Renewable Energy for Resilience & Adaptation

Workshop on Adaptive Actions Toward a Sustainable and Resilient Future
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Outline

- About NREL and JISEA
- Energy Technology Markets and Trends
  - Example: Wind Turbines
- Renewable Energy and Adaptation/Resilience
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**Mission**: NREL advances the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies and provides the knowledge to integrate and optimize energy systems.

**Example Technology Areas:**

- 2300 employees, plus more than 450 postdoctoral researchers, interns, visiting professionals
- 327-acre campus in Golden, Colorado & 305-acre Flatirons campus with the National Wind Technology Center near Boulder, Colorado
- 61 R&D 100 awards. More than 1000 scientific and technical materials published annually [www.nrel.gov/about](http://www.nrel.gov/about)
JISEA
Joint Institute for Strategic Energy Analysis

Connecting technologies, economic sectors, and continents to catalyze the transition to the 21st century energy economy.

www.jisea.org

Founding Members
JISEA’s Research Portfolio

- Clean Energy for Industry and Agriculture
- Energy System Integration and Transformation
- Advanced Manufacturing Analysis
- International Collaboration and Capacity Building
JISEA Sponsors:
Ability to convene consortia

Research Affiliates
Houston Advanced Research Center, Rice University Baker Institute, Energy Institute at University of Texas at Austin, Masdar Institute, Carnegie Mellon, Eskom, International Institute for Applied Systems Analysis, KTH Royal Institute of Technology, Renewable and Appropriate Energy Laboratory at UC Berkeley, Masdar Institute
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Global share of renewable electricity

Estimated Renewable Energy Share of Global Electricity Production, End-2018

73.8% Non-renewable electricity

26.2% Renewable electricity

15.8% Hydropower

5.5% Wind power

2.4% Solar PV

2.2% Bio-power

0.4% Geothermal, CSP and ocean power


Note: Data should not be compared with previous version of this figure due to revisions in data and methodology.
Global share of renewable energy

Estimated Renewable Share of Total Final Energy Consumption, 2017

79.7% Fossil fuels

- 2.2% Nuclear energy
- 7.5% Traditional biomass
- 10.6% Modern renewables
  - 2.0% Wind/solar/biomass
  - 3.6% Hydropower
  - 4.2% Biomass/solar/geothermal heat
  - 1.0% Biofuels for transport

Note: Data should not be compared with previous years because of revisions due to improved or adjusted data or methodology. Totals may not add up due to rounding.


Source: Based on OECD/IEA and IEA SHC.
Global growth of renewable power

Annual Additions of Renewable Power Capacity, by Technology and Total, 2012-2018

Additions by technology (Gigawatts)
- Solar PV
- Wind power
- Hydropower
- Bio-power, geothermal, ocean power, CSP

Total additions (Gigawatts)
- 181 Gigawatts

Note: Solar PV capacity data are provided in direct current (DC).

Renewable energy—not including hydropower—currently produces 10% of the total U.S. electricity generation. Within the next two years, this is expected to grow to 13%.

With hydropower, renewable energy is 17%.

With nuclear (19%), U.S. low-carbon electricity is 36%.

Variation by Location: Solar Generation as a % of Total Generation, 2014-2018, by U.S. State

Massachusetts Renewable Energy is Growing

Source: [https://www.mass.gov/info-details/renewable-energy-snapshot](https://www.mass.gov/info-details/renewable-energy-snapshot)
Massachusetts Energy System

Source: https://www.eia.gov/state/?sid=MA#tabs-1
New England Electric Energy

Percent of Total Electric Energy by Resource Type

*Data are subject to adjustments. This chart approximates the amount of generation by individual fuels used by dual-fuel units, such as natural gas-fired generators that can switch to run on oil and vice versa. Before 2016, generation from such units was attributed only to the primary fuel type registered for the unit.

**Includes pondage, run-of-river, and pumped storage.

***Renewables include landfill gas, biomass, other biomass gas, wind, grid-scale solar, municipal solid waste, and miscellaneous fuels. Hydro is not included in this category primarily because the various sources that make up hydroelectric generation (i.e., conventional hydroelectric, run-of-river, pumped storage) are not universally defined as renewable in the six New England states.

Costs for Renewables are Falling

Advanced energy technologies are providing real-world solutions by:
- Becoming increasingly cost-competitive
- Boosting the energy industry
- Providing jobs

Source: Lazard’s 2017 Levelized Cost of Energy Analysis, Version 11, 2 November 2017
Advanced grid integration studies

https://www.youtube.com/watch?v=li8jO-pKgvc&list=PLmIn8Hncs7bEl4P8z6-KClwbyrwANv4p&index=19
Electrification Futures Study

All Figures from NREL’s Electrification Futures Study: [www.nrel.gov/efs](http://www.nrel.gov/efs)
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Wind Turbines – Onshore and Offshore

Peetz Table Wind Energy Center
• Peetz, Colorado
• 430 MW, 300 turbines
• Opened 2001, expanded 2007
• Capacity Factor 34.5%

Block Island Wind Farm
• New Shoreham, Rhode Island
• 30 MW, 5 turbines
• 100 m hub height, 150 m diameter
• Opened 2016
• Capacity Factor 48% (projected)
Wind Market Growth Driven by Price Declines

Wind LCOE

Unsubsidized Wind LCOE

Wind capacity installed in Oklahoma, Iowa, and Kansas supplied 32%–36% of all in-state electricity generation in 2018. 14 states were greater than 10%.
Wind Machines – Scale, Capacity Factor Increasing, Manufacturing Costs Declining

Onshore: 2-3 MW
50 m blade length

**Avg. Wind Turbine Capacity Factors (% of capacity) by Build Year**
- 1998-2001: 24.5%
- 2004-2011: 32.1%
- 2014-2015: 42.6%

Compare: Natural Gas Plant: 56%; Coal Fired Plant: 53%; Nuclear: 92%; Solar Photovoltaic: 27%

Wind Energy Potential Increasing to More Places

140m Hub Height
‘Future’ Turbine Technology
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Energy Resilience Definition and Measures

The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions through adaptable and holistic planning and technical solutions

Adaptation measures used for energy resilience depend on the vulnerabilities and threats, but may include:

- Undergrounding critical lines
- Demand-side energy efficiency
- Diversifying generation
- Deploying distributed generation: PV, small wind, energy storage
- Deploying smart grids and micro-grids
Resilience Assessment

Potential Impacts + Probability of Occurrence

Risk Assessment Matrix:
Impact x Probability

Ranking of Threats and Vulnerabilities
High, Medium, Low

Resilience Options Evaluation:
Cost, effectiveness, feasibility

Resilience and Adaptation Strategies
https://www.nrel.gov/resilience-planning-roadmap/
Adaptation for PV Energy Systems

• Systems should be designed to be more resilient to hazards
  – Should include site-specific or hazard-based design, energy
    storage and islanding controls, site-specific storm preparation
    plans to further minimize damage
  – Codes and standards for technology design and deployment, such
    as hail, wind, temperature
• Sites should be evaluated for readiness for major storms
  – Ensure siting outside of known hazard zones where possible
  – Ensure ground mount arrays have appropriate civil engineering
    including soils analysis and drainage
  – Where possible, perimeter fences may be used to reduce wind
    loading on arrays
• Systems should be designed to withstand local hazards
  – Ensure that panel mounting equipment is rated for expected
    wind loads
  – Use through-bolting where possible rather than clamp-style
    mounting
  – Use fixed-tilt arrays (rather than tracking) to minimize failure due
    to torsional forces on rotating torque tubes
• Systems and grid integration should enable independent
  operations
  – Modeling to meet challenges with grid integration of variable
    resources
  – Legal framework and safety for islanding of systems for localized
    microgrid-based power
  – Workforce training to manage microgrids

Two PV systems in Puerto Rico post-hurricane Maria
that survived (top) and were damaged (bottom)
Adaptation of Wind Turbines for Bigger Storms

Current wind turbines face up-wind and use feathering or full shut down in high winds.

Hypothetical 50-megawatt offshore down-wind facing wind turbine for 25-meter deep waters in Gulf of Mexico.

Adaptation of hydropower to changing hydrological phases

- Countries that traditionally rely heavily on large (dammed) hydropower face increasing risk and reliability concerns during El Niño and La Niña hydrological phases
- Rainfall and snowmelt patterns are changing making hydropower resources more unpredictable, variable
- Aging infrastructure susceptible to a variety of hazards
- Adaptation:
  - Expand emphasis of system design on flexibility and resiliency at different time scales (daily to seasonal to interannual)
  - Increase coordination among dam operators and other end users (e.g. agricultural sector) to better serve all water needs while reducing sedimentation and resource volatility
  - Increase use of medium and long-range forecasting to enable better watershed planning and dispatch
  - Diversification of energy sources, including other renewable energy and natural gas

Power Plants Shut Down or Curtailed Generation due to Water Temperature or Availability (2006-2013)

Source: Union of Concerned Scientists, 2014
Adaptation and Resiliency Options of Electricity Production

Hydropower
- Affected by weather events / Reduced water storage capacity
- Monthly/Yearly concerns

VRE
- Variable and somewhat uncertain by nature
- Hourly or below concerns

Thermal Power
- Inflexibility of existing plants / Fuel supply uncertainties
- All time scales

How to ensure flexibility at different time scales?

Key Policy Options

Electricity Sector
- Generation mix diversification
- Demand-side management
- Storage systems
- Regional and international interconnections
- DERs
- Effective pricing mechanisms

Natural Gas Sector
- Investments in domestic production
- Import diversification
- Robust and competitive market
- Pipeline infrastructure expansion
- Underground storage
- Flexible LNG contracts and technologies

Effective Integration

Electricity & Natural Gas Interface

Electricity & Gas networks are interconnected energy infrastructures whose operation and reliability depend on one another. As the percent of gas and variable renewable power plants increase, the connection between these networks becomes increasingly important.

Goal of project is to:

Co-simulate power and natural gas network operations.
Model the Colorado interconnected power and natural gas networks and a test system with different renewable penetrations.
Determine value of coordination of day-ahead and intra-day operations.

Funded through JISEA sponsorship by:
- American Electric Power
- Environmental Defense Fund
- Hewlett Foundation
- Kinder Morgan
- American Gas Association
- Midcontinent Independent System Operator

Source: JISEA project in progress.
Clean Power Technologies for Oil & Gas Industry Operations: Electrification of the Wellpad and Platform via Microgrids

- Electrification of all equipment at wellpad connected via microgrid
- Power could consist of:
  - Field/Flare Gas fired generator
  - Solar PV/wind systems
  - Fuel cells
  - Energy Storage
    - Hydrogen
    - Batteries
  - Grid power (or offgrid)
- Benefits:
  - Resiliency during outages
  - Optimize for least cost
  - Reduce emissions
- Leverage work on
  - Remote bases & communities
  - Islands
Renewable Hybrid Energy Solutions

Co-location of Wind/PV and Agriculture

• Growing food crops under partial shade of solar energy infrastructure
• Can increase crop yields and reduce water needs in hot, dry conditions
• Can also co-locate with grazing areas and collect rainwater for irrigation and cleaning
• Cooler microclimate increases PV efficiency
• Provides a resilience buffer against extreme heat and addresses competing land use demands
Conclusions and Discussion

• Trend toward cleaner and lower cost energy that is more highly distributed
• Potentially increased electrification resulting in higher demand for power
• Renewable energy can help power, industrial, and agricultural systems reduce emissions, and operate more resiliently, but needs research
• Renewable energy technologies need to adapt to larger storms, changing temperatures, and greater variability of conditions
• Need improved standards, models, policies, and technologies to enable systems to adapt
Questions and Discussion

Thank you!