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Predicting intention to adopt solar technology in Canada: The role of knowledge, public engagement, and visibility

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ABSTRACT

Solar power (i.e., solar photovoltaic) accounts for about 0.3% of total electricity production in Canada. To enhance this contribution to energy supply from solar power, financial incentives and technological breakthroughs alone may not guarantee change. Drawing on a national survey of 2065 Canadian residents, we identify the determinants of technology adoption intention with the exemplary case of rooftop solar. Using a combination of latent and observed variables within a non-linear structural equation model, our analysis quantifies how a set of individual and community level factors affect adoption intention. Analysis reveals that the visibility of solar technology has a particularly strong effect on intention, lending support to social learning and social network theories of diffusion of innovation. Our findings also show that the perceived knowledge of energy systems and being publicly engaged in energy issues significantly increases adoption intention. These conclusions encourage policy options that enhance public engagement and the visibility of solar technology within neighborhoods and communities.

1. Introduction

Globally, electricity systems are undergoing significant transformation in response to energy and climate change policy and shifting cost structures for energy technologies like photovoltaic systems. Worldwide, installed solar capacity is reported to be 228 gigawatts (International Energy Agency, 2016), with utility-scale solar and distributed photovoltaic (PV) expanding "100% and slightly over 900%, respectively, between 2009 and 2015" (Energy Information Administration, 2016). In Canada, a country best known for its fossil fuel resources, investments in solar technology are growing steadily, particularly in the Province of Ontario where feed-in tariffs encourage adoption at commercial and household scales. Solar capacity in Ontario accounts for about 4.5% of total installed electricity capacity (National Energy Board, 2016). Yet, at the national level, solar capacity is hardly significant at approximately 1.0% of total capacity in 2014 (National Energy Board, 2016, p. 81). In reporting these numbers, the Canadian National Energy Board states that solar adoption across Canada is likely to depend on "local solar potential, costs and incentives, ease of integration with the existing grid, and further technological breakthroughs" (National Energy Board, 2016, p. 25). Although the contribution of solar technology to generation capacity remains low, this trend may change as federal and provincial governments push for renewable energy transition with 2016 commitments to phase out coal-fired power and to establish a national benchmark for carbon pricing (Government of Canada, 2016).

In addition to economic and technological issues that dominate public debates over renewable energy transition (Morton, 2006), social scientists identify a wider range of potential challenges to the broader adoption of renewable technology, and solar installations in particular. These challenges include individual factors such as knowledge, attitudes and political beliefs (Arkesteijn and Oerlemans, 2005), as well as system-wide factors, such as the blocking tactics of incumbent electricity producers (Hess, 2013). Moreover, well-documented public resistance to wind energy installations in Canada (Fast et al., 2016) underscore that financial incentives and technological breakthroughs alone are no guarantee of transition to a low-carbon future.

This paper contributes to the renewable energy policy and adoption literature using the exemplary case of rooftop solar in Canada. Our empirical analysis draws broadly on value-belief-norm theory (Wolske et al., 2017) to quantify the extent to which previously neglected latent individual and community level factors, plus informational and value orientations influence pro-environmental behavior. In particular, our contribution is centered on the role of visual exposure to solar technology adoption, as well as more generalized forms of knowledge about the energy system in Canada and public engagement in energy issues.

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Investigations into the role of attitudes, knowledge, and engagement are commonplace in technology adoption studies, but our non-linear structural equation model quantifies these latent variables in the generalized context of the whole energy system, rather than the technology-specific context of previous studies (e.g. Balcombe et al., 2014).

This study employs data from a national survey of 2065 Canadian residents who self-report adoption intentions as a proxy for future adoption behavior. We explicitly address a frequent empirical problem involving measurement error in complex latent constructs (e.g. environmental values) (Train et al., 1987). Our non-linear structural equation model (SEM) produces unbiased and efficient estimates in the presence of multiple simultaneous categories of latent factors (e.g. Daly et al., 2012).

Two research questions guide our analysis. First, is there a link between knowledge about energy systems, public engagement in energy issues and adoption intention? Second, is there a link between visual exposure to solar technology and adoption intention? Our empirical findings reveal that the combined experience of perceived knowledge, public engagement, and visual exposure to renewable energy technology significantly influences adoption intention, and through this cluster of community level variables, we make policy recommendations to enhance solar adoption through neighborhood and community level visibility of solar technology.

Before presenting analytical results, the following sections provide a review of literature and related theoretical concepts that give rise to our analysis as well as the methodological approach employed in the empirical analysis. We then discuss the empirical results and the paper concludes with a discussion of implications for research on solar adoption and policy options to enhance solar adoption.

2. Literature review: factors affecting solar adoption

Research on pro-environmental behavior is ubiquitous (Klöckner, 2013), but studies are more limited regarding the drivers of adoption of renewable energy technology at the household level. Solar adoption literature includes a study of factors influencing green electricity adoption in Dutch households (Arkesteijn and Oerlemans, 2005), the motivators and barriers related to the adoption of microgeneration technologies in the UK (Balcombe et al., 2014), social-psychological factors associated with solar power system adoption intentions in Taiwan (Chen, 2014), and socio-psychological patterns of photovoltaic investment in Austria and Italy (Braito et al., 2017). Common to these studies is their focus on internal and external drivers of behavior ranging from values, attitudes and knowledge to the mitigation of rising energy costs in specific jurisdictions; and a shared conclusion that aspects of cognition, social position, and communities of like-minded individuals appear to explain more of the variability in adoption intentions than standard socio-economic variables (e.g., income). For instance, Chen (2014) finds that environmental values are a significant predictor of adoption intention, and Arkesteijn and Oerlemans (2005) find that knowledge and visibility are important predictors of adoption.

From a theoretical and conceptual perspective, these studies range from straightforward claims about the link between environmental values and consumer decisions (Chen, 2014) to complex models integrating value-belief-norm (VBN) theory, diffusion theory, and theory of planned behavior (Wolske et al., 2017). We ground our analysis broadly in VBN theory, holding that "the root cause of pro-environmental behavior lies in values and emphasizes the importance of altruism directed at" human and non-human entities (Wolske et al., 2017, p. 137). As such, our study focuses directly on norms and information as social influences that inform attitudes towards a targeted intention or behavior (Fornara et al., 2016).

2.1. Environmental attitudes & values

VBN theory makes a strong claim regarding the assembly of cognitions and experiences that lead to observable environmental behaviors. Addressing the norms component later in this section, values are taken up within this study through the new ecological paradigm scale (Dunlap et al., 2000). Similarly, Clark et al. (2003), utilizing the new ecological paradigm scale as a measure of environmental concern, shows that such attitudes predict participation in a green electricity program. Poortinga et al. (2004) also offer empirical evidence that measures of environmental concern can explain variance in "intent-oriented measures of environmental behavior that directly or indirectly influence environmental qualities" (p. 88). Along these lines, Gadenne et al. (2011) find that consumers who are concerned about the environment are more likely to pay higher prices and to act to reduce emissions. Specific to solar adoption, using a green consumer values scale Chen (2014) finds that environmental values have a positive impact on ecological lifestyle and solar power system intentions. Consistent with this stream of literature, we expect latent environmental values to have a positive effect on adoption intention.

2.2. Knowledge

The role of knowledge in technology adoption behavior and decisions is a consistent focus in the literature dating back several decades (Labay and Kinnear, 1981). The claim here is that more knowledgeable consumers are more likely to understand the environmental concerns associated with carbon-intensive electricity generation systems and are more likely to appreciate the environmental benefits of investments in alternative renewable energy systems, including residential rooftop solar technology. Drawing on diffusion of innovation theory, Faiers and Neame, (2006, p. 1789) note that "adopters need to be knowledgeable of a product, and then be motivated to raise their awareness about it." They also clarify that early innovators tend to display more education and more knowledge about a technology, particularly the attributes of the technology that are attractive. Consistent with this theory, Arkesteijn and Oerlemans (2005) show a positive correlation between knowledge of energy systems and related adoption behavior.

Although these findings are consistent with classical adoption theory (Faiers and Neame, 2006), analysts are often skeptical of the role that knowledge plays in behavior change. The Knowledge Deficit Model (KDM), assumes that individuals are generally ignorant of facts (e.g. the economic and environmental benefits of solar technology). Therefore, according to the KDM, increasing factual knowledge will lead rational individuals to make better decisions. Yet, Árvai, (2014, p. 1246) notes that "decades of research in the decision sciences have shown that, in many contexts, better information and more education are largely disconnected from improved decision-making." Furthermore, it can be difficult to define what might constitute "improved decision-making" for different individuals. Those who are more fiscally focused, less altruistic, or less environmentally focused could make a knowledgeable decision not to adopt rooftop solar panels. In the context of this debate, we model the relationship between knowledge (perceived and factual dimensions outlined below) and adoption intention with attention to knowledge of energy systems, broadly defined. Given ongoing debates between diffusion theorists and critics of the KDM, we make no prior assumptions about the relationship between knowledge and adoption intention.

2.3. Engagement

Scholars point to the need for public engagement on energy-related issues to increase understanding, community support and sustainable pathways for a successful energy system transition. This focus on public engagement is described by Devine-Wright (2007) as a form of 'energy citizenship' that follows a tradition of scholarship in deliberative democracy (Gastil and Dillard, 1999) and environmental governance (Baber and Bartlett, 2005). The general claim here is that deeper levels of engagement in political life is desirable, and is expressed through