	$0	$0	$0	$0	$1,789	$1,789	$0	$22,271	$1,114	-$22,271
13	$0	$0	$0	$0	$1,789	$1,789	$0	$21,595	$1,080	-$21,595
14	$0	$0	$0	$0	$1,789	$1,789	$0	$20,885	$1,044	-$20,885
15	$0	$0	$0	$0	$1,789	$1,789	$0	$20,140	$1,007	-$20,140
16	$0	$0	$0	$0	$1,789	$1,789	$0	$19,358	$968	-$19,358
17	$0	$0	$0	$0	$1,789	$1,789	$0	$18,537	$927	-$18,537
18	$0	$0	$0	$0	$1,789	$1,789	$0	$17,674	$884	-$17,674
19	$0	$0	$0	$0	$1,789	$1,789	$0	$16,769	$838	-$16,769
20	$0	$0	$0	$0	$1,789	$1,789	$0	$15,818	$791	-$15,818
21	$0	$0	$0	$0	$466	$466	$240	$14,819	$741	-$14,819
22	$0	$0	$0	$0	$485	$485	$240	$15,334	$767	-$15,334
23	$0	$0	$0	$0	$504	$504	$240	$15,856	$793	-$15,856

24	$0	$0	$0	$0	$524	$524	$240	$16,384	$819	-$16,384
25	$0	$0	$0	$0	$545	$545	$240	$16,919	$846	-$16,919
26	$0	$0	$0	$0	$567	$567	$240	$17,459	$873	-$17,459
27	$0	$0	$0	$0	$590	$590	$240	$18,004	$900	-$18,004
28	$0	$0	$0	$0	$613	$613	$240	$18,555	$928	-$18,555
29	$0	$0	$0	$0	$638	$638	$240	$19,109	$955	-$19,109
30	$0	$0	$0	$0	$663	$663	$240	$19,666	$983	-$19,666
31	$0	$0	$0	$0	$690	$690	$240	$20,226	$1,011	-$20,226

In this case, the net cumulative balance never rises above zero (in fact, the project losses continues to increase). The return on investment over the first 30 years in this case is a discouraging –6% per year.

Example 2: Financial analysis of RISE 3-kW **self-financed scenario with SOP indexed to inflation** (debt ratio of 0; interest of 5% on personal debt; 20 year SOP contract, followed by net-metering)

Year (Start of)	**External Loan Remaining at start of Year**	Payment Made	Interest Paid	Principal Paid	Revenue	Funds payable to Self	O & M Costs	**Internal Loan Remaining at start of Year**	Interest on Personal Debt	**Cumulative Net Balance**
1	$0	$0	$0	$0	$1,789	$1,789	$0	$23,960	$1,198	-$23,960
2	$0	$0	$0	$0	$1,796	$1,796	$0	$23,369	$1,168	-$23,369
3	$0	$0	$0	$0	$1,804	$1,804	$0	$22,741	$1,137	-$22,741
4	$0	$0	$0	$0	$1,811	$1,811	$0	$22,074	$1,104	-$22,074
5	$0	$0	$0	$0	$1,818	$1,818	$0	$21,367	$1,068	-$21,367
6	$0	$0	$0	$0	$1,825	$1,825	$0	$20,617	$1,031	-$20,617
7	$0	$0	$0	$0	$1,833	$1,833	$0	$19,823	$991	-$19,823
8	$0	$0	$0	$0	$1,840	$1,840	$0	$18,981	$949	-$18,981
9	$0	$0	$0	$0	$1,847	$1,847	$0	$18,090	$904	-$18,090
10	$0	$0	$0	$0	$1,855	$1,855	$0	$17,147	$857	-$17,147
11	$0	$0	$0	$0	$1,862	$1,862	$0	$16,150	$807	-$16,150
12	$0	$0	$0	$0	$1,870	$1,870	$0	$15,095	$755	-$15,095
13	$0	$0	$0	$0	$1,877	$1,877	$0	$13,980	$699	-$13,980
14	$0	$0	$0	$0	$1,885	$1,885	$0	$12,802	$640	-$12,802
15	$0	$0	$0	$0	$1,892	$1,892	$0	$11,557	$578	-$11,557
16	$0	$0	$0	$0	$1,900	$1,900	$0	$10,243	$512	-$10,243
17	$0	$0	$0	$0	$1,907	$1,907	$0	$8,856	$443	-$8,856
18	$0	$0	$0	$0	$1,915	$1,915	$0	$7,391	$370	-$7,391
19	$0	$0	$0	$0	$1,923	$1,923	$0	$5,846	$292	-$5,846
20	$0	$0	$0	$0	$1,930	$1,930	$0	$4,215	$211	-$4,215
21	$0	$0	$0	$0	$466	$466	$240	$2,496	$125	-$2,496
22	$0	$0	$0	$0	$485	$485	$240	$2,394	$120	-$2,394
23	$0	$0	$0	$0	$504	$504	$240	$2,269	$113	-$2,269
24	$0	$0	$0	$0	$524	$524	$240	$2,118	$106	-$2,118
25	$0	$0	$0	$0	$545	$545	$240	$1,939	$97	-$1,939
26	$0	$0	$0	$0	$567	$567	$240	$1,731	$87	-$1,731
27	$0	$0	$0	$0	$590	$590	$240	$1,490	$74	-$1,490

28	$0	$0	$0	$0	$613	$613	$240	$1,214	$61	-$1,214
29	$0	$0	$0	$0	$638	$638	$240	$901	$45	-$901
30	$0	$0	$0	$0	$663	$663	$240	$548	$27	-$548
31	$0	$0	$0	$0	$690	$690	$240	$152	$8	-$152
32	$0	$0	$0	$0	$717	$717	$240	-$291	$0	$291
33	$0	$0	$0	$0	$746	$746	$240	-$768	$0	$768
34	$0	$0	$0	$0	$776	$776	$240	-$1,275	$0	$1,275
35	$0	$0	$0	$0	$807	$807	$240	-$1,811	$0	$1,811
36	$0	$0	$0	$0	$839	$839	$240	-$2,379	$0	$2,379
37	$0	$0	$0	$0	$873	$873	$240	-$2,978	$0	$2,978
38	$0	$0	$0	$0	$908	$908	$240	-$3,611	$0	$3,611
39	$0	$0	$0	$0	$944	$944	$240	-$4,279	$0	$4,279
40	$0	$0	$0	$0	$982	$982	$240	-$4,984	$0	$4,984
41	$0	$0	$0	$0	$1,021	$1,021	$240	-$5,726	$0	$5,726
42	$0	$0	$0	$0	$1,062	$1,062	$240	-$6,507	$0	$6,507
43	$0	$0	$0	$0	$1,104	$1,104	$240	-$7,330	$0	$7,330
44	$0	$0	$0	$0	$1,149	$1,149	$240	-$8,195	$0	$8,195
45	$0	$0	$0	$0	$1,194	$1,194	$240	-$9,103	$0	$9,103
46	$0	$0	$0	$0	$1,242	$1,242	$240	-$10,058	$0	$10,058
47	$0	$0	$0	$0	$1,292	$1,292	$240	-$11,061	$0	$11,061
48	$0	$0	$0	$0	$1,344	$1,344	$240	-$12,113	$0	$12,113
49	$0	$0	$0	$0	$1,397	$1,397	$240	-$13,217	$0	$13,217
50	$0	$0	$0	$0	$1,453	$1,453	$240	-$14,375	$0	$14,375
51	$0	$0	$0	$0	$1,511	$1,511	$240	-$15,589	$0	$15,589

In this scenario, the system has a payback of 30 years (with the cumulative net balance turning positive at the start of year 31).

12.4 Calculating Greenhouse Gas Emissions Reductions

For my environmental analysis, I determined the amount of greenhouse gas emissions from fossil fuel-based power plants that would be offset per kilowatt of installed solar PV generating capacity. Emissions factors (EF) for carbon dioxide, methane, and nitrous oxide emissions from coal[105] and natural gas based electricity generation were taken from the International Panel on Climate Change (1997) emissions reference manual. Pulverized coal and natural gas combined cycle electricity generation efficiencies and transmission efficiencies were used to convert emissions factors for fossil fuels to emissions factors for electricity from centralized power plants. The 100-year global warming potentials (GWP) for each of the gases were taken from the U.S. Department of Energy (2006). Together, I used these to calculate tonnes of carbon dioxide equivalents avoided per megawatt-hour of reduced fossil-fuel based electricity demand.[106]

Coal was examined because the Province has promised to shut down all coal-fired power plants in Ontario by 2009. Shifting to renewable energy sources such as solar would help displace this form of heavily-polluting electricity generation.

[105] Greenhouse gas emissions per tonne of coal vary considerably depending on the coal's composition of carbon, hydrogen, sulphur, ash, oxygen, and nitrogen, which changes from one coal mine to the next. An average value (3.6 g/MWh) typical of "hard coal" has been used here.
[106] IPCC (2006). U.S. Environmental Protection Agency (2002).

Natural gas-fired generation was examined because it is the cleanest of the fossil fuel based electricity generation options. Solar photovoltaics have been offered as a better option to building a natural gas plant in Toronto by opponents of the Portlands Energy Centre plan.

Solar was assumed to have a carbon dioxide emission coefficient of 0, though there are some emissions from the manufacturing of the systems (most notably from the production of silica for the PV panels). A lifecycle energy and emissions analysis has not been done here, but others have found solar PV to have a carbon dioxide payback of roughly 3 years.[107]

Example 1: Reduced Carbon Dioxide Emissions from Offset Coal Use

CO_2 Emissions from Coal = EF * (molecular weight of CO_2/ molecular weight of C) / (η_{coal} * $\eta_{transmission}$)

= 0.09288 tonnes CO_2/MWh*(44/12)/(0.35*0.93) = 1.05 tonnes CO_2 / MWh

Coal CO_2 Emissions Offset by Solar PV system = (tonnes CO_2/MWh from coal) *(PV panel electricity generation in kWh/year/kW_p)/(1000kWh/MWh)

= (1.05 tonnes CO_2/MWh)*(1,420 kWh/yr/kW_p)/(1000kWh/MWh) = 1.49 tonnes CO_2/yr/kW_p

Coal CO_2 Equivalent Emissions Offset by Solar PV system = (tonnes CO_2 / yr/ kW_p)*(GWP_{CO2})

= (1.49 tonnes CO_2/yr/kW_p)*(1 tonne CO_2e/tonne CO_2) = 1.49 tonnes CO_2e/yr/kW_p

Example 2: Reduced Methane Emissions from Offset Coal Use

CH_4 Emission Factor for Coal-based Electricity Generation = EF_{CH4} **/ (η_{coal} * $\eta_{transmission}$)**

= 3.6 grams CH_4 /MWh / (0.35*0.93) = 11.1 grams CH_4 / MWh

Coal-based CH_4 Emissions Offset by Solar PV system = (EF)*(PV panel electricity generation in kWh/year/kW_p)/(1000kWh/MWh)

= (11.1 grams CH_4 /MWh)*(1,420 kWh/yr/kW_p)/(1000kWh/MWh) = 15.7 grams CH_4/yr/kW_p

Coal-based CH_4 Equivalent Emissions Offset by Solar PV system = (tonnes CH_4 / yr/ kW_p)*(GWP_{CH4})

= (15.7 grams CH_4 /yr/kW_p)*(23 tonnes CO_2e/tonne CH_4) = 0.00036 tonnes CO_2e/yr/kW_p

Example 3: Reduced Nitrous Oxide Emissions from Offset Coal Use

N_2O Emission Factor for Coal-based Electricity Generation = EF_{N2O} **/ (η_{coal} * $\eta_{transmission}$)**

= 5.0 tonnes N_2O/MWh / (0.35*0.93) = 15.5 grams N_2O / MWh

Coal-based N_2O Emissions Offset by Solar PV system = (EF)*(PV panel electricity generation in kWh/year/kW_p)/(1000kWh/MWh)

= (15.5 grams N_2O /MWh)*(1,420 kWh/yr/kW_p)/(1000kWh/MWh) = 22.0 grams N_2O/yr/kW_p

Coal-based N_2O Equivalent Emissions Offset by Solar PV system = (tonnes N_2O/yr/kW_p)*(GWP_{N2O})

= (22.0 grams N_2O/yr/kW_p)*(296 tonnes CO_2e/tonne N_2O) = 0.0065 tonnes CO_2e/yr/kW_p

[107] Turner (1999), p.688.

12.5 Calculating the Cost of Greenhouse Gas Emissions Reductions

In order to find the cost of greenhouse gas emissions, I subtracted the average price of electricity in Toronto ($0.09/kWh) from the levelized cost of solar energy for both a debt ratio of 0 and 1 (in order to exhibit the range of costs under different financing scenarios). This represents the *additional* cost of providing the clean energy.

I then multiplied this additional cost (in $/kWh) by the amount of electricity produced annually by both a 1- and 3-kilowatt system. Finally, I divided these amounts (in $/yr) by the quantity of carbon dioxide equivalent emissions reductions per year from offsetting coal and natural gas, respectively, to get the cost per tonne of greenhouse gas emissions reductions.

Example 1: Cost of GHG Emission Reductions from Offset Coal Use from a 3-kW system
Additional cost of solar electricity = (Levelized cost of solar electricity) – (Price of Coal-based electricity)

= $0.51/kWh - $0.09/kWh = $0.42/kWh (under a self-financed scenario)

= $0.90/kWh - $0.09/kWh = $0.81/kWh (under a external loan-financed scenario)

Cost of greenhouse gas emissions reductions = (Additional cost of solar electricity)*(Electricity produced per year) / (CO_2e Emissions Offset per year)

= ($0.42/kWh)*(1420 kWh/yr) / 0.49 tonnes CO_2e/yr = $1,220/tonne (self)

= ($0.81/kWh)*(1420 kWh/yr) / 0.49 tonnes CO_2e/yr = $2,379/tonne (external)

Range of costs = $1,220 to $2,379 / tonne CO_2e for a debt ratio of 0 to 1 (using the RISE base scenario of external financing through an 8.25%, 10 year loan, or self-financing through a mortgage at 5% over a 20 year period)

12.6 Calculating Financial Paybacks and Emissions Reductions for Solar Thermal

The financial payback calculations for solar thermal are similar to those for solar PV, but revenues are based on offset electricity or natural gas purchases rather than on SOP or net-metering payments. Greenhouse gas emissions reductions are based on replacement of electric hot water heating, fuelled by coal-fired electricity generation (generation efficiency of 0.35 and transmission efficiency of 0.92), and natural gas water heaters (efficiency of 0.6).

Solar Thermal Water Heating: System Details	
Nominal System Size (m^2):	10
Module Cost ($/system):	$4,000
Module Cost ($/$m^2$):	$400
Operation and Maintenance:	0.02
Indirect cost factor	0.05
Module efficiency:	0.4
BOS efficiency:	0.9
Peak insolation (W/m^2):	1000
Average insolation (W/ m^2):	163.13
Average insolation (kWh/m^2/yr):	1430

Thermal Energy Produced (kWh/yr) = Nominal System Size * (η_{module} * η_{BOS}) * (I_a / I_p) * hours/yr

=10 m^2 * (0.4*0.9) * (163 W/m^2 /1000 W/m^2) * 8766 hrs/yr = 5148 kWh/yr

Operation and maintenance costs are assumed to average 2% of the initial capital costs per year – twice that in the PV case, due to increased complexity of thermal system, including plumbing and moving fluids.

C_{system} ($/kW) = ($C_{system(\$/m2)}$) / ($I_p$ / η_{module}) * 1000 w/kW

$= \$400/ m^2 / (1,000 W/m^2 / 0.4) * 1000 w/kW = \$1,000/kW$

$C (\$/kWh) = [(C_{system(\$/kW)}) * (CRF + OM)]/ [(hrs/yr)*(I_a / I_p)* \eta_{BOS}]$

$= \$1,000 * (0.1507 + 0.02) / [8766 * (163/1000) * 0.9] = \$0.13/kWh$