Paper # 72

CCS Project with Alstom's Chilled Ammonia Process at AEP's Mountaineer Plant

EPRI-EPA-DOE-A&WMA Power Plant Air Pollutant Control "MEGA" Symposium

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D Muraskin

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Baltimore, MD

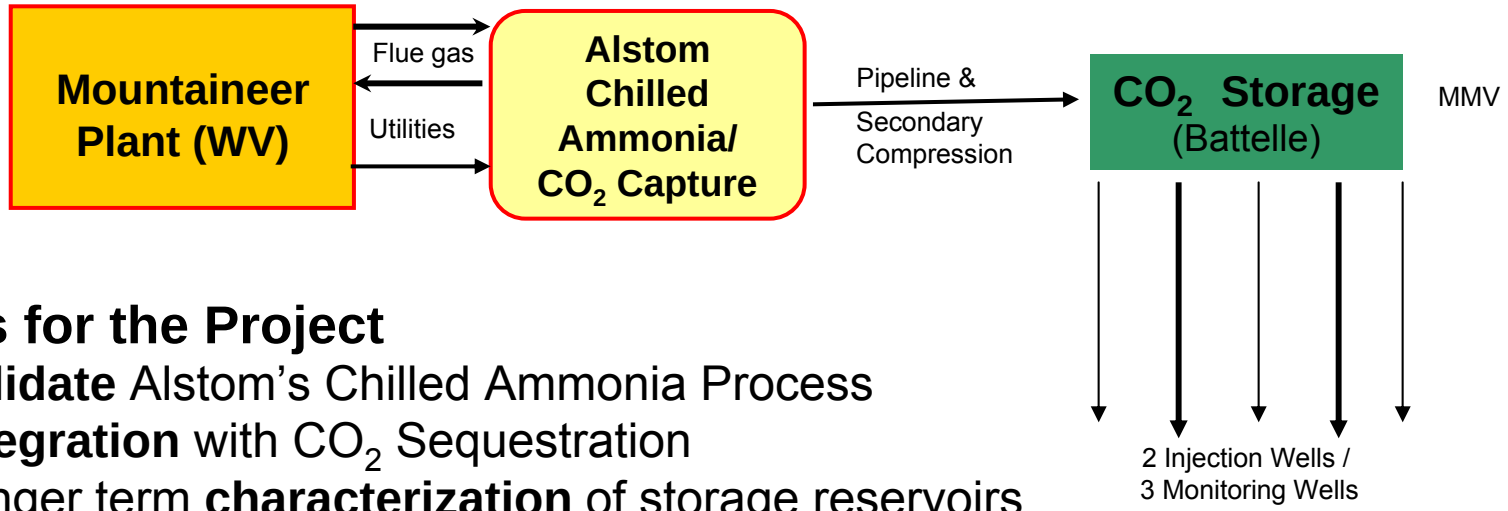
AEP AMERICAN ELECTRIC POWER

ALSTOM

Presentation Outline

- **Project Overview**
- **CO_2 Storage Characterization & Design**
- **CO_2 Storage System Operations**
- **Alstom Chilled Ammonia Process**
- **Conclusions**
- **Q&A**

Project Overview

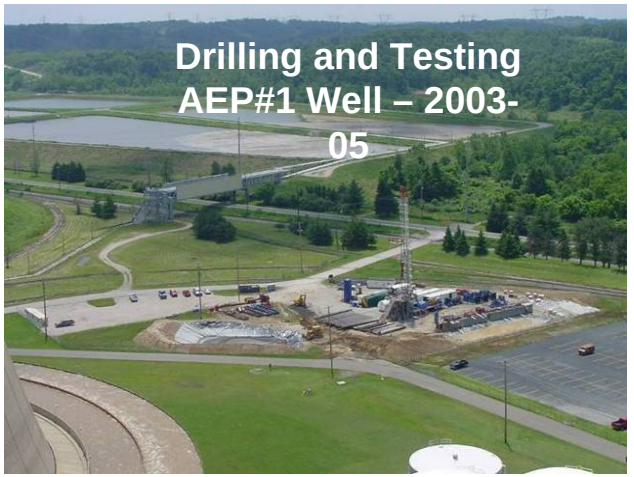


- **Goals for the Project**
  - **Validate** Alstom's Chilled Ammonia Process
  - **Integration** with CO_2 Sequestration
  - Longer term **characterization** of storage reservoirs
- **Flue Gas Slip Stream from Mountaineer Plant**
  - Equivalent to 20 MW (electric) from WFGD System
- **Capture and Store** ~100k metric tons of CO_2 per year
- **Project Milestones**
  - Started engineering, planning, & permitting — 3Q 2007
  - Started construction — 2Q 2008
  - Captured CO2 for first time — Sep 1 2009
  - Injected CO2 for first time — Oct 1 2009

Site Characterization Study

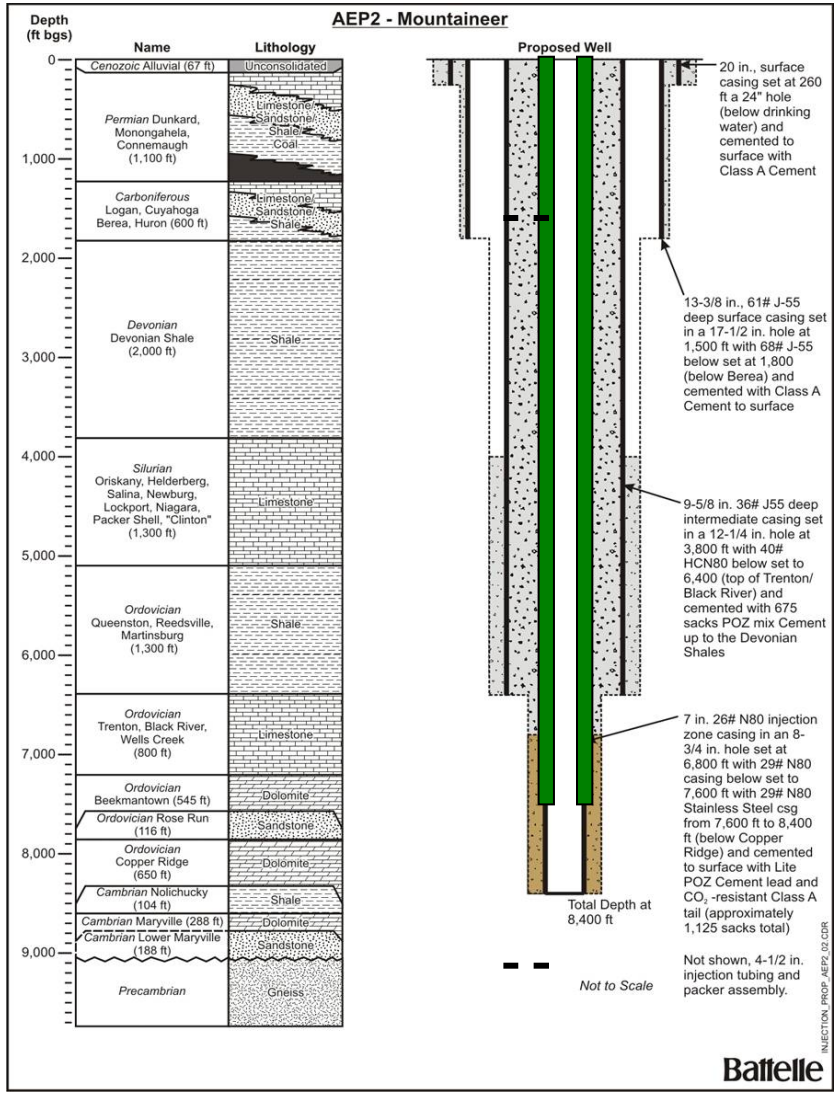
- **Site characterization** and feasibility assessment conducted in 2003 by Battelle & Others under **DOE funded project**
- **Foundational work** for AEP's CCS program
- Identified Two(2) feasible injection formations for CO_2:
  - **Rose Run** Sandstone (AEP-2, 7800 ft)
  - **Copper Ridge** B Zone (AEP-1, 8200 ft)
- Characterization study found **thousands of feet of "Cap Rock"** to contain the stored carbon dioxide


Seismic Survey Summer 2003


Drilling and Testing AEP#1 Well – 2003-05

Injection Well Design

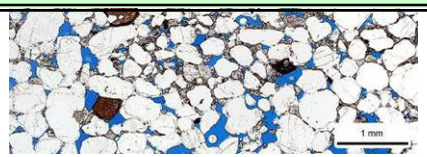
- **Well Design** an important means to contain CO_2 in reservoir
  - Ex. AEP-2 in Rose Run Sandstone
- Similar in design to **wastewater injection wells** used in oil & gas industry
- **Type V** Underground Injection Control permit issued by WVa DEP
- **Multiple cascading well casings**, to provide isolation from:
  - Shallow freshwater
  - Intermediate zones containing coal seams, oil & natural gas
- Stainless steel casing and CO_2 resistant cement deep injection well section



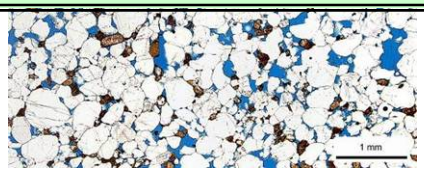
Full Core Samples
2003 Characterization Study

Rose Run Sandstone- 116 ft total thickness, 30 ft porous sandstone

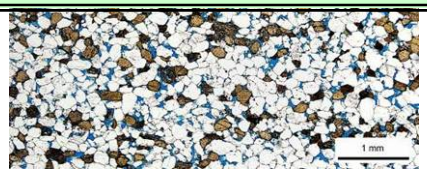
Hydraulic Core Tests 7763.5 ft
Lithology = Sandstone
Density = 2.68 g/mL
Porosity = 9.1%
Permeability = 36 mD



Hydraulic Core Tests 7775 ft
Lithology = Sandstone
Density = 2.64 g/mL
Porosity = 10.4%
Permeability = 49 mD



Hydraulic Core Tests 7819 ft
Lithology = Sandstone
Density = 2.63 g/mL
Porosity = 11.5%
Permeability = 36 mD



Data from Battelle

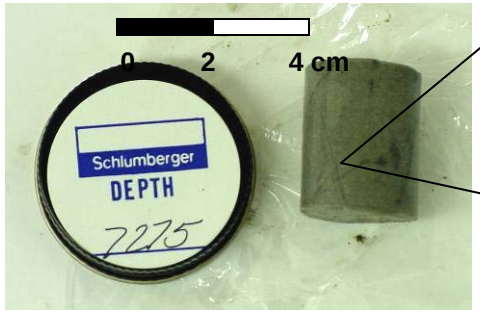
Porosity & Permeability suggested adequate storage reservoirs

Cap Rock Sidewall Cores

2003 Characterization Study

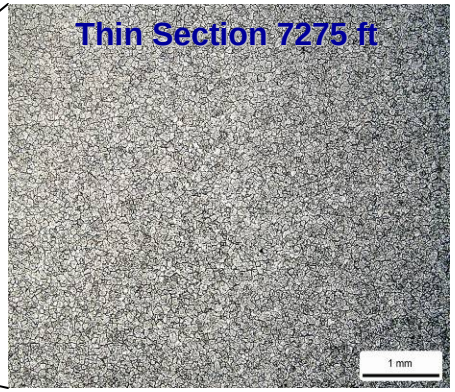
Beekmantown Dolomite 7210-7755 ft

Rotary Sidewall Core 7275 ft

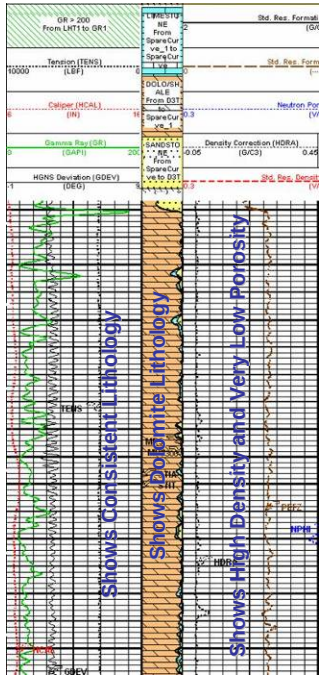


X100

Thin Section 7275 ft



Wireline Log 7100-7300 ft



Hydraulic Core Tests 7275 ft

Lithology	= Dolomite
Density	= 2.82 g/mL
Porosity	= 0.38%
Permeability	= <0.001 mD

Battelle Graphic

Low Porosity & Permeability indicate excellent cap rock to maintain CO2 storage

Data from Battelle

Well Monitoring System

Injection Well Monitoring

A - Flow rate, pressure, temperature
- Annulus pressure
- Corrosion monitoring
- CO_2 product analysis

Surface Leak Detection Methods

B – Shallow groundwater monitoring

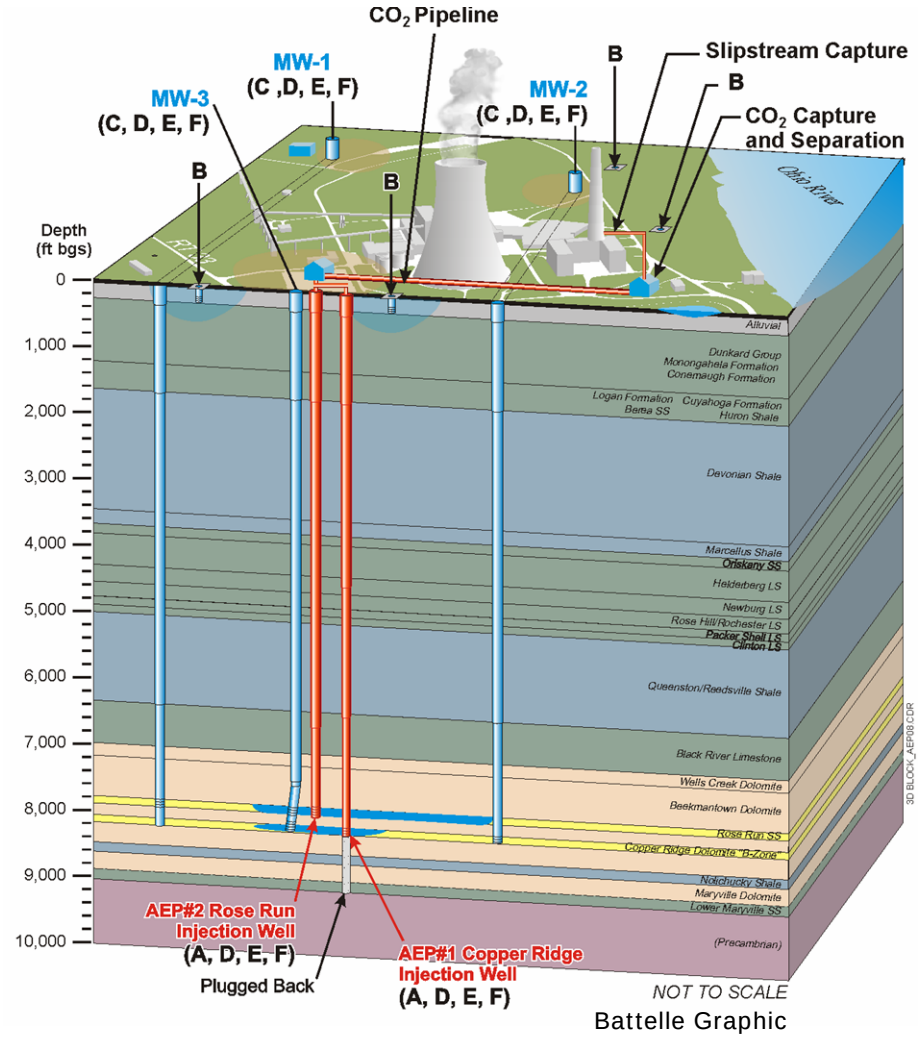
CO2 Tracking and Caprock / Confining Layer Monitoring Methods

C – Fluid sampling

D – Wireline logging

E – Pressure monitoring

F – Cross-well seismic survey



Battelle Graphic

Storage System Operations

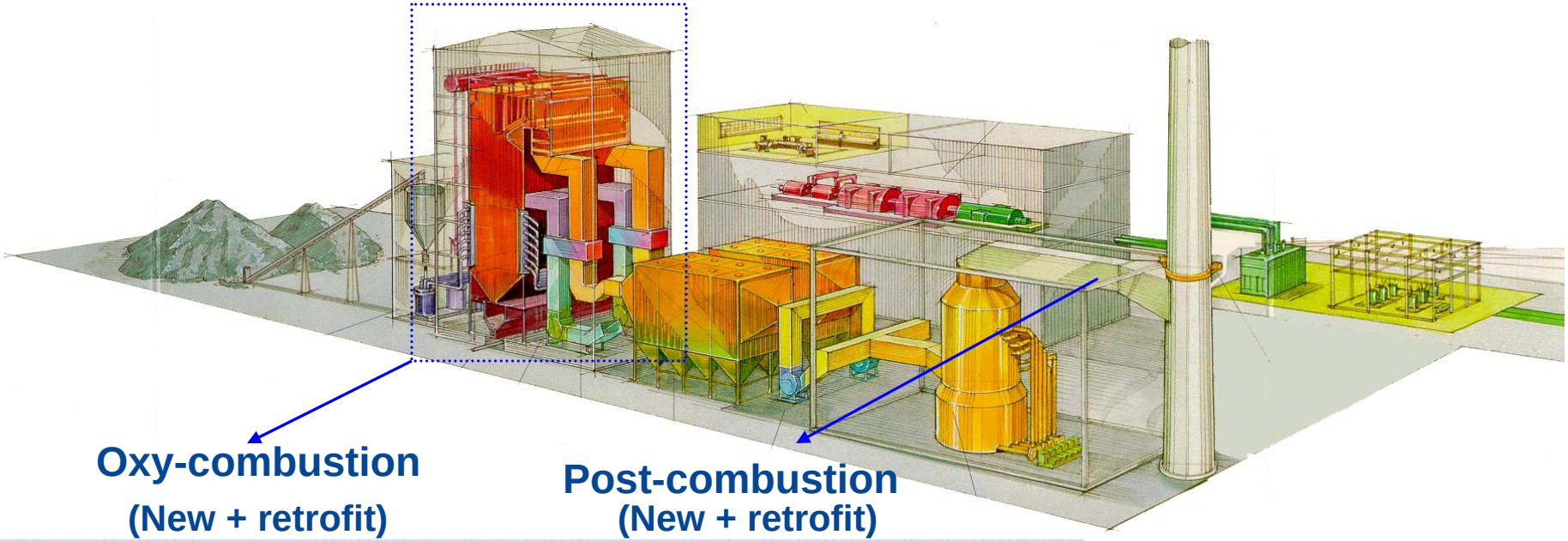
- Injectivity better than expected into AEP-1 Copper Ridge formation
- AEP-2 Rose Run slow to respond initially; better response recently
- Testing & Monitoring have confirmed CO_2 containment
- *Next steps*- To evaluate longer term reservoir behavior / storage capacity

Presentation Outline

- Project Overview
- CO_2 Storage Characterization & Design
- CO_2 Storage System Operations
- **Alstom Chilled Ammonia Process**
- **Conclusions**
- **Q&A**

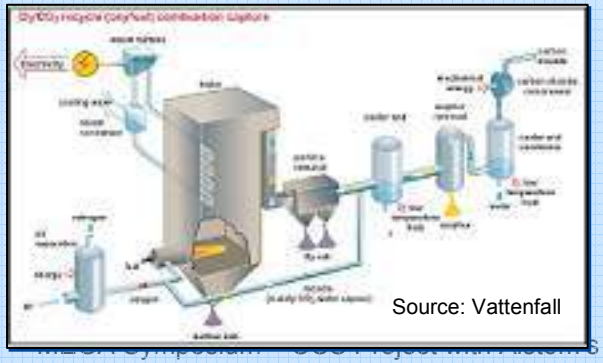
CO_2 Capture Technologies

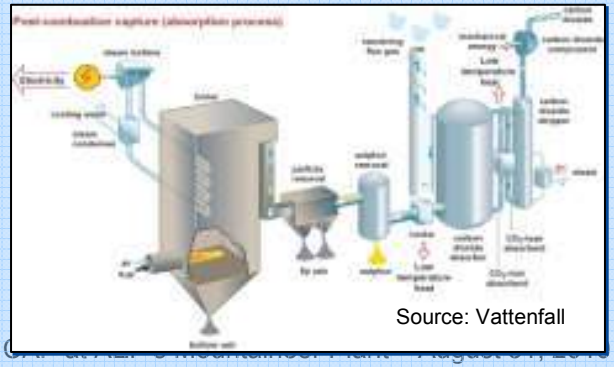
SOLUTIONS DEVELOPED BY ALSTOM



Oxy-combustion
(New + retrofit)

Post-combustion
(New + retrofit)

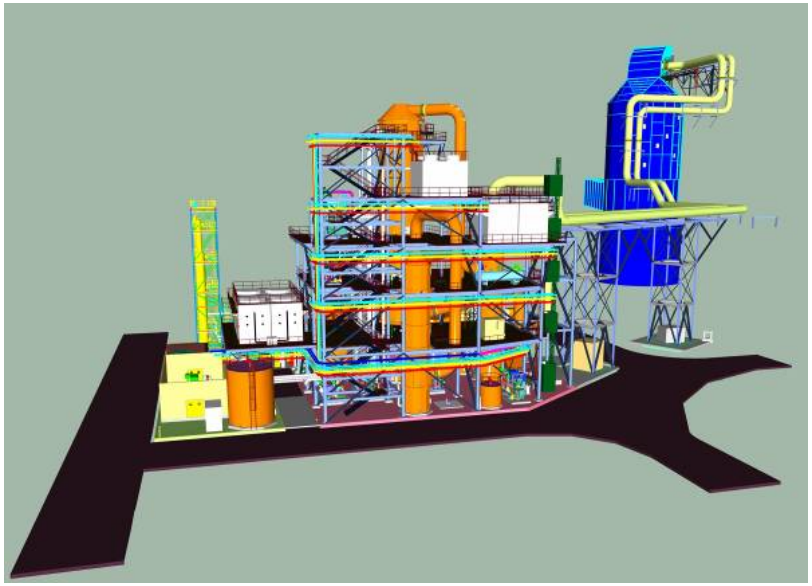




- ***Chilled Ammonia Process***
- ***Advanced Amines***
- ***Anti-Sublimation***

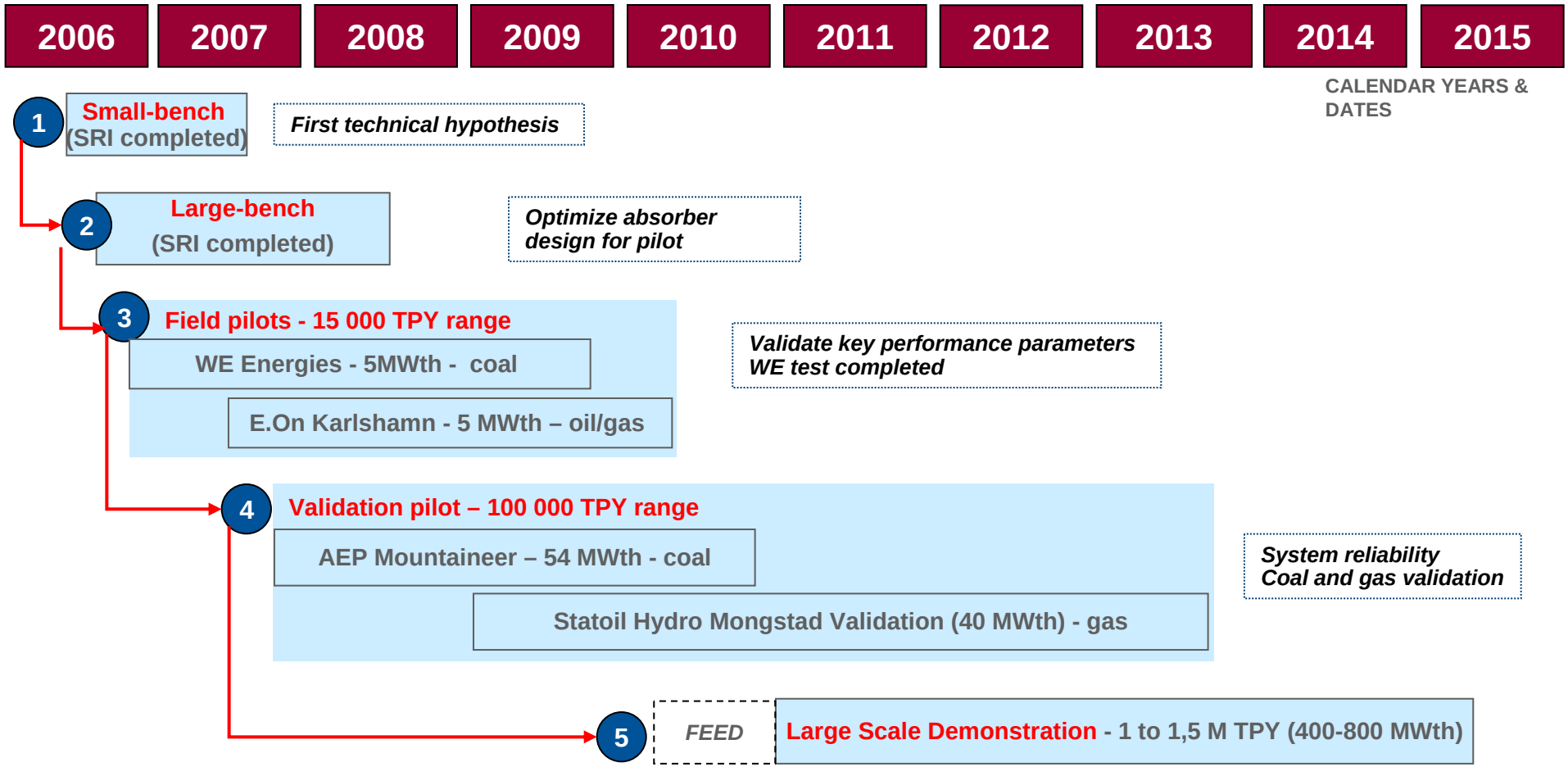
Chilled Ammonia Process Technology Features

- Energy efficient capture of CO_2
  - Utilizes ambient conditions / natural sources for flue gas cooling
- Can accommodate typical flue gas contaminants (SO_x, HCl, HF, NO_x)
- Flue gas exhaust conditions suitable for release to atmosphere
  - low ammonia slip
  - additional testing forthcoming
- High pressure regeneration
  - High purity CO_2 product, low moisture and ammonia
  - Reduced CO_2 compressor power
  - Lower regeneration energy, low vaporization of water from solvent
- Low cost and market stable reagent with potentially salable byproduct (ammonium sulfate) stream



AEP Mountaineer
Product Validation Facility
Chilled Ammonia Process
New Haven, WV

CAP Development Program
Summary Development Plan



Commercial Deployment in 2015

CAP Development Program
We Energies Field Pilot

Field Pilot Program

- Operational June 2008
- 7700+ hours of operation on flue gas from PRB coal through completion of program in Oct 2009
- Proof of Concept technology validation:
  - 90% CO_2 capture efficiency
  - NH_3 slip from DCC2 (~5 ppm)
  - 99^+% CO_2 purity; <10 ppm NH_3; < 2,000 ppm H_2O
  - Functional unit operations
  - Confirmation of process design tools

CO_2 Field Pilot at Pleasant Prairie

CAP Development Program
E.ON Karlshamn Field Pilot

Karlshamn Power Plant (Sweden)

CAP Field Pilot

Field Pilot Program

- Operational Apr 2009
- 1500+ hours of operation on flue gas from sulfur fuel oil ongoing
- Proof of Concept technology validation:
  - 90% CO_2 capture efficiency
  - Flue gas NH_3 slip (~5 ppm)
  - 99^{+}% CO_2 purity; <10 ppm NH_3; < 2,000 ppm H_2O
  - Functional unit operations
  - Confirmation of process design tools

AEP Mountaineer Product Validation Facility

Location	New Haven, WV
Capacity	100,000 tonnes CO_2/yr
	110,230 tons CO_2/yr
	275 tonnes / day
Size	~ 20 MWe
	50,584 scfm
CO_2 Capture Efficiency	75%
CO_2 Storage	Deep geological formations
CO2 Product	CO_2: 99.5+%
	H_2O: 600 ppmv
Upstream APC Equipment	ESP, WFGD, SCR,SO_3 Mitigation
Start-Up	September 1, 2009
Fuel	Bituminous Coal
Reagent	Ammonium bicarbonate \ carbonate
Absorber Column	Packing
Regeneration Energy	Steam – turbine extraction. Integration of steam condensate not included
Byproduct	Ammonium sulfate

Alstom's Chilled Ammonia Process at AEP's Mountaineer Plant,

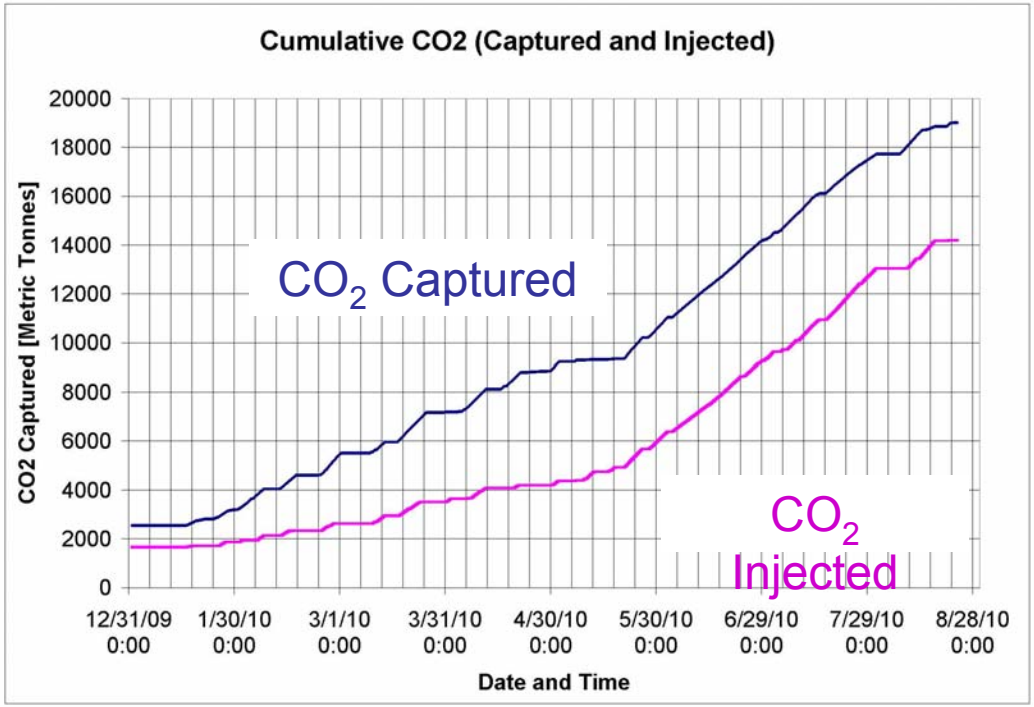
All pictures of the Mountaineer CO_2 Capture and Storage Project are the property of Alstom Power and/or AEP

AEP Mountaineer PVF Project Commissioning and Start-Up Experience

The following CAP issues were identified during initial operation resulting in modifications to improve operability

- Utilization \ handling of solid reagent
- Operation of flue gas cooling coils
- Turndown of refrigeration system and CO_2 compressor
- Regenerator feed solution heat exchanger network
- Adjustments to accommodate transient power plant operation

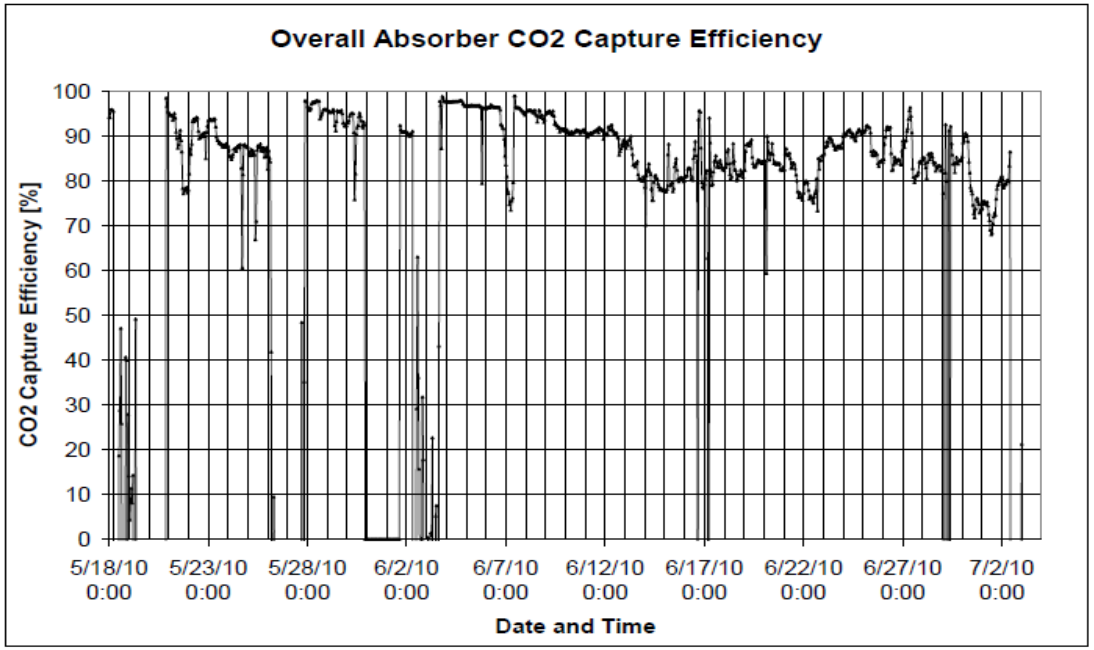
AEP Mountaineer PVF Project Operating Summary



- PVF operating hours: 4400+
- PVF capacity: 40-75%
- CO_2 captured: 19,000+ metric tons
- CO_2 injected: 14,000+ metric tons

AEP Mountaineer PVF Project Operating Data

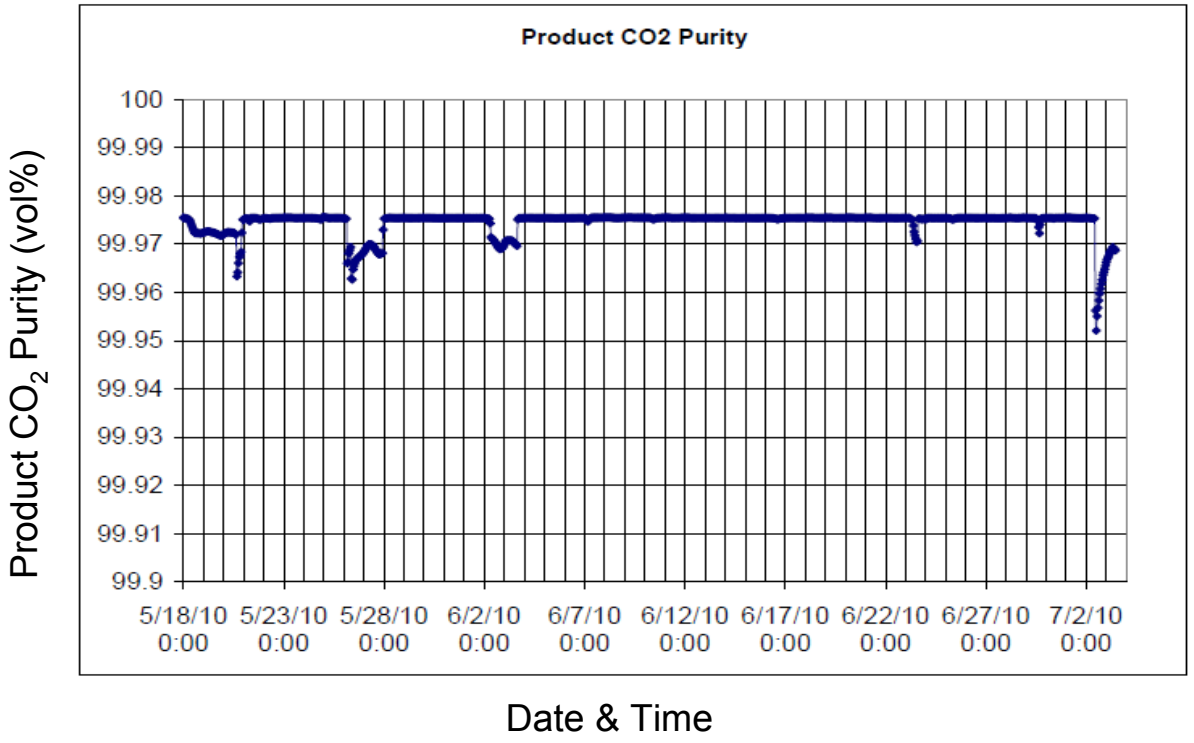
- CO_2 removal efficiency above design value of 75%
- Flue gas measurements taken from on-line FTIR instrumentation
- Values verified by mass balance, existing plant CEMS, and field measurements
- Operating data reflects measurements at various conditions, reduced capacity



Conditions shown include variations in scrubbing solution strength and plant capacity

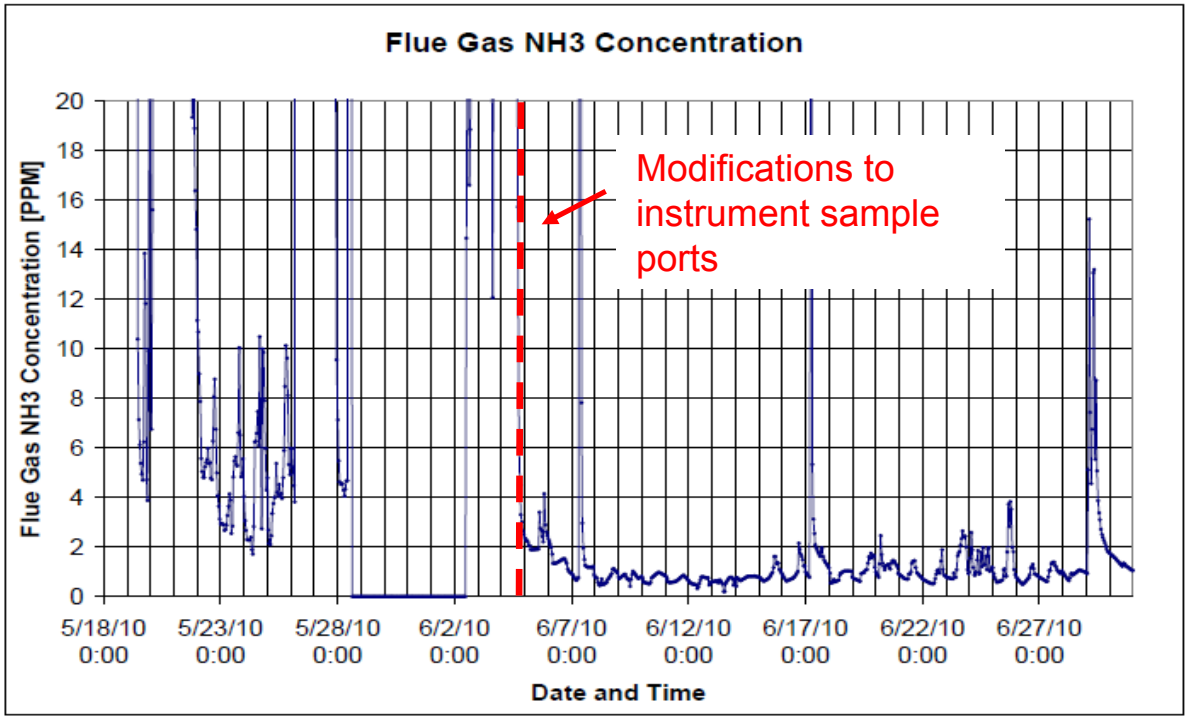
AEP Mountaineer PVF Project Operating Data

- High purity CO_2 product purity achieved on a consistent, stable basis
- Measurements obtained from on-line FTIR analyzer, consistent with field measurements
- Reported CO_2 purity obtained by difference from H_2O and NH_3 measurements



AEP Mountaineer PVF Project Operating Data

- Flue gas ammonia concentrations leaving the CAP maintained at low levels
- Flue gas ammonia measurements obtained using on-line FTIR
  - Initial on-line instrument inconsistent with field measurements
  - Sample port modifications made to improve on-line accuracy



AEP Mountaineer PVF Project Validation Program

Main objectives to be demonstrated in test campaign and validated with EPRI

- Energy consumption
- CO_2 removal efficiency
- CO_2 product quality
- System reliability

Conclusion

- The Chilled Ammonia Process has been operated at the bench scale, pilot and validation facilities. The plants have demonstrated:
  - CO_2 removal efficiency of 90%+
  - High purity CO_2 product (99.5%+)
  - Storage of CO_2 in geological formations
  - Ammonia emissions in the flue gas at desired levels
- Next steps for the AEP Mountaineer PVF
  - Implementation, tuning of modifications to achieve continuous, full load operation
  - Data collection and evaluation
  - Performance validation with EPRI
- AEP \ Alstom engaged in DOE funded commercial scale plant project

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CAP Development Program
AEP Mountaineer Product Validation

- Designed to capture 100,000 tonnes CO_2/year
- Captured CO_2 is sequestered into two wells on the plant property
- Commenced engineering and permitting in Sep 2007
- Started construction 2Q 2008
- First CO_2 captured 1st of September, 2009
- Injection started 1st of October, 2009
- Technology Validation Program initiated with EPRI

Alstom's Chilled Ammonia Process at AEP's Mountaineer Plant,

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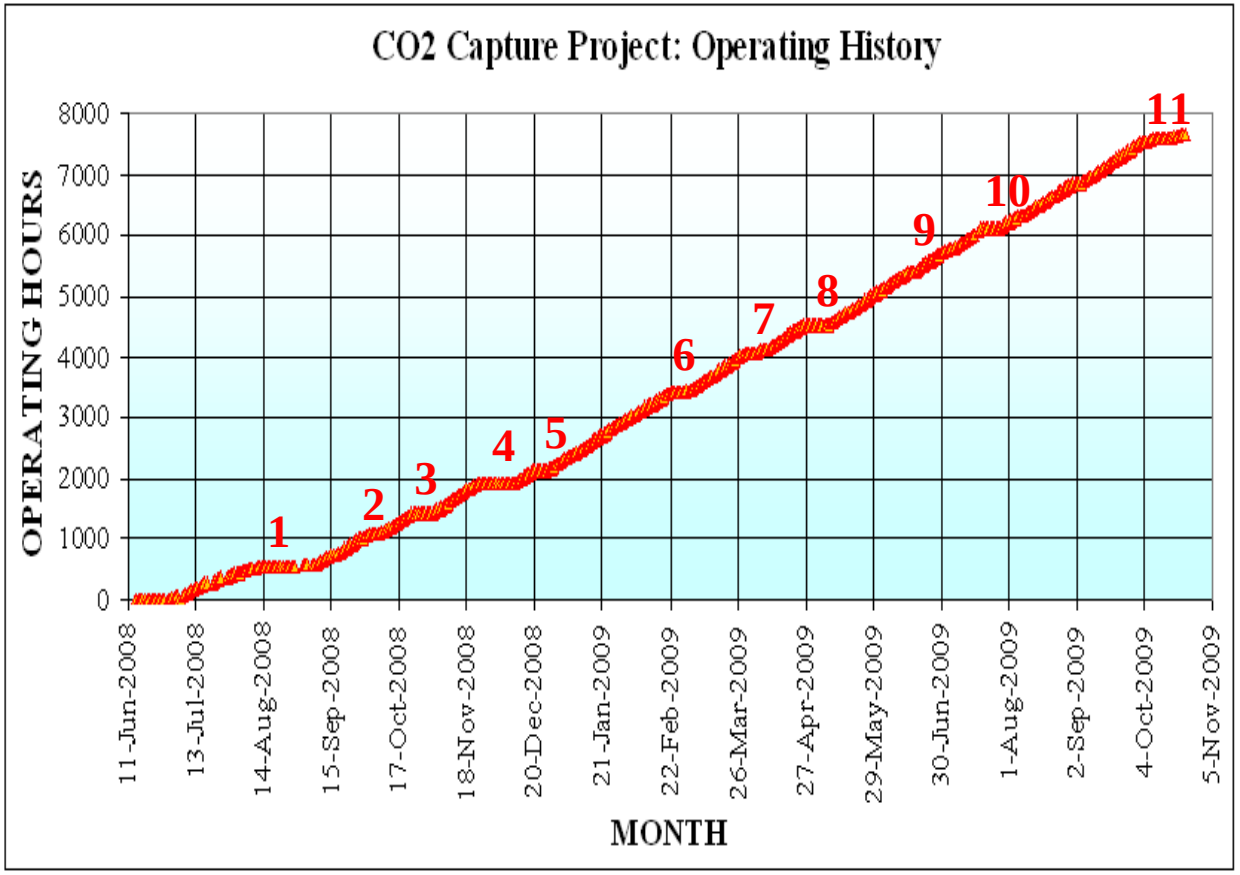
CAP Development Program
We Energies Operating History



1. Planned outage to support pilot modifications
2. Power Plant Forced Outage
3. Planned outage to support pilot modifications
4. Thanksgiving + Planned outage to support modification
5. Christmas Holidays
6. Power Plant Forced Outage
7. Planned outage for pilot maintenance
8. Unplanned outage for pilot maintenance (chiller)
9. Unplanned outage for pilot maintenance (stripper)
10. Planned outage to support pilot modifications
11. Outage –Regenerator Level Transmitter

Total operating hours - 7,717
Over 65% Availability

CAP Development Program
Main Partnerships & Projects Portfolio

Chilled Ammonia	Pleasant Prairie, WI (US) – **Coal**	5 MWt	EPRI / We / ALSTOM	Operational Jun08 to Oct09
	Karlshamm (Sweden) – **Oil**/**Gas**	5 MWt	e·on / ALSTOM	Operating since fall 2008
	Mountaineer WV (US) – **Coal**	54 MWt	AEP / ALSTOM	Operational since Sept 09
	Mongstad (Norway) – **Gas**	40 MWt	TCM Catching our Future / ALSTOM	Engineering on going
	Pioneer (Canada) – **Coal**	>150MWe	TransAlta / ALSTOM	Planned start-up 2015
	Commercial scale (US) – **Coal**	>200MWe	AEP / ALSTOM	Planned start-up 2015

Pilots in operation

Tests completed

* Project will include carbon sequestration

Projects in different regions with different fuels