

Pioneering the Permitting of Power CCUS Using Shell Cansolv Technology

Content

1. VPI
2. Immingham site
3. Humber Zero Project Update
4. Project Overview
5. Permitting Key Considerations

VPI tackles systemic challenges that emerge in the energy transition

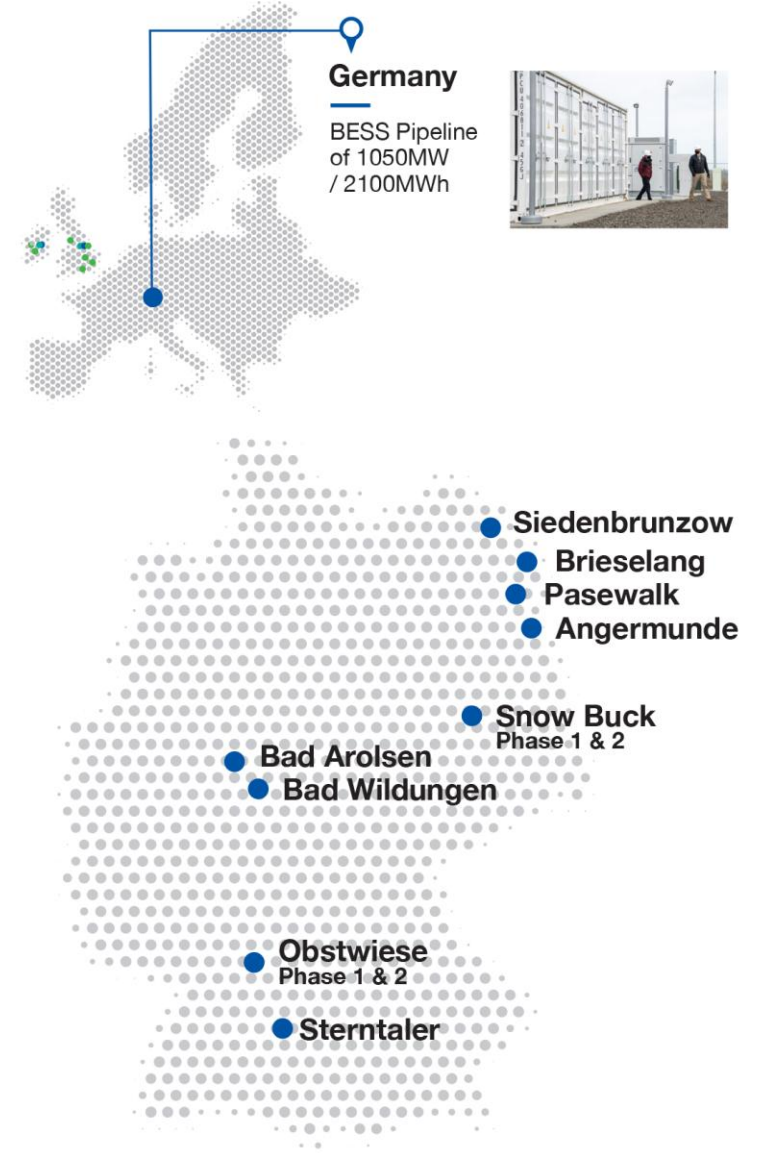
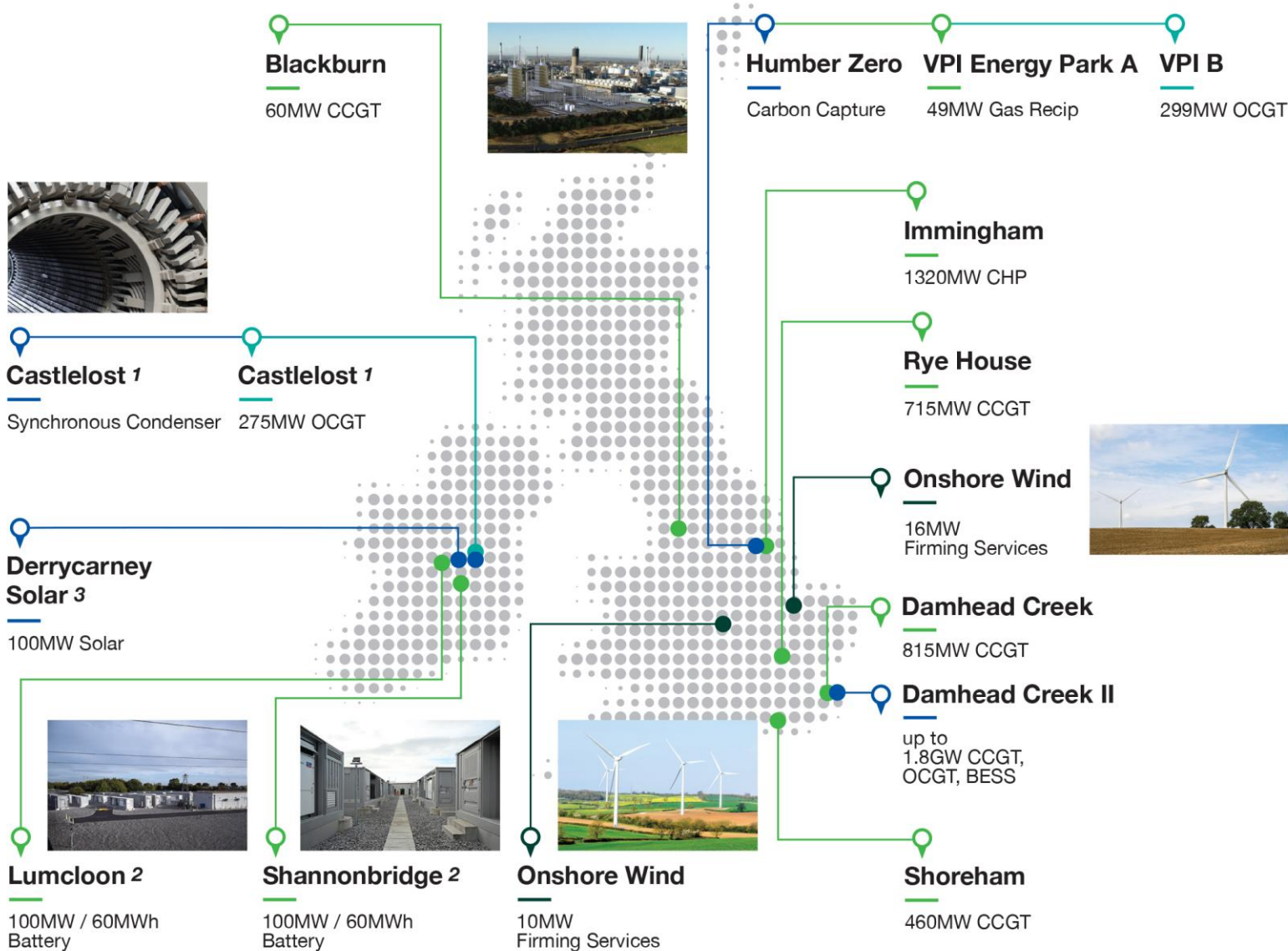
Need for more reliable power

Greater supply intermittency

Removing carbon from energy sources

Enabling uptake of renewables

VPI's growing portfolio



● Operational Assets ● Projects Under Construction ● Development Opportunity ● Partnership

1 51% ownership / 2 80% ownership / 3 75% ownership

VPI's site in Immingham

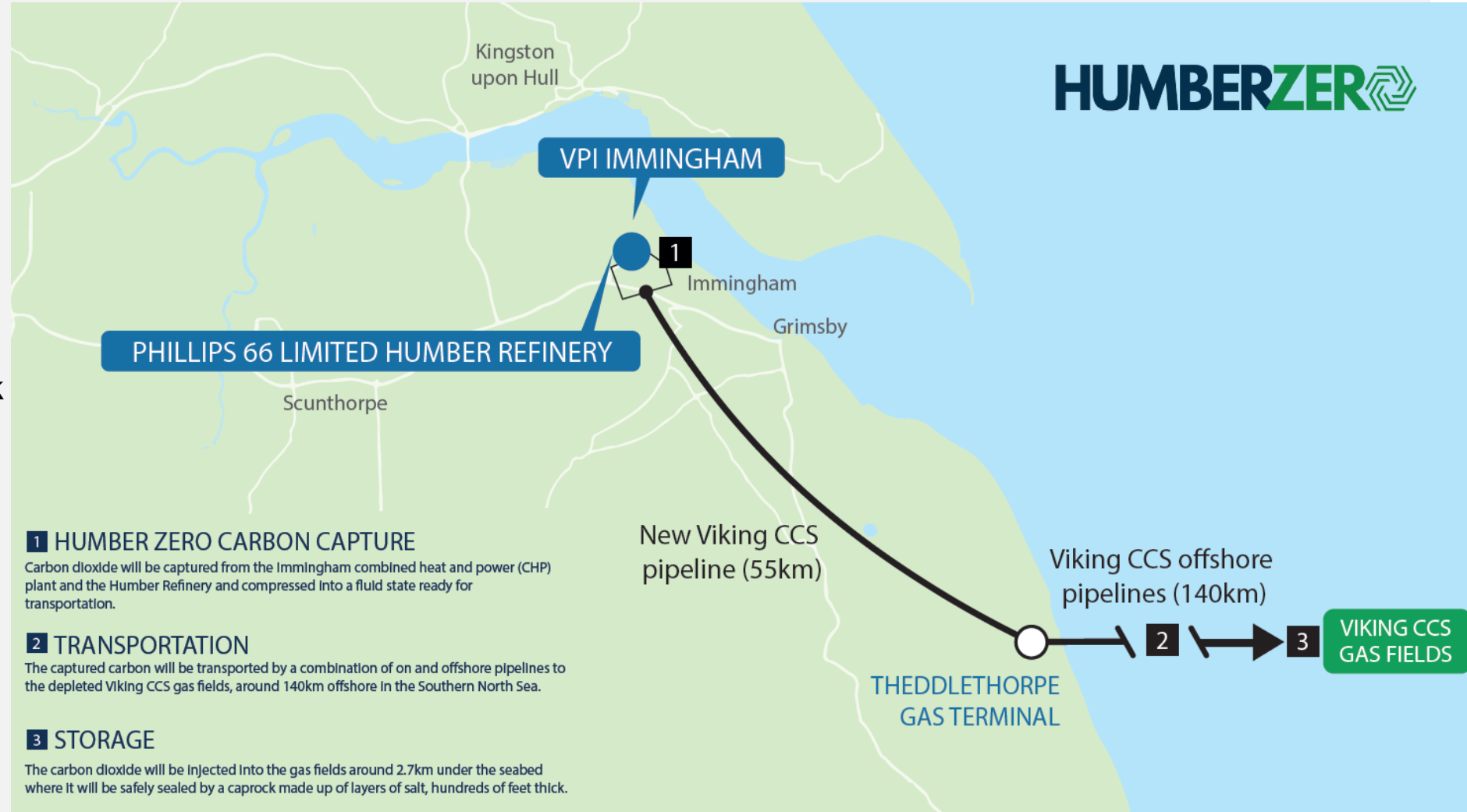


- VPI Immingham is a 1.2GW CHP plant, located in South Killingholme, North Lincolnshire
- It is the largest plant of its kind in the UK and Europe and has been in operation since 2004
- Provides power and steam to over 25% of the UK's refining capacity at the two co-located refineries: Humber Oil Refinery and Lindsey Oil Refinery
- It also provides flexible and low-cost power and grid stability services to meet up to 5% of the UK's electricity demand



The project in context...

- Close to store
- On doorstep of T&S network
- Much of pipeline already built



Humber Zero in numbers

Significant economic and social benefits for the Humber region.



Preventing the release of
3.3 million
tonnes CO2 annually



Targets
70%+
British supply chain

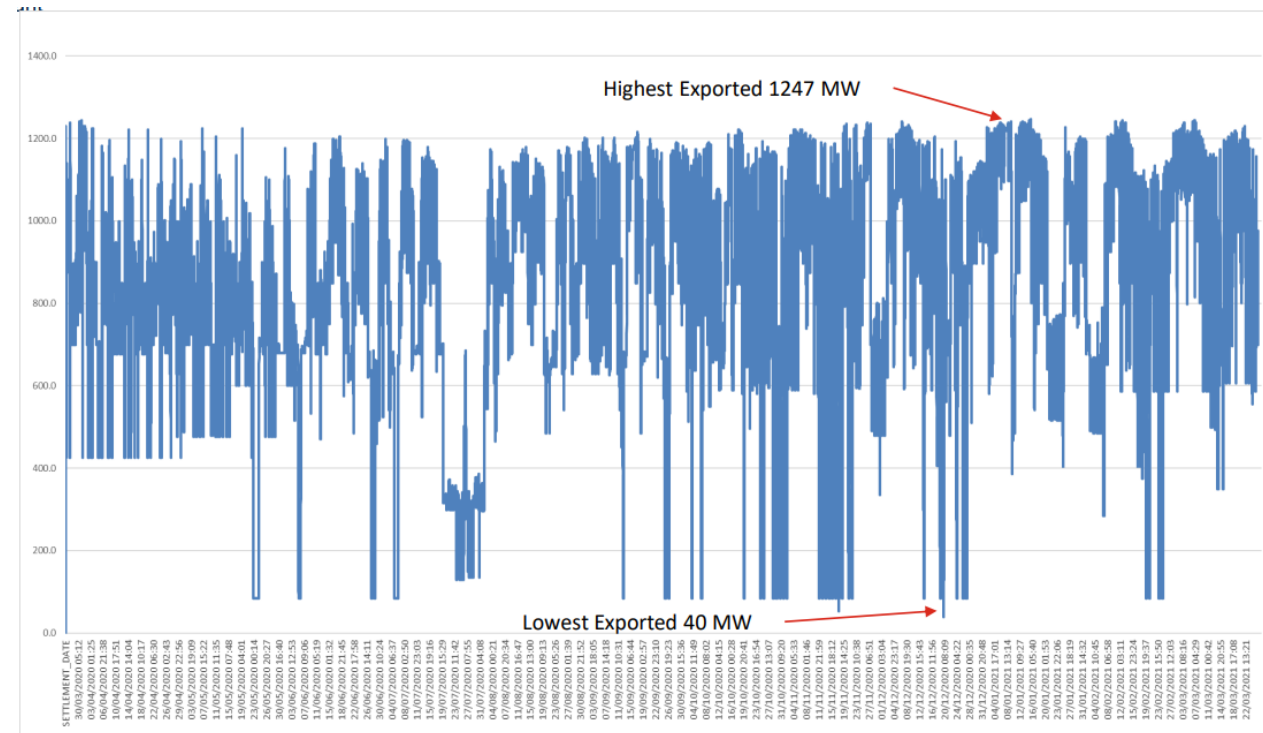


Creates around
1,500
Jobs in construction phase



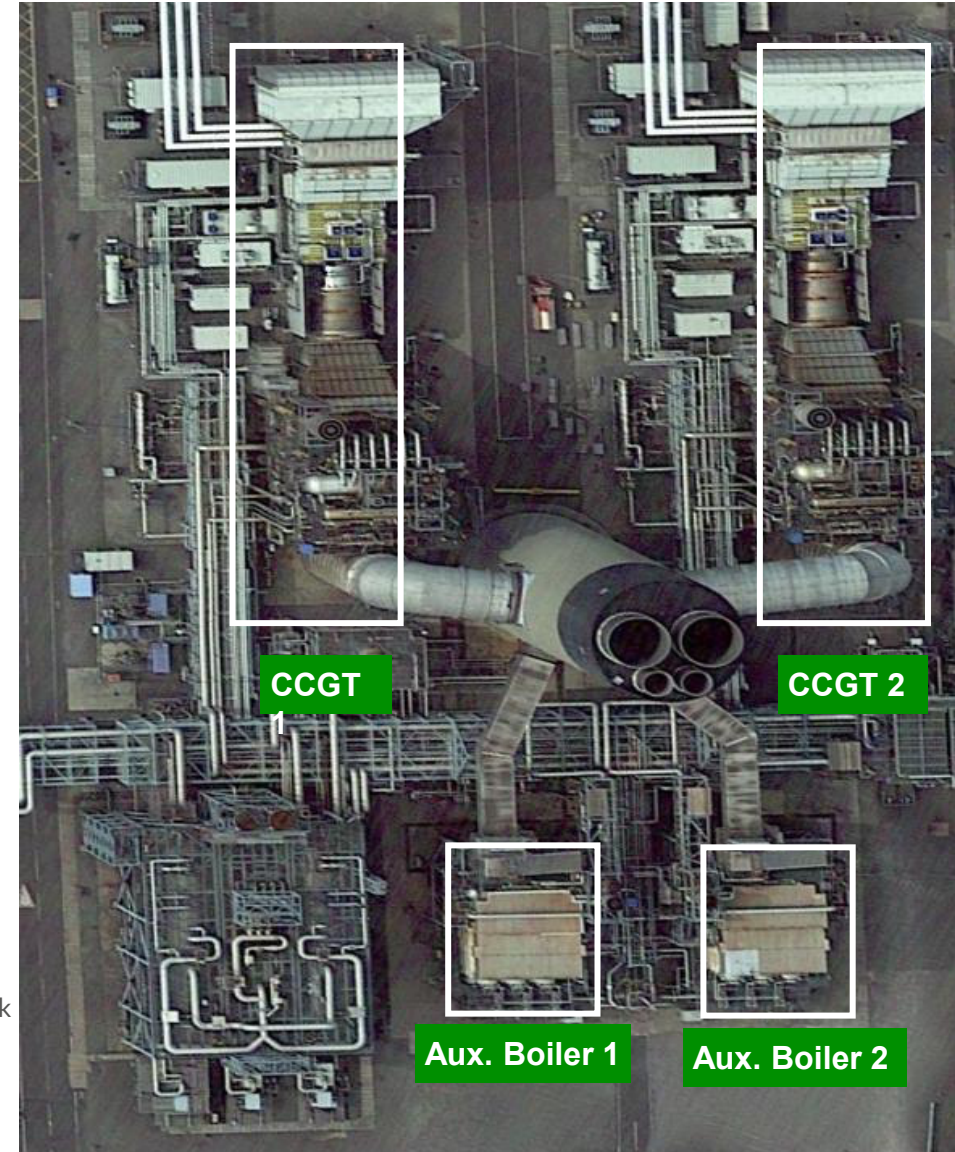
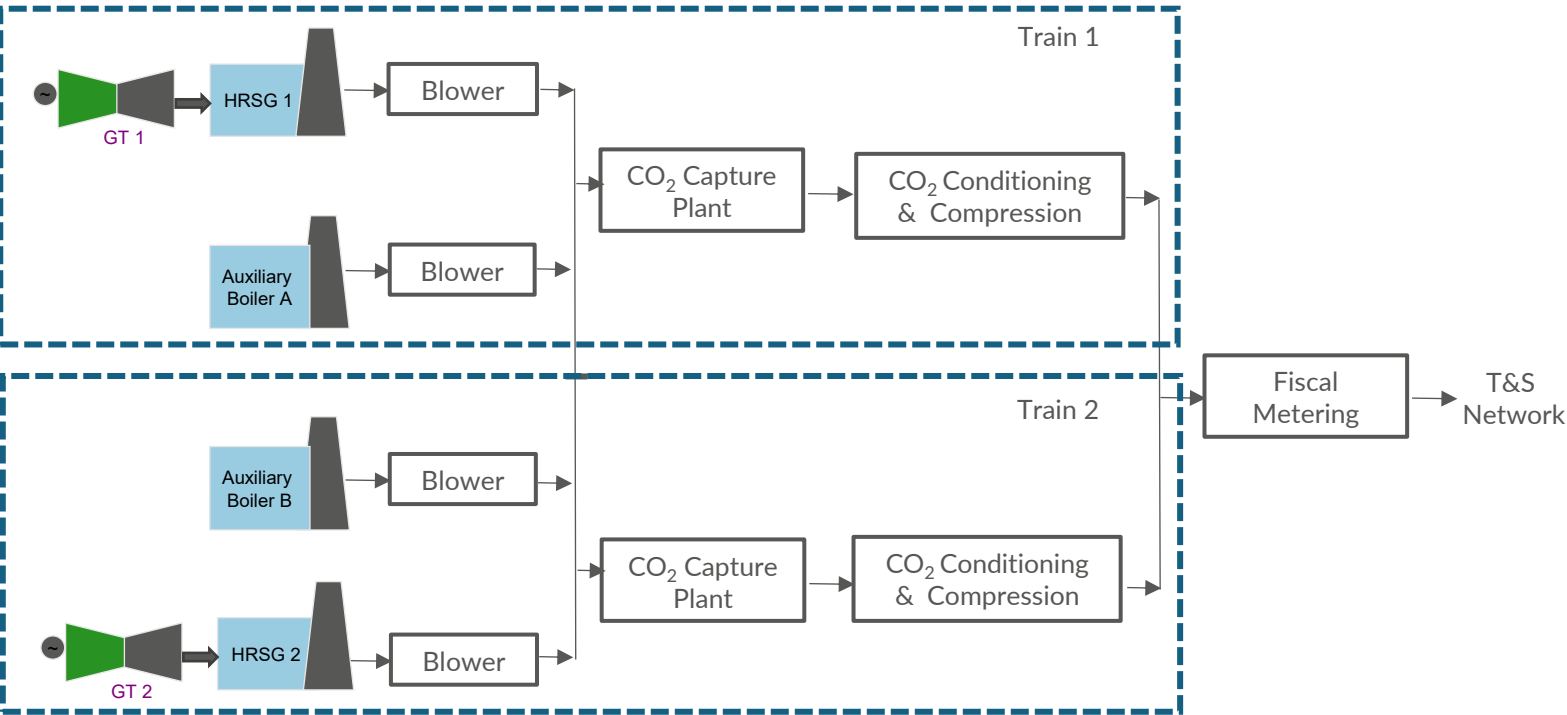
CHP + Capture Plant Operating Features

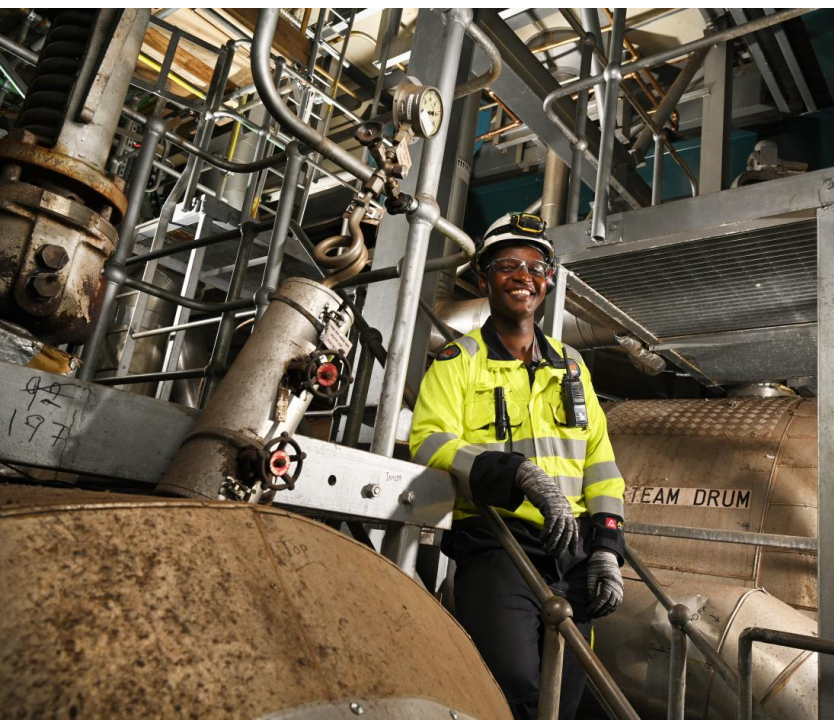
- Baseload operation due to uninterrupted steam and power supply to industrial users
- Flexible power supply to grid (ramp up and down from baseload)
- Gas Turbines and Auxiliary Boilers operate in various modes (configurations and loads)
- Two fuel sources: Natural Gas and Refinery Off Gas



Project Overview and Status

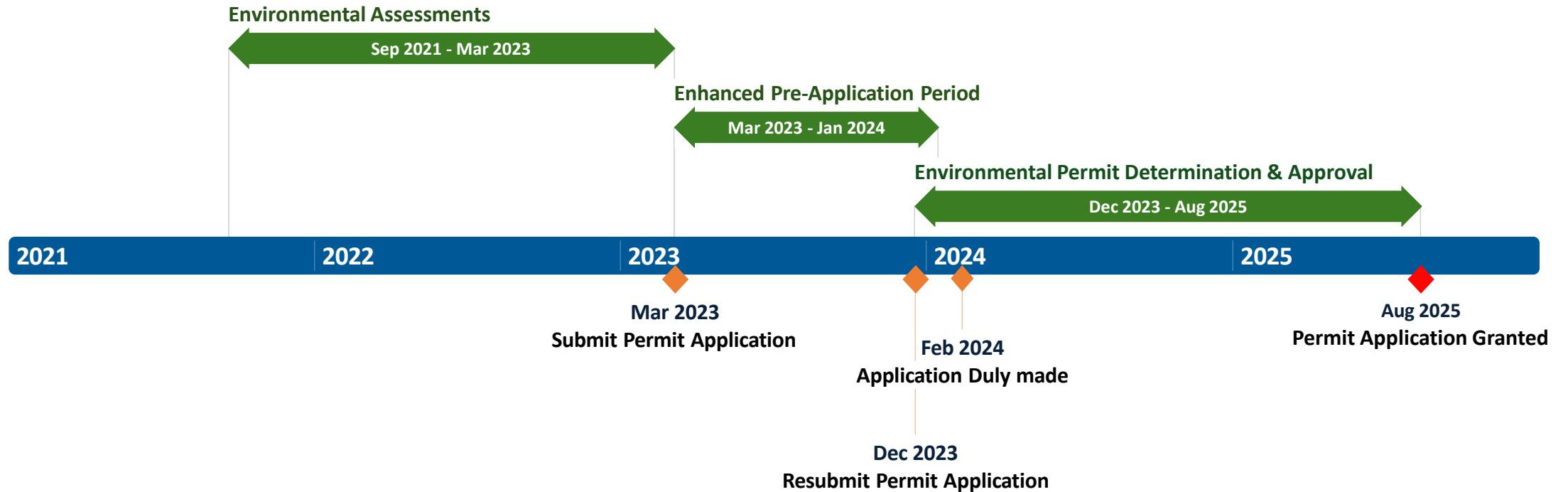
- 1.65 MTPA per Train
- Shell Cansolv Capture Technology
- FEED Completed
- Planning Consent Granted
- Environmental Permit Secured
- EPC Partnerships alignment in progress
- Awaiting DESNZ emitter selection for the Humber cluster





Permitting Timeline

Approximately 4 years to obtain the environmental permit, which is a substantial variation to Immingham CHP's existing permit



BAT Guidance Requirement - Technology Selection

Successfully securing environmental permit is underpinned by selecting the right post combustion capture technology

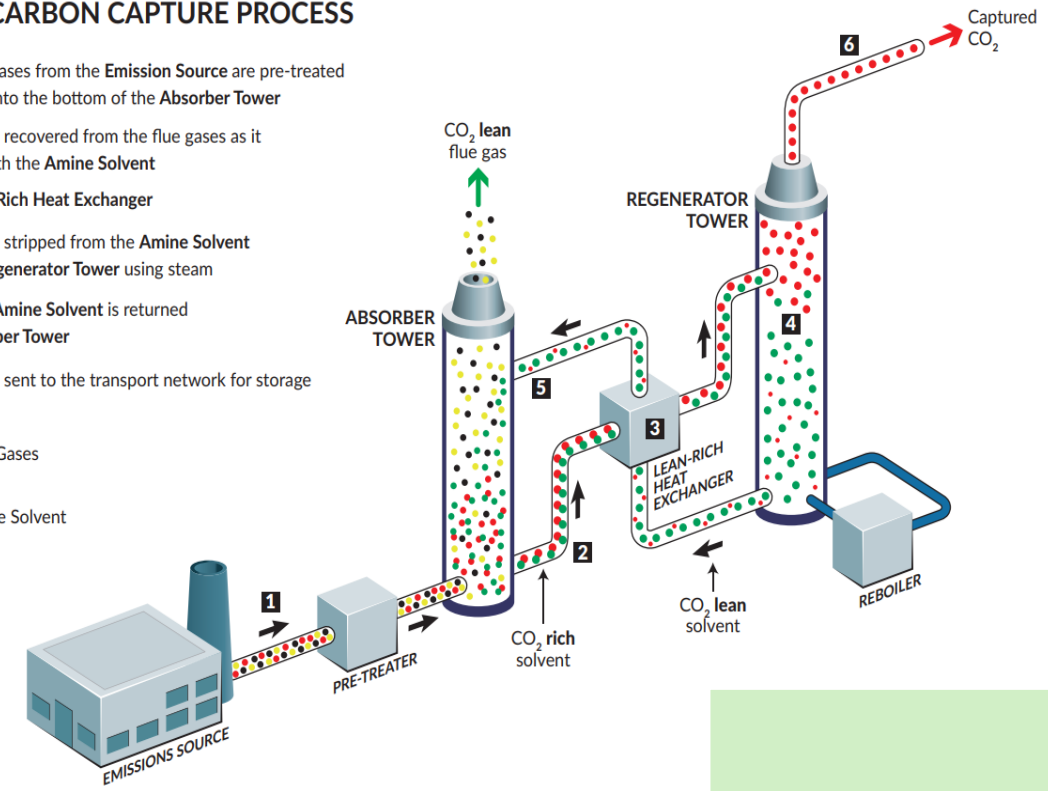
Key considerations

- Solvent stability
- Energy consumption
- Degradation
- Reclamation
- Operating experience/test campaigns
- Toxicological information
- Commercial scale project development experience
- Licensor support

THE CARBON CAPTURE PROCESS

- 1** Flue gases from the Emission Source are pre-treated and fed into the bottom of the Absorber Tower
- 2** CO₂ is recovered from the flue gases as it reacts with the Amine Solvent
- 3** Lean-Rich Heat Exchanger
- 4** CO₂ is stripped from the Amine Solvent in the Regenerator Tower using steam
- 5** Lean Amine Solvent is returned to Absorber Tower
- 6** CO₂ is sent to the transport network for storage

- Flue Gases
- CO₂
- Amine Solvent

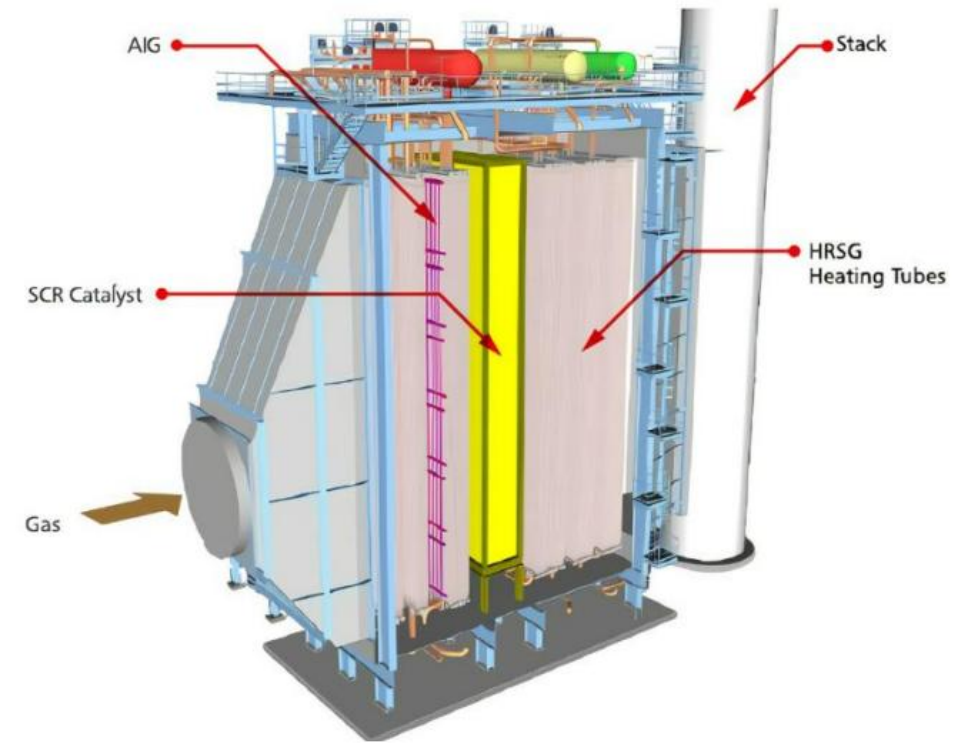


BAT Guidance Requirement - Air Emissions Risk Assessment

- Demonstrate that emissions would not lead to exceedance of any Air Quality Standard objectives, Environmental Assessment Levels, Critical Levels and Critical Loads
- Some amines can potentially degrade (chemically react with oxygen) and form nitrosamines and nitramines (collectively referred to as N-amines) both during the carbon capture process itself and also in the environment, following release to the atmosphere
- Model both direct and indirect N-amines emissions
- Published EALS does not exist for all known amines used in Carbon Capture
- Demonstrate suitability of proxy where toxicological information is not available
- Evidence the appropriateness of model input parameters for simulating amine reaction chemistry, in particular, reaction rate parameters and branching ratio
- Assess cumulative impact/in combination effect with other projects in planning

BAT Guidance Requirement - NO_x Control

- NO₂ reacts with amines to form degradation products. NO_x reduction is desirable to minimise NO₂ and consequently amine degradation and associated environmental impact
- SCR is normally installed in the HRSG at an appropriate temperature
- No space in the existing HRSG - up to 10m additional length may be required to accommodate a SCR
- The only feasible retrofit option is a tail-end solution i.e. implement a SCR in the new duct between the flue gas blowers and Direct Contact Cooler
- For existing plants with low NO_x (NO₂), selection of NO_x tolerant solvent is considered a more robust solution than retrofitting a SCR because:
 - prohibitive CAPEX investment for a relatively small amount of NO_x removal
 - Unintended consequences of Ammonia slippage and potential introduction of SO₃



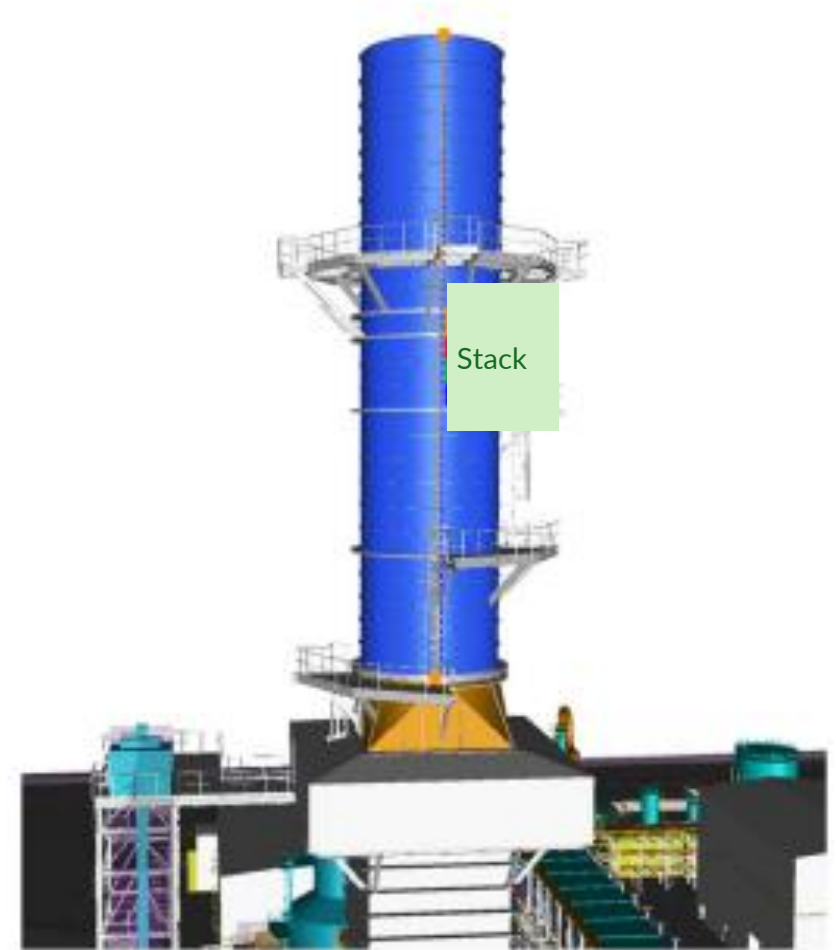
BAT Guidance Requirement – Absorber Design

Absorber Emission Abatement

- Water Wash
- Acid Wash
- Flue gas reheating
- Stack height
- Stack platform design

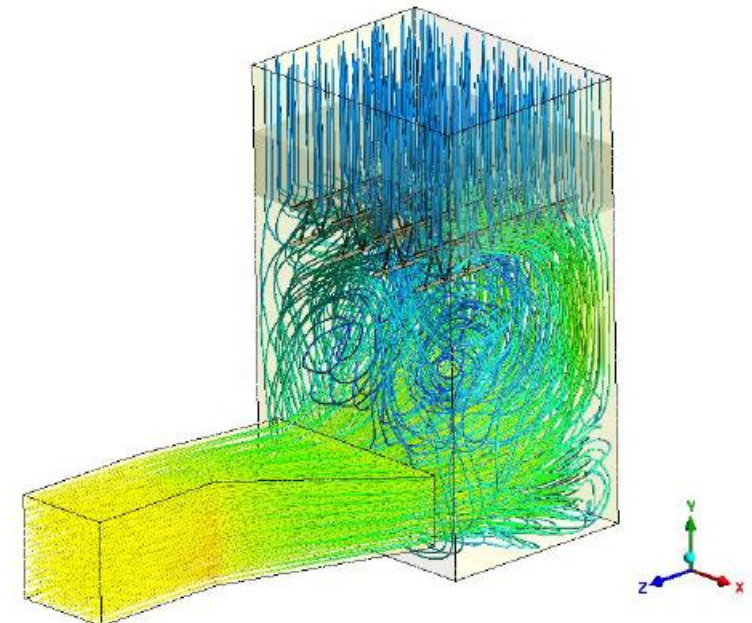
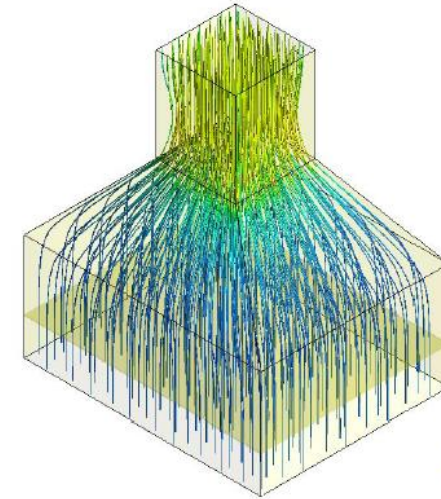
A holistic approach to Absorber design should consider:

- Emissions
- Project location and pollutant background concentrations
- Process Safety
- Waste Management



BAT Guidance Requirement – Emission Monitoring

- IED compliance for large combustion plant in abated operating mode requires additional CEMS in ducting prior to Absorber inlet
- ELV at Absorber stack is not applicable due to differences in the ELVs for the combined GT and Aux Boiler flue gases
- Need to demonstrate flue gas homogeneity at CEMS location prior to comingling
- Continuous and periodic emissions monitoring capability at the Absorber Stack



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VPI

Thank you