SMELTER OF THE FUTURE

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Contents

• Introduction:
  Consequences of the Paris climate agreement for the aluminium industry

• Smelter technology response:
  – Optimizing the Hall-Heroult process
  – Direct CO\textsubscript{2} emissions

• Opportunities through Industry 4.0 and digital technology
01 Introduction
The Paris agreement: ambitious climate targets

The Paris agreement will be instrumental in shaping the future technology development

- Target: Reduce global warming to «well below» 2 degrees, aiming for 1.5
- Significant actions will be needed in all sectors
- EU reaction will influence industry politics going forward
Increased urgency and focus on industrial emissions

Reducing industrial CO2 emissions
- Industry and heavy transport emit 60% of total in 2040 – in 2 degrees scenario
- CO2 budget (IEA): limited to approx. 11GT/y

Intensified competition among materials
- Environmental footprint takes hold as a differentiating quality – competing materials have significant potential for low footprint

Customer driven competition
- Competition btw peers on footprint
- Requirements from customers on transparency and low footprint

Early reductions may hedge future pressure?

Environmental credentials are fragile?

Market positions change and customers increasingly differentiate suppliers?

Plastics
- Coal content in Al

Steel
- New competitors (e.g. wood)

New competitors (e.g. wood)
Energy related emissions and process emissions reductions

• In a 2 degrees scenario, emissions need to be reduced by 50%, compared to Paris pledges
• In a below 2 degrees scenario, emissions need to be reduced by 75%
Our response – global view

Production processes, recycling and aluminium in the use-phase are all important

Production technology

Reduce energy consumption and emissions in our own processes

Recycling

Reduce waste and recover energy and value from used products through recycling

Aluminium in use

Develop products and solutions that reduce energy consumption and emissions in the use-phase
Our response - industry production view

Emissions from production steps in the whole value chain

Direct and indirect smelter emissions
Ton CO2 / ton aluminium

- South Africa: 18
- India: 16
- United States: 14
- China: 12
- Australia: 10
- Bahrain: 8
- UAE: 6
- Qatar: 4
- Saudi Arabia: 2
- Russia: 1
- United States: 0

Hydropower
- Coal
- Gas

Hydro’s certified 4.0 low-carbon aluminium

Maximum 4.0 kg CO2/kg Al

- Bauxite
- Alumina
- Anode
- Power generation
- Smelting
- Casting
- Other

Source: CRU
Our response – smelter view
Probably not one solution, but several initiatives spread out in time

Emission reductions, illustrative

- Implement BAT/BAP
- New zero direct emission technology
- Bio carbon?
Primary aluminium production can come under pressure

Aluminium industry going in the wrong direction – action needed
02

Smelter technology response
Is it possible to produce aluminium with 0 carbon footprints?

Prerequisite: All energy sources must be based on renewable energy

**New technology in «new» plants:**
- Inert anodes
- Chloride process
- Other exotic processes

**Build on the HH-process and existing plants:**
- Optimise operations
  - Digital/I4.0 stability
  - PFC control
- Energy consumption
- Bio carbon
- CO₂ capture – CCS/CCU

We will probably have Hall-Heroult plants for decades

**New technology:**
- 6000 $/t
- 70 Mt
- 400 B$
A new approach to the chloride process

Combine the chloride process with recycling of CO$_2$
**CO₂ capture and use – an option for HH smelters**

CCU is immature, but a wide range of options may become relevant

<table>
<thead>
<tr>
<th><strong>CO₂ capture concepts</strong></th>
<th><strong>CO₂ utilisation concepts</strong></th>
<th><strong>Solutions will be smelter-specific</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low concentration capture</td>
<td>Mineralisation</td>
<td>Definition of options driven by</td>
</tr>
<tr>
<td>Direct air capture concepts may be adapted to smelter off-gas</td>
<td>Mineralisation of CO₂ using local minerals to stable substances (e.g. carbonates) for use in products or to storage</td>
<td></td>
</tr>
<tr>
<td>- BHP recent investment in start-up</td>
<td></td>
<td>• Local resources</td>
</tr>
<tr>
<td>MEA capture</td>
<td>Chemicals</td>
<td>• Potential technology and value chain partners</td>
</tr>
<tr>
<td>Capture concepts developed for higher CO₂ concentrations are maturing</td>
<td>Conversion or inclusion of CO₂ into commodity chemicals, plastics or fuels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biologic conversion</td>
<td>• Smelter size, -configuration and – age</td>
</tr>
<tr>
<td></td>
<td>Conversion of CO₂ in biological processes. Algae processes producing bio mass e.g. for fish farming feed</td>
<td></td>
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</tbody>
</table>
Energy consumption - Karmøy Technology Pilot

60 HAL4e cells in operation – stabilizing operational performance

- 1st cell started January ‘18, all 60 cells by June ‘18
- Current efficiency and energy consumption on track towards verification of targeted values
- Optimization ongoing for performance
- Cathode performance according to expectations
- SoftSensor (Digital Twin) fully implemented and performing well
- Several Industry 4.0 elements under implementation
- PTM functionality not yet fully implemented, but being resolved (cover handling)
- Early operational challenges largely solved
03 Industry 4.0
We all seem to have the same vision of an autonomous Smelter 4.0
Smelter 4.0 vision – the autonomous smelter of the future

Karmøy technology pilot is step 1 towards the vision - control platform, connectivity and automation
Exploring improvement opportunities within automation

A substantial part of the portfolio targets HSE – a good way to create engagement and support

<table>
<thead>
<tr>
<th>Automatic casting of anode</th>
<th>Automatic charging and skimming</th>
<th>Pit monitoring</th>
<th>Safe zone monitoring – camera and personnel detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butts cleaning by robot and 3D scan</td>
<td>Automated Guided Vehicles (AGV)</td>
<td>Pit stripping</td>
<td>Mobile maintenance worker</td>
</tr>
</tbody>
</table>

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Machine learning/AI-engine/advanced analytics

- Many nice examples demonstrating the power of machine learning

- Will these techniques replace the need for domain competence?
Digital twins

Optimizing and stabilizing production by combining physical models and advanced analytics of process data
Trusted Data Layer

Data and results from analytics is made available for managers, operators, maintenance resources, process engineers and researches through Information portals, Analytics workbenches and Data science tools.

Intelligence Layer

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Data layer where data is managed and stored long term for use in various analytics use cases. Data transfer from source system are implemented based on use cases, but re-used to support new use cases.

Data sources

Data from APICS, cell control systems, sensors etc. are securely transferred to the cloud either real time or in batch (e.g. hourly or daily).
**Autonomous Cell**

**Sensors & Measurement**

- **Manual ACDM**: In-house version being implemented in all smelters
- **IACM**: In-house version being piloted in 2 smelters
- **Fiberlab/Starprobe**: Vendor-solutions implemented in all smelters
- **Smart breakers**: Development work to utilise breaker signals
- **PTM and indirect**: Development on how to utilise PTM and use indirect measurements
IACM - Individual Anode Current Measurements

If installed on every anode: tool to control PFC & big data insight – but needs to be low-cost!
The role of suppliers

- Technology development:
  - Fast, innovative, disruptive
  - New players (start-ups and vendors from other industries)
  - Traditional suppliers with pure mechanical solutions not competitive

- Consequence: Difficult to be at the forefront

- Will this lead to innovations in business models and collaboration models?
  - More pre-competitive collaboration
  - Development consortia of suppliers and producers
  - Cross-licensing of IP
  - Industry standards (Alu industry is small and scale is needed to bring down cost of sensors etc.)
Virtual control room
RTA
Aluminium Operations Centre

- Reduction:
  - 3000 cells managed from the Saguenay region (Quebec, Canada)
  - Technical support to Rio Tinto’s smelters worldwide, 24/7
  - Optimizing output of the different existing technologies
  - Centralized metal management for Saguenay area
  - Best practice sharing
  - Synergies implementation
  - Operations standardization

AOC activities and organization

Analysts real-time technical support
- Monitor continuously (24/7) pots of all supported smelters. (Graphs, alarms, measures, etc.)
- Identify deviations, diagnose issues, and prioritize actions.
- Provide coaching and technical support to operators.
- Remotely participate in technical meetings / LEAN info centers of supported sites.

AOC in the near future ...

Maximize synergies between disciplines
Virtual control rooms in other industries

Similar thinking in the oil & gas industry

Integrated Operation Centre – How does it work?

Field

IMS/Time Series Data
Equipment maintenance and event data
Production data
Local, regional or global external data (e.g. satellite data)

Data transfer from

Decision support to field

Integrated Operation Centre

Dashboard for monitoring and support
Cloud based architecture
Multidiscipline work force
Machine learning
Clear, common targets

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Concluding remarks

- Elements of the “Smelter of the future”
  - Zero direct CO$_2$ emissions
    - Probably more than 1 solution and a step-wise approach
  - Autonomous
    - No manual interference
    - Autonomous control system (digital twin)

- Short/medium-term development focus
  - Various approaches to reduce direct CO$_2$ emissions
  - New process measurement sensors
  - More automation like anode change and AGVs
  - Digital twins combining domain competence and data science
Hydro

We are aluminium