High-Volume Manufacturing of LiPF$_6$, A Critical Lithium-ion Battery Material

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Overview

Timeline
- Contract Start: April 16, 2010
- Contract End: April 15, 2013
- 16% Complete

Barriers
- Historically tight supply, global shortage of LiPF₆ in 2008
- Very difficult to produce at required quality, only 3 Asian producers
- Existing suppliers dependent on Chinese raw materials

Budget
- Total Project: $54.9M
  • DOE share: $27.3M
  • Honeywell Share: $27.5M

Partners
- Letters of intent from customers representing >50% of global demand
- Fully integrated on key raws
Relevance: All Lithium-Ion Batteries Require LiPF$_6$

- Build the first world-scale US manufacturing facility for LiPF$_6$
- Establish cost-effective domestic supply for critical material in the EDV supply chain
- Ensure the US-based lithium-ion battery industry has secure access to the highest quality LiPF$_6$ to avoid disruptions in supply and/or quality from foreign sources
Relevance

ARRA

• Creates 151 direct engineering and construction jobs as well as additional jobs at U.S.-based suppliers
• Creates 34 long-term professional and manufacturing jobs
  – Highest quality, lowest cost position ensures long-term viability
• All lithium-ion battery manufacturers and their EDV customers benefit from secure and cost-effective supply of LiPF₆

Vehicles Technology Program

• Reduce petroleum consumption
• Promote energy security
  – Avoid replacing imported oil with imported batteries/battery materials
  – Current Asian LiPF₆ producers dependent on Chinese raw materials

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Battery Size (kWh)</th>
<th>Annual Production</th>
<th>LiPF₆ (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEV</td>
<td>2</td>
<td>100,000</td>
<td>30</td>
</tr>
<tr>
<td>PHEV</td>
<td>15</td>
<td>100,000</td>
<td>200</td>
</tr>
<tr>
<td>EV</td>
<td>23</td>
<td>100,000</td>
<td>310</td>
</tr>
</tbody>
</table>
Critical Li-ion Battery Component – LiPF$_6$

Why Honeywell?

- Developed novel process to deliver highest purity LiPF$_6$ at the lowest cost
- Multiple letters of support confirming Honeywell’s quality
- Fluorine (HF) is ~50% of the raw material cost in LiPF$_6$
  - Honeywell is the world’s largest producer of HF
  - 50+ years experience in developing and scaling up new F-based molecules
  - Existing LiF supplier to Li-ion battery industry

![Honeywell Existing Products Diagram]
World Capacity for HF Production

### World HF Capacity*

<table>
<thead>
<tr>
<th>Location</th>
<th>HF capacity (K MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>413</td>
</tr>
<tr>
<td>Japan</td>
<td>157</td>
</tr>
<tr>
<td>China</td>
<td>700</td>
</tr>
<tr>
<td>Western Europe</td>
<td>266</td>
</tr>
<tr>
<td>ROW</td>
<td>154</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,690</strong></td>
</tr>
</tbody>
</table>

### Major North America HF Capacity*

<table>
<thead>
<tr>
<th>Company</th>
<th>HF capacity (K MT)</th>
<th>% NA share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honeywell</td>
<td>183</td>
<td>44%</td>
</tr>
<tr>
<td>Mexichem</td>
<td>100</td>
<td>24%</td>
</tr>
<tr>
<td>DuPont</td>
<td>82</td>
<td>20%</td>
</tr>
<tr>
<td>Solvay</td>
<td>35</td>
<td>8%</td>
</tr>
<tr>
<td>Others</td>
<td>13</td>
<td>4%</td>
</tr>
</tbody>
</table>

- HF is produced from fluorspar
- Today Japanese HF producers import fluorspar from China
- “In the future it is expected that China will increasingly add further value to acid-spar through the production of downstream products … rather than export the mineral.”

**Honeywell Has 44% of North America HF Capacity**

*“Economics of Fluorspar” Tenth Edition, 2009 by Roskill Information Services Ltd.*
Approach

- Honeywell has developed novel process to deliver highest purity with the lowest cost

- Leverage synergies unique to Honeywell
  - Existing know-how and assets to bring LiPF₆ to market quickly
  - Key raw materials on site
  - Qualified operations and management teams in place
  - Existing permits

- Phase 1 – Build LiPF₆ plant at Buffalo, NY facility
  - Fastest path to provide material for customer qualification
  - Team that invented process located on-site

- Phase 2 – Build world-scale LiPF₆ plant in Illinois
Buffalo Plant

- Developed and scaled up all new fluorine-based products since 1980s
- Existing production, safety and utility infrastructure
- Key personnel on-site

LiPF$_6$ Plant
In May of 2010, the DOE, Honeywell leaders and Buffalo officials commemorated Honeywell’s acceptance of the $27.3 million ARRA grant to produce LiPF₆ for vehicle batteries.

Pictured: Tien Duong, Department of Energy; David Franczyk, Buffalo City Council President; Andreas Kramvis, President and CEO of Honeywell Specialty Materials; Byron Brown, Mayor of Buffalo; U.S. Rep. Brian Higgins; and Jay Kelly, Honeywell Site Leader.

**Technical Accomplishments and Progress**

- **Environmental reviews complete**
  - Buffalo site received Categorical Exclusion CX designation
  - Illinois site Finding of No Significant Impact issued Sept 2010

- **Job Creation**
  - 36.7 jobs created in the last quarter
  - 5 new direct hires in 2010

- **Reporting**
  - In compliance with all DOE and ARRA reporting requirements

- **Completed all scheduled Milestones**
  - Basic engineering
  - Detailed design and procurement
  - Mechanical completion of Buffalo plant

- **Future Work**
  - Complete customer sampling and qualification
  - Complete detailed design of world-scale plant
  - Complete construction of world-scale plant
Summary

- All lithium-ion batteries need LiPF$_6$
- Secure supply of highest quality LiPF$_6$ is critical to success of DOE’s Battery Manufacturing Initiative
- Honeywell is uniquely positioned to deliver US production of LiPF$_6$
- Honeywell is meeting the goals of the ARRA and the DOE Vehicle Technologies Program
  - 36.7 jobs created in last quarter
  - $8.7M spent to date
  - All scheduled Milestones achieved