Deep Electrification in Refineries

A presentation by Wood.

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We are a global consulting and engineering company with world leading expertise across the energy and materials markets.

160+ year history	**c36,000** people
60+ countries	**c$6bn** revenue

Connected by our shared values of **care**, **commitment** and **courage**

AA leader rating from MSCI for environmental, social and corporate governance

Energy.

Oil & Gas | Hydrogen | Carbon Capture

Materials.

Minerals | Chemicals | Life Sciences

Decarbonisation Enabling clients to reach net zero through sustainable design and operations

Digitalisation Leading independent partner for operational technology and digital transformation

Our Capabilities

Through our specialist and extensive industry knowledge, understanding and expertise, Carbon Advisory supports clients with a range of decarbonization & sustainability services including but not limited to:

Emissions Baselining & LCA

- **GHG emission baseline**
- **Life Cycle Assessments**
- Product Carbon Footprint
- Quantify all aspects of **scope 1, 2 and 3**
- Aligned to standards such as ISO, GHG Protocol, CORSIA, EU Taxonomy, ISCC, RED, JOGMEC, IPHE and Global Battery Passport.

Decarbonisation Roadmaps

- **Decarbonisation roadmaps** with journey timlines, drivers and key milestones.
- Built on **technical & commercial expertise** to meet emissions targets
- Prioritised actions using **Marginal Abatement Cost Curves**
- Focused on **cost of carbon abated** for efficient reduction pathways

Policy & Market Guidance

- Strategic guidance on **decarbonisation policy**, **evolving regulatory frameworks**, and **certification standards**
- Integration of **technical expertise with policy insight** to support informed decision-making
- Deliver of high-level **market intelligence** on supply and demand dynamics

Energy Management

- Identify measures to reduce **energy consumption** and improve **operational performance**.
- **Energy Efficiency / Management Studies**
- Electrification of industrial equipment
- Heat pump integration

Environmental & Sustainability Consulting

- Environmental & Sustainability **Due Diligence**
- Environmental & Social **Impact Assessments.**
- Identify **physical and transitional climate risks** to support resilience planning.
- Circularity Studies

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Why Electrify?

- Scope 1 emissions reduction
- Often relatively simple project and operation
- Efficiency benefits
- Infrastructure is (partially) present

But…

- Not all applications are easy
- Power generation and new infrastructure dependent
- Competing decarbonisation methods

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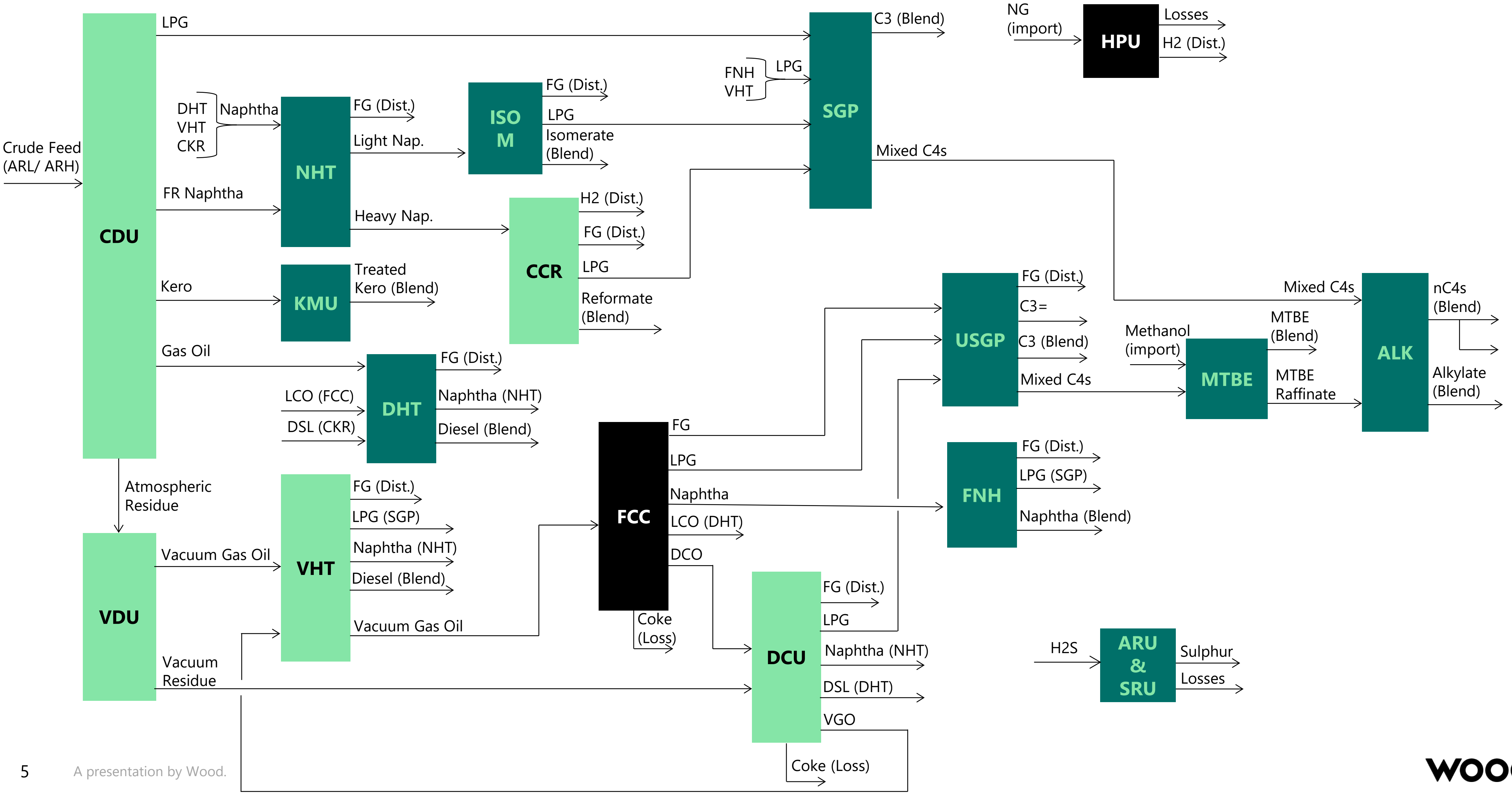
Where to Focus?



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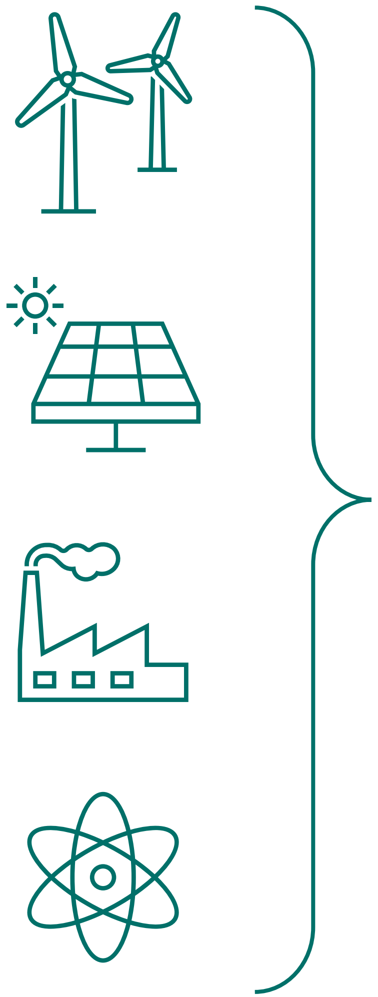

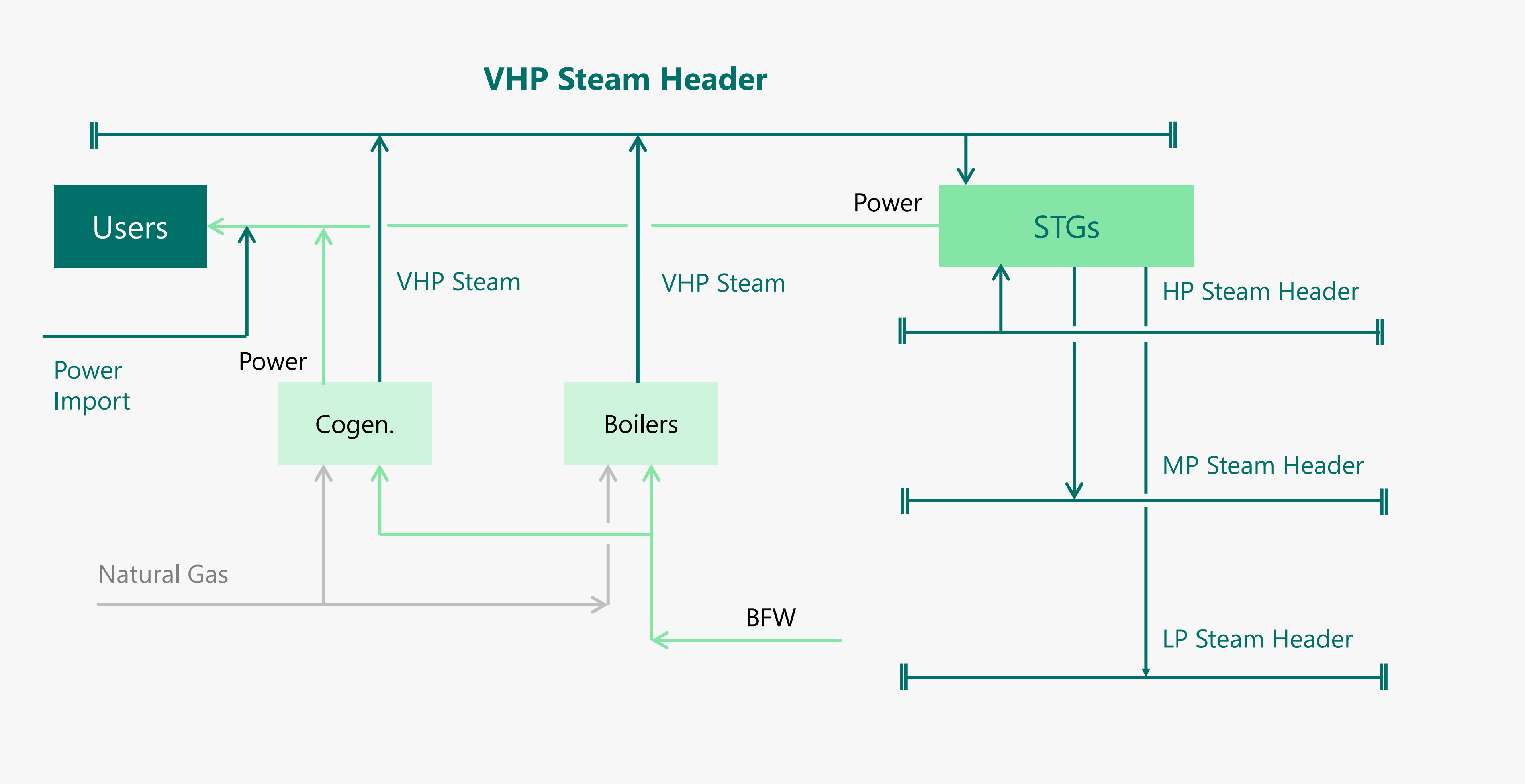

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Technology Assessment

- **Illustrative example for a site**
- **Weighted combination of criteria including:**
  - CAPEX
  - Technology Readiness Level
  - Shutdown dependency
  - Operations, reliability, maintenance
  - Emergency scenario impacts
- **Energy OPEX and overall economics have also been assessed**

	CO_2 Reduction Potential	CAPEX Effectiveness	Low Carbon Electricity Effectiveness	Maturity	Operations and Maintenance	Shutdown and Execution
Electric Process Heater (Large Residue)		**Medium**	**Medium**			
Electric Process Heater (High Temp)		**Low**	**Low**			
Electric Process Heater (Others)		**Medium**	**Medium**			
Electrolyser		**Low**	**Low**			
Mechanical Vapour Recompression		**Medium**	**High**			
Electric Drive (vs. Condensing Turbine)		**Very High**	**High**			
Electric Boiler		**High**	**Medium**			
Electric Tank Heating		**Low**	**Medium**			
Electric Heat Tracing		**Low**	**Medium**			

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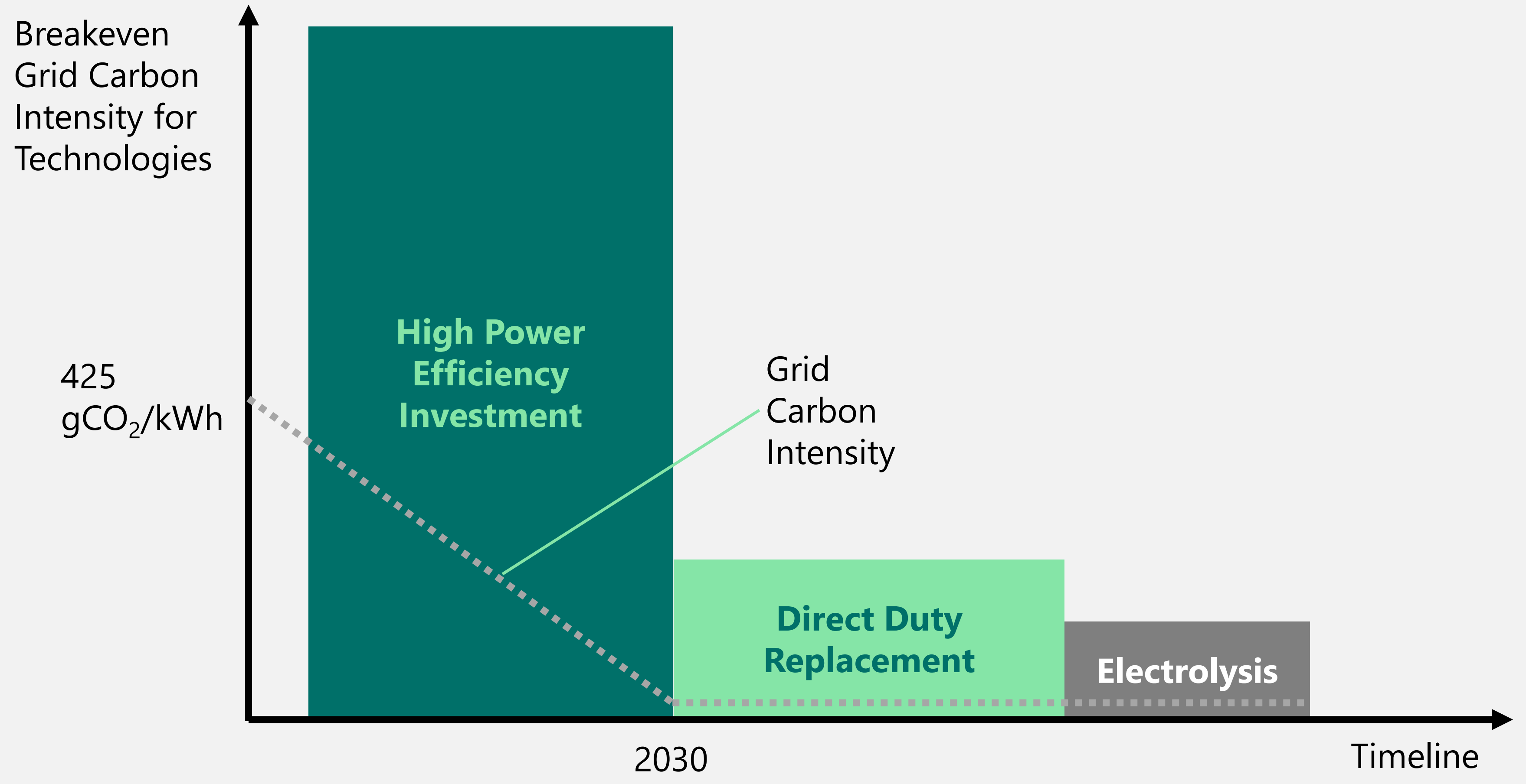
Timing Considerations



Potential Roadblocks

Roadblock	Response
Limited availability of low-carbon power	Cogeneration maintained
Delay in commercialisation of large residue electric heaters	Increased green hydrogen production Advances in hydrogen production Burner modifications for hydrogen firing
Delay in commercialisation of large residue electric heaters	Fuel gas firing maintained with CO_2 removed via Carbon Capture and Storage (CCS) technology. Also relevant where a fuel gas long position cannot be sufficiently mitigated
Low-carbon power availability	Delay of direct power-to-heat implementation (boilers, heaters)
Current inefficient condition of steam and condensate system	Avoid electric boiler investment Replacement of steam heaters/reboilers and tracing by direct electrical heating

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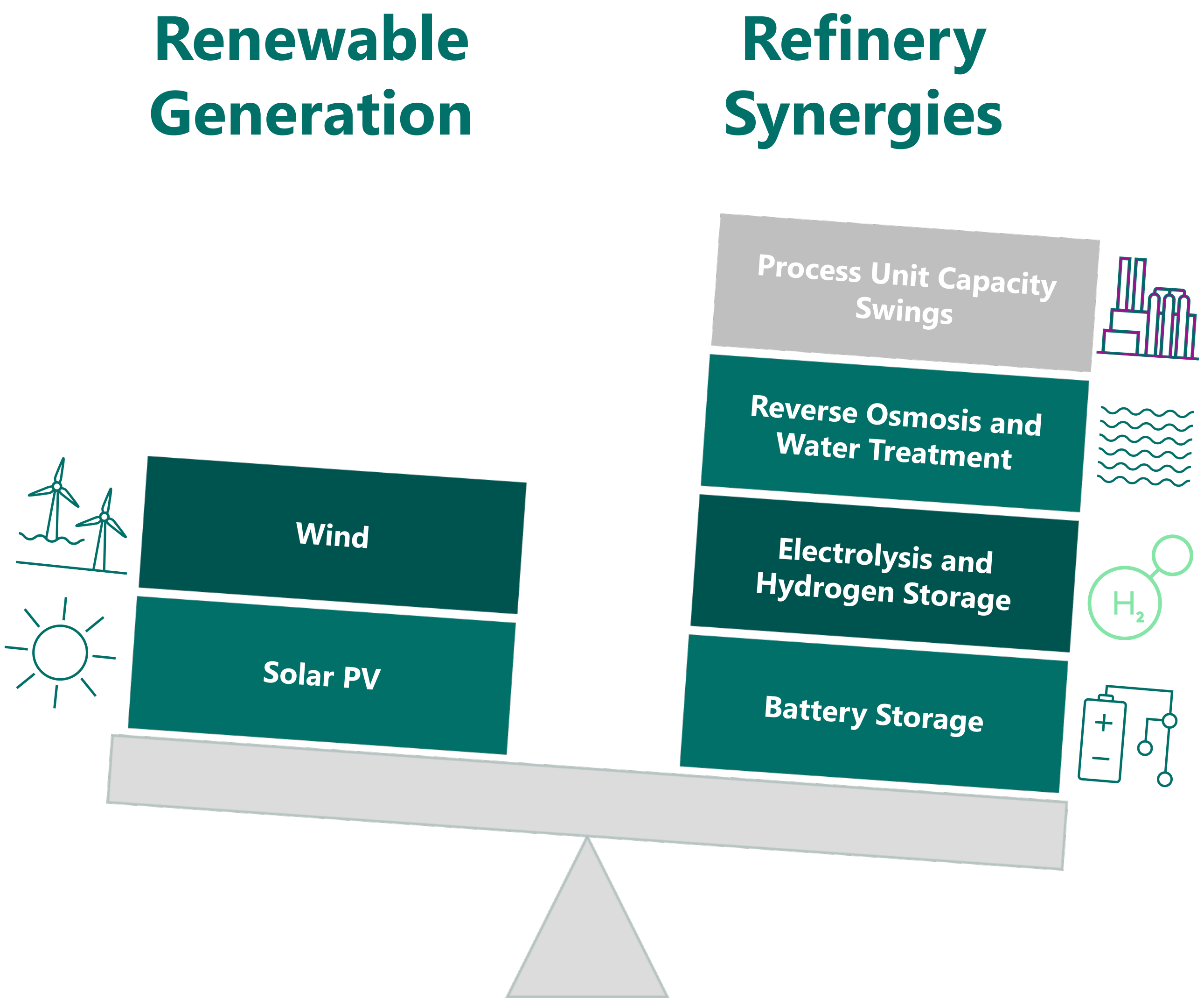
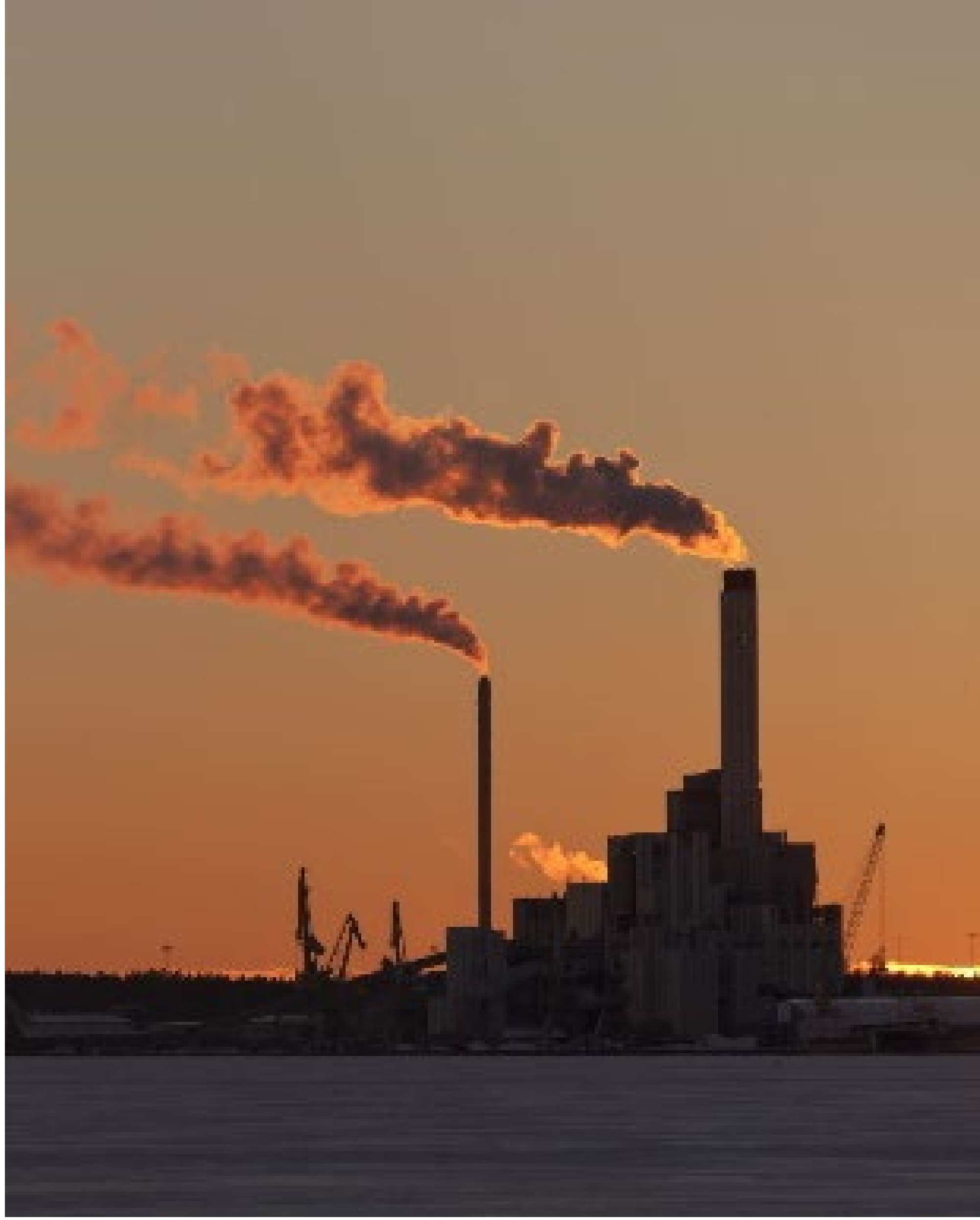
Electricity Storage





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Example Study Results

Study Aims and Approach

Ultimate Objective

Assess and quantify the potential of electrification as a GHG emissions reduction lever for the Refining Industry across three representative levels of refinery complexity

Phase 1
Baseline energy mix in refineries

Phase 2
Identification of opportunities for electrification

Phase 3
Quantitative impact and ranking of the electrification options

Phase 4
Identification of roadmaps for implementing electrification options to the baseline(s)

Focus on Collaboration with OGCI Members

- Workshops with the Energy Efficiency in Industry Workstream
- Screening of technologies – benefit and practical feasibility
- Roadmap scenario development – challenges for the member company assets

Key Decisions for Process Configurations

Configuration Goals

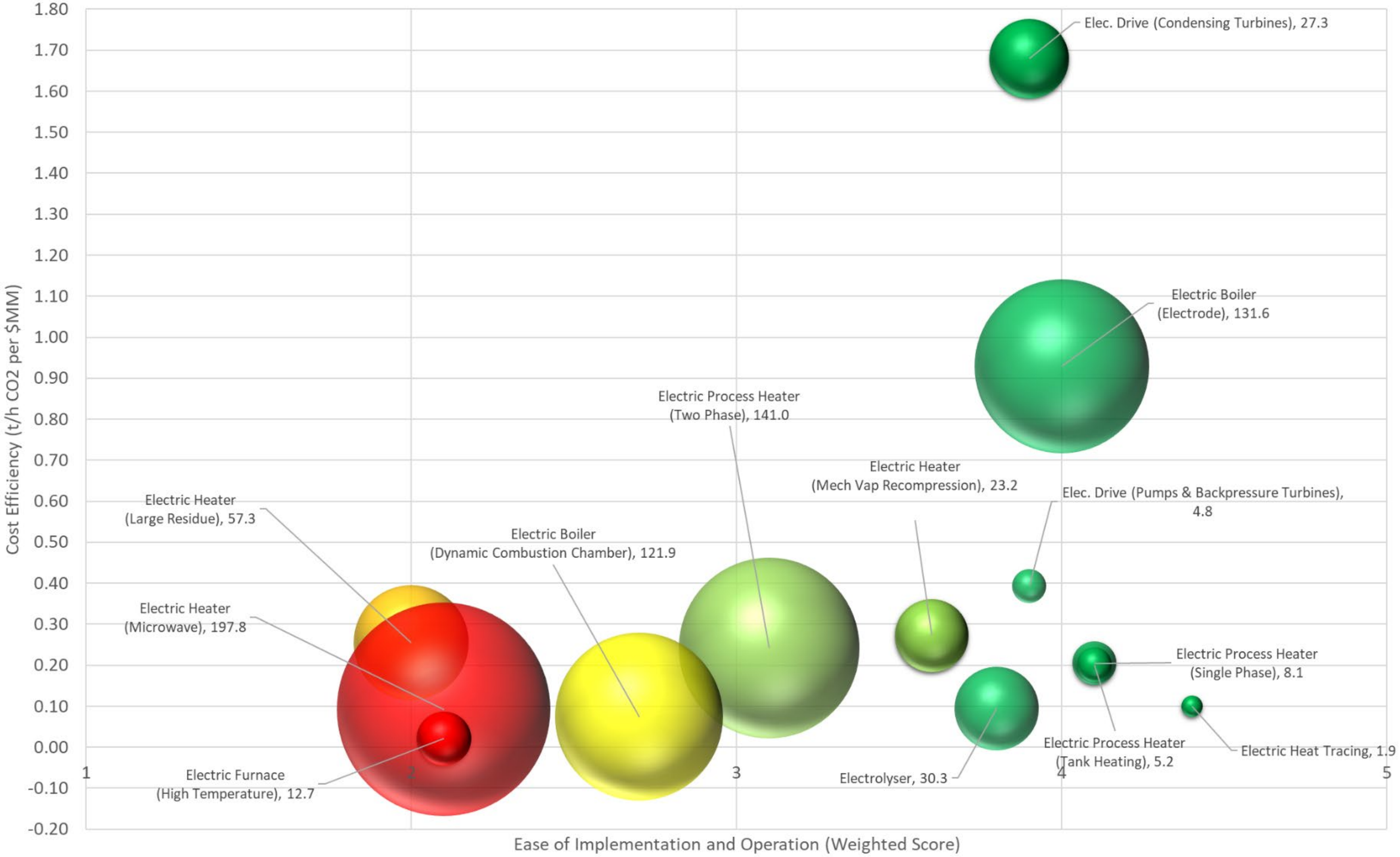
- Typical and common for the respective complexities
- Avoid unnecessary specific features
- Represent current and near-future fuels specifications (Euro-V)
- Differences in units to allow investigation of different site balances and unit challenges.

Low Complexity
- Hydroskimmer
- No STGs/GTGs

Medium Complexity
- VGO Hydrocracking
- STGs in steam system

High Complexity
- Full conversion with FCC & Coker
- STGs & Cogen

Ranking Output **Bubble Size = Site CO2 Saved (t/h); Colour = TRL**



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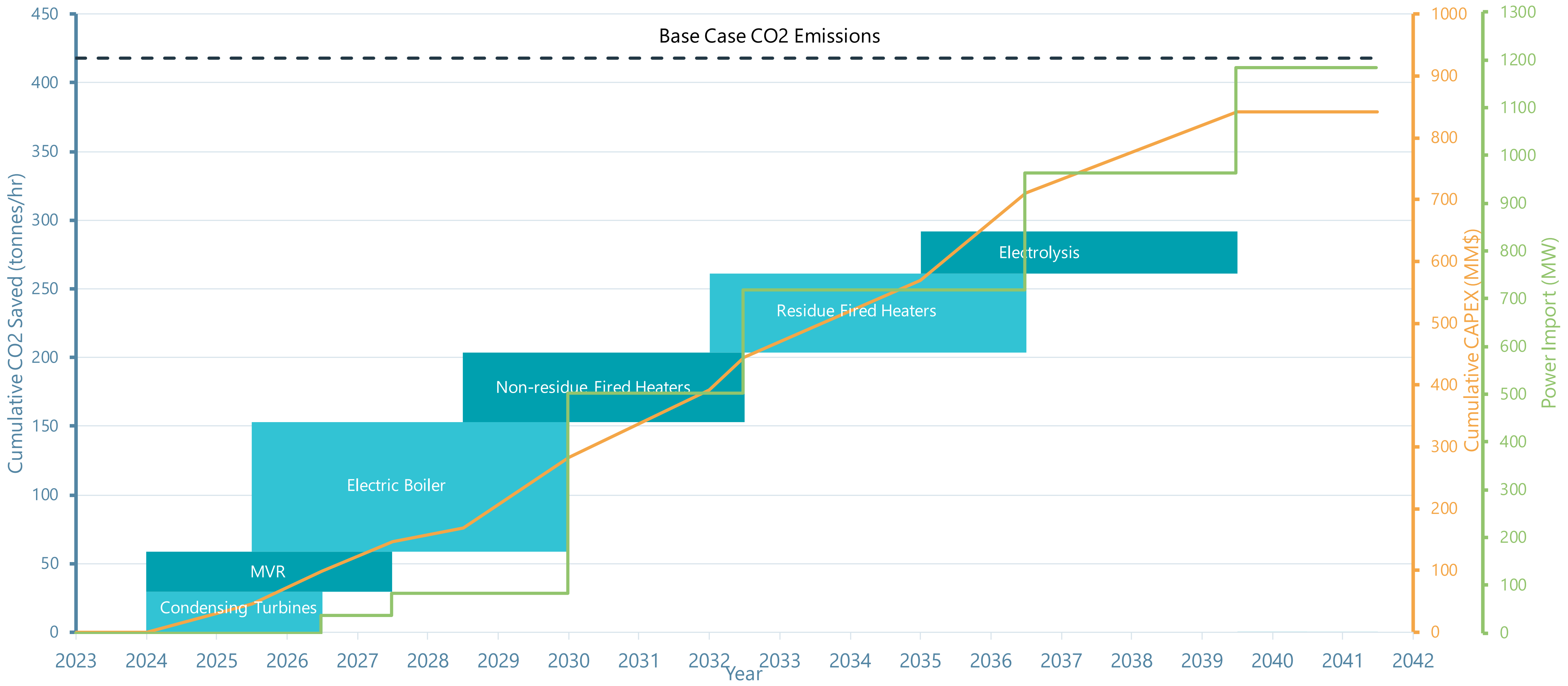
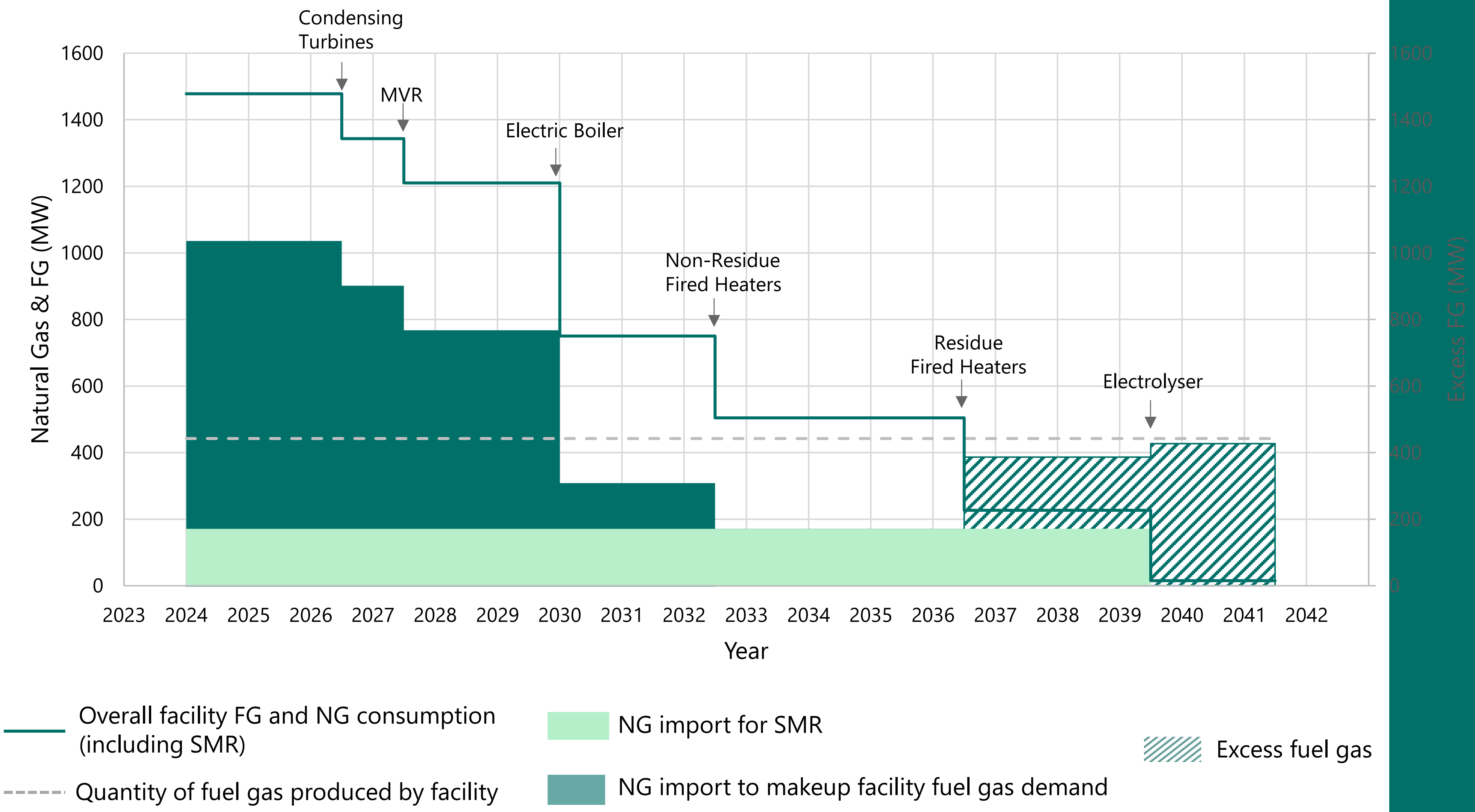
High Complexity Refinery Primary Roadmap



Example Refinery Fuel Gas Balance



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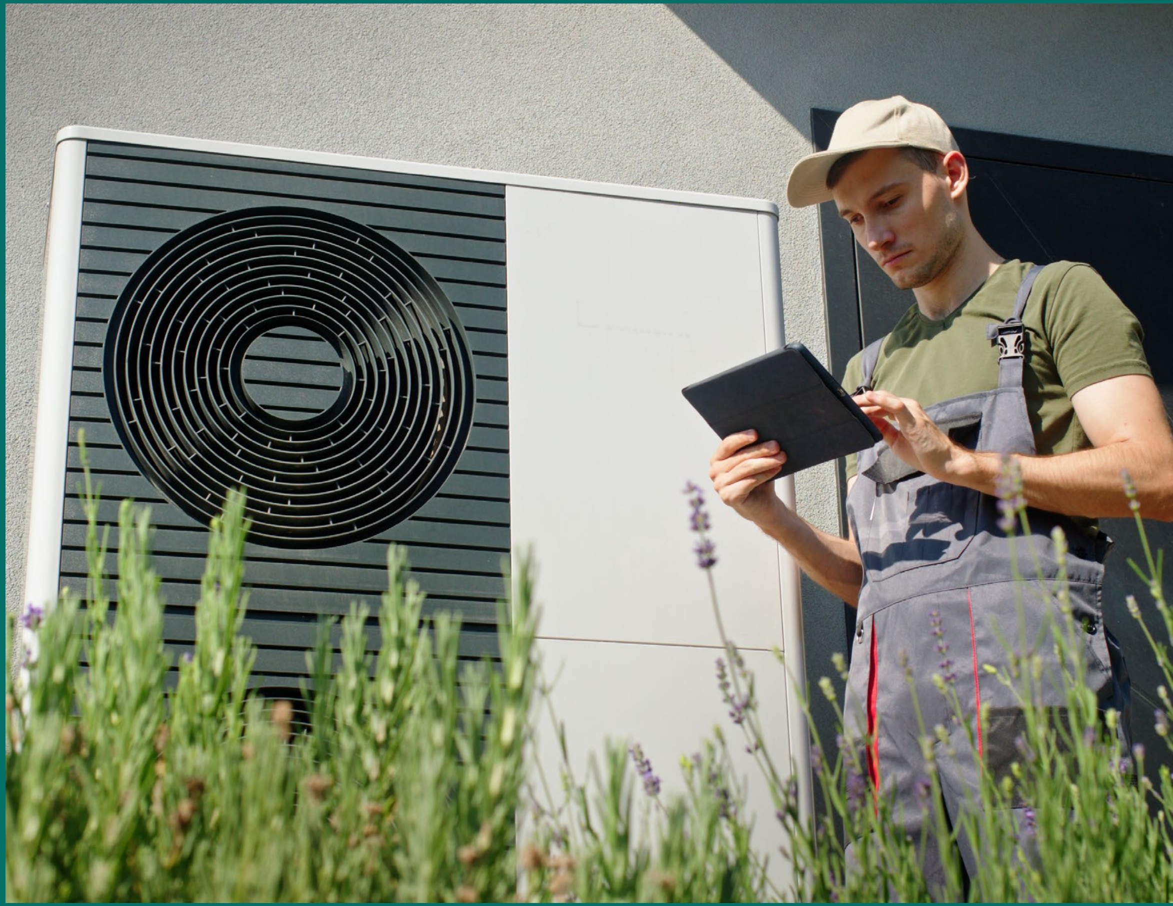
Technology Focus:
Heat Pumps in Refining



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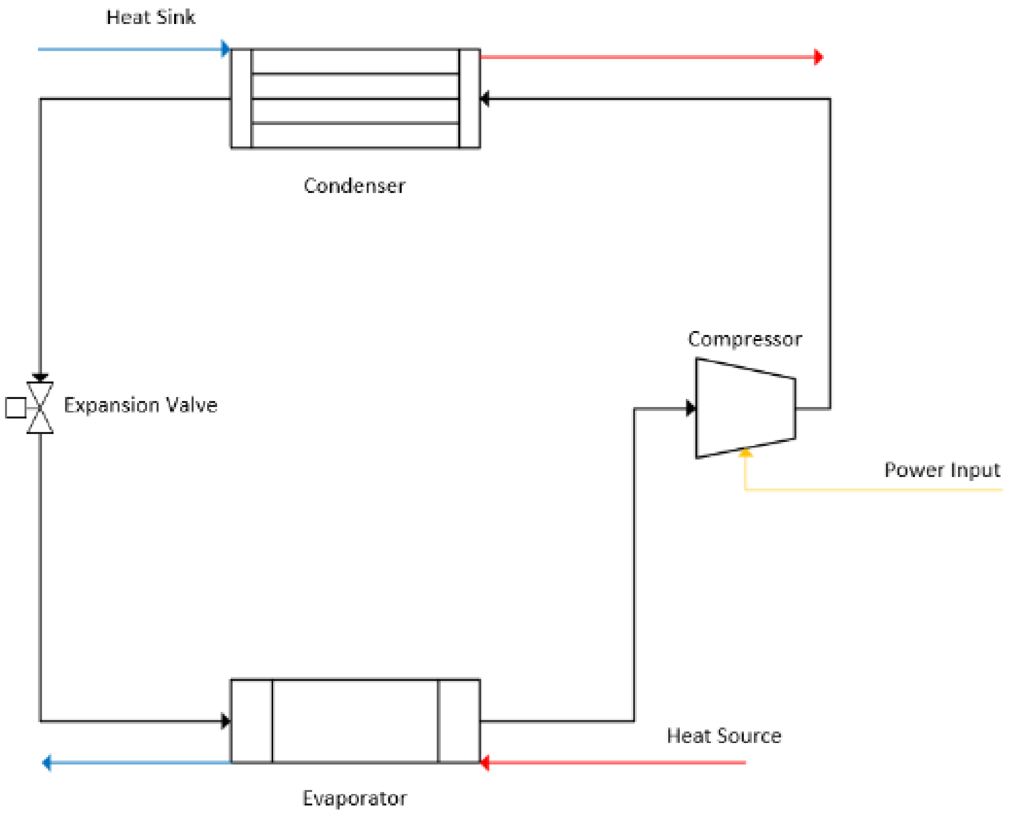
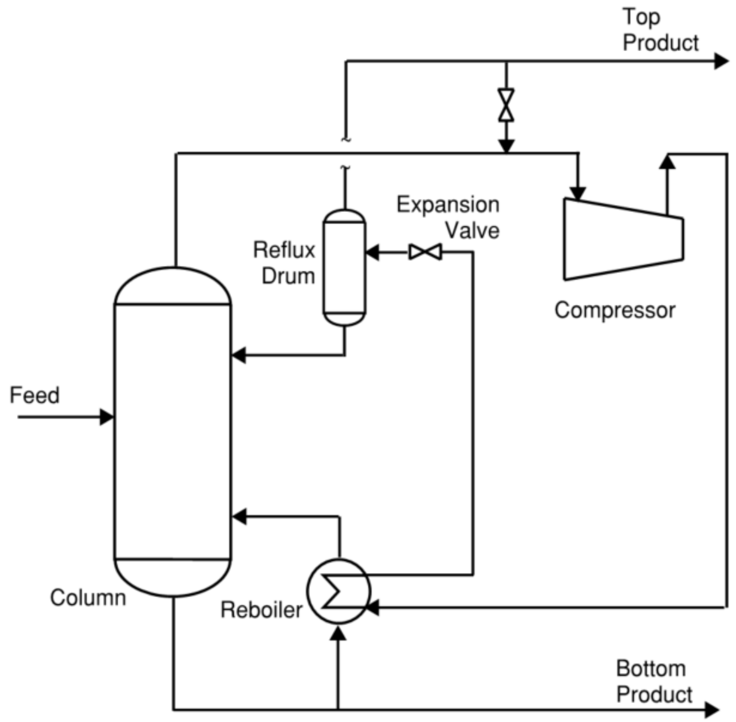
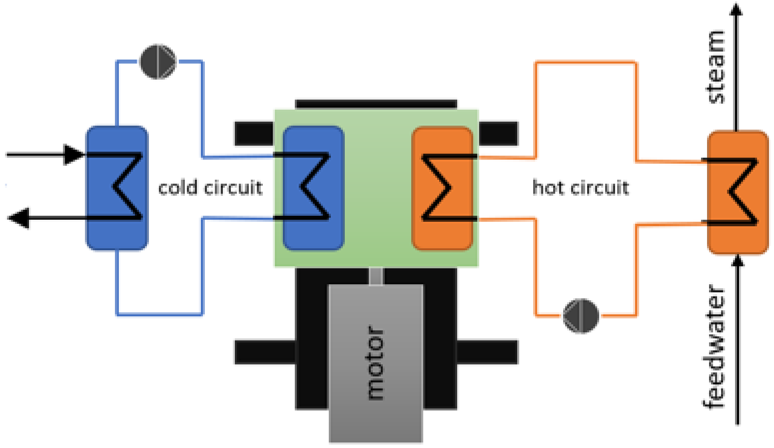
Heat Pumps – What and Why?

- Upgrade waste heat or environmental heat to useful levels with some electrical power input
- Key Parameter: **Coefficient of Performance**







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Available Industrial Heat Pump Technology

- Supply temperature most critical parameter
- For process temperature lifts above 100 °C, technology remains at small scale.
- Applications <230 °C with Mechanical Vapour Recompression and <250 °C Stirling
  - MVR uncommon with source T low and/or T lift high
- Applications <135 °C achievable with closed loop hot water/steam; <280 °C achievable by post-compression
- Ample offering for lower duties (<10 MW), requiring tailored designs at higher duties
- Refrigerant highly dependent on outlet temperature (little vendor experience >150 °C).

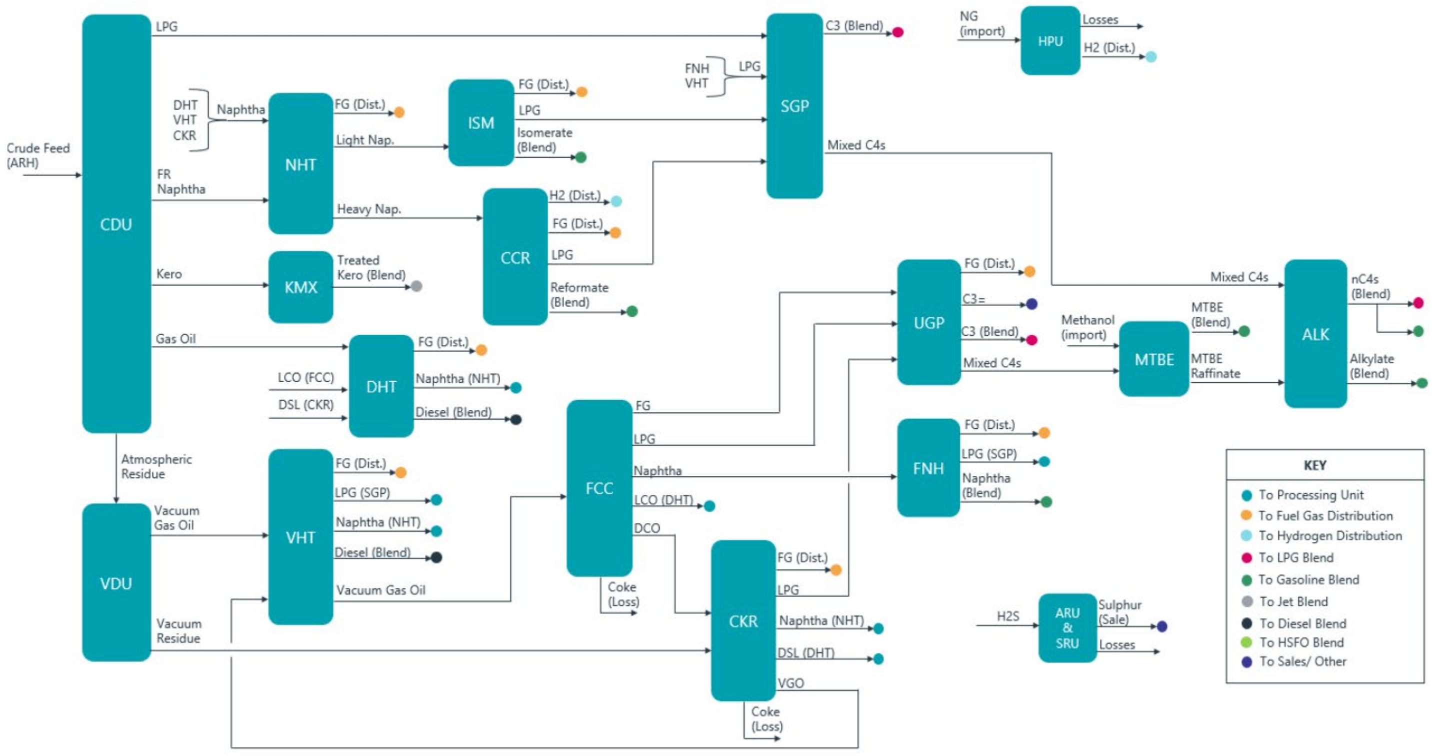
Type	TRL
Single-Stage – Various types	9
Single-Stage	9
Cascade	4-9
MVR - Open	8-9
MVR - Open or Semi-Open	6-9
Joule Cycle	6-7
Stirling Cycle	6-9
Transcritical Cycle	7-9
Chemical Adsorption Heat Transformer	9

Heat Pump Applications – Downstream

- Example high-potential applications:
  - ❖ Alkylation Unit: De-isobutaniser Reboiler
  - ❖ FCC: De-butaniser Reboiler
  - ❖ FCC: C3 Splitter Reboiler

- Large number of fractionation reboilers, ARU/SWS regen, etc.
- Aromatics and olefins applications also promising
- Large amount of high-quality waste heat available

Block Flow Diagram of a Fuels Refinery



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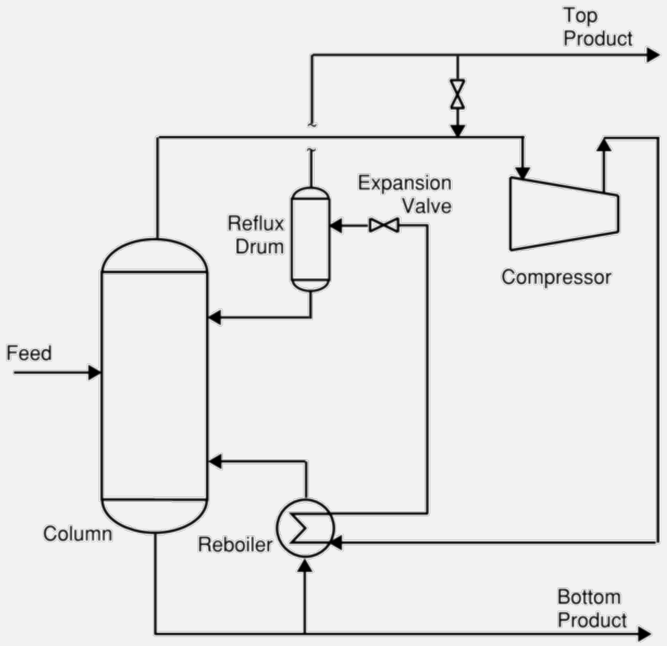
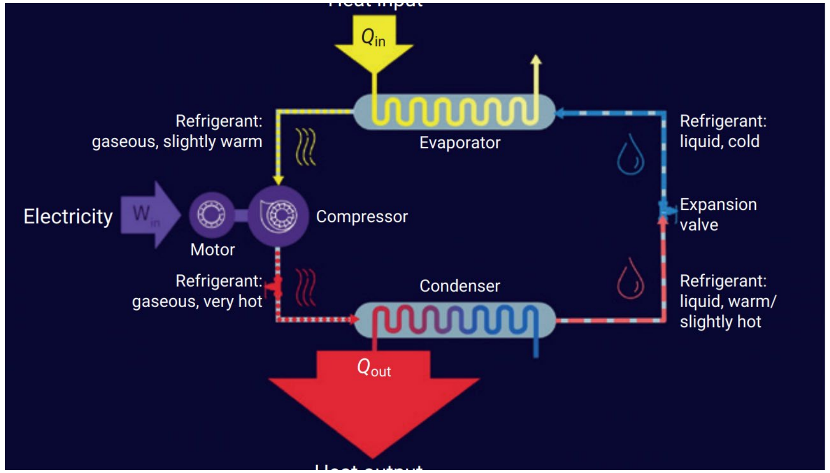
Heat Pump Capability

Ongoing comprehensive studies into the **application of heat pumps** across upstream, refinery, aromatics and olefins sites



Independent economic comparison from deep knowledge of the various available **closed loop and mechanical vapour recompression (MVR)** configurations

Rapid, reliable development of supporting **electrical infrastructure, plant modifications and total project cost** from industry leading project development experience



Close links with **multiple vendors** of closed loop, open loop, direct/indirect heat transfer and emerging technologies

Trusted partner in navigating **design choices** influencing widely varying cost, reliability and electrical consumption.

Key Findings from Deep Electrification Roadmaps

Full electrification requires large scale electrical infrastructure outside and inside the site boundary

Low carbon lifecycle power sources is able to reduce carbon emissions to very low levels

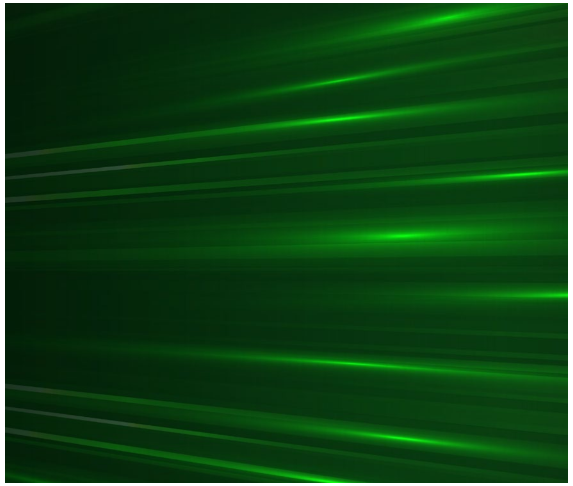
Electrolyser technologies are relatively expensive, though could provide buffering of renewable generation

Electrical efficiency in providing heat is a key driver for timeline of technology adoption

Electrification of steam production is relatively cheap and simple versus direct electrification of steam consumers

Routing of excess fuel to other consumers, such as chemicals, would be required at high degrees of electrification.

Existing cogeneration plants could have an ongoing role in an electrified site.



Economic Direction from Recent Studies

Reliable carbon pricing policies are essential for the economic viability and sustainability of electrification, especially for long-term investments.

Phased investment in technologies, considering capital efficiency, power efficiency, and Technology Readiness Level, remains beneficial with rising carbon prices.

Deep electrification Roadmaps with sufficient decarbonized power supply can result in low cost of abatement over the project life

Technologies such as Direct Electric Heating, Residue Heating, and Electrolysers require higher carbon prices or other incentives to be economically viable.

High power efficiency projects including Condensing Turbine Replacement and MVR, which can have negative carbon price requirements, should be prioritized early in the investment Roadmap.

Promising opportunities are being identified for potential heat pump applications, including steam raising and selected distillation operations.

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Industry Activity

01

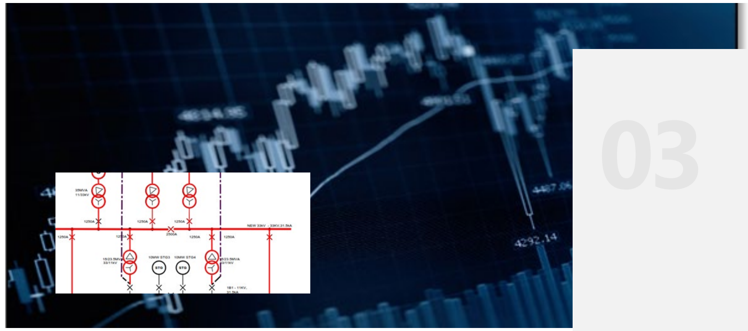
Electrification within Decarb Studies

- Interest groups and asset owners
- Comparisons between Hydrogen, Electrification and CCUS
- Comprehensive and independent

02

Fired Heater Electrification and Heat Pumps Technology

- Emerging technology development
- Revamp potential within the firebox
- High temperature heat pump technology selection



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Rapid Assessments for Screening

- Fast comparisons, full project costing and space requirements
- Rapid option feasibility screening across decarbonisation

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Any further questions/discussion, please reach out!

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