Alumina Production Growth in a Decarbonised World

With additional special topic:
Evaporation Retrofit with MVR -
A Pathway to Decarbonisation

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Why Write this Paper?

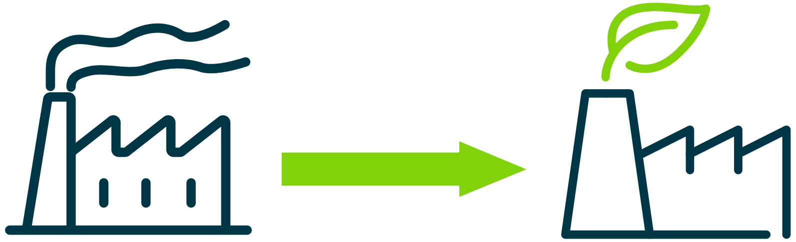
The alumina industry is decarbonising.

Sustainability including decarbonisation will drive a higher pace of technological change.

Chinese alumina growth is slowing.

<u>Key Questions:</u>

1. What does your new refinery look like?

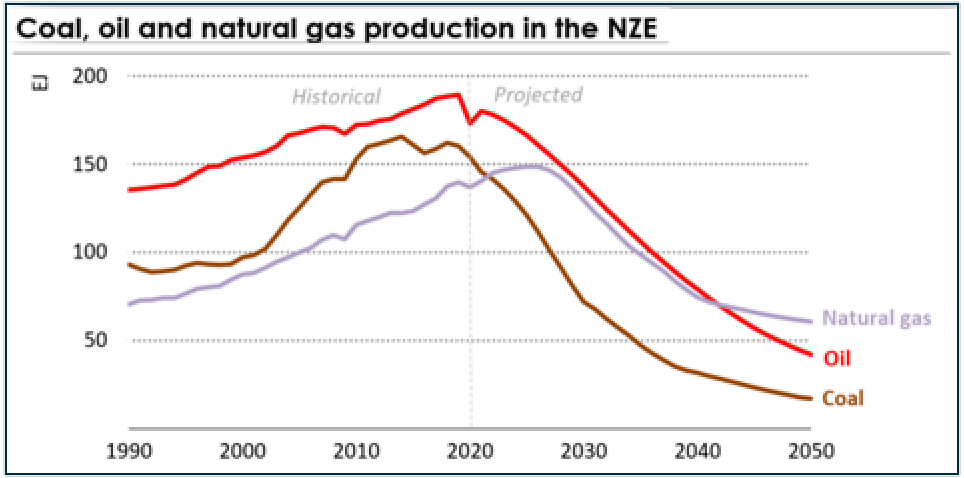


2. Where should your new refinery be located?

Context

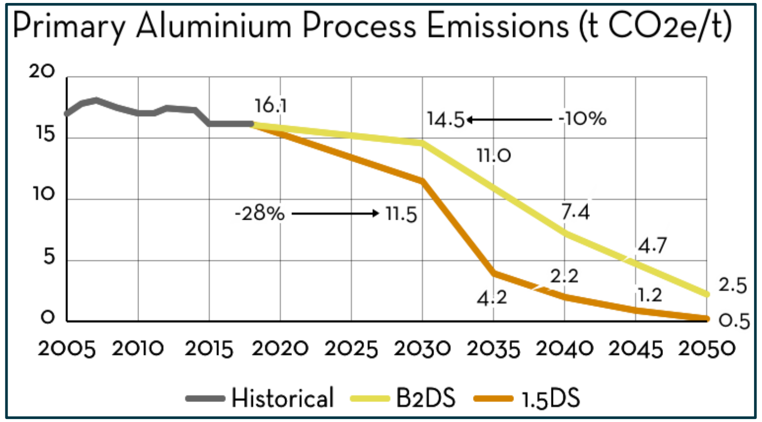
- 2050 "Net Zero" requires rapid global decarbonisation.

IEA "Net Zero by 2050" Report, May 2021



- Aluminium industry accounts for ~2% of global GHG emissions and must respond.
- International Aluminium Institute's 1.5DS Scenario shows rapid GHG decline over the 2030-2040 "Horizon 2" period

IAI, "1.5 Degrees Scenario", 2021



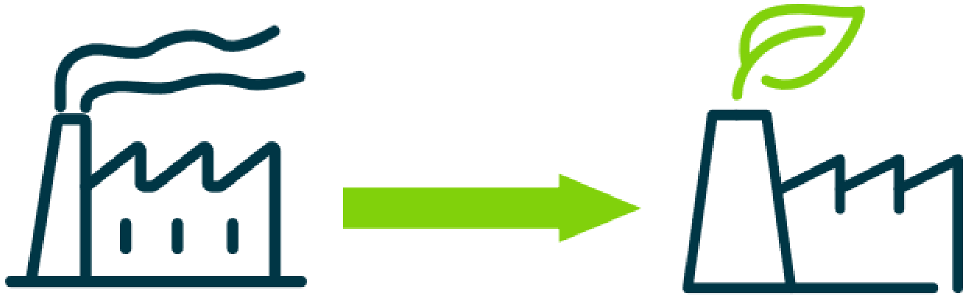
Looking Back to look Forward

- This talk employs some forward "crystal ball" gazing!
- But first, a look back to 2018
- In 2018 Worley speculated on 3 possible 2058 refinery scenarios:
  - "Business as Usual" – evolutionary
  - "Energy Centre" – price gap between stationary and transportable energy push refineries to the energy source.
  - "Local Renewables" - high decarbonised transportation costs push new refineries in proximity to bauxite mines.

<u>Learnings from the past 6 years with the acceleration of the Energy Transition?</u>

1. We can see elements of each scenario playing out.
2. The "Energy Centre" looks to be the more favoured medium term ("horizon 2").

PART I – What will your New Refinery look like?

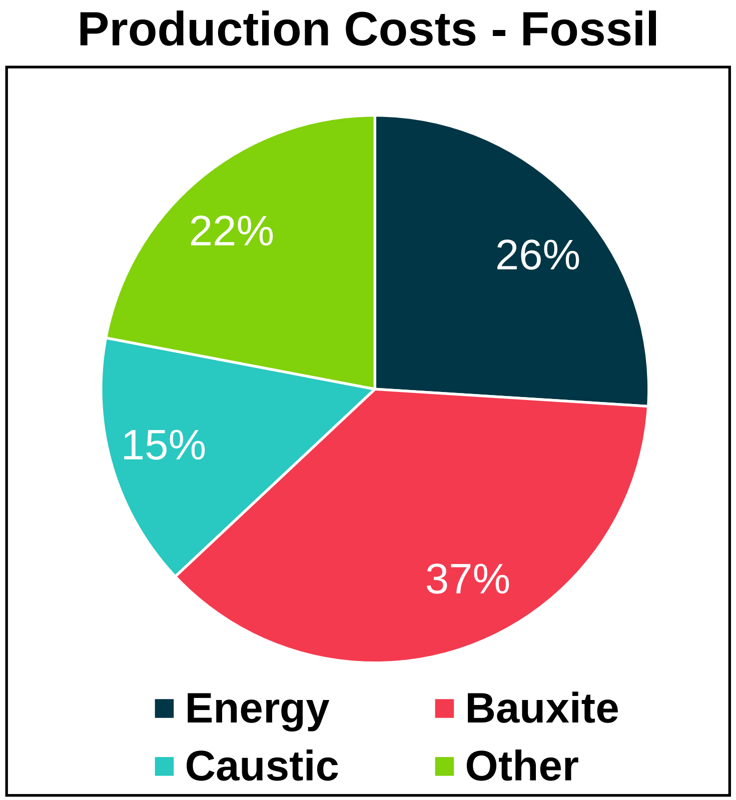


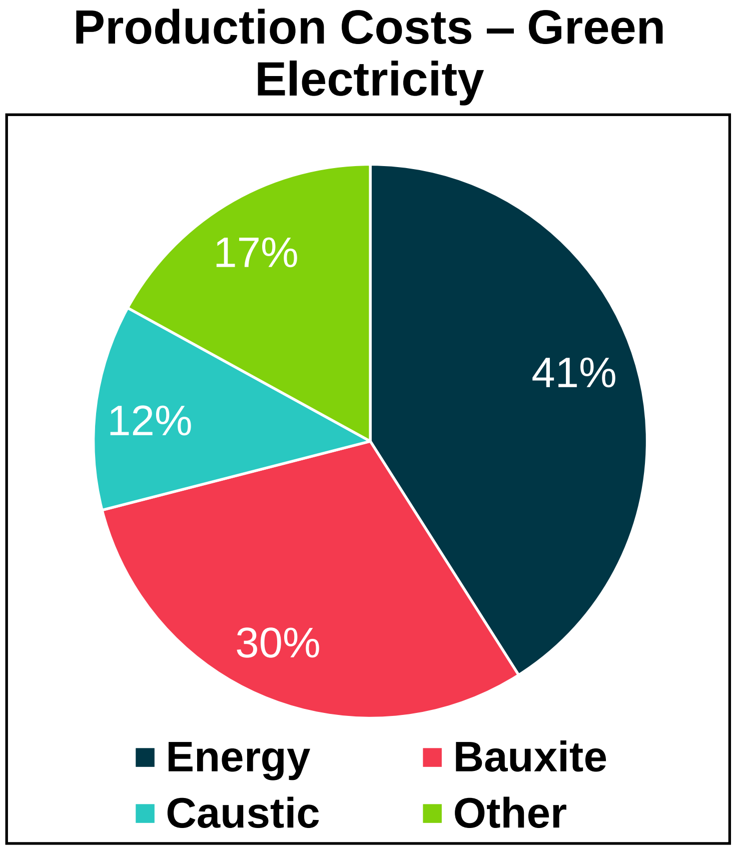
Refinery Energy Costs

The alumina industry's energy bill will become more important as the energy mix is decarbonised
....and will incentive energy efficient technology.

Energy costs could double!

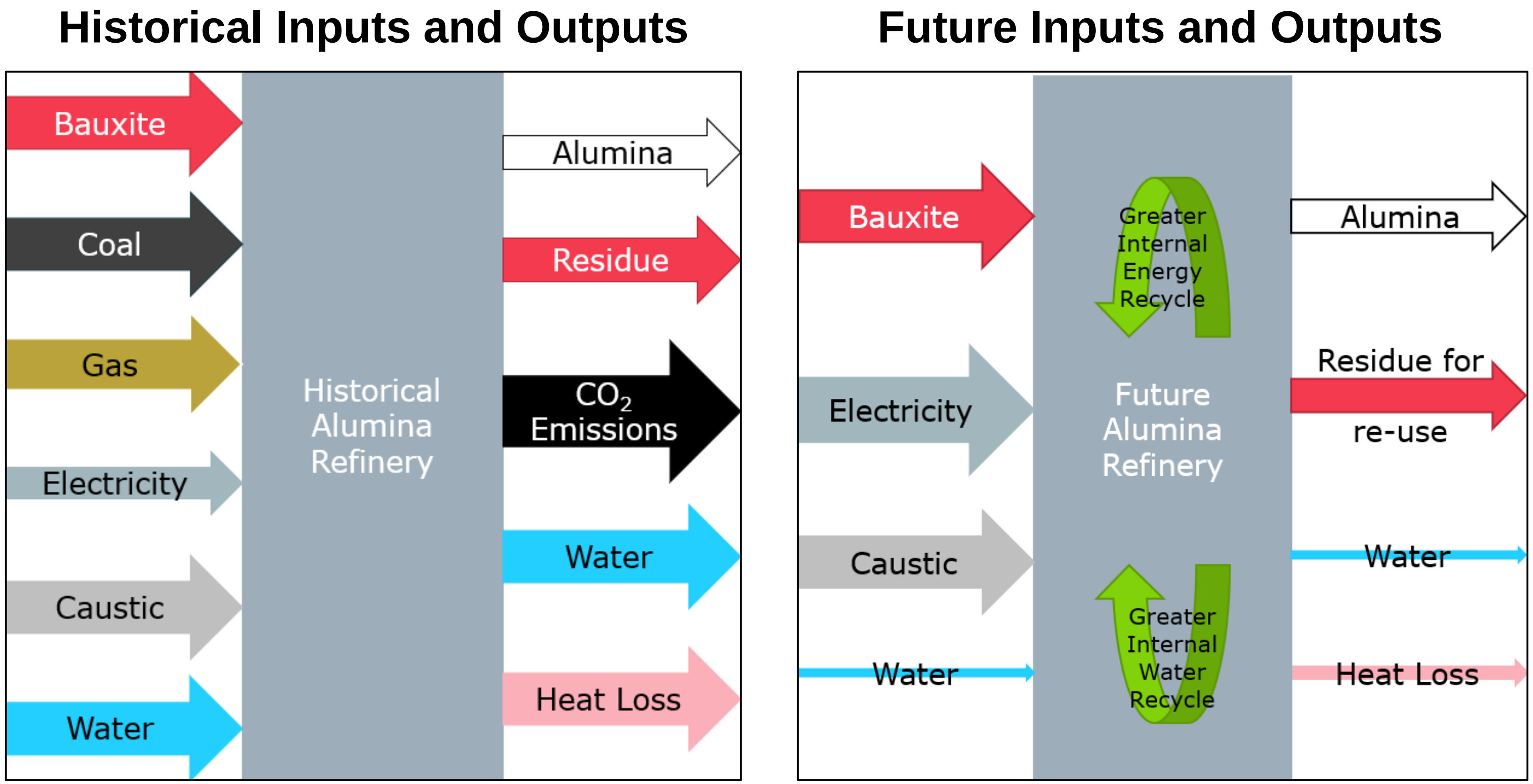
- "Typical" fossil costs of $7/GJ
- $50/MWh renewables (equivalent to $13.9/GJ)





Where are we heading?

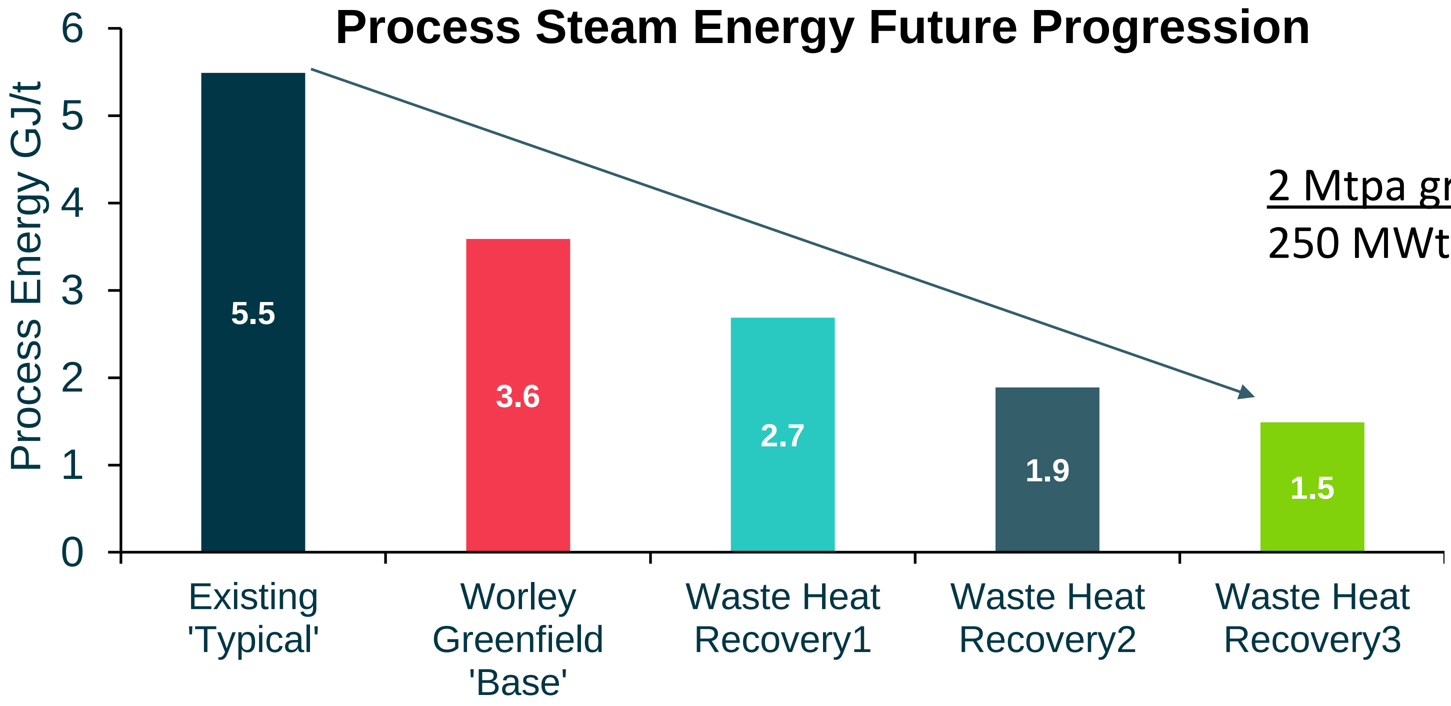
Changes in refinery technology, driven by the energy transition and waste reduction, will dramatically impact refinery inputs and outputs.



Where are we heading? Process Steam example

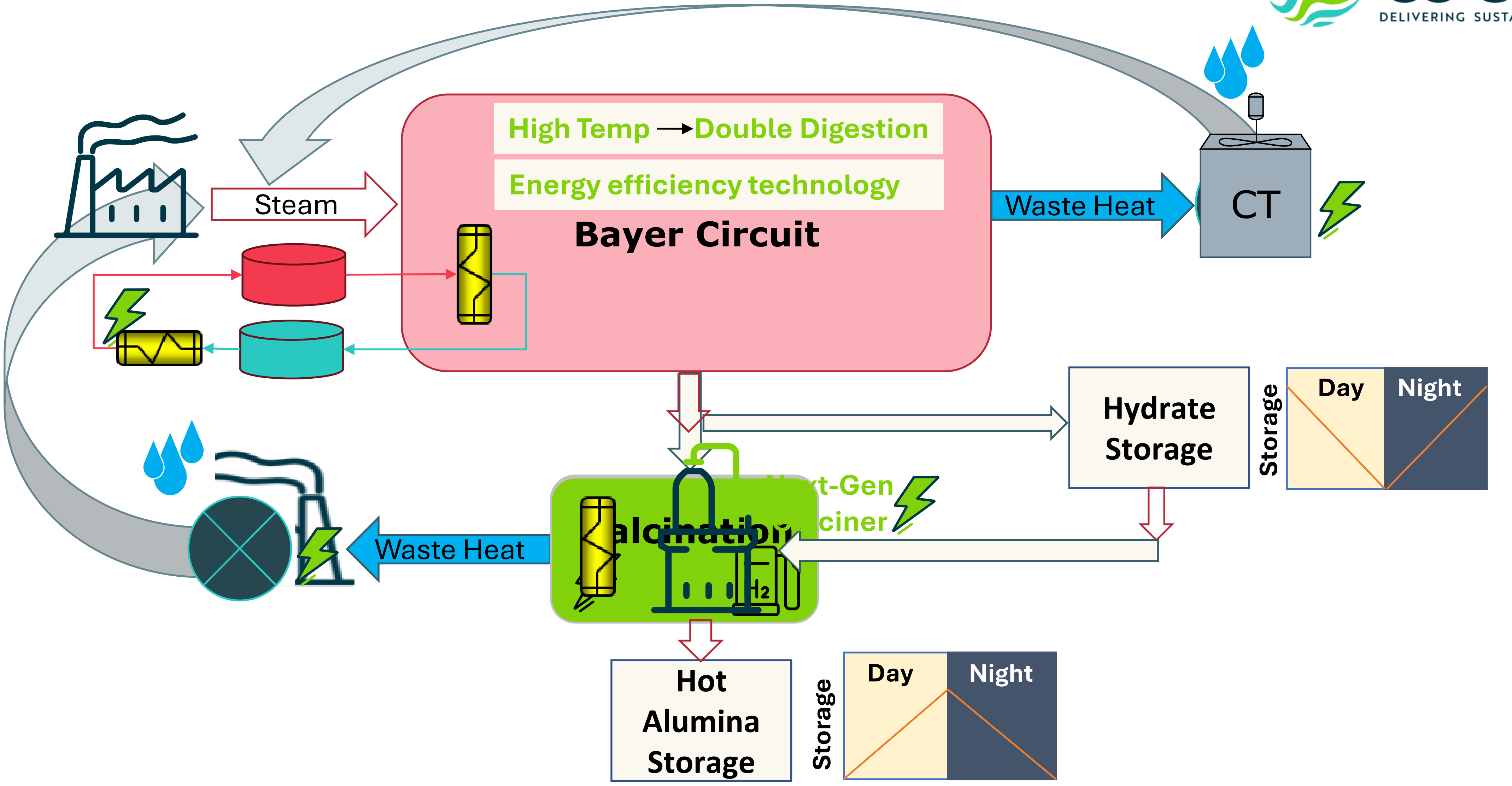
Process steam energy could reduce by >70% compared to a "typical" refinery or by ~ 60% versus greenfield best practice.

- Associated elimination of process steam CO_2 emissions.
- Associated ~80% reduction in refinery water consumption.



<u>2 Mtpa greenfield:</u>
250 MWth replaced with 100 MWe

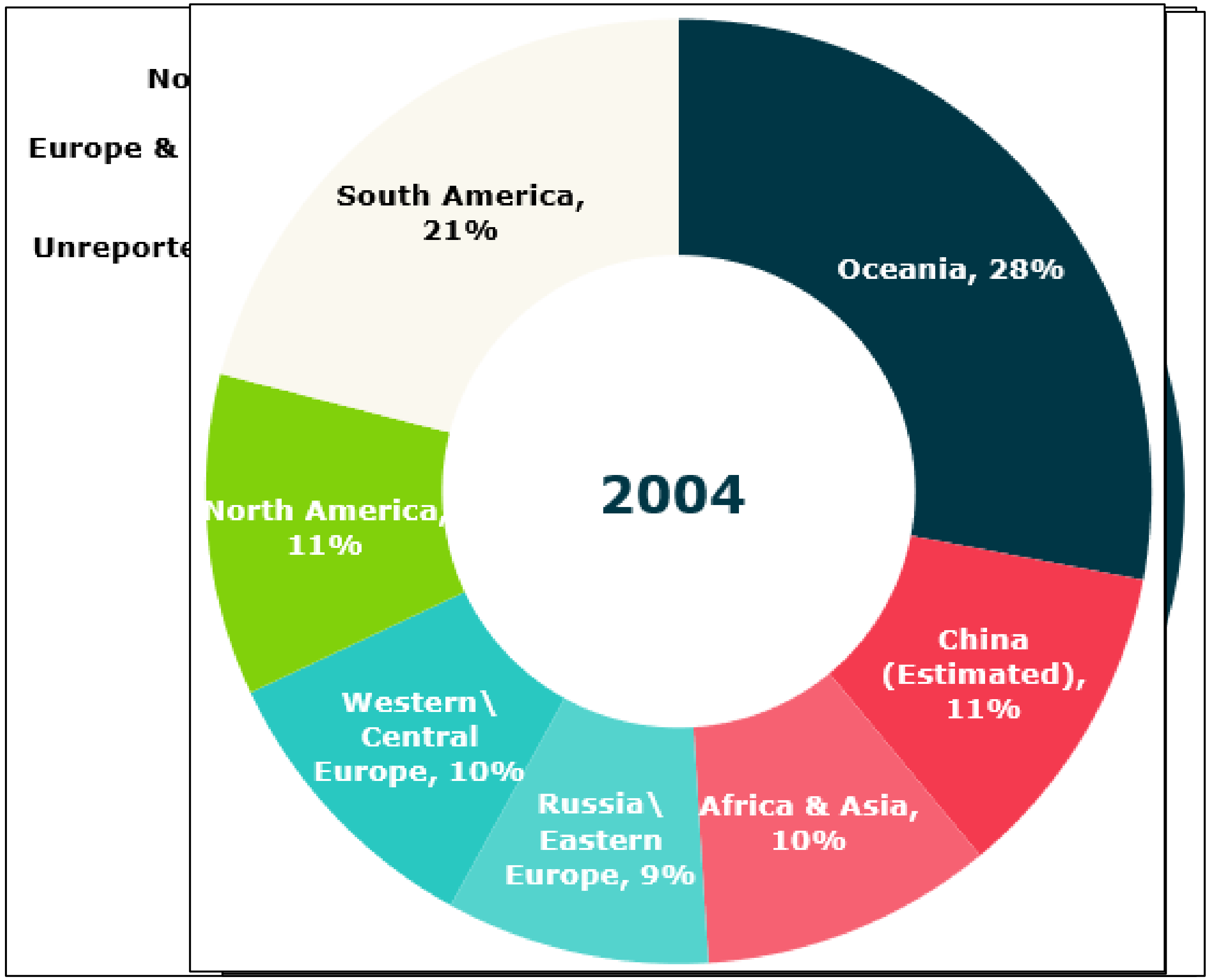
Energy source:	fossil boiler	Fossil boiler	Fossil boiler + electricity	electricity	electricity


High Temp → Double Digestion
Energy efficiency technology
Bayer Circuit
Steam
Waste Heat
CT
Hydrate Storage
Storage
Day
Night
Waste Heat
H_2
Hot Alumina Storage
Storage
Day
Night

PART II – Where will your New Refinery be located?

A Historical Perspective

- Alumina production over the past 70 years shows bursts of growth in specific regions.
- 50 years ago: half of global capacity in North America and Europe.
- 40 years ago: Australia represented ~ 1/3rd of global capacity.
- 20 years ago: China was 11% of world capacity. Today 58%.
- Current trends:
  - Chinese growth is slowing: CAGR <2% from 2019.
  - Ex-China Asian growth stepping up: CAGR >10%



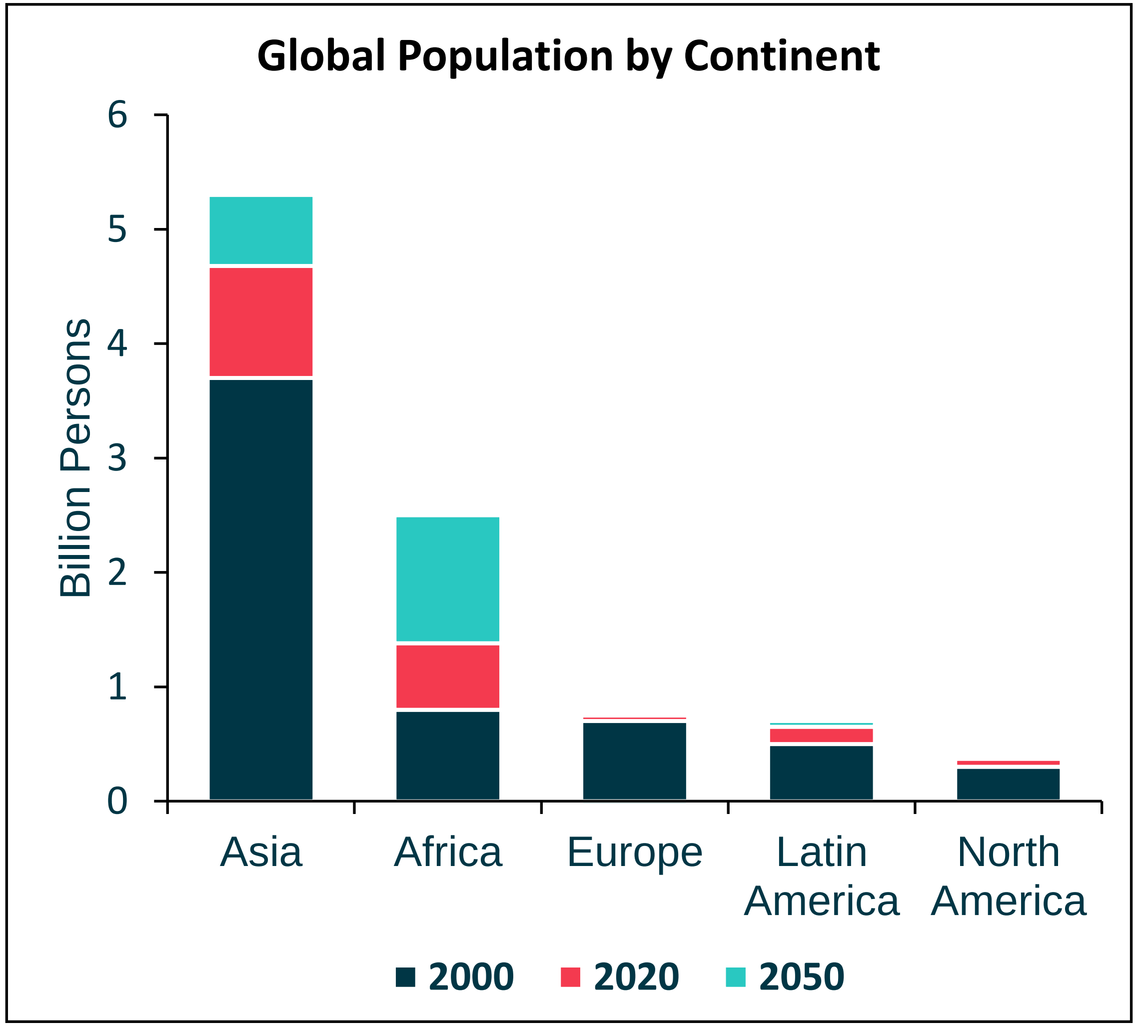
Key Traditional Drivers of Capacity Growth

- “Key drivers” affect the suitability of locations.
- Changes in these drivers has led to the historical patterns and this will continue.
- Examples:
  - China: strategic government support for aluminium value chain.
  - Australia: industry growth underpinned by low operating costs, but future growth now appears hampered by high labour costs.
  - Guinea: Political risk deterrent to date.

CAPEX	Location, Infrastructure, Methodology
OPEX	Bauxite (quality adjusted), Energy, Labour
Sales	Local / Regional / Global Market & Value Chain, Trade Synergies
Risk	Financing, Geopolitical, Partnerships, Contract Structures, ESG
Strategic	Nation Building, National Security, NGOs

Future Macro Trends - Global Population

- Africa and Asia will account for almost all population growth to 2050
  - +1.1 billion in Africa
  - +0.6 billion in Asia
- Africa increases by 212% from 2000 to 2050



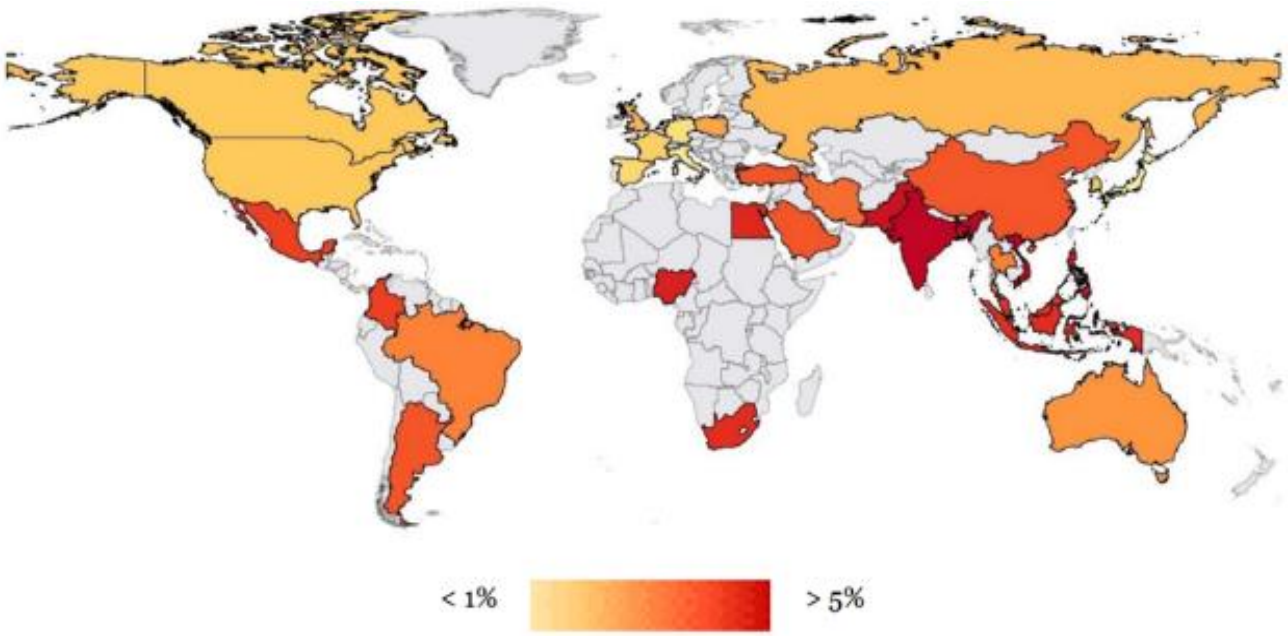
Future Macro Trends - GDP

The economic centre of the world is shifting!

- Future growth strongest in Emerging markets (E7)*
- In 1995 the E7 were half the G7's size; by 2040 the E7 could be double.
- By 2050:
  - 6 of the 7 largest economies could be "emerging", led by China (1st), India (2nd) and Indonesia (4th).
  - Vietnam, the Philippines and Nigeria are projected to be the biggest movers up the rankings.

Average Annual Real GDP Growth Rate 2016-2050

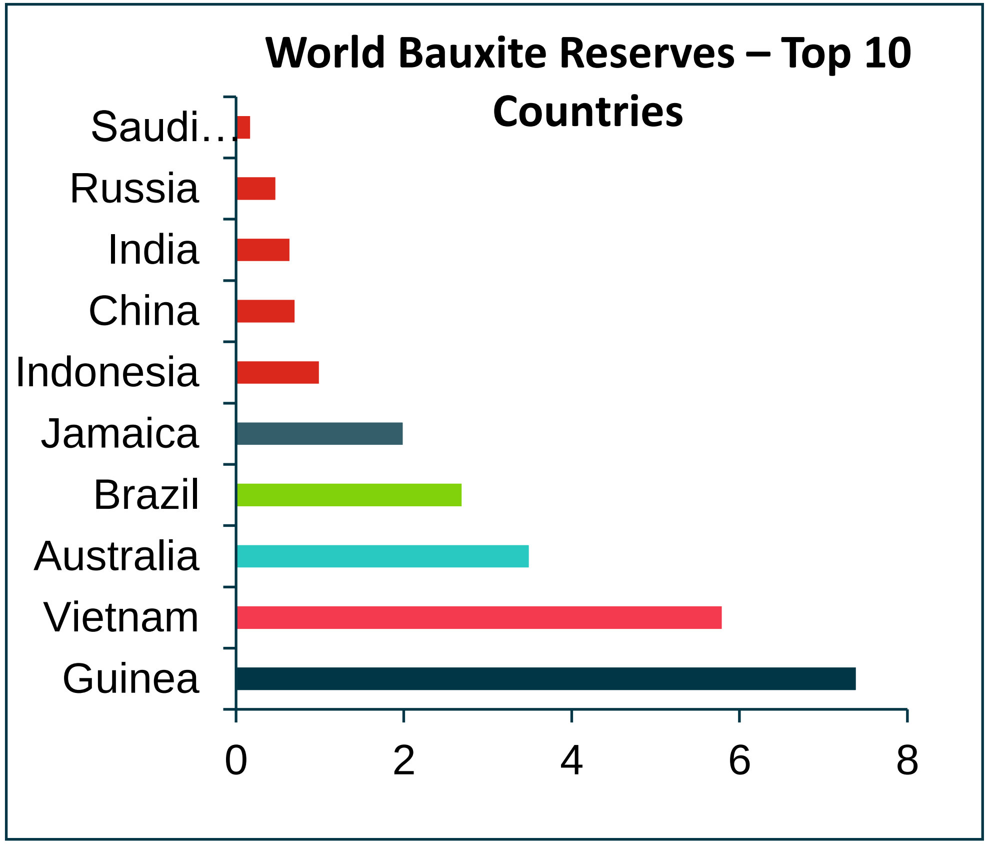
(PwC, 2017. The World in 2050 – Summary Report)



* E7: Brazil, China, India, Indonesia, Mexico, Russia, and Turkey

Global Bauxite Reserves

- Of the "Top 10" countries by reserves:
  - The "top two" hold **44%** of the bauxite reserves and produce **1%** of the world's alumina.
  - 3rd to 10th placed s hold **26%** of the bauxite reserves and produce **76%** of the world's alumina.
- Bauxite reserves lie mostly in emerging / developing economies.
- The top 2 countries (Guinea and Vietnam) lie in regions of high population and GDP growth.



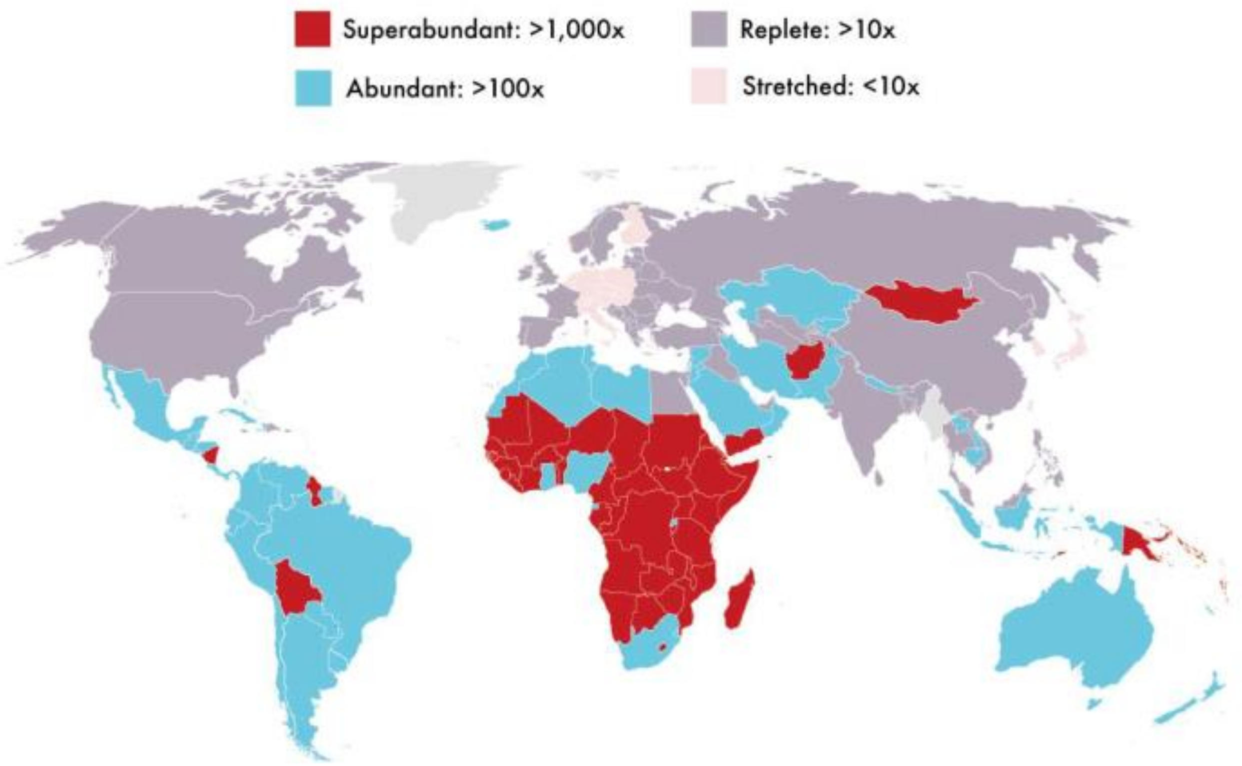
Refinery Location - Energy Transition Impact

- New refineries will be more likely in regions that offer low-cost carbon-free energy that are also near bauxite deposits.
  - Provides energy cost advantage while limiting bauxite transportation cost penalties.
  - If they can also address regional supply chain needs the opportunity will be more attractive.

Refinery Location - Energy Transition Impact

- The renewables opportunity appears strong in emerging markets.
- Africa stands out, having a 39% share of global solar plus wind technical potential.

Solar & Wind Technical Potential as a multiple of Energy Demand
(Carbon Tracker Initiative, 2021)

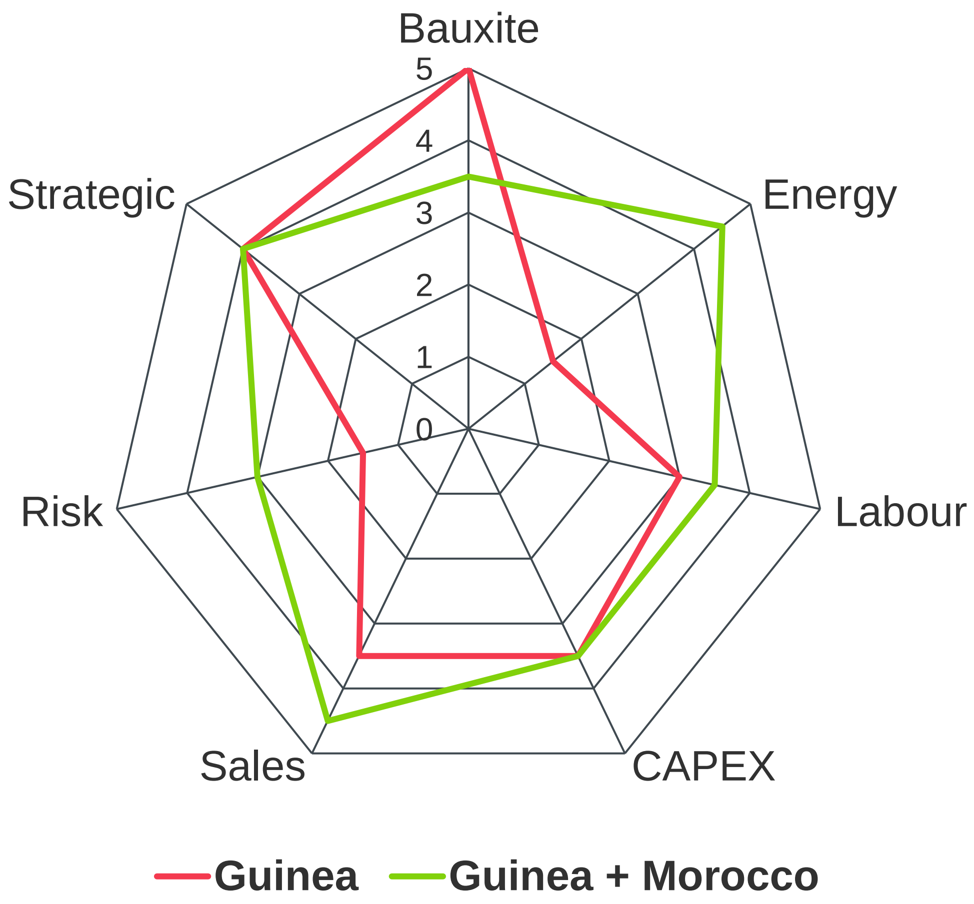


Refinery Location – "The Recipe"

- The refinery location drivers combine to create a "recipe" for development in any given country or region.
- What follows are subjective examples of some recipes for certain countries / regions
- A score of 70% or higher (24.5 out of 35), seems to indicate favourable conditions, based on history.

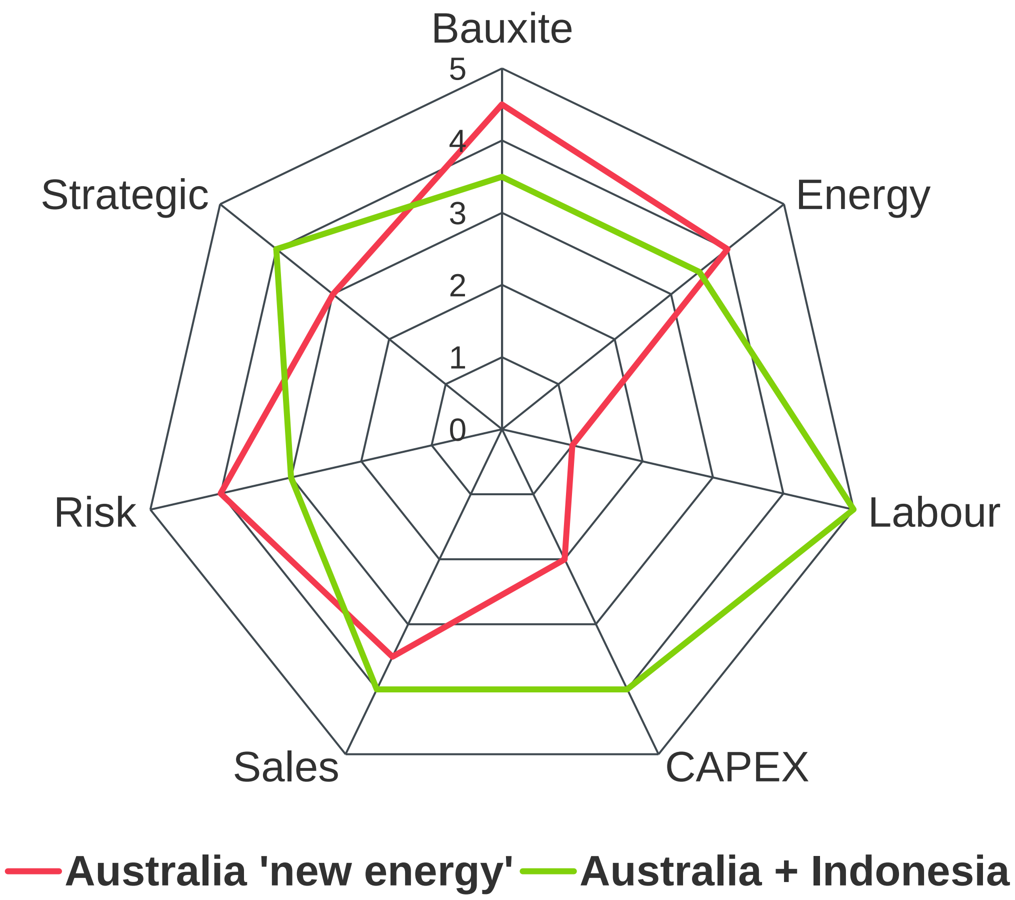
“The Recipe” – Guinea / Morocco Example

- Guinea score = **63%**
  - Pros: bauxite, strategic nation building
  - Cons: risk
- “African solution” Guinea bauxite + Moroccan refinery, score = **76%**
  - Pros: cheap renewables, lower geopolitical risk, strategic sales to both Europe and Africa, established infrastructure with world-scale world-scale phosphate chemicals industry.
  - Cons: bauxite shipping although relatively local



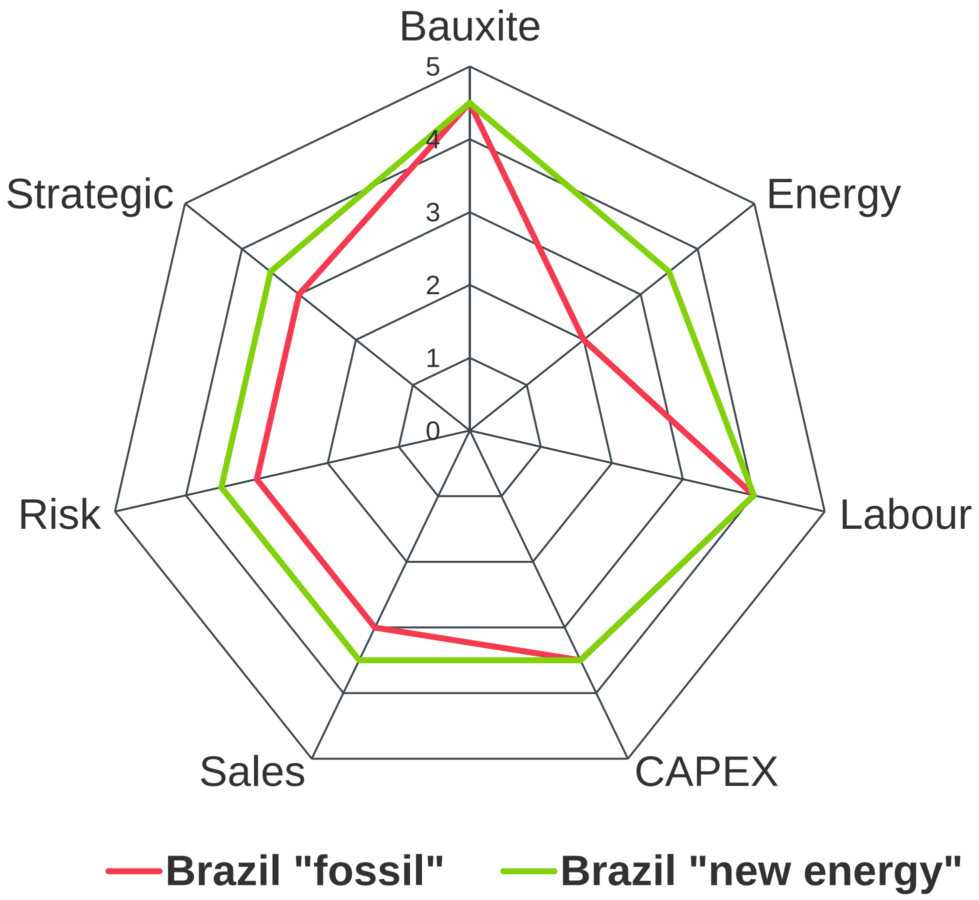
“The Recipe” – Australia / Indonesia Example

- Australian refinery based on “new energy”, score = **63%**
  - Pros: bauxite, renewable energy, low risk
  - Cons: high labour costs
- Australian “New Energy” + Indonesian refinery, score = **77%**
  - Pros: low labour costs and CAPEX, growing market, with access to renewables at a reasonable cost.



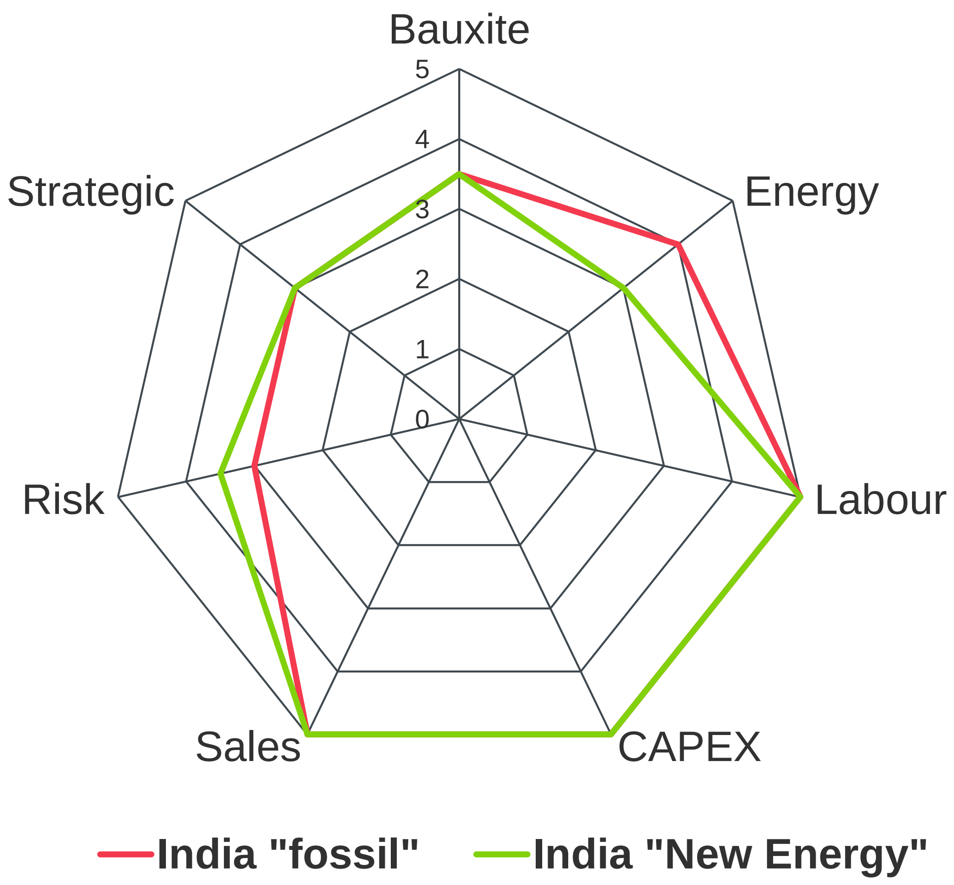
"The Recipe" – Brazil Example

- Brazil "fossil" score = **66%**
  - Cons: energy pricing
- Brazil "new energy" score = **74%**
  - Pros: competitive green energy with strategic potential to expand full aluminium value chain, lower ESG risk, regional Americas market.



“The Recipe” – India Example

- India “fossil” score = **81%**
    - Pros: labour, CAPEX, and captive sales market
    - Cons: securing bauxite access
- India “new energy” score = **80%**
    - Pros: As above with improved ESG risk
    - Cons: access to & appetite for green energy in a country to provides a captive growth market with 2070 net zero target.



Summary

- Future alumina refining growth points towards emerging economies: population, economic growth patterns, bauxite reserves….these trends are already playing out.
- Such trends will be enhanced by the future need for low cost, low carbon energy with minimised transportation costs.
- The design of new refineries will also be impacted by the energy transition and sustainability demands. These shifts are driving the most rapid technology development and change in refinery design since the early days of industry growth post World War II.
- To avoid regret capital, the impact of the energy transition needs to be factored into plans for new refineries, incorporating currently available technologies and preparing pathways for future developments.

Evaporation Retrofit with MVR A Pathway to Decarbonisation

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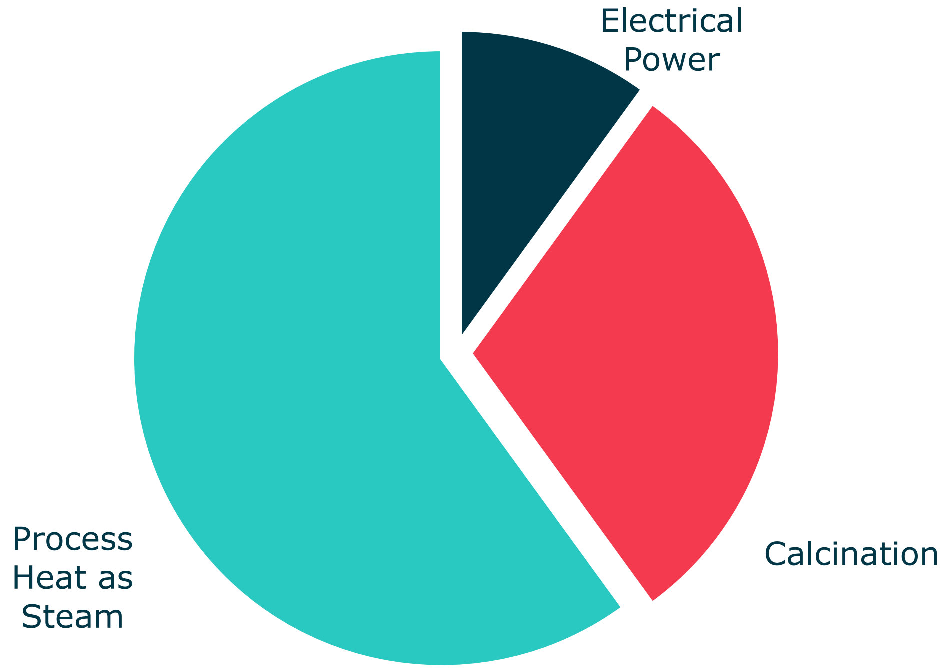
Alumina Refining Decarbonisation Challenges

- Refinery Energy Breakdown
  - Process heat and Calcination applications are difficult to abate
  - Fossil fuels (coal, fuel oil and gas) are currently widely used to generate steam for process heat and energy for Calcination

- Challenges
  - Incorporating emerging technologies that may have uncertainty and technical risk
  - Justification of significant investment in capital
  - Time pressures to meet decarbonisation targets (internally within the business and also external)



Decarbonisation Pathways

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01

ELECTRIFICATION

Advantage of low cost of renewable electrical energy

02

INNOVATIVE REFINERY TECHNOLOGY

Adapt refinery flowsheet and incorporate decarbonization themes

03

E-FUELS

Modify existing equipment to run on Hydrogen and other zero carbon fuels

04

CARBON CAPTURE

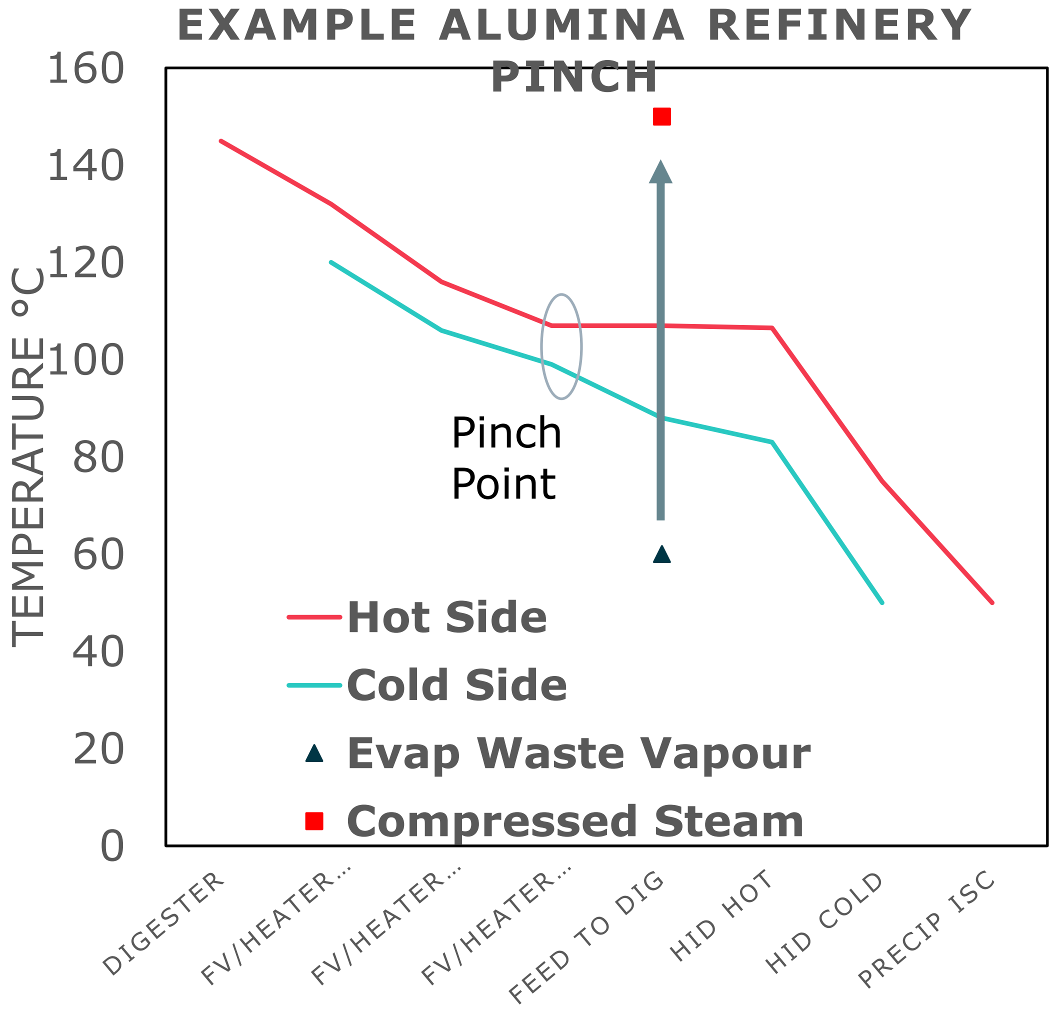
Prolong life of existing assets

What is MVR?

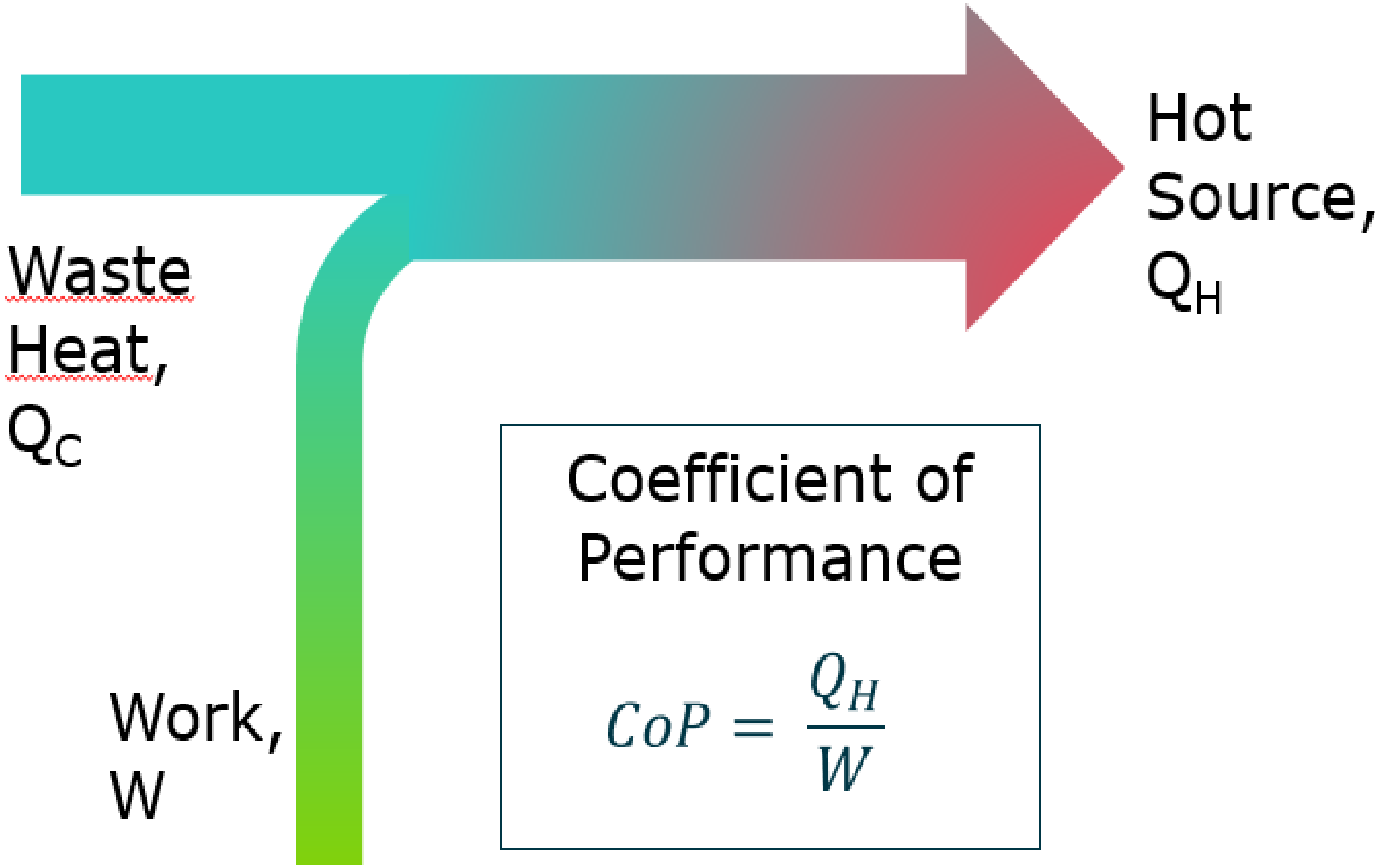
- Mechanical Vapour Recompression
  - Increasing the pressure of low pressure (waste) vapour (even under vacuum) from below the pinch point to useful steam above the pinch point

- Types of MVR equipment
  - Centrifugal fans
  - Rotary lobe compressors
  - Reciprocating or piston compressors
  - Multi-stage centrifugal compressors
  - Screw compressors

- Efficiency Gains over other Technologies
  - Coefficient of Performance (CoP) is greater than 1



Coefficient of Performance (CoP)



Coefficient of Performance

$$CoP = \frac{Q_H}{W}$$

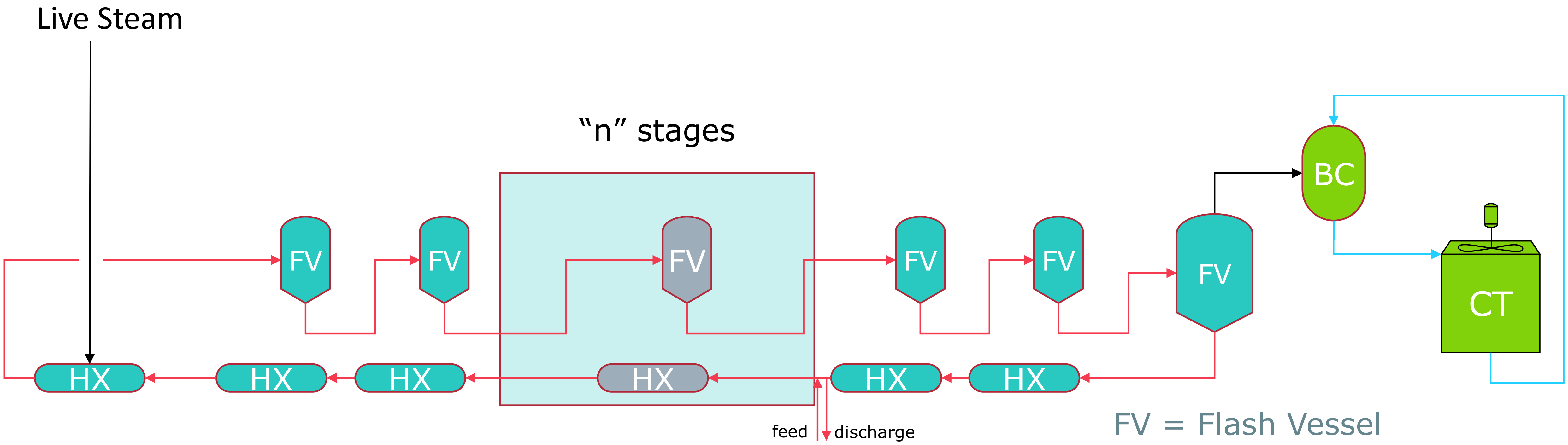
Retrofitting an Existing Evaporation Unit with MVR

- MVR retrofits applicable to all flash evaporation technologies
  - Multi-Stage Flash Evaporation
  - Falling Film Evaporation
  - Forced Circulation Evaporation

- Many possible configurations for retrofit
  - Series
  - Parallel
  - Hybrid – a mix between series and parallel

- MVR Sparing options

Multi-Stage Flash Example Existing (no MVR)

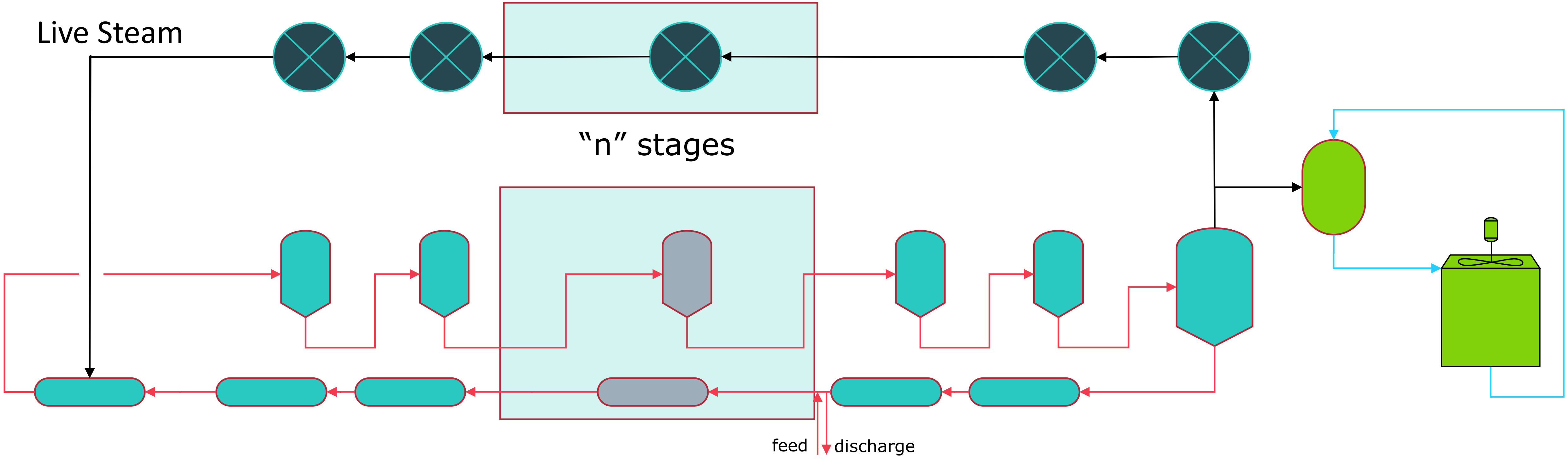


FV = Flash Vessel
HX = Heat Exchanger
BC = Barometric Condenser
CT = Cooling Tower

Energy Source → Live Steam

Waste Energy → Vapour lost to cooling water – heat ejected in cooling tower

Series



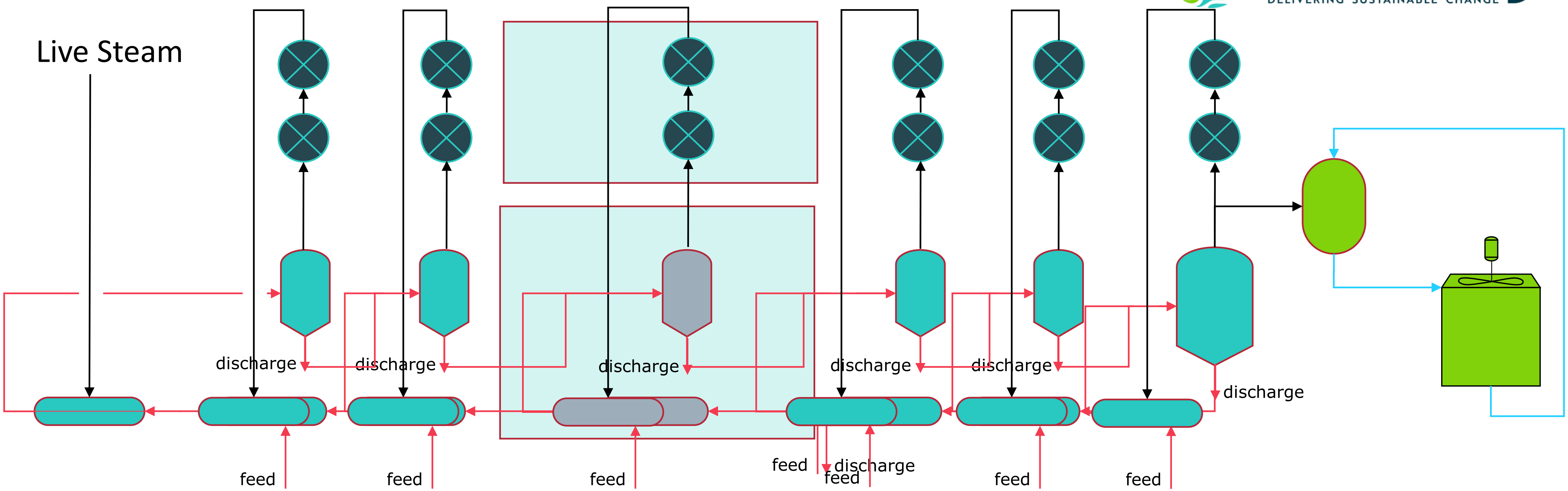
Energy Source → Electricity, live steam only for start-up

Waste Energy → Recovered

Minimal configuration changes

Several large MVR fans in series

Parallel



"n" stages

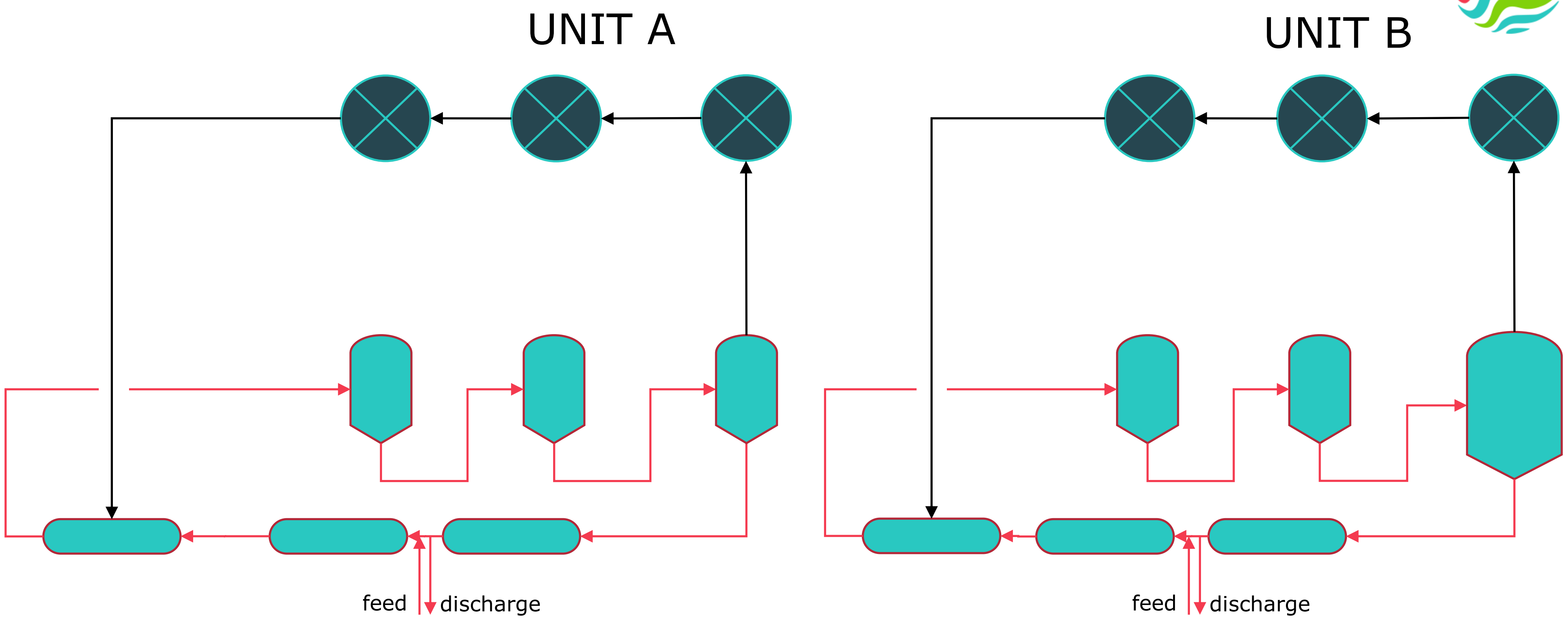
Energy Source → Electricity, live steam only for start-up

Waste Energy → Recovered

Evaporator units in parallel

Two stages of MVR fans to overcome BPE and provide driving force for heat exchange

Hybrid



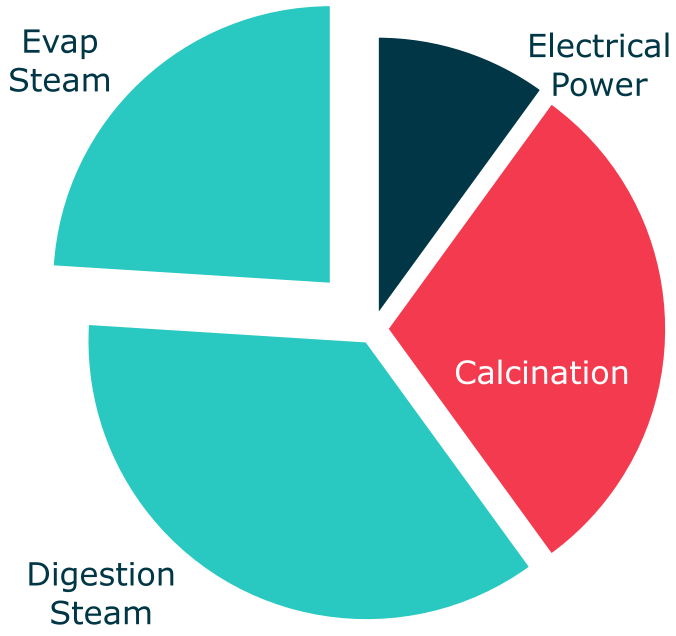
Combination of series and parallel – can split existing train into 2, 3 or more units

MVR Sparing and Availability

- Series / Hybrid
  - Utilise existing Barometric Condenser and Cooling Water circuit as standby for MVR
  - MVR availability expected to be higher than 90%
  - Achieve electrification benefits more than 90% of time
  - Minimise capital cost – no cost for additional MVR compressors and associated valving/piping

- Parallel
  - High MVR availability – only 2 MVR fans in series
  - Spare MVR fans not justified – minimal availability gain for significant capital
  - Smaller parallel units – smaller impact on evaporation rate when unit off for maintenance

Summary



- MVR on Evaporation
  - Electrifies up to 40% of refinery process heat (~2 GJ/t)
  - Recovers waste heat improving energy efficiency and
  - Recovers water which results in lower operational costs.
- MVR Retrofit of existing evaporation units
  - Utilises most of existing assets minimising capital
  - Known and proven technology
  - Excellent initial step for transitioning away from fossil fuels for steam raising
- Several MVR retrofit options available. Front-end engineering to select the best solution determining the key criteria and risks.
- Strategic value adding project with learnings for further MVR based electrification and decarbonisation.

Thank-you