An Analysis of the Climate and Financial Benefits of **Rooftop Solar Arrays** on Ontario's Single-Family Homes and the Barriers to Adoption

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ONTARIO CLEAN AIR ALLIANCE

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Overview

Ontario has great potential for rooftop solar power generation, which is good news as the need for this zero-carbon electricity is growing. Many single-family home rooftops can accommodate a 10 kW solar array or more, which is enough to generate as much electricity as the home uses over a year (net-zero electricity) while avoiding 1.5 tonnes of carbon emissions per year. That will increase to 3.9 tonnes per year by 2030 by displacing electricity from Ontario's increasingly gas-reliant electricity grid.

We recommend that the Government of Ontario take the following actions to encourage homeowners to install rooftop solar systems.

1	Standardize and lower the fees for connecting solar arrays to the electricity grid.
2	Raise the cap for simplified grid connections from 10 kW to 25 kW.
3	Pay homeowners for all net electricity exports.
4	Provide homeowners with grants to install rooftop solar systems in recognition of both the climate benefits and electricity system savings generated by such systems.

More rooftop solar will benefit all Ontarians by helping to phase-out our gas plants, reducing the need for new high-cost nuclear reactors and new electricity transmission infrastructure, and creating green jobs.

Many single-family home rooftops can accommodate a solar array which can generate

as much electricity as the home uses over a year

Introduction

Ontario needs more residential rooftop solar arrays. Rooftop solar is needed to help Canada fulfill its pledge to triple global renewable energy capacity by 2030[1], achieve net zero emissions by 2050, and support the growing need for electricity as our society transitions to low carbon technologies. Some estimates project that to achieve net zero emission by 2050 will require between one in nine or as many as one in three Canadian single-family homes to install rooftop solar arrays.[2]

By displacing generation from gas plants, rooftop solar arrays will reduce carbon emissions and harmful air pollution in Ontario. Furthermore, these arrays require no new land, no new transmission infrastructure, and can reduce electricity system line losses (wasted energy) because the electricity is generated where it is consumed. Rooftop solar is also good for the economy because widespread deployment will create skilled jobs and support Ontario solar manufacturing.

Rooftop solar arrays have benefits for homeowners too. Solar arrays have been shown to increase the resale value of homes[3], and when combined with batteries, they can supply power to a home during the power outages that are expected to become more common with climate change. Adding solar arrays can also help a home to save on utility bills and achieve net-zero electricity – when the solar arrays generate as much electricity in a year as the home uses.

This study looks at the emissions and financial impacts of investing in residential rooftop solar systems in Ontario and recommends policy measures that can increase adoption.

By displacing generation from gas plants, rooftop solar arrays will

reduce carbon emissions and harmful air pollution

Outcomes

This study looks at the impacts of installing 5 kW, 7.5 kW, 10 kW, 15 kW, 20 kW, and 25 kW solar arrays on single-family homes in Ontario. The financial analysis focuses on time of use (TOU) rate structures as these are the most economically favourable option. We have assumed a 25-year lifespan for solar photovoltaic (PV) panels and 15-year lifespan for the associated inverter. The PV panels are, in fact, likely to be productive for as long as 50 years, albeit with declining outputs. If a homeowner decides to upgrade the arrays after 25-years or more, there is a market for used solar panels.

The analysis accounts for roof slope and orientation, as well as system losses from snow, dirt, degradation and inefficiencies. The full methodology can be seen at the end of this report and the modeling spreadsheet is available on the Ontario Clean Air Alliance website.

Solar arrays can generate significant electricity in Ontario

Ontario has very significant potential for generating electricity through rooftop arrays. On average, just over 1,000 kWh can be generated for every 1 kW of solar arrays in a year (see **Table 1**). Although there are variations in solar potential within the province based on latitude and climate conditions, the variation is not very significant. We have used the average solar irradiation for the municipalities from the five utilities studied here (Toronto, Ottawa, London, Sudbury and Penetanguishene).

Table 1 | Annual solar panel electricity generation in Ontario

	kWh/yr
Ontario average generation (5 kW)	5450
Ontario average generation (7.5 kW)	8175
Ontario average generation (10 kW)	10,900
Ontario average generation (15 kW)	16,351
Ontario average generation (20 kW)	21,801
Ontario average generation (25 kW)	27,257

Ontario has very significant solar potential

According to the Ontario Energy Board, an average home uses 9,000 kWh of electricity per year[4] (see **Table 2**). Such a home could go net-zero electricity with a 9 kW solar array (annual electricity generation – annual electricity use = 0). If that home added an electric vehicle (EV) charged at home, the home would require a 12.5 kW solar array to go net zero. A home with a cold climate air source heat pump (ccASHP) and heat pump water heater (HPWH) would require a 17 kW array to go to net zero. Finally, if a home went all electric with an EV and heat pumps, a 20.5 kW solar array would be needed to make the home net zero.

Table 2 | **Annual Residential Electricity Consumption with EV Charging and Heat Pumps**

	kWh/yr	kW Solar for Net Zero Electricity
Ontario average residential use	9,000	9
Ontario average residential use with EV charging	12,852	12
Ontario average residential use with ccASHP & HPWH	17,467	17
Ontario average residential use with EV charging and ccASHP & HPWH	21,319	20

Most homes have the roof space to accommodate a large solar panel array. For example, a 1,000 square foot bungalow with a square base will typically have 1,200 square feet of roof space, which is usually enough to accommodate a 20 kW array[5]. In practice, many homes are larger than this (median total living area for Ontario homes is 1,650 sq ft)[6], but not all roof space will be suitably oriented or available for solar arrays. Solar arrays are also ideally installed on roofs that have recently been resurfaced or have long lasting surfaces (e.g., metal roofs).

Solar arrays benefit our society by reducing electricity carbon emissions

Solar arrays are a source of zero carbon emissions electricity. In Ontario, the electricity generated helps to avoid generation from gas-fired power plants, which in turn helps us achieve our climate goals. In 2024, a 10 kW solar array in Ontario will help us avoid 1.5 tonnes of carbon emissions. By 2030, that same array will let Ontario avoid 3.9 tonnes of emissions per year because of the province's growing reliance on gas generation during the peak hours when rooftop solar can be providing low carbon electricity instead. By 2030, a 10 kW array will offset the emissions equivalent of 1.2 passenger vehicles per year.[7]

When solar arrays, or indeed any product is made, some carbon emissions are generated. These are sometimes called the embodied carbon or upfront carbon emissions. For solar panels, these emissions are decreasing as China moves to cleaner electricity for manufacturing and as other countries, such as Canada, increase solar panel production. An analysis by the International Energy Agency

Solar arrays are a source of

zero carbon emissions electricity

puts the average carbon emissions from a 1 kW solar panel at roughly 300 kg[8]. With Ontario's current grid, it would take an average of two years of zero carbon electricity generation to cancel the embodied carbon from manufacturing the solar panels, leaving decades of carbon-free electricity generation.

Nearly 39% of the electricity generated by rooftop solar occurs during the residential time-of-use (TOU) rate's peak-hours, and a further 34% is generated during TOU rate's mid-peak hours. These are times when our grid sees its highest demand and is most reliant on polluting and inefficient gas power plants. Furthermore, as our society electrifies home heating, transportation and many industries, rooftop solar can add capacity to the grid during peak demand times and reduce the need to invest in new grid capacity.

Nearly 39% of rooftop solar generation is
during TOU peak hours

Solar arrays have high upfront costs for homeowners

On average in Ontario, the full cost of a 5 kW array is roughly $20,000, while a 7.5 kW array will cost $25,000 and a homeowner will pay nearly $30,000 for a 10 kW array (the incremental cost for each additional kW of solar arrays during an installation is roughly $2,000). The total cost of installation includes the cost of the panels, inverter, optimizers and other equipment, plus the labour cost of installation, and fees for the safety inspection, utility connection, and building permits. (Often quotes will include all costs for installing solar arrays but it is always good to check.)

Prices will vary depending on the system, roof conditions, extras (such as snow guards and squirrel guards), and even geography. Utility application and connection fees vary significantly between utilities (see **Tables 3** and **4**)[9].

Table 3 | Utility application plus connection fees for solar arrays under 10 kW (including GST/HST)

Utility	Application + Connection Fees
Toronto Hydro	$565 + variable connection fee
Hydro Ottawa	$1,449
London Hydro	$1,130
Hydro One	$904
Greater Sudbury Hydro	$538
Alectra Utilities	$437

Table 4 | Utility fees associated with connecting solar arrays over 10 kW (including GST/HST)

Utility	Connection Impact Assessment Study Fee	Application and Connection Fees
Toronto Hydro	$1,695 (10-20 kW) $2,260 (20-50 kW)	Varies by project
Hydro Ottawa	$1,130	Varies by project
London Hydro	$565 (10-20 kW) $6,215 (20 kW-500 kW)	$1,130 (10-20 kW) $28,250 (20-500 kW)
Hydro One	$2,321	Varies by project
Greater Sudbury Hydro	Varies by project	$857
Alectra Utilities	$1,695	$437

Time of use pricing generates greater savings than tiered pricing with solar in Ontario

The electricity bill savings from installing rooftop solar is highest with time of use (TOU) and ultra low overnight (ULO) rates[10] (see **Table 5**) since a home's daytime net electricity exports to the grid are credited at high rates while a home's electricity imports from the grid at night are charged at low rates. There is negligible difference in the savings between TOU and ULO rates.

Tiered rates provide the lowest savings, even for homes with high electricity needs. Homeowners should consider their own electricity use patterns to determine which rate structure will provide them with the largest electricity bill savings.

Table 5 | Average Ontario homeowner annual electricity bill savings with a 10 kW solar array with different utility rate structures

	TOU Rates	ULO Rates	Tiered Rates
2024 Savings	$1,584	$1,580	$1,288

The electricity bill savings...
is highest with time of use (TOU) and ultra low overnight (ULO) rates

Rooftop solar investment paybacks

Rooftop solar payback years will vary by geography due to differences in utility connection fees, solar potential, and local utility rates. **Table 6** shows the payback years for five Ontario municipalities for different sized systems using today's electricity rates. Penetanguishene is the Alectra Utilities municipality used. (No data (ND) is provided for projects where the application and connection fees vary on a case-by-case basis.)

Rooftop solar **payback years** will vary by geography

Table 6 | Payback years for solar arrays using TOU rates in Ontario municipalities, assuming today's electricity rates

Utility	5 kW	7.5 kW	10 kW	15 kW	20 kW	25 kW
Toronto Hydro	ND*	ND	ND	ND	ND	ND
Hydro Ottawa	32	27	24	ND	ND	ND
London Hydro	29	25	22	20	19	26**
Greater Sudbury Hydro	31	26	24	ND	ND	ND
Alectra Utilities	29	25	23	21	20	19

*ND = no data, these utilities do not have fixed application and connection fees for the given systems
**London has very high connection fees for systems over 20 kW

Table 7 shows the pay back periods for solar arrays assuming residential TOU rates increase by 2% per year.

Table 7 | Payback years for solar arrays using TOU rates in Ontario municipalities, assuming electricity rates rise by 2% per year

Utility	5 kW	7.5 kW	10 kW	15 kW	20 kW	25 kW
Toronto Hydro	ND	ND	ND	ND	ND	ND
Hydro Ottawa	25	22	20	ND	ND	ND
London Hydro	23	20	19	17	16	22
Greater Sudbury Hydro	24	21	20	ND	ND	ND
Alectra Utilities	24	21	19	18	17	16

Table 8 shows the pay back periods for solar arrays assuming residential TOU rates increase by 4% per year.

Table 8 | Payback years for solar arrays using TOU rates in Ontario municipalities, assuming electricity rates rise by 4% per year

Utility	5 kW	7.5 kW	10 kW	15 kW	20 kW	25 kW
Toronto Hydro	ND	ND	ND	ND	ND	ND
Hydro Ottawa	21	19	17	ND	ND	ND
London Hydro	20	18	16	15	15	19
Greater Sudbury Hydro	21	18	17	ND	ND	ND
Alectra Utilities	20	18	17	16	15	15

The best paybacks are seen with larger arrays because a significant portion of the upfront costs are independent of the size of the array (connection and inspection fees, inverter costs and labour costs). To achieve the best paybacks, under the current net metering rules, homeowners should invest in the largest system that can fit on their roof while aiming to generate no more than their total electricity use per year since homeowners are not paid for any net annual exports to the Ontario grid (annual electricity produced beyond what the home consumes in a year).

Assuming residential electricity rates rise by 2% per year, rooftop solar panel paybacks are in the range of 16 to 25 years. If electricity rates rise by 4% per year, the paybacks are in the range of 15-21 years. The industry standard for solar panel lifespan is 25-30 years[11] but they are expected to continue to generate electricity for as long as 50 years, albeit with increasing losses. Solar inverters will typically be replaced after 15 years (the cost of one replacement inverter is included in this analysis).

Financial incentives have proven to increase the adoption of rooftop solar arrays[12]. Table 9 shows the payback periods for solar arrays for Alectra Utilities' customers with financial incentives of $1,000 and $2,000 per kW assuming TOU rates rise by 2% per year.

Table 9 | Payback years for Alectra Utilities' customers for solar arrays with upfront incentives assuming TOU rates rise by 2% per year

	5 kW	7.5 kW	10 kW	15 kW	20 kW	25 kW
No incentives	24	21	19	18	17	16
$1,000/kW incentives	19	16	14	13	12	12
$2,000/kW incentives	15	11	9	8	7	6

The best paybacks are seen with larger arrays

Policy Recommendations

Policies that encourage homeowners to install solar arrays on their roofs will provide the following benefits for Ontario:

1. Reduce smog and greenhouse gas pollution by helping to phase-out gas power;
2. Reduce the need for new high-cost nuclear reactors;
3. Increase the supply of clean, safe, zero emissions electricity to meet our future electricity needs;
4. Reduce our need for new transmission capacity because the electricity generated is used locally;
5. Reduce energy losses during the transmission and distribution of electricity from centralized power stations to homes[13];
6. Reduce the outflow of Ontario dollars to purchase fossil gas and uranium from Western Canada and the United States; and
7. Create more jobs in Ontario.

Utilities should offer fixed and low-cost application and connection fees for projects less than 25 kW

There are currently very significant differences in fees that local utilities charge homeowners to apply for and get connected to the grid through net metering. In many cases, the fees are assessed on a case-by-case basis that can add time and complexity to the process. For small projects such as those on residential rooftops, these fees can add uncertainty and cost barriers to the installation of rooftop solar systems.

Solar arrays provide
multiple benefits for Ontario

Ontario utilities should look to Alectra (servicing Barrie, Guelph, Mississauga and others) where the application and connection fees are fixed at $437 for projects less than 25 kW. This is far lower than the fees charged in other areas. In London Hydro service areas, the fees are $1,130 for projects less than 20 kW but jump to a staggering $28,250 for projects over 20 kW.

The Ontario Energy Board should raise the cap for simplified and low-cost connection screening to 25 kW or higher

Currently in Ontario, microgeneration projects (e.g. solar panels and home batteries) with a combined export capacity of greater than 10 kW require an additional connection impact assessment. Connection impact assessments are used to determine the impact of the solar arrays on the local electricity utility's distribution grid and can add thousands of dollars to the overall cost of the project (see **Table 4** for the fees). Instead of a full connection impact assessment, these small projects could undergo simplified and low-cost connection screening.

There is no scientific or safety rationale for the 10 kW threshold for connection impact assessments. In Alberta[14], British Columbia[15], Manitoba[16], New Brunswick[17], Newfoundland[18] and Saskatchewan[19], the cap for simple and low-cost connections is 100 kW or more, and in Quebec it is 50 kW[20].

In the United States, the Interstate Renewable Energy Council recommends a 25 kW export cap for simplified connection screening at a recommended customer cost of $100 (US$)[21].

The Ontario Energy Board should follow the lead of other North American jurisdictions and raise its cap for simple and low-cost connection screening to 25 kW or higher. A higher cap would encourage homeowners to install larger solar arrays which would reduce our need for polluting gas plants and higher cost nuclear reactors – reductions that would benefit all Ontarians. Any additional fees for the simplified connection screening should also be standardized at a fixed, low rate.

Rooftop solar owners should be paid for their net exports to their local utility

Ontario's net metering program allows homeowners to export their surplus power to their local electric utility when their solar systems are producing more power than their home needs. The homeowners earn credits for these exports which can be used to pay for their electricity imports from the grid when their home's electricity needs are greater than the output of their solar arrays (e.g., at night or during the winter).

Credits can only be carried over for one year, however. This means that if the home's annual exports to the grid are greater than its annual imports, the owner will not be paid for the net exports of low emission solar power to the grid. Instead, the local utility (e.g., Toronto Hydro) will earn a profit by selling the home's surplus clean electricity to its next-door neighbour for a price of up to 28.6 cents per kWh[22].

This is unfair and counterproductive.

A higher cap

would encourage homeowners to install larger solar arrays which would reduce our need for polluting gas plants and higher cost nuclear reactors

Large power companies like Ontario Power Generation are paid for every kWh of electricity that they provide to our electricity grid from their gas plants and their nuclear reactors. Similarly, homeowners should also be paid for every kWh of solar electricity that they provide to the grid.

Not compensating owners for surplus generation is also counterproductive since it eliminates the financial incentive for homeowners to install larger solar arrays that will enable them to make net exports to the grid. Ontario needs more solar power to phase-out polluting gas power and to reduce the need for high-cost new nuclear reactors and to meet growing demand for electricity. Therefore the Government of Ontario should amend its *Net Metering* regulation to require utilities to pay homeowners fair prices for all the electricity that they provide to the grid.

Utilities should make grid connections within 10 days

Many Ontario homeowners have shared their frustrations with delays in getting solar panel approval and connections to the grid.

Ontario's municipal utilities and Hydro One should be required to connect residential solar PV systems to the electricity grid within ten days after an application is submitted and provide timely communications and other assistance when issues arise that may delay connections.

Reducing the upfront capital cost barriers to the installation of rooftop solar

A major barrier to installing more residential solar arrays is their high upfront capital costs. Currently, the paybacks for investments in rooftop solar arrays are 16-25 years if residential electricity rates rise by 2% per year. Financial Incentives of $1,000 to $2,000 per kW would reduce these times to 6-19 years.

Financing is available from a variety of sources including the federal Greener Homes Loans[23] and municipal financing such as Toronto's Home Energy Loan Program[24]. The Greener Homes Loans program provides zero-interest financing for loans of up to $40,000 repayable over ten years. However, the loan terms are typically shorter than the paybacks for solar arrays, which is a barrier to participation by low-income households.

Homeowners should be paid

for every kWh of solar electricity that they provide to the grid

Conclusions

Solar arrays on single family home rooftops can help Ontario to decarbonize its grid, increase electricity production to support electrification, reduce air pollution, and stimulate the economy.

On average, a 10 kW rooftop array in Ontario will avoid 3.9 tonnes of carbon emissions from gas-fired power plants per year by 2030 while generating electricity predominantly during peak demand times. While residential solar arrays of 5 kW or greater can meet our electricity needs at times and in areas where it is needed, they have high upfront costs and long payback periods (16-25 years assuming electricity rates rise by 2% per year).

Solar adoption can be promoted by reducing application and connection fees; raising the cap for low-cost grid connections to 25 kW; paying homeowners for their net electricity exports to their local utility; and providing financial incentives that reduce the payback times for new rooftop solar installations.

A prosperous and healthy Ontario depends on more homes adopting solar arrays for the benefit of all, but we need to reduce the red tape, correct the unfair purchasing policies for net exports to the grid, lower the high upfront capital costs and address other barriers that are blocking our path to a cleaner and lower cost electricity system. The potential is there -- we just need better tools to tap into it!

A prosperous and healthy Ontario depends on

more homes adopting solar arrays

for the benefit of all

Methodology

Solar panel upfront costs are based on installed cost quotes from 37 sources excluding the connection, Electrical Safety Authority (ESA) inspections and building permit fees. Connection, inspection and building permit fees were obtained for each applicable city.

Hourly solar potential by city was obtained from Environment Canada databases[25]. Solar irradiation outputs were zeroed in January when solar arrays are likely covered in snow. The hourly irradiation output was capped at 5/6 of the annual peak because we assume the inverter is sized at 5/6 of the size of the solar array to optimize cost and output. Using this data, the percent of the annual solar irradiation occurring in each TOU/ULO block was calculated.

Average kWh generated per kW of solar arrays for each city was obtained from the National Renewable Energy Laboratory (NREL) PVWatts calculator[26] (January generation excluded due to assumed snow coverage). The calculator includes a 14.08% system losses factor to account for dirt, degradation, system inefficiencies, power outages and more. The average of the outputs at azimuths 90°, 135°, 180°, 225° and 270° was calculated to account for the fact that roofs may be facing east, south, west, and anything in between.

The average kWh/kW/yr for each TOU/ULO block was the product of the percent of solar irradiation for each block and the average annual kWh/kW. For the tiered rate structure, we assumed an average use of 750 kWh/month based on an Ontario Energy Board report[27]. For the fully electrified home, we added 321 kWh/month for EV charging, 66 kWh/month for water heating with a heat pump water heater (HPWH: EF of 3.75)[28], and 1279 kWh/month for the six winter months for space heating with a cold climate air source heat pump (ASHP: SCOP of 2.7)[29].

The annual savings from solar arrays equals the price of electricity supply multiplied by every kWh of solar generation plus the avoided per kWh delivery, transmission and regulatory charges.[30] GST and Ontario Electricity Rebate are also applied.

The 2024 and 2030 marginal emissions factor the each TOU period was calculated by taking the average emissions from an Ontario gas power plant (390 g CO2e/kWh)[31] multiplied by the percentage of time gas is on the margin for the TOU period[32]. The annual greenhouse gas emissions avoided with the solar array was calculated using this marginal emission factor, the percentage of annual solar generation that occurs during each TOU period and the annual kWh of electricity generated by the array.

Assumptions

- The kW size is the size of the solar arrays, not the inverter. The inverter is assumed to be 5/6 the size of the array
- roof can support solar arrays and includes 1.5 ft overhangs
- roof mounted with a 4/12 pitch
- roof is angled between 90-270' relative to North
- roof will not require resurfacing over the lifetime of the solar arrays
- roof is not shaded
- solar arrays are kept clean
- excluded solar output in January when arrays are likely covered in snow
- annual electricity production does not exceed annual electricity use
- 14.08% system losses due to dirt, degradation, power outages and system inefficiencies (NREL PVWatts default value)
- maintenance costs have not been included
- the installed cost of one inverter replacement is included
- for tiered pricing, assumed even demand and over summer and winter with solar output decreasing higher tier rates before lower tier rates
- one Electrical Safety Authority Inspection per installation
- 17 W per square foot of solar panel based on typical panel sizes

Sources

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Hydro Ottawa, Shawn Carr, Manager Customer Experience
London Hydro, Jac Vanderbaan, VP Operations & Planning
Greater Sudbury Hydro, Serge Robillard, Supervisor Engineering
Alectra Utilities, Linas Medelis, VP Customer Service
Hydro One, Michelle Micallef, Team Leader Hydro One Networks Inc.

10 For details of time-of-use and ultra-low overnight rate structures, see https://www.oeb.ca/consumer-information-and-protection/electricity-rates

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30 In these calculations, the line lost adjustment factor is not applied to electricity costs and distribution rates but is applied to transmission and regulatory charges. Subtracted from these savings is the cost of the electricity added to the grid and which is lost in transmission. In other words, customers are effectively charged for electricity that they add to the grid but which is lost in transmission (calculated using the price of electricity, the kWh of solar generated and the line loss adjustment factor).

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32 IESO Customer Relations April 8, 2024 response to Jack Gibbons, Ontario Clean Air Alliance (Inquiry #6854).