Mechanical Vapour Recompression (MVR) – A technology for low carbon Alumina refining

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OIL & GAS | ZINC, SILVER & LEAD | ALUMINUM | IRON ORE & STEEL | COPPER | NICKEL | GLASS | CONNECTIVITY & NETWORK SOLUTION | SOFTWARE | POWER

Contents

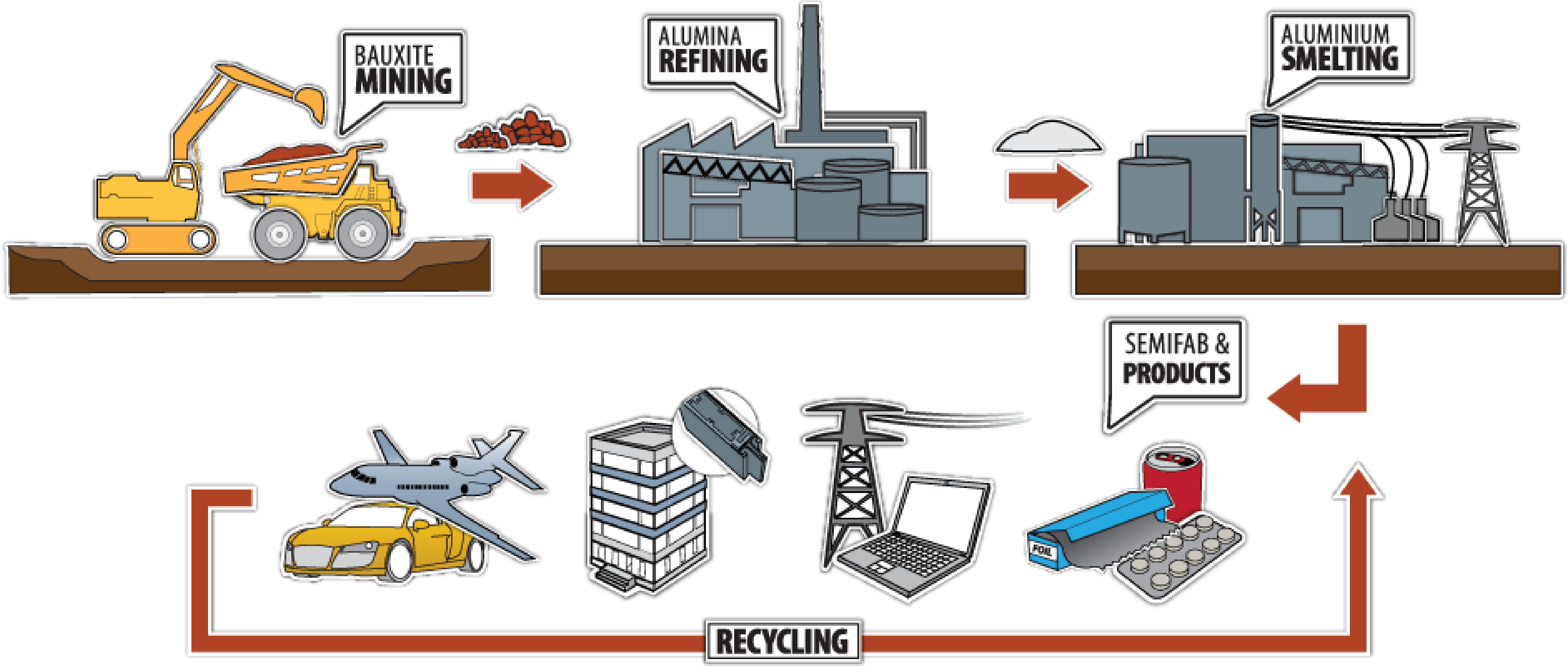
Aluminium - The Metal of Future

THE METAL OF THE FUTURE

Aluminium is the 2^{nd} most important metal in the world today, with evolving applications in a sustainability-conscious world.

- Al is Light weight
- Al is strong
- Easily recyclable
- Highly temper able

Aluminium manufacturing process



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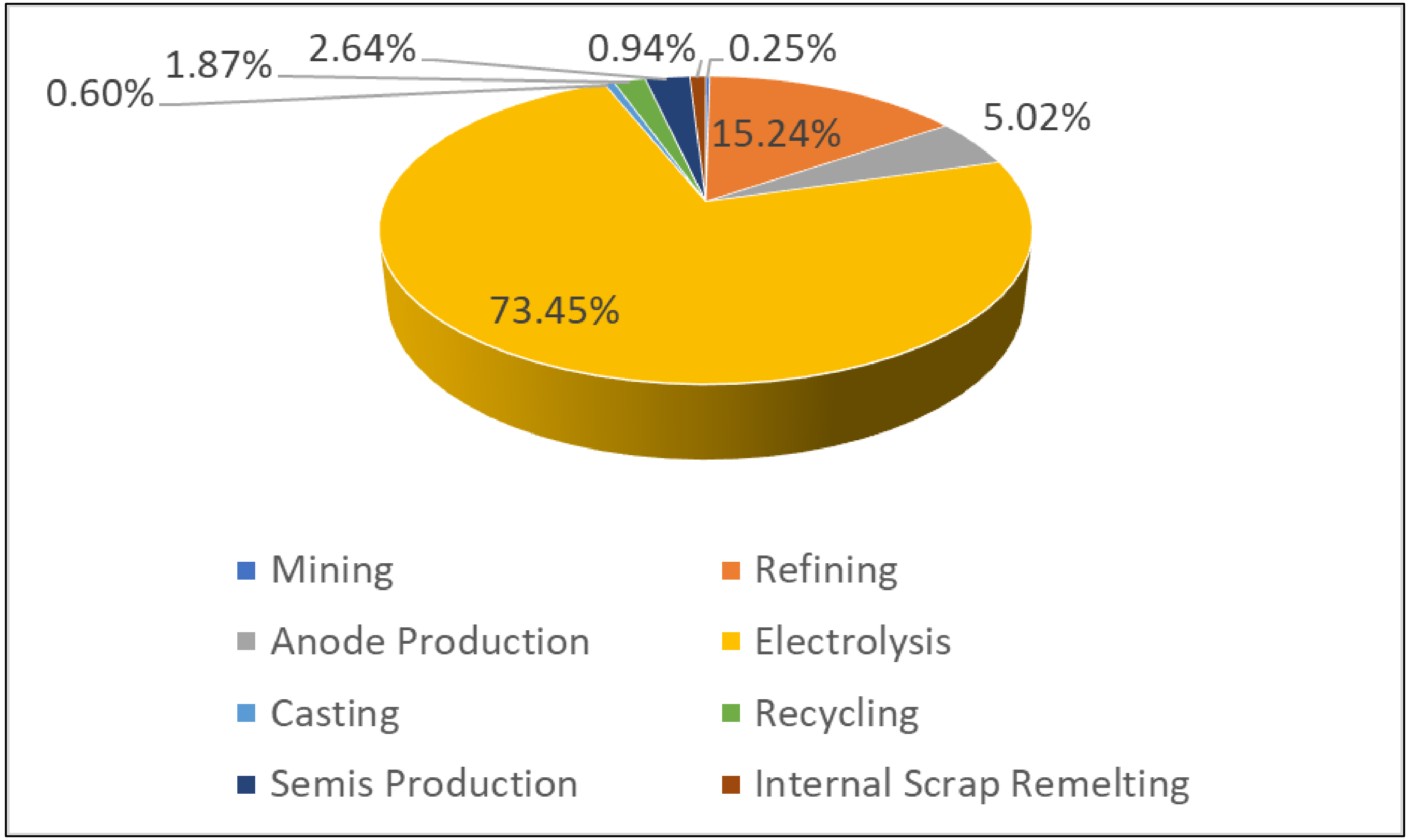
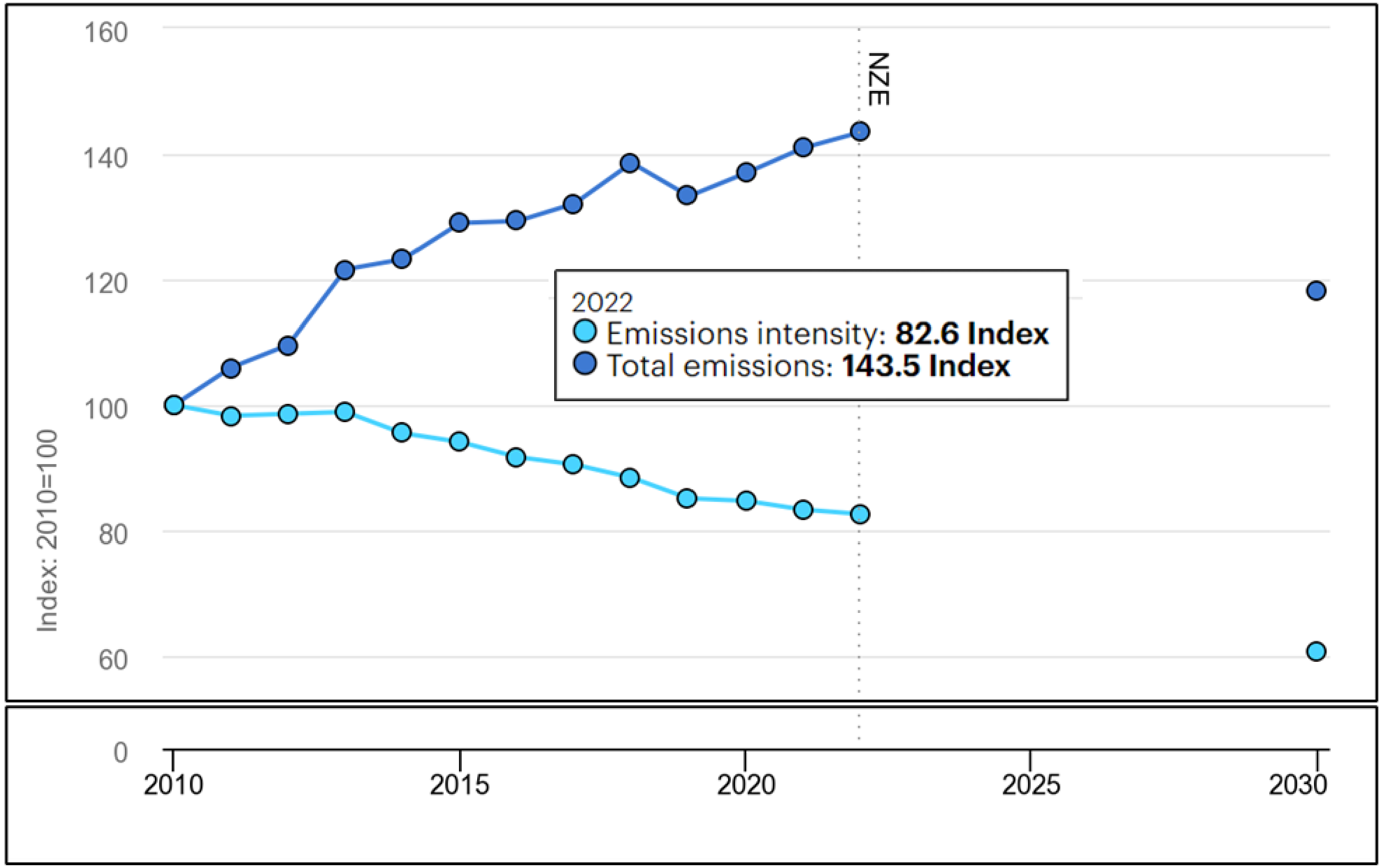
Greenhouse Gas & CO_2 Emissions – Aluminium Sector

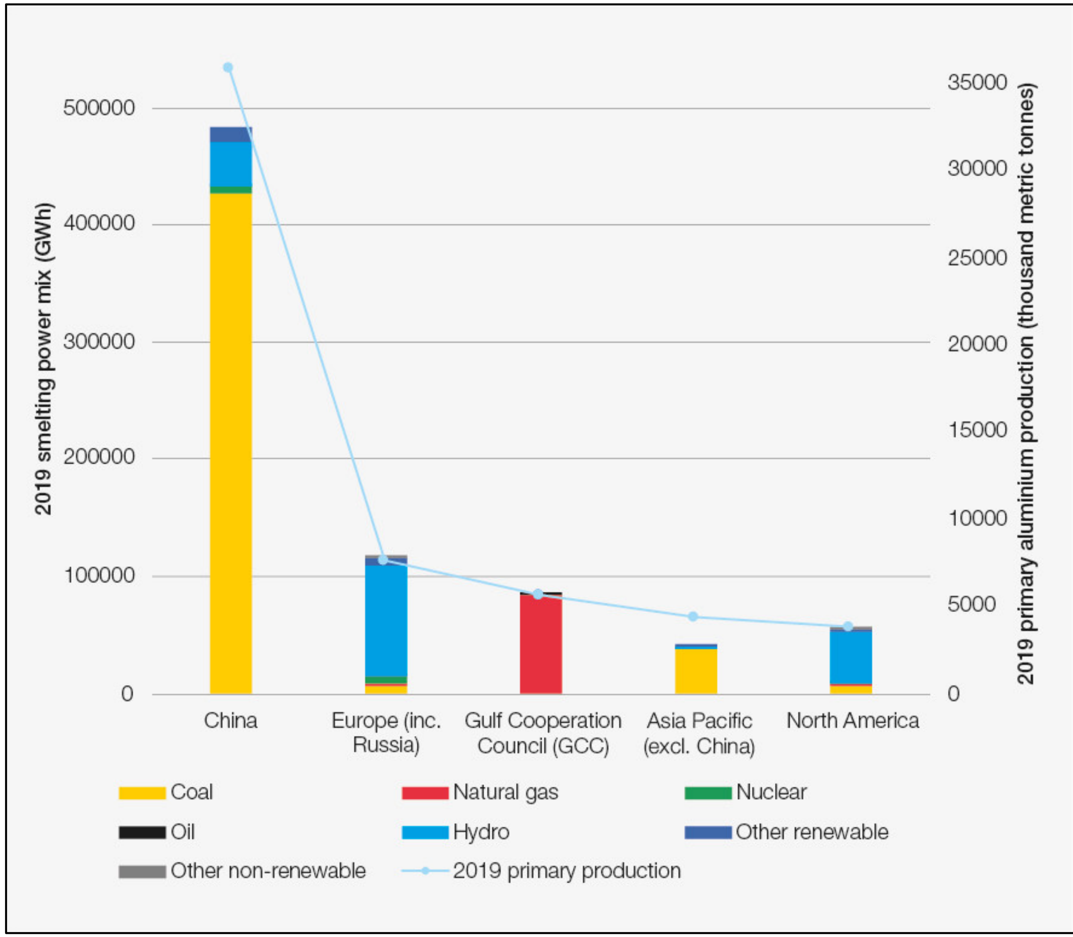


70% of GHG emissions coming from fossil fuel-driven Bayer process heating circuit
30% produced during the high-temperature calcination process

Data Source : https://international-aluminium.org/statistics/greenhouse-gas-emissions-aluminium-sector/
Date of Issue: 25 January 2023 Prepared by Saprativ Basu, R&D, Vedanta Ltd.

CO2 emissions under NZE (2010-2030)





- Sources: IEA calculations, including inputs from IAI Statistics.
- Notes: Excluding internal scrap currently

- ❑ 270 Mt Direct CO_2 emissions in 2022
- ❑ 1 Gt Total emission
- ❑ ~3% of the world's direct industrial CO_2 emissions

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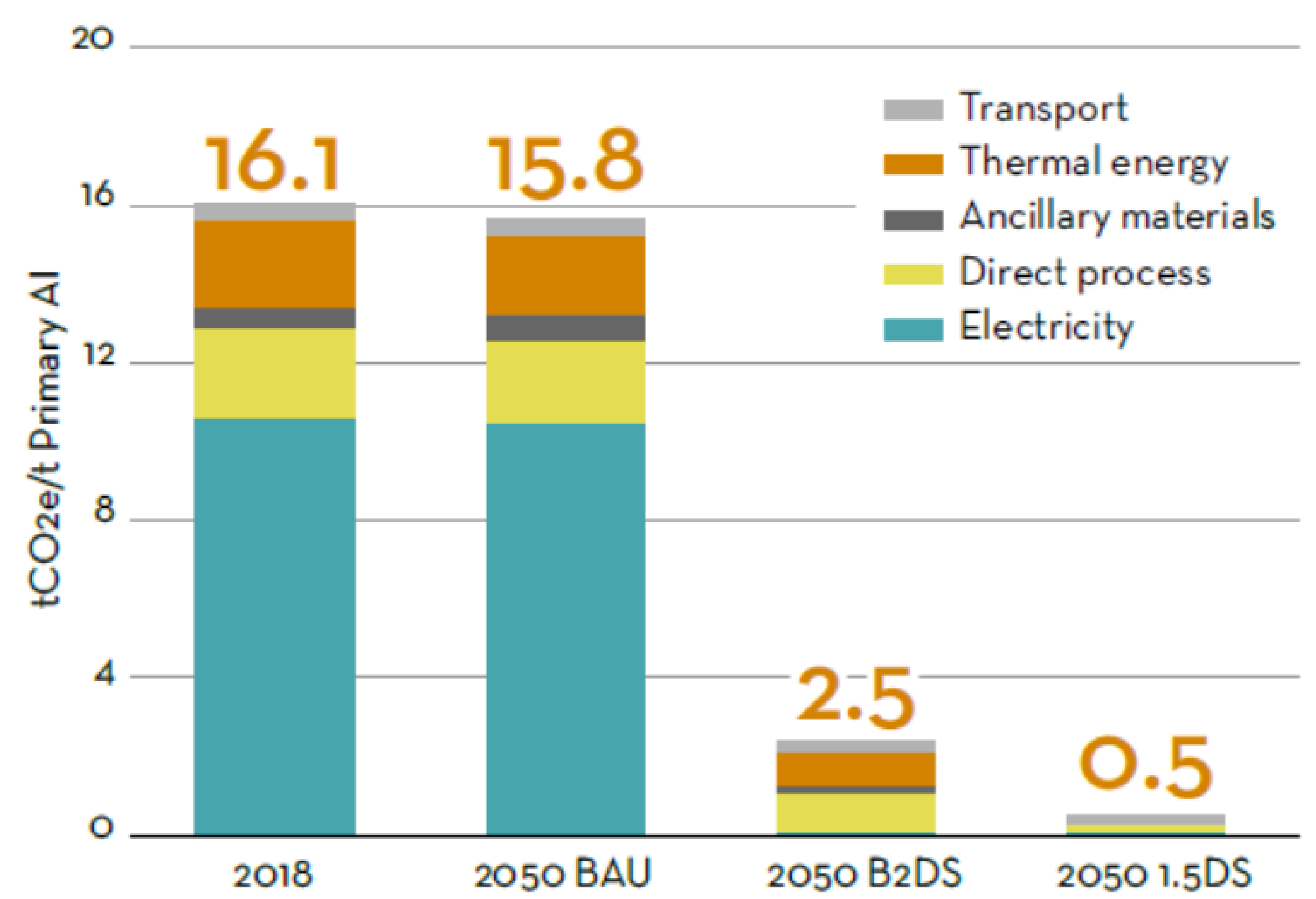
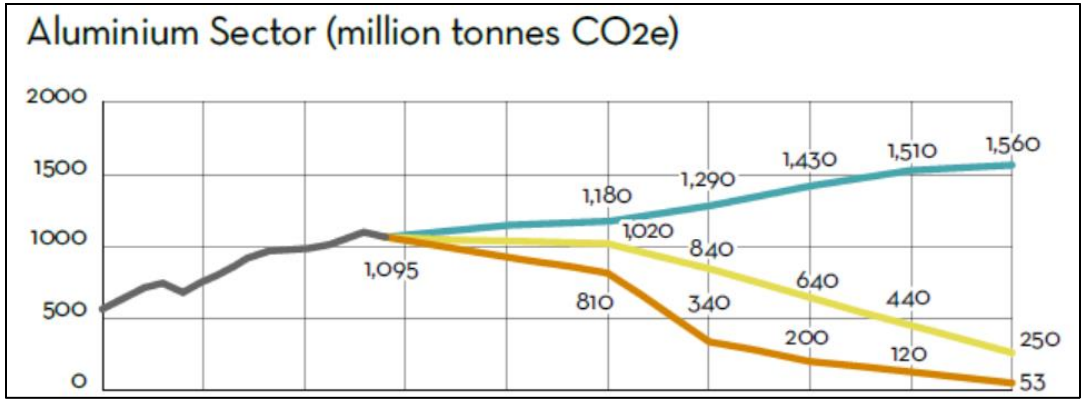
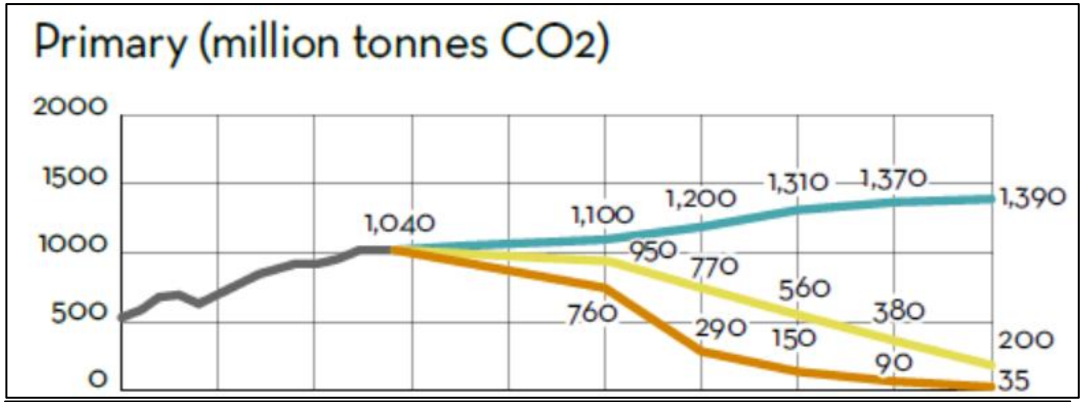
NZE 1.5 DEGREES SCENARIO: A MODEL TO DRIVE EMISSIONS REDUCTION by 2050

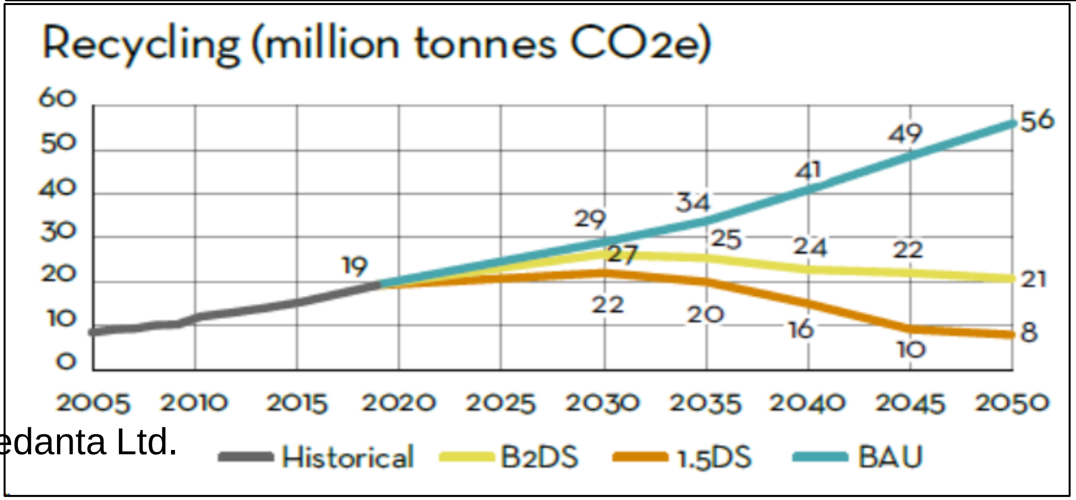
vedanta
transforming for good



*The dataset for alumina refining has been revised retrospectively to reflect a change in modelling assumptions for the process.







BAU – 'business as usual' scenario
B2DS – 'Beyond 2 Degrees' scenario
1.5DS – '1.5 degree' scenario

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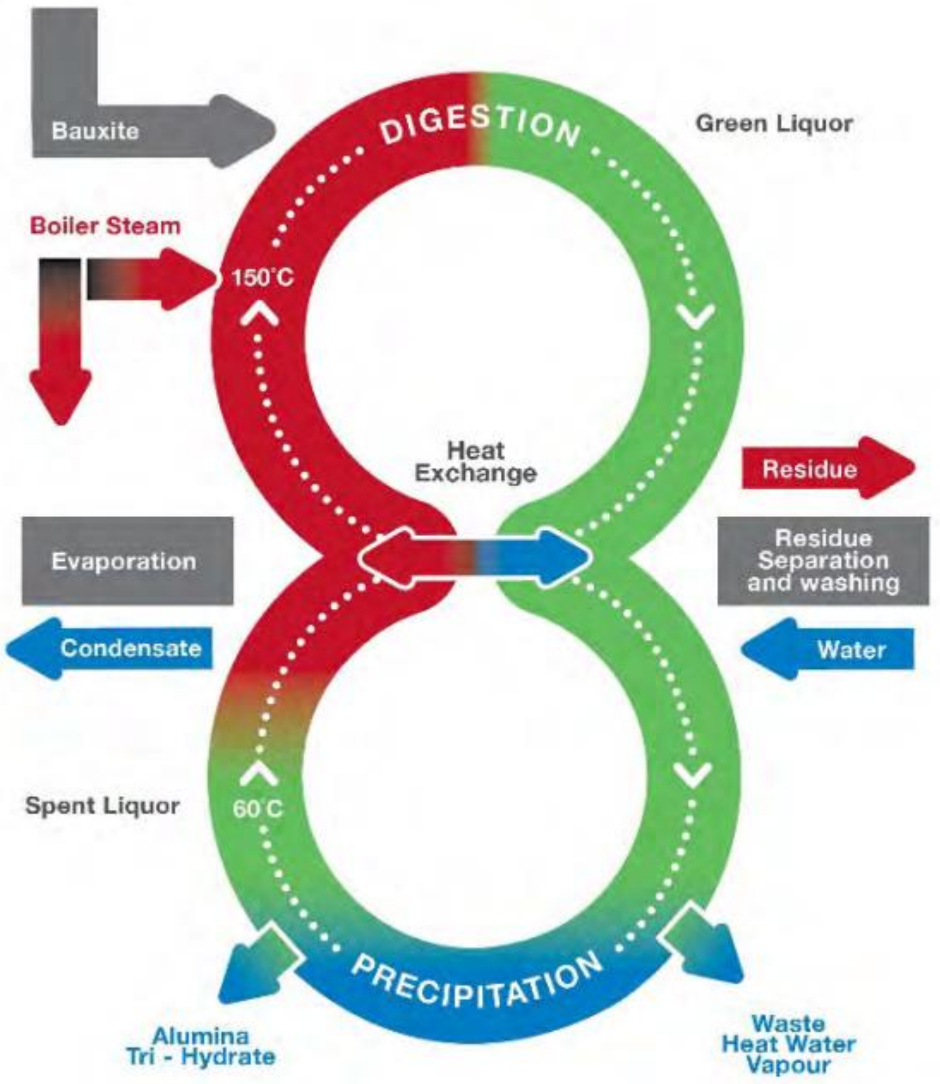
Bayer's Process of Alumina Refining

- Bauxite ores are processed at 140–170°C to extract alumina, referred to as low temperature and high temperature digestion at around 250°C to achieve good alumina recovery.

- In both cases the Bayer liquor, a recirculating solution of caustic soda, dissolved aluminium, and water, is heated to the required temperature using **steam**.

- The hot Bayer liquor extracts the alumina-bearing components from bauxite (**digestion**), residual solids are removed, and the liquor is then cooled to precipitate alumina tri-hydrate crystals (**precipitation**). These are collected and calcined to form alumina.

- The remaining 'spent' liquor is then reheated and some water is removed by evaporation to increase the caustic concentration again before it is recirculated back to digestion (**evaporation**).



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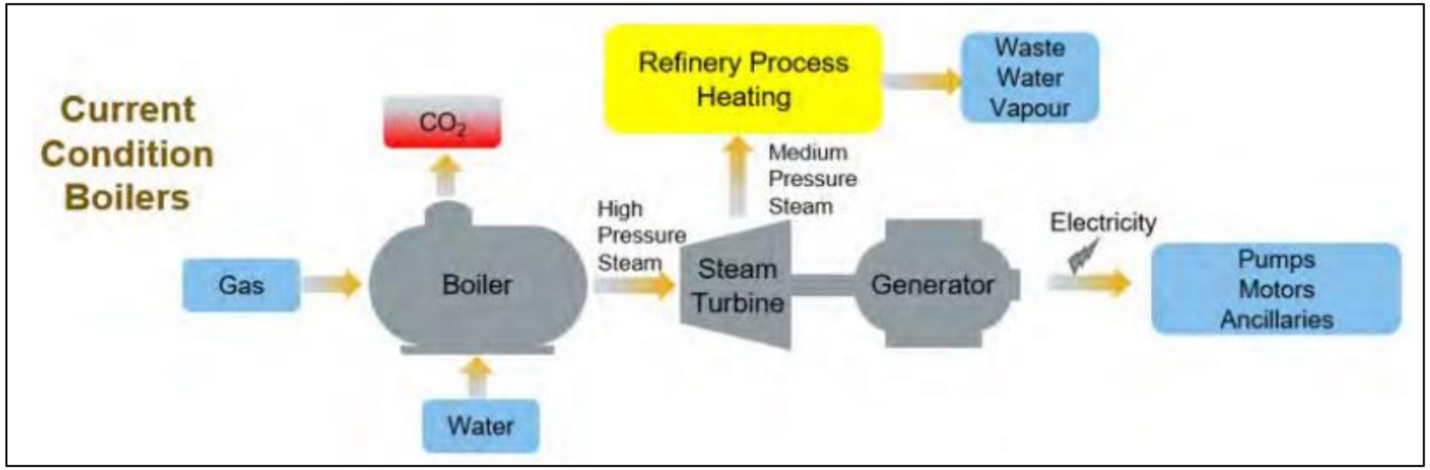
MVR – A replacement for fresh steam

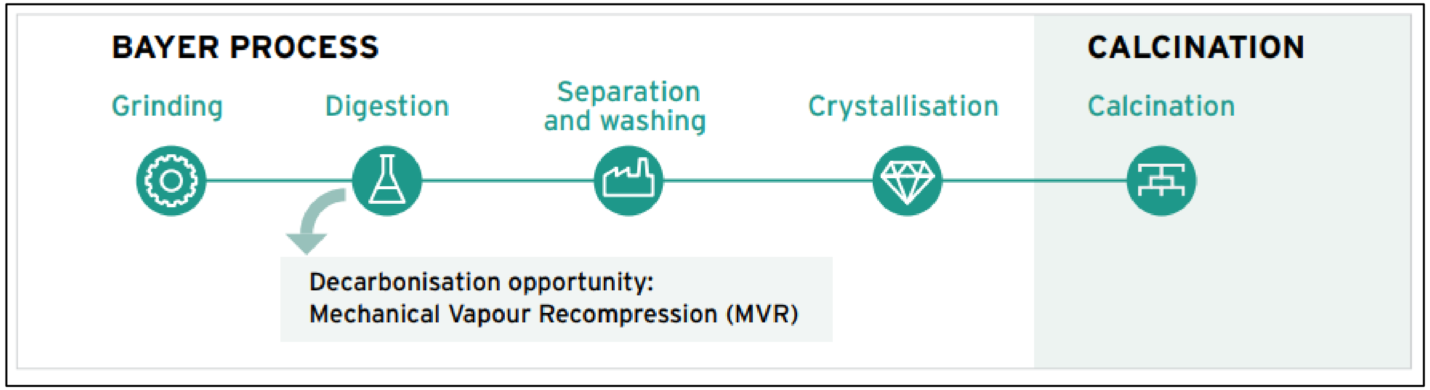
- Traditionally, steam is supplied to the digestion process from coal-fired boilers or as discharge from the steam turbine of a combined cycle electrical power plant.

- ~85% of the energy input to the refinery leaves as low-grade heat, unable to be re-used with the current technology.

- Renewable energy-driven MVR provides the opportunity to decarbonize steam generation within the Bayer process.

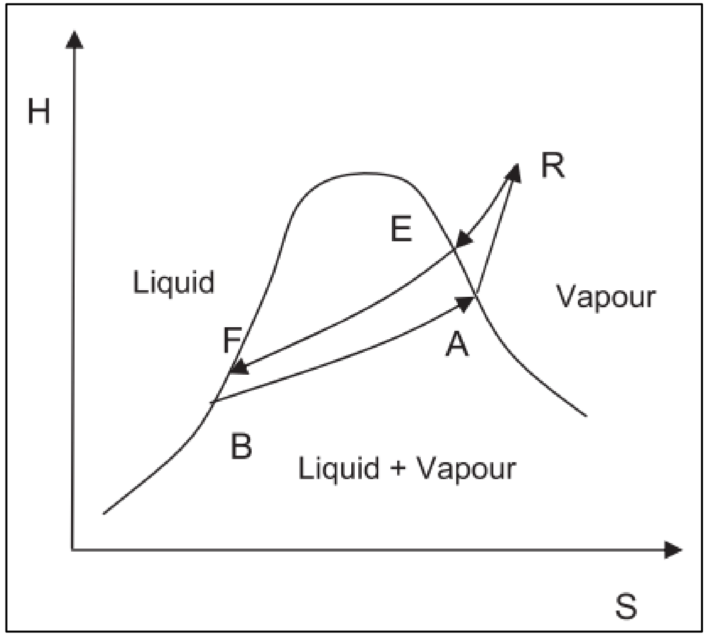
- MVR powered by renewable energy represents an attractive and sustainable means of upgrading and reusing the low-temperature waste vapor from the digestion step.



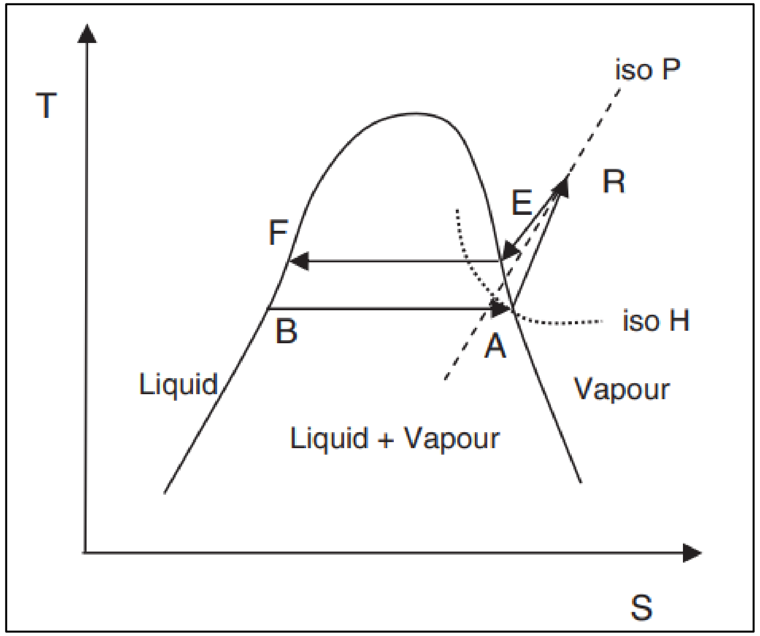


Mechanical Vapour Recompression

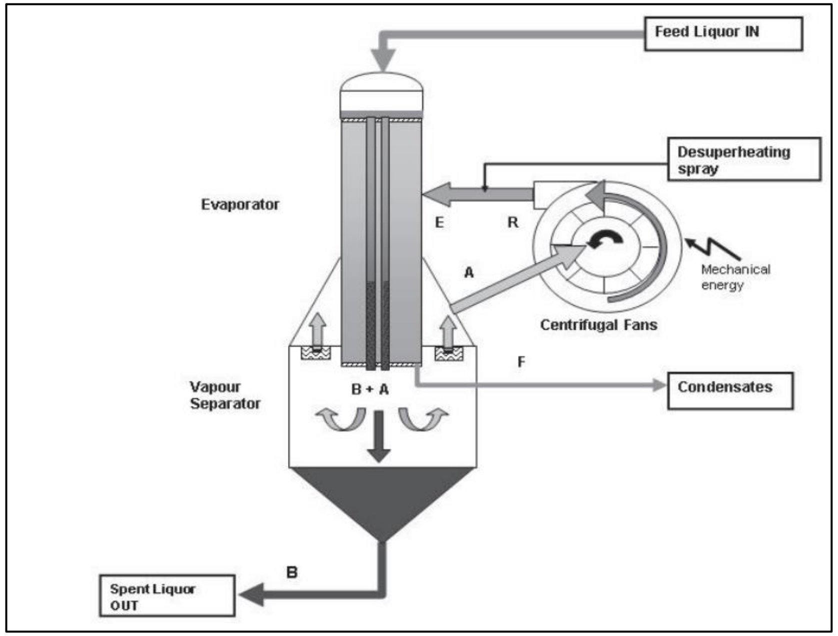
- Mechanical Vapour Recompression (MVR) is a technology based on the re-use of the vapor produced by evaporation, as the heating medium, after having increased its temperature and pressure by mechanical compression.



Enthalpy diagram for the thermodynamic cycle of MVR evaporation



Entropy diagram for the thermodynamic cycle of MVR evaporation



Mechanical vapour recompression (MVR) equipment

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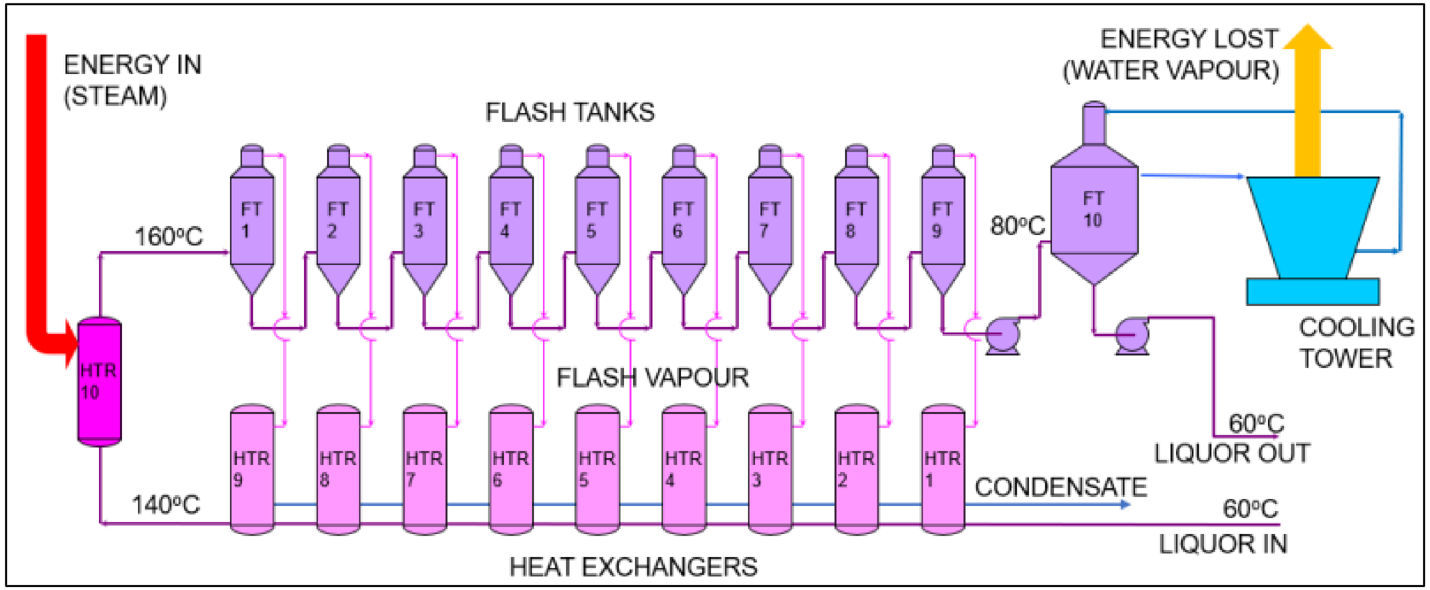
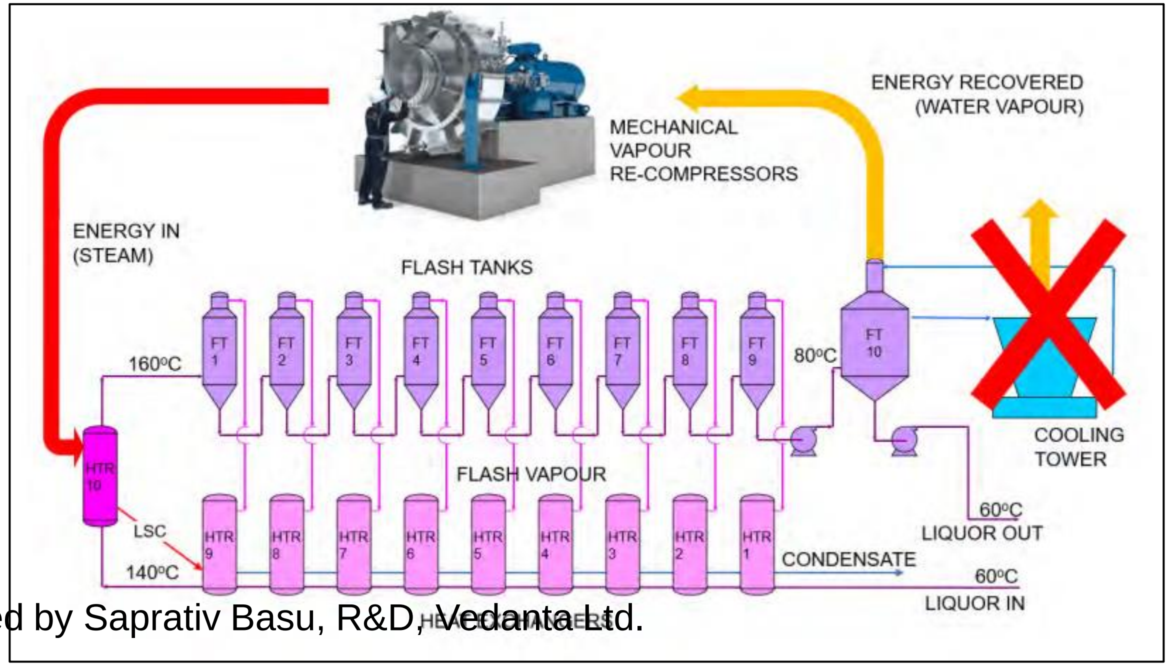
MVR retrofit to conventional evaporation energy flow (1/4)

- **Evaporation**
- Precipitation
- Calcination
- Digestion





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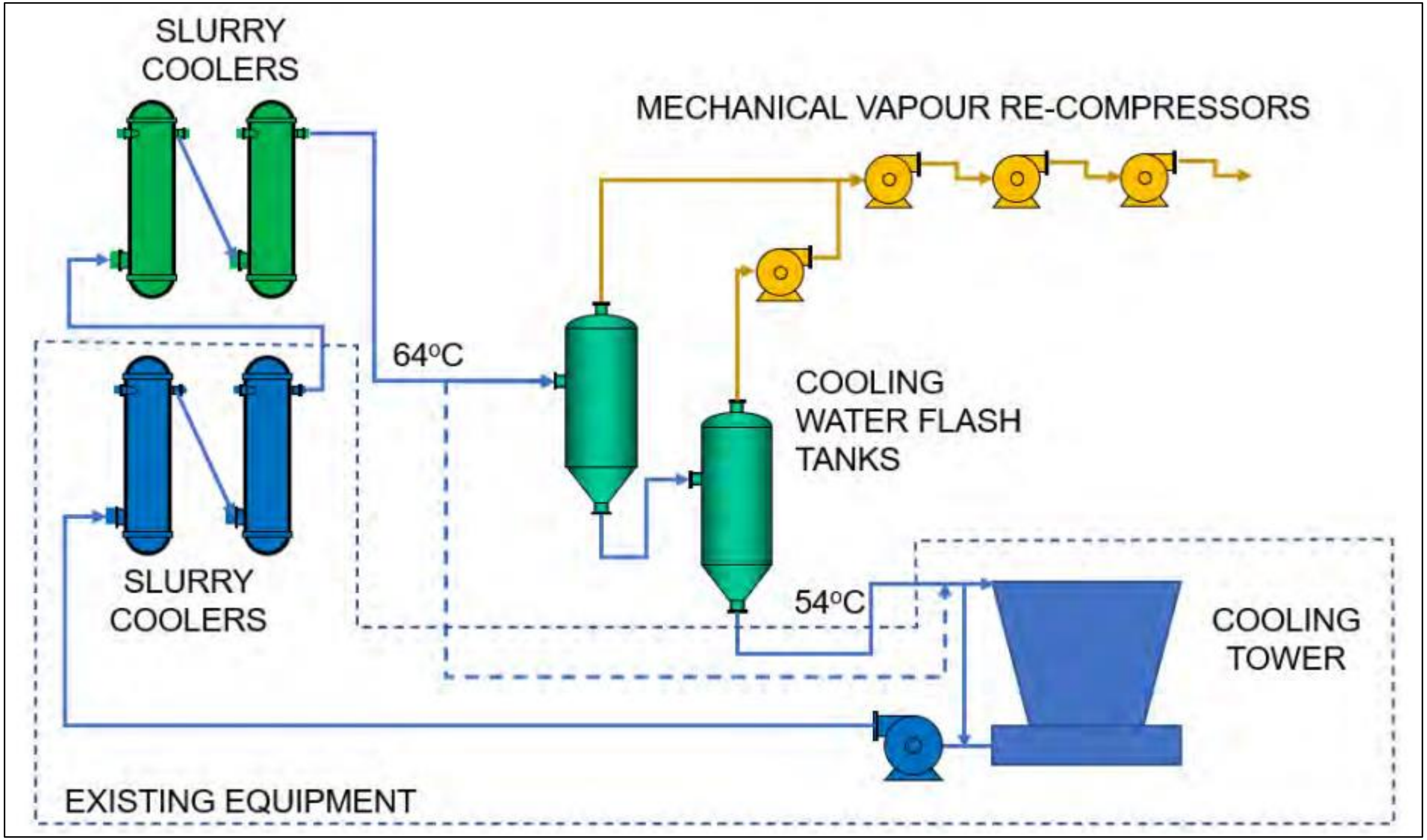
MVR retrofit to conventional evaporation energy flow (2/4)

- Evaporation
- **Precipitation**
- Calcination
- Digestion



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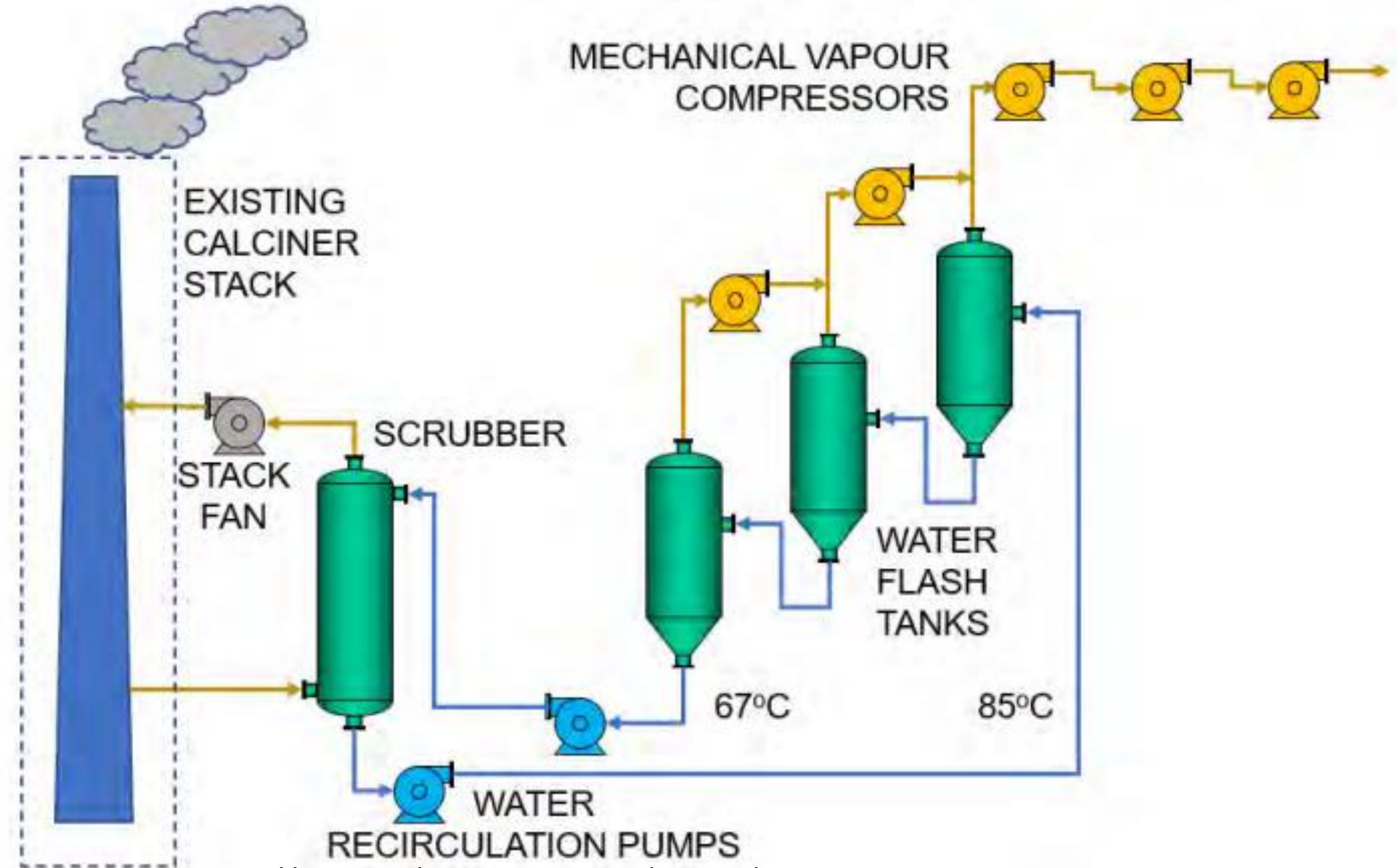
MVR retrofit to conventional evaporation energy flow (3/4)

- Evaporation
- Precipitation
- **Calcination**
- Digestion



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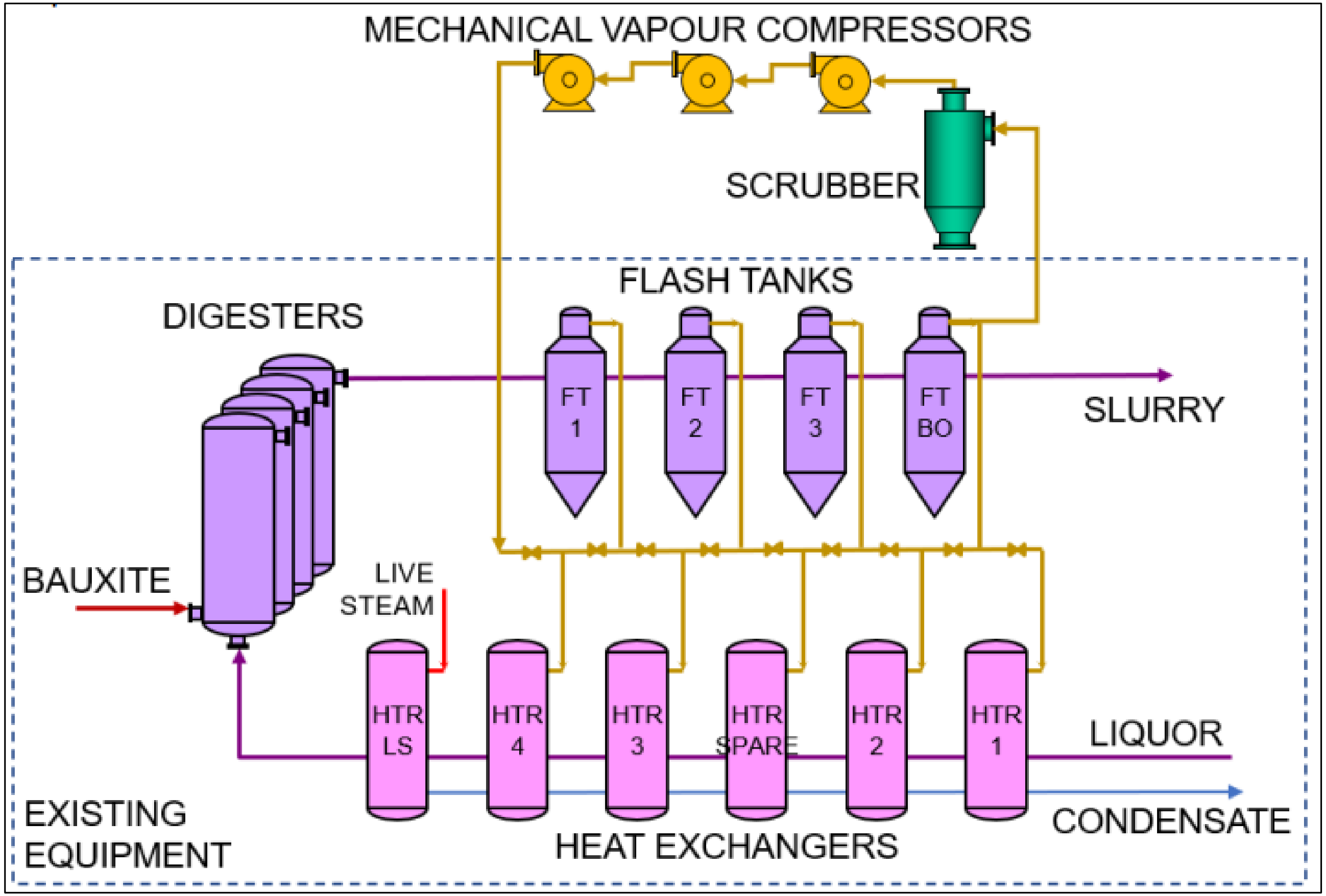
MVR retrofit to conventional evaporation energy flow (4/4)

- Evaporation
- Precipitation
- Calcination
- **Digestion**



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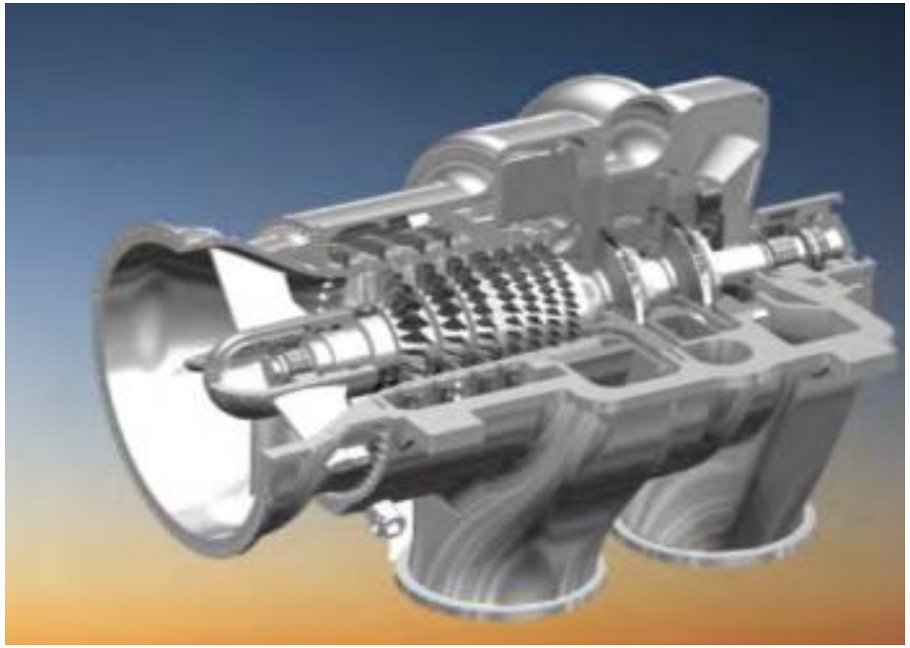
Compressor Types

Low speed centrifugal.

High speed centrifugal



High Speed Axial Flow

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Carbon abatement comparison

Low Temperature Refinery

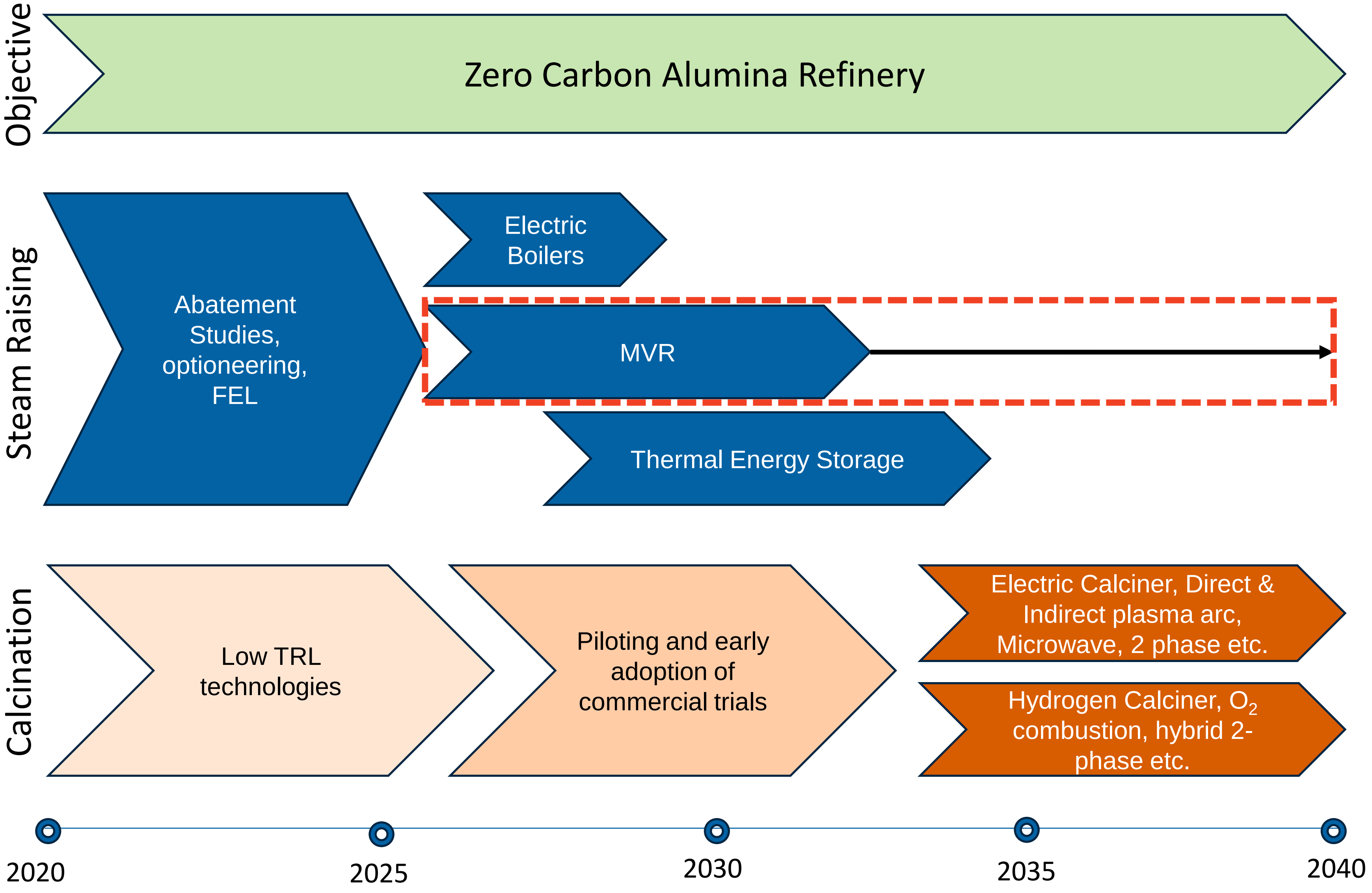
- Import additional power to drive MVR as well as to replace their existing generation of steam
- Compress waste vapour to a lower pressure to make digestion steam – consume less power
- MW–h per GJ steam consumption displaced – 0.01
- Carbon Displaced – 0.34-ton CO_2/ ton alumina

High Temperature Refinery

- Only needs to import additional power for MVR
- Compress waste vapour to a higher pressure to make digestion steam – consume more power
- MW–h per GJ steam consumption displaced – 0.11
- Carbon Displaced – 0.28-ton CO_2/ ton alumina.

Alumina Decarbonization Pathways to Net Zero

- Electricity will become the primary energy source in the future. This will drive electrification of alumina refineries where practical.
- Energy storage is a key piece of the puzzle to secure reliable energy supply.
- Steam raising is likely to be via electric boilers, MVR, thermal energy storage, with site specific solutions tailored to meet site circumstances.
- Calcination technology development is required to determine the best path forward. Various H2, electric and hybrid options remain viable.
- CCUS is projected to play a smaller role in specific geographies.



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Why MVR is backed for alumina refining

- MVR appears to be the **lowest cost method** to rapidly decarbonize the Bayer process in the alumina industry. Power consumption per ton of steam could be substantially lower than electric boilers and hydrogen, therefore significantly less renewable power infrastructure investment required.
- **Minimizes the external infrastructure** required to generate process heat from renewable resources.
- The compressor systems **require about one third the renewable power** of direct electrification using electric boilers, and about one quarter the renewable power of hydrogen.
- **High technology readiness level** — large-scale deployment could start in the medium term.
- Significant **water savings**.

KPIs	Unit	Base Case	Full MVR
Total Refinery Energy Consumption	GJ/tAl2O3	1	0.7
Steam Consumption	GJ/tAl2O3	1	0
Power Consumption	kWh/tAl2O3	1	2.6
CO2 Emissions	tCO2/tAl2O3	1	0.2
Water Consumption	t/tAl2O3	1	0.2

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