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Rays of Equity: Overcoming Toronto's Solar Barriers

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Introduction

As the world grapples with an escalating global environmental crisis, the need for innovative approaches continues to increase. Adoption of energy-efficient solutions is poised to play an increasingly important role in achieving net zero,[1] yet as governments across the world accelerate the green transformation, an often-overlooked challenge to successfully achieving carbon neutrality is a relative lack of adoption of energy-efficient solutions by low-income households.[2]

Empirical data shows that rooftop solar uptake numbers are lowest among lower-income households,[3] [4] as they often face barriers in adopting energy-efficient updates such as private solar panels. [5] This is despite the existence of publicly and privately financed programs such as direct subsidies, third-party solar panel leasing arrangements, and clean energy generation rebates offered through feed-in tariffs.

Canada is a growing nation, and its energy demand is projected to rise significantly in coming decades.[6] At the same time, Canada's rooftop solar uptake rate is lacking compared to other countries[7] and would need to be increased manyfold to meet its potential net-zero targets.[8]

Despite the increasing financial viability of private use rooftop solar panels due to their declining costs and their potential for addressing energy poverty through lowering energy costs and meeting the increasing energy demand through local energy generation, there is a lack of research into the existing barriers to adopting rooftop solar panels among lower-income households in Canada. In context of ensuring an equitable transition to green energy and addressing existing energy poverty issues, there is a growing need to inquire why low-income households face barriers to adopting energy-efficient solutions such as rooftop solar panels and explore ways of addressing these barriers through specific policies and programs.

This research aims to better understand the barriers faced by lower-income households in adopting private-use solar panels as energy-efficient solutions in Toronto. The study attempts to perform a nuanced comparative analysis of policies influencing household decisions in Toronto with other jurisdictions across the world, to produce an assessment of existing policies and procedures and conduct a transferability assessment of successful projects. It does so by engaging in a comparative study with

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[1] Susanna Berkouwer and Joshua Dean, "Behavioral Barriers to Energy Efficiency Adoption in Kenya: Evidence from Cookstoves," *AEA Randomized Controlled Trials*, September 29, 2017, https://doi.org/10.1257/rct.2484-6.0.
[2] Rohan Best and Andrea Chareunsy, "The Impact of Income on Household Solar Panel Uptake: Exploring Diverse Results Using Australian Data," *Energy Economics* 112 (August 2022), https://doi.org/10.1016/j.eneco.2022.106124.
[3] Best and Chareunsy, "The Impact of Income on Household Solar Panel Uptake: Exploring Diverse Results Using Australian Data," *Energy Economics* 112 (2022)
[4] Best and Chareunsy, "The Impact of Income on Household Solar Panel Uptake: Exploring Diverse Results Using Australian Data," *Energy Economics* 112 (2022)
[5] Eric O'Shaughnessy et al., "The Impact of Policies and Business Models on Income Equity in Rooftop Solar Adoption," *Nature Energy* 6, no. 1 (November 9, 2020): 84–91.
[6] Canada Energy Regulator Government of Canada, "Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050 – Data Supplement," CER, November 29, 2023.
[7] International Energy Agency, "Canada 2022 – Analysis," IEA, 2022, https://www.iea.org/reports/canada-2022.
[8] Judy Mitri, "Dunsky Report Defines Potential for Onsite Solar to Help Canada Achieve Net-Zero," Canadian Renewable Energy Association, December 14, 2023.

Stuttgart, Germany, as well as a multitude of case studies from Australia and California, to better understand different approaches to increasing uptake of solar panels on lower-income households.

Methodology

The aims of this paper will be achieved primarily through the following methodology:

a) Identifying barriers to low-income solar adoption across global jurisdictions that will be conducted through meticulous literature review on energy poverty, utilization of rooftop solar panels for poverty alleviation, and analysis of existing programs and policies, as well as persisting challenges that low-income households might face.
b) Conducting a test of viability of solar panels, using average yearly solar irradiation data for Toronto and southern Ontario. Data for average renewable energy generation per kWp of installed solar panel capacity includes depreciation of efficiency of solar modules over time. Data for average energy consumption estimations acquired through the Ontario Energy Board.
c) Analyzing and reviewing of existing programs offered by the municipality of Toronto and the province of Ontario through their respective websites to identify persisting barriers to solar uptake.
d) Performing a transferability test for insights from existing literature to apply to barrier findings, producing an overview of all applications without any specific endorsement.

Literature Review

Solar panels have been historically regarded as a tool for the upper-income households, as their installation cost has been high in the past.[9] [10] This has led governments and jurisdictions across the world to adopt policies incentivizing installing rooftop solar panels that were aimed primarily at the upper-class households. However, the cost of solar panels has been steadily decreasing over the last decade, thanks to technological advancements and economies of scale and their potential to address the issues of energy poverty has increased. Despite this, research shows that a majority of existing policies within the United States and Canada are still tailored towards the high-income households.[11] This arises the issue of inequity when it comes to adopting energy efficient solutions such as solar panels, where lower income households that stand to benefit the most from the rooftop solar panels are also their lowest adopters. One study found that a household making USD200,000 was four times as likely to adopt a solar panel compared to a household earning less than USD50,000.[12] It is important to consider whether installing solar panels actually leads to poverty reduction and addresses energy justice.

An even bigger issue with the existing programs from both public and private backgrounds is ensuring an equitable green transition, where a shift to renewable energy brings more energy independence to the lower-income households. In view of this, a study revealed results of an assessment of existing green energy generation incentives across the German municipalities, specifically the feed-in tariffs, which

[9] Kimberly S. Wolske, Paul C. Stern, and Thomas Dietz, "Explaining Interest in Adopting Residential Solar Photovoltaic Systems in the United States: Toward an Integration of Behavioral Theories," *Energy Research & Social Science* 25 (March 2017): 134–51.
[10] Eric O'Shaughnessy et al., "The Impact of Policies and Business Models on Income Equity in Rooftop Solar Adoption," *Nature Energy* 6, no. 1 (November 9, 2020): 84–91.
[11] O'Shaughnessy et al., "The Impact of Policies and Business…," *Nature Energy* 6, no. 1 (2020).
[12] O'Shaughnessy et al., "The Impact of Policies and Business…," *Nature Energy* 6, no. 1 (2020).

reimburse households that generate renewable energy for electricity they feed back into the grid. Those households' electricity price ends up being lower thanks to the feed-in tariffs that are supposed to incentivize green energy generation among households. The study found that these policies primarily benefit the higher-income households that already own solar panels and other means of generating clean energy, at the expense of middle and lower-income households who have to contribute to paying for the feed-in tariffs through increased levies and higher electricity charges.[13] Germany's feed-in tariff system and the levies that were imposed to pay for it have increased various inequality measures, as the levy for the feed-in tariff increases, the benefit from the program is distributed to a very limited number of households that own photovoltaics, which fall overwhelmingly in the higher-income strata.[14]

In an environment where lower-income households face the highest energy burden, meaning that they pay the highest percentage of their income on energy,[15] policies like Germany's feed in tariffs are shown to increase inequity and perpetuate the inequitable access to green energy. Lower-income households have more to gain from rooftop solar panels as they are paying a higher share of their income on energy overall, but their uptake rates are the lowest among all income levels. Solar panels were also found to be more effective in reducing energy burden among lower-income households than with their higher-income counterparts, suggesting that a reevaluation of existing policies is needed to accelerate solar uptake rates among lower-income households.[16]

One of the most significant differences between high- and lower-income households is their energy burden, which indicates what percentage of disposable income is spent by a household on monthly energy needs. Lower income households face higher energy burden, which increases likelihood of cyclical poverty, affects household's mental and physical wellbeing, increases incidence of winter deaths, and hampers access to local economic developmental opportunities.[17] A comprehensive study across the U.S. found that low-income households spend more than three times the share of their income on energy, compared to non-low-income households (8.1% vs 2.3%).[18] This has significant implications for developing an energy transformation policy that addresses intrinsic energy inequities, especially as the global green transition aims to overhaul how we meet our energy needs. Existing energy burden and rising energy demand in Ontario[19] would put an even bigger weight on lower-income households. Utilizing rooftop solar panels as sources of autonomous and more affordable energy would be one of the ways to alleviate high energy burden and address the issue of energy justice for lower income households. This is confirmed by a study of about 500,000 households with residential rooftop solar panel across the United States, which found that installing rooftop solar panels consistently reduced energy burden levels across all income groups, with reduction for lower-income households being the most pronounced.[20] This

[13] Simon Winter and Lisa Schlesewsky, "The German Feed-in Tariff Revisited - an Empirical Investigation on Its Distributional Effects," *Energy Policy* 132 (September 2019): 344–56, https://doi.org/10.1016/j.enpol.2019.05.043.
[14] Winter and Schlesewsky, "The German Feed-in Tariff Revisited…," *Energy Policy* 132 (2019): 344–56,
[15] Sydney P. Forrester et al., "Modeling the Potential Effects of Rooftop Solar on Household Energy Burden in the United States," *Nature Communications* 15, no. 1 (June 1, 2024).
[16] Forrester et al., "Modeling the Potential Effects of Rooftop…" *Nature Communications* 15, no. 1 (2024).
[17] Forrester et al., "Modeling the Potential Effects of Rooftop…" *Nature Communications* 15, no. 1 (2024).
[18] Ariel Drehobl, Roxana Ayala, and Lauren Ross, "How High Are Household Energy Burdens?," American Council for an Energy-Efficient Economy, September 2020.
[19] Independent Electricity System Operator, "Ontario's Energy Future," The Independent Electricity System Operator, 2024.
[20] Forrester et al., "Modeling the Potential Effects of Rooftop…" *Nature Communications* 15, no. 1 (2024).

consistent reduction also held for modelling effects of installing photovoltaics that included loan and lease payments by the households.[21]

Upfront Cost Barriers & Direct Subsidy Programs

Significant upfront costs associated with purchasing and installing rooftop solar panels has been identified as a significant barrier to solar uptake.[22] Households with less disposable income tend to have less savings and thus cannot afford to invest a large sum of money at once, meaning that their uptake rates are directly affected by income levels. One way of addressing this are subsidies and incentives that directly lower the cost for installing photovoltaic modules at the initial phase of purchase and installation. Australia has one of the highest rooftop solar uptake rates in the world, and this research looked at the effects of its Small-scale Renewable Energy Scheme (SRES), a direct upfront cost subsidy, on increasing uptake among lower-income households by addressing the barrier of insurmountable upfront costs.

The subsidy amount from SRES depends on a multitude of factors and is calculated based on how much capacity is being installed, what zone of solar irradiation capacity the household belongs to (defined by Australia's Clean Energy Regulator), and aggregate potential for future energy generation, calculated through a certificate per 1 mWh of energy.[23] A study estimated that an average rooftop solar panel system, with a capacity of 3 Kw, would have received a subsidy of about one third of the model's full price.[24]

A comprehensive, zip-code based assessment of the effects of the SRES, controlling for other locally implemented leasing support schemes, found that the scheme had a positive effect on rooftop solar uptake, with an elasticity of 1.2, meaning that a 1% increase in subsidies constituted to a 1.2% increase in solar uptake. While the effects of SRES specifically on lower-income solar uptake are yet to be assessed, the difference in uptake rates across income levels found in the study suggests that the middle-income households stand as the biggest beneficiaries of the scheme.

Stuttgart's Solar Offensive program is a comprehensive funding strategy for Photovoltaic system installations across the city. The program funds all costs related to planning, construction and all other accompanying costs related to installing solar panels, including scaffolding, electrical equipment, meters, static strengthening of the building, and other structural adjustments related to the roof of buildings. The funding is provided per kWp of installed capacity and is disbursed prior to the commencement of the project to install solar panels. The rate is EUR350 per kWp for normal roofs and EUR450 for green roofs. It is notable to state that the photovoltaic modules themselves are not funded, and households must rely on federal incentives for solar panels, one of which is the abolition of the VAT on all photovoltaic modules.[25] Solar Offensive program also provides support for tenants and mortgage holders, provided there is a written agreement between the parties. The Solar Offensive program applies to all house types, including detached housing and apartments and has a separate funding scheme for installation of energy storage batteries to enhance households' autonomy from the grid.

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[21] Forrester et al., "Modeling the Potential Effects of Rooftop..." *Nature Communications* 15, no. 1 (2024).
[22] Monisha Shah et al., "Affordable and Accessible Solar for All: Barriers, Solutions, and On-Site Adoption Potential," National Renewable Energy Laboratory, 2021.
[23] Rohan Best, Paul J. Burke, and Shuhei Nishitateno, "Evaluating the Effectiveness of Australia's Small-Scale Renewable Energy Scheme for Rooftop Solar," *Energy Economics* 84 (October 2019): 104475.
[24] Best et al, "Evaluating the Effectiveness of Australia's…." *Energy Economics* 84 (October 2019.
[25] Bundesrepublik Deutschland, "FAQ „Umsatzsteuerliche Maßnahmen Zur Förderung Des Ausbaus von Photovoltaikanlagen"," Bundesministerium der Finanzen, 2023. Translation provided by: Google Translate.

This seems a fairly comprehensive policy; however, it is peculiar that city's unified Solar adoption strategy does not fund direct purchase of photovoltaics, but rather the accompanying costs that come with the process. This is an important difference between other direct subsidy programs, like the SRES scheme from Australia, and the Solar Offensive. Usually, upfront cost subsidies cover direct PV costs, but in Stuttgart's case, focus is on accompanying costs rather than modules themselves, suggesting that the magnitude of subsidies offered for the overall installation of solar panels is underutilized in Stuttgart, which limits the reduction in upfront costs for Stuttgarter low-income households. While this scheme still offers a direct upfront subsidy, it does not apply to the largest cost of rooftop solar installations – purchase of PV panels themselves. Absence of any municipal or provincial policy that makes purchasing PV modules more accessible is potentially hampering rooftop solar uptake in Stuttgart, especially among lower-income households who cannot afford to pay the full upfront costs for solar panels. This presents a persistent barrier for lower-income households trying to gain better access to solar panels – when subsidies for installation are limited, the effect of these subsidies would not be as pronounced.

Eligibility Barriers & PACE Financing Programs

Apart from facing barriers such as unbearable upfront costs, low credit scores and inaccessible eligibility requirements are also widely accepted to be significant barriers for low-income households in securing financing options for rooftop solar panels. A study by the National Renewable Energy Laboratory found that an overwhelming majority of solar panel adopters have excellent, or prime credit scores, which is only true for a fraction of households with less disposable income.[26] Most third-party financing options such as power-purchasing agreements or leases require a solid credit history and sound underwriting conditions, which may posit an additional barriers for low-income households to securing these financing opportunities that would allow them to afford solar panels without facing significant upfront costs.

One of the most consistently discussed options for increasing rooftop solar uptake in cases of these barriers have been residential Property Assessed Clean Energy (PACE) financing programs. PACE entails financing rooftop photovoltaic deployment through property tax financing, where either a utility provider, a third party, or a governmental agency purchase photovoltaic systems for households, cost for which is repaid for by the households through their property taxes.[27] PACE programs have potential to accelerate PV adoption because of no initial cost for households and lighter eligibility requirements, both of which are significant barriers to low-income families.

Typically, underwriting for PACE funding options are based on assessing property-related mortgage repayment history, owner's bankruptcy, property tax repayment history, rather than the owner's credit history or their debt-to-income ratio.[28] This extends eligibility for PACE programs to many lower-income households that may not have been eligible for other financing options. Moreover, PACE repayment terms are directly tied to property taxes which secures a longer payment period with lower interest rates. This may provide a sound alternative to other, more unsecured financing options for photovoltaic installation

[26] Monisha Shah et al., "Affordable and Accessible Solar for All: Barriers, Solutions, and On-Site Adoption Potential," National Renewable Energy Laboratory, 2021.
[27] Jeff Deason and Sean Murphy, "Assessing the Pace of California Residential Solar Deployment: Impacts of Property Assessed Clean Energy Programs on Residential Solar Photovoltaic Deployment in California, 2010-2015," eScholarship, University of California, April 4, 2018.
[28] Deason and Murphy, "Assessing the Pace of California Residential Solar…," eScholarship, University of California, 2018.

that usually feature higher interest rates and larger monthly payments due to shorter payment terms.[29] While the effect of PACE programs has not been analyzed specifically on lower-income households' rooftop solar uptake rate, a study found that PACE was directly responsible for a 12% increase in rooftop solar uptake in California's large cities.[30] PACE programs' more palatable eligibility and repayment conditions, along with the fact that households assume ownership of solar panels, suggests that these kinds of programs would be a sound option for increasing uptake rates among lower-income households.

PACE programs are different from most photovoltaic leasing options, where utility providers or third parties purchase and install photovoltaics on behalf of customers, in that most leasing programs that do offer installation of solar panels with no upfront costs usually retain ownership over them. The costs for these panels are repaid through fixed monthly payments that are derived from the leasing arrangement, or through Power Purchase Agreements (PPAs) which charge money for every kilowatt-hour of electricity generated by the installed solar panels. PACE programs give direct ownership of rooftop panels to households, which is better suited to address energy poverty concerns of lower-income households: they get to own the solar panels by the end of the repayment period, and if they decide to sell their property prior to that, repayment responsibilities would be handed over to new owners. There are some solar companies that do grant ownership of financed solar panels to households through their leasing arrangements, but PACE programs were found to offer smaller interest rates with longer repayment periods in many cases, in addition to more accessible eligibility requirements.[31]

PACE programs across different jurisdictions differ in their delivery providers and funding sources, ranging from privately administered and financed to fully publicly provided service delivery. There are also cases with mixed responsibilities for funding and program administration, such as the New York City Energy Efficiency Corporation, a non-profit private organization that relies on public financing to deliver energy-efficient upgrades,[32] or the Connecticut Green Bank, which relies on both public and private sources.[33]

Homeownership and Apartment Style Barriers

People across the world are increasingly moving to denser urban population centers and share of apartment-style living spaces is increasing. Many of these apartments are nested in medium or high-rise buildings, with many households living within one building. In view of the different nature of roof ownership in case of apartment-style buildings, it is important to analyze the dynamics of installing solar panels on roofs of apartment-style buildings that house multiple families.

Apartment style buildings have more roof space available for solar panel installation, which is 48% for low-rise and about 38% for medium and high-rise buildings, higher than space available on roofs of

[29] Deason and Murphy, "Assessing the Pace of California Residential Solar….," eScholarship, University of California, 2018.
[30] Deason and Murphy, "Assessing the Pace of California Residential Solar….," eScholarship, University of California, 2018.
[31] Deason and Murphy, "Assessing the Pace of California Residential Solar….," eScholarship, University of California, 2018.
[32] Robert Stewart, "Decarbonization of Buildings in Canadian Cities: Using Property Assessed Clean Energy (PACE) Financing to Attract Private Capital," *SSRN Electronic Journal*, 2023.
[33] Stewart, "Decarbonization of Buildings in Canadian…," *SSRN Electronic Journal*, 2023.

detached houses, according to one study.[34] However, one major distinction between different styles of apartments is the number of households that would rely on the rooftop solar panels, and ownership style of the building itself. Compared to detached or semi-detached houses, most apartment buildings are either in shared ownership between all residents or fall under a housing corporation and/or a developer company ownership and are not owned by individual households. Since owner's permission or agreement of all residents would be necessary to make any structural changes or additions to the building, it would be highly unlikely for a single household to install a solar panel module solely for their use, as it would limit roof access to other residents and raise equity concerns. This means that, in most cases, rooftop solar panel installation cost, lease payments, and consequently ownership, would be shared between all residents or a corporation that owns and manages the building.

A study from Australia found negative correlation between renting and solar uptake, indicating that households that rent are less likely to adopt solar panels.[35] Middle-income households and mortgage owners were the most propense to solar uptake, which suggests that some level of concern over electricity prices contributes to rationale behind purchasing rooftop solar panels. These findings suggest that homeownership is a statistically significant determinant of solar uptake, with property owners and mortgage holders being the most likely and renters the least likely to adopt solar panels.

Landlords who often times rent out or lease their properties are less likely to pursue energy-efficient updates because the benefit from such investments in form of lower energy bills would be enjoyed by the tenants. While at the same time, tenants are less likely to make large investments in fixed, immobile energy efficient upgrades like solar panels because of their long payout period – tenants might simply find somewhere else to live before the investment would have paid for itself.[36] [37] Numbers speak to the magnitude of this issue – it was found that, in Australia, Only 3.9% of rented households had rooftop solar panels, compared to 20.2% of owned ones.[38] Another study concluded that owners were 7.8% more likely to own any type of energy efficient appliances than renters.[39] This yields that neither the landlords nor the tenants have the financial incentive to invest in rooftop solar panels, and tenants, who are more likely to be lower income, as they do not own property themselves, are unable to access the savings in energy bills that rooftop solar panels could offer

There are many different ways to organize and manage shared installation, ownership, and consumption of rooftop solar panels for apartments, but regardless of a strategy chosen, governance issues and

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[34] M.B. Roberts, A. Bruce, and I. MacGill, "Opportunities and Barriers for Photovoltaics on Multi-Unit Residential Buildings: Reviewing the Australian Experience," *Renewable and Sustainable Energy Reviews* 104 (April 2019): 95–110.

[35] M.B. Roberts et al, "Opportunities and Barriers for Photovoltaics….," *Renewable and Sustainable Energy Reviews* 104 (2019).

M.B. Roberts et al, "Opportunities and Barriers for Photovoltaics….," *Renewable and Sustainable Energy Reviews* 104 (2019).

[36] M.B. Roberts et al, "Opportunities and Barriers for Photovoltaics….," *Renewable and Sustainable Energy Reviews* 104 (2019).

[37] Nadia Ameli and Nicola Brandt, "Determinants of Households' Investment in Energy Efficiency and Renewables: Evidence from the OECD Survey on Household Environmental Behaviour and Attitudes," *Environmental Research Letters* 10, no. 4 (April 1, 2015).

[38] Best et al, "Evaluating the Effectiveness of Australia's…." *Energy Economics* 84 (October 2019).

[39] Ameli and Brandt, "Determinants of Households' Investment in Energy Efficiency…." *Environmental Research Letters* 10, no. 4 (2015).

disagreements between many parties that have a stake in high-capacity buildings are possible to arise.[40] Disagreements between the landlords, building owners, and tenants might hamper or even prevent installation of rooftop solar panels. One study from Germany that looked at ways to incentivize landlords and property owners to make long-term energy efficient upgrades like rooftop solar panels suggested allowing landlords to raise rent after making energy-efficient upgrades, in circumstances where they are not normally allowed to do so.[41] However, it remains to be seen if sanctioning rent increases actually leads to a more equitable access to energy for lower-income households. Another suggested method for improving rooftop solar uptake for apartment-style buildings comes from a study in Australia, where there is precedent of building developers installing rooftop solar panels for shared use of all units – the "Riverdale Flo Project" is reported to have installed a cumulative 180 kWp capacity on the roof of their building, which would amount to about 2kWp of energy for each household.[42] This arrangement is estimated to meet about half of each household's energy needs. Separately, it was calculated that a shared rooftop solar panel system in Melbourne could meet somewhere between 1 and 5 kWp of energy demand on apartment buildings, depending on number of units.[43] However, these projects and apartment complexes are not tailored to low-income households, and effect of such policies on solar uptake specifically with that demographic remains to be seen.

Results

Toronto's Climate Vision and Goals

"TransformTo" – Toronto's climate transformation plan aims to cut city's carbon emissions by 65% by 2030.[44] For this goal, it is important to understand that the majority of Toronto's emissions come from the energy sector, which makes it clear that for the city to achieve its climate goals, its energy sector needs to be decarbonized. Energy generation is provincial authority, and the city of Toronto has limited authority over the source of its energy supply, which is projected to become more carbon intensive as Ontario's nuclear power plant decommissioning dates are approaching.[45] A study estimated that Toronto is unlikely to meet its 2030 climate targets without transformative action across all sectors.[46] If Toronto was to decarbonize its energy supply, which is regulated by the provincial authority, a reasonable way of doing so would be local energy generation that would be carbon neutral. This process of autonomizing energy

[40] M.B. Roberts et al, "Opportunities and Barriers for Photovoltaics….," *Renewable and Sustainable Energy Reviews* 104 (2019).
[41] Ameli and Brandt, "Determinants of Households' Investment in Energy Efficiency…." *Environmental Research Letters* 10, no. 4 (2015).
[42] M.B. Roberts et al, "Opportunities and Barriers for Photovoltaics….," *Renewable and Sustainable Energy Reviews* 104 (2019).
[43] M.B. Roberts et al, "Opportunities and Barriers for Photovoltaics….," *Renewable and Sustainable Energy Reviews* 104 (2019).
[44] City of Toronto, "Transformto Net Zero Strategy," City of Toronto, June 28, 2024, https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/transformto/
[45] Kimberley R. Slater et al., "Assessing Climate Action Progress of the City of Toronto," *Buildings and Cities* 3, no. 1 (2022): 1059–74
[46] Kimberley R. Slater et al., "Assessing Climate Action Progress of the City of Toronto," *Buildings and Cities* 3, no. 1 (2022): 1059–74

generation has potential to reduce Toronto's reliance on gas-fired power plants and address energy equity concerns through reducing electricity price costs.

Financial Viability of Solar Panels in Toronto

Even if rooftop solar panels are indeed found to be effective in addressing energy poverty among lower-income households, there is a need to analyze their financial viability in the GTA, given the region's solar irradiation rates and costs of photovoltaic systems. According to the Natural Resources Canada, Toronto's average annual photovoltaic capacity was estimated to be around 1174 kW/h, per one kW of south-facing, 15-degree tilt capacity photovoltaic solar panel installed.[47] Ontario Energy Board estimated that an average household in the Greater Toronto Area (GTA) consumed about 680 kWh of energy every month, which would amount to 8160 kWh per year.[48] This would yield that a 7-kW capacity rooftop solar panel would be enough to fulfill energy needs of an average GTA household. Costs for solar panels vary depending on various factors like efficiency levels, peak performance capacity, type of supplier, but if we were to estimate cost for an average 7-kW rooftop solar panel system, it would amount to around $18,000-21,000 in Ontario.[49] Is this financially viable considering electricity prices and the cost of this estimated rooftop system? An aggregated study by Canada Energy Regulator concluded that residential solar energy generation would be a net money saver for households in Ontario, especially southern and eastern parts of the province where solar irradiation is the highest.[50] As calculated, the break-even price per kW/h of solar capacity installed over its lifetime would be lower than the electricity prices in the province, which indicates relative financial viability, considering geographic factors that influence energy generation.

Barriers to Low-income Solar Uptake in Toronto

To make an assessment of barriers faced by low-income households in Toronto area specifically, based on the barriers identified through the literature review, this paper analyzed the existing programs and incentives on municipal and provincial scale that are applicable to rooftop solar panel upgrades, identifying three key initiatives: the Home Energy Loan Program (HELP) and High Rise Retrofit Improvement Support Program (Hi-RIS) by the city of Toronto, and the Net Metering Program by Ontario Energy Board.

Toronto's HELP is a financing program for any type of energy-efficient upgrades, which allows applicants access to up to CAD125,000 over a period of maximum of 20 years, and rooftop solar panel projects are included.[51] However, the program's eligibility and disbursement conditions make it intrinsically unavailable and inaccessible to lower-income households. HELP is a PACE program, meaning that repayment for its funding grants is through property tax liens over a longer term period, with fixed, relatively low interest rates. Payment period for solar panels for example can stretch up to 20 years.

[47] Natural Resources Canada, "Photovoltaic Potential and Solar Resource Maps of Canada," Natural Resources Canada, June 13, 2024.
[48] Ontario Energy Board, "Defining Ontario's Typical Electricity Residential Customer," Ontario Energy Baord, December 2023.
[49] Corey Lee, "How Much Does Solar Energy Cost in Ontario?," Green Integrations, March 7, 2024.
[50] Canada Energy Regulator Government of Canada, "Canada Energy Regulator / Régie de l'énergie Du Canada," CER, November 28, 2023.
[51] City of Toronto, "Transformto Net Zero Strategy," City of Toronto, June 28, 2024.

However, the eligibility criteria for this program possess a barrier to accessing it for low-income households. Only owners of detached houses are eligible to access HELP, with no provisions for apartment-style buildings, which are more likely to house lower-income households. Second, applicants must either be owners of the house or request special approval for mortgaged properties. Since we know that lower-income households are less likely to be property owners, and especially owners of detached houses, HELP's lack of provisions or considerations of leases means that its eligibility requirements run a risk of leaving many lower-income households out.

Apart from eligibility issues, HELP's disbursement process also poses a significant barrier to lower income households. Namely, a maximum of 30% of the loan's approved amount can be distributed prior to the completion of the improvement project, which means that applicants have to secure majority of funding for materials, installation, and storage applications with their own funds. The program disburses the remaining funds only after the improvement has been completed and verified by the city authorities. This poses a significant challenge for lower-income families who are far less likely to have the funds readily available to purchase and install solar panels. Even though HELP does cover the full costs of the upgrades as a loan, it only does so after the upgrades have been carried out and deployed and a significant number of finances have been spent out of a homeowners' pocket.

Toronto's High Rise Retrofit Improvement Support Program (Hi-RIS) is another PACE-type project by the municipality that seeks to fund energy-efficiency upgrades for high-rise apartment buildings that were built prior to 1990.[52] Hi-RIS makes funds available for all eligible upgrades, including solar panels, for apartment building owners, with the consent of all residents to make such improvements. Similar to HELP, this PACE program also offers a long repayment period with fixed payments that are tied to property taxes, but it also faces similar drawbacks – majority of approved funding is disbursed after the project has been carried out, meaning that the applicants have to secure most of initial funding on their own. There is a provision that allows initial disbursement for contractors to carry out the work, however other costs are not included.

Ontario's Net Metering program enables existing small renewable energy producers to benefit from providing excess electricity to the grid. The program allows households that generate energy through zero carbon means to receive credits on their energy bills for electricity that was produced in excess and was provided to the grid, this would be especially beneficial during the times of peak supply from solar panels during the day, when electricity generation reaches its peak, to offset lower output during the rest of the day. However, the very nature of this program is what limits its benefits to lower income households – it is for existing renewable energy sources, for households that already possess rooftop solar panels or other zero-emission sources of energy, which are overwhelmingly higher-income households. As lower-income households have a smaller share of installed renewable energy capacity, they stand to benefit less from programs like these, at benefit of more affluent households. This is another barrier for lower-income households – existing programs in Ontario are designed primarily for the upper-income strata, but the cost for these programs is spread out across the population through taxes that raise money to fund them. An earlier study from various German municipalities confirmed this trend in existing net-metering or feed-in tariff programs across jurisdictions – the primary beneficiary of such programs is the upper class, but everyone including the lower-income households ends up paying for them in levies, which perpetuates energy poverty and inequitable access to renewables.[53]

[52] City of Toronto, "High-Rise Retrofit Improvement Support Program (Hi-RIS)," City of Toronto, July 11, 2024.
[53] Winter and Schlesewsky, "The German Feed-in Tariff Revisited…," *Energy Policy* 132 (2019): 344–56.

Apart from existing programs by both municipal and provincial governments that are not accessible to lower-income households, there are other inherent barriers to rooftop solar adoption for this demographic in the GTA. As discussed, solar adoption for households living in apartments becomes more complicated and requires consensus of all involved parties. In addition to limits to roof space and capacity for each unit to share the generated electricity, potential for installing rooftop solar panels on apartments is also hampered by a shortage of total roof space relative to energy demanded by every household that resides within an apartment. Since more solar panels are needed to be installed to generate enough electricity for all residents, there are higher risks to roof facilities and its structure. For solar panels to be efficient, they need to be angled properly, usually at 15 to 30 degrees, and achieving this angle might require additional structural changes and additions to the roof that incurs higher costs and risk to the building structure.[54]According to Statistics Canada, about 44.2% of all dwellings in Toronto are apartment-style, where rooftop solar adoption is more complicated due to physical reasons discussed just now.[55] We also know that, because lower-income households are much more likely to live in apartment-style buildings, which were not designed for rooftop solar panels and may require additional structural fixes, their access to renewable energy generation sources is also disproportionately affected.

As of 2021, 48% of all Toronto residents were renters,[56] and homeownership has been identified as a key determinant of PV solar adoption, where renters are much less likely to invest in rooftop solar panels or receive energy efficient upgrades from their landlords simply because neither of the parties has the incentive to invest in them. At the same time, lower-income households are more likely to be renters due to lack of capital to buy a home or afford a mortgage agreement. It follows then that lack of homeownership and incumbent lack of policies that encourage landlords to make energy efficient upgrades is also a barrier to low-income households in accessing cheaper energy through rooftop solar panels.

Conclusion and Recommendations

At this point, it would be beneficial for this research to apply insights gathered from the above findings to provide possible policy recommendations that could address the barriers faced by lower-income households to adopting solar panels in the GTA. While many of the aforementioned programs and approaches have been shown to positively impact solar uptake and have potential to mend inequitable access to green energy, it is important to rationalize how transferable and applicable they would be to Toronto, considering differences in demographics, housing types, and political dynamics between different levels of government. This assessment seeks not to endorse any specific policy proposals and argue for their implementation in Toronto, but to find ground for their potential applicability and effectiveness, given the local political, economic, and social realities.

Direct incentives and Subsidies

Direct incentive programs that rely on government funding to reduce prices for solar panels and fund a part of their purchase and installation costs are expensive to carry out but have been shown to directly

[54] M.B. Roberts et al, "Opportunities and Barriers for Photovoltaics….," *Renewable and Sustainable Energy Reviews* 104 (2019).
[55] Government of Canada, Statistics Canada, "2021 Census of Population, Toronto," Focus on Geography Series, 2021 Census - Toronto (Census metropolitan area), October 4, 2023.
[56] City of Toronto, "Toronto Housing Data Book," City of Toronto, April 12, 2023.

impact uptake rate[57]. There are studies that stipulate that direct financial incentives related to upfront costs for lower-income households have the largest potential for increasing rooftop solar penetration among this demographic.[58] While effects on low-income households specifically have not been quantified, it is reasonable to predict that a direct reduction in upfront cost for solar panel installation would positively affect the financial calculus of acquiring rooftop solar panels for low-income households. This can be stated because inability to pay high costs before the returns from installing solar panels have been realized are a significant barrier to low-income households' decision to proceed with energy efficient upgrades. Some examples include the SRES program in Australia, Germany's abolition of VAT for all solar panel purchases, Stuttgart's Solar Offensive program, and the 30% tax credit for photovoltaic rooftop solar panels in the United States.[59] These show different ways of reducing upfront costs for households, SRES through a calculated subsidy that depends on how much capacity is being installed and the amount of potential energy to be generated, a VAT reduction through an overall reduction in the price level of solar panels, and tax rebates that offer refunds for purchases of solar panels. Analysis of Toronto's HELP however showed us that incentives that reimburse costs for purchases already made are less effective in stimulating low-income solar uptake than are programs that reduce costs prior to purchases being made, because lower-income households are less likely to possess funds to make these purchases in the first place. Stuttgart's approach to reducing upfront costs differs from other strategies by instead focusing on funding installation process of solar panels and costs related to roof structure, scaffolding, and other improvements not related to purchasing PV modules themselves. Low-income households would also face these upfront costs and would need additional assistance in covering them, especially considering the fact that they are more likely to live in buildings that were not meant to have solar panels[60] and would need additional structural support and adjustments to the roof structure to make way to solar panel installation. Stuttgart's Solar Offensive approach could be one of the ways of addressing these cost concerns and making purchase of solar panels more financially viable for lower-income households. It was found that direct subsidies targeted at lower-income households had the highest success in expected vs actual increase in solar adoption, compared to leasing or PACE arrangements and Solarize campaigns.[61] This finding calls for further research into full impacts of direct upfront incentives on low-income solar uptake, considering the fact that options like third-party leasing, power-purchasing agreements, or PACE do not feature upfront costs at all, which is considered a significant barrier to solar adoption that still persists, on a lesser scale, in case of direct subsidies.

PACE Application Strategies

In the realm of financing options for solar panels, PACE programs have been postulated by scholars across the literature to be a better alternative to third-party leasing options and purchase-power agreements, thanks to much lower interest rates, extended repayment terms, and lighter eligibility conditions making the program more accessible to the lower-income households. For such measures to be effective in Ontario, the provincial government would need to enhance customer protection and set up a correct environment for private capital investments by creating a regulatory framework and energy

[57] Best et al, "Evaluating the Effectiveness of Australia's…." *Energy Economics* 84 (October 2019).
[58] Eric O'Shaughnessy et al., "The Impact of Policies and Business Models on …," *Nature Energy* 6, no. 1 (2020).
[59] Office of Energy Efficiency & Renewable Energy, "Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics | Department of Energy," US Department of Energy, April 2024.
[60] Bovarnick Ben and Lucas Johnson, "Barriers and Solutions to Low and Moderate-Income Solar Adoption," Yale Center for Business and the Environment, accessed September 1, 2024.
[61] Eric O'Shaughnessy et al., "The Impact of Policies and Business Models on …," *Nature Energy* 6, no. 1 (2020).

efficiency improvement standards for PACE programs, just like California's PACE Preservation and Consumer Protections Act of 2016 for instance.[62] Within this goal, it is recommended that the province also set up and enforce the Savings to Investment Ratio to ensure that savings from improved energy efficiency are enough to cover the financing cost of Solal panel installation.[63] These would be essential to safeguarding households against predatory behavior from third-party PACE providers and prevent issuing of unsafe financing agreements.

So far, Toronto's two PACE programs – HELP and Hi-RIS are exclusively publicly funded, managed and delivered programs, but experience from different jurisdictions shows us that this need not be the only way, and that there is potential in harnessing private capital and third-party service delivery tools to further increase solar uptake rates among lower-income households. As discussed, there is already precedent to this in New York, where public funds are used by a private corporation to deliver such programs. A publication from University of Toronto's Institute on Municipal Finance and Governance suggested a similar approach in Toronto, through using Low Carbon Cities Canada (LC3) network organizations, particularly the Atmospheric Fund that is based in Toronto.[64] The submission argues that the Atmospheric Fund and similar organizations are naturally well-suited for PACE program delivery as they possess ample resources for decarbonization activities that could be leveraged for efficient PACE program delivery.[65] Should Ontario successfully craft legislation and regulatory framework on PACE financing, PACE program implementation for lower-income households could also greatly be enhanced by more private sector involvement in program rollout. Literature posits that public sector is constrained by limited availability of funds that may hamper the pace of PACE programs and their scale.[66] Privately funded and delivered solutions have the capacity to extend the scale of PACE financing options and attract much larger volumes of capital, which has potential to address energy inequity among lower-income households as availability of PACE programs increases, provided the provincial government makes necessary regulations and sets up a healthy environment for equitable and sustainable implementation of PACE agreements between consumers and the private sector. This has been demonstrated by California's experience, where Sonora County in norther part of the state doubled its solar uptake rate thanks to PACE programs, compared to neighboring counties without them.[67] Private sector has driven the absolute majority of PACE program implementation in California, supported by ample regulatory policies from the state government.[68]

Net-Metering and Feed-in Tariff Models

Net-metering programs, feed-in tariffs and similar schemes would only succeed in an environment where a significant amount low-income households already possess means of generating green energy, which is not currently the case in Toronto. As discussed, the current effect of these policies on increasing solar uptake are limited and have been shown to negatively affect overall equality levels by levying higher cost

[62] California State Legislature, "Bill Text," Bill Text - AB-2693 Financing requirements: property improvements., September 2016.
[63] Stewart, "Decarbonization of Buildings in Canadian Cities…" *SSRN Electronic Journal*, 2023.
[64] Stewart, "Decarbonization of Buildings in Canadian Cities…" *SSRN Electronic Journal*, 2023.
[65] Stewart, "Decarbonization of Buildings in Canadian Cities…" *SSRN Electronic Journal*, 2023.
[66] Stewart, "Decarbonization of Buildings in Canadian Cities…" *SSRN Electronic Journal*, 2023.
[67] Nadia Ameli, Mauro Pisu, and Daniel M. Kammen, "Can the US Keep the Pace? A Natural Experiment in Accelerating the Growth of Solar Electricity," *Applied Energy* 191 (April 2017): 163–69.
[68] Deason and Murphy, "Assessing the Pace of California Residential Solar….," eScholarship, University of California, 2018.

for funding these programs through taxes and higher electricity tariffs. It can be argued that net-metering, feed-in tariffs and similar programs provide an incentive to install solar panels due to cheaper energy generation costs and potential benefits from selling excess electricity to the grid, however there is lack of statistically significant evidence and replicable conclusions on impact of such incentives on lower-income solar adoption. So far, the effect of feed-in tariffs has been shown to have impacted inequality levels because of uneven distribution of benefits of such programs that benefit the higher-income households already possessing means of clean energy generation. A positive step in distributing the potential benefits of such programs was taken in 2022, when Ontario's net metering incentive was extended to third-party solar panel operators and to power-purchasing agreement holders,[69] which means that panels that are either leased or acquired under PACE and other leasing options can also see potential earnings from selling excess generated capacity to the grid, positively affecting calculus for extended financial savings by solar panels.

Homeownership and Apartment Types

Lower-income households who rent are legitimately disinterested in purchasing solar panels, which they see as immobile and expensive investments in a market with high property turnover, where any immovable, long-term investment would benefit their landlords more than them. Raising energy efficiency standards for landlords has been discussed to have potential to nudge them to pursue gradual adoption of rooftop solar panels. This could achieve higher levels of energy equity for the lower-income households who rent these properties as their energy bills would be lower thanks to installation of solar panels. A similar approach was taken by New York with its Law 97,[70] setting emission limits for all buildings and a fine system to encourage compliance with such limits, also designed to incentivize adoption of energy-efficient and climate-neutral upgrades. However potential indirect effects of the above approaches on rental prices and housing supply are yet to be researched.

Along with raising energy efficiency standards, Ontario could take steps to amend its building code to mandate all newly constructed buildings to have structural capacity to host solar panels. This approach can stimulate installation of solar panels on new complexes and projects, similar to Melbourne or Riverdale Flo projects. This would also alleviate potential future costs related to retrofitting and structurally adjusting roofs to be solar-panel compatible, for newly built apartments.

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[69] Ontario Energy Board, Net metering, *Consumer Information and Protection.*
[70] Stewart, "Decarbonization of Buildings in Canadian Cities…" *SSRN Electronic Journal*, 2023.

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