Clean Energy Transition: Reflections on the Past Decade

NREL Industry Growth Forum
Dr. Dan E. Arvizu
Laboratory Director

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Energy Market Fundamentals

Globally interconnected
Driven regionally
Shaped by public policy
Technology enabled
Investment, infrastructure and finance guide development

Energy is the “life blood” for economic growth, prosperity, and societal advancement.

9/25/2015
Energy mix is changing

Global renewable industry growing, but faces challenges

Public policy evolving—mostly local

Unconventional gas a growing focus with geographic disparities

Infrastructure investments will be made, requirements are changing

Technology is creating a platform for disruptive change

Updated 3/13/2015
A Profound Transformation is Required

Today’s Unsustainable Energy System

- Limited fuel diversity
- Subject to price volatility
- Inefficient and rigid
- Significant carbon emissions
- Delivery systems vulnerable
- Aging infrastructure

Future Sustainable Energy System

- Diverse supply options
- Affordable, stable and reliable
- Efficient and flexible
- Carbon neutral
- Secure and resilient
- More consumer driven

TRANSFORMATION

Updated 3/10/2015
The Past Decade: An Evolving Focus

2005
“Getting a seat at the table”

2007
“Thinking differently about energy”

2009
“Articulating potential of RE and EE”

2011
“Facing barriers to speed and scale”

2013
“Creating environment for systems integration”

2015
“Managing dimensions required for transformation”
2005/2006—Getting a Seat at the Table

- The **Colorado Renewable Energy Requirement Initiative**, also known as **Initiative 37**, was approved in November 2004 with 53.6% of the vote
- Required a percentage of retail electricity sales be derived from renewable sources, beginning with 3% in the year 2007 and increasing to 10% by 2015
- Local utilities opposed the amendment
U.S. Renewable Energy Contributions
Percent of Total Non-Hydro Electric Generating Capacity

- Oil: $21-100/BBL
- Coal: $20 - $25/ton
- Natural Gas: $4.00-$8.03/MCF

Fossil fuel price assumptions for the forecast year range from:

High: Progressive policy change & rapid technological advancement
Medium: moderate policy & technological change
Low: minimal policy, slow technological change, greater reliance on fossil fuels
2007/2008—Thinking Differently

- Convened experts at the Santa Fe Institute
- Recast the issue
- Take a systems perspective
- Not what we produce but how it’s used
2009/2010—Articulating the Potential

Setting the Bar Higher – Gigawatt-Scale Renewables

- **Solar Vision**: 10% U.S. electricity by 2025
- **Wind Vision**: 20% U.S. electricity by 2030
- **Energy Independence & Security Act 2007**: 36 billion gallons of renewable fuels by 2022
2011/2012—Facing Barriers to Speed and Scale
Focus on the How

The technical potential for renewables is enormous.
Renewable Power Capacities in World, EU-28, BRICS, and Top Seven Countries, 2015

*not including hydropower

REN21 Renewables 2015 Global Status Report
Global Renewable Energy Proportion of Power Generation

- Canada: 76%
- Spain: 43%
- UK: 19%
- Germany: 28%
- US: 13%
- Japan: 11%
- China: 22%
- Brazil: 71%
- S. Africa: 2%
- India: 6%
- Australia: 16%

Source: Oxford Energy, China Electricity Council, BDEW, UK Govt, REE, NRCAN, EIA, USEA, Bloomberg New Energy Finance

Michael Liebreich, New York, 14 April 2015

@MLiebreich #BNEFSummit
2013/2014—Creating the Environment for Systems Integration

Analyzing, validating, partnering to reduce risk
Global Gross Power Generation Capacity Additions 2010-2013 (GW)

**Fossil Fuel**
- Forecast
- 2010: 105
- 2013: 141
- 2015: 110
- 2020: 91
- 2025: 62
- 2030: 64

**Clean Energy**
- Forecast
- 2010: 93
- 2013: 143
- 2015: 164
- 2020: 208
- 2025: 242
- 2030: 279

Sources:
- Underlying data is from GREMO 2014
- Source: Bloomberg New Energy Finance
2015—Managing Dimensions Required for Transformation

- Disruptive technologies
- Differentiated energy services
- Disintermediation of the value chain
- Distributed resources
Disruptive Technologies
Disruptive Technologies

Deployment and Cost for U.S. Land-Based Wind 1980-2012

Deployment and Cost for A-Type LED Lights 2008-2012

Deployment and Cost for Solar PV Modules 2008-2012

Deployment and Cost for Electric Vehicles and Batteries* 2008-2012

Differentiated Energy Services

Six Services

- Shelter and Comfort
- Safety and Security
- Durable Goods
- Feedstocks, Fuels, and Chemicals
- Information and Access
- Mobility
## Technologies Enabling Energy Services

<table>
<thead>
<tr>
<th>Shelter &amp; Comfort</th>
<th>Durable Goods</th>
<th>Feedstocks, Fuels and Chemicals</th>
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<tbody>
<tr>
<td>Low-cost storage</td>
<td>Bio manufacturing</td>
<td>Biomass catalytic conversion to specialty and commodity chemicals</td>
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<tr>
<td>Design control and sensors</td>
<td>High value roll-to-roll processing</td>
<td>Synthetic biology conversion to specialty and commodity chemicals</td>
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<td>Microgrids and management</td>
<td>Sustainable advanced composites</td>
<td>Process intensification/integration</td>
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<td>Discretionary load efficiency</td>
<td>Advanced energy materials</td>
<td>Kerfless Si wafering PV manufacturing</td>
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<td>Off-site construction and disaster rebuilding/recovery</td>
<td>Keflless Si wafering PV manufacturing</td>
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<tr>
<th>Information &amp; Access</th>
<th>Mobility</th>
<th>Safe Secure &amp; Reliable Power Systems</th>
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<tbody>
<tr>
<td>Intelligent, scalable energy systems and tools</td>
<td>Next gen electric vehicles</td>
<td>Secure and reliable microgrids</td>
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<td>Networked grids/microgrids</td>
<td>Low-cost RE H2 techs</td>
<td>Rapid response microgrids</td>
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<tr>
<td>Intelligent energy agents and devices</td>
<td>Data; Management, connectivity &amp; security</td>
<td>Reliable personal “nano-grids”</td>
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<td>Energy enabled personal services</td>
<td>Fuels/engine optimization</td>
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<td>Bio-based materials</td>
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Distributed Resources
Disintermediation of the Value Chain
Invent the Future We Desire

TECHNOLOGY
- Cyber-attacks with long/widespread outages
- Physical disruptions with long/widespread outages (e.g., weather, attacks)
- Improved flexibility management (technical aspects)
- Electrification of the transportation sector

POLICY AND REGULATORY
- Final EPA Section 111 (d) rules
- National carbon market or carbon tax (policy)
- Policies to accelerate prevention of/recovery from cyber attacks
- Improved flexibility management (policies and regulations)
- Evolved regulations and policies focused on value of services
- Inability to, or high cost of, interconnection
- Improved bulk system interconnections and sub-hourly markets

MARKET
- National carbon market or carbon tax (market)
- Improved flexibility management (market aspects)
- Evolved market rules focused on value of services
- Improved bulk system interconnections and sub-hourly markets

FINANCING
- Reduce capital uncertainties for clean generation (VRE, clean coal, nuclear), DG, bulk and distributed storage, value of services (flexibility, interactivity), and cyber-attack and physical disruption prevention
- Increased capital and financing for consumer-purchased resources
- Natural gas (NG) pipeline expansion limits, and NG fracking environmental restrictions

UTILITY BUSINESS MODELS
- Evolved business models focused on value of services
- Improved flexibility management (business aspects)
- Involvement of non-utilities (including third-party owners, customers) with different interests/business cases
To achieve a clean energy vision, we must...

- Invest in innovation
- Invent the future we desire
- Improve access to capital
- Partner on a global scale
For more than 35 years, NREL has delivered innovation impact enabling the emergence of the U.S. clean energy industry.

For more information, please visit our website at www.nrel.gov