JISEA Joint Institute for Strategic Energy Analysis

Clean Energy Technologies for Oil & Gas Industry Operations

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NREL NATIONAL RENEWABLE ENERGY LABORATORY · COLORADO SCHOOL OF MINES · Colorado State University · Massachusetts Institute of Technology · STANFORD UNIVERSITY · University of Colorado Boulder

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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:

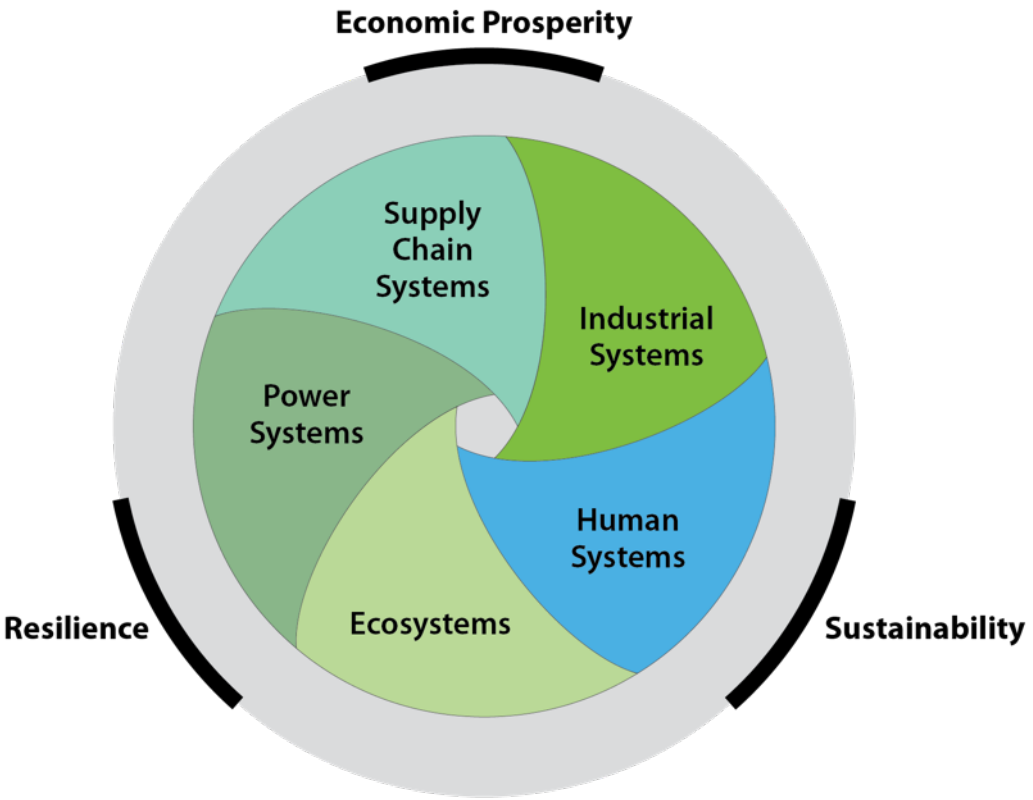
- 2050 employees, plus 400 postdoctoral researchers, interns, visiting professionals
- 327-acre campus in Golden, Colorado & 305-acre National Wind Technology Center 13 miles north
- 61 R&D 100 awards. More than 1000 scientific and technical materials published annually

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.



Founding Members

NREL National Renewable Energy Laboratory · Colorado School of Mines · Colorado State University · Massachusetts Institute of Technology · Stanford University · University of Colorado Boulder

JISEA Sponsors:
Ability to convene consortiums

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

Outline

- Energy Technology Markets and Trends
- Systems Integration of Renewable Energy and Oil & Gas
  - Electricity Generation – Natural Gas Pipelines
  - Hydrogen @ Scale
- Renewable Energy for O&G Operations

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Renewable Energy Is Diverse

WIND

Onshore

Offshore

SOLAR PV

Distributed & Micro Grids

Utility Grid Connected

HYDROPOWER

Large & Small

Wave & Tidal

BIOMASS & WASTE

HYDROGEN & GAS

GEOTHERMAL

CONCENTRATING SOLAR

BATTERIES & STORAGE

EFFICIENCY & HEAT USE

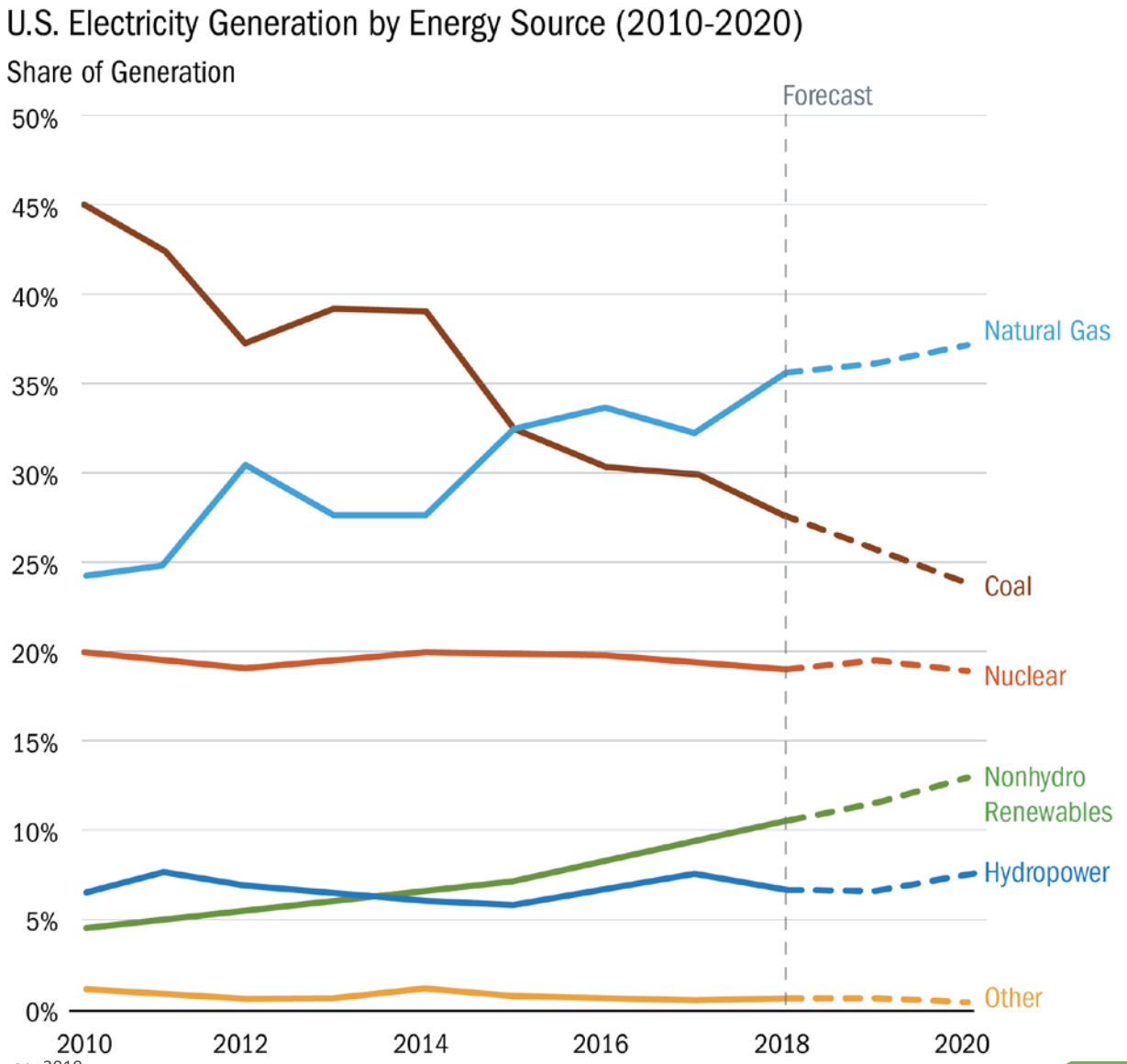
Images from https://images.nrel.gov/

U.S. Electricity Trending to Gas and Renewables

Renewable energy—not including hydropower—currently produces 10% of the total U.S. electricity generation.

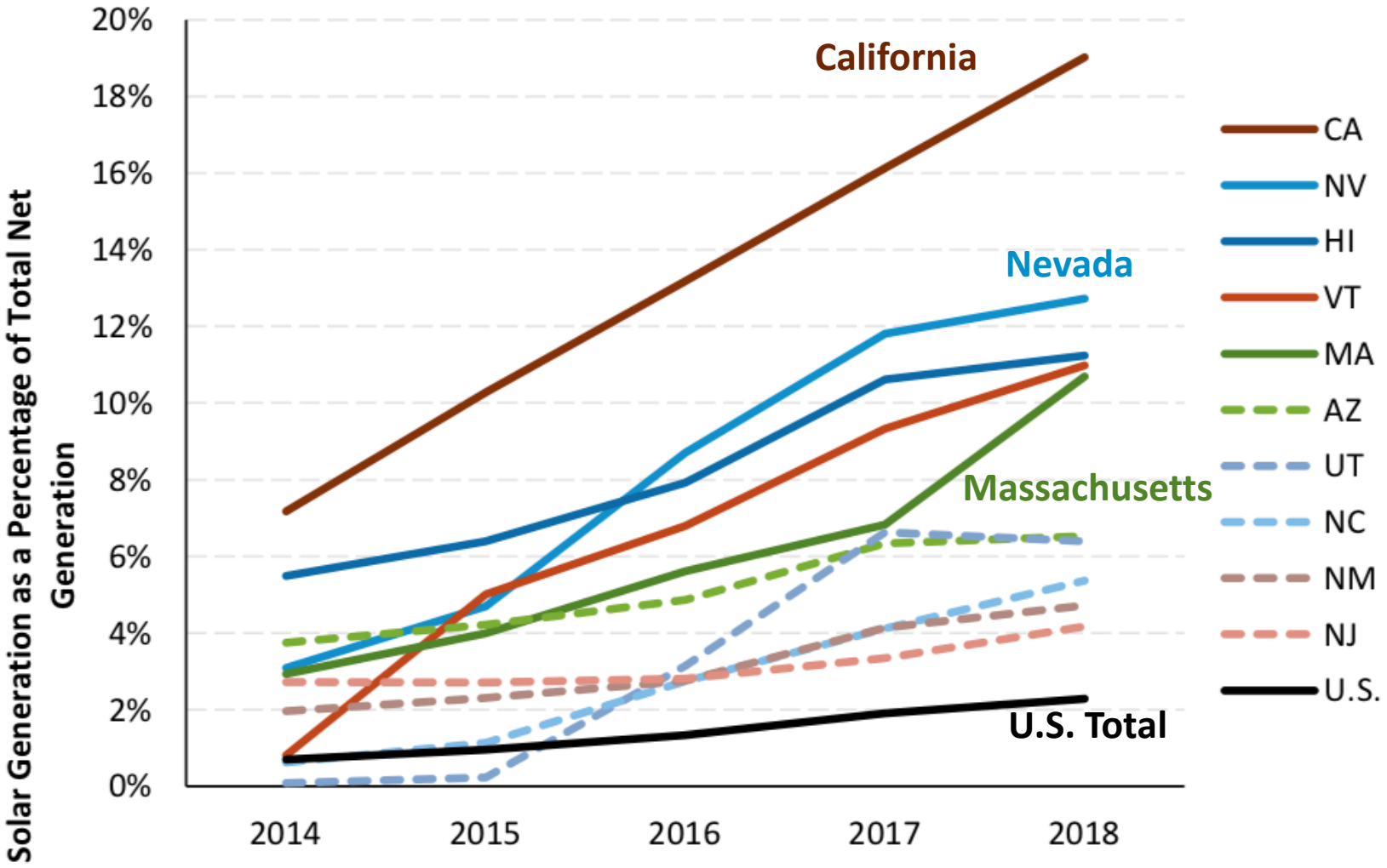
Within the next two years, this is expected to grow to 13%.

With hydropower, renewable energy is 17%.



Source: United States Energy Information Agency, *Today in Energy,* 18 January 2019

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

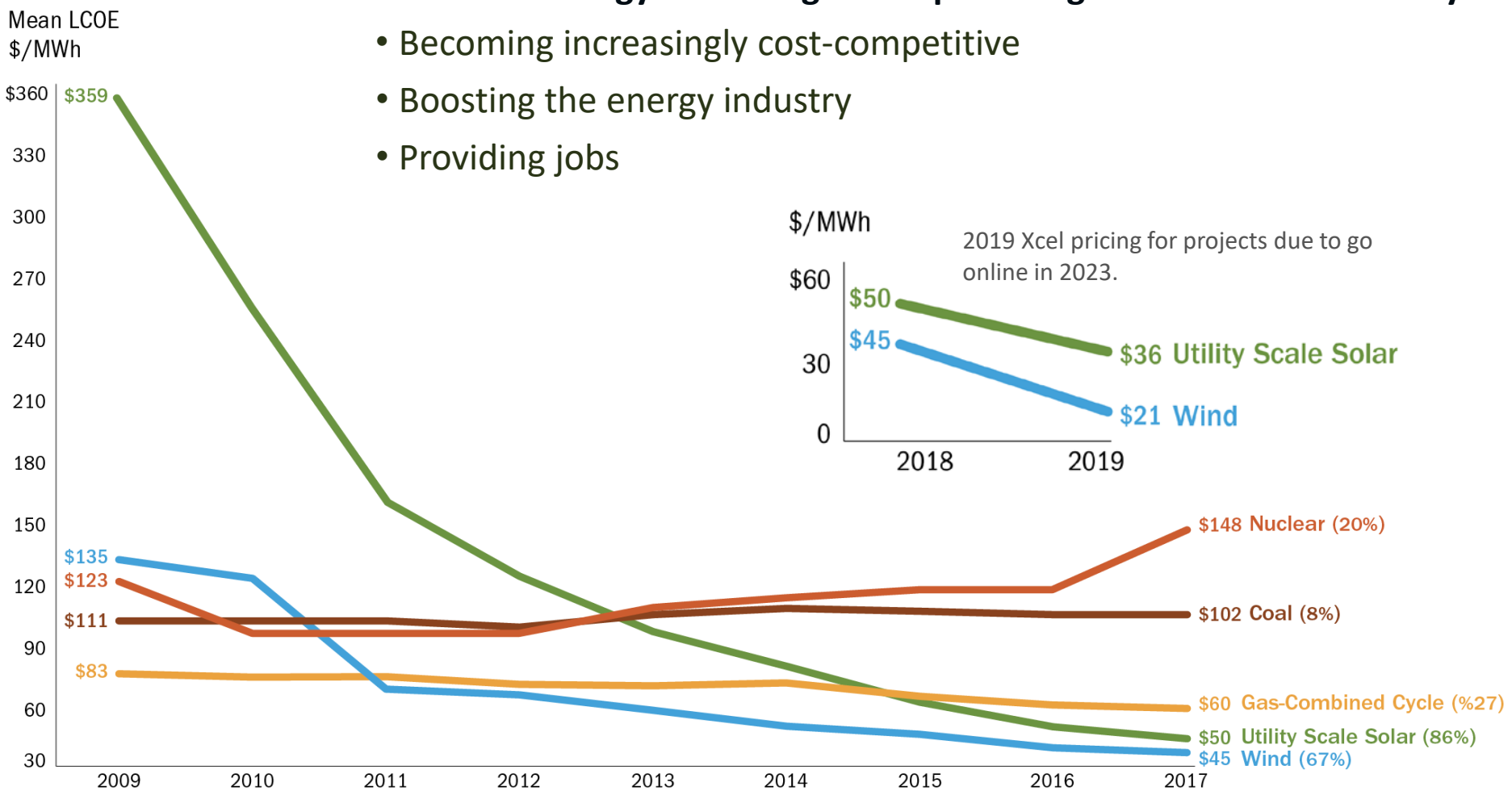


Source: NREL, Q4 2018/Q1 2019 Solar Industry Update, May 2019.

Costs for Renewables are Falling

Advanced energy technologies are providing real-world solutions by:

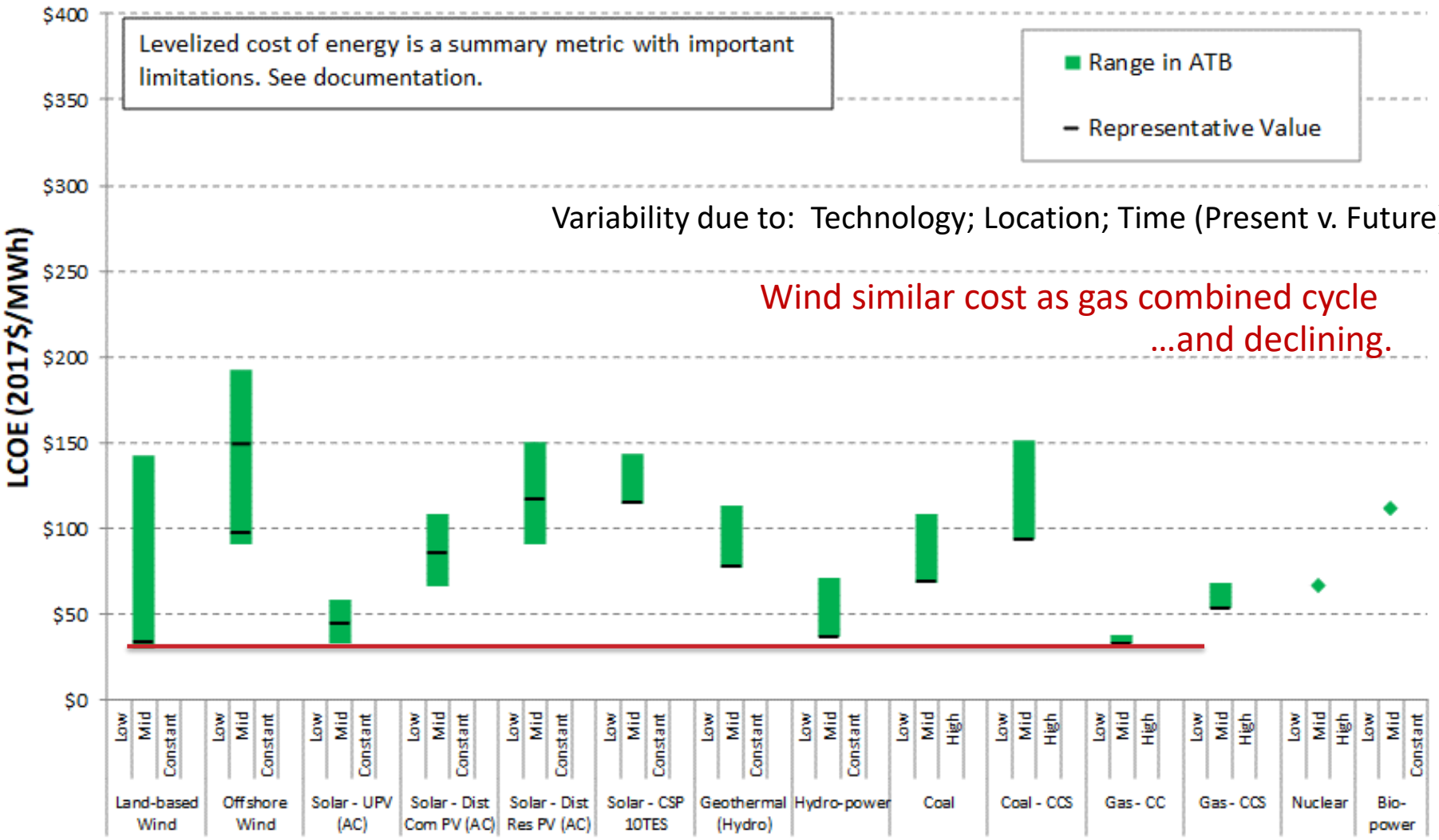
- Becoming increasingly cost-competitive
- Boosting the energy industry
- Providing jobs



Source: *Lazard's 2017 Levelized Cost of Energy Analysis,* Version 11, 2 November 2017

Cost of Renewable & Traditional Electricity Equalizing

Levelized Cost of Electricity ranges by technology. Values are in 2017$.



2019 ATB LCOE range by technology for 2017 based on R&D financial assumptions

Source: National Renewable Energy Laboratory Annual Technology Baseline (2019), http://atb.nrel.gov

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Electricity Generation: Electric-Natural Gas Interface Study

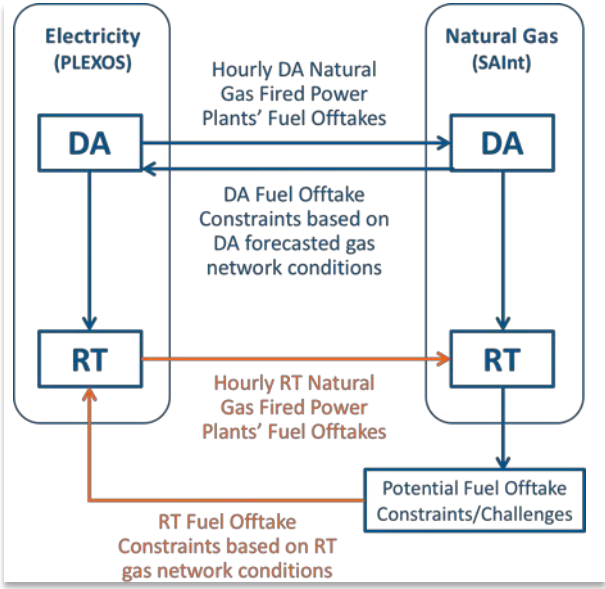
Electricity & **Gas** networks are **interconnected** energy infrastructures whose operation and reliability depend on one another. As the percent of gas and variable renewable power plants increase, the connection between these networks becomes increasingly important.

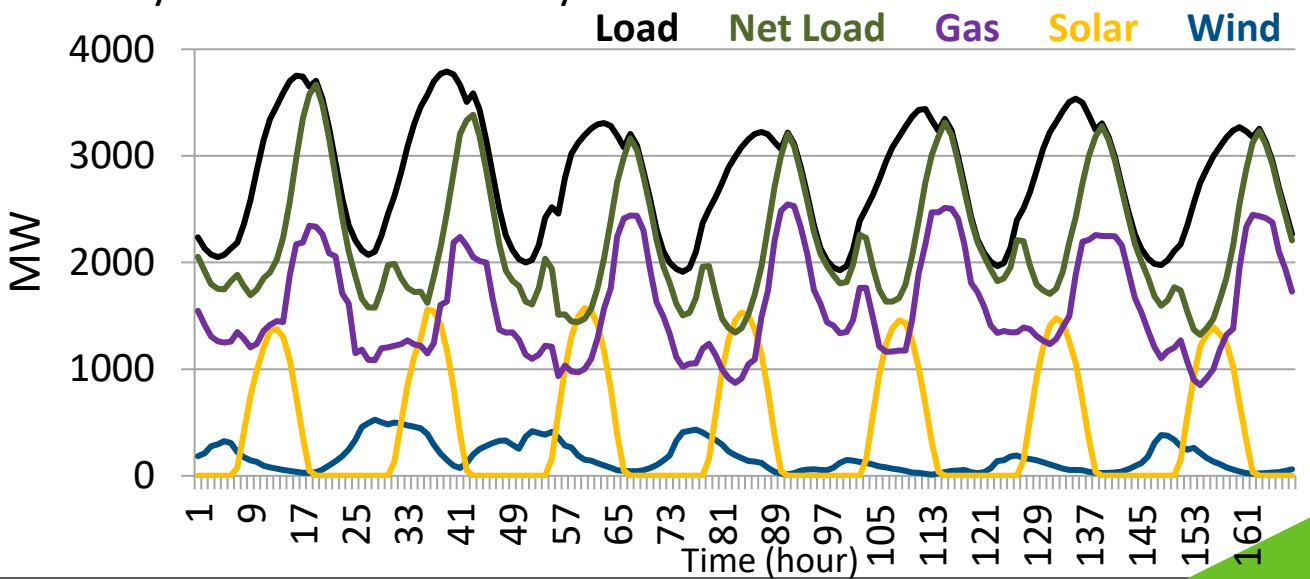
Goal of project is to:

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:

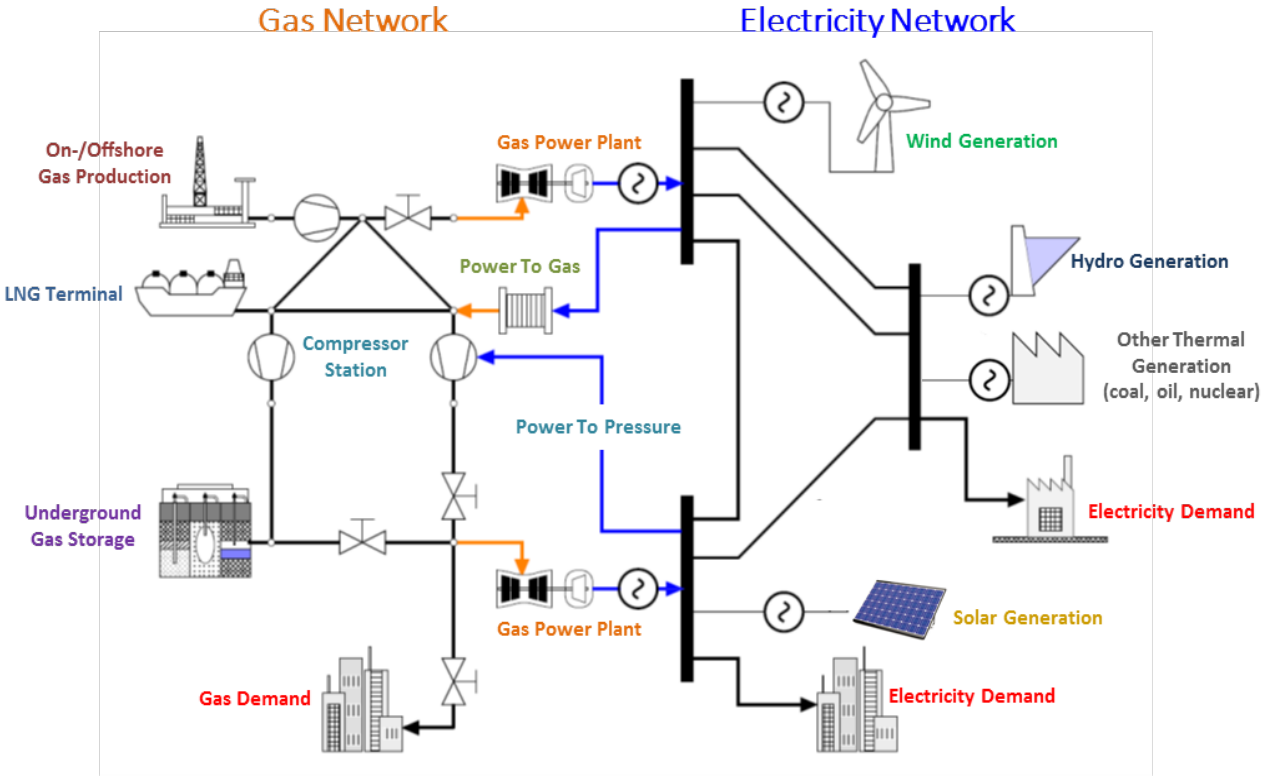
- American Electric Power
- Environmental Defense Fund
- Hewlett Foundation
- Kinder Morgan
- American Gas Association
- Midcontinent Independent System Operator

Source: JISEA project in progress.

A Third Phase of the Electric-Natural Gas Interface Study

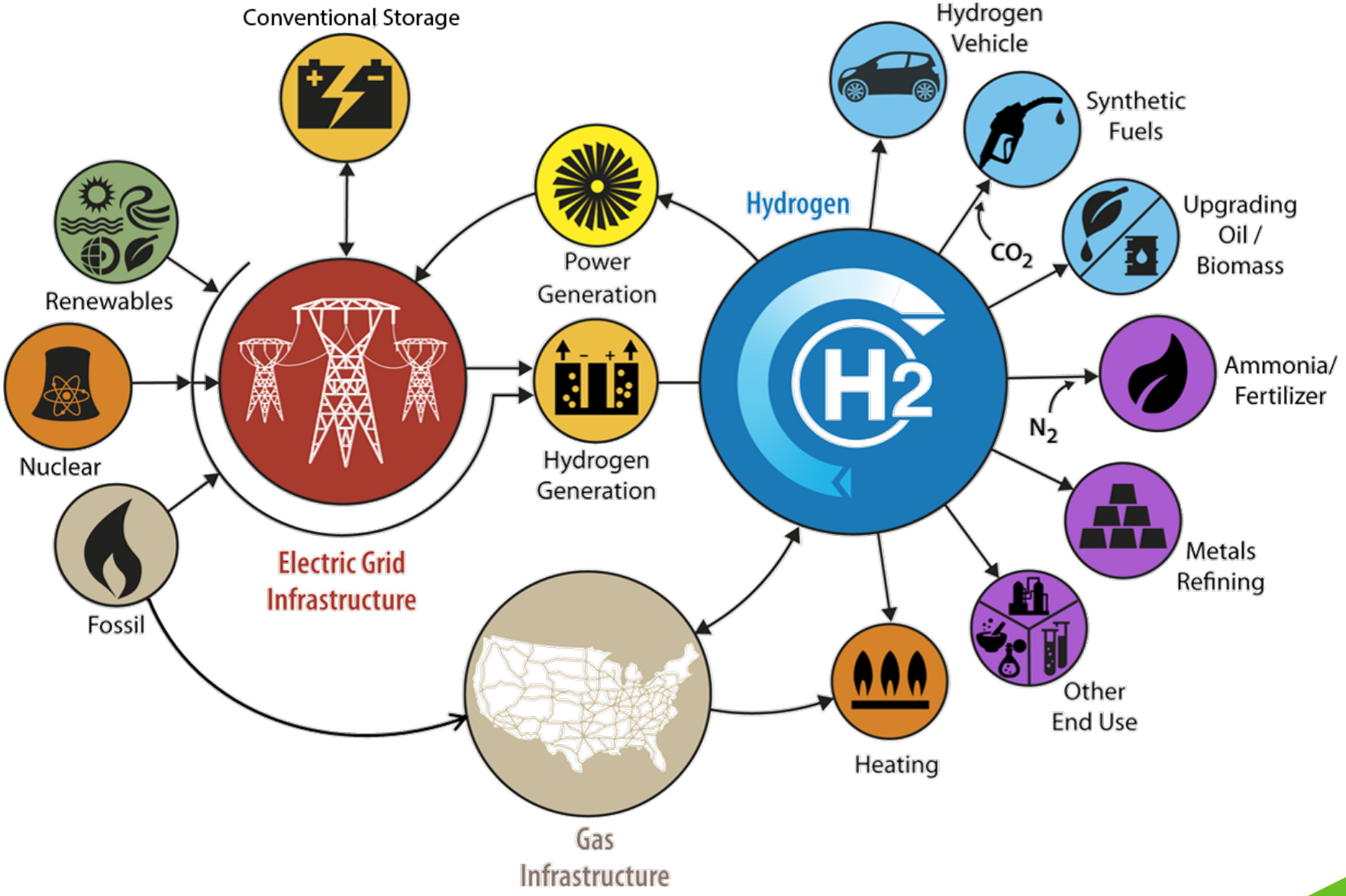
By leveraging the **co-simulation platform** for modeling coordinated electric power and natural gas system operations developed in the first two phases of the project, a third phase could address the following relevant questions for different regions in the United States:

- What are the impacts of **power to gas** (hydrogen) on electricity and gas network operations in an effort to **reduce** renewable **curtailment** and overall energy systems **emissions**?
- What are the impacts of an **extreme weather event** or of **contingency** in the electricity or gas network on the reliable operation of both critical energy infrastructures?
- To what extent do electricity and natural gas networks impact each other's **security of supply** and **resiliency**?

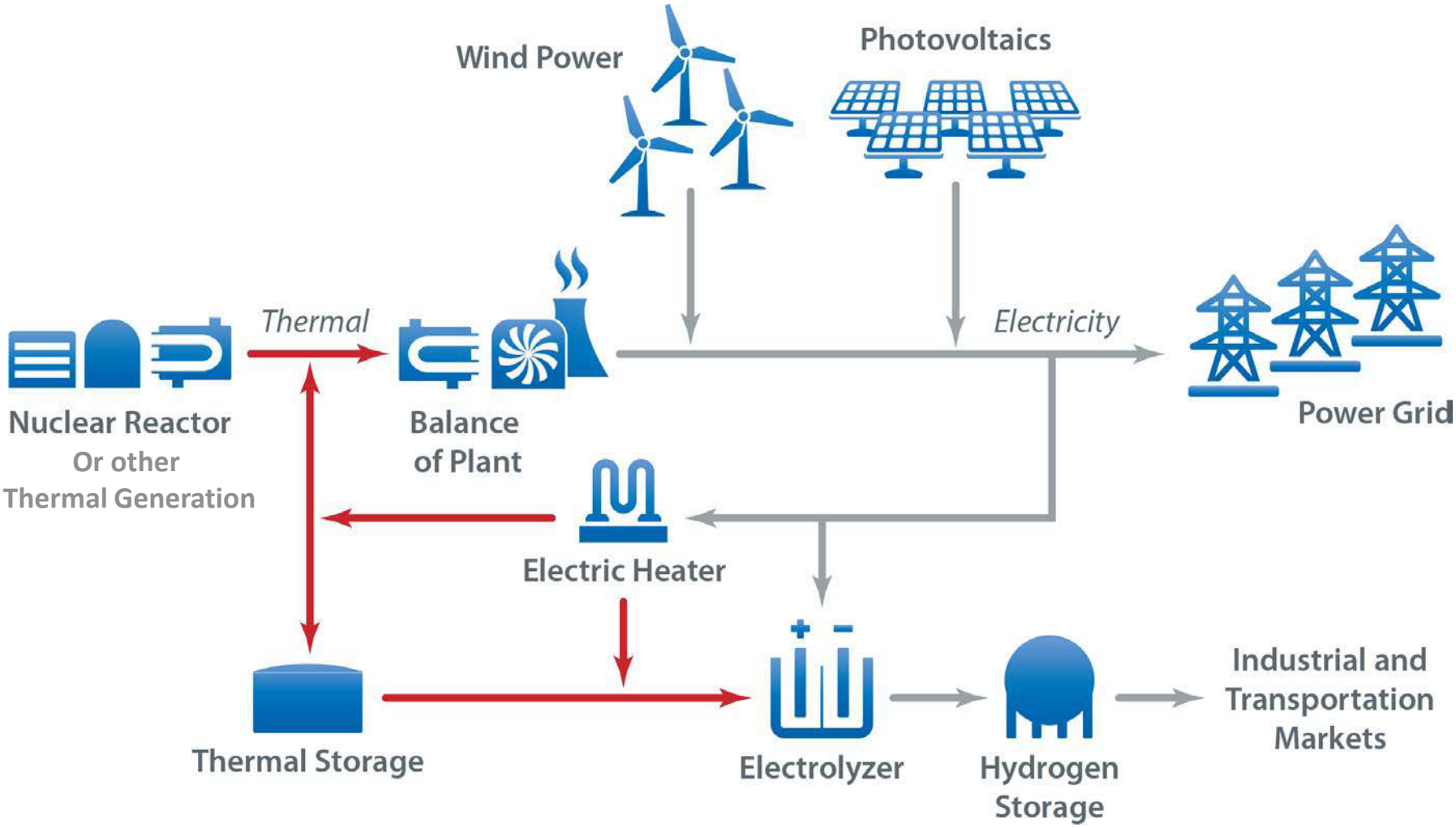


Source: encoord

Hydrogen @ Scale



Renewable Hybrid Energy Solutions



Sources: Ruth et al. 2016; Bragg-Sitton et al. 2016

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Started with a Workshop Series

Co-Sponsored with IEA Gas & Oil Technology Programme

Workshop 1: Nexus of Oil & Gas and Renewables in the Energy Future, NREL, Sept 2017

Keynote: Colorado Governor John Hickenlooper

Purpose: Explore how the renewable energy industry and oil & gas industry can work together for a clean energy future

Key Topics:

1. Renewable energy for oil and gas operations
2. Efficient use of process heat and water
3. Gas and renewable energy for utilities
4. Industry investment in renewable energy

Workshop 2: Brussels, Belgium (October 2018)

www.gotcp.net/17-09-golden




Clean Energy for Oil & Gas Consortium

JISEA established a collaborative program for the identification, development, modeling & analysis, and demonstration of clean power for oil and gas operations. The program will:

- Support the identification, development, and adaptation of **highly reliable, cost-effective clean energy solutions** for oil and gas operations
- Perform techno-economic analysis and **site-specific optimization** of combinations of renewable and conventional generation, storage, and energy conservation
- With industry partners, **demonstrate the most promising technologies** for validation of performance in a variety of field environments, while analyzing optimization scenarios.

Value Proposition

Demonstrate reliable, affordable, clean power for oil & gas operations.

- **Reduce risk to operations**
- **Collaboratively identify 'best practices' to reduce cost**
- **Access to unique, world class capabilities**
- **Leverage research/testing dollars**

Program Approach

Phase 1:

Identify potentially highly reliable, cost-effective clean energy solutions for priority energy needs of oil and gas operations

Analyze and model site- and technology-specific solutions considering: Innovation, Performance, Costs/Savings, Deployment Potential, Project Value, Technical Risk, Business Viability

Phase 2:

Objectively evaluate real-world performance in a variety of field environments to determine return on investment and impact on environmental and social license.

Prepare analysis results to inform decisions on technologies with broad deployment potential

Phase 1: Site Evaluation

- Potential site selection for renewable integration and comparative analysis of sites using REopt™
- Assessment of clean technology requirements and identification of technologies
- Geospatial resource analysis of sites for appropriate clean technological applications.

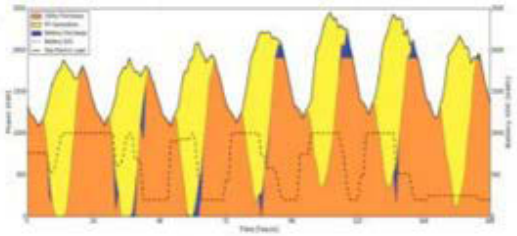
REopt: Decision Support Throughout the Energy Planning Process

Optimization • Integration • Automation

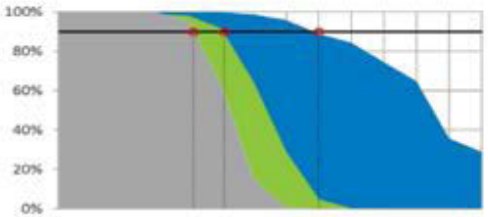
REopt:
https://reopt.nrel.gov

Master Planning	Economic Dispatch	Resiliency Analysis
• Portfolio prioritization • Cost to meet goals	• Technology types & sizes • Optimal operating strategies	• Microgrid dispatch • Energy security evaluation

Cost-effective RE at Army bases



Cost-optimal Operating Strategy



Extending Resiliency with RE

Analysis Overview

- Two case studies being done using publicly available data and assumptions:
  - Refinery in Louisiana
  - Well site in Pennsylvania's Marcellus Shale
- Preliminary analysis evaluates the opportunity for solar photovoltaics, wind turbines, and/or a battery energy storage system (BESS)
- Future iteration of analysis will consider the opportunity for thermal energy technologies, such as solar steam, biogas, electrification of thermal processes, energy efficiency measures, and/or carbon capture and sequestration (CCS)
- Convening a consortium of industry to obtain load and generation data and evaluate these clean energy technologies at actual oil and gas sites.

Current members:

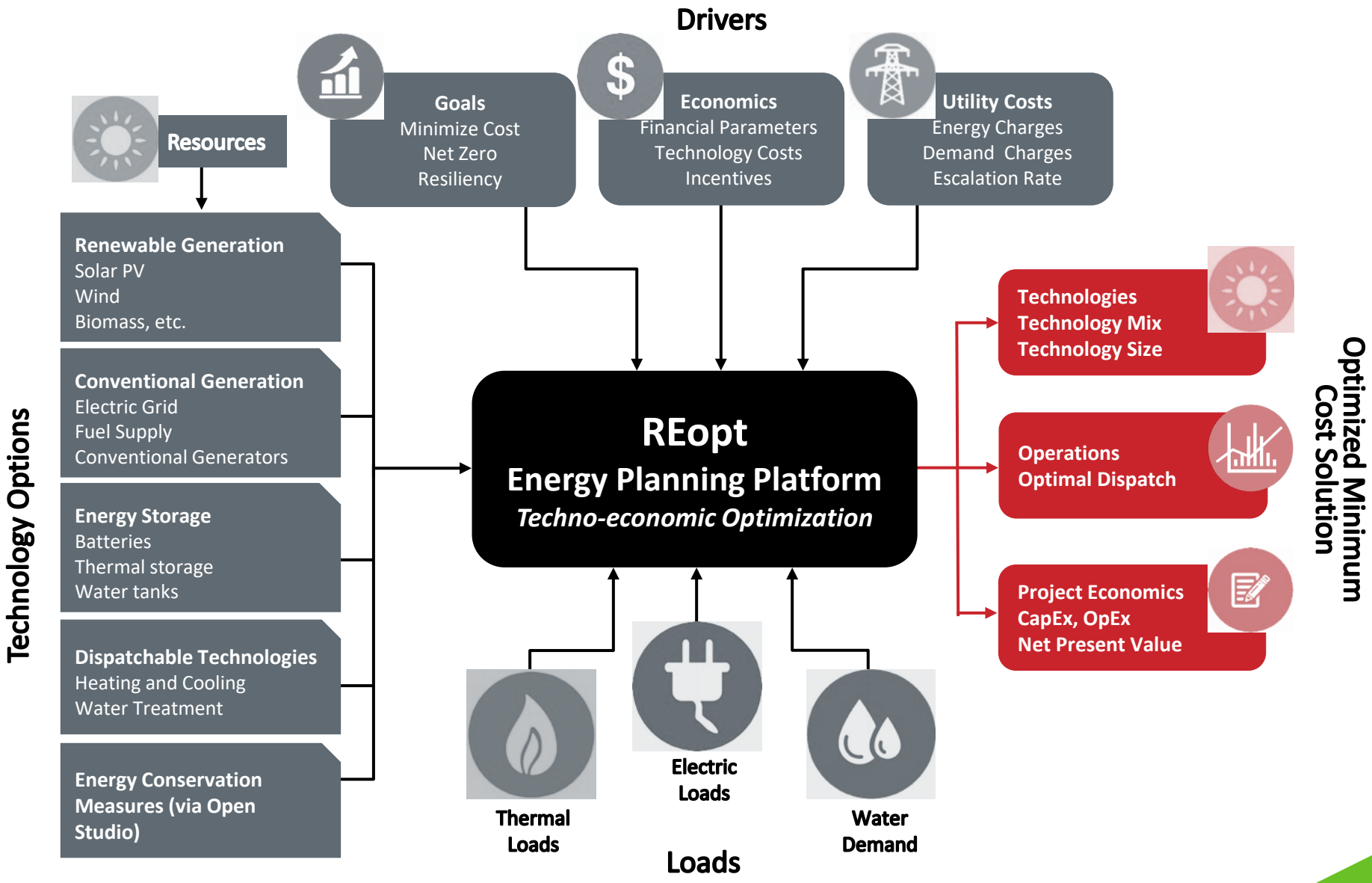
- Baker Hughes
- Conoco Phillips
- Extraction Oil and Gas
- INGAA Foundation

Consortium planning site analysis at:

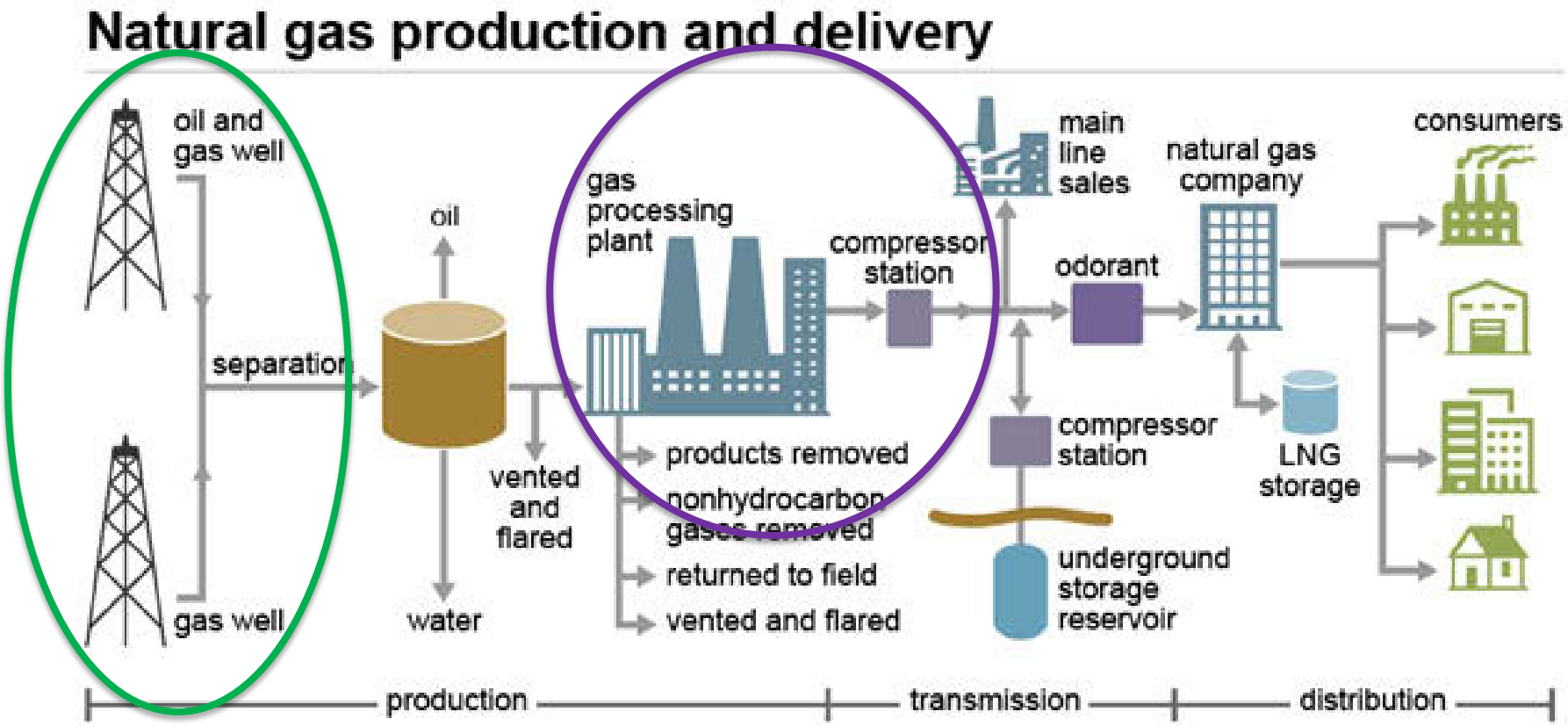
Offgrid upstream Western U.S. site

Mid-stream pipeline/compressor station

REopt Model Overview



Data (+ Gaps) for Natural Gas Operations



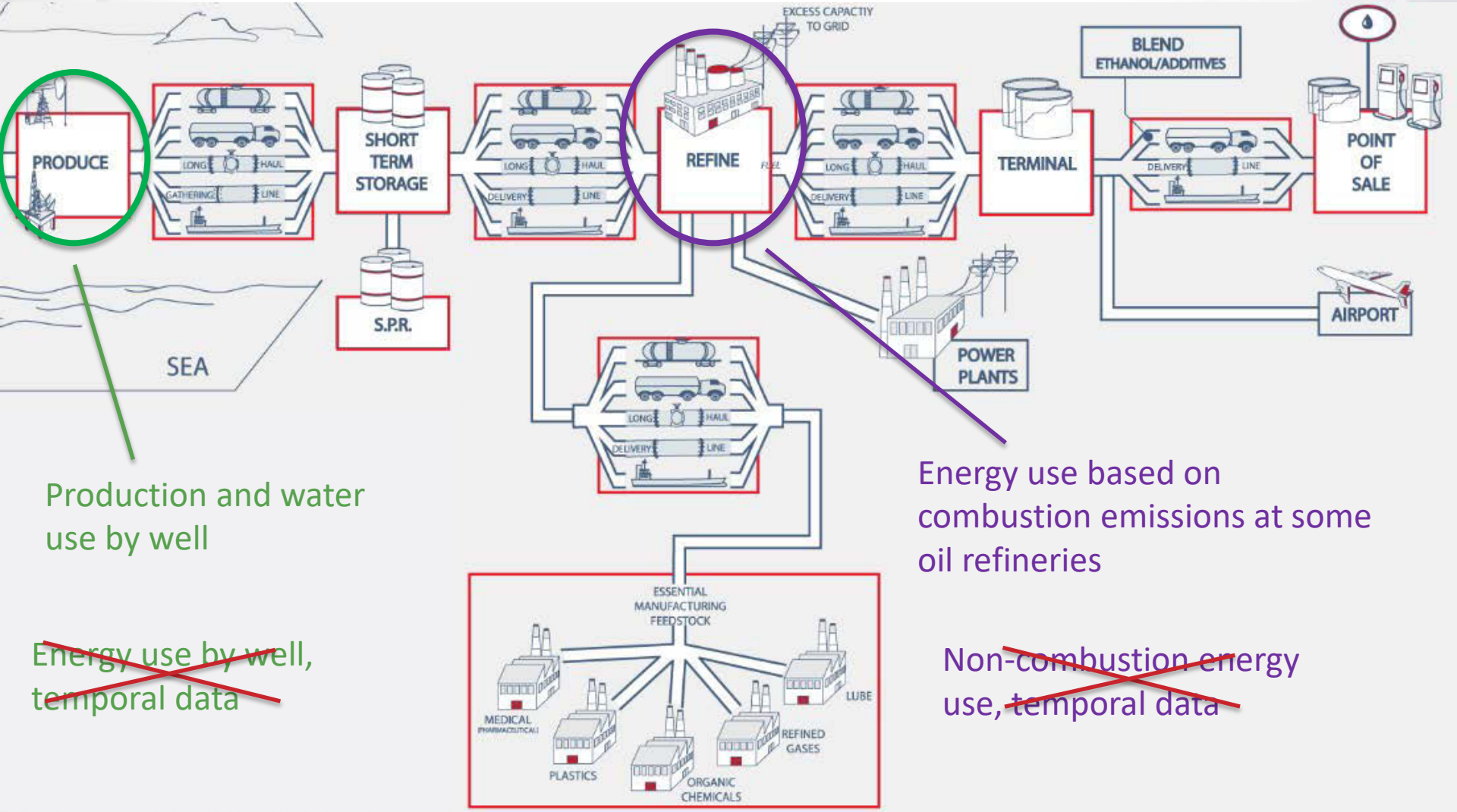
Production and water use by well

~~Energy use by well, temporal data~~

Energy use based on combustion emissions at some gas processing plants and compressor stations

~~Non-combustion energy use, temporal data~~

Data (+ Gaps) for Oil Operations



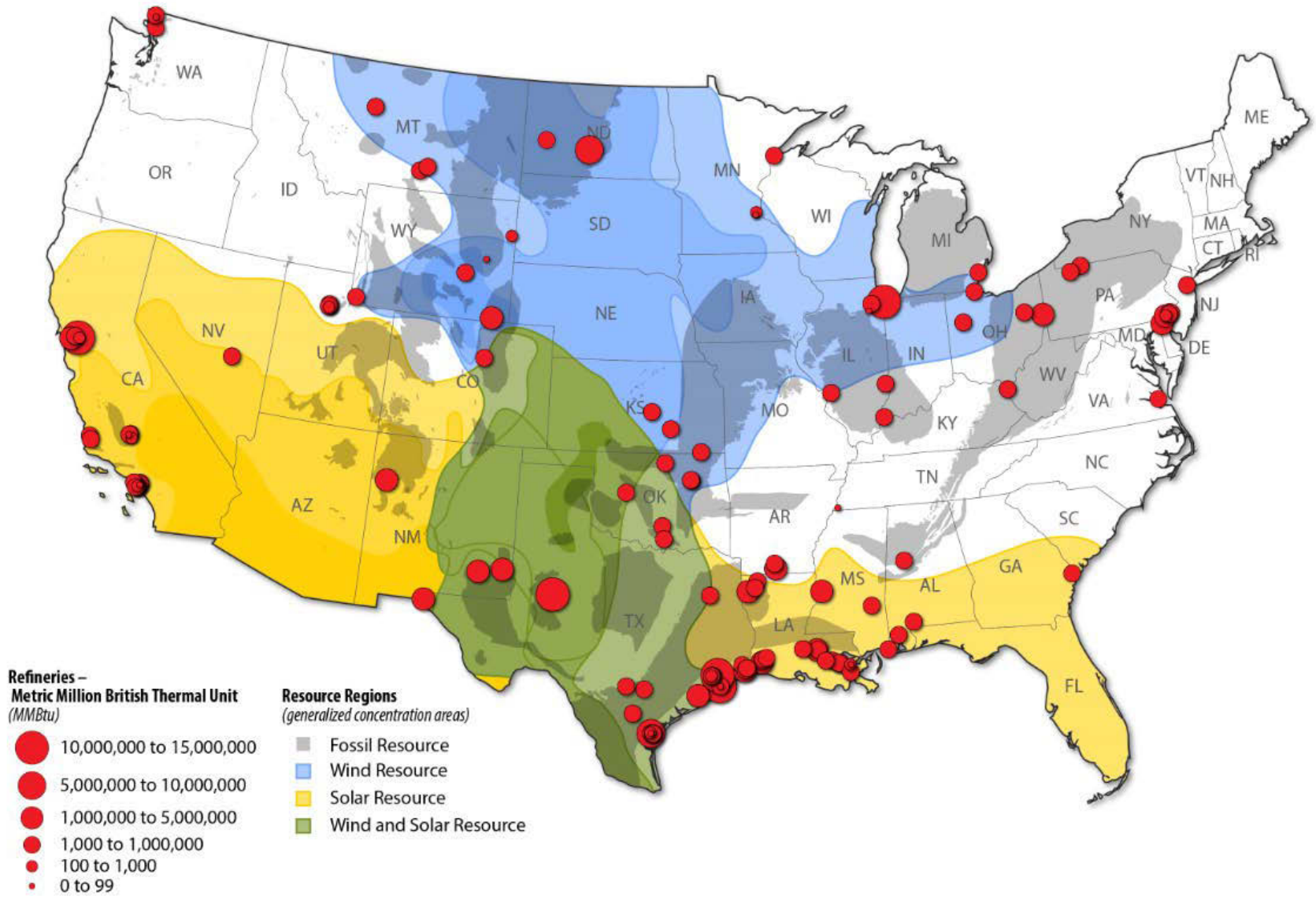
Production and water use by well

~~Energy use by well, temporal data~~

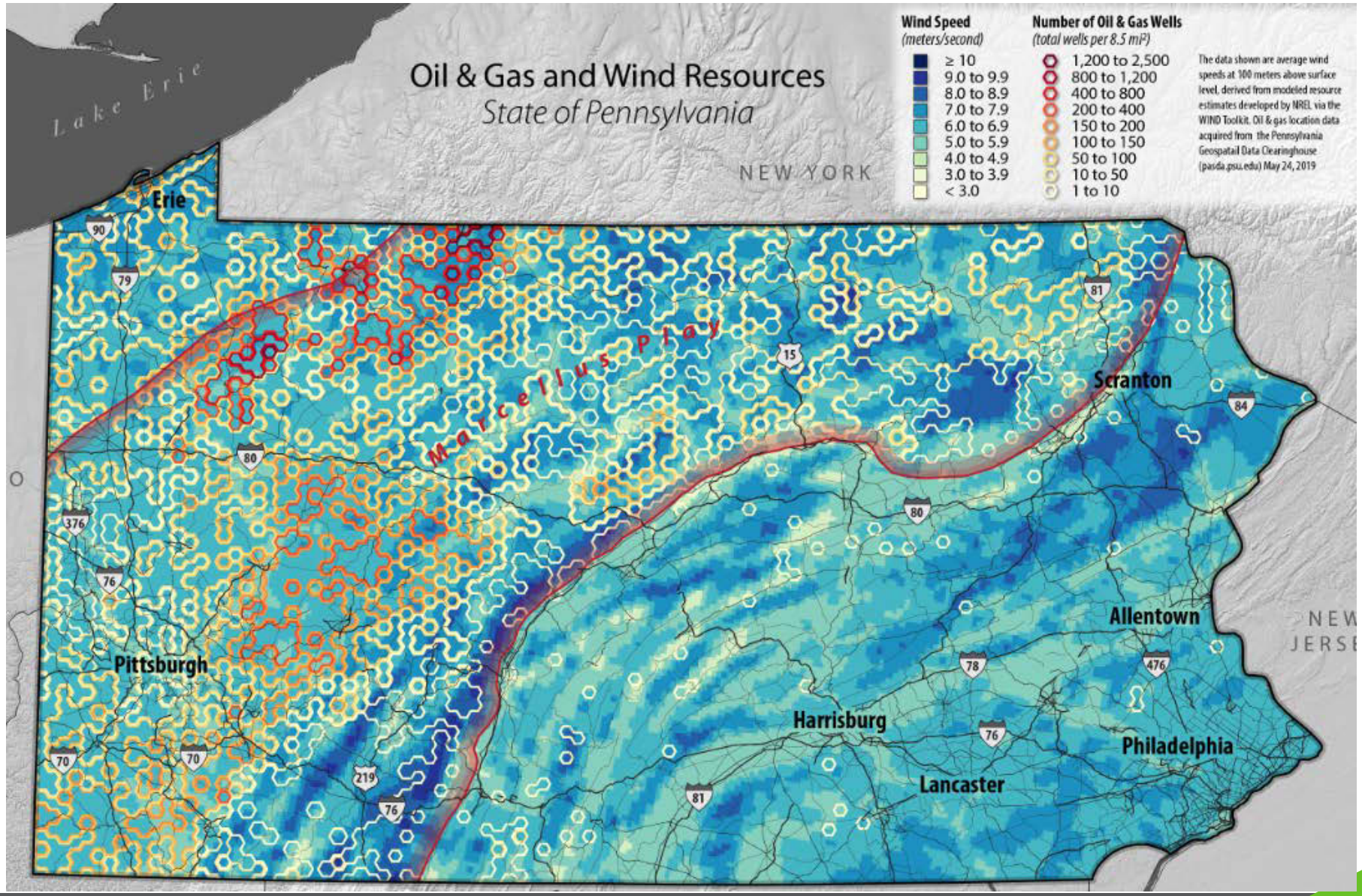
Energy use based on combustion emissions at some oil refineries

~~Non-combustion energy use, temporal data~~

Many refineries may have great wind AND solar resources



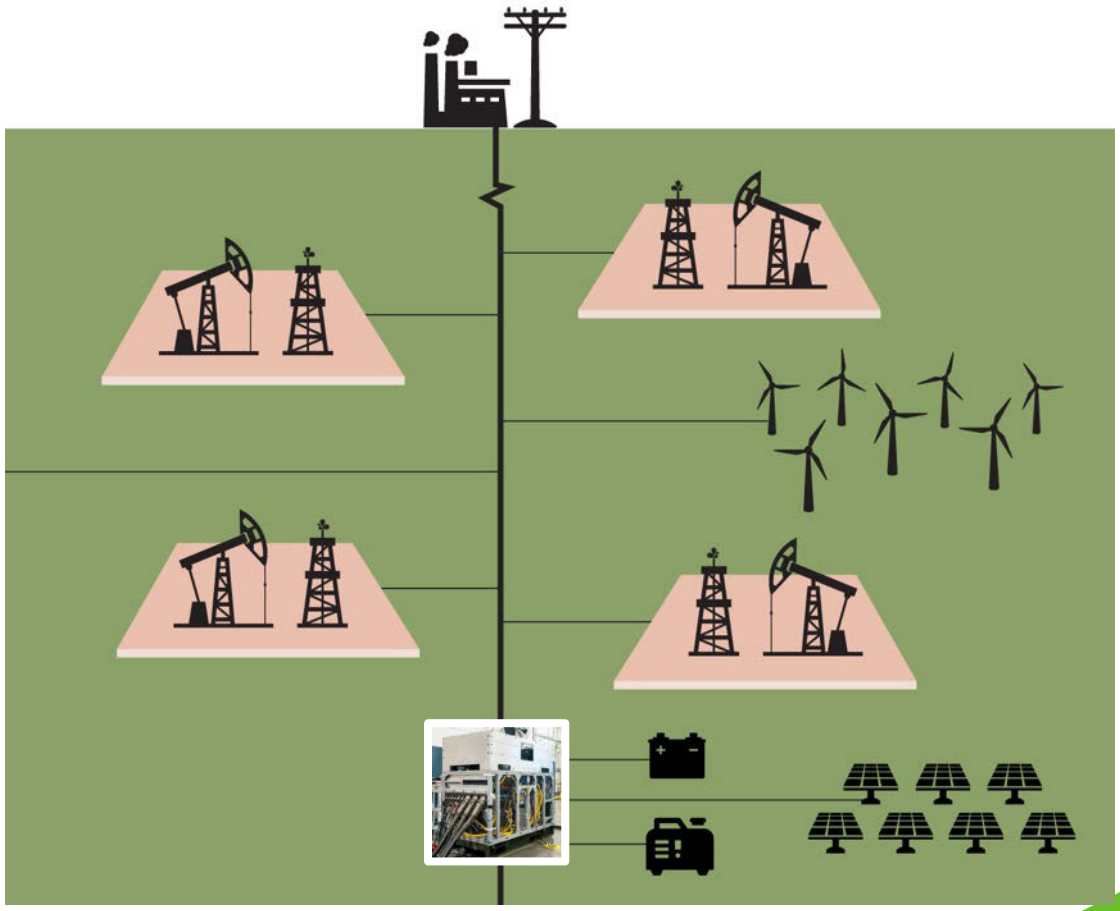
Marcellus Play: some wells near good wind resources (dark blue)



Example Onshore Power Solution: 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

Opportunities for Collaboration: Design of complete system, technology evaluation & selection, "utility in a cube" technology



Example Offshore Power Solution: Offshore Wind for Platform Power & Water Injection

- Electricity from the turbine is used to power pumps, treatment, and injection
- Integrated with microgrid and energy storage
- Feasibility study by DNV-GL shows that the system has higher operational costs but lower capital expenditure that over a 20-year life-cycle is competitive with alternatives

Opportunities for Collaboration: Grid design & system modeling, wind turbine evaluation & selection, operational modeling

Source: https://www.dnvgl.com/energy/feature-articles/win-win-wind-powered-water-injection.html

Example Thermal Solution: Enhanced Oil Recovery using Concentrating Solar Power (CSP)

Miraah

Customer: **Petroleum Development Oman**
Location: **Amal, Oman**
Status: **Under construction**
Energy Production: **1,021 MW thermal (1 GW)**

Opportunities for Collaboration: Modeling of operations, technology design optimization, and technoeconomic site analysis

Miraah CSP system designed to:

- Produce 6,000 tons of solar steam each day for thermal EOR operations.
- Save 5.6 trillion Btus of natural gas each year.
- Reduce CO2 emissions by more than 300,000 tons each year.

http://www.glasspoint.com/markets/projects/

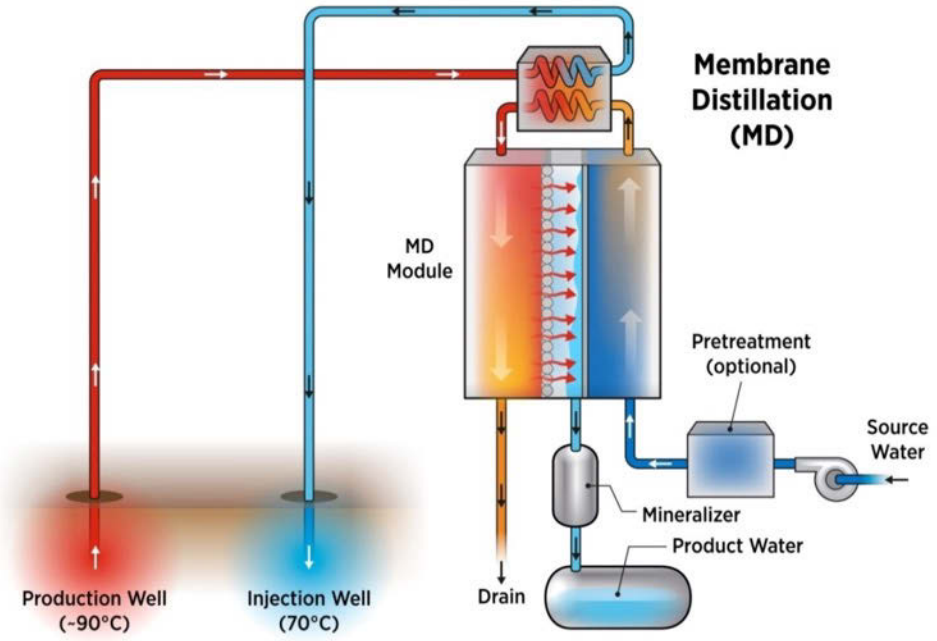
Example Thermal Solution: Geothermal-powered Desalination Technologies

NREL is working to develop desalination technologies with geothermal

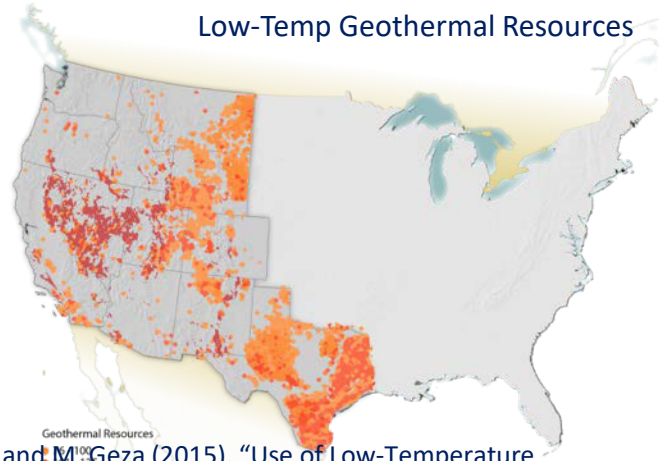
- Partnership with Colorado School of Mines
- Pilot plant development in the U.S. Southwest
- Development of a geothermal desalination decision support tool

Key research benefits include:

- ✓ Access to and development of data on cutting-edge RD&D in brackish water desalination technology
- ✓ Demonstration pilot
- ✓ Decision support tool to identify promising new locations



Low-Temp Geothermal Resources



Membrane Distillation has advantages for renewable energy integration:

- Uses low-temp (< 90ºC) thermal energy
- Suitable for high-salinity, poor-quality source water
- Compatible with sensible heat transfer
- Amenable to small-scale units
- Potentially low-cost membranes

Turchi, C., Akar, S., Cath, T., Vanneste, J., and M. Geza (2015). "Use of Low-Temperature Geothermal Energy for Desalination in the Western United States." NREL/TP-5500-65277

Phase 2: Technology Evaluation

- 3-5 year program with 3-9 month test periods per technology
- Techno-economic analysis, highlighting economic benefit
- System engineering, design, and field testing with partners and vendors
- Publication and sharing of generalizable results

Systems Engineering

Cost of Energy

Capital Costs (CapEx)	Balance of System Capital Cost (CapEx)	Finance	Operation and Maintenance (OpEx)	Net Annual Energy Production (AEP_{net})
NREL Cost and Scaling Model (CSM) • Model based on empirical relationships and scaling equations •Data from developers, renewable industry stakeholders, and literature reviews	**NREL Balance of System (BOS) Model** •Model based on empirical relationships and scaling equations •Data from developers, renewable industry stakeholders, and literature reviews	**NREL Cost of Energy Review** •Fixed charge rate •Discount rate (weighted average cost of capital [WACC]) •Economic operational life •Effective tax rate •Present value of depreciation	**NREL Cost of Energy Review** •Informed by DOE's Wind Vision study and input from industry stakeholders	**NREL Systems Advisor Model (SAM)** •Idealized power curve •Simplified layout •Distribution for resource •Applies plant losses and availability

Summary of Renewable Energy for Oil & Gas Program

Value Proposition:

Demonstrate highly reliable, affordable, clean power for oil & gas operations.

Program Results:

Operational, financial, and environmental improvements within oil & gas operations

Governance:

Consortium of industry partners to leverage resources for benefit of those involved, supported and managed by JISEA.

Structure of Program:

- Phase I: Program design, analysis, and development
- Phase II: Multi-year program with 3-12 month technology pilot tests
- Periodic reporting and access to new technology

Current status and schedule:

Finalizing Phase I general analysis, starting specific site analysis

Four sponsors with additional partners and data sources welcome!




Thank you!

www.jisea.org

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