Hydro Technology

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Our long-term strategy for higher value creation

Better Bigger Greener

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Hydro overall technology strategy

The three pillars of Hydro's technology strategy

1 Operational excellence and utilization of technology



2 Electrolysis technology – the heart of an Al company

3 Product solutions supporting future growth in Al demand and sustainability




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Transforming the way we use energy

Energy efficient low-emission electrolysis	Lighter vehicles	Zero energy buildings	Increase solar energy efficiency	Packaging that reduces waste	Recycling and reuse
					
Reduce energy consumption, improve cell efficiency, CO2 capture ready cells	Reduce fossil fuel consumption and GHG emissions by making cars lighter	Reduce energy consumption and GHG emissions from buildings	Reduce fossil fuel emissions by contributing to making solar energy solutions lighter, simpler and cheaper	Reduce GHG emissions from food production by conserving and protecting food better	Reduce waste and energy consumption in a world of limited resources by recycling aluminium endlessly
Primary production	**Aluminium in use**				**Recycling**

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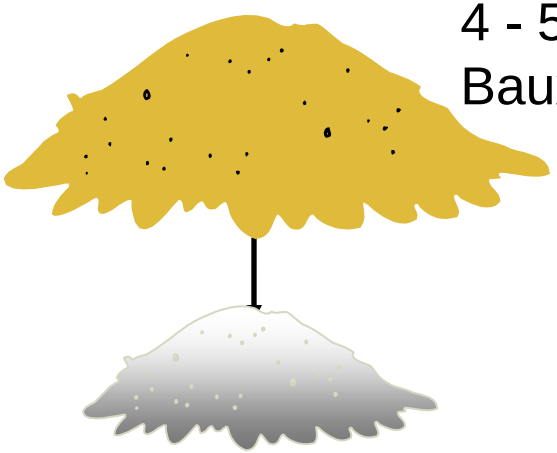
Raw materials to produce 1 kg aluminium



4 - 5 kg
Bauxite

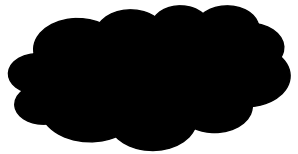
$Al_2O_{3,\ Electrolyte} + x\ C \longrightarrow 2\ Al + mCO_2 + nCO$

2 kg
Aluminium oxide

+

0.5 kg
Carbon

+



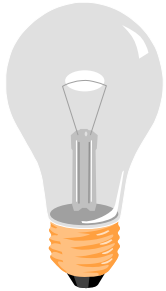
1,5-2 kg

50 g
Aluminium fluoride

+

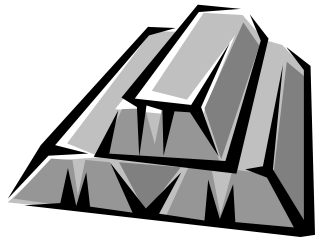
50 g
Cryolite

+



13 - 15 kWh
Electrical energy

=



1 kg
Aluminum

Figures are approximate – depending on technology

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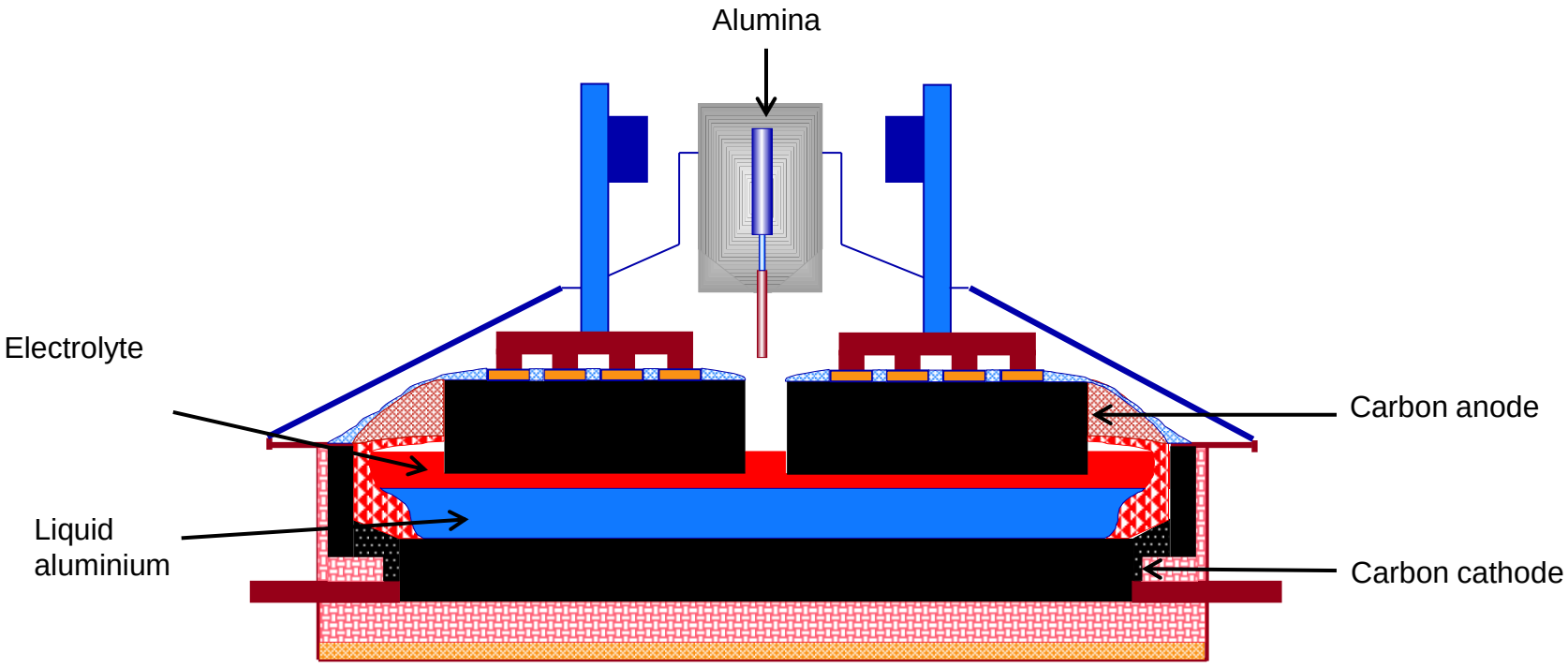
Aluminium Reduction cell



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Technology development for Hydro smelters

Traditionally strong focus on amperage increase

120 kA

250 - 316 kA

295 - 314 kA

400- 450 kA

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Sunndal
390/515 kt Al pr. year

Qatalum site preparation

10 million tonnes of landfill

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The world’s largest aluminium plant built in one stage

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R&D Organization

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R&D Locations in decentralized structure

RTD Reference Center,
Sunndalsøra in Norway

Sunndal
Raufoss
Årdal
Oslo
Karmøy
Porsgrunn
Tønder
Eupen
Neuss
Bonn
Ulm
Toulouse

Holland, MI

HAL4e Reference Center,
Årdal in Norway

Doha

Hydro's die innovation center,
Eupen in Belgium

Technal Brand Development Centre,
Toulouse in France

Hydro Research and Development Center,
Bonn in Germany

- Primary Metal Technology hubs
- Mid- and Downstream R&D units

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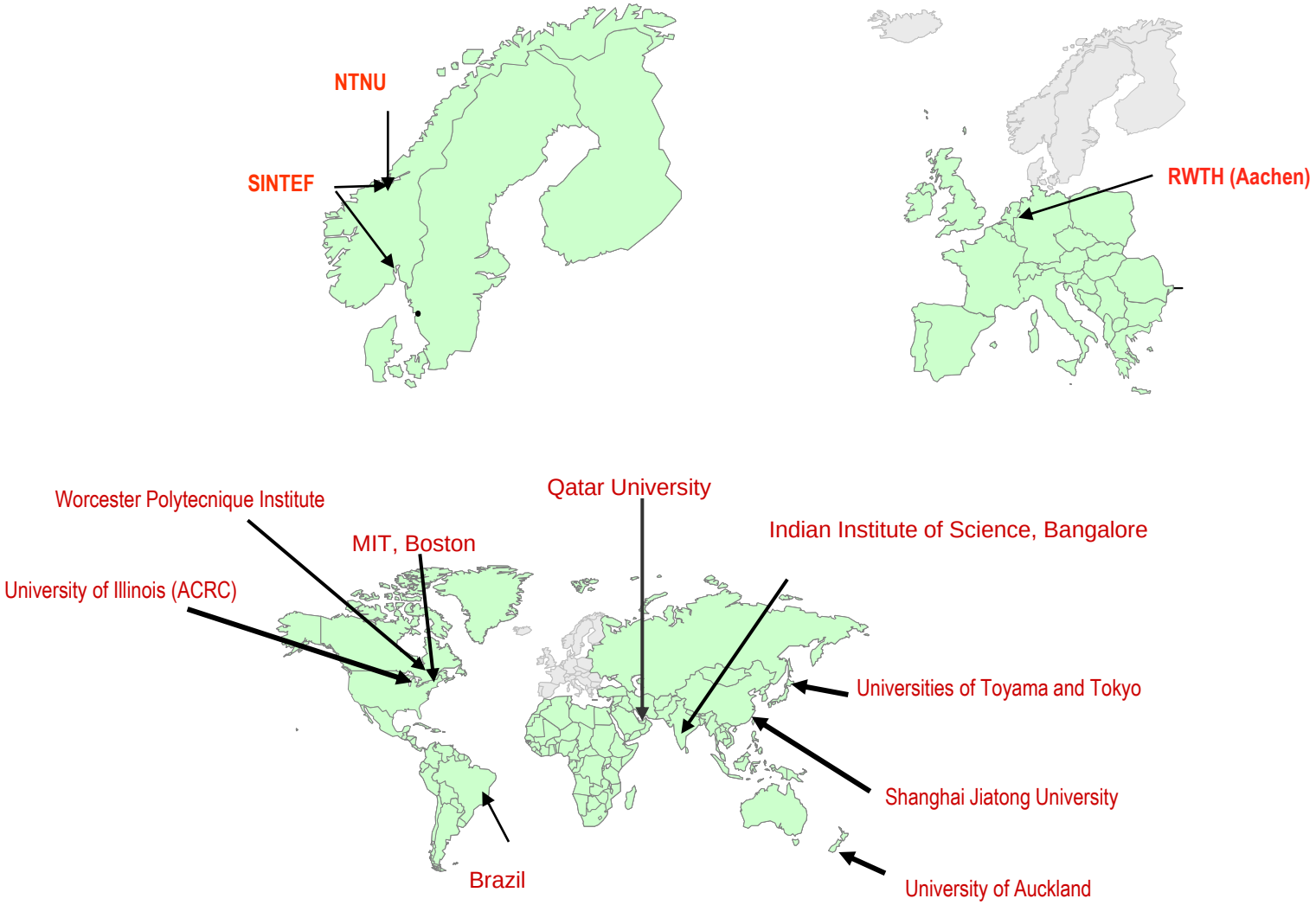
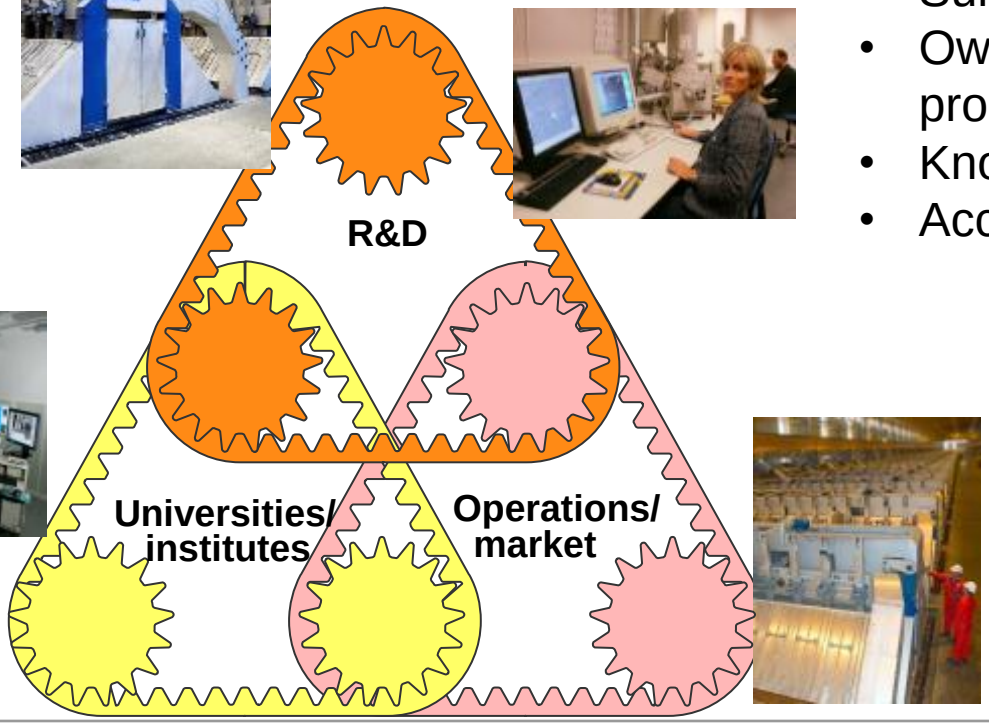
Strategic University/R&D- partners



Academic network is part of R&D value creation and innovation



- Active role in professorships
- Funding PhD and master thesis
- Summer jobs
- Ownership in joint research programs
- Knowledge sharing
- Access to plants

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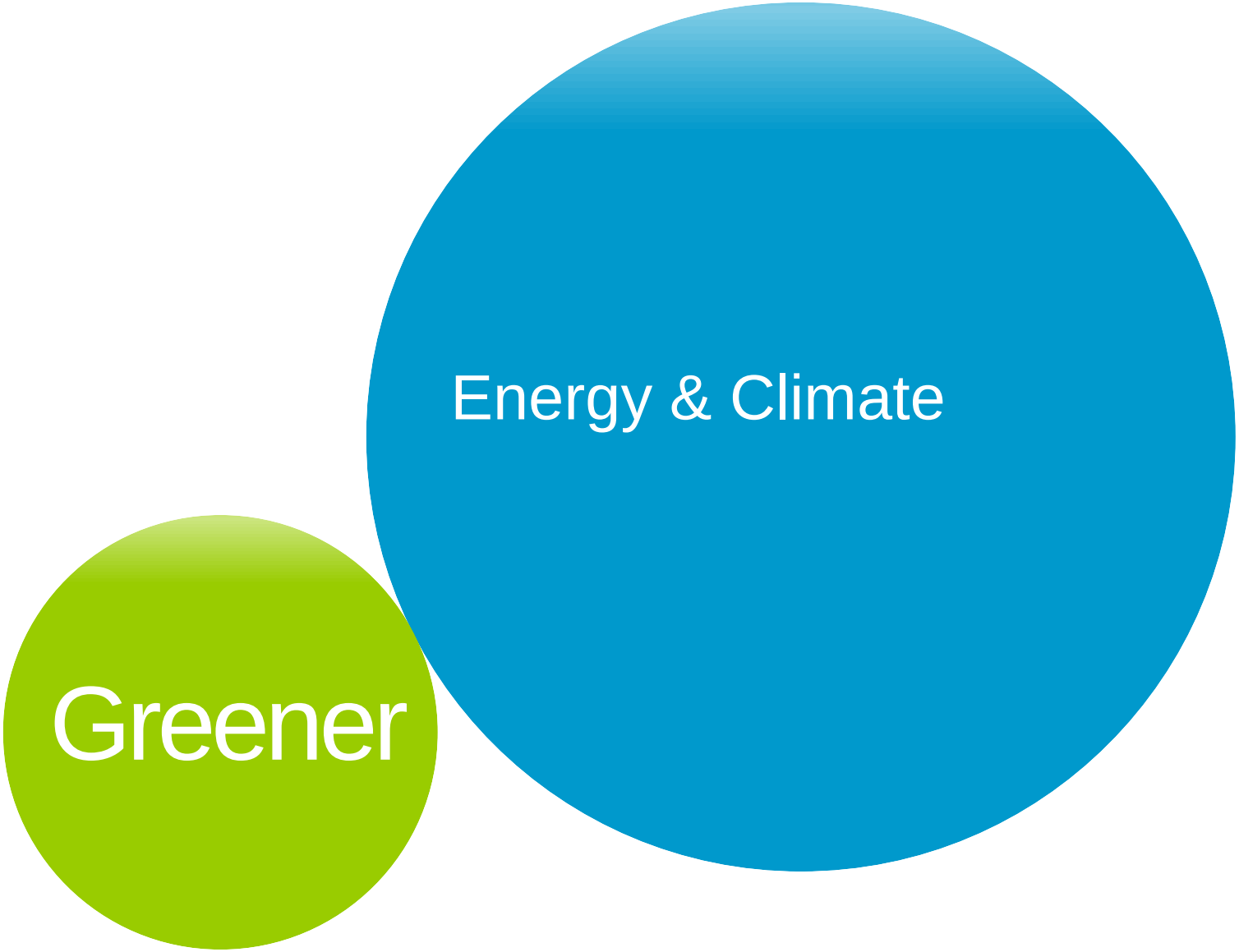

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We have established industry's most ambitious climate strategy

Supported by the three pillars of Hydro's technology strategy

Energy and primary production

Reduce emissions, increase efficiency

Aluminium in use

Maximize user-phase benefits

'End-of-life'

Increase recycling, back to the loop

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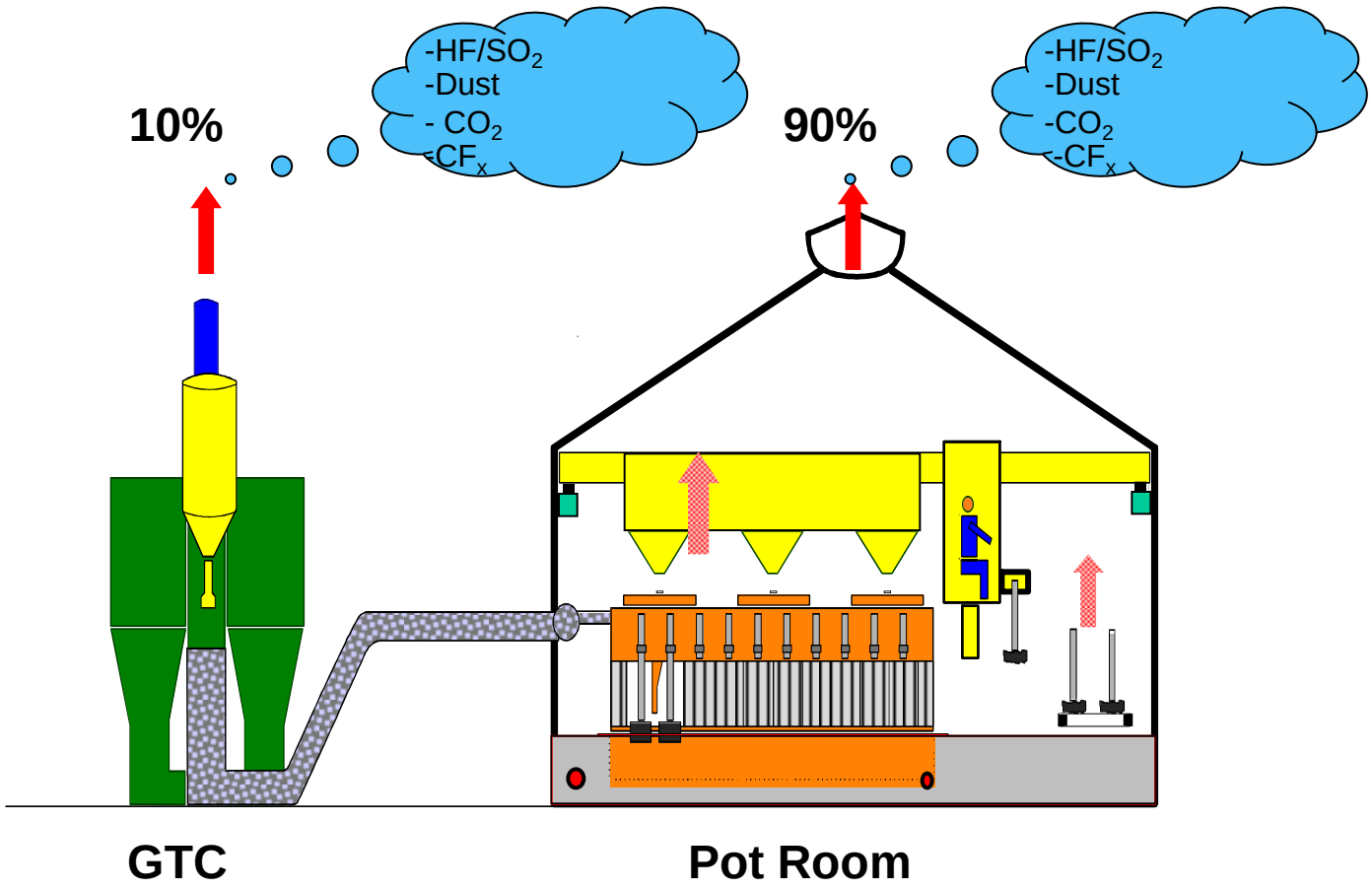
Emissions to air from electrolysis



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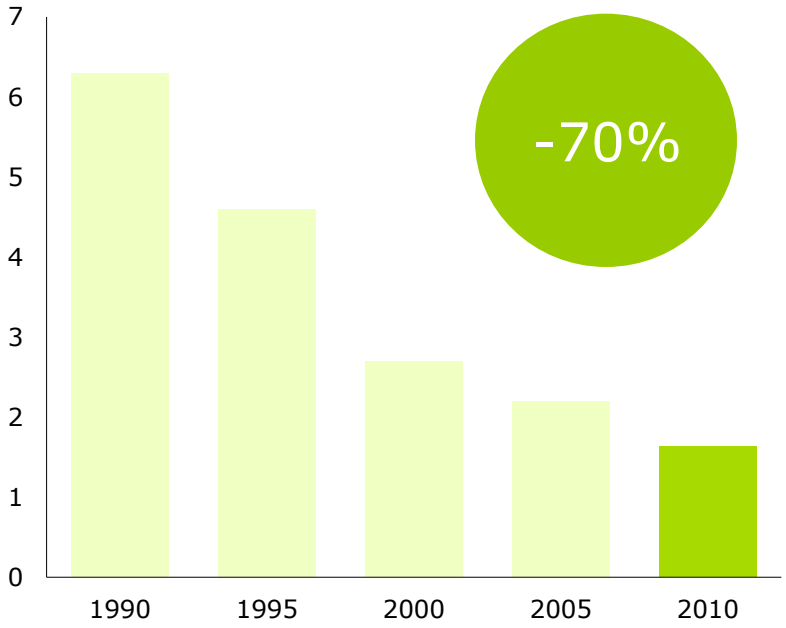
Hydro meets climate challenge

Major reductions in CO_2e- and energy consumptions

Lower emission from Hydro plants

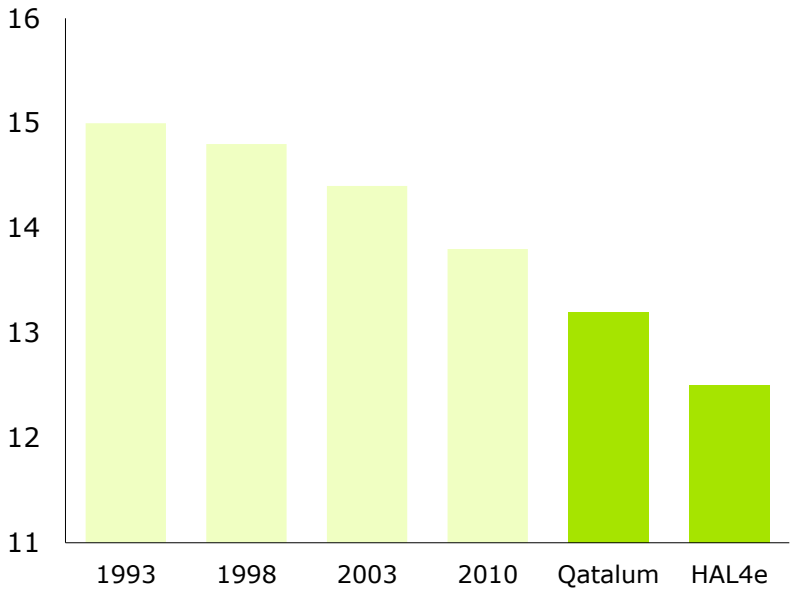
Kg CO_2e / Kg aluminium



Average specific emissions from Hydro's Norwegian smelters

Lower energy consumption in Hydro plants

KWh / Kg Aluminium



Average specific energy consumption from 100%-owned Norwegian smelters

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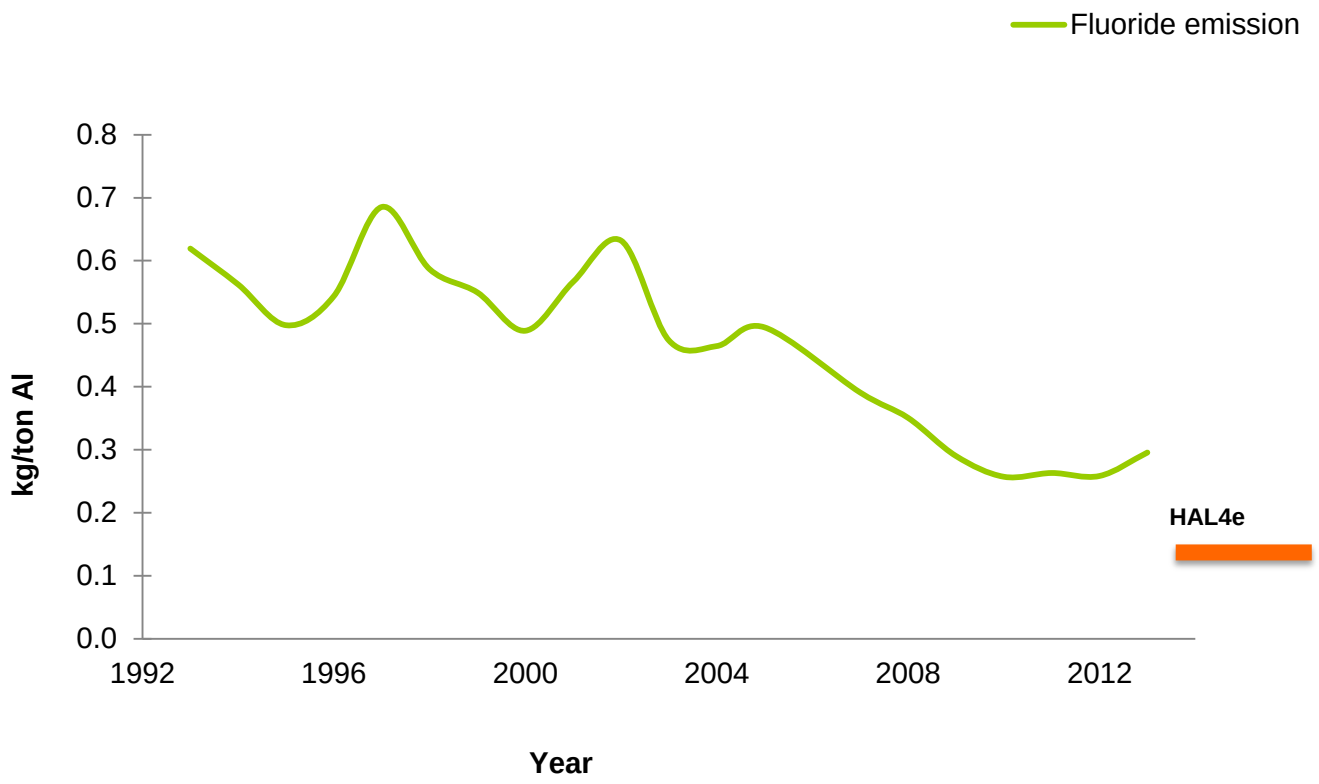
Norwegian smelters 1993-2013

Fluoride emission to air



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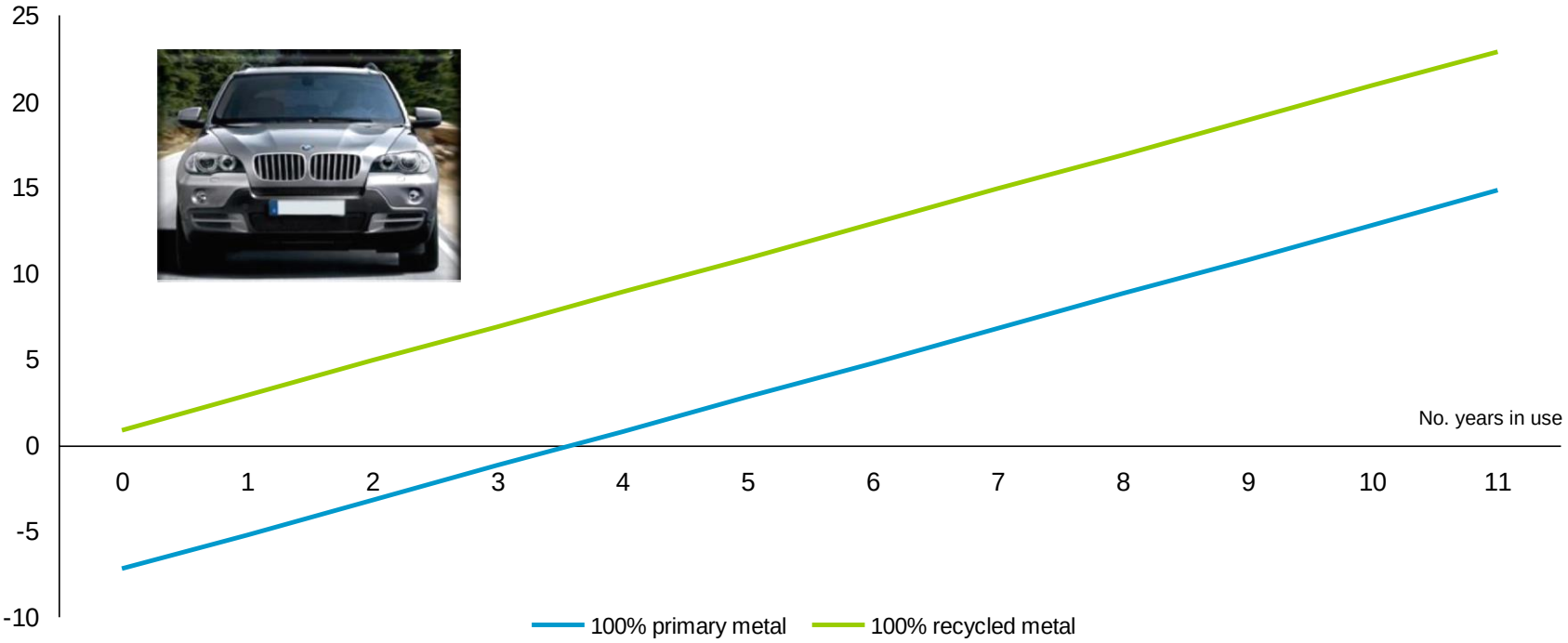
Lifecycle perspective: Replacing steel with aluminium in vehicles helps cut CO_2 emissions

Kg CO_2 saved/kg aluminium replacing steel in cars*



* Incl. Full value chain CO_2 emissions in production of (primary and recycled) steel and aluminium
Assuming 1 kg of aluminium replacing 2 kg of steel in car applications

Source: IFEU

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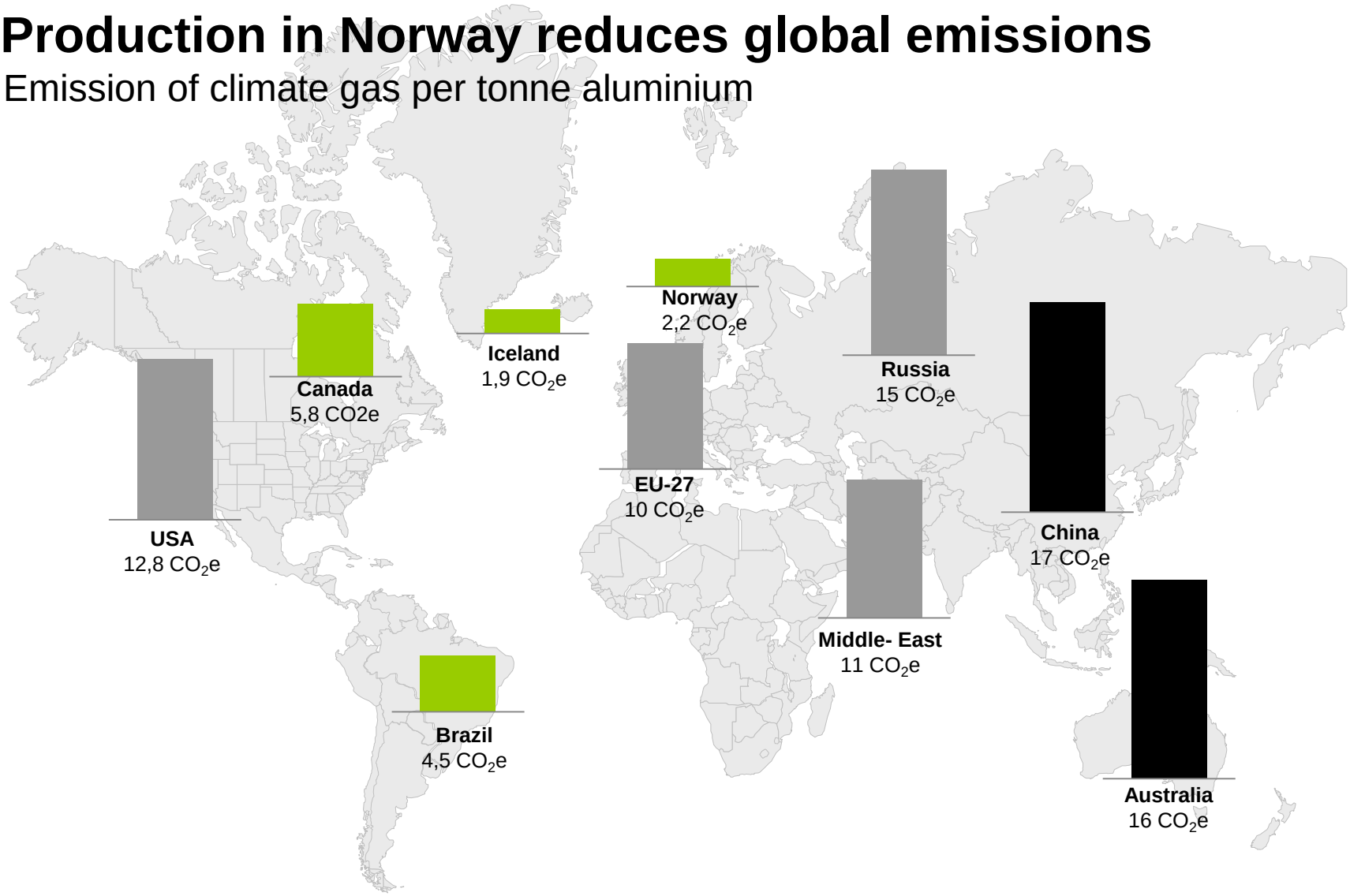
Production in Norway reduces global emissions

Emission of climate gas per tonne aluminium



Source: Institut für angewendte Ökologie (Öko-institut e.V.) , report to the EU commission, 12. May 2011. Figures from 2008. Brazil: national energy-mix.

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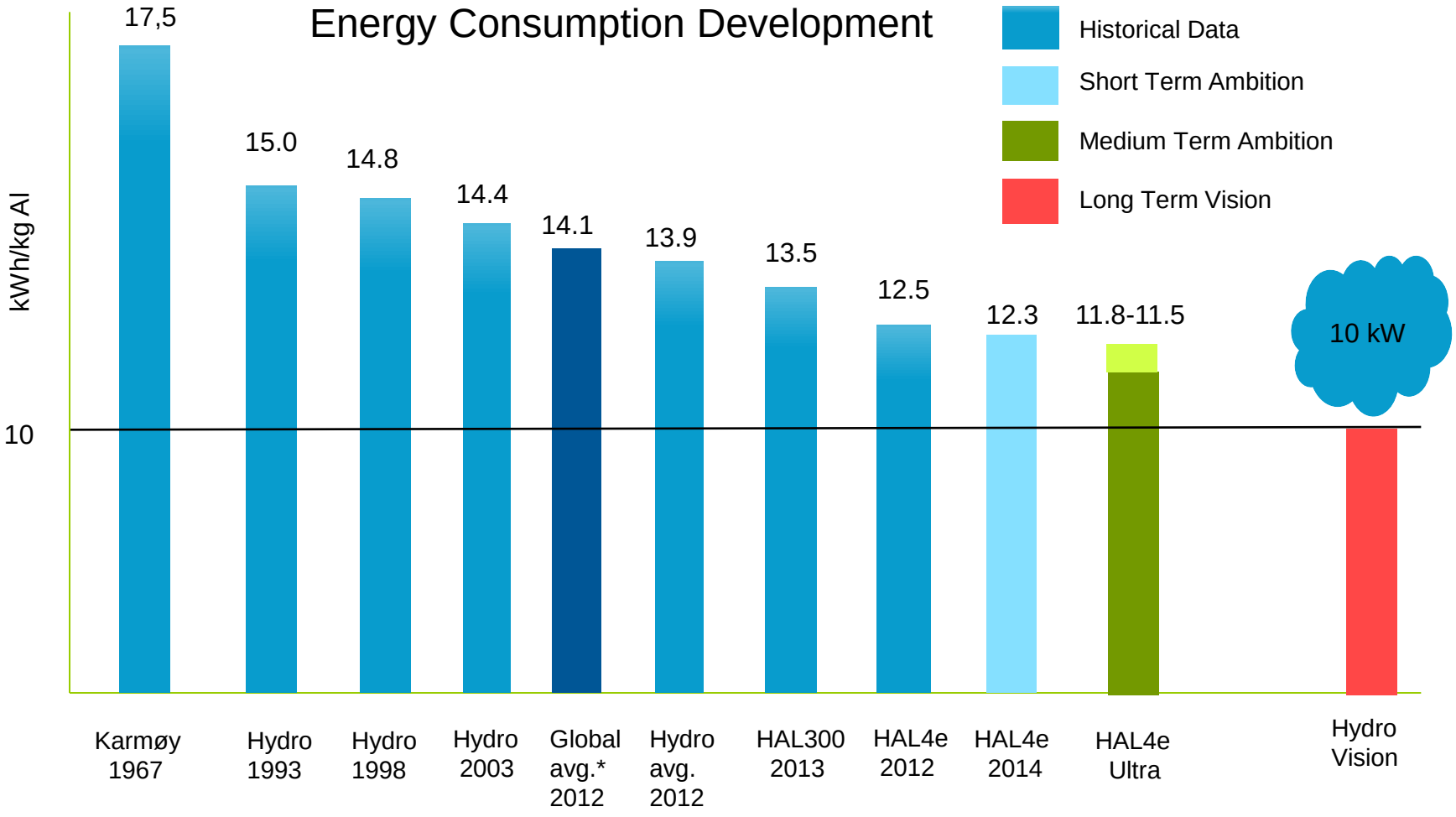
Hydro Smelter Technology – Energy efficiency



* Global average ex. China

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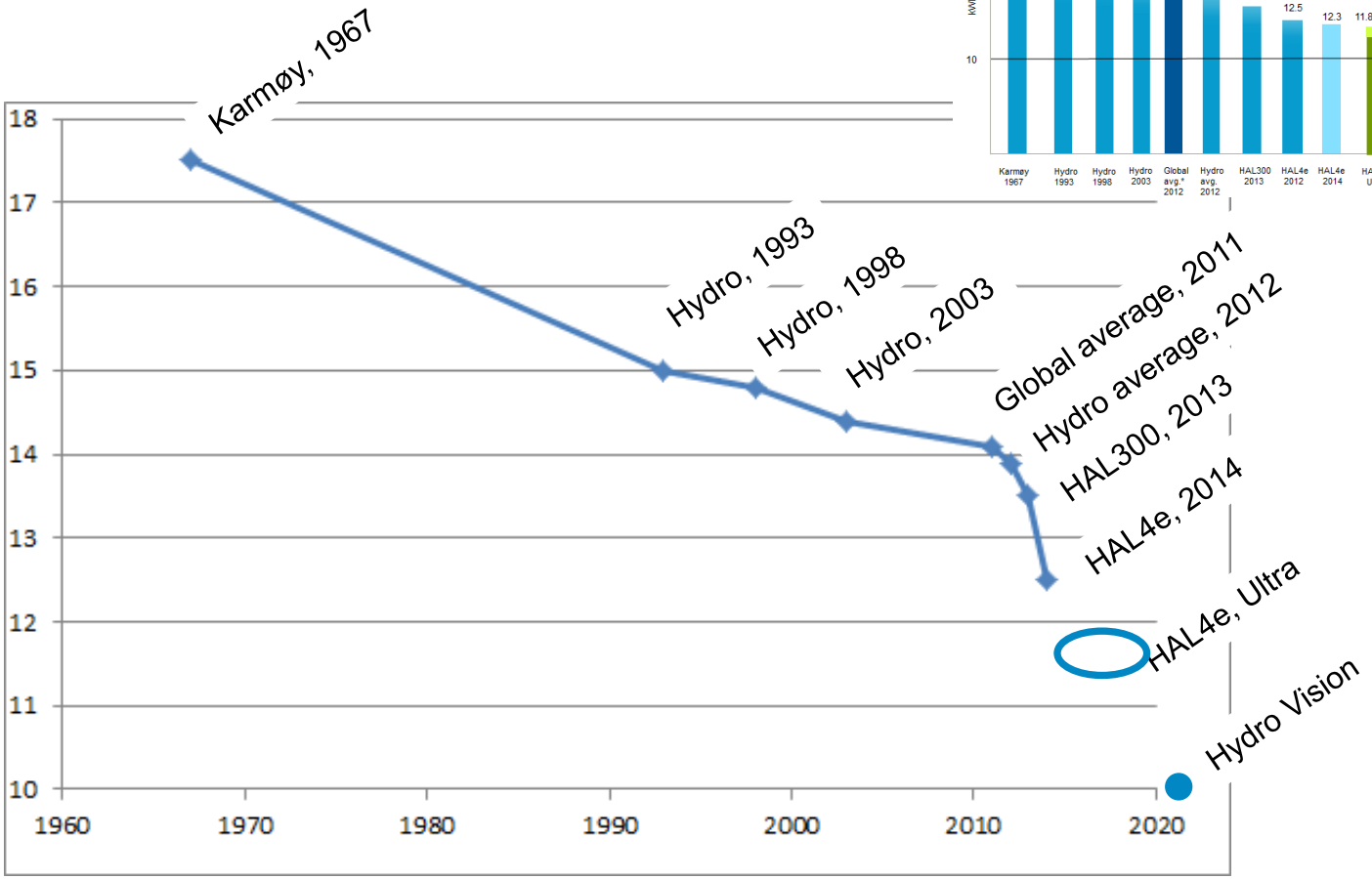
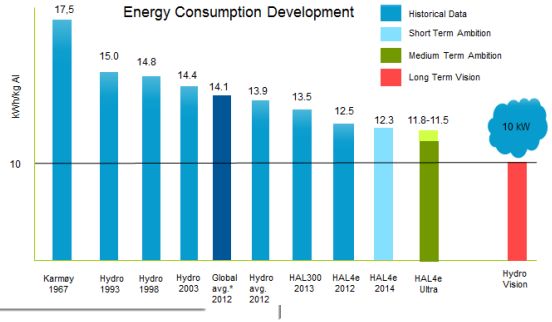
Systematic effort in order to reduce energy consumption





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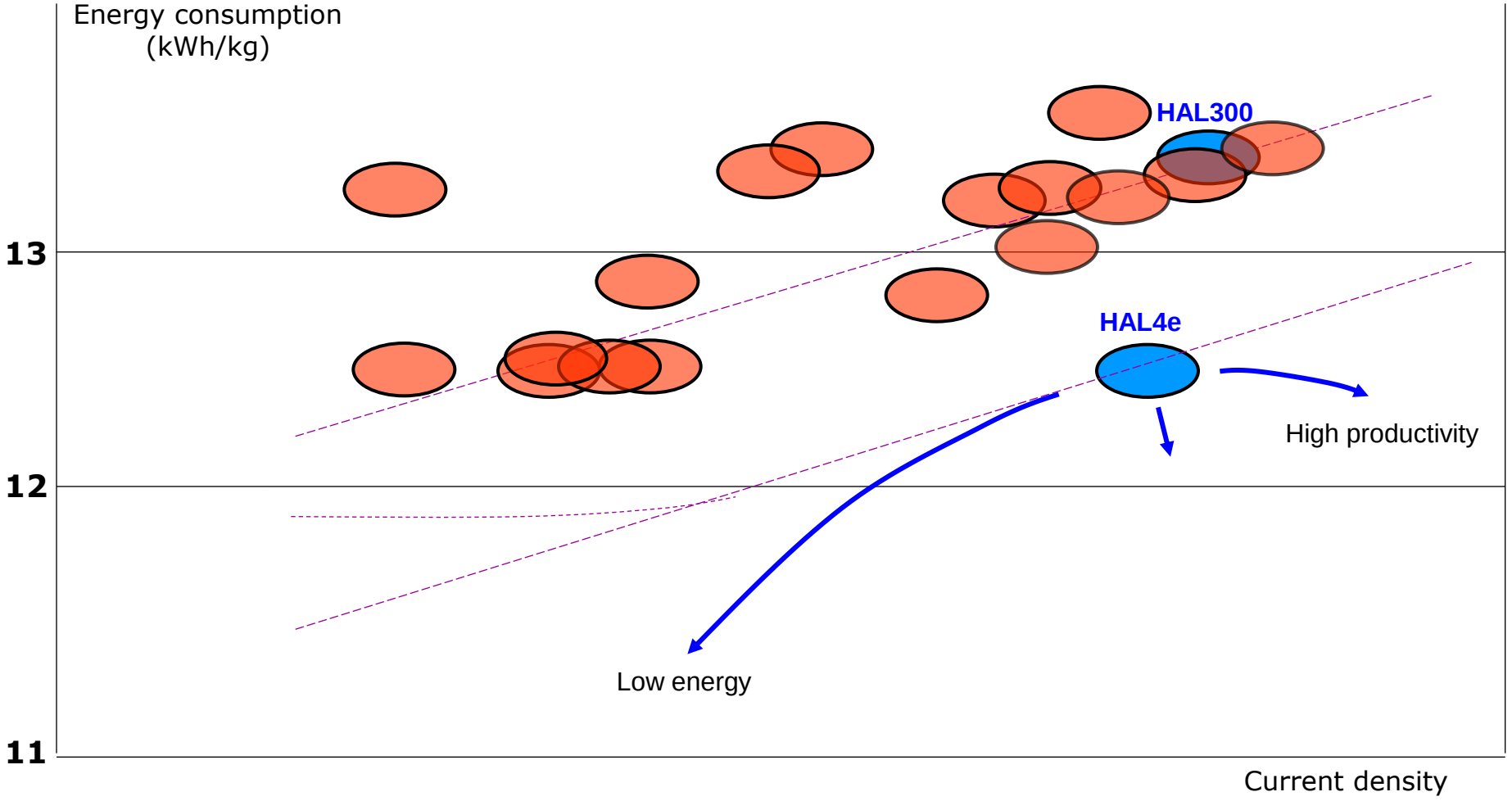
Targeting high productivity & low energy consumption



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Cell Technology
HAL4e

Better

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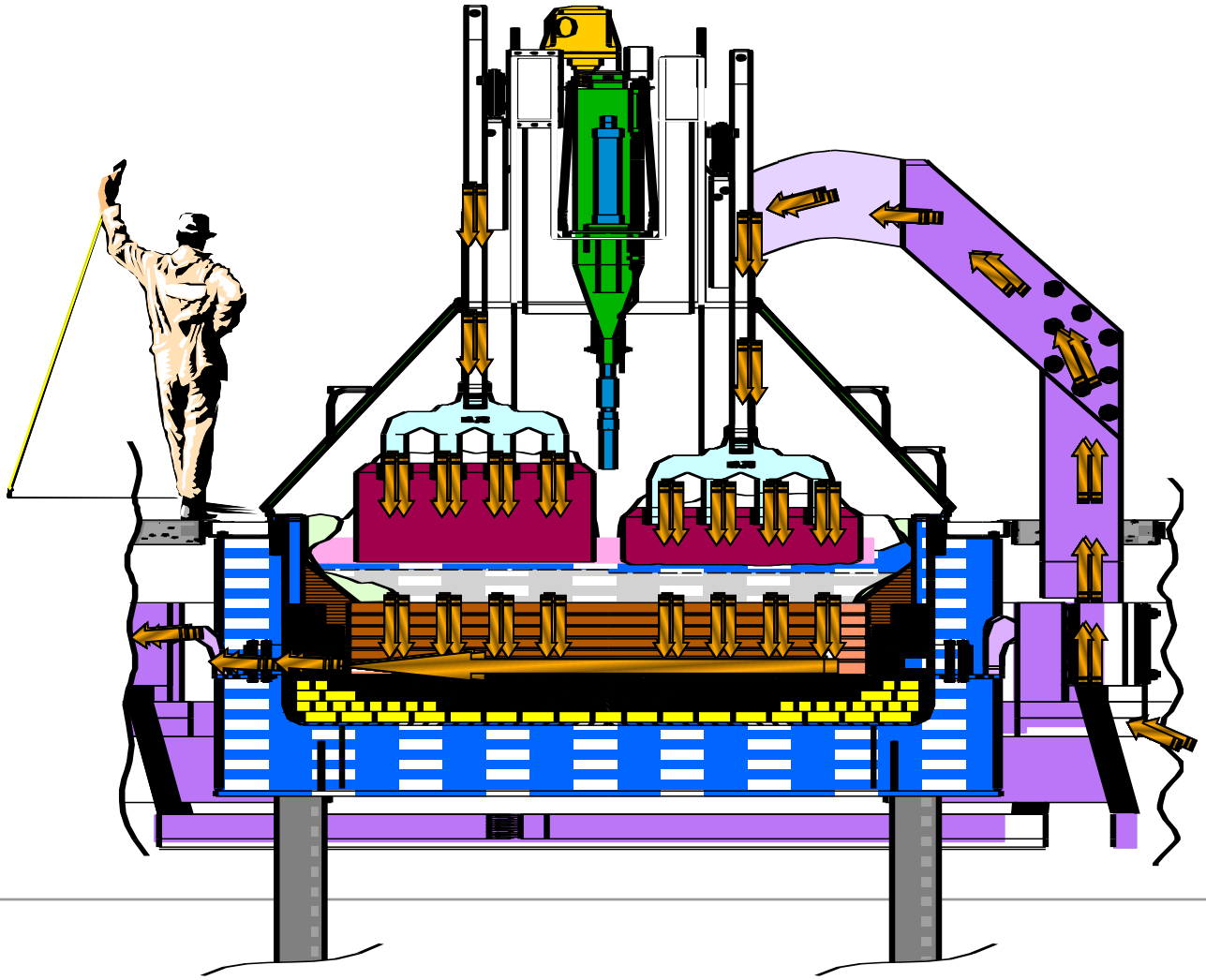
Aluminium cell



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HAL4e in operation since May 2008 – now at 450 kA

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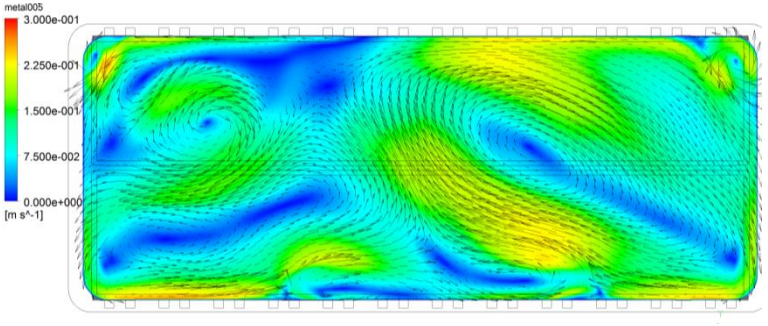
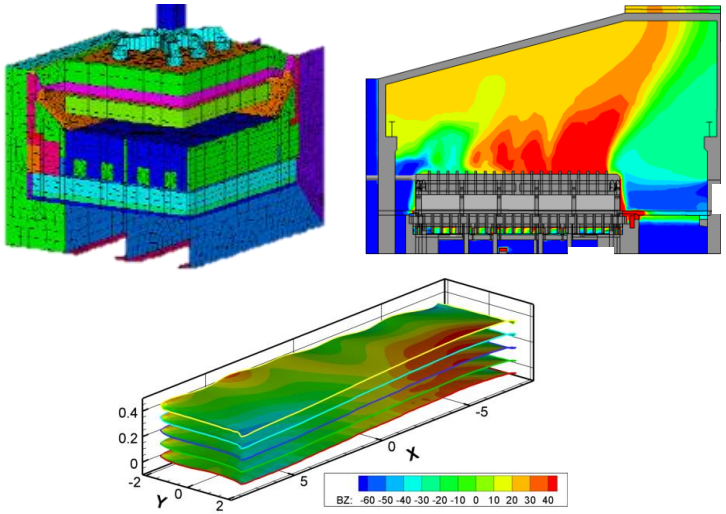
Technology need to be implemented

Bridging R&D and full production





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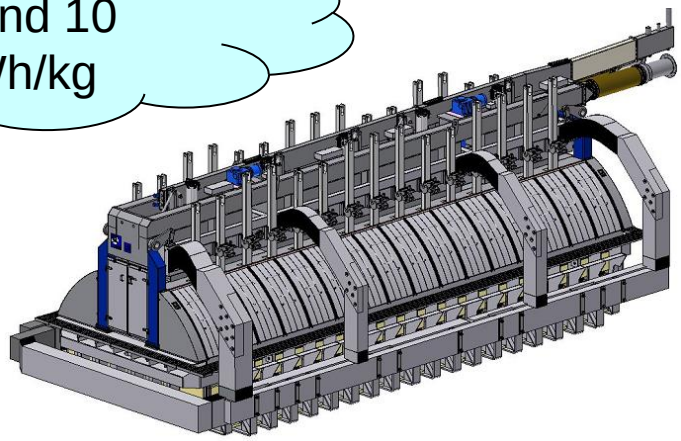
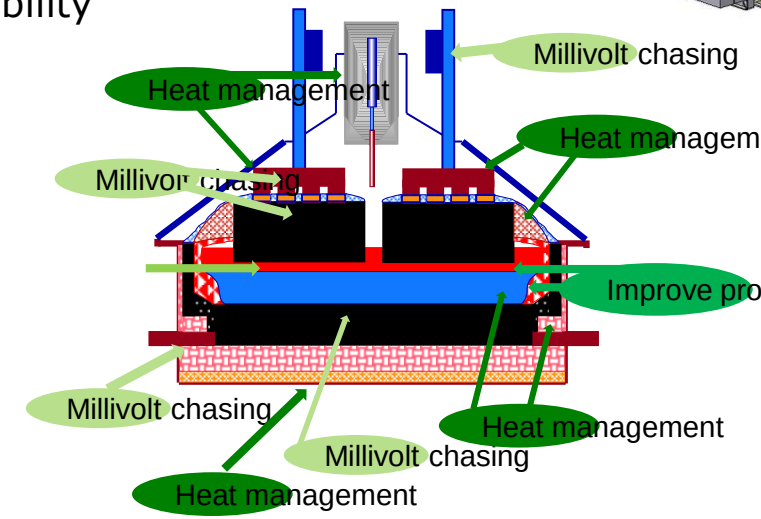
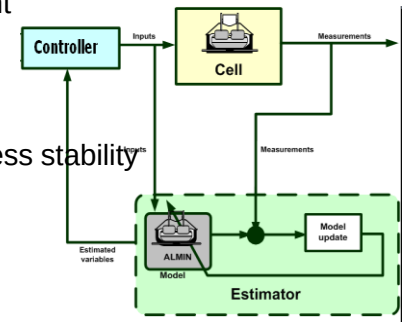
Towards 11 kWh/kg...

... and 10 kWh/kg



- Millivolt chasing & bottleneck removal
- Operate at shorter interpolar distance
- Improved process control & stability
- Improved feeding technology
- Heat balance challenges
- New materials
- Heat recovery





Spin-off technology elements and increased competence into Hydro plants

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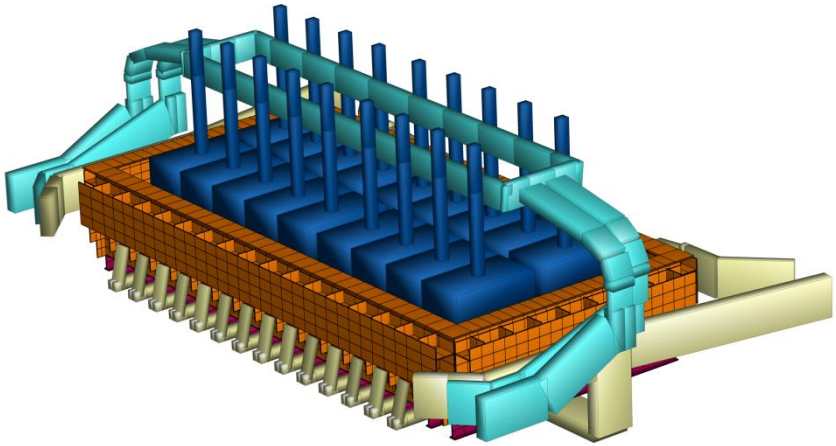
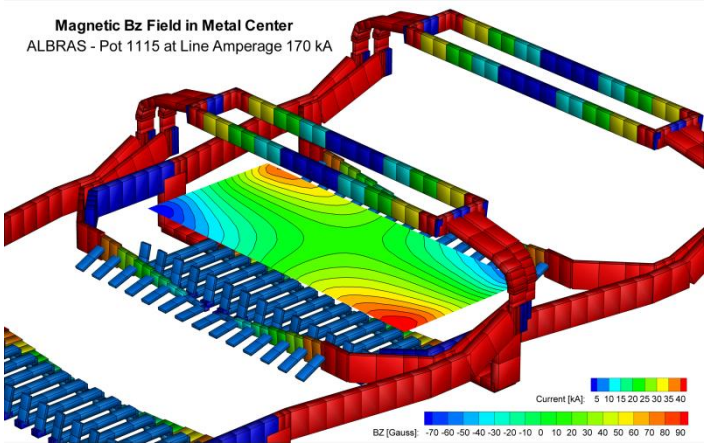
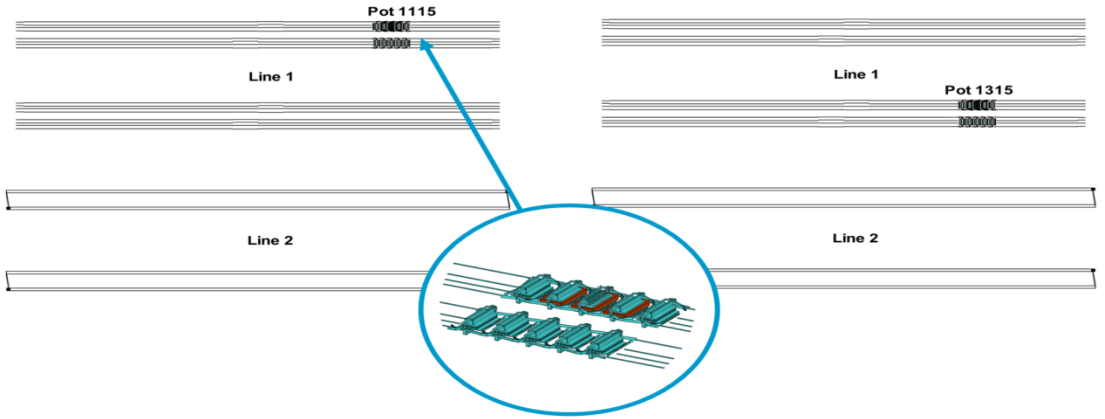
Magnetic Field Calculations





Potline Models for Magnetic Field Calculations



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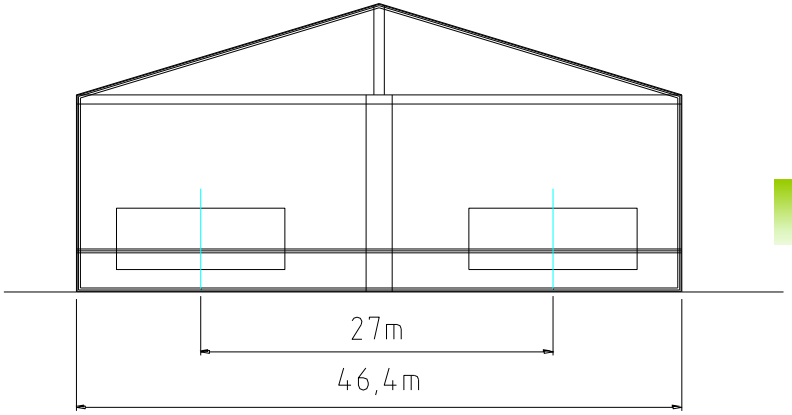
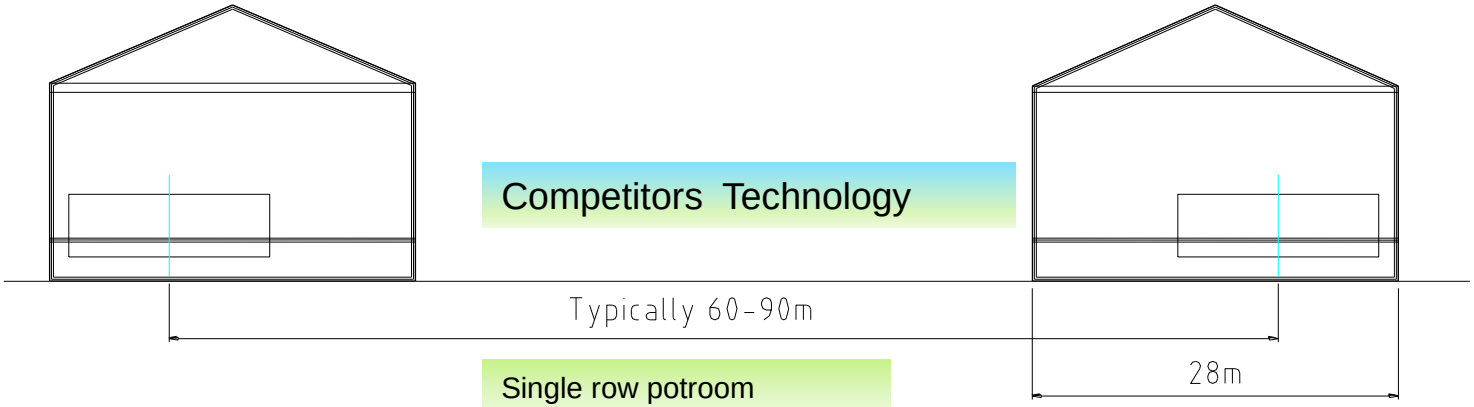
Hydro Double pot-room Technology



Hydro's Technology

HAL250 potroom



Competitors Technology

Single row potroom

Double potroom Qatar

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HAL4e Pilot Plant Project
- Location on old Søderberg site at Karmøy

Pilot Plant 74.000 tpy

Existing 190.000 tpy

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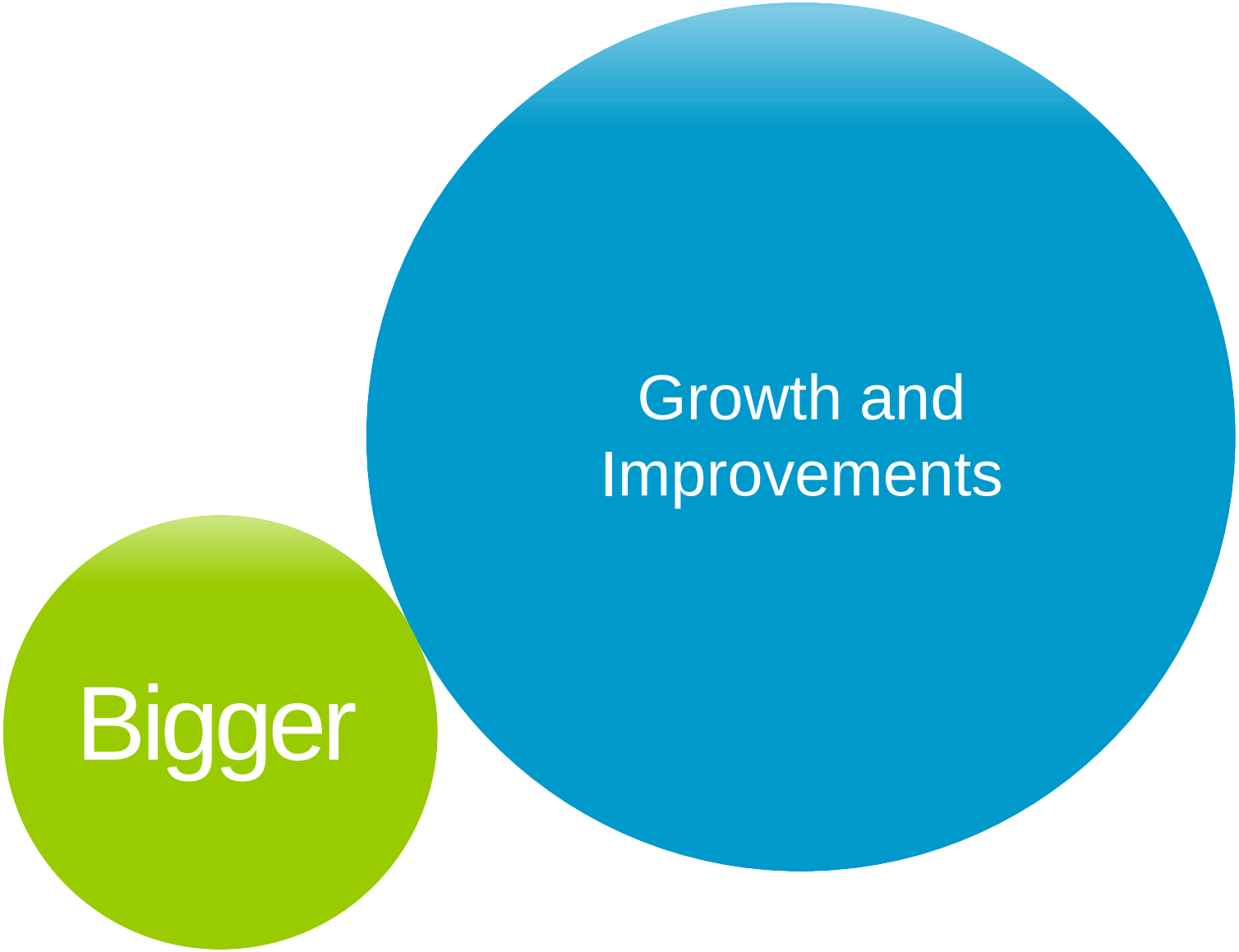

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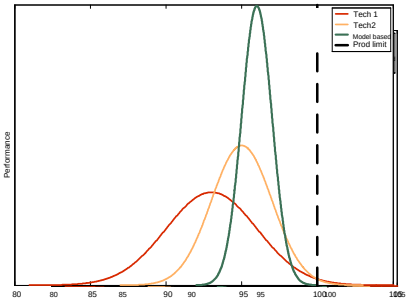
Investing in developing our precision culture

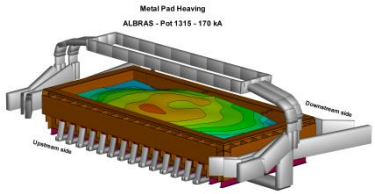
World-class production requires stability

- Fire fighting
- Stability
- Precision culture



Process Control

Technology step



Levers for success – capitalizing on technology and competence

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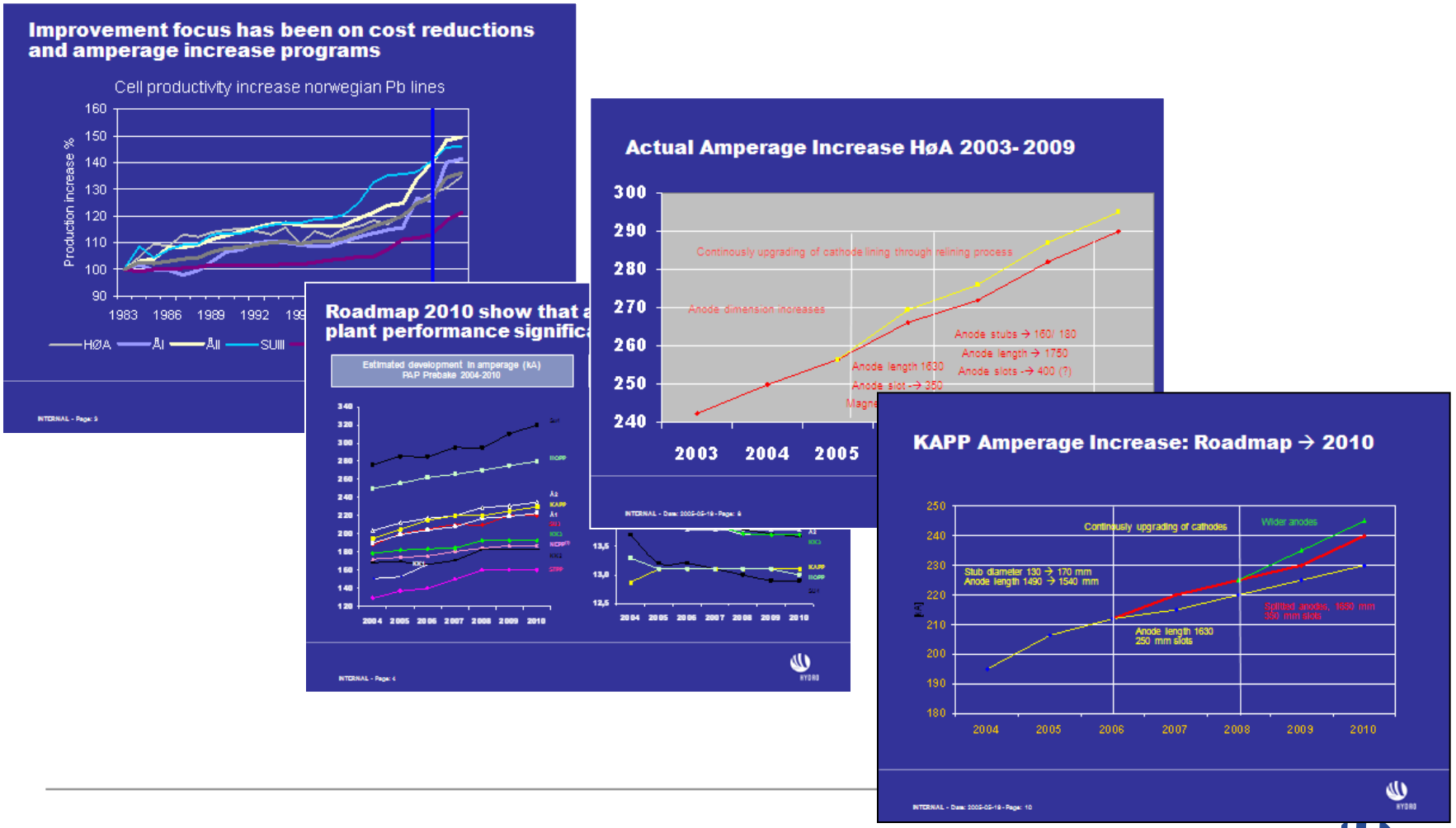
We have a history of continuous growth and improvements:

Metal volume from existing potlines has increased with more than 100.000 tons over some years



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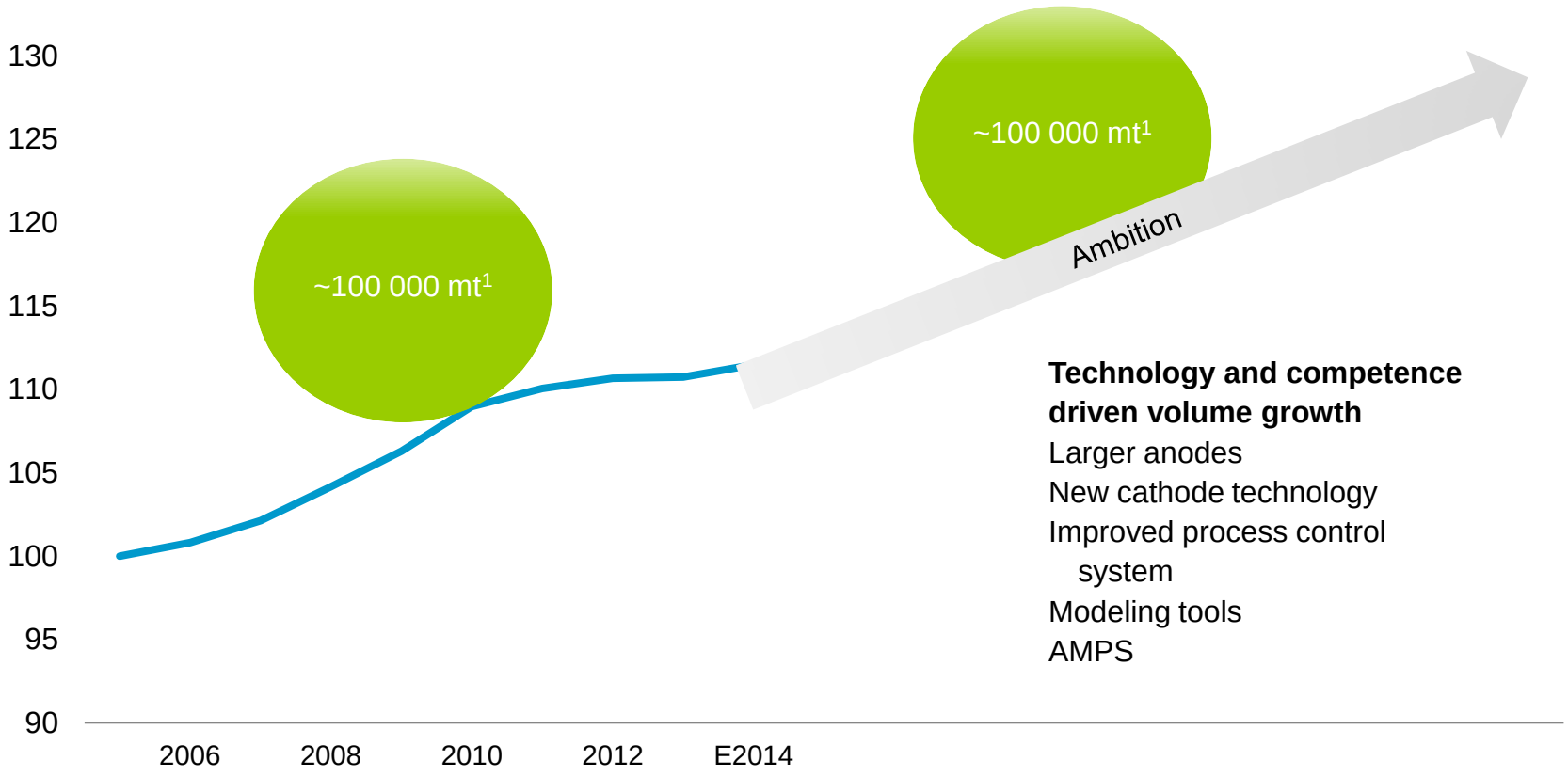
Fully-owned smelters – increasing output from existing lines, gaining productivity

Production development in Norwegian fully-owned smelters, indexed from 2005



Technology and competence driven volume growth

Larger anodes
New cathode technology
Improved process control system
Modeling tools
AMPS

1) Not including Hydro Husnes

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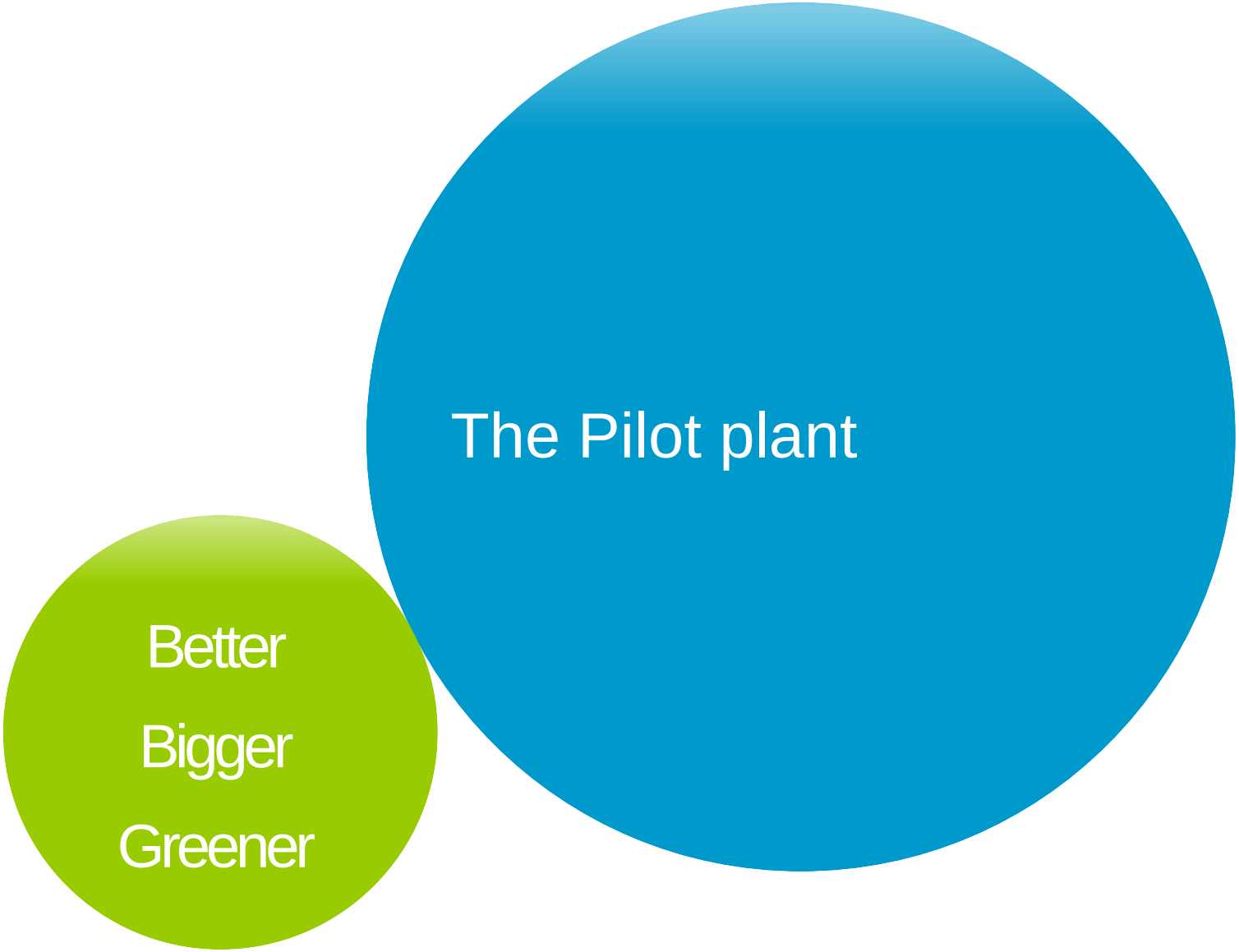

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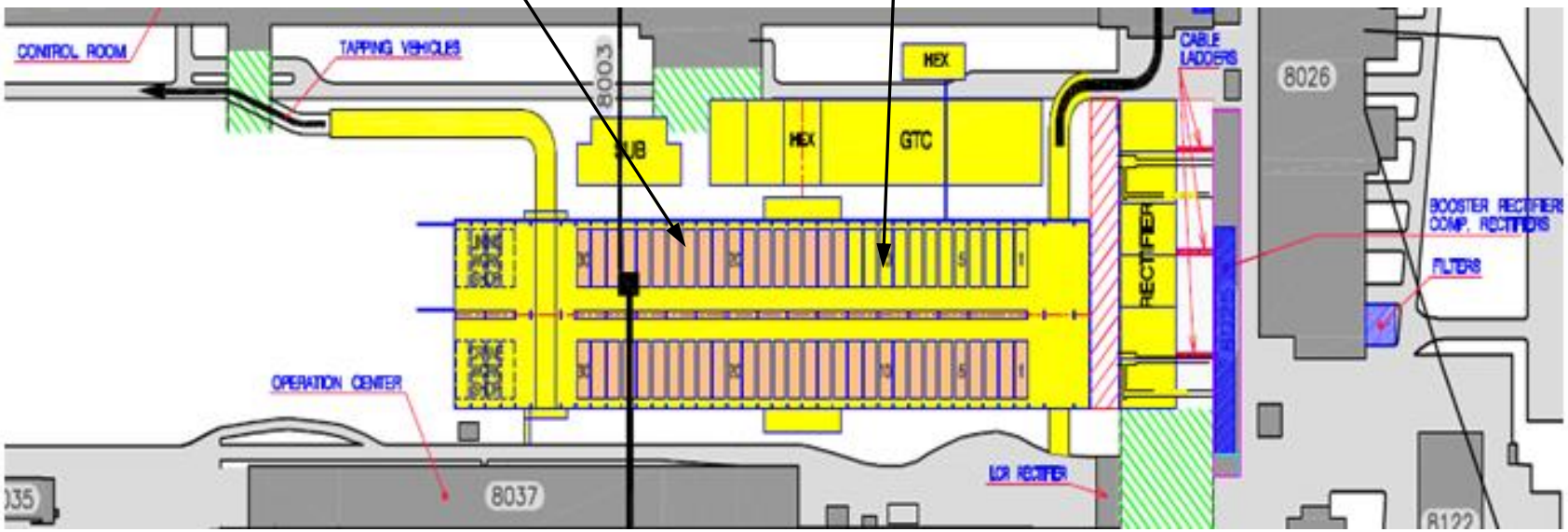
HAL4e Pilot Plant – 60 cells, 74 ktpy

48 cells: HAL4e
450 kA @ 12.3 kWh/kg

12 cells: HAL4eUltra
415 kA @ 11.8-11.5 kWh/kg



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