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Modeling the value of integrated U.S. and Canadian power sector expansion☆

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ABSTRACT

The U.S.-Canadian power system has evolved into a highly integrated grid. Cross-border transmission and coordination of system operations create an interconnected power system with combined imports and exports of electricity of greater than 77 TWh per year. Currently, more than 5 GW of new international transmission lines are in various stages of permitting and development. These transmission lines may enable even greater integration and coordination of the U.S. and Canadian systems, which can in turn increase the reliability and flexibility of North America's electricity grid and help address challenges associated with integrating high levels of variable renewables. Using a version of the National Renewable Energy Laboratory's Regional Energy Deployment System (ReEDS) model that incorporates Canada, this analysis quantifies the differences in the evolution of the power system under scenarios in which cross-border transmission capacity is restricted to today's levels, and scenarios in which new transmission is less restricted. These impacts are analyzed under a "business-as-usual" reference scenario and a scenario in which deep cuts in power sector carbon dioxide emissions levels are achieved. A set of key impact metrics is analyzed, including 1) the composition of generating capacity by technology, 2) system costs, 3) wholesale electricity prices, 4) international electricity exports and imports, 5) transmission capacity, and 6) carbon dioxide emission levels. When new cross-border transmission is not allowed, the United States needs additional capacity (primarily natural gas and renewable energy) to meet domestic needs, while total Canadian capacity is lower because less capacity is needed to export to the United States. This effect is amplified under the carbon cap scenario. Impacts vary on a regional basis, largely due to the different relative sizes of the generation portfolio between countries and regions and the relative impact from cross-border electricity trade. The total impact from restricting cross-border trade on carbon emissions and average wholesale electricity prices is limited, due to the relative size of the domestic power systems and the cross-border trade volume. Cross-border transmission capacity is projected to more than double under the unrestricted transmission capacity scenarios, which exceeds the rate of projected domestic transmission capacity additions in each country.

1. Introduction

In support of the joint goal to increase clean power to 50% of electricity generated across North America by 2025, leaders from the United States, Canada, and Mexico have recognized the "important role that cross-border transmission lines can play in cleaning and increasing the reliability and flexibility of North America's electricity grid" (The White House, 2016). Over the past decades, the U.S.-Canadian power system has evolved into a highly integrated grid. Today, three of eight North American Electric Reliability Corporation (NERC) reliability regions span the

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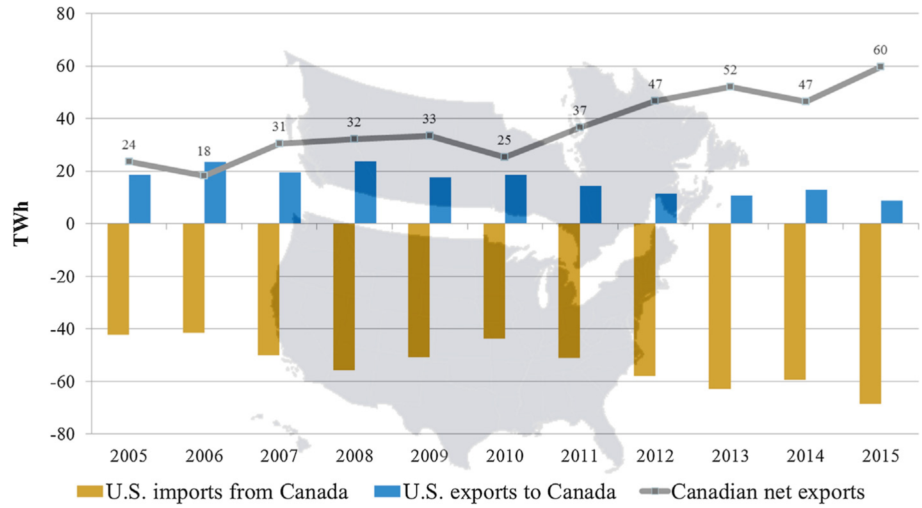

Fig. 1. U.S. electricity imports and exports from/to Canada (2005–2015).
Source: EIA (2016a); 2015 values from NEB (2016a).

U.S.-Canadian border[1] and international power-system coordination has increased through development and expansion of international transmission lines and direct exchange of information (EIA, 2012).[2] In 2015, average daily electricity transfers between the United States and Canada exceeded 211 GWh. (NEB, 2016b).

As a traditionally nonstorable commodity, electricity requires an instantaneous physical balance of supply and demand at all nodes. This fundamental attribute of electricity has made the benefits of longstanding international trade and market integration particularly relevant. The unrestricted flow of electricity across regions can help meet this physical balance by providing wider access to capacity and ancillary services. The growing share of renewable energy generation in both countries is "a key reason for expanding integration and [cross-border] transmission capacity" (Antweiler, 2016). Some associated key benefits from power system integration and cross-border electricity trade include:

1. Improved reliability and redundancy (e.g., Antweiler, 2016; Hobbs et al., 2005)
2. Increased flexibility (e.g., Milligan et al., 2015)
3. Reciprocal load smoothing[3]
4. Portfolio effects (e.g., Antweiler, 2016)
5. Economies of scale (e.g., DOE, 2015)
6. Diluted local market power (e.g., Market Surveillance Committee of the California ISO, 2002)
7. Optimal resource siting (e.g., Ibanez and Zinaman, 2016)
8. Lower energy costs (e.g., Hobbs et al., 2005; DOE, 2015).

The advantages of an integrated electricity system may be particularly relevant for power systems with increased renewable energy penetration, which typically require increased system flexibility in the form of increased cycling of conventional power plants, increased balancing power and frequency regulation, and modified distribution and transmission networks (Van Oostvoorn, 2009; Milligan et al., 2015; Brinkman, 2015). Among the set of available flexibility options (see e.g., Milligan et al., 2015), access to neighboring markets and larger balancing areas may constitute "significant opportunit[ies] for expanding access to affordable, low-carbon energy" (Ibanez and Zinaman, 2016).

Building on these prior findings, this study explores the value of U.S.-Canada cross-border transmission under an evolving power system. Using a version of the National Renewable Energy Laboratory's (NREL's) Regional Energy Deployment System (ReEDS) model (Short et al., 2011) that incorporates Canada (Martinez et al., 2013; Zinaman et al., 2015; Ibanez and Zinaman, 2016), we quantify the differences in the evolution of the power system under scenarios in which cross-border transmission capacity is restricted to today's levels, and scenarios in which new transmission is unrestricted. We explore if and how allowing new transmission builds impacts (1) the composition of generating capacity by technology, (2) system costs, (3) wholesale electricity prices, (4) international electricity exports and imports, (5) transmission capacity, and (6) carbon dioxide emission levels. Furthermore, we analyze how these impacts differ under a scenario in which deep cuts in carbon dioxide emissions levels are achieved.

Due to the relative size of the U.S. and Canadian electricity systems,[4] the effects from electricity system integration are more pronounced at the regional level. Results are presented at the national, independent system operator (ISO)/regional transmission operator (RTO) zone (New York [NY-ISO], New England [NE-ISO], and Midcontinent [MISO]) and the Western Electricity Coordinating Council [WECC][5]) level.

2. The U.S.-Canadian integrated power system

The United States and Canada share one of the largest bilateral electricity trading relationships in the world, which serves as an example for a highly integrated international transmission system (EIA, 2012). From the perspective of the United States, electricity imports from Canada have increased steadily at an annual average

[1] The three NERC reliability regions that span across the U.S.-Canadian border include the Western Electricity Coordinating Council (WECC), Midwest Reliability Organization (MRO), and the Northeast Power Coordinating Council (NPCC). In addition, the WECC spans the U.S.-Mexican border between California and northern Baja California (WECC, 2016).

[2] For example, see the recently signed Memorandum of Understanding between the United States, Canada, and Mexico on the sharing of energy-related data and definition of terms (Source: http://www.nrcan.gc.ca/energy/international/nacei/18102).

[3] For instance, seasonal variation in electric demand (e.g., the Canadian load typically peaks in the winter, while the U.S. load peaks in the summer) (EIA, 2015a).

[4] U.S. electricity generation exceeded Canadian electricity generation almost sevenfold in 2015.

[5] WECC is a regional entity of NERC.