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
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

[Logos of the founding members]
Workshop Series with IEA GOT

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
• Planned Collaborative Program and Discussion
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Renewable energy is diverse

WIND
Onshore

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

Estimated Renewable Energy Share of Global Electricity Production, End-2017

- 73.5% Non-renewable electricity
- 26.5% Renewable electricity
- 16.4% Hydropower
- 5.6% Wind power
- 2.2% Bio-power
- 1.9% Solar PV
- 0.4% Ocean, CSP and geothermal power

Global growth of renewables in all sectors

Estimated Renewable Share of Total Final Energy Consumption, 2016

- 79.5% Fossil fuels
- 2.2% Nuclear energy
- 7.8% Traditional biomass
- 10.4% Modern renewables
  - 4.1% Biomass/solar/geothermal heat
  - 3.7% Hydropower
  - 1.7% Wind/solar/biomass/geothermal/ocean power
  - 0.9% Biofuels for transport

Global growth of renewables in all sectors

Global Renewable Power Capacity, 2007-2017

- World Total: 2,195 Gigawatts
- Global renewable power capacity

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

Global PV market expected to grow

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

Onshore: 2-3 MW
50 m blade length

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

Levelized Cost of Electricity ranges by technology. Values are in 2015$. Colored bars illustrate range across all representative plants in the ATB. Black bars illustrate the representative ATB plant characteristics that align with the type of plant that would likely be built in today’s market.

2017 ATB LCOE range by technology for 2030 based on current market conditions

Variability due to: Technology; Location; Time (Present v. Future)
Cost of Renewable Electricity at Auctions Driving Decrease

Cost of Renewable Electricity at Auctions Driving Decrease

Electrification Futures Study

All Figures from NREL’s Electrification Futures Study: [www.nrel.gov/efs](http://www.nrel.gov/efs)
Electrification Futures Study

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Outline

- Energy Markets and Trends
- Clean Power for Oil and Gas Industry
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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.

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.

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

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 98°C, 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 Madison, 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

- Electricity
- Gas
- Oil

Upstream Energy Demand Sources

- LIQUIDS HEATING: 15%
- GAS TREATMENT: 7%
- WATER PUMPING: 12%
- OIL PUMPING: 8%
- GAS COMPRESSION: 58%


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

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• Planned Collaborative Program and Discussion
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

Drivers
- Goals: Minimize Cost, Net Zero, Resiliency
- Economics: Financial Parameters, Technology Costs, Incentives
- Utility Costs: Energy Charges, Demand Charges, Escalation Rate

Resources
- Renewable Generation: Solar PV, Wind, Biomass, etc.
- Conventional Generation: Electric Grid, Fuel Supply, Conventional Generators
- Energy Storage: Batteries, Thermal storage, Water tanks
- Dispatchable Technologies: Heating and Cooling, Water Treatment
- Energy Conservation Measures (via Open Studio)

Technology Options
- REopt: Energy Planning Platform
  - Techno-economic Optimization

Technologies
- Technology Mix
- Technology Size

Operations
- Optimal Dispatch

Project Economics
- CapEx, OpEx, Net Present Value

Optimized Minimum Cost Solution

Other Activities:
- Prioritize oil & gas energy needs
- Secure partners and test sites
- Develop test protocols
- Establish legal agreements

Economics
- Financial Parameters
- Technology Costs
- Incentives

Utility Costs
- Energy Charges
- Demand Charges
- Escalation Rate

Goals
- Minimize Cost
- Net Zero
- Resiliency

Technologies
- New Technologies
- Existing Technologies

Utilities
- Electric Grid
- Fuel Supply

Conventional Generation
- Electric Grid
- Fuel Supply
- Conventional Generators

Energy Storage
- Batteries
- Thermal storage
- Water tanks

Dispatchable Technologies
- Heating and Cooling
- Water Treatment

Energy Conservation Measures (via Open Studio)
- Energy Conservation

Thermal Loads
- Heating and Cooling

Electric Loads
- Demand

Water Demand
- Treatment

Optimal Dispatch
- Operations

Net Present Value
- Financial Parameters
- Technology Costs
- Incentives

Phase 1: Analysis and Program Design

- Analysis
- Program Design

ReOpt
- Energy Planning Platform
  - Techno-economic Optimization

Resources
- Renewable
- Conventional
- Storage

Technology Options
- REopt
  - Energy Planning Platform
- Technologies
  - Mix
  - Size

Goals
- Minimize Cost
- Net Zero
- Resiliency

Economics
- Financial Parameters
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Utility Costs
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Drivers
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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**

<table>
<thead>
<tr>
<th>Capital Costs (CapEx)</th>
<th>Balance of System Capital Cost (CapEx)</th>
<th>Finance</th>
<th>Operation and Maintenance (OpEx)</th>
<th>Net Annual Energy Production (AEP_{net})</th>
</tr>
</thead>
</table>
| **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 (BOS) Model**
  - Model based on empirical relationships and scaling equations
  - Data from developers, renewable industry stakeholders, and literature reviews |
| **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 |
| **Cost of Energy Review**
  - Informed by DOE’s Wind Vision study and input from industry stakeholders |
| **Systems Advisor Model (SAM)**
  - Idealized power curve
  - Simplified layout
  - Distribution for resource
  - Applies plant losses and availability |

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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

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**Current status and schedule:**
Completed input from industry, seeking sponsors for Phase 1
Aim to complete Phase 1 by Spring 2019
Questions and Discussion

Thank you!
Disclaimer

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