North American Renewables Integration Study (NARIS)

Cooperative Research and Development Final Report

CRADA Number: CRD-16-00633

NREL Technical Contact: Gregory Brinkman

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5C00-80821
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Cooperative Research and Development Final Report

Report Date: August 26, 2021

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the final CRADA report, including a list of subject inventions, to be forwarded to the DOE Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Natural Resources Canada

CRADA number: CRD-16-00633

CRADA Title: North American Renewables Integration Study (NARIS)

Responsible Technical Contact at Alliance/ National Renewable Energy Laboratory (NREL):

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Sponsoring DOE Program Office(s):

Three Office of Energy Efficiency and Renewable Energy (EERE) offices were involved:

1. Wind Energy Technologies Office (WETO)
2. Solar Energy Technology Office (SETO)
3. Water Power Technologies Office (WPTO)

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1 Year 2, Modification #2 Year 3, Modification #3	$1,650,000.00 $1,650,000.00 $1,700,000.00
TOTALS	$5,000,000.00

Executive Summary of CRADA Work:

The goal of the study is to help inform and assist power system planning entities, electricity system operators, government energy agencies, legislators and regulators to better understand the planning, engineering, operational, and economic implications of integrating large amounts of wind, solar and hydro energy into the Canadian, US and Mexican electrical systems.

Summary of Research Results:

This section will describe where each task from the Joint Work Statement (JWS) is discussed in the public report entitled "The North American Renewable Integration Study: The Canadian Perspective" by Brinkman et al. (https://www.nrel.gov/analysis/naris.html). Most JWS descriptions also include an example result or figure in this document, with bigger conclusions, discussion, and more material in the referenced public report.

Task 1: Data Synthesis

Much of this task is represented in sections 1 and 2.2 of the report. Section 1 (the introduction) also discusses much of the open-source data developed for this work, and the data that could possibly be open-sourced in the future. North America has some of the best wind and solar resource in the world, and all regions have excellent wind or solar resources nearby. Figure 1 shows the wind resource in North America, and the three domains (boxes in Figure 1) that were used in this study. Domains B and C (covering northern Canada and southern Mexico) were developed specifically for this study. Historical hourly wind speed data were modeled for 2007-2014 for domains B and C, and 2014 for domain B (2007-2013 existed from previous work for Domain B).

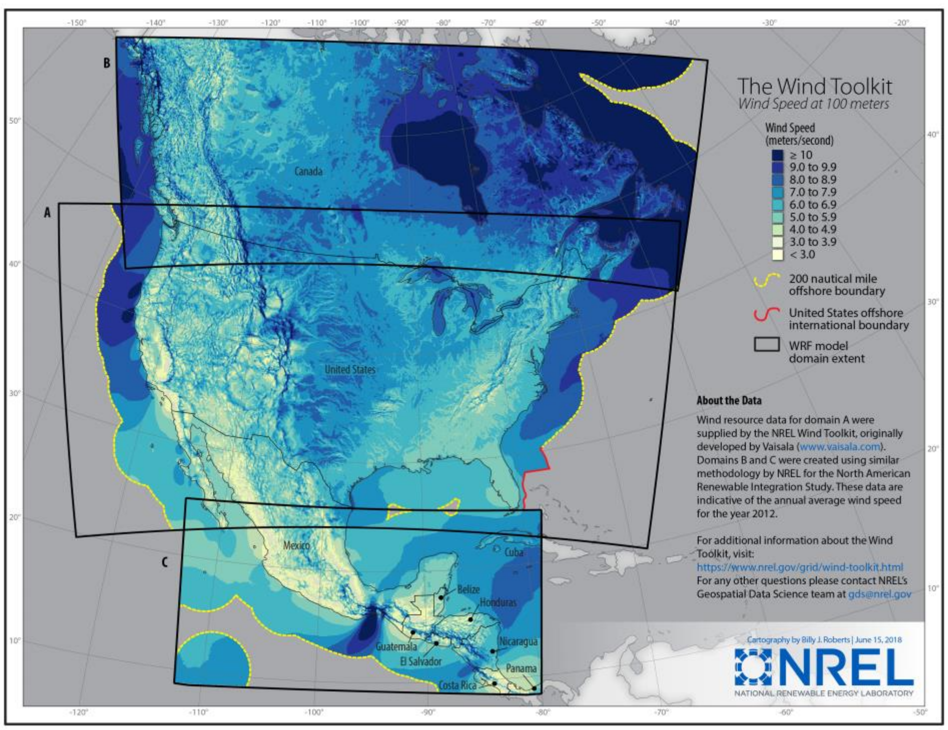

Figure 1. The Three Domains Used in NARIS for wind modeling

Tasks 2 and 3: Portfolio Creation and Transmission Expansion

The NREL ReEDS (Renewable Energy Deployment System) model was used to generate the utility-scale generation expansion and transmission expansion. The NREL dGen model was used for behind-the-meter solar adoption projections. These are covered in section 2.1 and much of section 3. These models optimize and project the buildout of the power system through the year 2050. Figure 2 shows the resulting annual generation by generator type from the ReEDS and dGen models for Canada. Note that hydropower and wind generation dominates all scenarios in the year 2050.

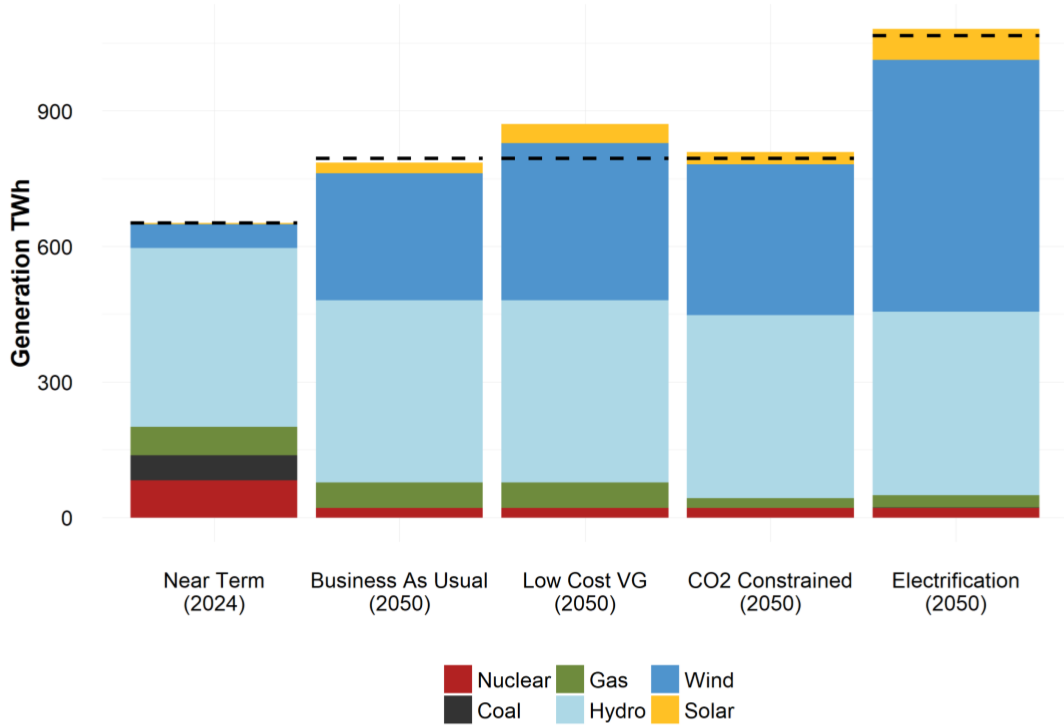

Figure 2. Generation by resource type in Canada in the core scenarios

Annual energy load is indicated by the dashed line.

Figure 3 shows the additional transmission infrastructure that is developed in the model. There is significant new capacity between and within all three countries in North America, including Canada-US connections in the western and eastern portions of the continent. The Low Cost VG scenario has higher continental wind and solar penetrations, and this motivates more transmission infrastructure.

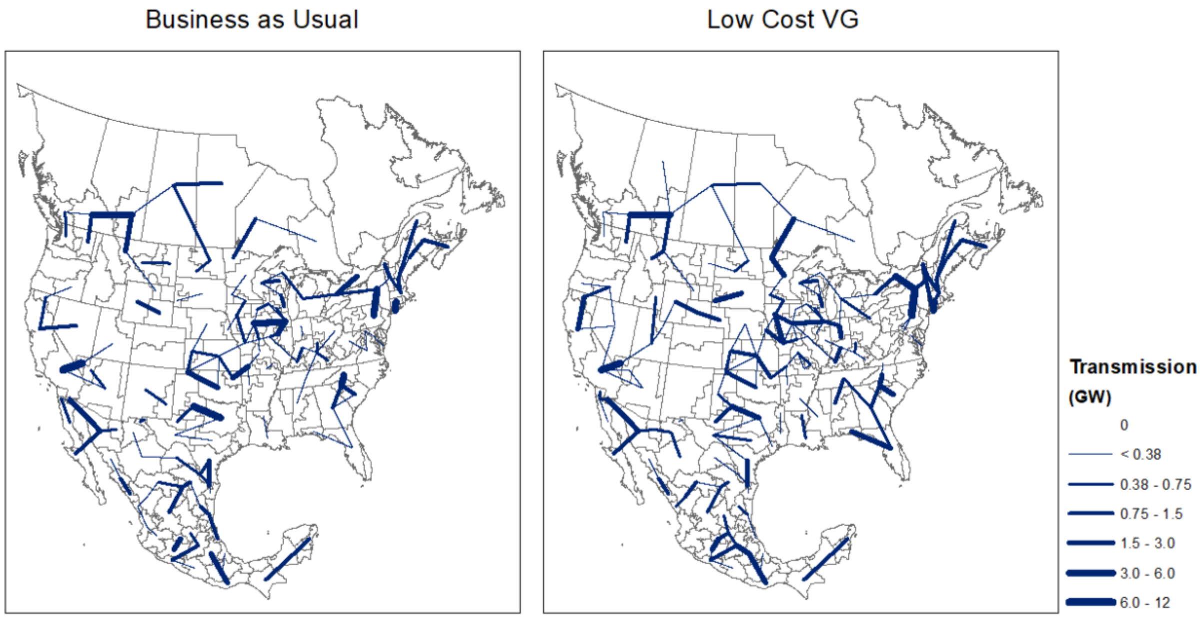

Figure 3. New transmission capacity in the Core Scenarios

Note that the lines on this map represent transmission interfaces between the zones in the model, and typically represent aggregated transmission lines.

Task 4: Integration Studies

The PLEXOS unit commitment and dispatch modeling and the Probabilistic Resource Adequacy Suite (PRAS, specifically developed for NARIS) represent the integration studies task. These are covered in sections 2.1 and much of section 3. Figure 4 shows the dispatch of Canadian generators during a high load period for the continent. There is significant generation from all generation types during this entire week, while excess Canadian generation (that is not needed for Canadian load) is exported to the US at all hours. Figure 5 shows another time period, when load in the US is lower and Canada imports during most daytime hours, and exports during night hours. This demonstrates some of the benefits of the interconnected North American grid.

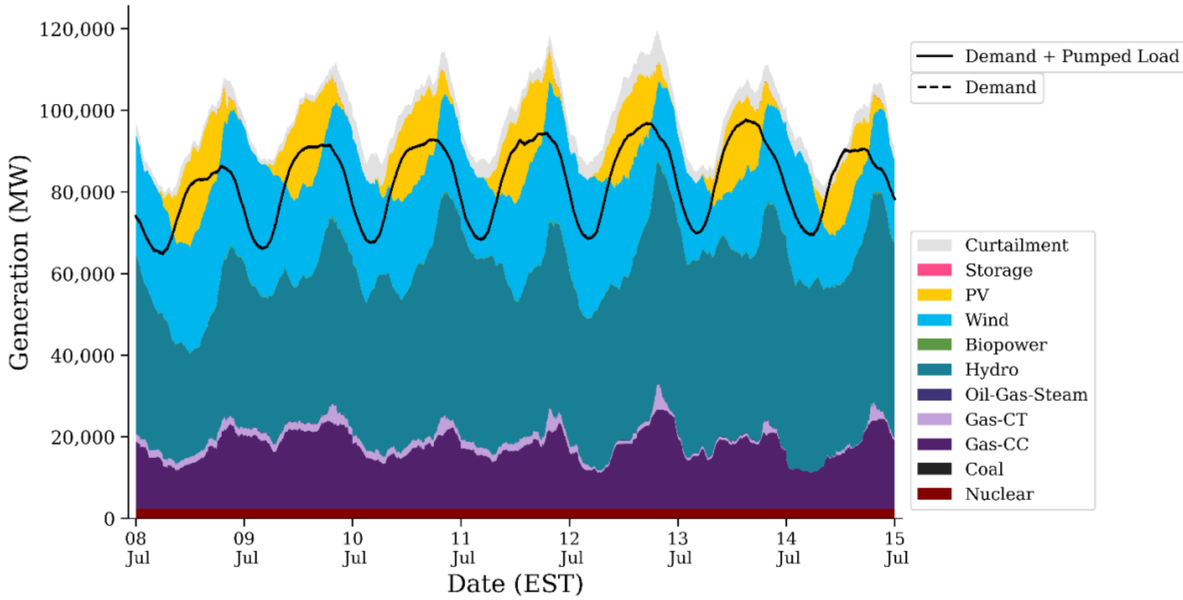

Figure 4. Canadian generation dispatch stack for July 8th – 14th in the Low Cost VG 2050 scenario (a very high load period continent-wide)

Note that the line represents Canadian demand (including losses), so generation in excess of the line is exported to the US. During this continental high-load time period, Canada exports significantly to the US at every hour.

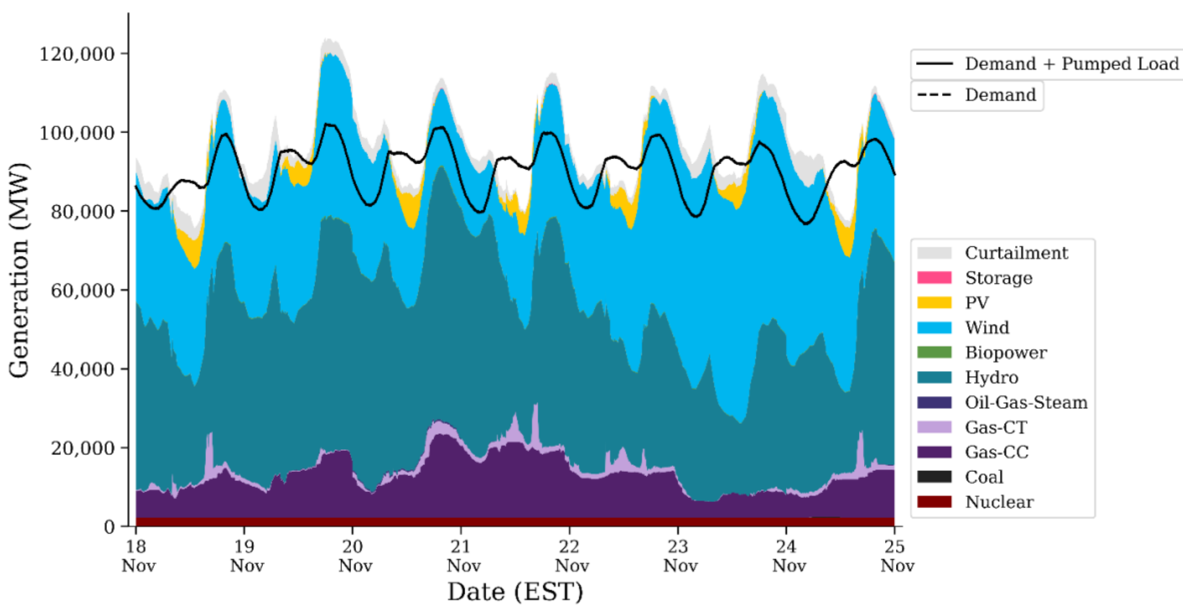

Figure 5. Total Canadian generation dispatch stack for November 18th – 24st (Low Cost VG 2050)

Task 5: Mitigating Measures

The discussion of mitigating measures, and how different technologies can make it easier to operate the future electric power system. Figure 5 below shows how inter-regional transmission impacts costs. This shows some of the cost impacts of the dispatch benefits shown above from the exchange of power between countries. Continent-wide, the impacts of reduced transmission expansion and utilization could be $70 - $180 billion USD (cumulative through 2050). While a relatively small percentage of the total costs, the value of these impacts is significant.

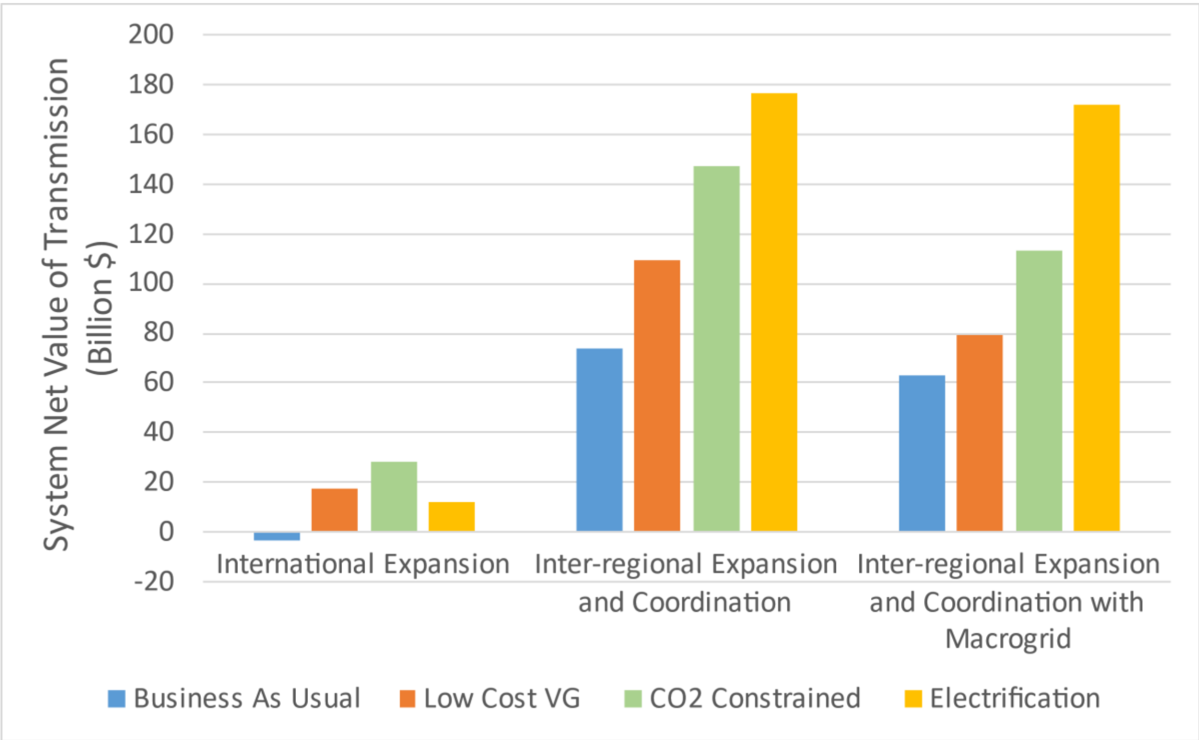

Figure 6. Continent-wide cost impacts from restricting inter-regional transmission builds

Task 6: Technical Review

Technical Review was performed throughout the study, including six in-person meetings of the Technical Review Committee.

Task 7: Final Reporting

The final report and associated animations and web content represent the product for this task. The website links to all of this content: https://www.nrel.gov/analysis/naris.html

Subject Inventions Listing: None

ROI #: None