The G7 and Decarbonization:
U.S. Electricity and Industry Strategies
Jon Creyts
September 30, 2015
Sources of perspectives
Summary perspectives

Techno-economic pathways exist or will quickly emerge to support full decarbonization of the U.S. power grid well before end of the century. Near-term institutional reform will be critical to accelerate the transformation. Specific issues to address include

- Business model reform
- Efficiency capture
- Grid intelligence
- Gas co-evolution

Creating a zero carbon industrial base is likely to be much more challenging. While efficiency and electrification are necessary steps, carbon process dependency for several of the most important energy-consuming sub-sectors is likely to limit progress. Specific issues to address include

- Improved efficiency capture (e.g., motors, steam, waste heat)
- Alternative processes/substitutes (e.g., BOF steel, bulk chemicals)
- Biomass development
- Capital
Decarbonizing the Power Sector
Reinventing Fire electricity scenario

Source: Reinventing Fire
From Carbon to Silicon
Demand Has Flattened

US Electricity Consumption 1980 - Present

Source: EIA AEO 1980 - Present
20-40% savings on HVAC is possible rapidly

Why don’t we?

$100

Automated email if no more ink

$10,000

No email if filter must be changed
HVAC represents 26% of U.S. electricity

TWh, 2010

Electricity consumption: 3,887 (74%)

HVAC: 1,021 (26%)

Industrial: 88
Residential: 446
Commercial: 487
IT-driven approaches to energy efficiency

<table>
<thead>
<tr>
<th>Nest</th>
<th>Bidgely</th>
<th>Opower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart thermostat (automated)</td>
<td>Disaggregation and improved behavior</td>
<td>Comparative information and improved behavior</td>
</tr>
<tr>
<td>5% savings</td>
<td>7% savings</td>
<td>2% savings</td>
</tr>
</tbody>
</table>
Wind and Solar are Competitive in Wholesale Markets

<table>
<thead>
<tr>
<th>SUPPLY</th>
<th>Texas</th>
<th>North East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility scale wind</td>
<td>$23.50</td>
<td>$35.72</td>
</tr>
<tr>
<td>ERCOT 2014</td>
<td>$35.72</td>
<td></td>
</tr>
<tr>
<td>PJM 2014</td>
<td></td>
<td>$39.43</td>
</tr>
<tr>
<td>Texas</td>
<td>$38.70</td>
<td>$50.31</td>
</tr>
<tr>
<td>California</td>
<td></td>
<td>$53.26</td>
</tr>
<tr>
<td>Utility scale solar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERCOT 2014</td>
<td></td>
<td></td>
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<tr>
<td>CAISO 2014</td>
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</tr>
</tbody>
</table>

Average 2014 wind PPA price according to EERE 2014 Wind Technologies Market Report
Wind production weighted 2014 ERCOT Hub Average DA LMP
Wind production weighted 2014 PJM N Illinois Hub Average DA LMP

Solar PPA price for July 7, 2015 NV Energy PPA with First Solar Inc.—with a 3% escalation
Solar production weighted 2014 ERCOT Hub Average DA LMP
Solar production weighted 2014 CAISO SP15 Average DA LMP
The Economics of Load Defection: PV+Batteries

Westchester, NY – increasing proportion of load served by PV and batteries economically – no subsidies assumed

Source: Economics of Load Defection, RMI, 2015
How can conventional generation compete?

<table>
<thead>
<tr>
<th></th>
<th>Required investment</th>
<th>Fuel costs</th>
<th>Operation &amp; maint. costs</th>
<th>Emissions</th>
<th>Pace of innovation</th>
<th>Availability</th>
<th>Resilience</th>
<th>Mode of construction</th>
<th>Support by society</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rising, $b over years</td>
<td>Volatile</td>
<td>Stable or rising</td>
<td>Significant</td>
<td>Slow</td>
<td>~90% availability; unpredictable</td>
<td>Brittle, fragile in extreme weather</td>
<td>Each plant is a prototype</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>~99.5% availability; predictable</td>
<td>Islandable</td>
<td>Mass-produced commodity</td>
<td>High</td>
</tr>
</tbody>
</table>
The Economics of Flexibility: Shifting Loads

Under reduced export compensation, load is scheduled to coincide with PV generation

Uncontrolled load profile

Flexible load profile

Move load into PV production hours

Other load  AC  DHW  Dryer  EV  Battery  PV
Hawai‘i, United States: affordability and independence
New Jersey, United States: Resilience
Corporate World: Resilience

New Apple Headquarters
Adoption lagging economics

PV prices are falling faster than projected in RF ... however, installed capacity is much behind

Source: Reinventing Fire
Decarbonizing the Industry Sector
Projected decline in U.S. industry sector fuel use, 2010–2050

Source: Reinventing Fire
Doubled energy productivity

1. Energy Efficiency
   - Motors
   - Buildings
   - Steam systems
   - Waste heat recovery

2. Combined heat and power

3. Process efficiency

4. Structural shift
Integrative design to go further
2010 Energy consumption share by sector

- Petroleum and Coal Processing
- Petroleum Refining
- Petrochemicals
- Basic Organic Chemicals
- Chemicals
- Paper Products
- Primary Metals
- Other
- Transportation equipment
- Electronics
- Other
- Paper Mills
- Paperboard Mills
- Alumina and Aluminum
- Iron and Steel Mills
- Fabricated metals
- Plastic products
- Food products

Source: US EIA Manufacturing Energy Consumption Survey, RMI Processing
## Process decarbonization prospects

<table>
<thead>
<tr>
<th>Subsector</th>
<th>Energy requirements (ranked)</th>
<th>Low carbon pathways</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum and coal processing</td>
<td>Natural gas, petroleum, coal</td>
<td>Alternative heat sources, markets for residuals</td>
<td>Most heat from waste products</td>
</tr>
<tr>
<td>Paper products</td>
<td>Natural gas, coal, electricity</td>
<td>Alternative heat sources, sustainable harvesting</td>
<td>Economics</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Natural gas, natural gas liquids, coal</td>
<td>Different synthesis processes; alternative heat sources</td>
<td>Petroleum precursors difficult to replace, waste as fuel</td>
</tr>
<tr>
<td>Primary metals</td>
<td>Natural gas, electricity, coal, coke</td>
<td>Increase recycling (e.g., EAF), electrification</td>
<td>Carbon metallurgy, capital replacement</td>
</tr>
</tbody>
</table>
Thank you

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