

Energy Efficiency & Renewable Energy

North American Renewable Integration Study



WBS#: 1.2.1.404

Hydropower Program

October 8, 2019

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NREL

Project Overview

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Project Summary	Project Information	
The North American power system is evolving—how we generate and consume	Project Principal Investigator(s)	
electricity is changing and becoming increasingly meteorologically dependent. A modern power system can take advantage of the diversity of resources and consumption to provide reliable, affordable, sustainable power to everyone. Opportunities will exist for new and existing grid technologies (including hydropower and pumped storage). The North American Renewable Integration Study (NARIS) will analyze the challenges and opportunities of transitioning to a modern power system	Greg Brinkman, NREL	
in North America through the year 2050. It is a partnership between the U.S.	WPTO Lead	
Department of Energy (DOE), Ministry of Energy in Mexico (SENER), and Natural Resources Canada (NRCan).	Sam Bockenhauer	
Project Objective & Impact		
The key questions this study has been designed to address include: • How reliable and affordable will the electric grid be in a variety of scenarios?	Project Partners/Subs	
 What technologies (e.g., storage, demand response) and operating practices (e.g., regional cooperation) are most important to reliable and affordable operation? What are the potential benefits of hydropower flexibility and the impacts of wet and dry conditions on the grid? Are these solutions robust under a wide variety of scenarios and meteorological conditions? What are the benefits of interregional and international cooperation in planning and operations? 	Ministry of Energy in Mexico Natural Resources Canada Technical Review Committee of 40 organizations, primarily utilities and grid operators.	
	Project Duration	
understanding of planning and operations in a modern grid. Enabling more detailed work by national labs and others is a key goal of this work. Understanding some of the nuances of value on the future grid is particularly important for understanding the value of hydropower and pumped storage hydropower. This requires some of the most detailed data sets and modeling yet performed at this scale for a long-term study.	 Start: Fall 2016 Complete (pre-report): Fall 2019 	

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Hydropower Program Strategic Priorities

Environmental R&D and Hydrologic Systems Science

Big-Data Access and Analysis

Technology R&D for Low-Impact Hydropower Growth R&D to Support Modernization, Upgrades and Security for Existing Hydropower Fleet Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration

Alignment with the Hydro Program

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Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration

- Understand the needs of the rapidly evolving grid and how they create opportunities for hydropower and pumped storage hydropower.
- Investigate the full range of hydropower's capabilities to provide grid services as well as the machine, hydrologic, and institutional constraints to fully use those capabilities.
- Optimize hydropower operations and planning—alongside other resources—to best use hydropower's capabilities to provide grid services.
- Invest in innovative technologies that improve hydropower capabilities to provide grid services.

NARIS is focusing on the long-term evolution and modernization of the grid through 2050. This includes detailed capacity expansion planning modeling and simulated operations of the grid and market. This allows us to simulate and inform the variety of different ways that hydropower can function in the future grid to contribute to reliability, resilience, and affordability.

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Pro FY17–FY19 Q1 & Q2 (O	ject Budget ctober 2016–March 2019)
Costed	Costed	Costed	Total Costed	Total Authorized
\$348K	\$398K	\$240K	\$986K	\$1,433K

Management and Technical Approach

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- Partnership between DOE, SENER, and NRCan
- Cofunded and comanaged by DOE's Wind Energy Technologies Office, Solar Energy Technologies Office, and Water Power Technologies Office



 New, continental-scale methods and data are being developed for each of these models and analysis.

End-User Engagement and Dissemination Strategy

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- Ongoing communication and coordination involves engagement with the technical review committee (TRC) of 40 organizations (mostly grid operators and utilities).
- Hydro analysis will be reviewed in more detail by a subgroup of the TRC.



- Due to the review needs of three countries, we are not engaging audiences outside the TRC until the end of the project. This will focus on:
 - Presentations (by study team and enabling TRC members to present on the study)
 - Interactive (web) content and visualizations
 - Data and open-source tools
 - Reports and journal articles.

Technical Merit and Relevance

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North America has incredible wind/water/solar resource.

The grid is evolving to become more meteorologically dependent, and a modern power system can take advantage of the diversity of resources.



- Industry needs methods, tools, and data to study detailed, continental-scale questions about system integration, transmission, operational practices, and enabling technologies.
- We are creating open models and data where possible to inform questions about system integration and enable stakeholders to further the work.

Novel Need for Detail in Continental Modeling

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POWER FLOW CASE IMPORTS (GridDB)

100+ cases representing all U.S./Canada interconnections, 12-year span, load flow periods, automated import

GENERATOR PARAMETERS

Detailed analysis of historical operating parameters, such as heat rate and minimum generation levels

LOAD

Detailed meteorologically consistent load data (adjustable to future conditions)



(RComSt.

DNREL

GATE-E BONKROO

(B.BesStor

UNREL





METEOROLOGY

7 years of 5-min time resolution data for wind and solar generators consistent with load



200 400 600 800 Generation (MW)

EVI-PRO

DINREL



PARTNERSHIP AND TECHNICAL REVIEW

Ongoing review of all data, assumptions, and methods by system operators and others

Capacity Expansion Scenario Analysis (ReEDS)

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- Continental model developed
- Model run for 40 different combinations of assumptions, including:
 - Wind and solar costs
 - Gas price
 - Transmission cooperation (interregional and international)
 - Electrification.
- Interactive tool for technical review and (eventually) communication/outreach.



Probabilistic Resource Adequacy Suite (PRAS)

- Tool developed for NARIS, continental data populated by capacity expansion tool
- Simulates billions of different grid conditions
 - Consistent meteorology for wind/solar/load
 - Randomized outages.
- Identifies contribution of renewables to reliability
- Identifies key infrastructure for reliability.



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First draft visualization Red shows periods of highest risk of unserved

Note change of regions

during different seasons and

energy

times of day.







Operational Simulation/ Production Cost (PLEXOS)

- Continental-scale model with detailed representation and realistic interregional interactions via geographic decomposition
- 5-minute time resolution, will model 7 years of meteorology (not done yet)
- Understand how grid operates, forecast error impacts, benefits from transmission, etc., in detail
- Comparisons with capacity expansion simplified dispatch, with feedback from learning

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Key Hydro-Focused Analysis

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- Value of hydropower flexibility
 - Based on a sensitivity with increased levels of flexibility from the standard assumptions and one with decreased levels of flexibility
- Analysis of wet and dry conditions
- Value of contribution toward resource adequacy
 - Hydropower plays a very key role in resource adequacy, especially in the high-wind/-solar scenarios

Low-cost storage sensitivity

 Informs what the grid could look like with increased storage, in the form of batteries and pumped hydro.

Future Work

- Complete hydropower-focused analysis in PLEXOS
 - Flexibility sensitivities
 - Wet/dry sensitivities.
- Summarize study findings to the public
- Public report
 - Focus on visualizations
 - Capacity expansion (interactive)
 - Operational
 - Reliability/resource adequacy (partially interactive) for understanding how the grid operates during tail events (follow-on work for "extreme events").



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Thanks! Questions?

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Distributed Generation Modeling (dGen)

- Continental model developed (extended from U.S. tool)
- Agent-based model using lidar and extensive socioeconomic data to understand adoption
- County-level resolution in the United States
- Price feedback with capacity expansion tools (ReEDS).

Shading Tilt Azimuth **Rooftop Suitability Results** Installed Capacity (MW) All Sectors - 2050 < 10 10 - 50 50 - 100 00 - 250 500 - 1000 eere.energy.gov



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LIDAR & Building Footprint Data

Renewable Energy Potential (reV) Geospatial Tool

- Enables consistency between tools involving petabytes of data
- New 5-minute WRF modeling for wind analysis in the United States (2014), Canada (2007–2014), Mexico (2007–2014)
- Detailed geospatial analysis of scenarios possible (e.g., interactive siting analysis for a variety of assumptions)
- Downscaling solar data to 5minute resolution for entire continent, creating time- and meteorologically consistent forecasts.





