PART I: Overview of AP Technology reduction cell development philosophy

Bernard Allais, Director Technology Sales & services - smelter Aluminium
Part I: Overview of AP Technology reduction cell development philosophy

Key parameters of a smelter

The Platform approach (HP versus LE)

Greenfield, expansion and creeping
An aluminium smelter: two paramount indicators

CAPEX $/t pa

IRR = 12%

OPEX $/t pa
An aluminium smelter: Key parameters

Site/project
Infrastructure (port, road, ...)
Site conditions
Power block
Financial incentives
Unit cost (power, labour, ...)
Local currency

Technology
Site area
CAPEX productivity
Cell productivity
Plant productivity
Power efficiency
An aluminium smelter: Technology parameters

**Capex**
- Site area
- CAPEX productivity
- Project time

**Opex**
- Power efficiency
- Current efficiency
- Manpower productivity
- Cell life
- Performance over cell life
- Operational robustness
## An aluminium smelter: Technology parameters

<table>
<thead>
<tr>
<th><strong>Capex</strong></th>
<th><strong>Opex</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>For most smelters, there is « low variability » in investment for:</td>
<td>Modern Hall Heroult process « low variability » ratios:</td>
</tr>
<tr>
<td>Casthouse (ingots)</td>
<td>Alumina consumption</td>
</tr>
<tr>
<td>Anode Rodding shop</td>
<td>1.92 – 1.94 t / t Al</td>
</tr>
<tr>
<td>General workshops</td>
<td>Carbon consumption</td>
</tr>
<tr>
<td></td>
<td>0.395 – 0.440 t /t Al</td>
</tr>
<tr>
<td>Less than 20% smelter cost</td>
<td>International Prices</td>
</tr>
</tbody>
</table>
Aluminium smelter: Size matters…

Tomago 840 cells AP18 550 000t pa
Alouette 594 cells AP30 580 000t pa
336 cells AP60 540 000t pa

Steel – 25%
Boilerwork – 25%
Aluminium smelter: Time matters…

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
</tr>
</tbody>
</table>

- **Concept Study**
- **Feasibility Study**
- **Prefeasibility Study**
- **FEED**
- **Project Construction & Commissioning**
- **Start-up & ramp-up**
- **Financing**

- **Site work**

Typical 2 cells /day

Impact \( \sim +10 \text{ M$} / -7 \text{ days} \)
Aluminium smelter: Design matters…

Cell productivity, measured as production per square meter, is the key driver of a cell technology advantage

- higher production for cathode surface leading to
- higher production for potroom building

<table>
<thead>
<tr>
<th>Normalised (Production per m² of cathode surface)</th>
<th>AP24</th>
<th>AP40</th>
<th>AP60</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>97</td>
<td>100</td>
<td>117</td>
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</tbody>
</table>
Aluminium smelter: Cell design impact 1/2

<table>
<thead>
<tr>
<th></th>
<th>MWh/t</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Target</td>
<td>Best</td>
<td>Av. - High</td>
</tr>
<tr>
<td>Cell – DC Energy</td>
<td>11.8</td>
<td>12.8</td>
<td>13.3</td>
</tr>
<tr>
<td>Others</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Plant Consumption</td>
<td>12.3</td>
<td>13.4</td>
<td>14.0</td>
</tr>
</tbody>
</table>

Impact:

-1 x 120MW turbine

+ 48 cells

OPEX

30 M$ savings/y
Aluminium smelter: Cell design impact 2/2

Cell life
Performance over cell life
Current efficiency
Robustness

Impact:

+1% CE ~ + 4000 t/y
+1 y cell life ~ 4 M$/y savings
Aluminium smelter: Labour productivity

Cell productivity changes also lead another key driver of a smelter technology advantage, the labour productivity expressed in t/FTE/y

<table>
<thead>
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<th></th>
<th>AP24</th>
<th>AP40</th>
<th>AP60</th>
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<tbody>
<tr>
<td>t/FTE/y – approx. for 550 000t pa</td>
<td>330</td>
<td>480</td>
<td>650</td>
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</tbody>
</table>

**Impact:**

~ 15 M$/y savings
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Key parameters of a smelter

The Platform approach (HP versus LE)

Greenfield, expansion and creeping
AP60 and APXe cell platforms

Progress in AP technology

SEC (kWh/kgAl)

AP 50

Low Energy

AP Xe

High Productivity

AP 60

Same platform

Amperage (kA)
AP60 and APXe cell platforms

Optimal cell size

- Super-structure
- Alumina feed
- Shell
  - Pot control
  - Operating equipment
  - Building
- Busbars
- Gas flow
- Anode assembly
- Shell ventilation
- Cathode & lining

Common to both AP60 / APXe

Customised to AP60 / APXe
Technology platform application: Cell technology to be implemented

- NPV and Cut-off point influenced by power block size and country local costs

Difference in Net Present Value (Millions of USD)

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<thead>
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<tbody>
<tr>
<td>10</td>
<td>-300</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>-200</td>
<td>100</td>
</tr>
<tr>
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<td>-100</td>
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<tr>
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<td>70</td>
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<tr>
<td>80</td>
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Where in the world?

- HP platform
- LE platform
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Key parameters of a smelter

The Platform approach (HP versus LE)

Greenfield, expansion and creeping
Greenfield/ Major expansion

1st Phase: Greenfield

2nd Phase: Expansion
Capacity: x 2
CAPEX: < 80% GF
Creeping

3rd Phase: Asset Optimisation / Creeping

Building the business case <- Cell Technology capability & Existing plant bottlenecks

1. Establish the cell target (kWh –kA)
2. Assess the impact on plant
3. Define the pathways in potline
4. Estimate costs

Capacity ~3 -15%
CAPEX ~0 -10% GF
Conclusion

At investment time, technology can:

decrease CAPEX per tonne of capacity
decrease time to production
decrease future OPEX per tonne

During operation, technology can:
continuously improve asset utilisation
Thank you!

Delivering a responsible future!