Barriers to Large Scale Grid Penetration of Renewables
High MW Electronics – Industry Roadmap Meeting
December 11, 2009

David J Prend
Managing General Partner, RockPort Capital Partners
Let’s step back to late 1970s

Carter – “Moral Equivalent of War”
PV on the White House

David Prend
Engineer in Advanced Energy Technologies,
Bechtel Corporation, 1980
Is technology really the problem?

February 1981

“In the case of energy....often the obstacles are not technological but institutional.”

November 2009

“The obstacles are primarily political, not technological.”
The importance of learning curves

Source: NREL and US Department of Energy
Solar learning curve

PV Module Production Experience (or “Learning”) Curve

“80% Learning Curve”: Module price decreases by 20% for every doubling of cumulative production.

Source: NREL
The impact of incentives

Source: NREL

"BIG 3" Experience
(It works . . . !)
Wind learning curve

Learning rate ~10%

i.e. for every double of cumulative capacity, cost of wind power decreases by 10%

Incentive effects on US installed wind capacity

Source: AWEA
Grid technologies currently exist

<table>
<thead>
<tr>
<th>Grid</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide area networks</td>
<td>Flow batteries</td>
</tr>
<tr>
<td>Smart meters</td>
<td>Pumped hydro</td>
</tr>
<tr>
<td>Substation automation</td>
<td>Compressed air</td>
</tr>
<tr>
<td>Home area networks</td>
<td>Flywheels</td>
</tr>
<tr>
<td>Real time monitoring and control</td>
<td>Electrochemical capacitors</td>
</tr>
<tr>
<td>Microgrids</td>
<td>NAS batteries</td>
</tr>
<tr>
<td>Demand management</td>
<td>Lead-acid batteries</td>
</tr>
<tr>
<td>High MW power electronics</td>
<td>Li-ion batteries</td>
</tr>
</tbody>
</table>
Large scale penetration is feasible

2008 Renewables Penetration

Source: IEA

2020 Model for California

Source: Scientific American, November 2009
R&D spending on energy vs. other sectors

**Industry**

Source: Booz & Co

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**Government**

Source: AAAS

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**R&D as a % of sales**

- Software / internet
- Healthcare
- Aerospace / defense
- Auto
- Chemicals / energy

- R&D as a % of sales

**Congressional budget (2009)**

- DOD
- NIH
- DOE

- Congressional budget (2009)
Global government spending on energy R&D

Source: Journal of Energy Policy, Schilling and Esmundo, 2009
How level is this playing field?

Source: Environmental Law Institute, 2009
How level is this playing field?

Federal Electricity Subsidies 2002-2007
(Billions of 2007$)

<table>
<thead>
<tr>
<th>Direct Expenses</th>
<th>Tax Incentives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>Nuclear$^1$</td>
</tr>
<tr>
<td>$6.2</td>
<td>$0.0</td>
</tr>
<tr>
<td>Fossil Fuel R&amp;D</td>
<td>Fossil Fuel</td>
</tr>
<tr>
<td>3.1</td>
<td>13.7</td>
</tr>
<tr>
<td>Renewables R&amp;D</td>
<td>Renewables</td>
</tr>
<tr>
<td>1.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Transmission Improvements</td>
<td>Transmission and Other</td>
</tr>
<tr>
<td>0.8</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>Total:</strong> 11.5</td>
<td><strong>Total:</strong> 18.2</td>
</tr>
</tbody>
</table>

$^1$The GAO report excludes low cost loans, and the federal liability insurance program provided to nuclear operators, which significantly subsidizes their operations.

The real problem is demand...and financing

- Question: how much capital investment would it take to increase (non-hydro) renewables from today’s level to 20%?

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total US electricity generation*</td>
<td>3,972,423,000 MWh</td>
</tr>
<tr>
<td>Total (non-hydro) renewable generation*</td>
<td>130,516,000 MWh 3.3%</td>
</tr>
<tr>
<td>* Rolling 12 month total as of August 2009 (EIA)</td>
<td></td>
</tr>
<tr>
<td>20% of Total US electricity generation</td>
<td>794,484,600 MWh</td>
</tr>
<tr>
<td>Additional generation from (non-hydro) renewables</td>
<td>663,968,600 MWh</td>
</tr>
</tbody>
</table>

**Capital investment required to reach 20% target (billions)**

<table>
<thead>
<tr>
<th>Installed Cost ($/W)</th>
<th>15%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2.50</td>
<td>$1,263</td>
<td>$947</td>
</tr>
<tr>
<td>$3.00</td>
<td>$1,516</td>
<td>$1,137</td>
</tr>
<tr>
<td>$3.50</td>
<td>$1,769</td>
<td>$1,326</td>
</tr>
</tbody>
</table>

- Answer: More than a trillion dollars!
How do we access large pools of capital to fund deployment?

- **Feed in Tariffs**
  - “United States of Gainesville”

- **Utilities**
  - Cost recovery through “rate basing”
Conclusions

- Deal with demand side and supply will be there
- Focus on institutional barriers rather than technical barriers