



CCPilot100+ Test Results and Operating Experience

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IEAGHG PCCC2

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A graphic with the words "enabling" and "energy" in a large, white, sans-serif font. The word "enabling" is positioned above "energy". The letters of "energy" are filled with a photograph of a city skyline at night, with lights from buildings and streets visible. The background of the graphic is dark with horizontal light streaks, suggesting motion or energy. A blue triangular shape is visible on the right side of the graphic.

enabling energy

Contents

Doosan Power Systems Overview

Doosan Carbon Capture Technologies

Test Facilities and Demonstration Projects

Ferrybridge CCPilot100+

Next Steps

Development Roadmap to Scaling-Up

Summary

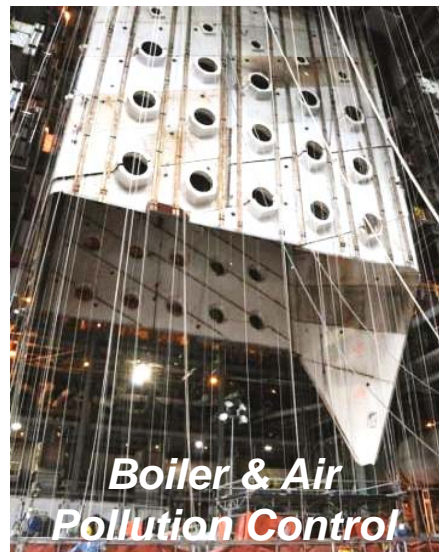


Our Products and Services

Doosan Power Systems

Doosan Lentjes and Doosan Babcock

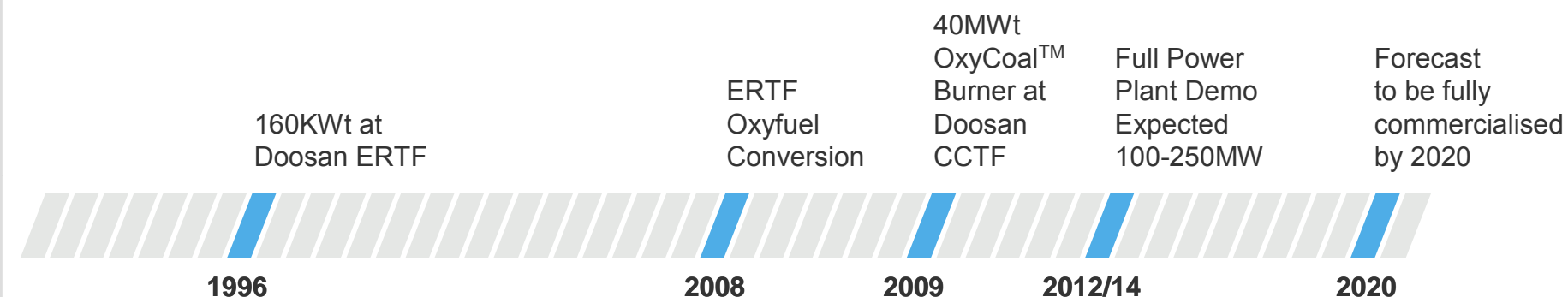
Doosan Skoda Power



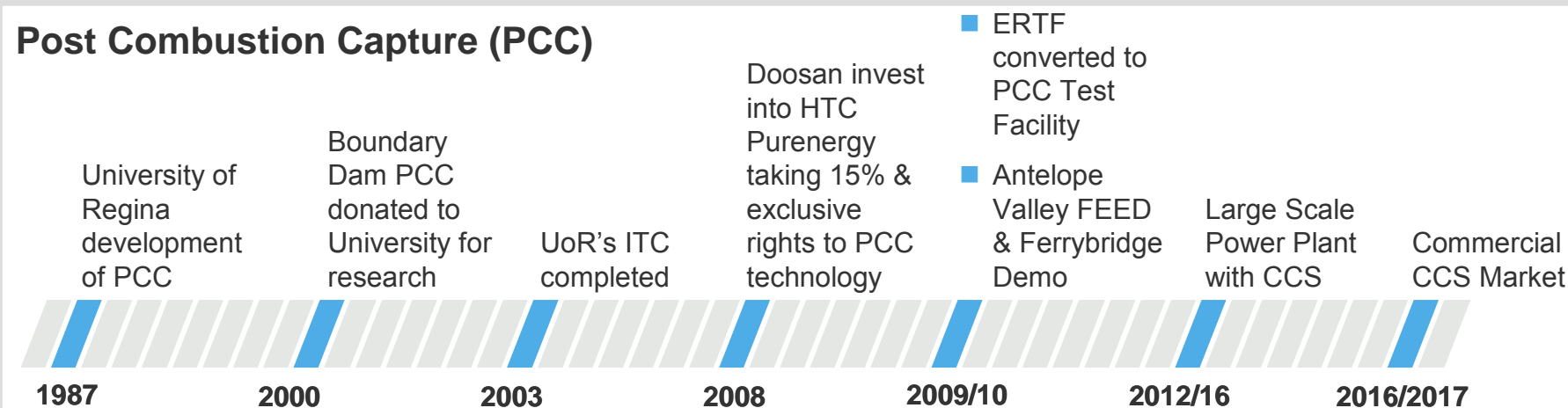
Doosan Carbon Capture Technologies

25 years of experience in carbon capture

Oxyfuel



Post Combustion Capture (PCC)



Test Facilities and Demonstration Projects

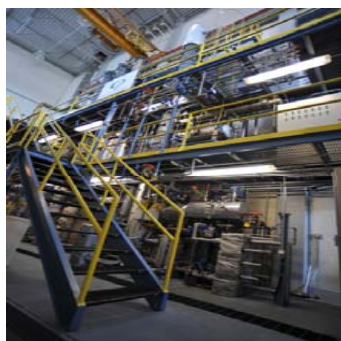
Performance demonstrated on wide range of fuels and different plant configurations

Facilities and technology create a winning edge

20+ years of demo

ITC, 1 t/day

- Opened in 2003
- Flue gas from natural gas combustion
- Includes equipment to study corrosion, material selection, solvent degradation and kinetics



UoR's Boundary Dam, 4 t/day

- Commissioned in 1987
- Dedicated to post-combustion capture since 2000
- Captures CO₂ from flue gas emitted from lignite-fired boiler
- Upgraded in 2007 to evaluate advanced process with RS-2



Industry scale

ERTF, 1 t/day

- Commissioned in 2010
- Ability to test wide range of coals and other fuels
- High degree of flexibility and accuracy to test wide range of solvents and other modifications



Ferrybridge, 100 t/day

- Largest post carbon capture demonstration plant in the UK
- Long-term testing and validation of process and solvent performance
- Evaluate transient conditions and process control
- Extensive monitoring planned



Ferrybridge CCPilot100+

- PCC demonstration plant using DPS' technology.
- 100 t/day slip stream from a 500MW_e unit on SSE's Ferrybridge Power Station, making it the largest PCC demonstration in the UK.
- Two year test programme, fast-tracked build, operating March 2012.
- Funded by all the project partners.
- Lessons learned to be incorporated into future designs.

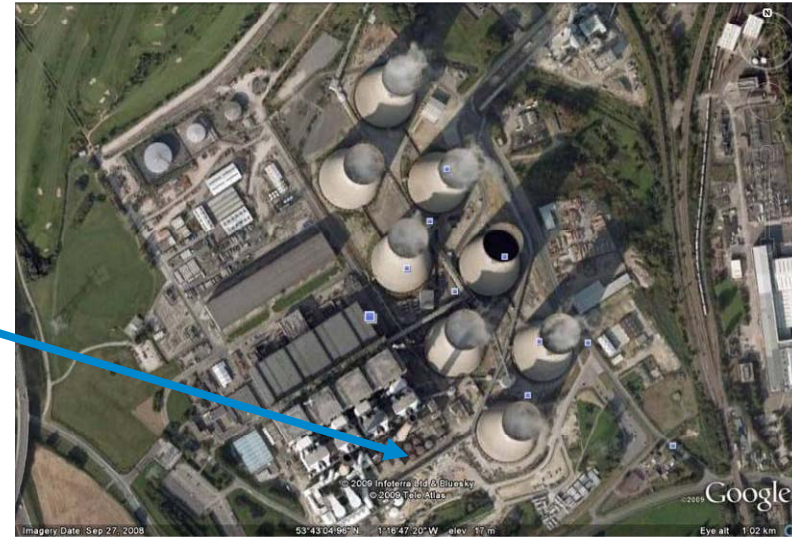


Technology Strategy Board
Driving Innovation

Moving Forward:
The Northern Way



CCPilot100+ Project Location



CCPilot100+ Test Programme Key Parameters

The test campaigns comprise a combination of parametric testing and exposure testing in order to;

- Assess the durability of the solvent,
- Permit process optimisation,
- Provide data on plant design and scale-up.



Key Parameters

- CO₂ capture rate and product compositions.
- Steam consumption at reboiler.
- Amine and degradation product atmospheric emissions.
- Absorber column efficiency.
 - Column CO₂ composition and temperature profiling.
- Power and water consumption under differing operating regimes.
- Optimisation of thermal integration.
- Solvent testing and formulation for efficiency and durability.
- Performance of construction materials including polymers.
- Comparison of performance with other pilot plant for scale-up.



CCPilot100+ Test Measurements and Instrumentation

Liquid Analysis

On site laboratory – off-line liquid analysis

- Solvent
 - Amine Concentration
 - Conductivity
 - Density
 - pH
 - Heat Stable Salts (HSS) Concentration
 - Bound Amine
- Water (Ion Chromatography)
 - Cooling Water
 - Waste Water

Development of on-line liquid analysis

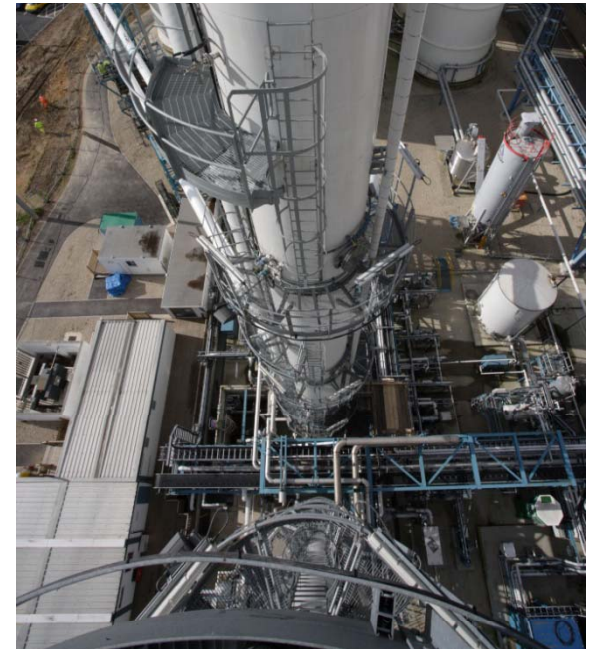
- Solvent
 - Solvent Concentration
 - CO₂ Loading



CCPilot100+ Test Measurements and Instrumentation

Process Conditions and Gas Analysis

- Gas and solvent flow rates, temperatures and pressures.
- On-Line Gas Analysis
 - FT-IR – Extractive multi-point heated sampling system
 - Ammonia Tuneable Diode Laser – Cross-duct, non-extractive
 - ppm Oxygen Micro-Fuel Cell – Extractive, cold sampling system
- Manual Gas Analysis
 - FGD Polisher Performance
 - PCC Based Emissions
 - Solvent Carryover
 - Degradation Products



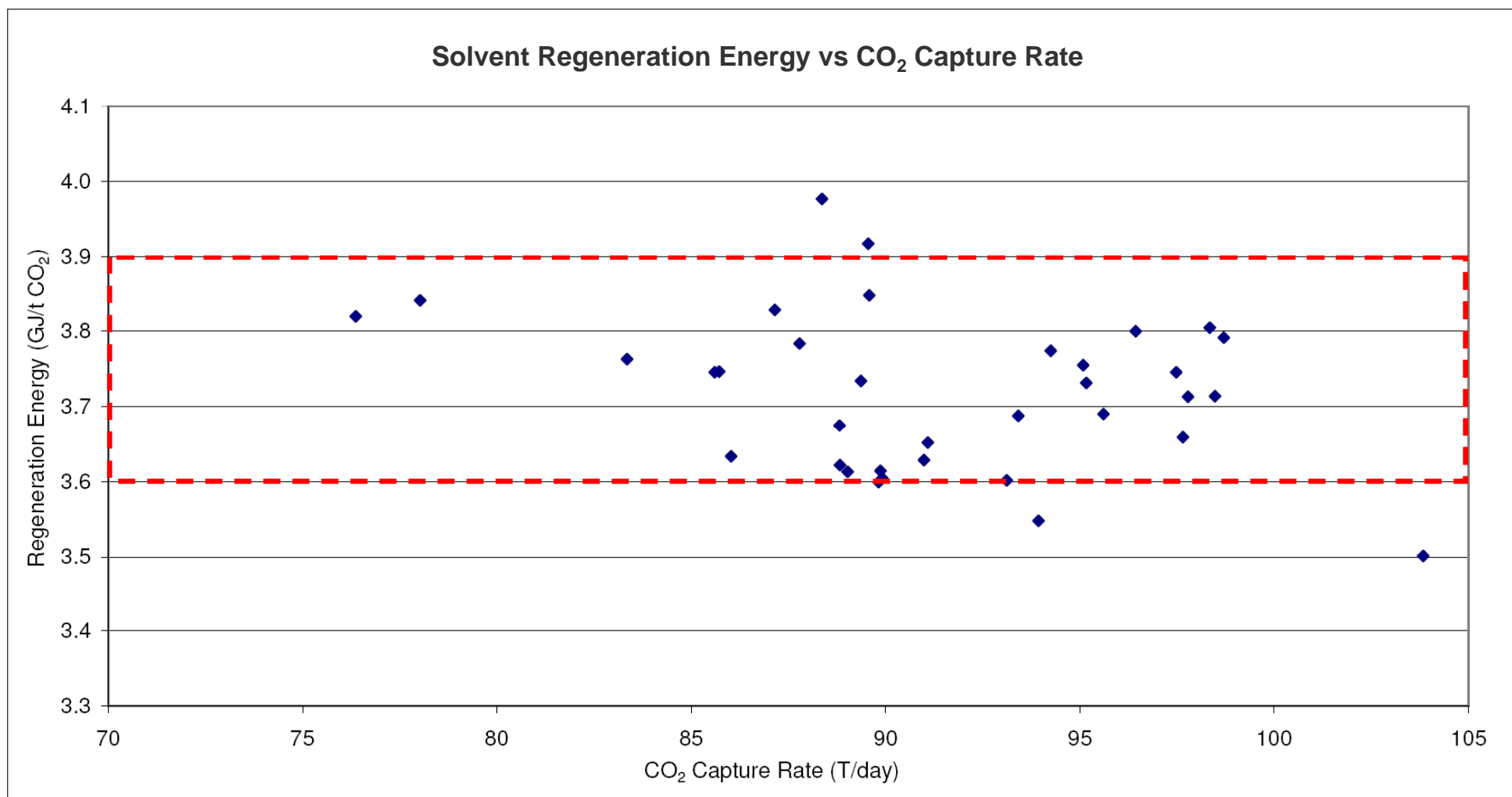
CCPilot100+ Current Status



- Commissioned to run on MEA.
- Plant handed over to SSE Operations Group March 22nd 2012.
- 1000+ hours of running time recorded with 30%w/w MEA with water.
 - Detailed analysis of results on-going.
- 900 hours of running time recorded to date on RS2™.
 - Performance Optimisation and Solvent Degradation Testing on-going.
- UK Environment Agency and SSE interface
 - positive dialogue.
 - supportive of emissions measurement & control to develop standards during the test programme.
- **100+t/day CO₂ capture achieved at 90% capture efficiency.**

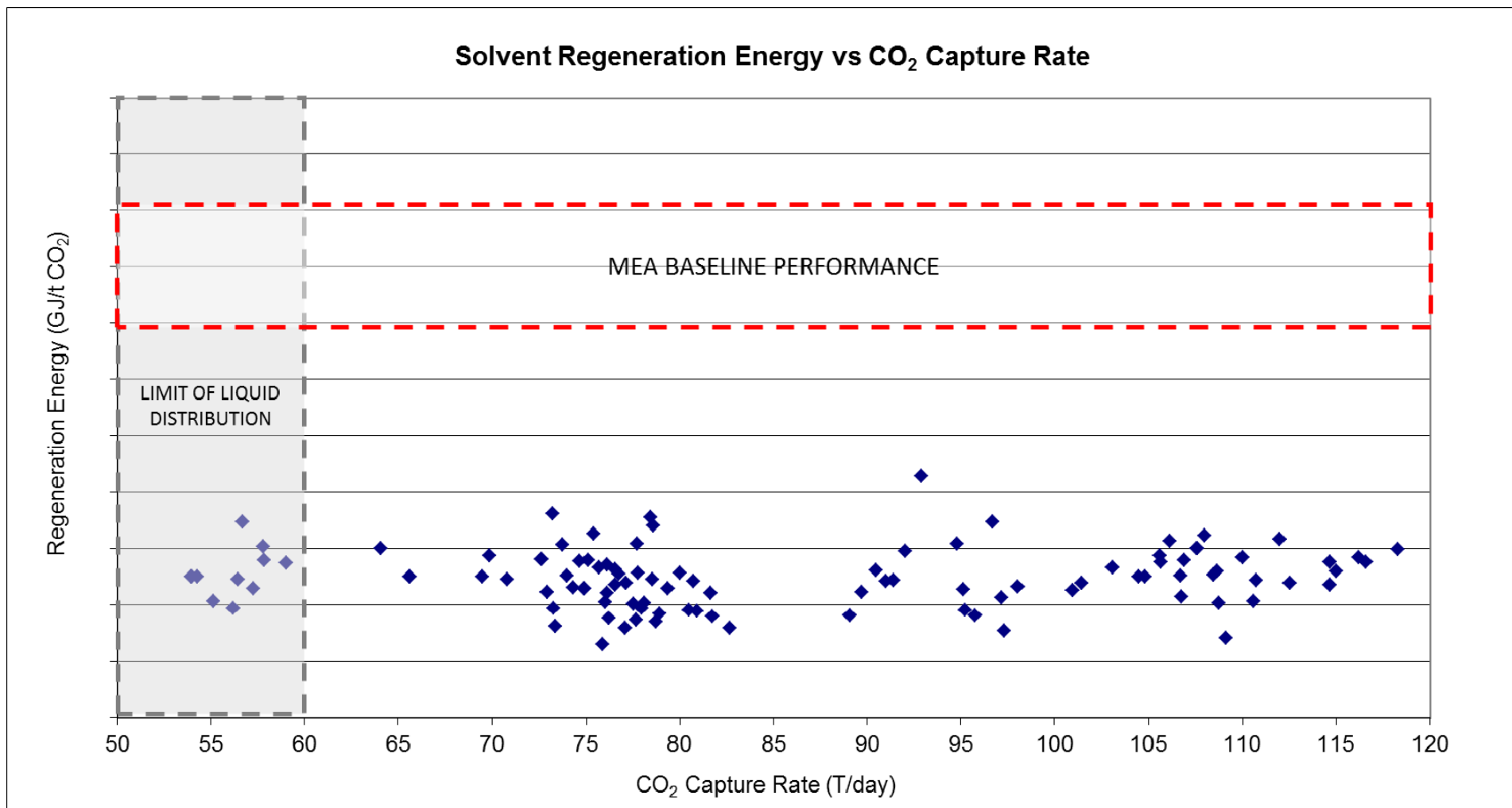
CCPilot100+ : MEA Baseline Results

MEA preliminary results show good agreement with publically available test data
– typical quoted values of 3.6 to 3.9 GJ/t CO₂



CCPilot100+ : RS2 Baseline Results

Preliminary results show a decrease in solvent regeneration energy when compared to MEA baseline performance.



NOT TO SCALE



CCPilot100+ Operating Experience

- Good working relationships developed with
 - SSE Ferrybridge Station and CCPilot100+ staff.
 - Environment Agency.
 - Main process plant item suppliers.
 - C&I equipment suppliers.
 - Analytical instrument suppliers.
- Commissioning
 - Development of analytical techniques.
 - On-line solvent analysis instrumentation.
 - Confirmation of plant operational envelope.
- Testing and Operation
 - Selection of manual gas analysis contractor.
 - Liaison with Environment Agency.
 - Assessment of control system - cycling of plant through start-up, shut-down and other transient conditions.
 - Operation of plant at minimum turndown and increased throughput for full BoP assessment.
 - Process monitoring - solvent behaviour and process optimisation.



Next Steps

- Complete RS-2™ testing Q4 2013
- Process Modelling Validation
 - Development of modelling techniques for scale-up
- Detailed Data Analysis
 - Assessment of measurement accuracies
 - Assessment of BoP for scale-up
- Advanced PCC materials testing
 - Corrosion resistant alloys, polymer resins and anti-corrosion coatings.
- Solvent Reclaimer Operation
 - Analysis of solvent degradation products
- On-line liquid and gas analysis throughout test programme.



Knowledge Transfer

Commitment to maximising the scientific benefit of the CCPilot100+ project

- Knowledge Dissemination and Information Sharing - **ONGOING**
- Complementary R&D Projects at partner Universities - **ONGOING**
 - Use of operational results to support areas of CCS related research.
- Continuing Professional Development - **COMPLETED**
 - Day visits.
 - Industrial Awareness Module.
 - CCPilot100+ one month site secondments.



DPS Development Roadmap to Scaling-Up

Emissions reduction
test facilities
1 t/day to 4 t/day CO₂



Slipstream
100 t/day CO₂ ≈ 5MW_e
Ferrybridge



Large demonstration
project(s)
slipstream
~3000 t/day CO₂ ≈ 150MW_e



Where we
are now

Commercialisation
full scale plant
10,000 t/day CO₂ ≈ 500MW_e
15,000 t/day CO₂ ≈ 800MW_e



In Summary

- Successful achievement of 100+ t/day of CO₂ captured at 90% efficiency.
- Solvent regeneration energy for 30%w/w MEA in agreement with literature values.
- RS2™ performance and solvent degradation testing on-going.
- Provision of invaluable knowledge for incorporation into the full commercial deployment of PCC technology.
- Development of robust procedures, operating guarantees and competitive performance.
- Improving the technology offering through capital and operational cost reduction.
- Working closely with utilities and environmental agencies to develop measurement and control standards to further bolster confidence in post-combustion capture.



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Thank you

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