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Harnessing the Sun: Reviewing the potential of solar photovoltaics in Canada

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ABSTRACT

Over the past decade, a number of jurisdictions have taken significant steps to encourage the diffusion of solar photovoltaic technology (PV). Supportive policy frameworks have been widely adopted, spurring deployment and driving down the cost of PV components. The increased competitiveness of this technology presents a promising opportunity for meeting energy needs in a low-carbon fashion. Indeed, a growing body of research suggests that PV could produce significant quantities of energy. However, the diffusion of PV in Canada has been comparatively slow and GHG emissions in this jurisdiction are on an upward trajectory. As a result, we explore the potential of PV in Canada in regards to: (1) the scale of possible contributions to energy supply and GHG abatement, and (2) the particular functional roles and niches this technology could occupy looking out to 2050. In doing so, this study reviews the current status of knowledge on PV potential in Canada and argues that estimates which revolve around technical parameters such as solar irradiance, module efficiency, and land area (and even those that include some reference to current prices), are limited in their ability to understand the place this technology might actually occupy in Canada in coming decades. While technical potential is an important consideration, the interrelated economic, socio-political, and environmental influences need to be taken into account. This paper discusses the nature of these influences and explores PV potential in the context of key features of possible low-carbon pathways for Canada.

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1. Introduction

Over the past decade, solar photovoltaic technology (PV) has received increasing interest as a promising low-carbon energy option. Policymakers in many countries have attempted to encourage the development and diffusion of PV by implementing supportive policies such as the Feed-in Tariff (FiT) [1]. With this

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aggressive support, global PV capacity has risen from 1.4 gigawatts (GW) in 2000 to over 100 GW in 2012 [2], and PV module prices have dropped from $4 per watt in 2008 to under $1 per watt in 2012 [3]. The increased competitiveness of PV offers new opportunities with respect to its potential contributions to energy supply and GHG abatement. A number of studies have begun to consider the appropriate place of this technology in longer term energy system evolution, suggesting that PV may have a sizeable role to play in the transition to low-carbon emission energy systems [4–8].

Despite the international trend, in Canada PV has been comparatively slow to emerge as an option for transforming electricity networks and broader energy systems. The low-carbon transition will necessitate substantial adjustments to electricity production and consumption. Notwithstanding the high proportion of hydroelectricity in Canada's existing generation mix (roughly 60% of electricity output), in 2012 the sector accounted for 88.3 megatonnes of CO_2 equivalent or 13% of Canada's total GHG emissions [9]. Moreover, the broader decarbonization of energy systems will necessitate radical changes to the way society provides those energy services which are not now generally powered by electricity, including transportation and space-heating. At present, Canadian GHG emissions remain on an upward trajectory and even the country's modest 2020 target of reducing emissions 17% below 2005 levels will be out of reach without more vigorous intervention [10]. This is to say nothing of attaining the more ambitious GHG reduction goals that are likely for 2030 or 2050. It is within this context that PV may offer a number of promising opportunities for energy provision and GHG emission abatement in Canada.

In this paper we approach PV potential in Canada from two angles, enquiring about both (1) the scale of the contribution PV could make to energy provision and GHG abatement, and (2) the particular functional roles or niches that PV might occupy looking forward to 2050. To gain traction on these interrelated questions, we review the current status of knowledge on PV potential in Canada. We argue that estimates which revolve around technical parameters such as solar irradiance, module efficiency, and land area (and even those that include some reference to current prices), are limited in their ability to understand the place this technology might actually occupy in Canada in coming decades. While technical potential is an important consideration, it sheds little light on the interrelated economic, socio-political, and environmental influences that will shape future energy trajectories [11]. The paper discusses the nature of these influences and explores PV potential in the context of key features of possible low-carbon pathways for Canada.

The paper starts with an overview of the current policy and market context for PV in Canada, and considers estimates of the solar resource, as well as features of PV technologies and their applications. It moves from estimates of PV energy output and potential GHG emissions reductions to offer an assessment of important constraining and enabling factors. The analysis concludes by identifying some features of possible low-carbon pathways in Canada and their implications for the potential role of PV.

2. Policy and market context for PV deployment in Canada

In Canada, electricity-related decisions fall primarily under provincial jurisdiction, with regional governments playing the largest role in terms of policy engagement around PV. As a result of this fragmented policy environment, each province offers different rates for electricity generated by PV systems under a variety of policy and regulatory conditions. Most provinces provide net-metering options for PV generation, whereby electricity from a PV system net of consumption is exported to the grid at the retail electricity price or some other established rate [12]. Some jurisdictions (e.g., The Northwest Territories) provide direct subsidies for a portion of the system costs. Canada's largest province of Ontario is unique in that it offers premium rates for electricity generated by grid-connected PV systems under 20 year power purchase agreements as part of a provincial FiT program (2009–ongoing). Current FiT rates for PV vary by installation size and application as reflected in Table 1. As the capital costs and long-term risks associated with installing PV can be a significant barrier, a FiT helps to mitigate uncertainty by providing a stable return on investment. The substantial FiT rate offered for PV in Ontario has attracted sizeable private investment (but also opposition from those complaining about upward pressure on utility rates).

Table 1
Ontario Power Authority past and present price schedule for PV.

Renewable technology	Capacity	FiT version 1 (October 2009) $/kW h	FiT version 2 (April 2012) $/kW h	FiT version 3 (August 2013) $/kW h
Solar PV				
Rooftop	≤ 10 kW	0.802	0.549	0.396
	> 10 kW ≤ 100 kW	0.713	0.548	0.345
	> 100 kW ≤ 500 kW	0.635	0.539	0.329
	> 500 kW	0.539	0.487	N/A
Ground-mounted	≤ 10 kW	0.642	0.445	0.291
	> 10 kW ≤ 500 kW	0.443	0.388	0.288
	> 500 kW ≤ 5 MW	0.443	0.350	N/A
	> 5 MW	0.443	0.347	N/A

The policy regime surrounding renewable energy technologies in Ontario has made the province a prominent location for the deployment of PV. Other Canadian regions have seen only limited diffusion in comparison. As of 2012, Ontario was the site of 99% of PV installed capacity nationwide [12]. The latest figures (see Fig. 1) place cumulative installed capacity for PV in the province of Ontario at 1019 megawatts (MW) as of the end of 2013, with an additional 1120 MW under development for completion by 2017 [13].

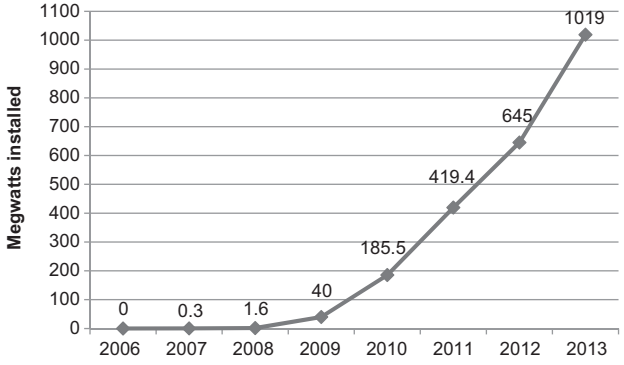

Fig. 1. PV deployment in Ontario, Canada. *Note*: Data was drawn from the Ontario Power Authority's progress report [13].

This deployment context highlights the fact that the rollout of PV in Canada is currently, and will remain for some time, dependent on policy support. Even with precipitous declines in PV module prices, relatively inexpensive electricity rates (as illustrated in Fig. 2) and the lack of a national carbon pricing mechanism severely constrain the diffusion of PV [14]. Moreover,