

# Pathways forward For CCS on Natural Gas Power Systems

For the United States Energy Association

Washington, D.C.

April 22, 2014

**ALSTOM**  
*Shaping the future*

# Alstom

Equipment & services for power generation  
**Alstom Thermal Power**



Equipment & services for power transmission  
**Alstom Grid**



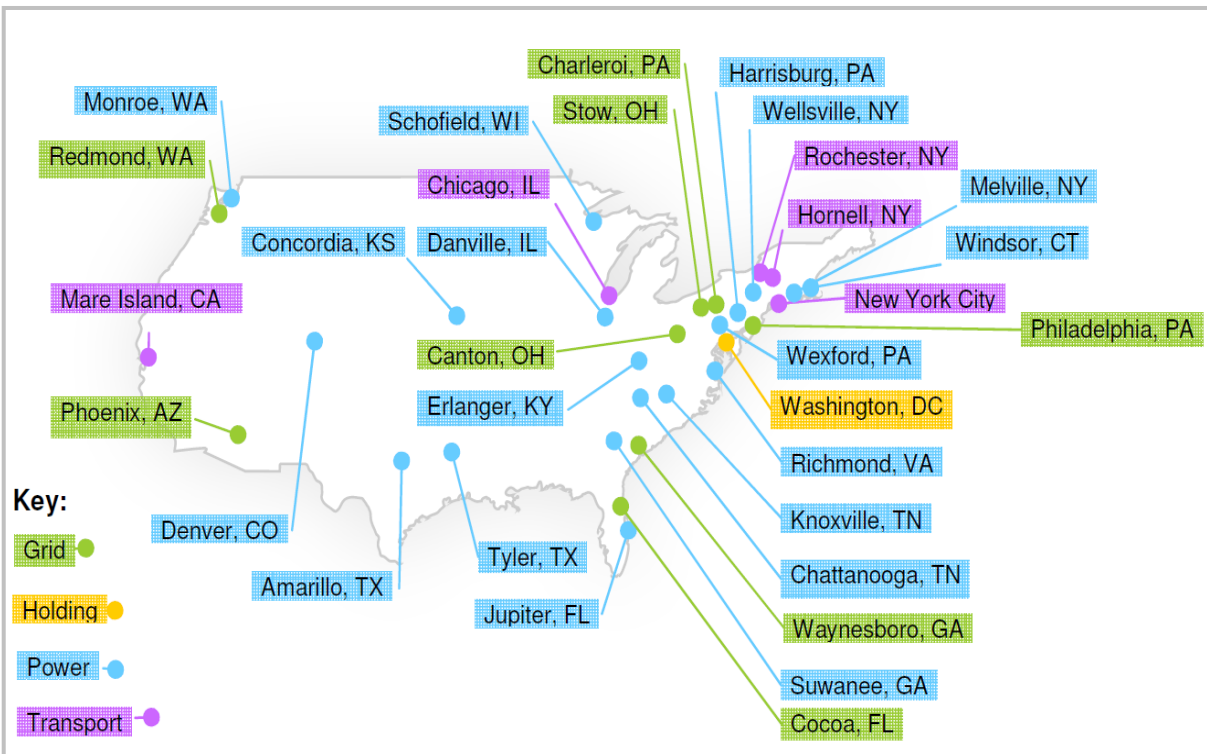
**Alstom Renewable Power**



Equipment & services for rail transport  
**Alstom Transport**



# Alstom in the US



## TRANSPORT

### Passenger Focused Rolling Stock

- Largest plant in North America
- 7000 Metro cars produced in the US
- ACELA high speed train (160 mph)

### Train Control systems

- Leader in mass transit
- Proven PTC solution with 10 yrs experience

### Train life services

- Leader in mid-life overhauls and renovation
- Materials management and fleet maintenance for transit and freight operators

## POWER

- Power generation solutions for all major energy sources in the US
- Clean power technologies (emissions treatment, CO2 capture)
- Major investments in gas turbines and wind

## GRID

- Expertise in power quality and reliability improvement
- Key technology leader in next generation smart grids

- More than 100 years of presence in the U.S.
- \$3.5 billion in sales / 8,000 employees in 45 states
- Major manufacturing centers in the states of TX, TN, NY, CT
- Recent investments in TN and TX will create 600 green jobs for U.S. workers

# Alstom in the US



- Equipment in **50%** of all U.S. power plants

- Advanced software managing more than **40%** of all power flowing on the U.S. grid



- **7,000** U.S. subway and rail cars were manufactured or modernized on an Alstom production line



# Alstom CCS roadmap

## TESTS COMPLETE



**AEP Mountaineer**  
USA - 58 MWth  
Chilled Ammonia, Coal



**Vattenfall Schwarze Pumpe**, Germany  
30 MWth, Oxy - Lignite



**EoN Karlshamn**  
Sweden - 5 MWth  
Chilled Ammonia, Oil



**Total Lacq**  
France - 30 MWth  
Oxy - Gas



**WE - Energie**  
USA WI - 5 MWth  
Chilled Ammonia, Coal



**DOW Chemical Co.**  
USA, WV  
Adv. Amines - Coal

## OPERATING



**EDF Le Havre**  
France - 5 MWth Adv.  
Adv. Amines - Coal



**TCM Mongstad** Norway  
40 MWth, Chilled Ammonia, CHP  
RCC Offgas



**Alstom BSF Windsor**  
US - 15 MWth  
Oxy - Coals



**Alstom GPU Pilot (Mobile)**  
0.3 MWth



**Alstom Labs Växjö**  
Sweden - 0.25 MWth  
Post. C.-multi purpose



**DOE/Alstom Windsor**  
US - 3 MWth  
Chemical Looping, Coal



**RFCS EU - Darmstadt**  
Germany - 1 MWth  
Chemical Looping - Coal

## LARGE-SCALE PROJECTS (under development)



**White Rose CCS Project**  
UK - 426 MWe  
Oxy Hardcoal

# Awarded FEED for White Rose



## White Rose CCS Project, located at DRAX Power Plant (Selby-UK)



## Windsor US pilot Learning important for White Rose – DOE funding



# TCM Chilled Ammonia – Validation Plant



## Design Basis

- CO2 Sources:
  - Flue gases from natural gas CHP plant
  - Off-gases from the RFCC ←
- Validation plant, designed to capture:
  - 80 ktons CO2/year (RFCC) & 22 ktons CO2/year (CHP)
- Incorporation learning from previous pilots
- Unique Validation Features / Expectations

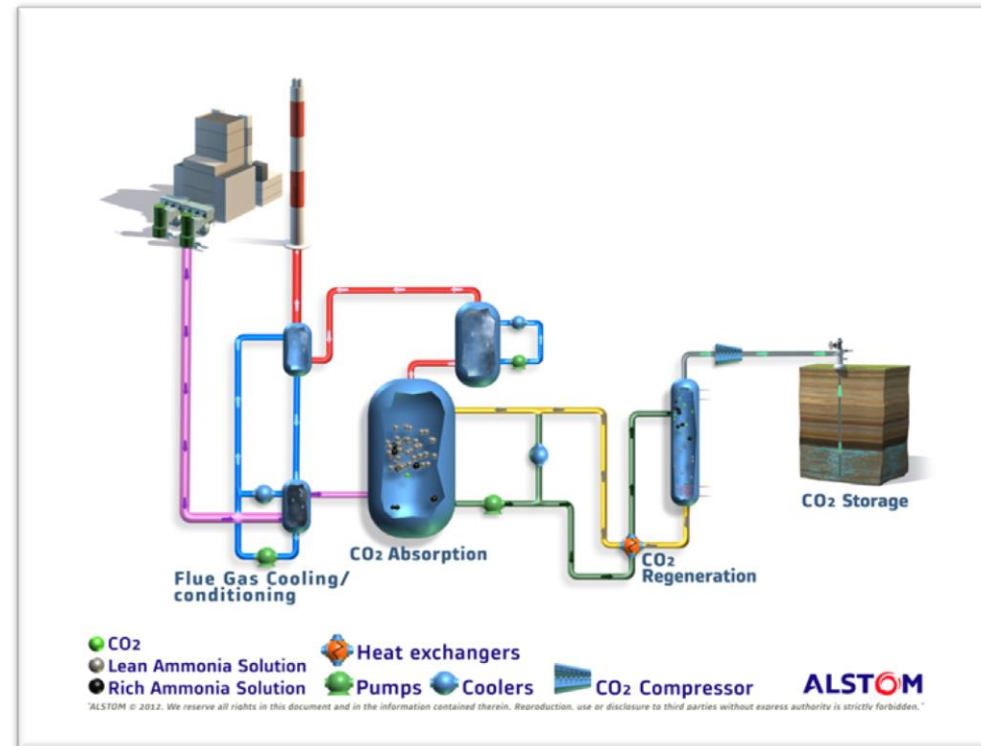
## Design Features

- Compact and efficient layout (1300 m<sup>2</sup>)
- 150 tonnes of piping
- 62 control valves
- 39 Sampling Points
- 642 Inputs to DCS

# Chilled Ammonia Process Technology Overview

## Advantages

- Energy-efficient capture of CO<sub>2</sub>
- High CO<sub>2</sub> purity (99.5+ vol%)
- Low CO<sub>2</sub> compression power (High P Regen)
- Tolerant to flue gas oxygen and other impurities
- Stable solvent, no degradation
- No emission of volatile degradation products
- Low-cost, globally available reagent
- Valuable byproduct: ammonium sulfate



A 'Leading' Post Combustion Technology



# Early Test Results

Parameter	Test A - Target	Measured Data
Flue Gas Rate	45,000	45,000 - 47,000
CO2 Capture Rate	85%	85-93%
Regenerator Steam	3200 kg/hr	3200-3700 kg/hr

Parameter	Test B - Target	Measured Data
Flue Gas Rate	35,000	35,000
CO2 Capture Rate	85%	83-86%
Regenerator Steam	2250 kg/hr	2130-2285 kg/hr
NH3 Emissions	2 ppm	1-2 ppm
Availability	>90%	>90%



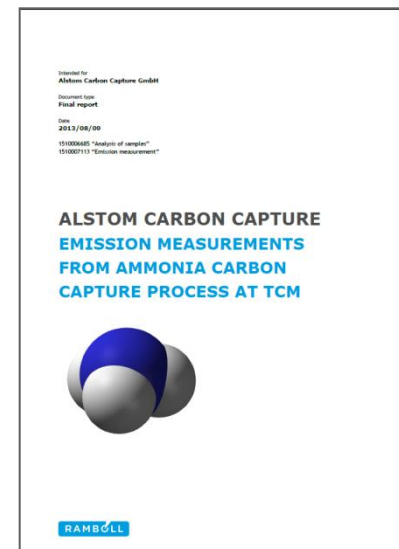
# Third Party Emissions Testing



Isokinetic samples taken on  
17 July 2013

Compound	Detection Limit	Measured Data
Ammonia (*)		0.40 mg/Nm <sup>3</sup>
Aldehydes	< 11 µg/m <sup>3</sup>	nd
Alkyl amines	< 17 µg/Nm <sup>3</sup>	nd
N-Nitrosamines	< 2 µg/Nm <sup>3</sup>	nd
Nitramines	< 0.020 µg/Nm <sup>3</sup>	nd
Total Nitrosamines	< 1 µg/Nm <sup>3</sup>	nd

(\*) - 0.4 mg/Nm<sup>3</sup> = 0.5 ppmv



**CAP confirmed as an environmentally friendly technology**

# Further Test Strategy

- Overall system: Entire CAP facility
  - Unit operations & subsystems:
    - Absorber systems regenerator system, etc.
  - Auxiliary systems: Chiller, Co2 wash, etc.
  - Control: Transient studies
- 
- **Tests will focus on performance both with CHP flue gas and refinery RFCC gas**



# Summary on TCM

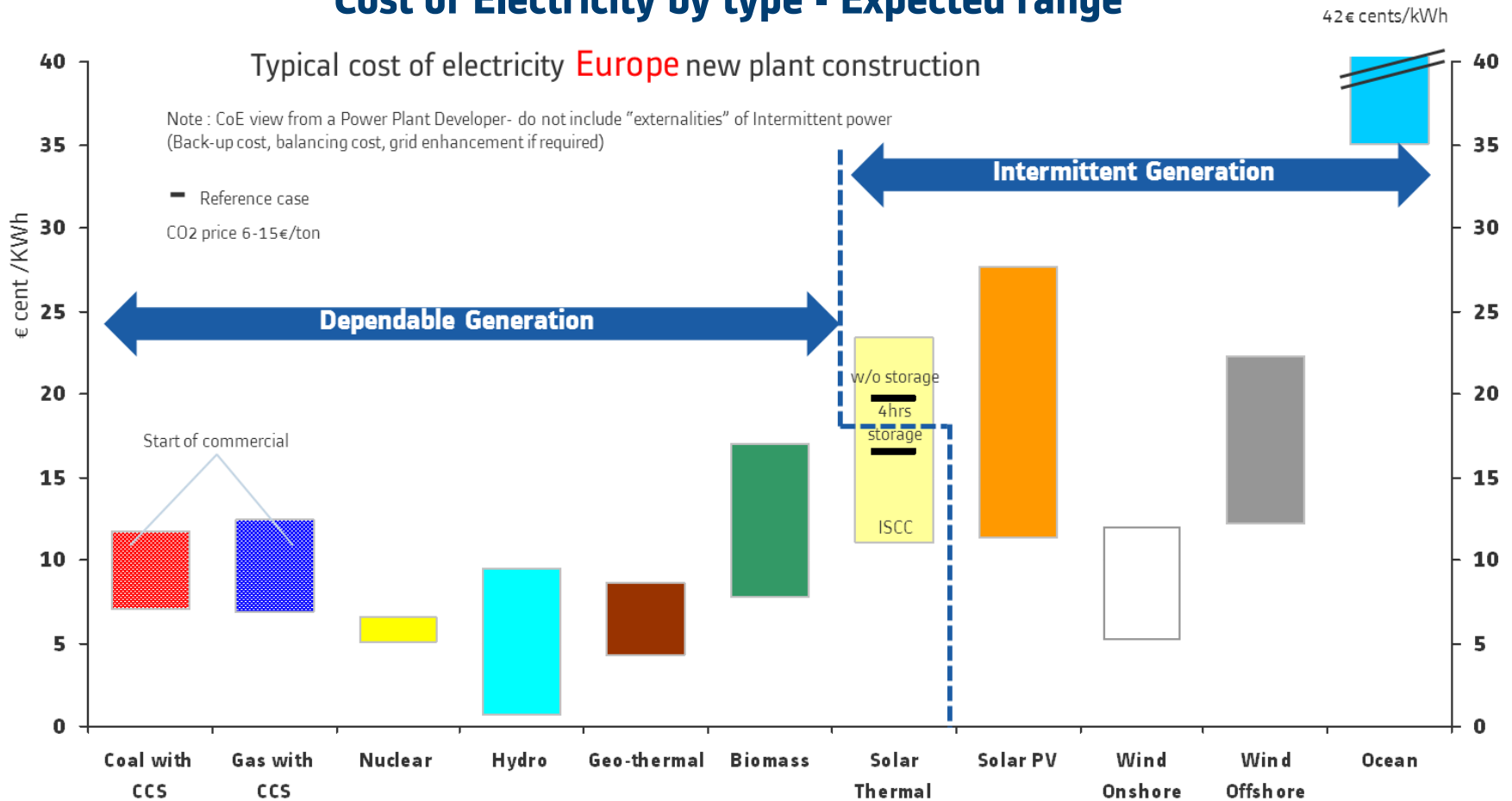
- TCM plant is an **important step in the CAP roadmap**, ready for demos which will lead to commercial technologies.
- **First operations and performance feedback are in line with Alstom's predictions** and reconfirms the Benefits and Advantage of Alstom's CAP Technology
- Alstom and TCM have agreed to extend the CAP **Operational Test phase to November 2014**
- Norway & TCM have shown leadership in developing the TCM facility - Alstom is proud to be part of it, and we are excited about our continued partnership





# Cost Projections

## Investment decision for low carbon New PP over next 5 years Cost of Electricity by type - Expected range



Source : Alstom analysis 2013

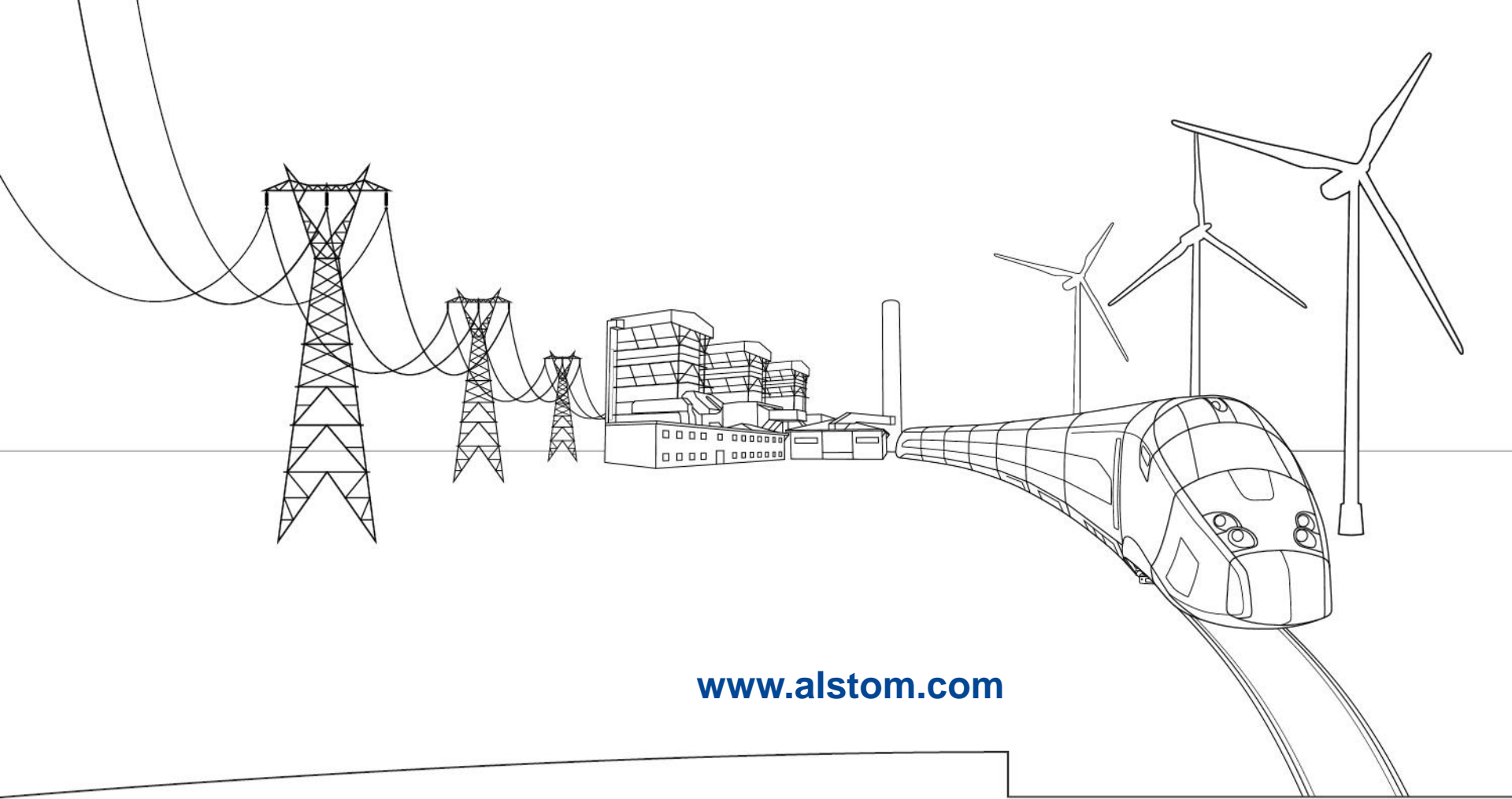
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# Conclusion

- Alstom has a leading position in CCS
- The technologies (1st Generation) are ready for scale up
- Need large scale demos in order to make the largest improvements in cost and performance and move down the "learning curve"
- Government support is needed - policy, market incentives (like renewables have), and where appropriate, other revenue streams (e.g. EOR)
- 2nd Generation technologies are needed for the long term and need to be developed now





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