JISEA Joint Institute for Strategic Energy Analysis

A vision for the Hydrocarbon-Renewable Nexus: Synergies from a system integration perspective

IEA Gas and Oil Technology Collaboration Programme: Workshop on the role of the renewable and hydrocarbon nexus in accelerating the energy transition

Brussels, 11-12 October 2018

Jill Engel-Cox, Director, Joint Institute for Strategic Energy Analysis




NREL National Renewable Energy Laboratory
Colorado School of Mines
Colorado State University
MIT 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:

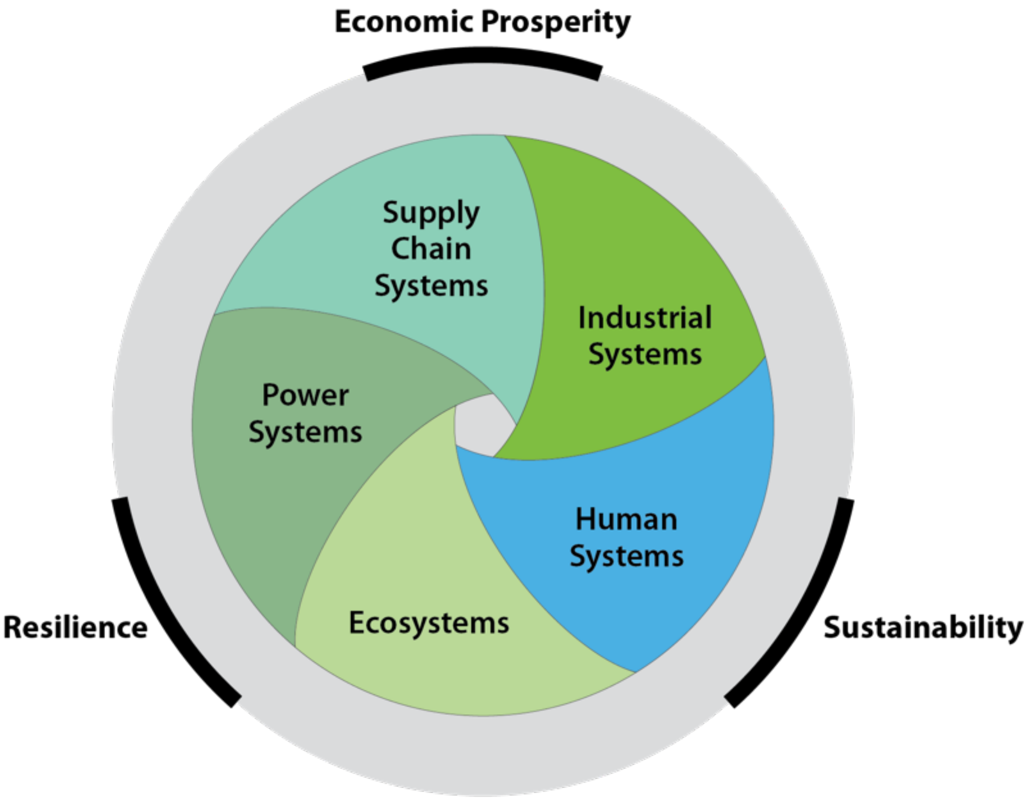
- 1800 employees, plus 400 postdoctoral researchers, interns, visiting professionals
- 327-acre campus in Golden, Colorado & 305-acre National Wind Technology Center 13 miles north
- 61 R&D 100 awards. More than 1000 scientific and technical materials published annually

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

Workshop Series with IEA GOT

IEA GAS & OIL TECHNOLOGY COLLABORATION PROGRAMME

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)

Workshop 3: Texas or California (Spring 2019)

www.gotcp.net/17-09-golden

Outline

- Energy Markets and Trends
- Clean Power for Oil and Gas Industry
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Renewable energy is diverse

WIND
Onshore

Offshore

SOLAR PV
Residential: 1-10 kW scale

Commercial: 1-20 MW

Utility: 50-1000 MW

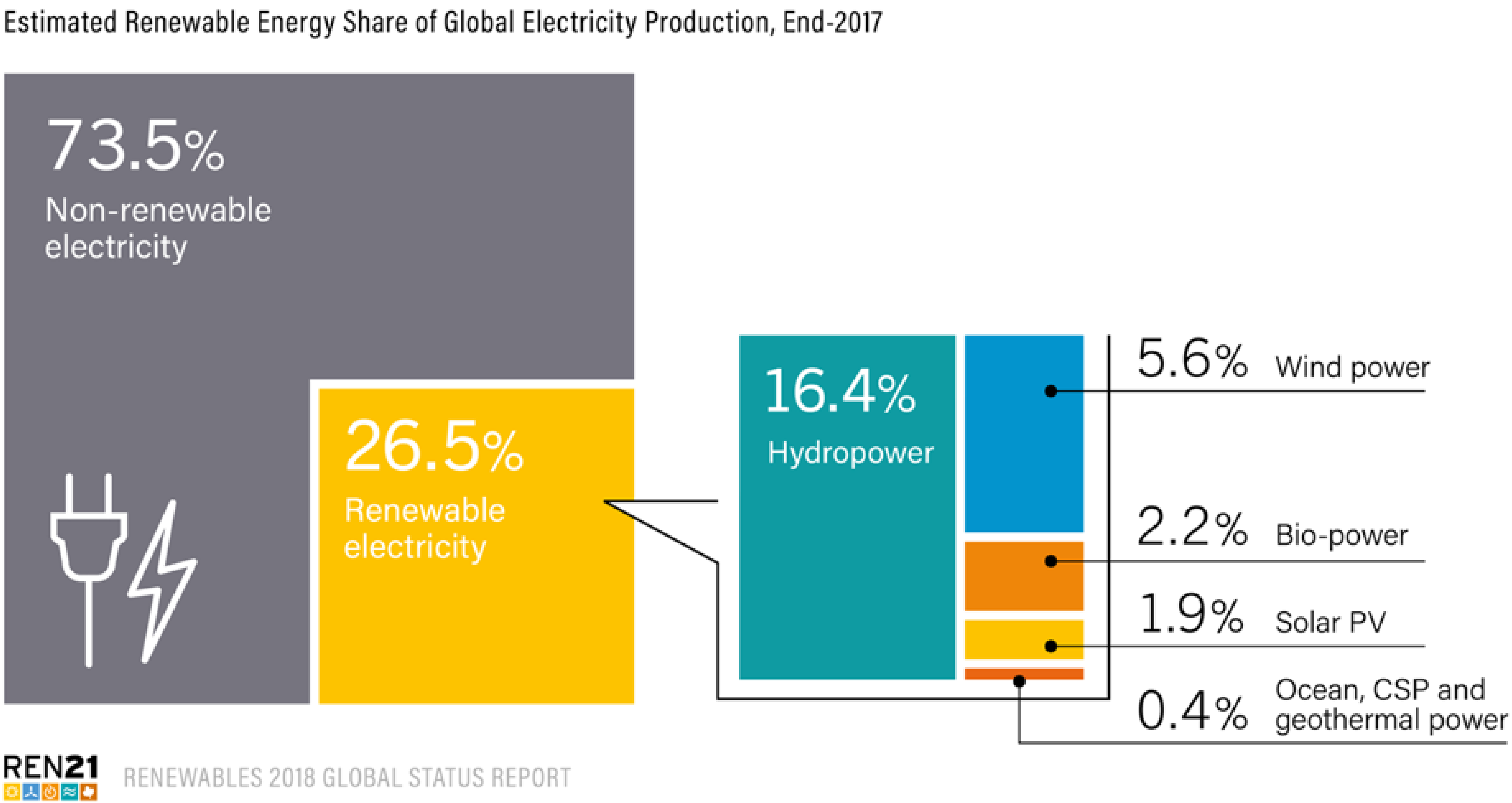
GEOTHERMAL

CONCENTRATING SOLAR

BIOMASS

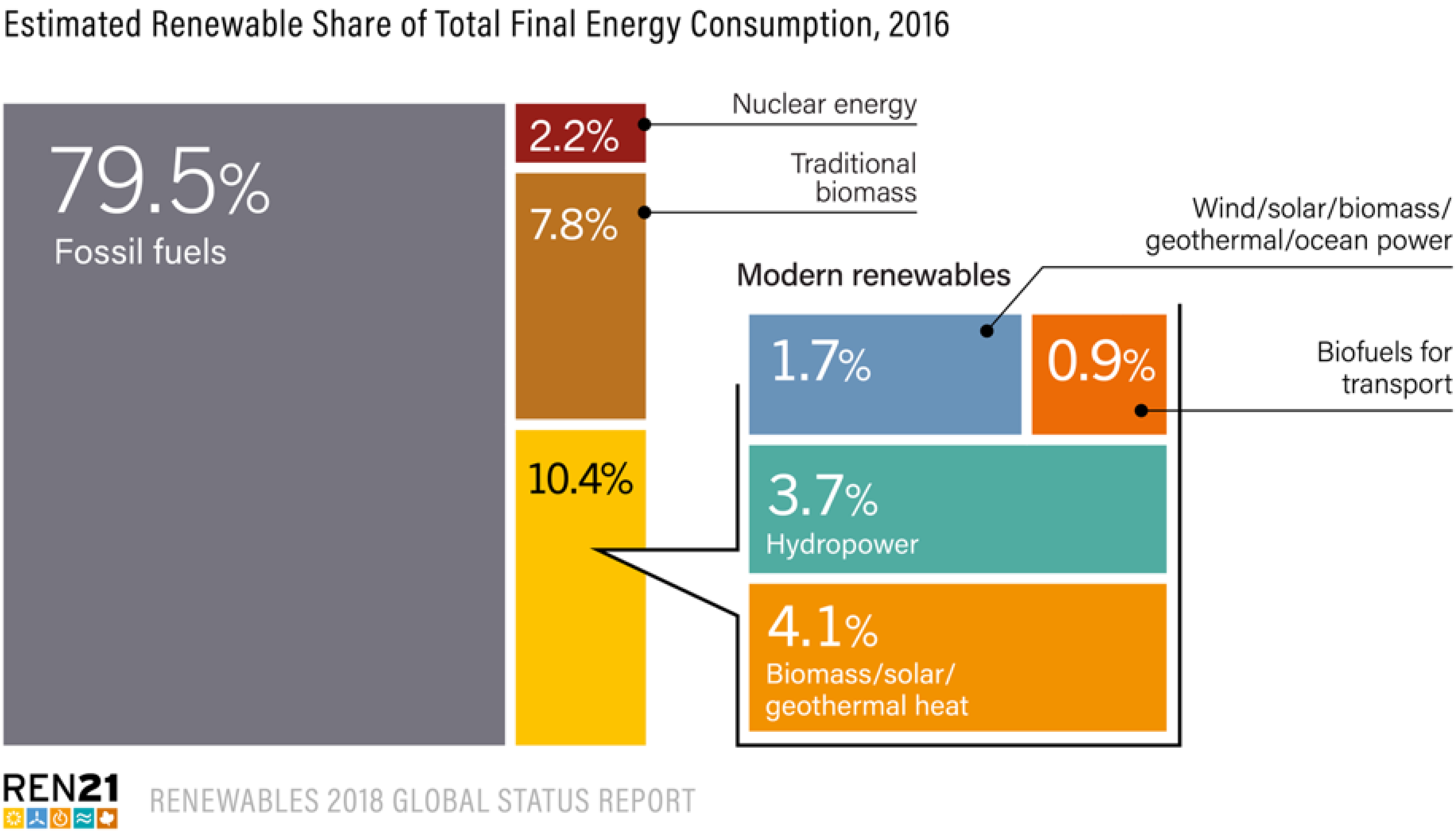
Images from https://images.nrel.gov/

Global growth of renewables in all sectors



Source: REN21 Renewables 2018 Global Status Report, http://www.ren21.net/gsr-2018/

Global growth of renewables in all sectors



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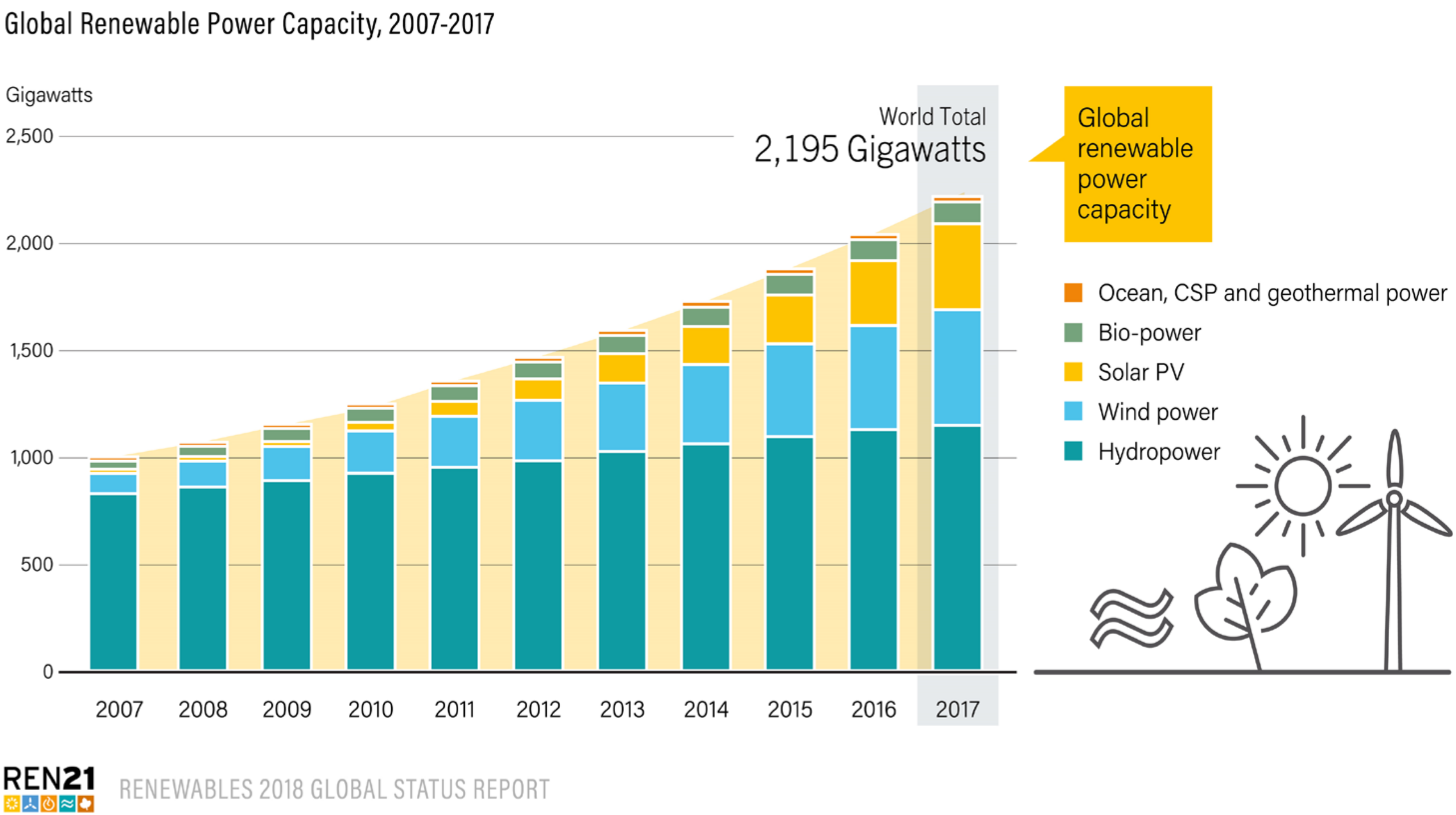
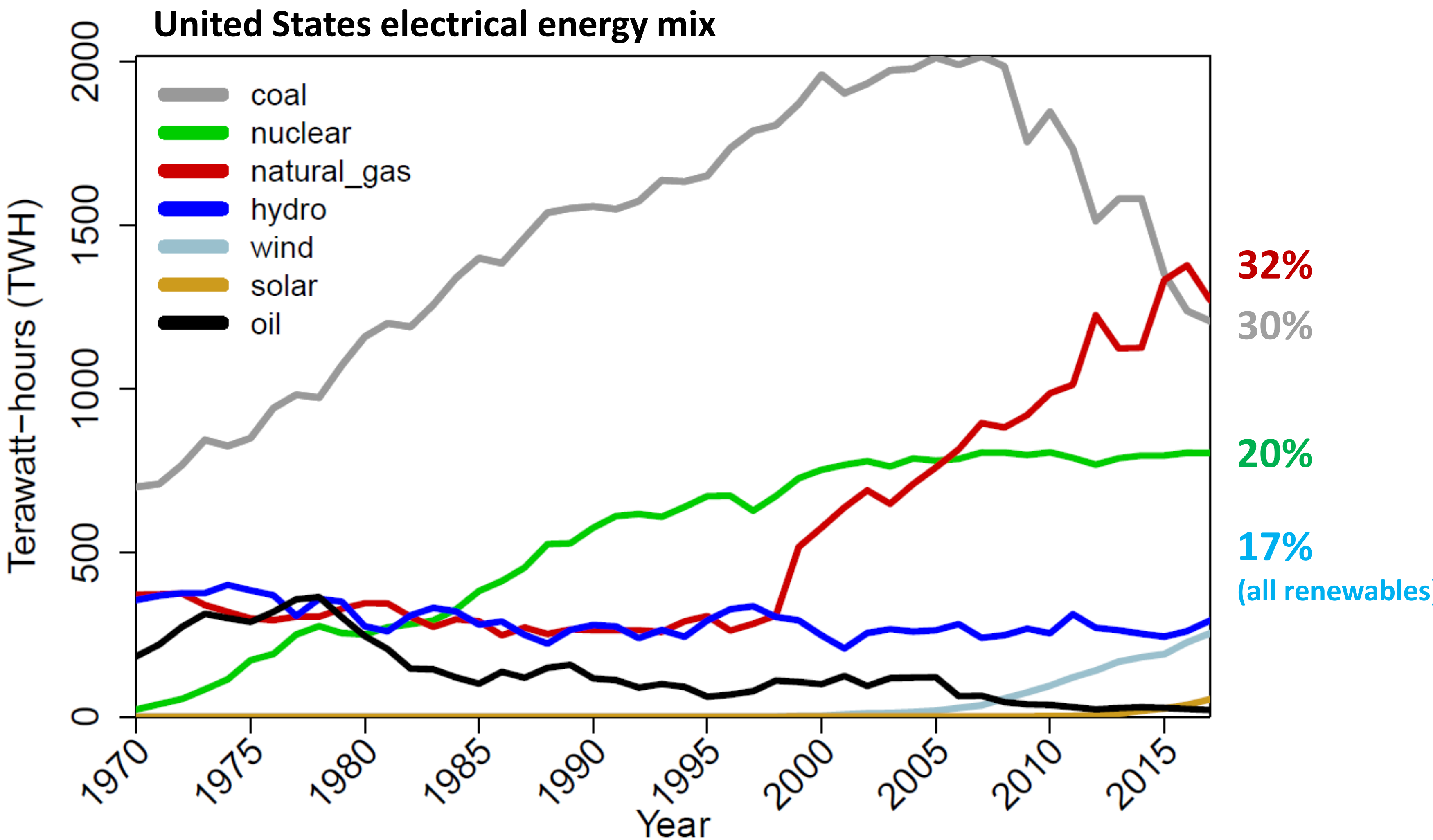


Source: REN21 Renewables 2018 Global Status Report, http://www.ren21.net/gsr-2018/

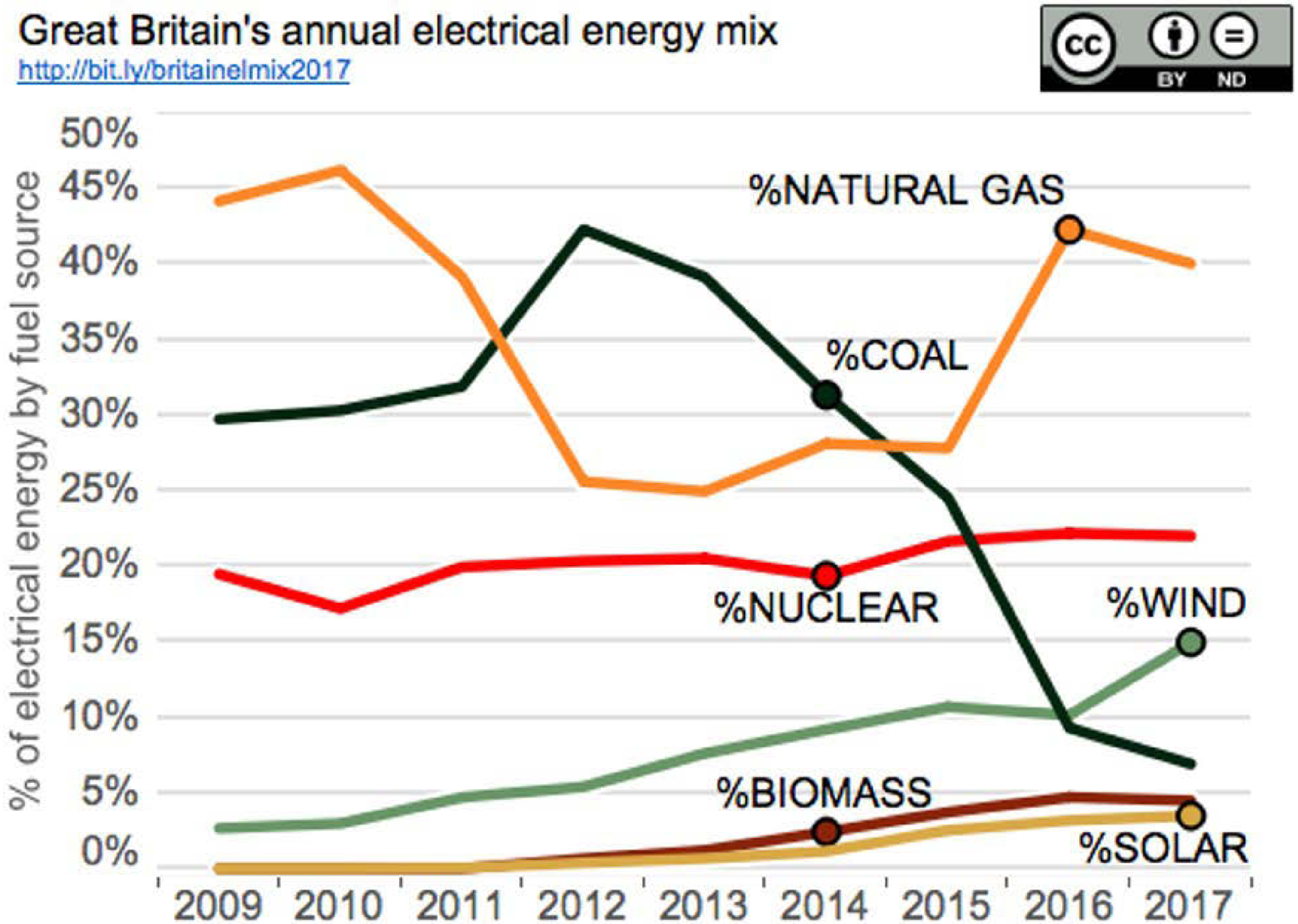
Electricity Trending to Gas and Renewables



Power sector is undergoing profound transformation, shifting from coal to natural gas and renewable power generation.

Source: EIA Electric Power Monthly and Form EIA-923.

Electricity Trending to Gas and Renewables



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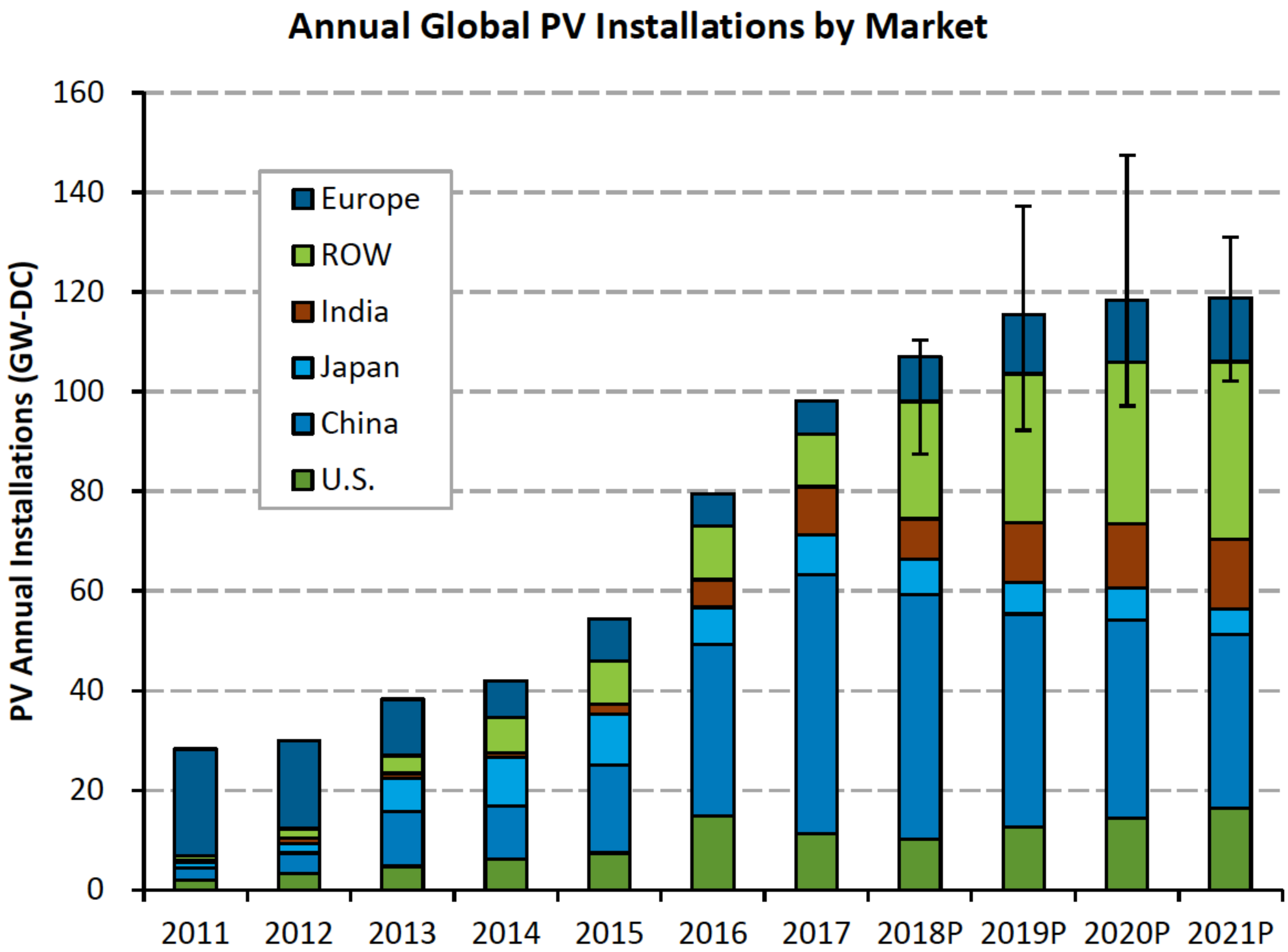
Source: Wilson, G. and I. Staffell, Winds of change: Britain now generates twice as much electricity from wind as coal, The Conversation, 5 Jan 2018, https://theconversation.com/winds-of-change-britain-now-generates-twice-as-much-electricity-from-wind-as-coal-89598.

Global PV market expected to grow



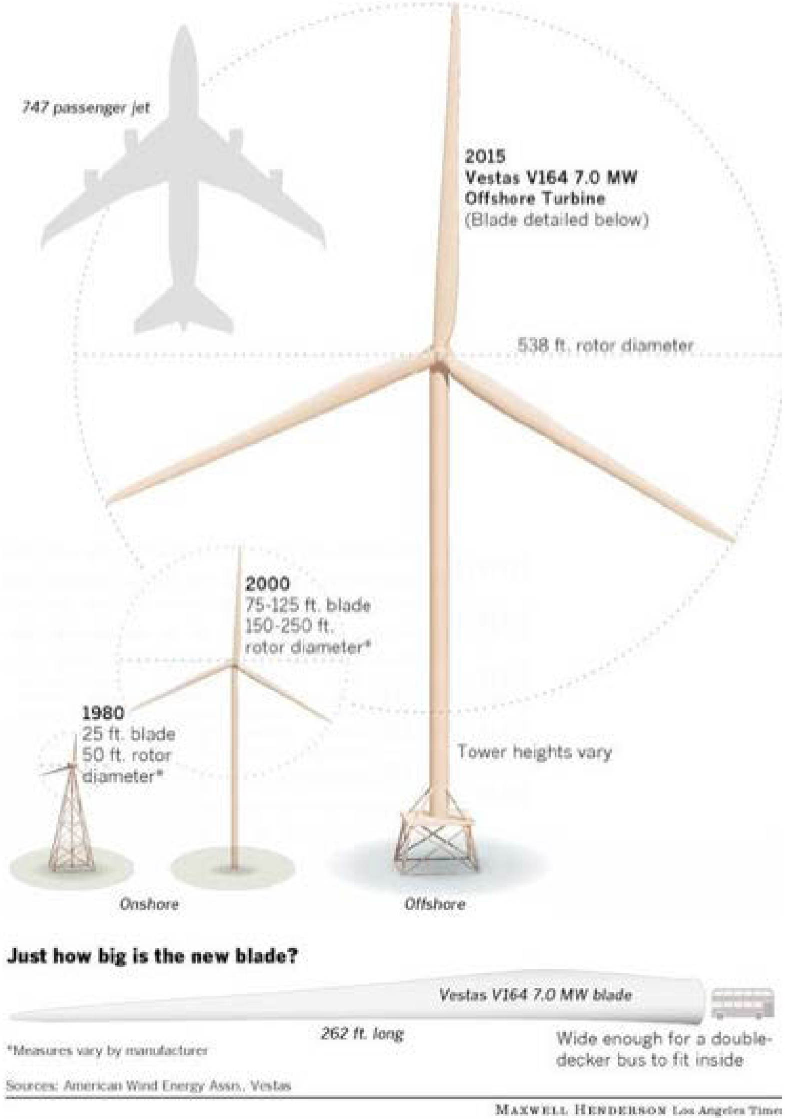
Source: NREL, Q4 2017/Q1 2018 Solar Industry Update, May 2018.

Wind Machines – Scale, Capacity Factor Increasing, Manufacturing Costs Declining

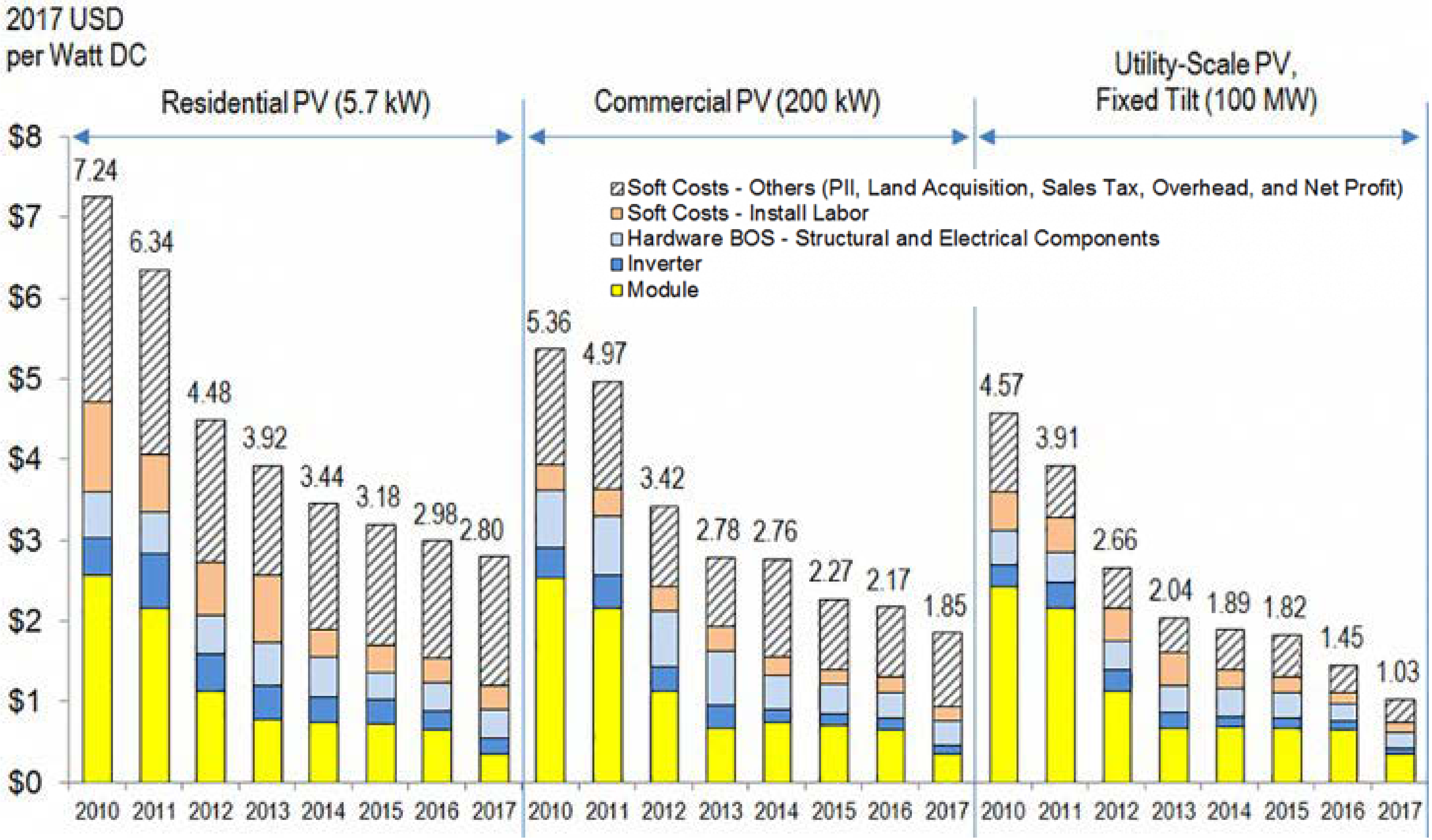
Avg. Wind Turbine Capacity Factors (% of time running) by Build Year

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%



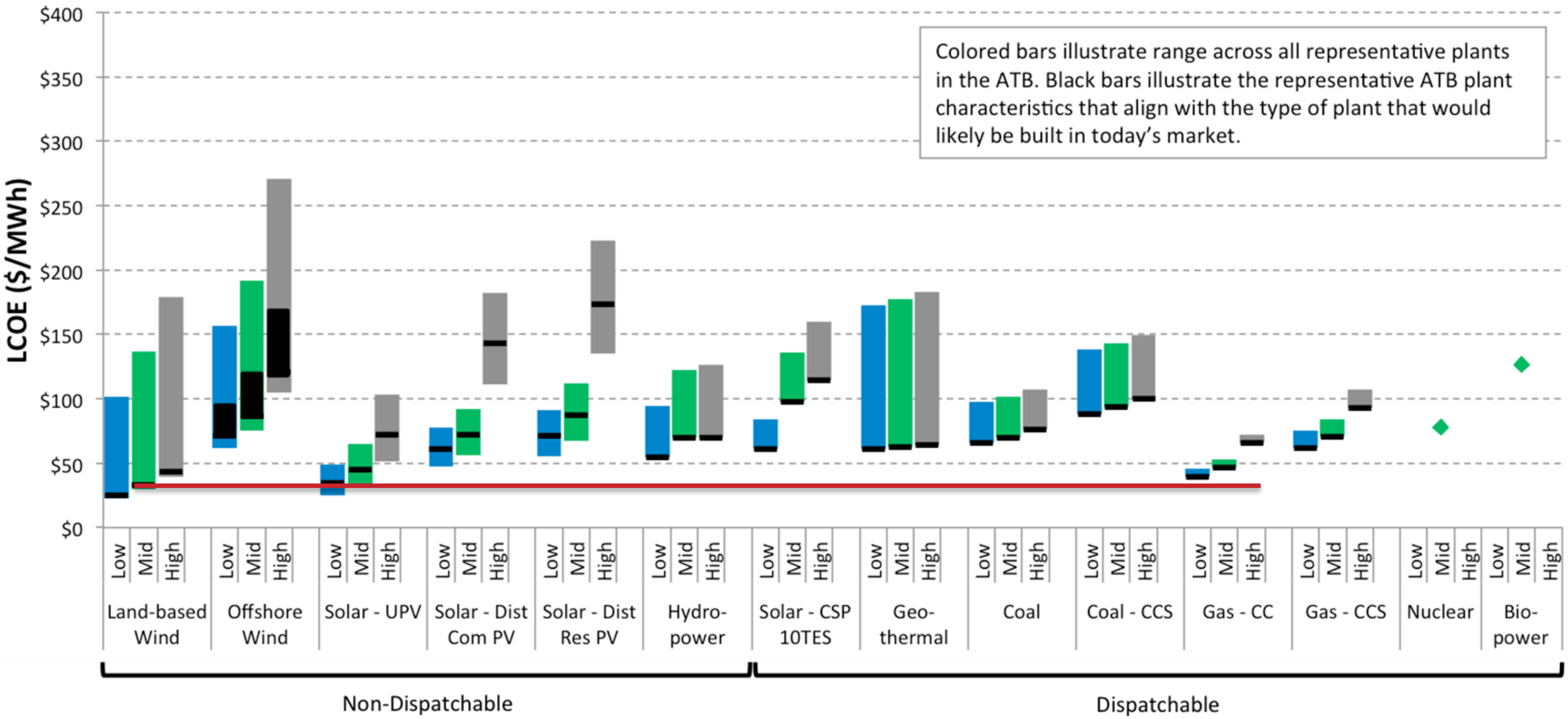
PV System Installation Prices



Source: NREL. The U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017, https://www.nrel.gov/news/press/2017/nrel-report-utility-scale-solar-pv-system-cost-fell-last-year.html

Cost of Renewable & Traditional Electricity Equalizing

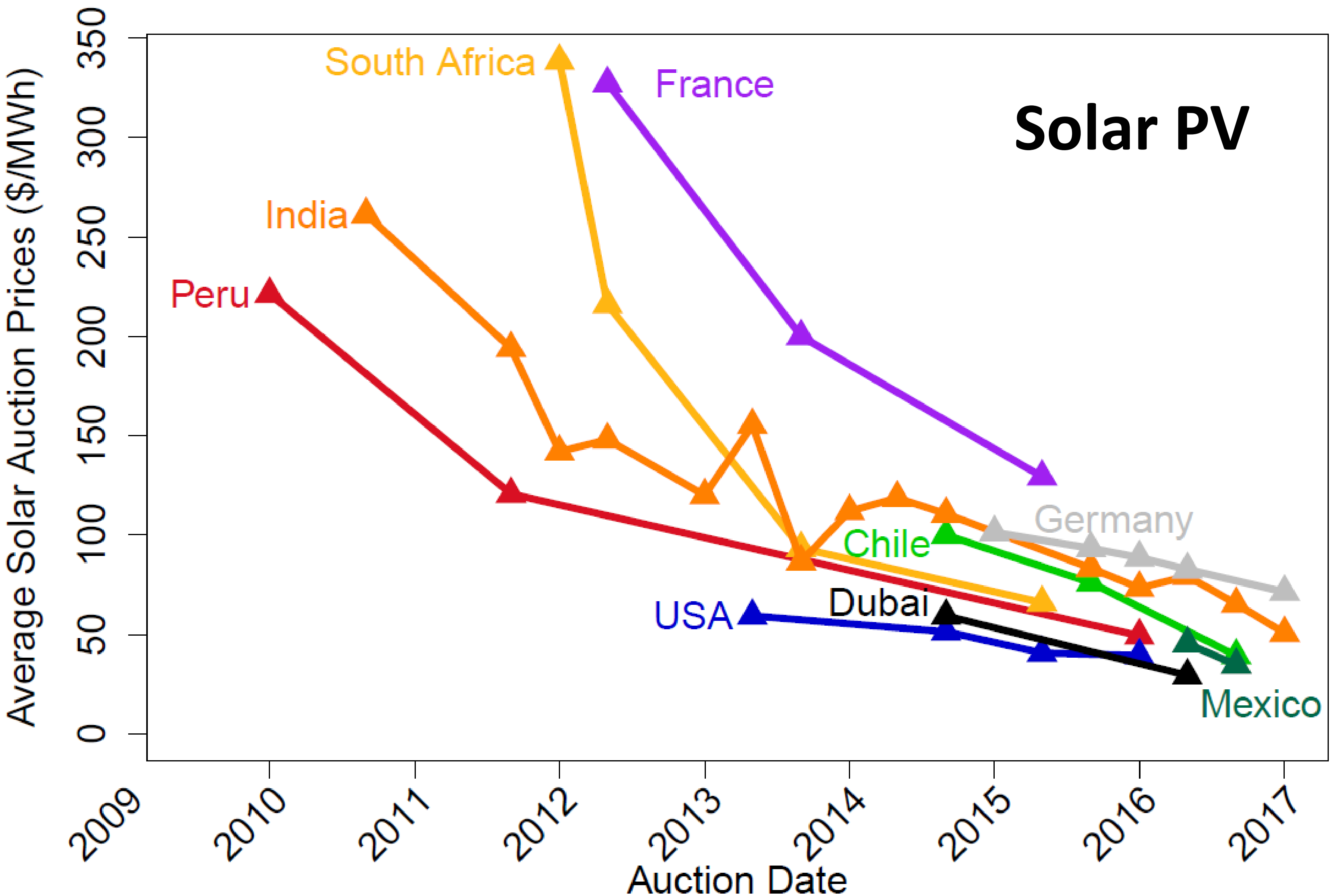
Levelized Cost of Electricity ranges by technology. Values are in 2015$.



2017 ATB LCOE range by technology for 2030 based on current market conditions
Source: National Renewable Energy Laboratory Annual Technology Baseline (2017), http://atb.nrel.gov

Variability due to: Technology; Location; Time (Present v. Future)

Cost of Renewable Electricity at Auctions Driving Decrease



Source: IRENA Renewable Energy Auctions: Analysing 2016 (2017)

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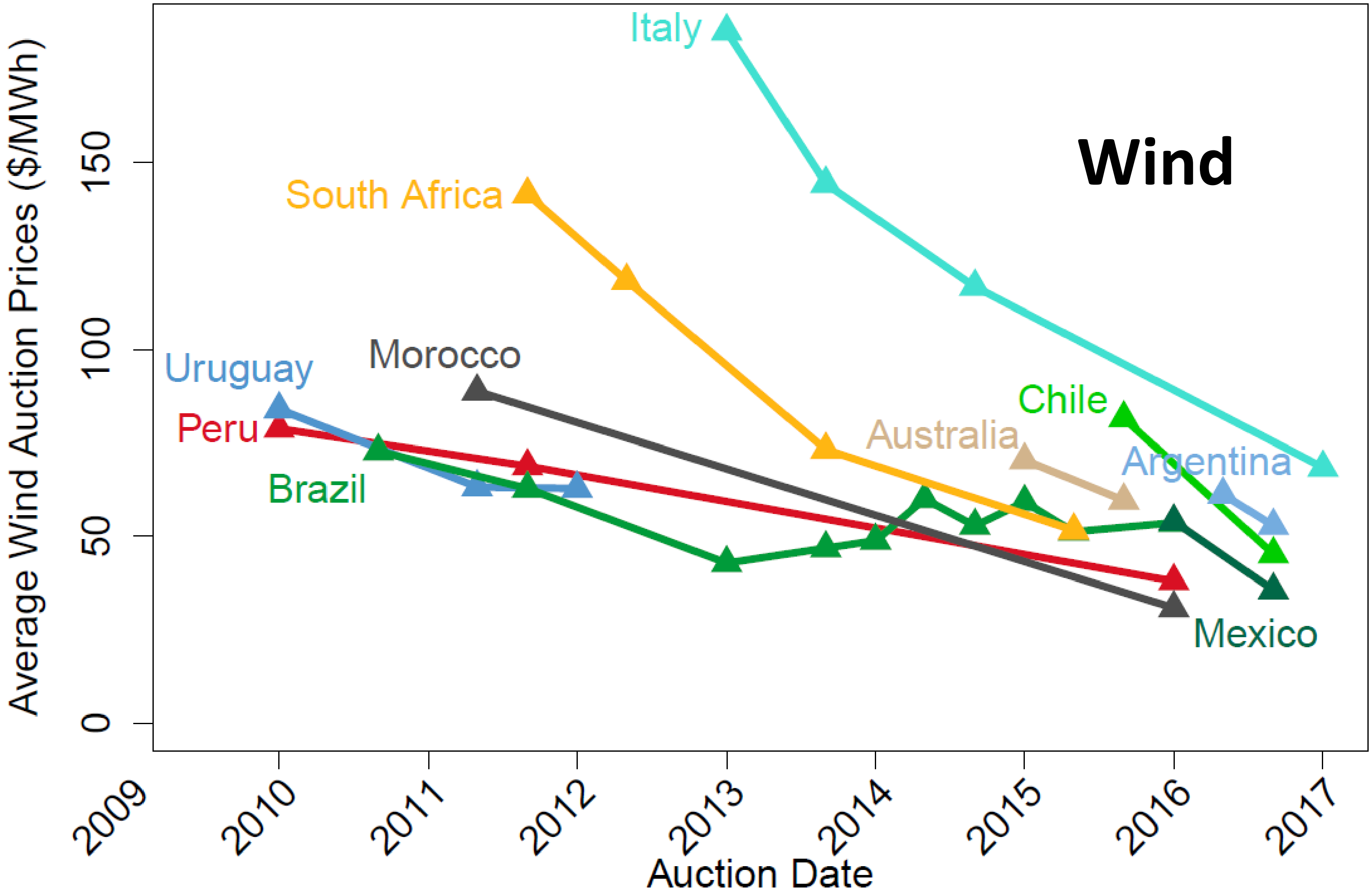

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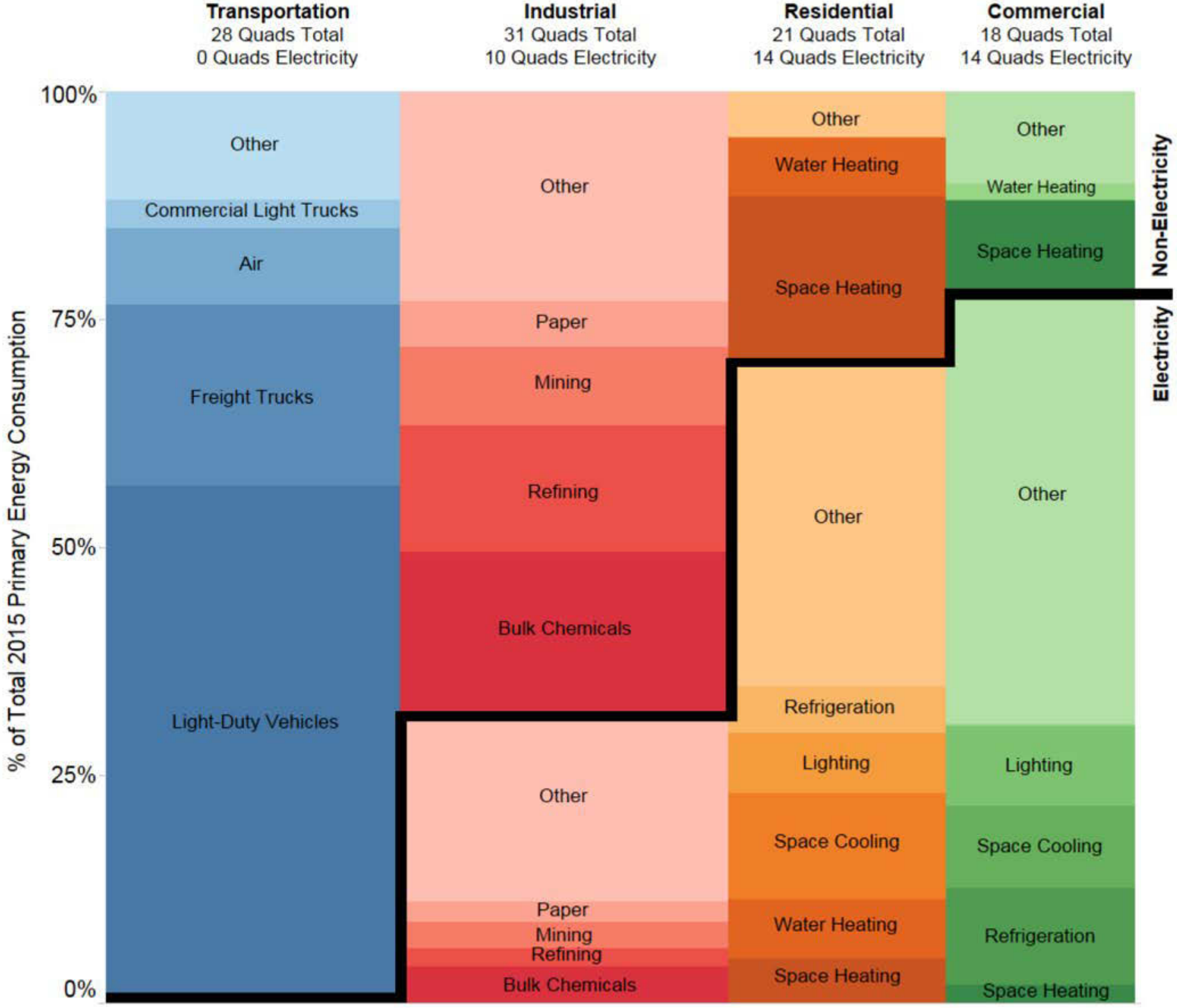
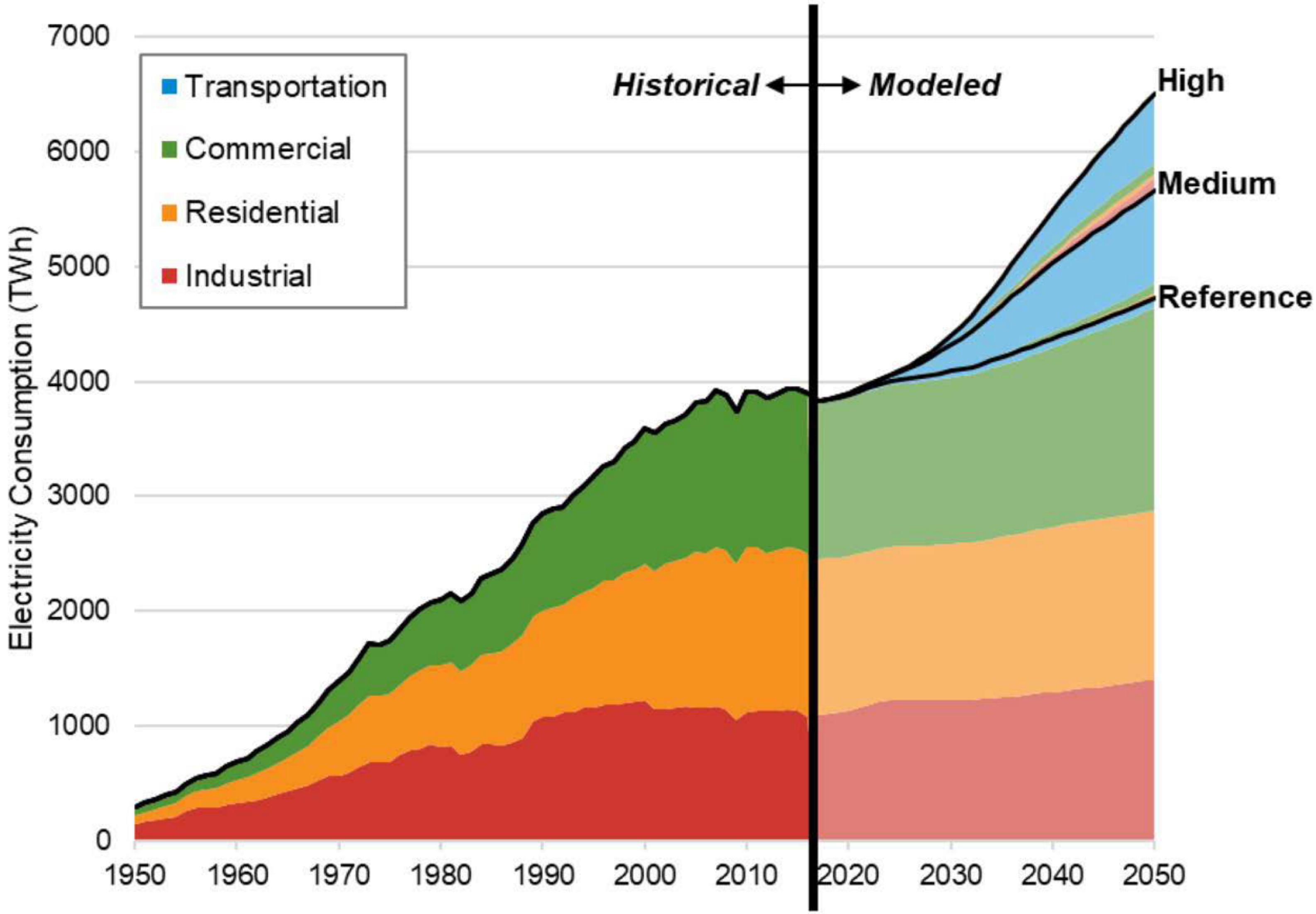
Electrification Futures Study



All Figures from NREL's Electrification Futures Study: www.nrel.gov/efs

Electrification Futures Study



All Figures from NREL's Electrification Futures Study: www.nrel.gov/efs

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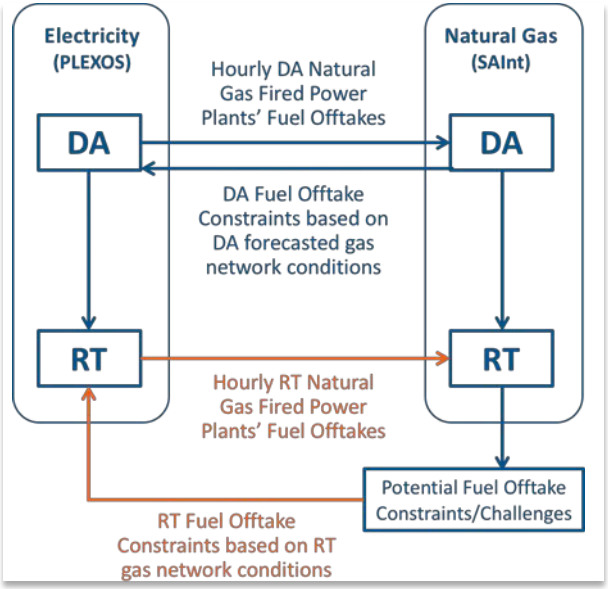
Electricity Generation: Electric-Natural Gas Interface Study

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:

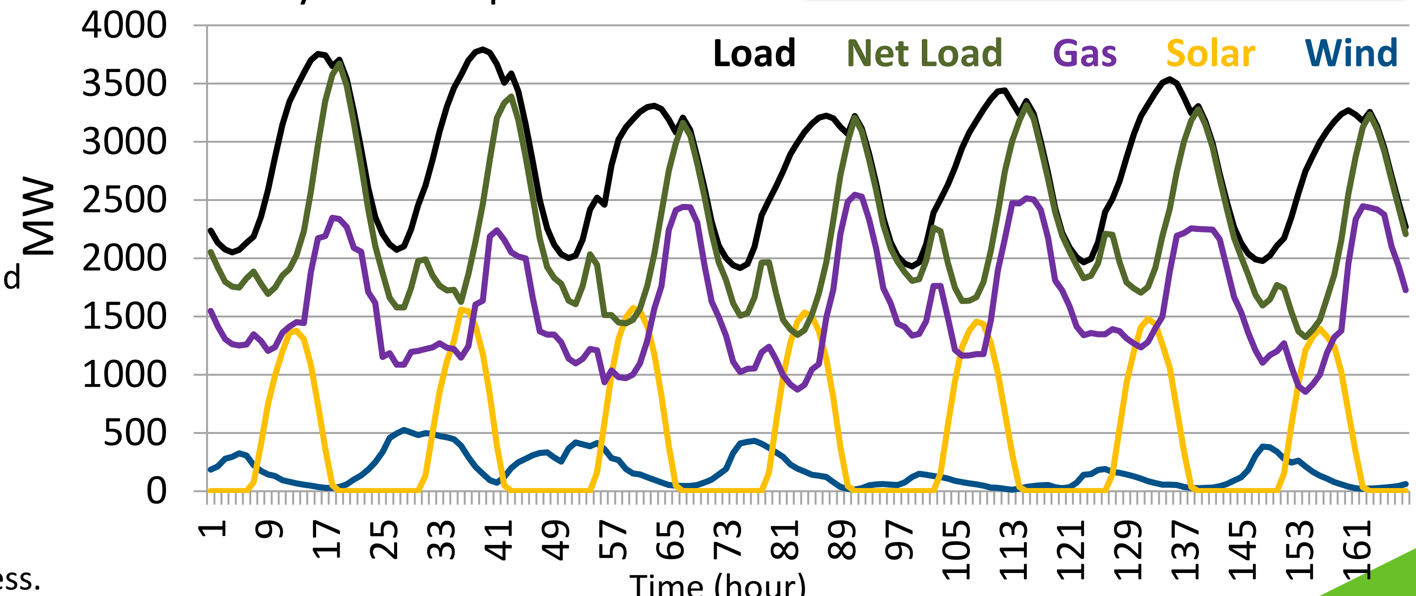
Co-simulate power and natural gas network operations.

Define an interconnected power and natural gas test system

Determine value of coordination of day-ahead 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.

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

Chevron/BrightSource Solar-to-Steam Demonstration Facility

- Location: Coalinga, CA
- Facility Size: 100 acres
- Steam Production: 29 MWt (megawatts thermal)
- Electrical Output Equivalent: Approx. 13 MWe (megawatts electric)
- Tower Height: 327 feet
- Number of Heliostats / Mirrors: 3,822 heliostats; 7,644 mirrors
- Years of Operation: 2011-2014

Coalinga, CA, Sep. 4, 2015
A four-year project at a Chevron Corp. enhanced oil recovery wellsite in California's central valley came and went with no plans to replicate it.

www.naturalgasintel.com/articles/103562-potential-for-solar-assisted-eor-in-california-oilfield-still-unfulfilled

www.brightsourceenergy.com/coalinga#.V-QUkjsSfPE

Example:
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)

Miraah will be one of the largest solar plants in history.

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 CO_2 emissions by more than 300,000 tons each year.

www.glasspoint.com/markets/projects/

Example:
Geothermal Power from Oil Field Water Supply Wells

Hot brine from wells may be used to generate electricity using facilities with Organic Rankin Cycle technologies.

Will Gosnold leads a University of North Dakota Partnership with Continental Resources, Access Energy, Olson Construction, Basin Electric Cooperative, and Slope Electric Cooperative. Project details include:

- Project is located at Cedar Hills Field, which is a water flood EOR operation in Rhame, ND.
- 2 hz water supply wells produce 98C, 51 kg/s, 3000 ppm TDS water from the Lodgepole formation.
- Access Energy delivered two 125 kW ORC units to the site, & power production commenced Apr 2016.
- An analysis indicates the Madision, Red River and Bakken formations could yield sufficient water to be economic for co-produced electrical power.

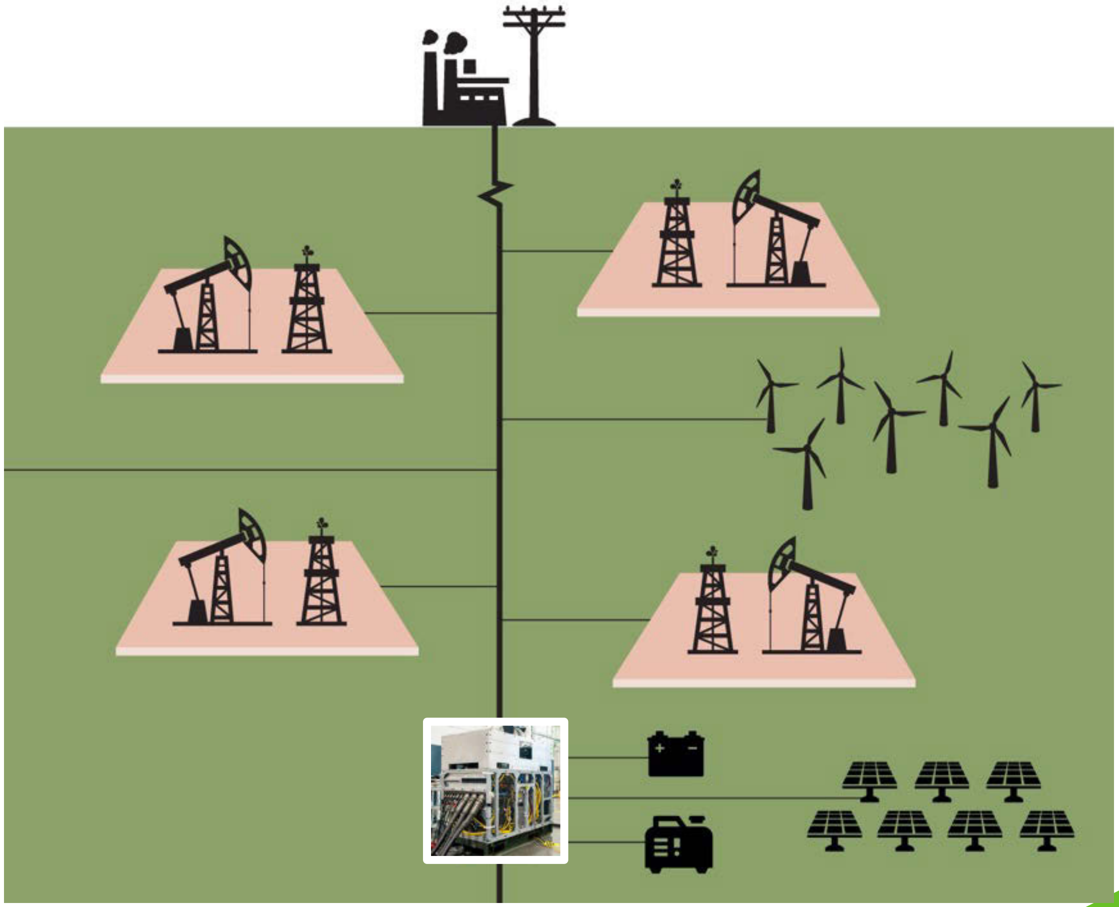
Opportunities for Collaboration:
Site and grid integration, technology evaluation, and technoeconomic site analysis

Source: 2016 SMU presentation by will.gosnold@engr.und.edu

Potential Comprehensive Approach: 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

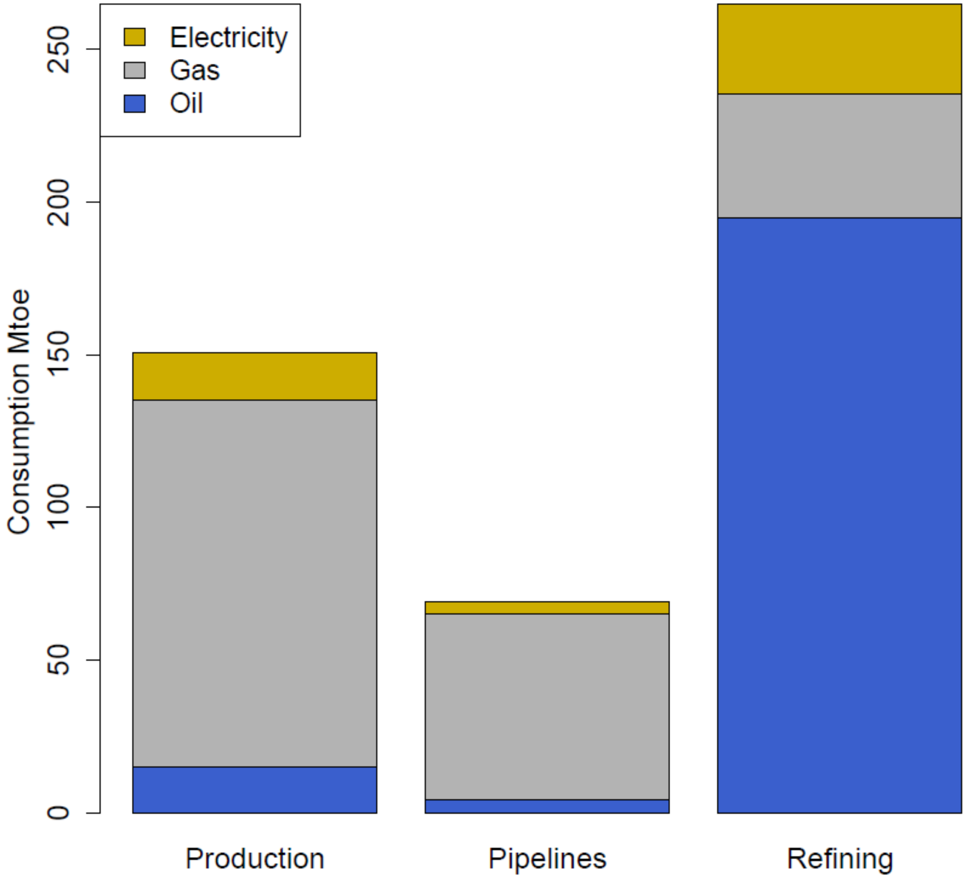
Opportunities for Collaboration: Design of complete system, technology evaluation & selection, "utility in a cube" technology



Initial Literature Findings on Opportunity

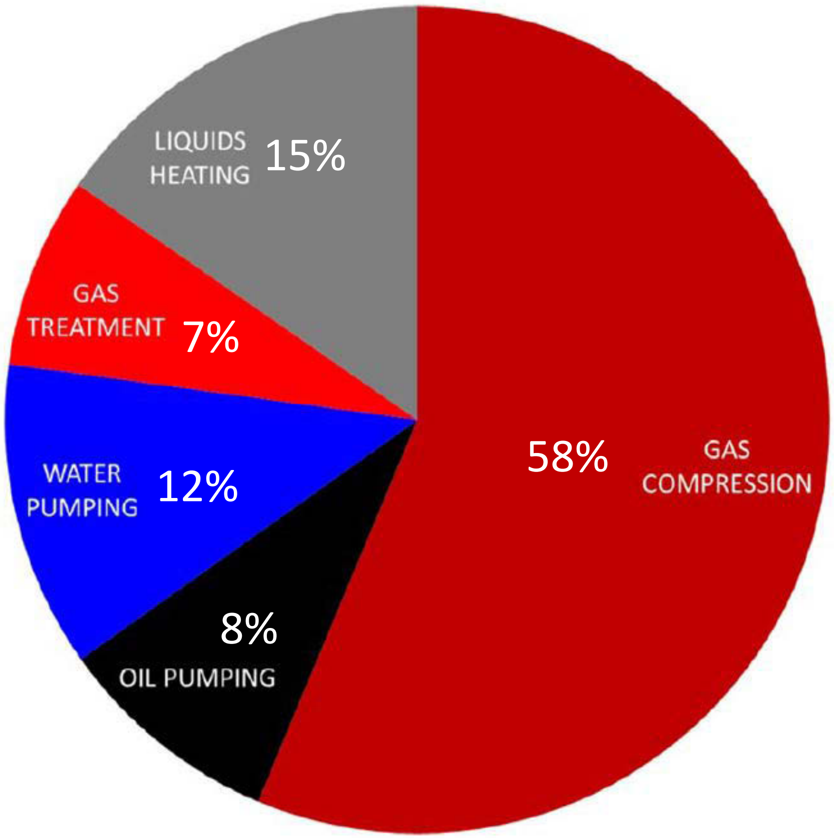
10% to 25% (unconventional) of oil is self-consumed in production, transportation, & refining
(Source: Halabi, et al., 2015; Wesoff, 2015)

Estimated Energy Use by Oil and Gas Operations



Source: Energy Consumption in Oil and Gas Industry, upcoming JISEA paper. Adapted from (Halabi, et al., 2015).

Upstream Energy Demand Sources



Source: SPE-190578-MS. BP Upstream Energy Demand Sources (2017). Upstream Energy Benchmarking: Identifying Energy Improvement and GHG Reduction Opportunities For Current and Future Operations, Including Technology Gaps.

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What is needed for clean energy technologies to be part of oil and gas operations?

- Engineering design assessment for clean energy technologies
- Field deployment, measurement, and verification of test systems
- Development and maturation of technology applications
- Technology support services
- Training for skilled resources in clean technologies
- Program management and protocols




Purpose and Summary

Value Proposition:

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

Definition: Clean power technologies include renewable energy technologies, battery and hydrogen storage, efficiency and heat recovery, natural gas-based power, or a combination of these and other clean technology options.

Program Results:

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

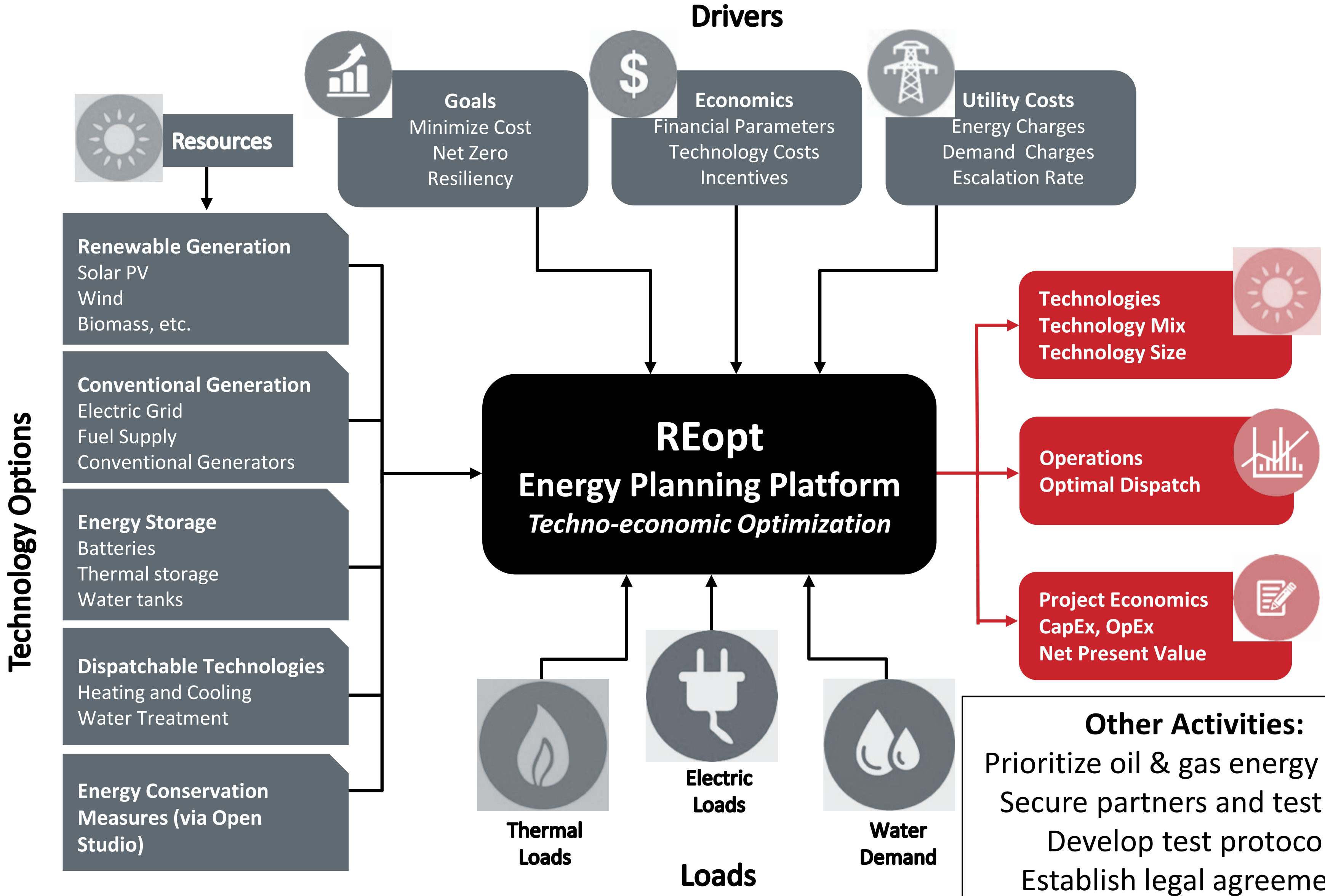
Governance:

Consortium of industry partners to leverage resources for the benefit of those involved, supported by renewable energy experts at NREL, and managed by JISEA

Structure of Program:

- Phase I: energy and technoeconomic analysis, program design, development
- Phase II: 3-5 year program with 3-12 month technology pilot tests
- Periodic reporting and access to new technology

Phase 1: Analysis and Program Design



Other Activities:

Prioritize oil & gas energy needs

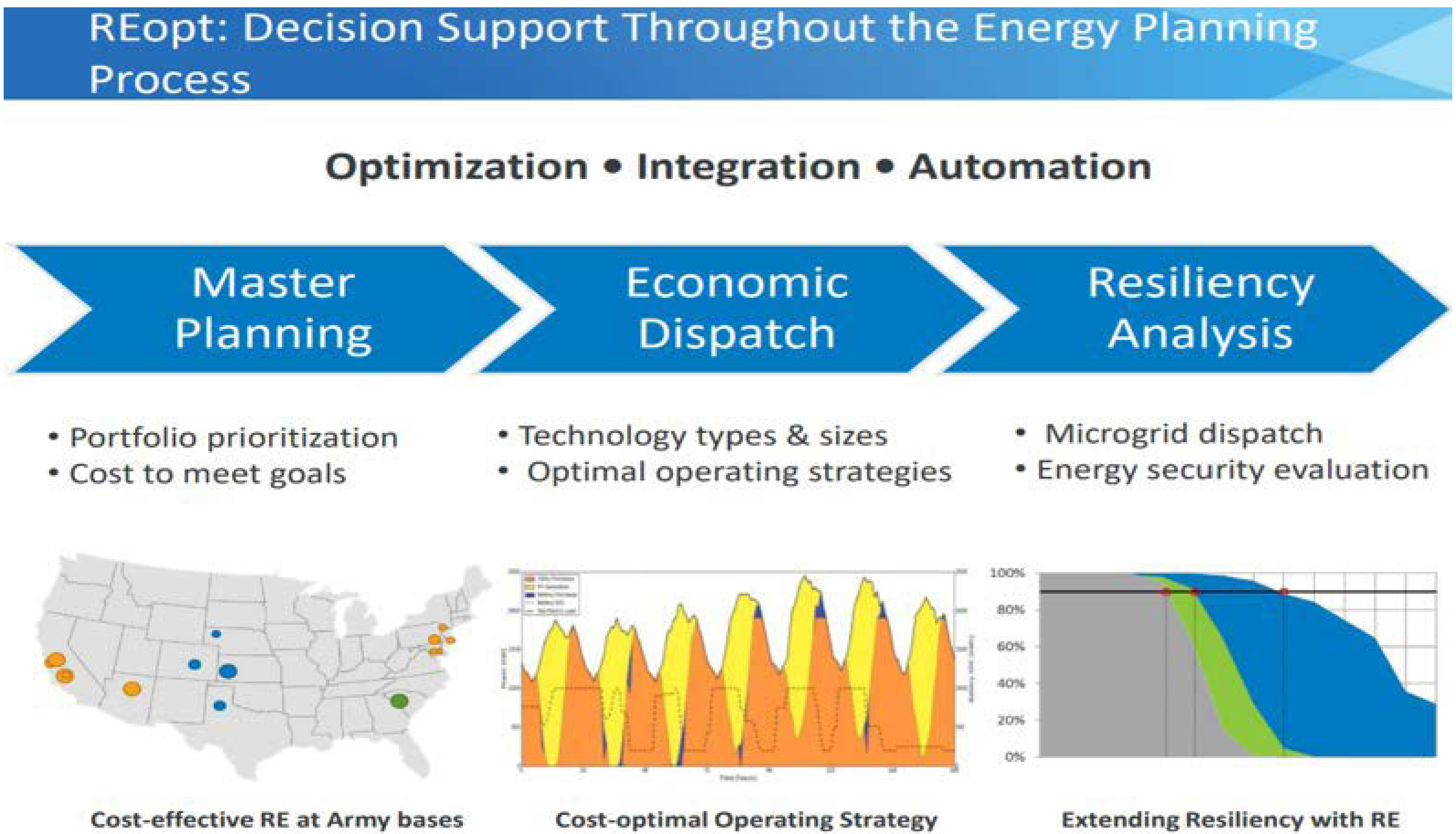
Secure partners and test sites

Develop test protocols

Establish legal agreements

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.



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)

Cost and Scaling Model (CSM)
- Model based on empirical relationships and scaling equations
- Data from developers, renewable industry stakeholders, and literature reviews

Balance of System Capital Cost (CapEx)

Balance of System (BOS) Model
- Model based on empirical relationships and scaling equations
- Data from developers, renewable industry stakeholders, and literature reviews

Finance

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

Operation and Maintenance (OpEx)

Cost of Energy Review
- Informed by DOE's Wind Vision study and input from industry stakeholders

Net Annual Energy Production (AEP_{net})

Systems Advisor Model (SAM)
- Idealized power curve
- Simplified layout
- Distribution for resource
- Applies plant losses and availability

Benefits to Collaboration and Program Status

- **Reducing risk to operations** until concept/solution is proven with actual field testing
- **Collaboratively identify 'best practices' to reduce cost** and improve environmental and cost performance across the spectrum of oil and gas development process
- **Access to unique, world class capabilities** for analytics, modeling, and testing from a U.S. national laboratory
- **Leveraging research/testing dollars** through a consortium program

Current status and schedule:

Completed input from industry, seeking sponsors for Phase 1

Aim to complete Phase 1 by Spring 2019

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Questions and Discussion

Thank you!

Disclaimer

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