Negative Marginal Cost Electricity: An opportunity for low-cost value-added hydrogen production

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Negative Electricity Prices

• Two types of negative electricity price
  – Negative price (P) < $0
  – Negative marginal price (P) ≤ variable cost (VC)

• Characteristics
  – Typically found in competitive wholesale markets
  – Increasing prevalence in N. America and Europe
  – Symptom of inherent inefficiency in balance of electricity supply and demand
  – Inverse of peaking problem (occurs when supply > demand), but similar economic outcome
Negative Electricity Prices: Prevalence

• European Energy Exchange (EEX)
  – About 1% of prices in 2009 were < 0€/MWh

Source: Marco Nicolosi, based on data from EEX, BDEW and ENTSO-E; Nicolosi, Marco. Wind power integration and power system flexibility? An empirical analysis of extreme events in Germany under the new negative price regime. Energy Policy Volume 38, Issue 11 2010 7257 - 7268
Negative Electricity Prices: Prevalence

- U.S. Regional Power Markets
  - Areas with a large share of wind capacity, limited demand flexibility, and transmission constraints

Percent of hours with negative prices in selected U.S. wholesale markets.
Source: Huntowski, Frank, Patterson, Aaron, and Schnitzer, Michael. Negative Electricity Prices and the Production Tax Credit. The NorthBridge Group. September 2012.

Negative Electricity Prices: Drivers

- Efficient markets incorporate marginally relevant opportunity costs (Nicolosi, 2010)
- Technical constraints on supply-side flexibility (IESO, 2011)
- Policy-driven market effects value non-core attributes irrespective of underlying value of electricity (Huntowski, 2012)
- Price Inelasticity of Demand for electricity
- Market manipulation, i.e. loss-leader strategy and other anti-competitive actions
HOEP & Zone Hourly Price – Jan-May ‘13
Ontario – HOEP and Zones Prices

2009 Hourly Prices

2010 Hourly Prices

2011 Hourly Prices

2012 Hourly Prices

Atikokan, Pineportage, Thunderbay, Andrews, Canyon, Npiroqfalls, HOEP

Hourly Prices

<-1500
<-750
<-100
<0
<33
>33

<-1500
<-750
<-100
<0
<33
>33

<-1500
<-750
<-100
<0
<33
>33

<-1500
<-750
<-100
<0
<33
>33
Bid Price by Demand, 2009-May 2013
Ontario’s Wholesale Electricity Market

• Hybrid structure with competitive bidders and quasi-regulated/contractual participants
• Energy-only market, i.e. no capacity auctions
• Recent trends and future directions
  – Reduced supply flexibility from gas/oil/renewable displacement of coal
  – Retrofitted baseload plants for increased flexibility
  – Increasing demand responsiveness (reducing peak only) via smart grid technologies and variable retail pricing structures
  – Greatly increased renewable capacity (particularly wind) online during next 5 years, wind dispatch in 9/2013
Wholesale Power Market Inefficiencies

• Supply and demand disconnects
  – Geographic
  – Temporal
  – Value

Generation Output by Fuel Type

Wholesale Market Charges, Weighted Average YTD

$102.40/MWh or 10.24 ¢/kWh


Global Adjustment (GA) Effect

• Global Adjustment charge = difference between market prices and guaranteed generator payments - $6.46 bill. and more than twice average weighted HOEP in 2012

Data Source: IESO, Global Adjustment Archive
Further From Equilibrium

• Power buyers pay total charge, and are indifferent among allocation of components
• 18-Month forecast HOEP range between CA$15.07 and CA$23.11 per MWh (Navigant, 2013)
• GA charge is “cost” of low HOEP; non-market payment that yields no additional output
• Surplus Baseload Generation (SBG) shutdown events tripled losses in early 2013 to 310 GWh from 106 GWh in same period of 2012 (IESO, 2013)
Market Efficiency – Future Trends

• Resource Shift: lower supply flexibility, increased price volatility

• Higher Baseload Generation: increase curtailment/shutdown events -> capacity utilization and fixed cost recovery

• Lower HOEP/MCP: increased Global Adjustment charge, reduced productivity of electricity payments

• Increased GHG Focus: shift greater share of emissions to transportation sector
Conceiving a Solution

• Traditional electric system management strategies
  – Peak-oriented: manage (i.e., lower) peak demand
  – Reliability-oriented: ensure adequate peak supply

• NEW PROBLEM: increasing amount of price-inelastic electricity supply and unproductive electricity charges

• Increase demand via dispatchable load to achieve optimal MCP; reduce GA charge, increase available reserves, productivity of electricity payments, and improve fixed cost recovery for baseload generators
# Cost of Hydrogen Electrolysis

<table>
<thead>
<tr>
<th>Cost of Hydrogen Production from Water Electrolysis, 2015 DOE</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
<td>%/kg H₂</td>
</tr>
<tr>
<td>Electrolysis System</td>
<td>$0.50</td>
</tr>
<tr>
<td>Electricity</td>
<td>$3.10</td>
</tr>
<tr>
<td>Production Fixed O&amp;M</td>
<td>$0.20</td>
</tr>
<tr>
<td>Production Variable Costs</td>
<td>$0.10</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$3.90</td>
</tr>
</tbody>
</table>

**Notes:**
- Does not include cost of compression, storage, dispensing hydrogen.
- Electricity cost assumed at average of $0.07/kWh.
Production Cost per kg of H₂

Assuming system efficiency (LHV) of 72%, and other operating and financial assumptions of US DOE’s Distributed Electrolysis H2A model.
Incorporating Dispatchable Hydrogen Production via Electrolysis

• Two approaches
  – Dispatch to eliminate negative electricity prices, i.e. pay for $\text{H}_2$ production by eliminating marginal opportunity costs
  – Dispatch to target floor MCP (or HOEP) so that payments being made anyway support additional units of output
Applications of Hydrogen

• Since Hydrogen is produced to increase efficiency of electric system, good case for its consideration and use as a public good

• Potential benefits
  – Use to facilitate transition to hydrogen-based transport system
  – Stationary electric generation during peak
  – Hydrail on urban lines during peak demand times provides additional demand/supply flexibility
Questions?

Thank You

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