

An aerial photograph of a river flowing through a dense forest. The water is a vibrant blue-green color, and the surrounding trees are lush green. The riverbed is visible, showing rocks and pebbles. The overall scene is serene and natural.

Towards 100% Renewable Energy Pathways: A Research Roadmap

Denver, CO
May 14-15, 2019

Workshop Purpose

- Develop a coordinated international research roadmap to address the technical challenges associated with incorporating very large amounts of variable generation (wind and solar) into the energy supply mix
- Recognize that all deep decarbonization scenarios involve
 - increasing utilization of renewable resources
 - integration of electrical, thermal and gas systems
 - increasing electrification of energy end-use sectors, including transportation, buildings and industry
 - critical social science dimension
- Focus on the issues of operating a power system with 100% instantaneous penetration of inverter-based resources in a reliable and economic manner
- The bookend scenario of 100% annual energy from renewables will also be considered as a limiting case for illustrative purposes, but is not the focus of the workshop

Workshop Expectations

- Provide a research framework to allow cooperation among multiple independent parties.
- Gain recognition that not all regions will follow the same pathways at the same time, but the chosen pathways must lead to a common destination.
- The pathways should identify major technology development needs, analytical efforts, and decision points needed to support the selected path.
- Resulting roadmap will allow parties, working in a loosely coordinated fashion, to make progress toward common goals while taking advantage of advances in other international efforts.

Workshop Organization

- Limited to approximately 60 participants by invitation only
- Roll-up-your-sleeves workshop will require your full attention and engagement
- Cooperative international effort across all regions and all segments of the industry
- Tried to achieve some regional and industry balance
- Attendees are assigned to one of five tracks, with each track serving as an active working group with continuity over the course of the two days
- Size of the groups are limited to facilitate brainstorming and interaction during the workshop

Introduction to Workshop Tracks

- **Track 1: Adequacy**
Chair: **Aaron Bloom**, NextEra Analytics
Rapporteur: **Hannele Holttinen**, IEA WIND Task 25
- **Track 2: Volts and Amps**
Chair: **Jason MacDowell**, GE
Rapporteur: **Abraham Ellis**, Sandia National Lab
- **Track 3: Distribution Systems, Microgrids and Customers**
Chair: **Debbie Lew**, GE
Rapporteur: **Ben Kroposki**, NREL
- **Track 4: Flexibility, Operations and Balancing**
Chair: **Aidan Tuohy**, EPRI
Rapporteur: **Chris Greig**, University of Queensland; Visiting Professor, Princeton
- **Track 5: Markets**
Chair: **Erik Ela**, EPRI
Rapporteur: **Daniel Kirschen**, University of Washington

Agenda Overview (1)

- **Opening Session**

Chair: **Mark Ahlstrom**, President, ESIG Board of Directors

- **A Word From Our Sponsor**

Ric O'Connell, GridLab

- **A Sense of Urgency**

Michael O'Boyle, Energy Innovations

- **Workshop and Agenda Overview**

Charlie Smith, Executive Director, ESIG

- **Research Roadmap**

Mark O'Malley, Chief Scientist, NREL; Chair, ESIG Research & Education Working Group

Agenda Overview (2)

- **Background Session: Where Are We At, Where Are We Going, and How Will We Get There**

Chair: **Ric O'Connell**, GridLab

- **Where Are We At**
Vera Silva, CTO, GE Renewables and Grid Business
- **Where Are We Going**
Nick Miller, Consultant
- **Possible Pathways Towards 100% RE: How Will We Get There**
Mark Ahlstrom, President, ESIG Board of Directors
- **Group Discussion**

Agenda Overview (3)

- **Session 1:** Topic Scopes and Issues: Parallel Tracks with short issue orientation presentation
- **Session 2:** Topic Research Roadmap Outlines: Parallel Tracks
- **Session 3:** Topic Elements of the Research Framework: Parallel Tracks
- **Report-out:** All tracks report back to entire group following each session

Agenda Overview (4)

- **Wrap-up Session: Progress Review and Next Steps**

Moderator: Jonathan O'Sullivan, Eirgrid

- **Accomplishments and Next Steps**
Mark O'Malley, NREL/ESIG
- **Closing Remarks**
Mark Ahlstrom, ESIG

Attendee Representation

- Geographic Representation

- Asia 3
- Australia 1
- Europe 7
- North America 40
- South America 2
- International 3

- Industry Segment

- Government 1
- Industry 27
- Research 28

Track 1: Adequacy Participants

- Moderator: Aaron Bloom, NextEra Analytics
- Rapporteur: Hannele Holttinen, IEA WIND Task 25

- Steve Beuning, Holy Cross Energy
- Paul Denholm, NREL
- Brandon Heath, MISO
- Tim Heidel, Breakthrough Energy
- Jim McCalley, Iowa State University
- Michael Milligan, Consultant
- Rodrigo Moreno, U. of Chile
- Mark O'Malley, NREL
- Kevin Pera, Xcel Energy

Track 2: Volts and Amps Participants

- Moderator: Jason MacDowell, GE
- Rapporteur: Abraham Ellis, Sandia National Lab

- Thorsten Bülo, SMA Solar Technology AG
- Julia Matevosyan, ERCOT
- Nick Miller, HickoryLedge
- Mahesh Morjaria, First Solar
- Ryan Quint, NERC
- Goran Strbac, Imperial College
- Tim Green, Imperial College

Track 3: Distribution Systems, Microgrids and Customers

- Moderator: Debbie Lew, GE
- Rapporteur: Ben Kroposki, NREL

- Miroslav Begovich, Texas A&M
- William D'haeseleer, KU Leuven
- Xiaoming Feng, ABB
- Andy Hoke, NREL
- Barry Mather, NREL
- Ric O'Connell, GridLab
- Kazuhiko Ogimoto, The University of Tokyo
- Charlie Smith, ESIG

Track 4: Flexibility, Operations and Balancing

- Moderator: Aidan Tuohy, EPRI
- Rapporteur: Chris Greig, Princeton University

- Francisco De La Rosa, CENACE
- Shuanglei Feng, China Electric Power Research Institute
- Alain Forcione, Hydro-Québec
- Andrew Groom, AEMO
- Michael O'Boyle, Energy Innovation
- Vera Silva, GE
- Ramteen Sioshansi, The Ohio State University
- David Schweizer, PJM
- Sonya Twohig, ENTSO-E
- Wesley Yeomans, NYISO
- Ning Zhang, Tsinghua University

Track 5: Markets

- Moderator: Erik Ela, EPRI
- Rapporteur: Daniel Kirschen, University of Washington

- Mark Ahlstrom, NextEra Energy Resources
- Bernardo Bezerra, PSR
- Bethany Frew, NREL
- Eric Gimon, Energy Innovation
- Udi Helman, Helman Analytics
- Cathy McClay, National Grid
- Richard O'Neill, FERC
- Jonathan O'Sullivan, EirGrid
- Matt Prorock, Great Plains Institute
- Bruce Rew, SPP
- Linda Steg, University of Groningen

Track Work Product Expectations

- Identify the major knowns and unknowns which must be dealt with to answer the important questions and resolve the important issues
- Identify major alternative pathways that may be followed at different times and places in arriving at the final destination
- Identify the basic engineering physics which will govern any pathway selected
- Provide a research framework and identify the major choices which must be made in order to reach the final destination
- Identify technology development, analysis work, major decision points and consequences of delaying or not making important decisions

Workshop Outcomes

- The near-term outcome is to be able to identify a common destination where grid following inverters, grid forming inverters and synchronous machines (generators or condensers) can operate seamlessly with one another as the state of the system resource mix continually changes from very low to very high inverter based resource (IBR) penetration
- The longer term outcome is to analyze the bookend scenario of 100% annual energy from renewables
- Summarize what has been accomplished, what remains to be done, and identify the steps to complete the roadmap.

Thank You!

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Connect with @ESIG



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Energy Systems Integration Group

Charting the Future of Energy Systems Integration and Operations

