SUSTAINABILITY IN THE CARBON SUPPLY CHAIN

Les Edwards
Rain Carbon Inc.
About the Presenter

- Les Edwards, Rain Carbon Inc. (les.edwards@raincarbon.com)
- Current role: VP Production Control and Technical Services
- Location: Houston, Texas
- Degrees: BSc. (University of Western Australia), MBA (Tulane University, New Orleans).
- Background: Rain Carbon/CII Carbon: 1998 - Present
  Comalco (now RioTinto): 1987-1998
- Regular presenter/contributor at TMS
  - Leader of TMS Anode Technology Course
  - 2 x Program Organizer of Electrode Technology Sessions
  - 4 x Light Metals Best Paper Awards
  - >30 Technical papers & 6 patents
Rain Carbon Inc.

Co-generated energy

TiO₂

Anodes

RCI’s calcining kilns

Calcined petroleum coke

Aluminum smelting

Aluminum

Green petroleum coke, a by-product of oil refining

RCI’s coal tar distillation plants

Coal tar pitch

Advanced Materials and Chemicals

Resins, modifiers, aromatic chemicals, LiB precursors and others

Rain Carbon upcycles byproducts into a wide range of value-added products

www.raincarbon.com
Presentation Outline

- Carbon raw materials and contribution to smelter CO₂ footprint.
- CPC production and opportunities to improve sustainability.
- Pitch binders and cathode lining materials.
- Bio-based carbon alternatives.
- Inert anodes.
- Summary and conclusions.
Carbon Use in Al Production (kg C/ton Al)

- Coal Tar Pitch (CTP)
- Calcined Petroleum Coke (CPC)
- Anode Production (550-600)
  - Gross Consumption
  - Recycled Anode Butts 140
  - Net Carbon Consumption (390-460)
- Spent Pot Lining (SPL)
- Cathode Blocks
- Alumina metal

CO$_2$, SO$_2$, PFC’s

Net Carbon Consumption:
- 1400-1650 kg CO$_2$
- 140 kg SO$_2$, PFC’s
- <10 kg CO$_2$, SO$_2$
Carbon Supply Chain
CO₂ Footprint Contribution

• What is the materiality of CPC, CTP and anode CO₂ emissions to total smelter footprint (cradle-to-gate)?

* Modeling based on GaBi Professional database

Will do a deep dive into CPC production which is largest contributor to anode footprint prior to use.
CPC Production Overview

- Combustion of volatile matter (VM) in GPC and loss/combustion of coke fines (~10%) generates a large amount of heat.
- Emissions include CO$_2$, H$_2$O, SO$_2$, NOx and solid particulate matter (SPM).
Example: Vizag Calciner

- Located in Visakhapatnam on East coast of India (Andhra Pradesh State).
- Rain Carbon and India’s largest calciner with annual CPC production of 500 kt/yr.
- 2 x 68 m long rotary kiln calciners.
- Requires ~700 kt/yr of GPC.

ICSOBA 2020: Sustainable CPC Production at the Vizag Calciner
Process Overview

Addition of Waste Heat Recovery and FGD Significantly Improves Sustainability
### Key Input/Output Data

#### Inputs

<table>
<thead>
<tr>
<th>Input</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPC Feed Tons (Wet Tons)</td>
<td>MT</td>
<td>679,282</td>
</tr>
<tr>
<td>Hydrated Lime Use</td>
<td>MT</td>
<td>20,010</td>
</tr>
<tr>
<td>Power Use by Plant</td>
<td>MWh</td>
<td>50,897</td>
</tr>
<tr>
<td>Thermal energy from fuel combustion</td>
<td>MWh</td>
<td>5,995</td>
</tr>
</tbody>
</table>

#### Outputs

<table>
<thead>
<tr>
<th>Output</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPC Production</td>
<td>MT</td>
<td>504,660</td>
</tr>
<tr>
<td>Power generation</td>
<td>MWh</td>
<td>309,422</td>
</tr>
<tr>
<td>CO₂ Emissions</td>
<td>MT</td>
<td>365,061</td>
</tr>
<tr>
<td>SO₂ Emissions from Kiln to Pyroscrubber</td>
<td>MT</td>
<td>9,766</td>
</tr>
<tr>
<td>SO₂ Emissions from Cold Stack</td>
<td>MT</td>
<td>146</td>
</tr>
<tr>
<td>Sulfated Lime Byproduct</td>
<td>MT</td>
<td>31,895</td>
</tr>
<tr>
<td>Average Stack SO₂ Concentration</td>
<td>mg/Nm³</td>
<td>55</td>
</tr>
<tr>
<td>Average Stack SPM Concentration</td>
<td>mg/Nm³</td>
<td>60</td>
</tr>
<tr>
<td>Average Stack Flow Rate</td>
<td>Nm³/h</td>
<td>180,000</td>
</tr>
</tbody>
</table>

- CO₂ emissions significant.
- Plant uses ~15% of energy generated and exports 85%.
- Amount power equivalent to power plant burning 115,000 tons coal/yr.
- SO₂ removal efficiency very high at ~98%.
Product Carbon Footprint: CPC

Product Carbon Footprint of CPC (Scenario 1)

<table>
<thead>
<tr>
<th>Global Warming Potential [kg CO₂-eq.] per Functional Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>-300</td>
</tr>
</tbody>
</table>

- Lime for Desulfurization
- Process emissions from calcination
- Lubricants from refinery (Dedust oil)
- Petroleum coke from refinery
- Thermal energy from combustion of heavy fuel oil
- Electricity generation

CPC Production [kg CO₂eq.]

<table>
<thead>
<tr>
<th>Reference data for CPC production</th>
<th>CPC produced at Rain Carbon Vizag facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>445 kg CO₂e</td>
<td>248 kg CO₂e (-44%)</td>
</tr>
</tbody>
</table>

Functional Unit (FU) = 1 ton Aluminum

- Modeling with GaBi database.
- Power exported to grid receives CO₂ credit/offset.
- India national grid emissions factor: 0.82 tons CO₂/MWhr power.
Carbon Footprint - Anodes

Product Carbon Footprint of Anode Production including CPC (Scenario 2)

2021 collaborative study with smelter & GPC supplier underway to better quantify emissions.

Goal is to compare to model output.

<table>
<thead>
<tr>
<th>Anode Production [kg CO₂ eq.]</th>
<th>Global Warming Potential [kg CO₂ eq.] per Functional Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPC from calcination (Reference)</td>
<td>445 (770 kg CO₂e)</td>
</tr>
<tr>
<td>Calcination process (Vizag)</td>
<td>99 (573 kg CO₂e (-26%))</td>
</tr>
<tr>
<td>GPC from refinery</td>
<td>149</td>
</tr>
<tr>
<td>Coal tar pitch from distillation</td>
<td>84</td>
</tr>
<tr>
<td>Anode production</td>
<td>241</td>
</tr>
</tbody>
</table>

Reference data for CPC production:
- 770 kg CO₂e

CPC produced at Rain Carbon Vizag facility:
- 573 kg CO₂e (-26%)
Other Improvements in Calcining

• A shaft calciner offers more sustainable CPC production vs rotary kiln.
  – GPC fines loss is lower (3-5%) so more tons CPC/ton GPC.
  – Lower fines loss = less CO₂ and SO₂.
  – Closed loop water cooling system for CPC.

• New RCI calciner will have NH₃ scrubber = NH₄SO₄ byproduct.
Anhydrous Carbon Pellets

• An innovation aimed at further reducing fines loss and emissions.
• Enhances product quality with production of higher bulk density pellets.
• Construction of commercial plant underway.
Sustainability Issues With Coal Tar Pitch Binder Use

- Use of CTP has come under increased regulatory pressure due to PAH content (carcinogenic).
- Most smelters use CTP in liquid form to reduce OH&S risk but more controls being added.
- Significant work done to explore lower PAH pitches
  - Petroleum pitches have 10x lower PAH (EPA) levels. Hybrid pitches are CTP/PP blends. LM 1971 – 2019, ICSOBA 2019.
  - Hybrid pitches used successfully in past in prebake smelters and extensively in Soderberg smelters.
  - High and very high SP pitches (130-180°C) promising but economics have moved in wrong direction LM 2015, 2017.
Developments with Cathode Lining Materials

• Ramming pastes traditionally produced with CTP.

• A significant number of suppliers offer “green” ramming pastes using binders like molasses or very low PAH CTP materials (like CARBORES®).
  – Is now a regularly used material in the industry.
Bio-Carbon Alternatives

• Substantial work done in multiple studies to evaluate bio-derived carbons.
  – Hydro Aluminium: LM 2010 (charcoal).

Challenging due to low density, high reactivity, low coking value etc.
Inert Anodes

• Now 20 years since 2001 TMS keynote session on inert anodes.

• Triggered by Wall St. report issued in 2000 titled “An Aluminum Revolution”.

• Full commercial implementation projected within 2-3 yrs.

• Inert anodes remain very desirable goal for industry but technology development is complex and challenging.
Inert Anodes

• Will eliminate smelter CO₂, SO₂ and PFC process emissions + carbon supply chain emissions.

• ELYSIS approach combines inert anodes with wettable cathodes.

• Rusal has large IA program.

• Energy penalty vs carbon anode cells significant (Solheim LM 2018).

• Supply chain emissions from IA & wettable cathodes not known.
Summary and Conclusions

- Carbon supply chain emissions (CPC + CTP + anode production) contribute ~15% to hydro based smelter CO₂ emissions and ~4% for smelters using coal powered smelter emissions.
- Addition of waste heat recovery and FGD systems improves sustainability of CPC production.
- Efforts to find more sustainable carbons will continue but limited success to date. Eco-friendly ramming pastes now routinely used.
- Carbon anodes likely to remain in use for foreseeable future but work on inert anode development will continue.
- There are many opportunities to reduce carbon related emissions and the industry should continue to pursue these.