Carbon Capture Technology for Flue Gas Applications

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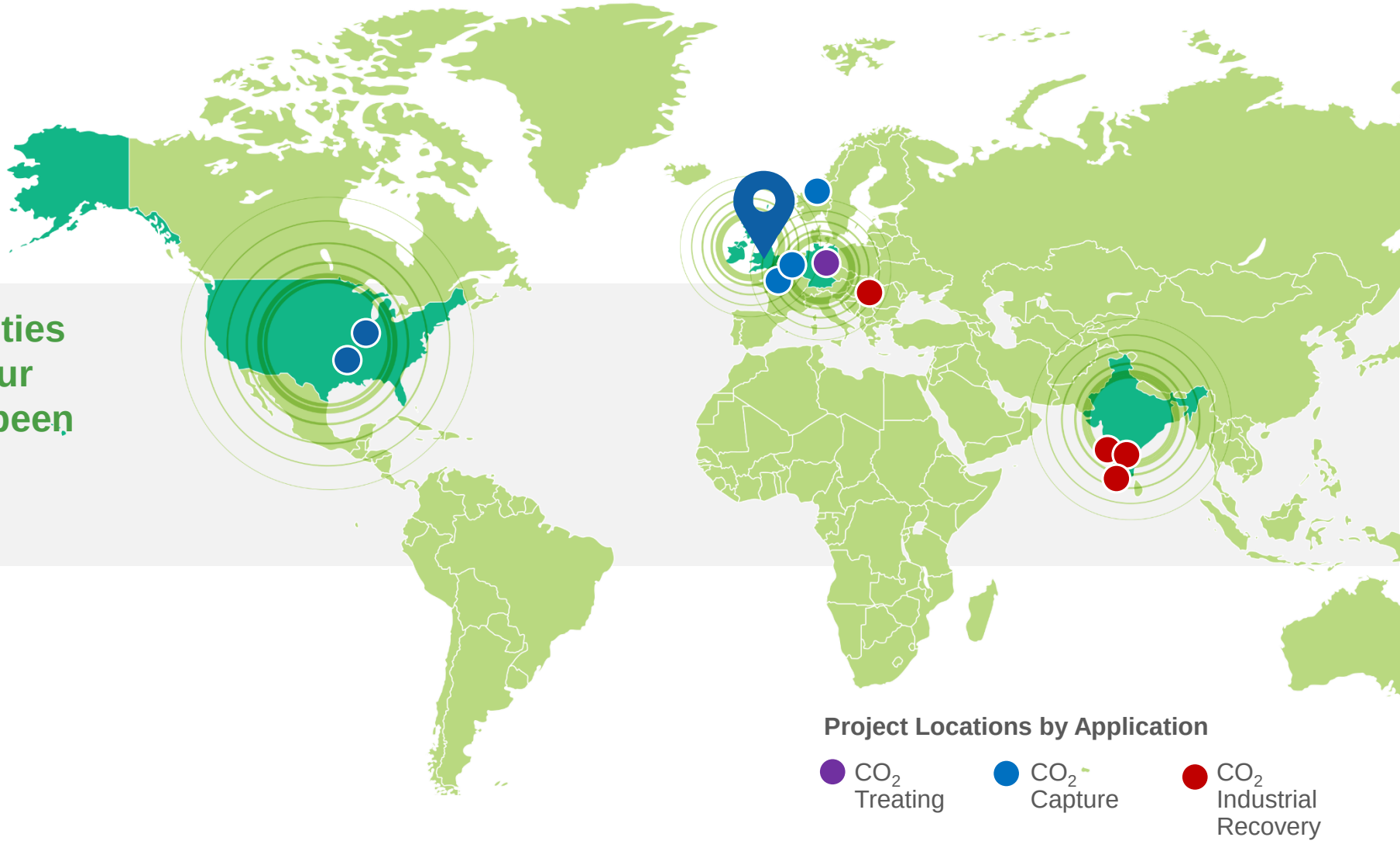
Agenda

- Introduction
- Technology Overview
- Case Studies

Presence and Experience

Carbon Clean Solutions is headquartered in the UK, with offices in USA, Germany and India.

We have 25 facilities globally where our technology has been deployed.



Introduction to Carbon Clean Solutions

We’ve made industrial decarbonisation a commercial reality

Carbon Clean Solutions is an established global leader in providing CO_2 capture technology.

Our advanced technology is proven to dramatically reduce to the cost of carbon capture – enabling industrial emitters to reduce CO_2 emissions.

Applications in Industry

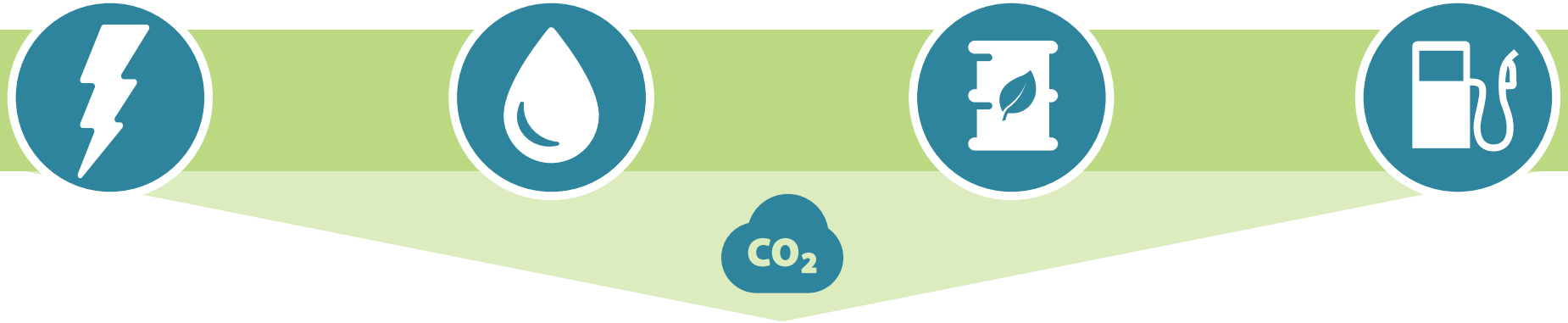
Our breakthrough technologies make carbon capture a commercial reality in a variety of industrial settings

Power
- Flue gas and boilers -

Chemicals
- Soda Ash, Urea, Methanol -

Renewables
- Biogas and biofuels -

Oil and Gas
- Gas treating & EOR -

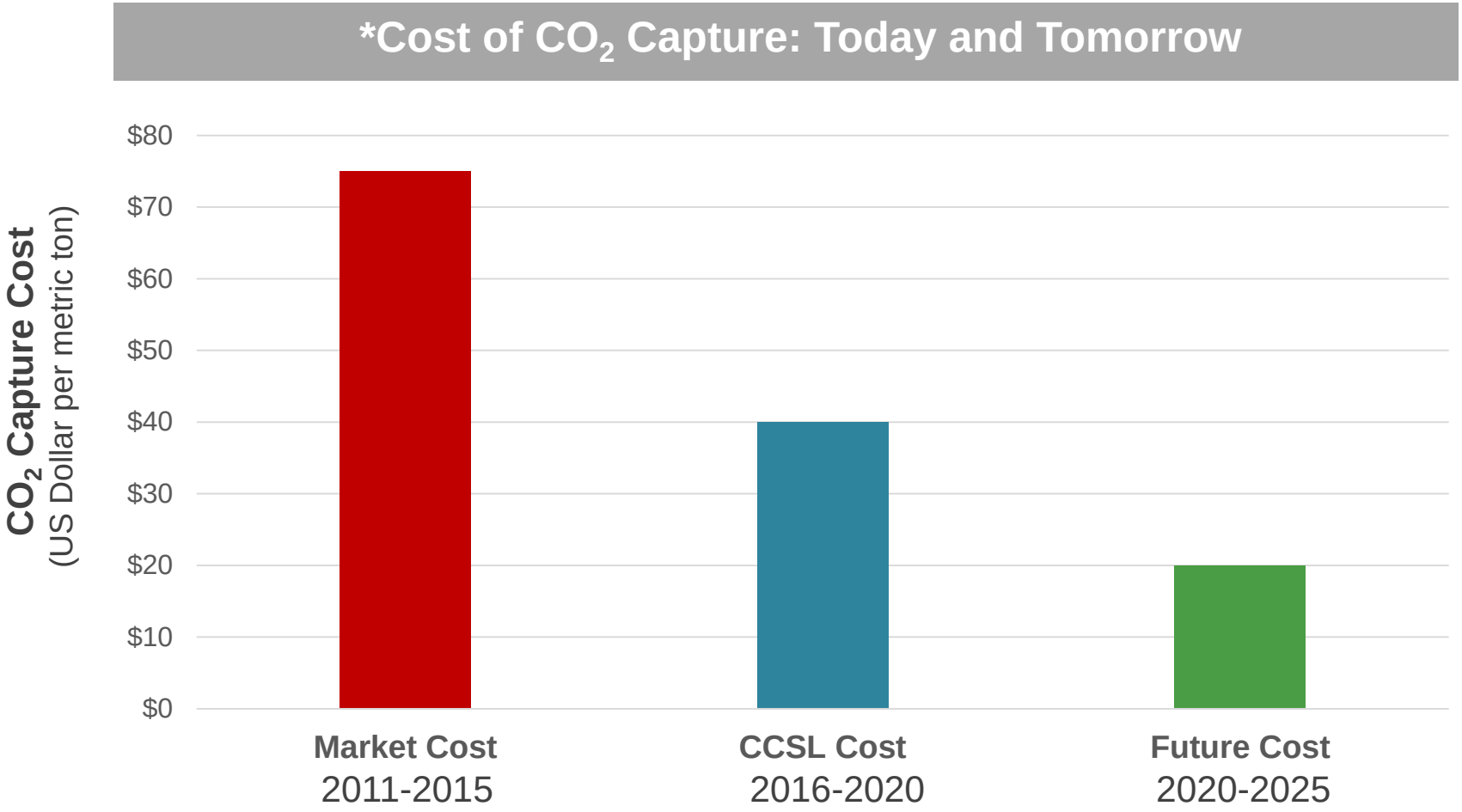


We can recover CO_2 for industrial reuse

Our systems are proven at 25+ sites around the world:
affordable carbon capture solutions can improve the bottom line while reducing greenhouse gas emissions.

CO_2 Capture Economics

Our technologies can achieve carbon capture at a cost of USD $40 per metric ton, a figure that continues to improve.



*Lifecycle cost: includes capital and operating costs, W. European location basis, excludes downstream CO_2 compression

Partner benefits

CCSL Company

Carbon Clean Solutions

- Our focus is on providing the most cost-effective CO_2 capture and separation technology – basic engineering design and solvent
- Flexible business models help to drive projects at a local level with engineering, procurement, construction (EPC) partners
- Our engineering know-how and patented solvent chemistry makes it easier to design and execute CO_2 capture projects
- Our technology creates significant savings by driving down the operating and capital costs for CO_2 capture plants to $40/ton and a target of less than $40/ton

VEOLIA

TNO

APPLY SØRCO

U.S. DEPARTMENT OF ENERGY

Department of Energy & Climate Change

TECHNOLOGY CENTRE MONGSTAD

WORLD ECONOMIC FORUM

Technology Pioneer

CCSL Company

Drop-In solvent for improved performance

Our advanced solvents reduce operating costs, emissions, and waste for new and existing Co2 capture systems.

‘PPB’ level solvent emissions in lean gas

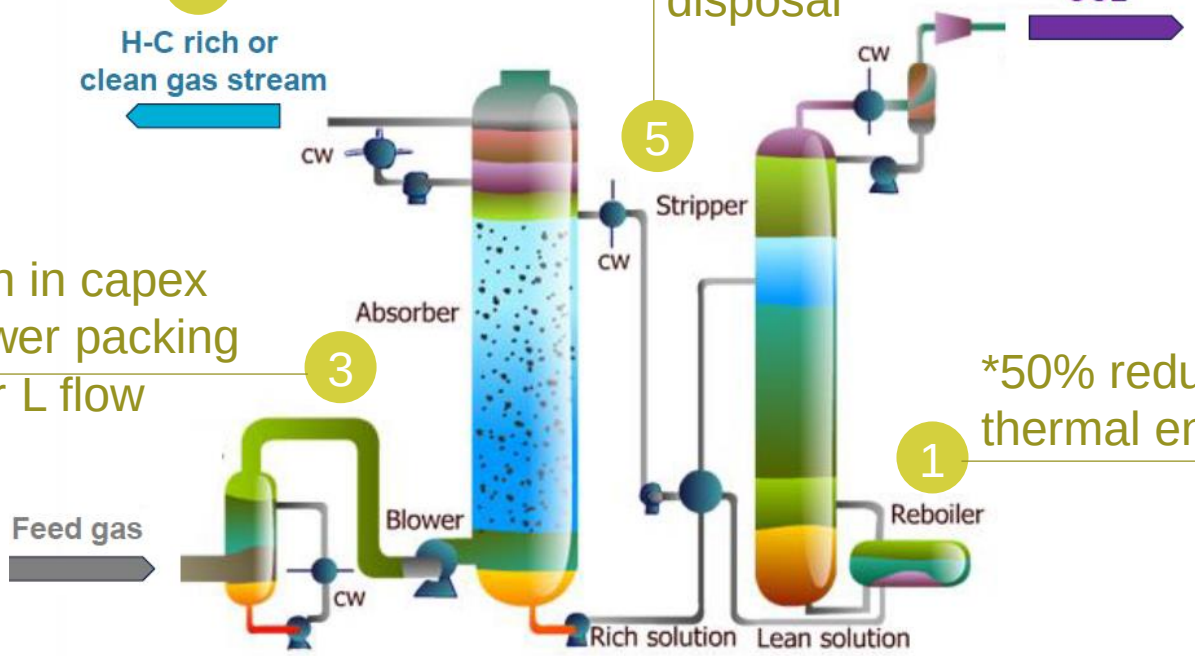
4

*75% less solvent disposal

5

10% reduction in product CO_2 compression power

6



*30% reduction in capex due to 33% lower packing and 50% lower L flow

3

*50% reduction in use of thermal energy

1

2

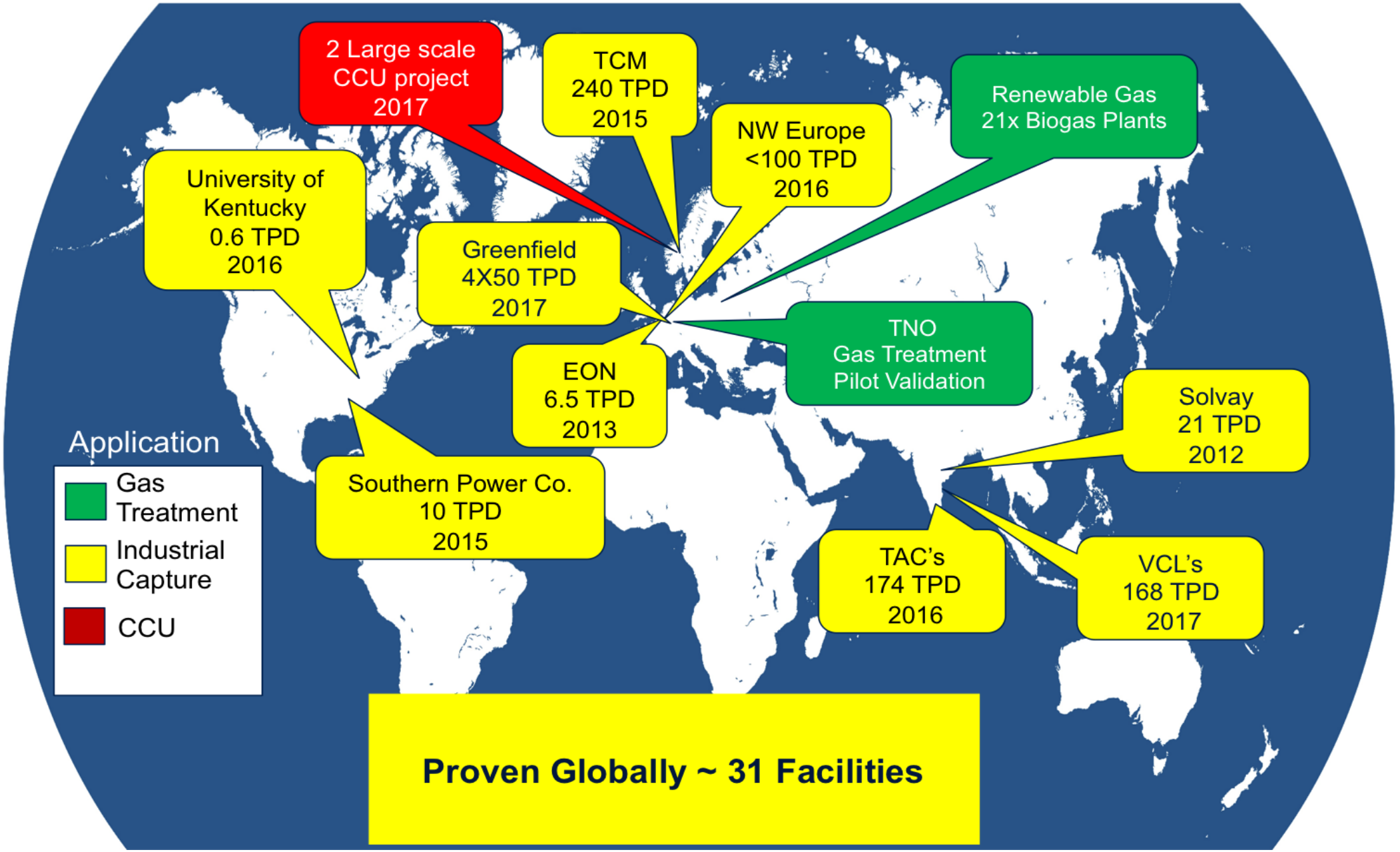
*75% reduction in solvent make-up

*Conventional CO2 recovery benchmark is a monoethanolamine (MEA) based chemical absorption process

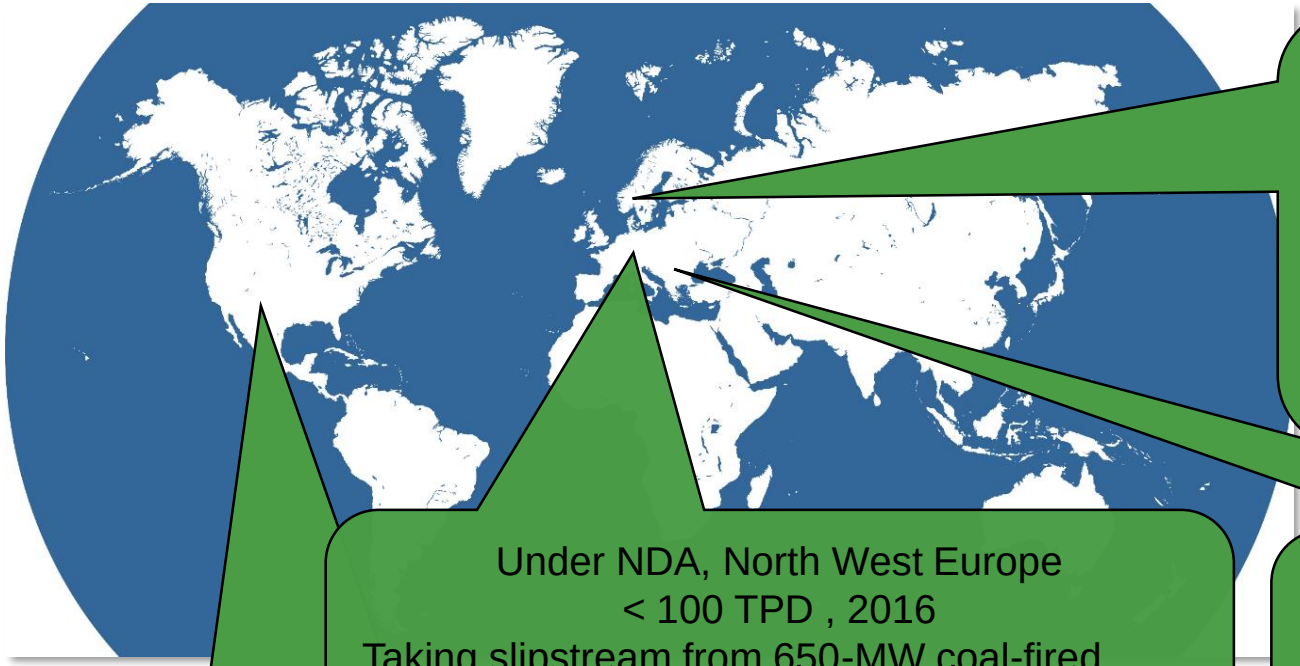
Technology

Global Technology Case Studies

CCSL Company



Validation Case Studies - CDRMax



TCM - Norway
240 TPD, 2015
Taking slipstream from Statoil's refinery CHP & RCC flue gas

- ~3.8 vol% CO_2 and 16% vol% O_2
- ~10 vol% CO_2 and 8 vol% O_2

Under NDA, North West Europe
< 100 TPD , 2016
Taking slipstream from 650-MW coal-fired power plant

- ~13 vol% CO_2 and 8 vol% O_2

EON (TNO) - Netherlands
6.5 TPD, 2013
Taking slipstream from EON's 250-MW coal-fired Maasvlakte power plant

- ~10.5 vol% CO_2 and 8 vol% O_2

Southern Power Co (NCCC) - USA
10 TPD, 2014
Taking slipstream from Southern Company coal fired power plant and simulated natural gas combined cycle flue gas

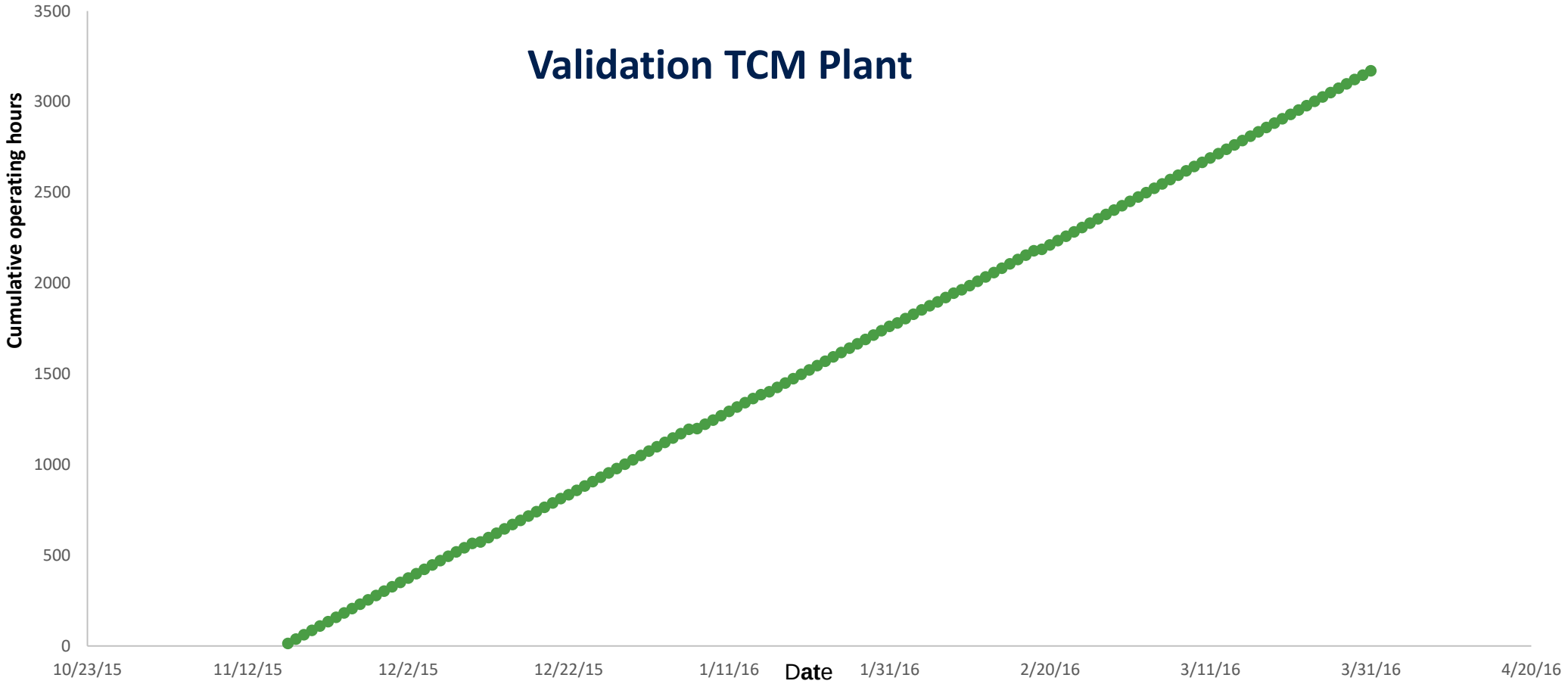
- ~4 vol% CO_2 and 16% vol% O_2
- ~12 vol% CO_2 and 8 vol% O_2

Technology Validation

- Reliability & Solvent stability
- Corrosion
- Environmental emissions
- Energy penalty

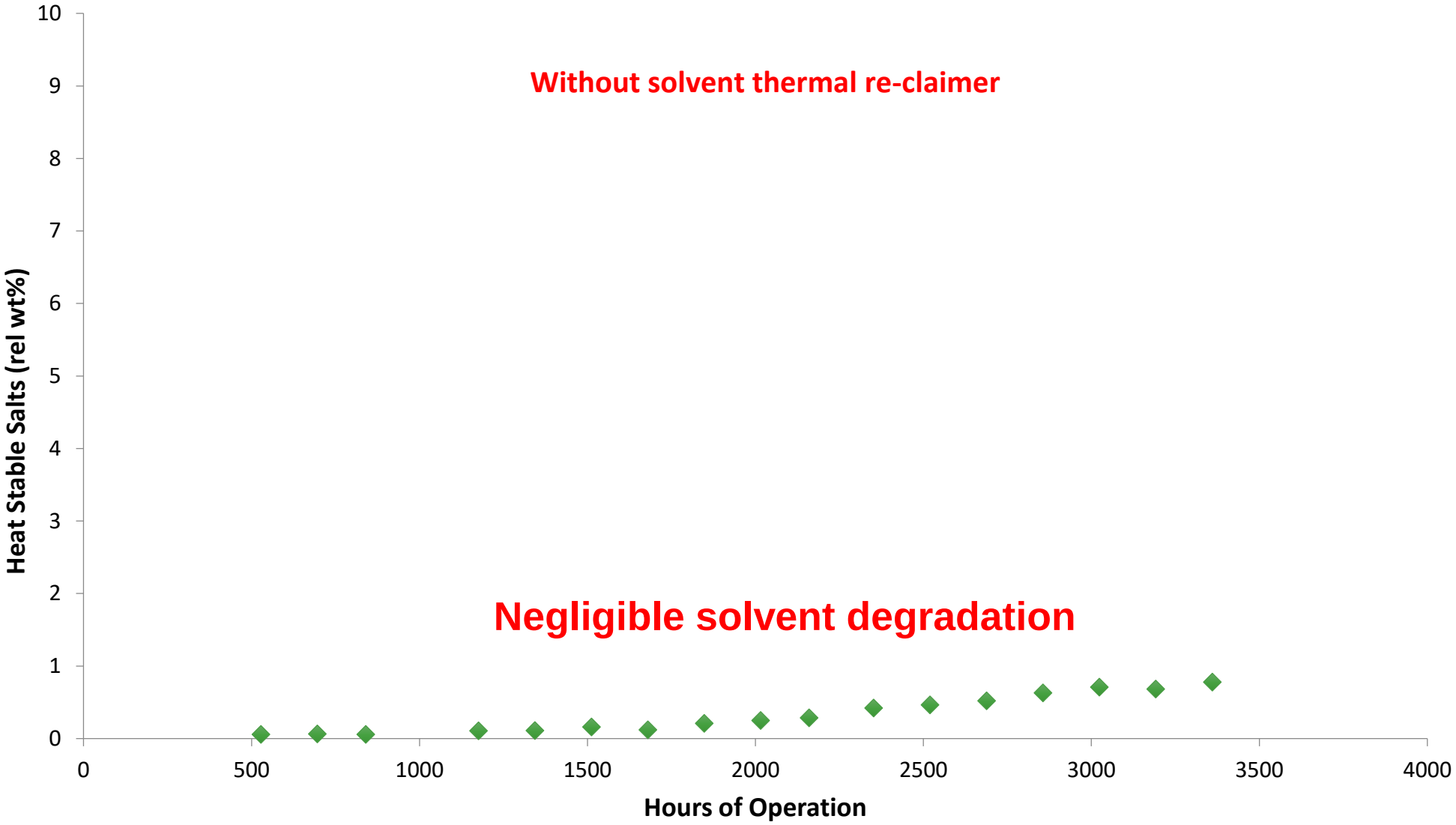
100% Plant Reliability

- Successfully demonstrated CO_2 capture of more than 25,000 tons CO_2
- No loss of run time due to CDRMax solvent issues



Validation of 100% Plant Reliability at NCCC, E.ON, TCM & NWE plant

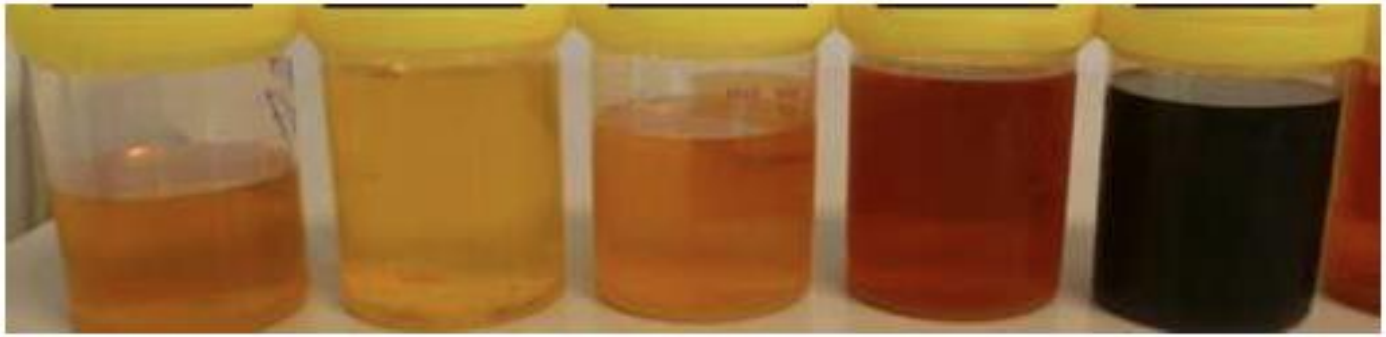
Superior Solvent Stability



Validation TCM plant

Superior Solvent Stability

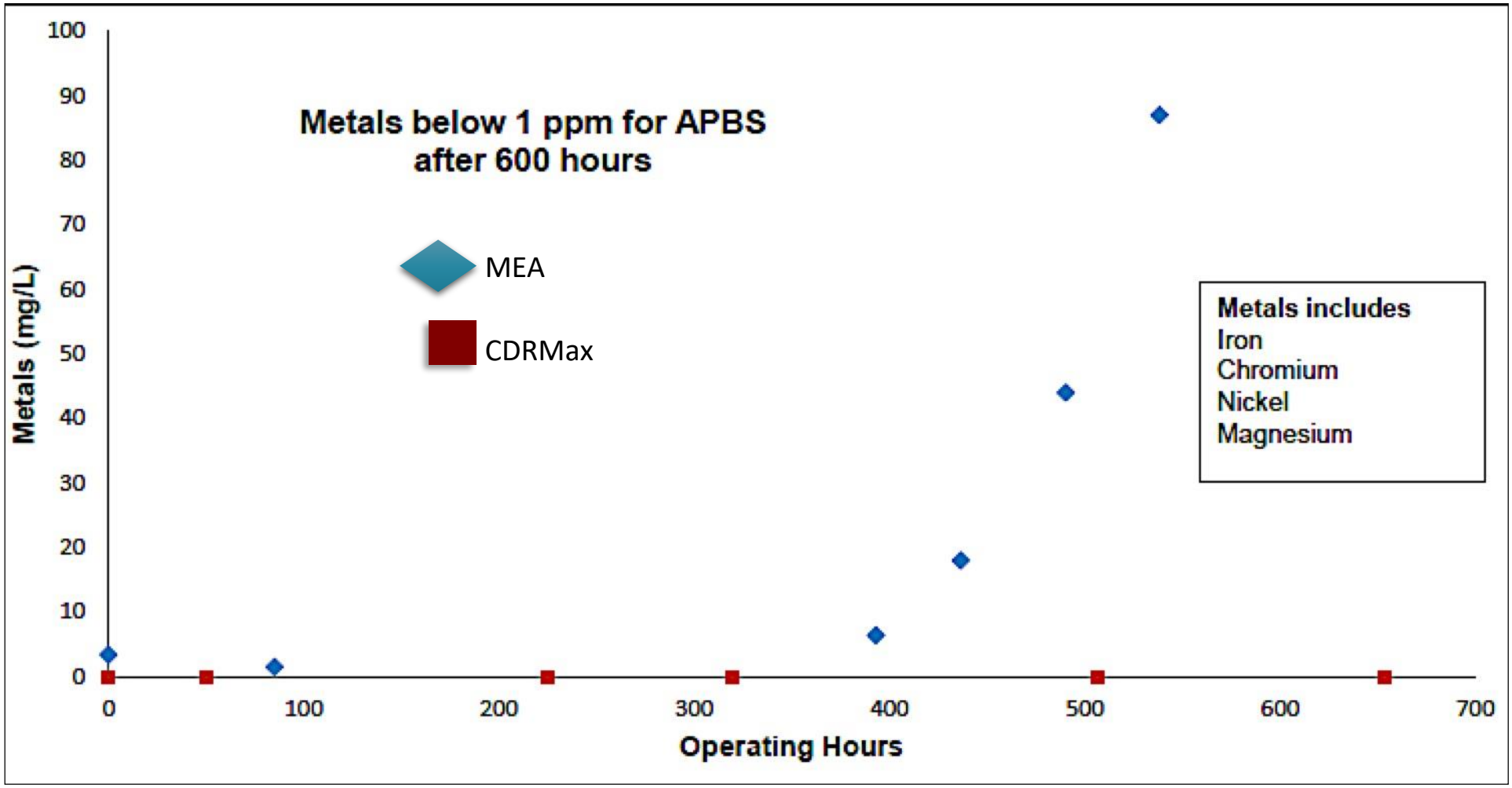
MEA visual change in 1000 operating hours



APBS visual change in 1000 operating hours

Validation E.ON plant (without solvent re-claimer)

Corrosion Data - E.ON Plant



Dissolution of metals from SS304 with CDRMax solvent is 90 times lower than MEA

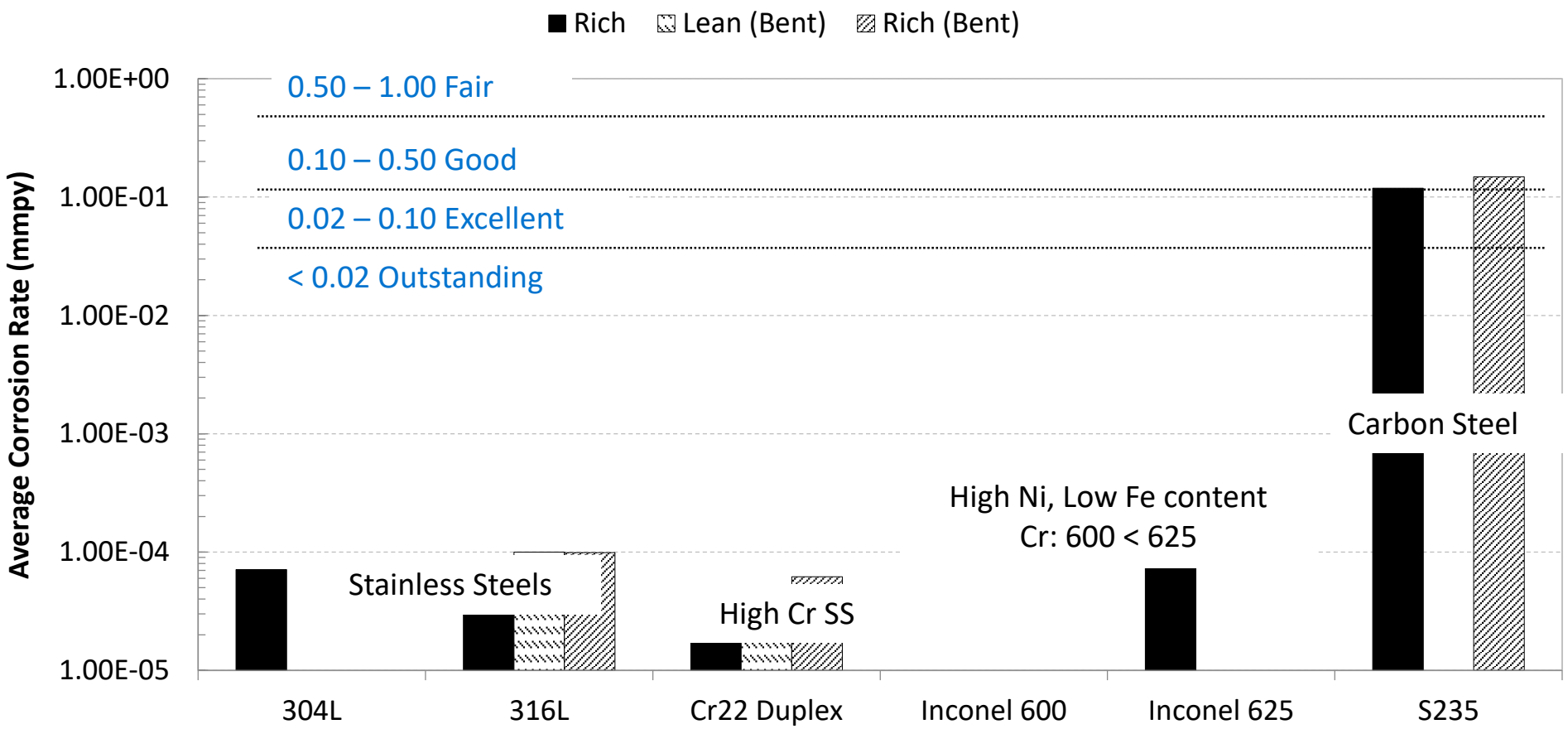
Corrosion Data - NCCC

Dissolution of metals from with CDRMax solvent MEA solvent comparison

Dissolved Metals in Fresh and Rich Solvents (all ppb wt) [1, 2]				
Metal	**Fresh MEA**	**Fresh CDRMax**	**Aged MEA**	**Aged CDRMax**
Arsenic	< 12	53.2	219	114
Barium	< 12	<10	265	11.8
Cadmium	< 12	< 5	< 10	< 5
Chromium	< 12	42.2	**45,090**	**2,120**
Selenium	44.1	41.8	**1,950**	**660**

1) MEA testing in 2012 (Wheeldon, June 2012). No corrosion inhibitor. 316L SS. 300 hrs operations
2) CDRMax testing in 2014. No corrosion inhibitor. 316L SS. ~ 500 hrs operations .

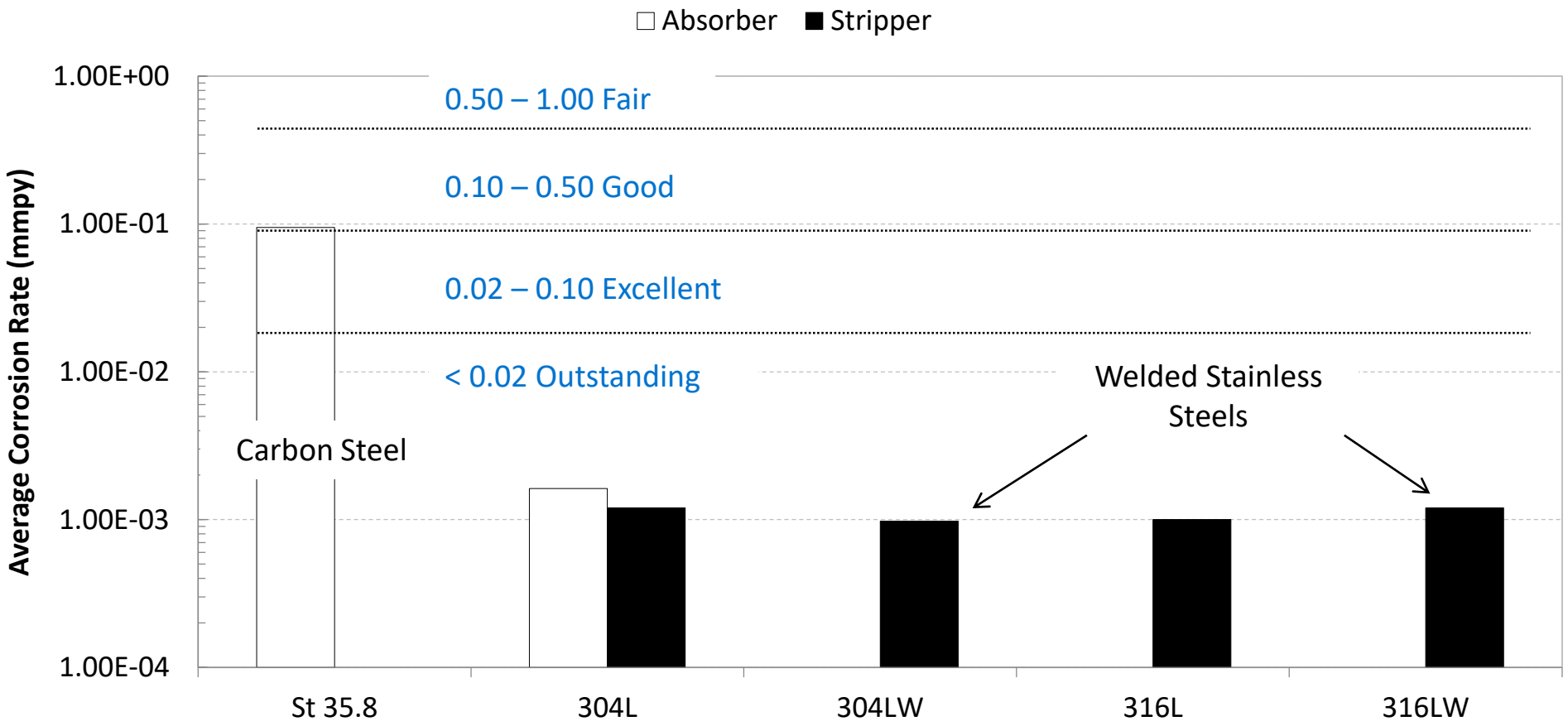
Corrosion Data - TCM



Parameter	Loading	T	P	pH	[CO2]	Linear Velocity	Duration
UoM	Lean/Rich	°C	bar(g)		mol/mol	m/s	Hours
Value	Lean	119	5.5	10.4	0.13	1.1	3500
	Rich	105	6.0	9.2	0.46	1.1	3500

Average conditions of corrosion coupon exposure environments at the TCM campaign

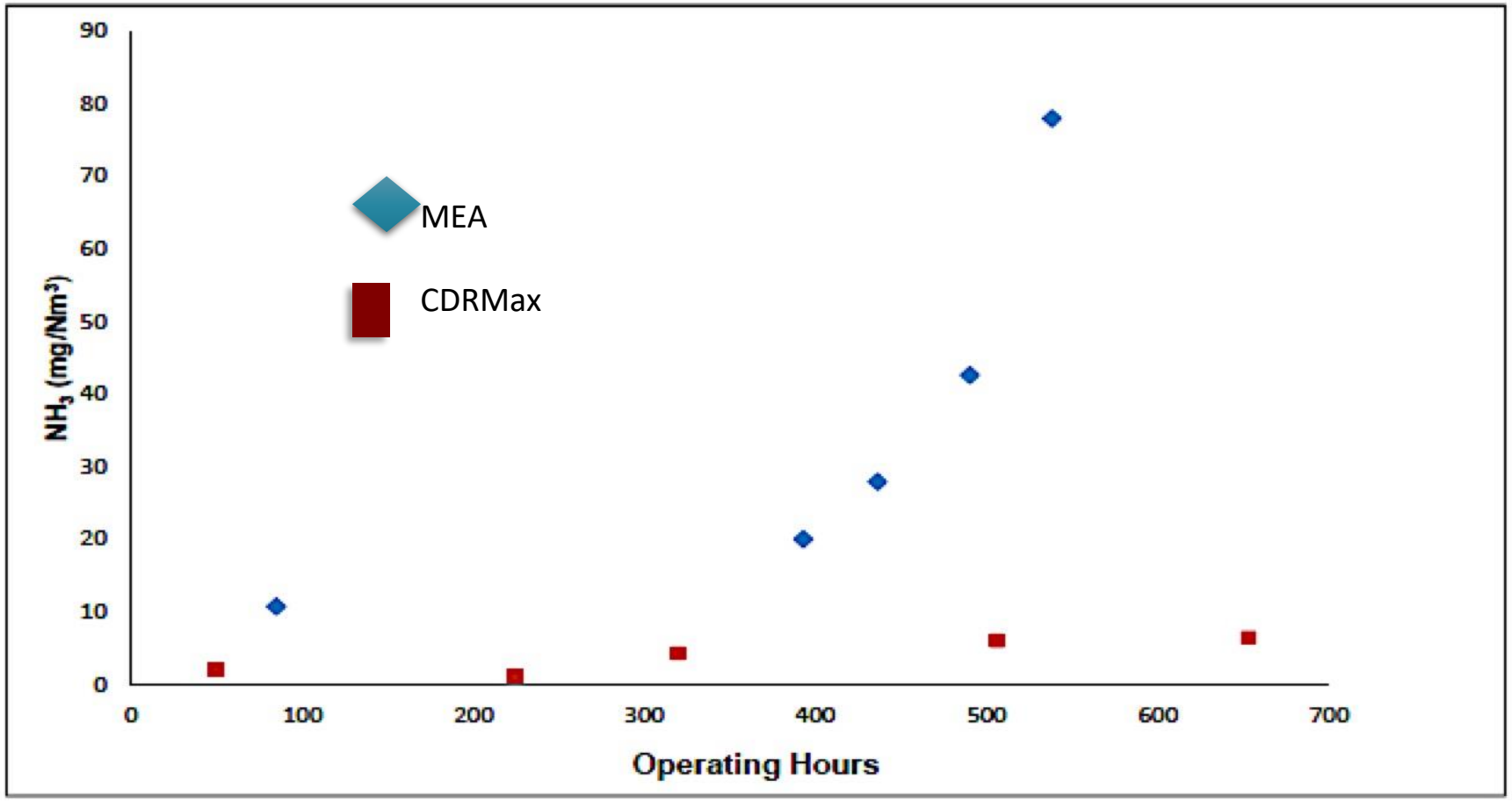
Corrosion Data – NWE



Parameter	Location	Temperature	Pressure	[CO2]	Duration
UoM	N/A	°C	bar(g)	mol/mol	Hours
Value	Absorber	23 – 46	0	0.41	1000
	Stripper	107 – 123	0.3 – 1.3	0.12	1000

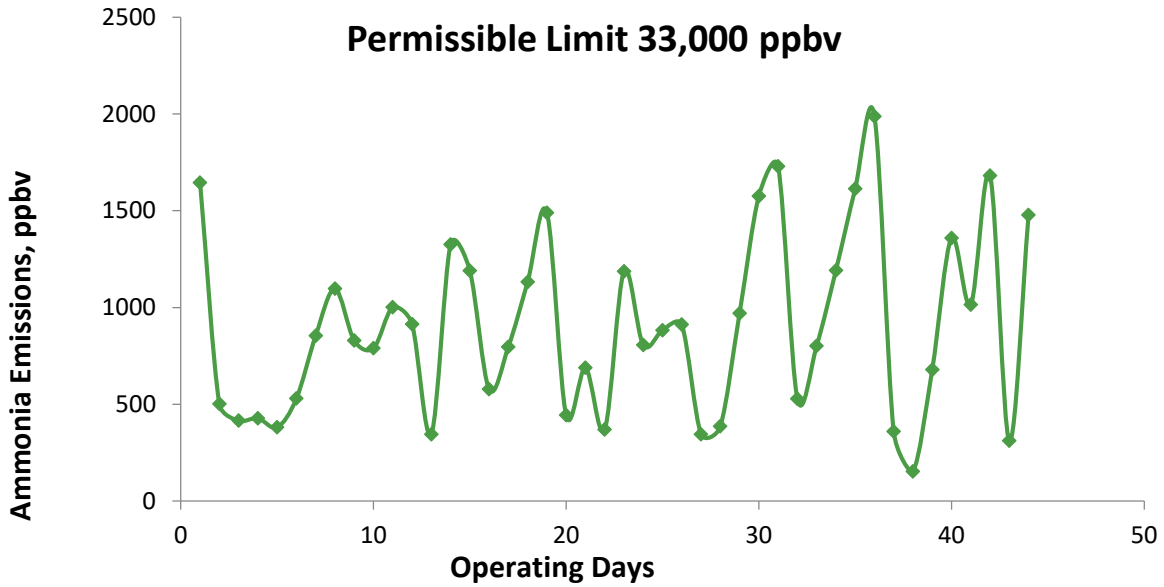
Average conditions of corrosion coupon exposure environments at the N.W.E. campaign

Oxidative Degradation Data - E.ON

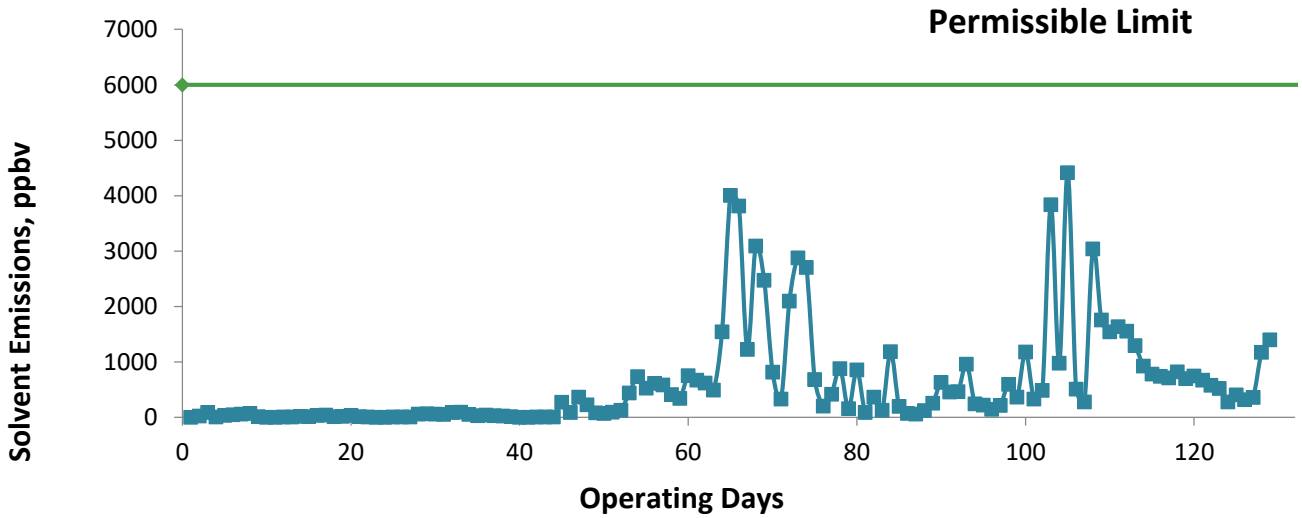


- Ammonia emissions indicator of the oxidative degradation
- CDRMax solvent top-up 8-10 times less than that for MEA

Far Below Current Emissions Permissible Limit



With CDRMax solvent 15-30 times less ammonia emissions than permissible limit



Successfully operated consistently within the permissible limit of solvent emissions.

55x times less aerosols emissions

CDRMax solvent exhibit inherent capability to limit aerosols solvent losses & meet stringent emission limits

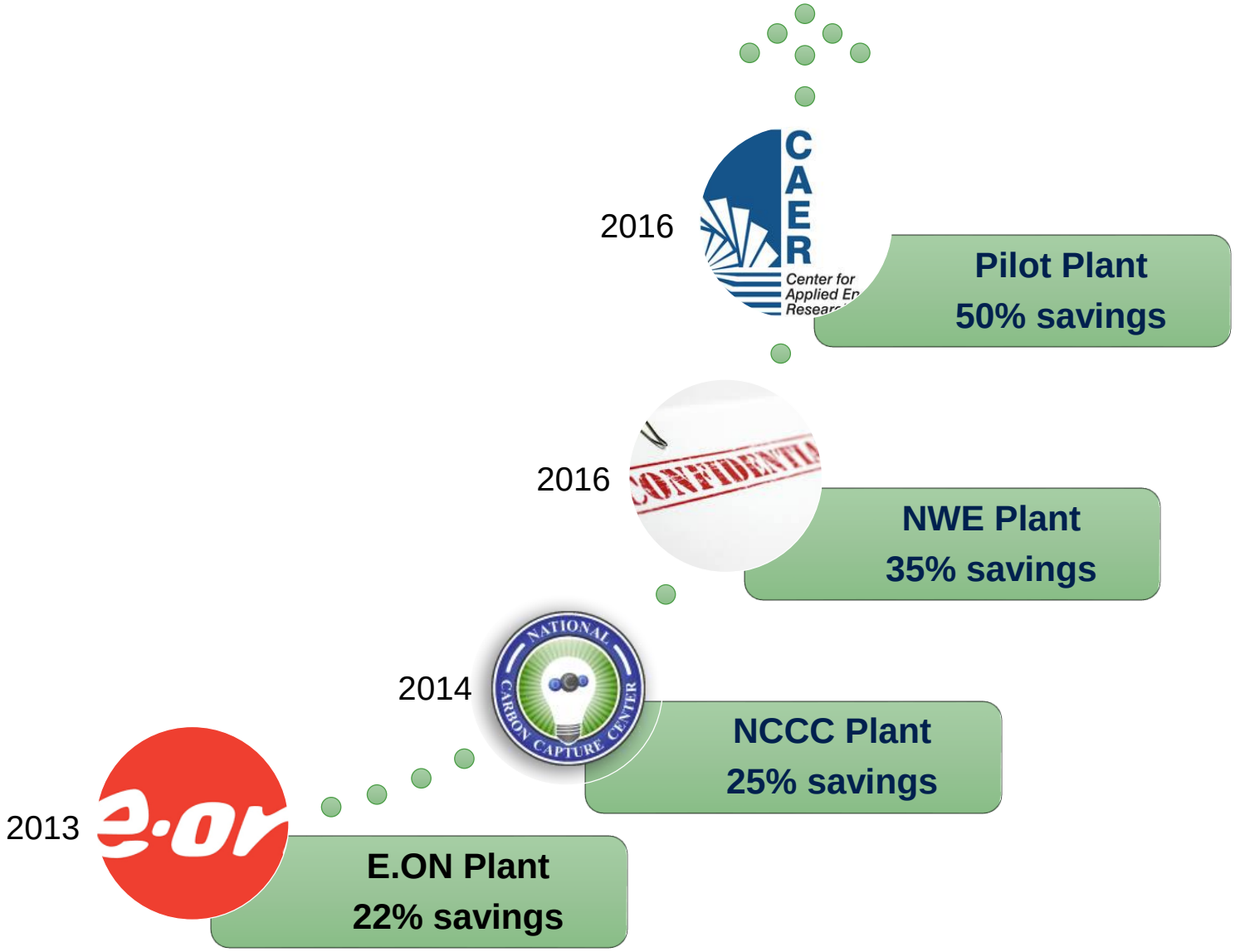
Significant improvement in health & safety aspects

CDRMax aerosols emissions
28 mg/Nm^3

MEA aerosols emissions
1587 mg/Nm^3

Continuous Improvement in Energy Consumption

Energy comparison to MEA
(Coal fired post combustion CO_2 capture plant)



Key Unique Selling Points (USP) of CDRMax Technology

Reductions in capital and operating costs

- 40 % lower OPEX and 30 % Lower CAPEX than conventional CO_2 capture technology

Low solvent emissions

- Atmospheric solvent emission at the ‘parts per billion’ (ppb) scale

Solvent Technology Readiness Level (TRL) = 8/9

- Technology proven and deployed at full scale
- Commercially available, globally

High availability and reliable performance

- No operational issues resulting in 100 % plant availability and efficient performance

Validated scale up models

- Developed simulations and models for technology and process scale-up, which have been validated at all scales

Extensive experience on any type of flue gases

- Versatile solvent technology can be applied to any type of flue gas for efficient and economical CO_2 capture

Case Studies

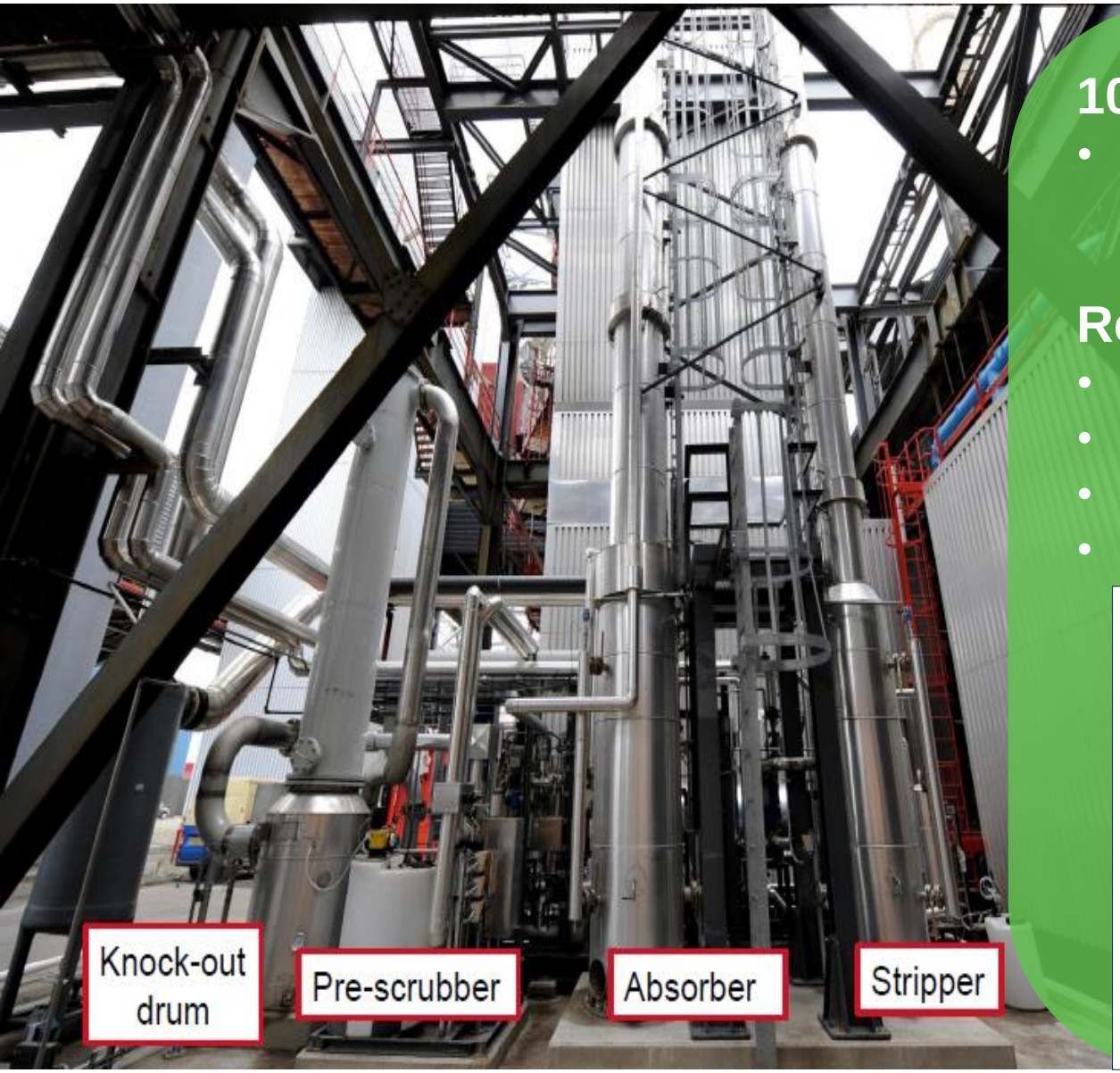
10MW CO2 Capture to Chemicals Project in India




10MW Coal power plant CO2 capture:

- CO2 converted to chemicals
- FEED completed 2015
- Commissioning October, 2016
- CCSL's engineering design

Pilot: 6.5 TPD at EON Benelux, Netherlands

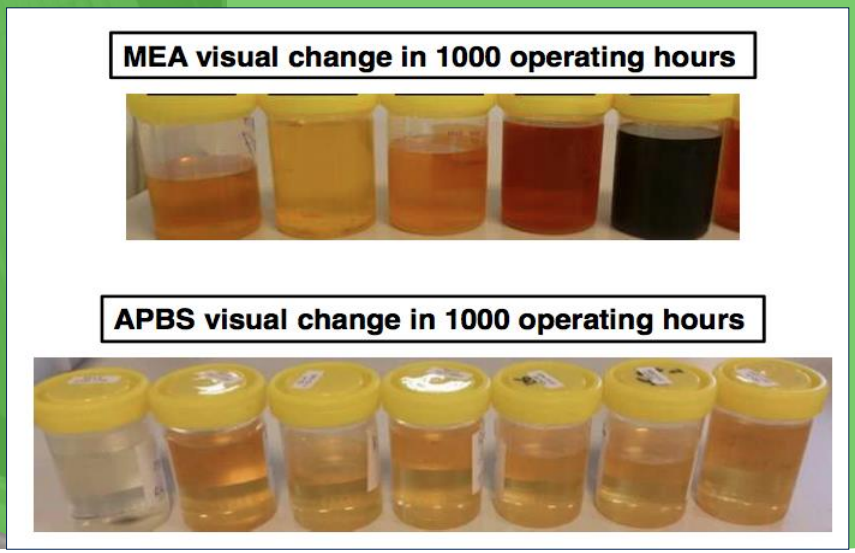


1000 hour test campaign:

- Coal / biomass fired power plant campaign (CO_2 concentration 12 vol%)

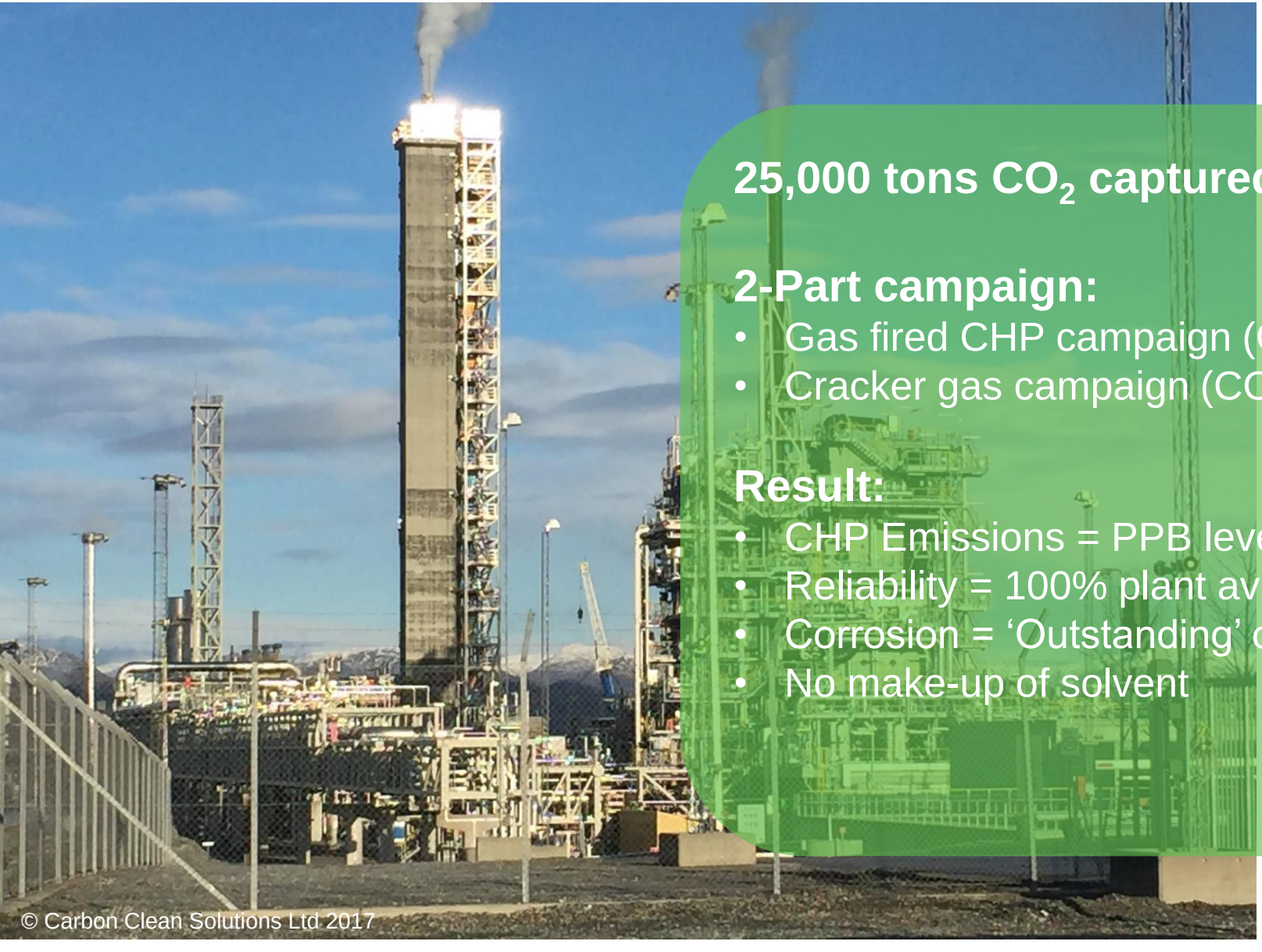
Result Vs MEA campaign:

- Minimal degradation of solvent
- 15x reduction in corrosion
- 10x reduction in ammonia emissions
- 50x reduction in aerosol emission



Demo: 240 TPD at Technology Centre Mongstad, Norway

World Largest Most Advanced CO2 Capture Facility



25,000 tons CO_2 captured over 3500 hours

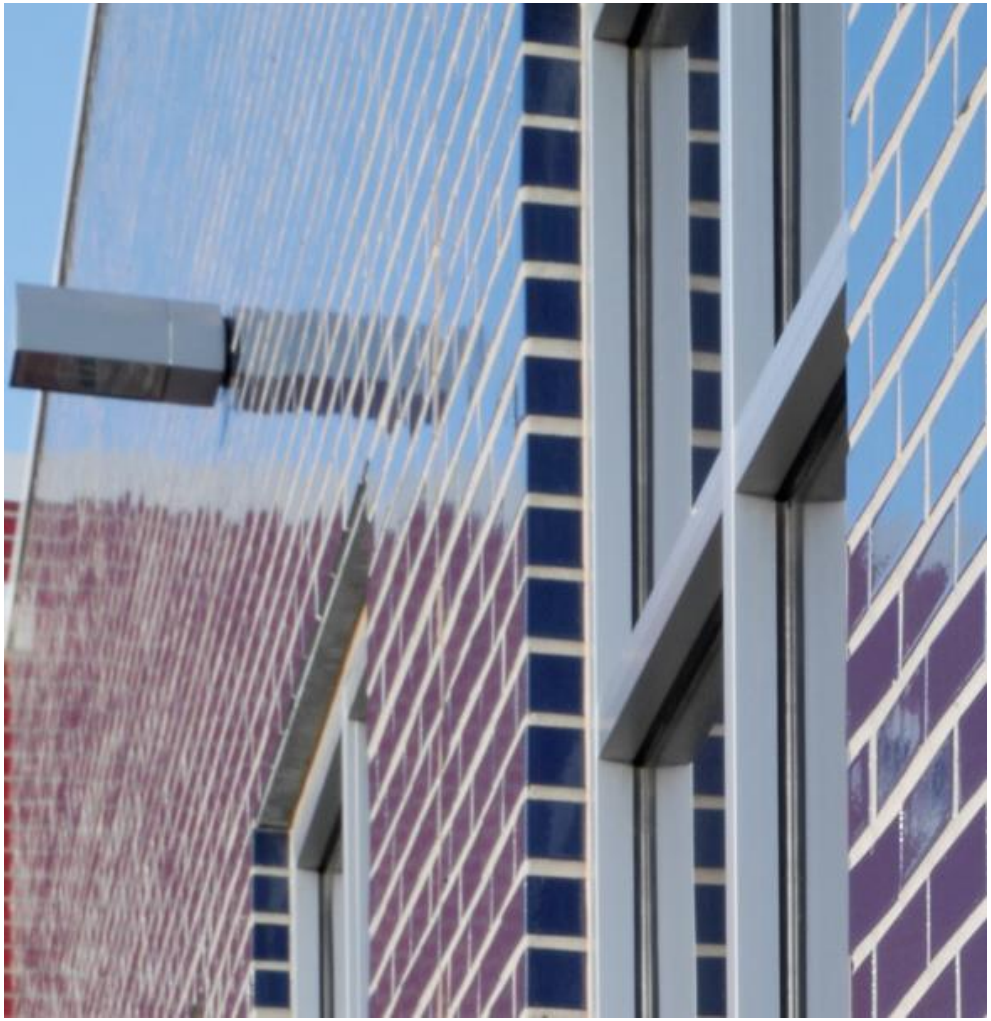
2-Part campaign:

- Gas fired CHP campaign (CO_2 3.6 vol%)
- Cracker gas campaign (CO_2 13 vol%)

Result:

- CHP Emissions = PPB level solvent emissions
- Reliability = 100% plant availability
- Corrosion = 'Outstanding' quality for SS 304L
- No make-up of solvent

Specialty chemicals: greenfield project



Client: Vishnu Chemicals

Location: India

CO2 capture: 168 TPD

Project description: Produce own CO2 for use in production of Sodium Dichromate, Strontium Carbonate and Barium Carbonate, used in ceramic glazes.

Timing: Currently in construction, delivering in 2017

Large Scale CCUS Project – greenfield project

Client: KEA (Waste to Energy Plant Oslo city)

Location: EU

CO2 capture: 1500 TPD (75 MW) flue gases

Project description: Complete Decarbonisation of Waste to Energy Plant of Oslo city

Timing: Pre-FEED / FEED Stage

Large Scale CCUS Project – greenfield project

Client: Yara

Location: EU

CO2 capture: 1000 TPD (50 MW) flue gases

Project description: CO2 capture from reformer flue gases of Urea plant.

Timing: Pre-FEED / FEED Stage

Contact Us

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