# Updated Overview of Alstom's Efforts to Commercialize Oxy-Combustion for Steam Power Plants

John Marion
Armand Levasseur, Fank Kluger, Andreas Back, Thierry Pourchot, Benedicte Prodhomme, Olaf Stallman

Presentation to IEA 3rd Oxy-Combustion Conference [ OCC3 ]
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Ponferrada, Spain

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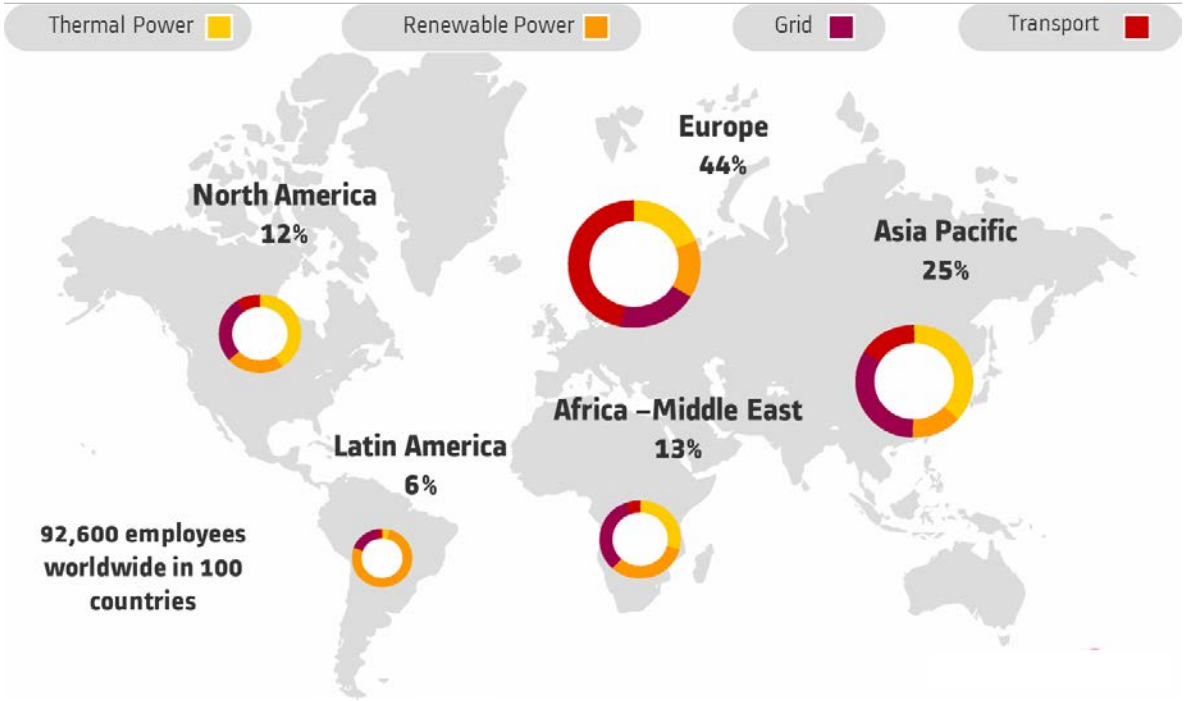
[g]*Alstom Carbon Capture GmbH, Lorenz-Schott Strasse 4, Wiesbaden,* ***Germany***

# Alstom Leader in Clean Power



**13 CCS pilots several large-scale demo projects in development**

Alstom is a full scope supplier of all major power plant components and turnkey plants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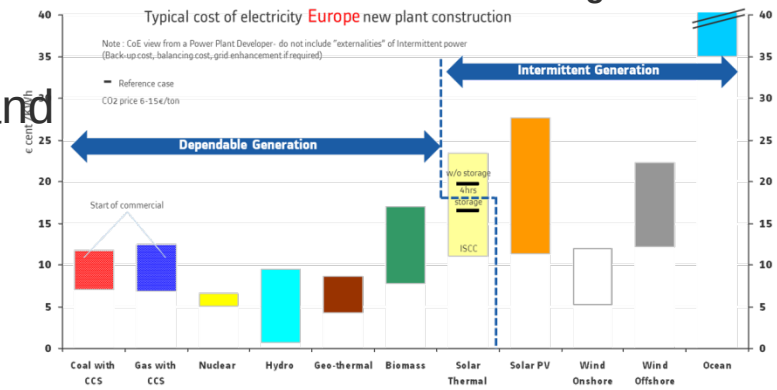
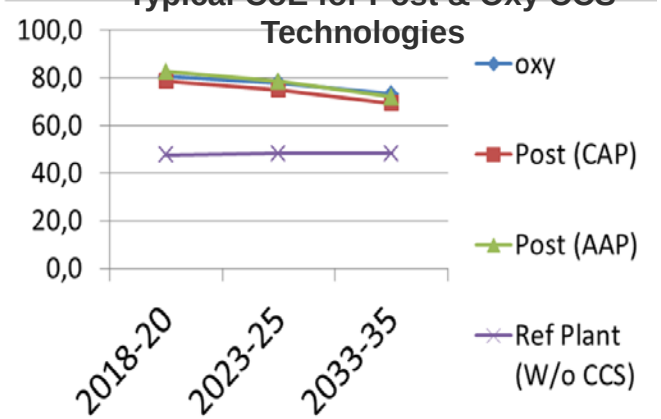
# Why Oxy-Combustion:

- **Robust** - developed from existing components
- **Flexible :**
  - ✓ Applicable all types of boilers, firing systems and fuels
  - ✓ Options for operational flexibility
  - ✓ Retrofit and "Oxy-Ready" can be addressed
- **Scale-up:**
  - ✓ No constraints anticipated for large commercial units up to 1000 MWe, high efficiency with ultra-supercritical cycles
- **Cost competitive** - with other CCS as well as other low carbon technologies
- **Environmentally-friendly :**
  - ✓ Emissions: No new chemicals introduced to plant
  - ✓ High CO2 capture rates (>90%)

**Typical CoE for Generation from Low Carbon Technologies**




**Typical CoE for Post & Oxy CCS Technologies**




Source : Alstom analysis – 2013– New PC power plants with CCS including transport and storage . NEurope

A robust and competitive solution



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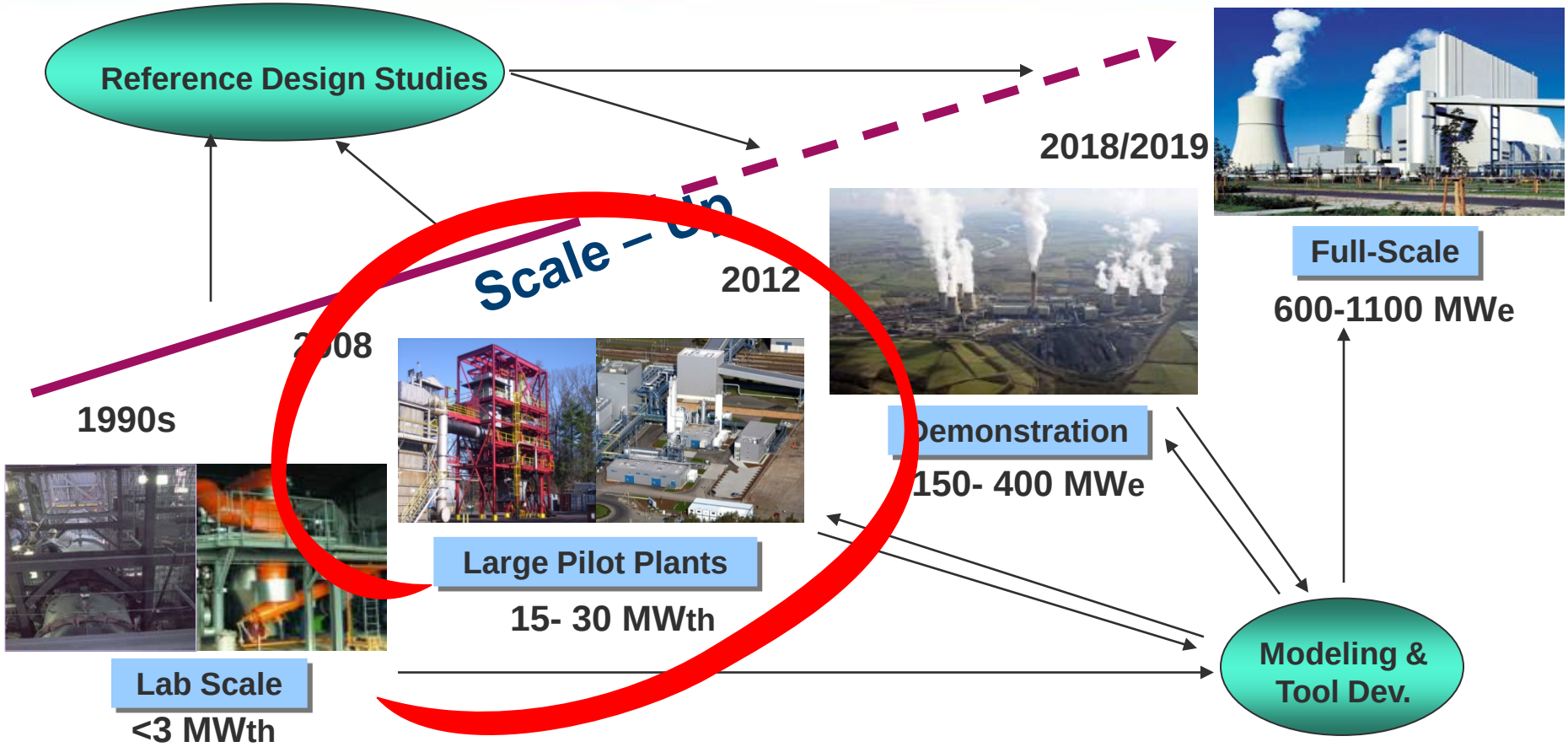
# Alstom Oxy-Combustion Technology Development Steps

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# 30 $MW_{th}$ Oxy-Combustion Pilot Plant at Vattenfall's Schwarze Pumpe station, Germany

**First oxy pilot plant** with complete train for $CO_2$ separation and capture

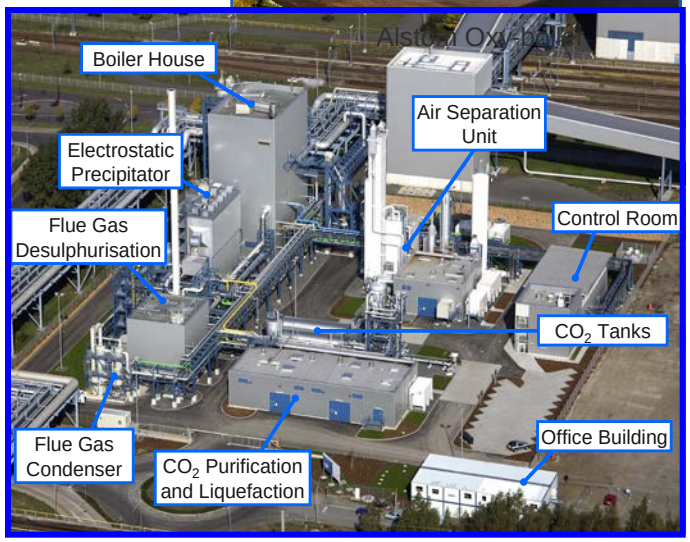
- Alstom supplied the Boiler, ESP and other components of the flue gas path
- Technology Partnership with Vattenfall to advance of the Oxyfuel technology

**Operation started September 2008**

- More than 10,000 operation hours and 10,000 tons of $CO_2$ >10,000 tons
- Tests with two lignites (low/high sulfur)
- Test phases with Alstom Burners (Design A+B) finished

Alstom Oxy-burner

Alstom boiler




**Wealth of knowledge gained** on design, performance and operation

Uwe Burchhardt & other Vattenfall presentations; also F. Kluger



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# 15 $MW_{th}$ Oxyfuel Pilot Plant Alstom Labs, Windsor, CT, USA

**Comprehensive Program :**

- **5 Years** (Sept. 2008 – April 2014)
- **~21.5 MUSD**

**Large Pilot Completed:**

- Evaluated the impacts of different oxy process options and boiler design parameters
- (combustion, heat transfer, pollutant emissions, deposition, corrosion …)
- **Coals tested (low S Bit (WV), high S Bit (Ill), Sub-bit (WY), Lignite (ND, DE)**
- Evaluated, improved, and validated engineering and computational tools

**Scale-Up Completed:**

- Development of design guidelines
- Commercial **Reference Designs**
- **Demonstration Design**
- **Ready for large demonstration**

Oxy-Combustion Pilot with AQCS & GPU – Alstom, Windsor, CT, USA



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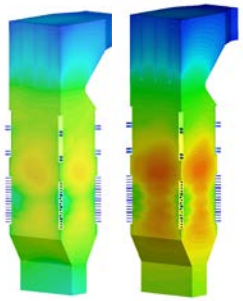
# Oxy T-Fired Boiler Development Project Status

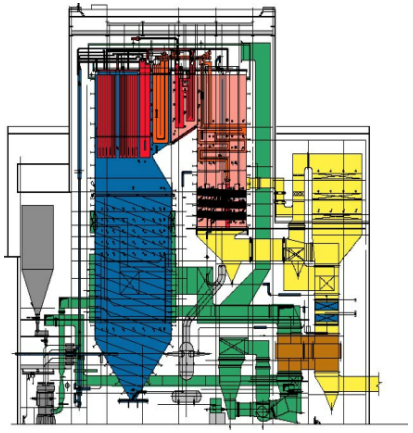
## Accomplished

- Process and CFD Screening **Completed**
- Modifications For Oxy-Firing **Completed**
- Campaign 1 **Completed**
  Sept. 2009 – PRB subbituminous coal
- Campaign 2 **Completed**
  Feb. 2010 - Low S bituminous coal
- Campaign 3 **Completed**
  April 2010 - High S Illinois Bit coal
- Campaign 4 **Completed**
  2010 - North Dakota lignite
- Campaign 5 **Completed**
  Aug. 2011- Schwarze Pumpe lignite
- Campaign 6 – Test 1-3 **Completed**
  Dec.11, Sept.12, Nov.12 – Advanced Concepts and Pollutant Control

## On-Going

- Tools & Modeling Refinement and Validation
- Design Guidelines
- Reference & Demo Designs







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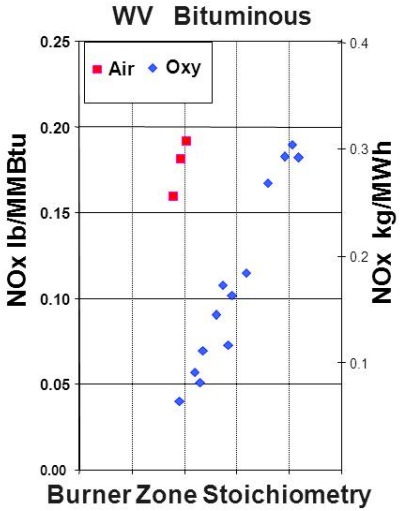
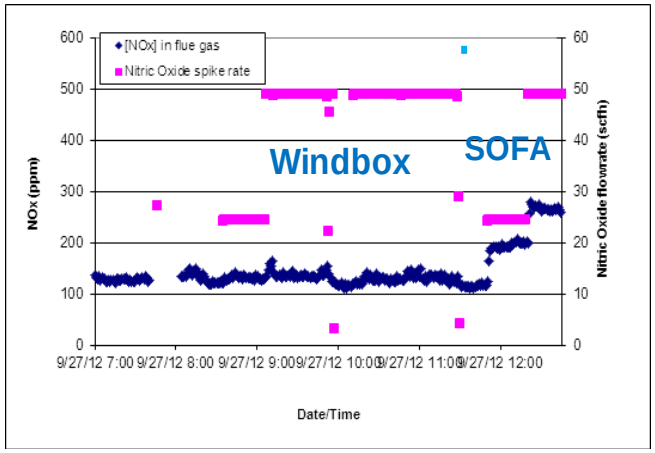
# Oxy 15 MW T-fired Testing in BSF
# Example of Results: Combustion and Emissions




Lower NOx During Oxy-firing

## NOx SpikingTests

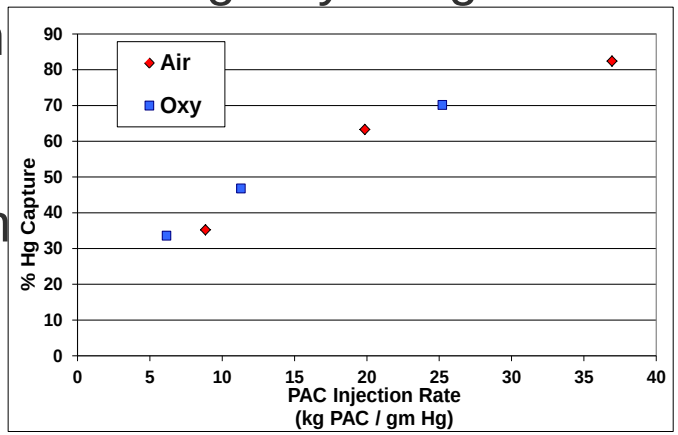
- NOx returned to windbox reburned
- NOx returned to SOFA not destroyed

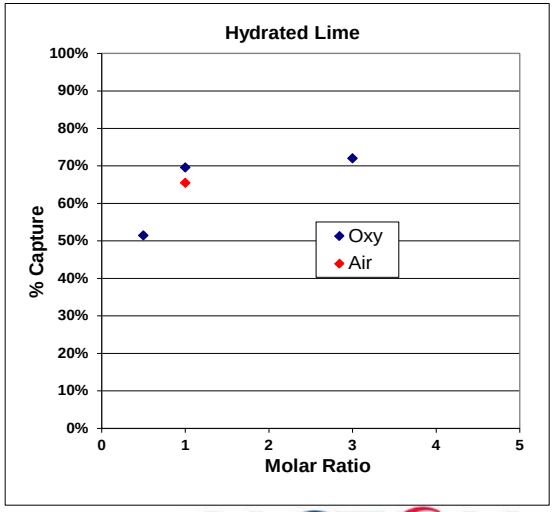



## Pollutant Control

- **Hg control** injection of PAC Optimize between Boiler and GPU
- **SO3 control** injection of Na-based and Ca- based additives

Sorbents Behavior Similar During Oxy-firing



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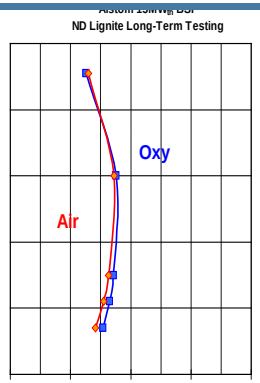
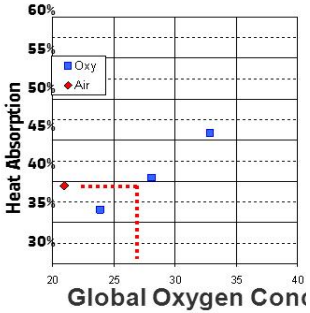
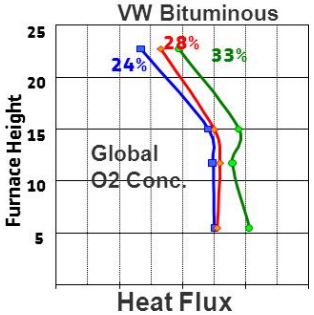
# Oxy 15 MW T-fired Testing in BSF
# Example of Results

## Optimize Thermal Performance

Ability to control heat flux profile with recycle flow rates and with oxygen distribution into furnace



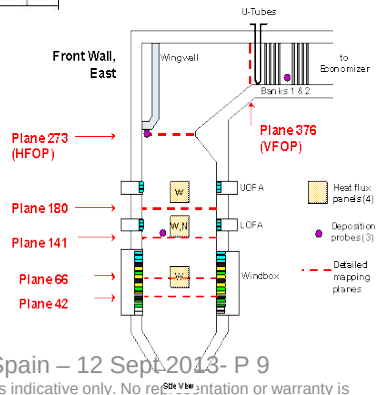



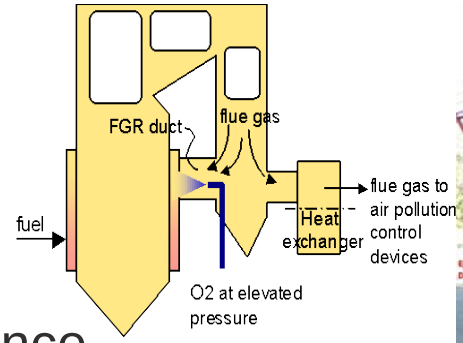

Minimize difference between average and peak values enables lower recycle rates

## Detailed In-Furnace Mapping

- Gas Temperature
- Gas Composition
- Heat Flux




## Advanced Concepts



## Close Coupled Recycle

- Enables downstream equipment savings

## Eductors

- Able to achieve 100% secondary gas recycle with single eductor and O2 motive gas. Ideal for high temp recycle applications.



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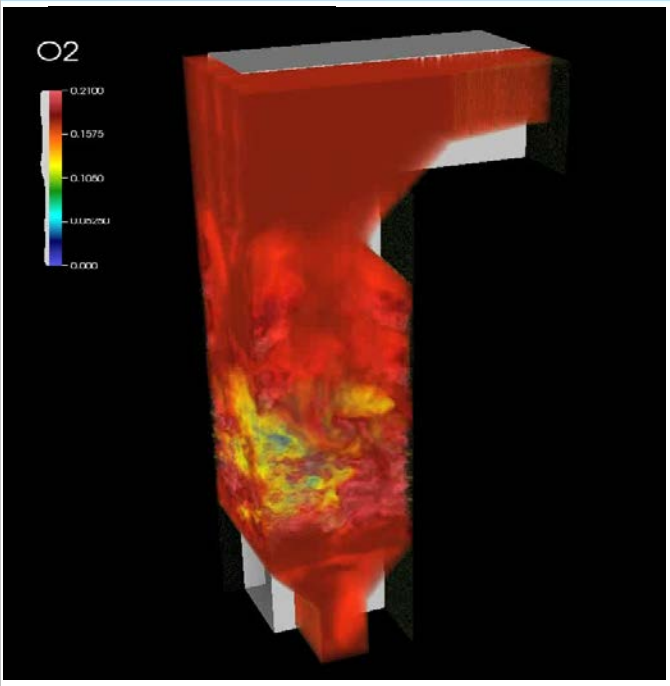
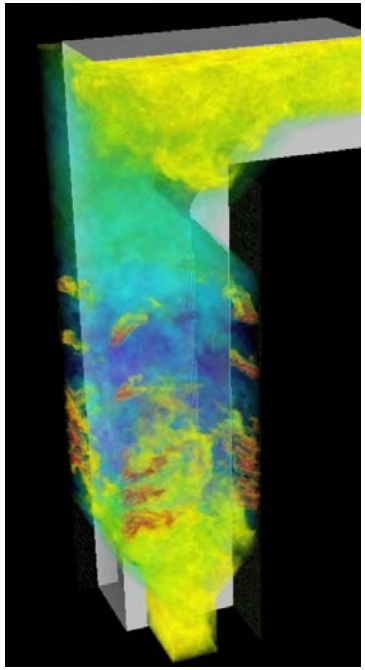
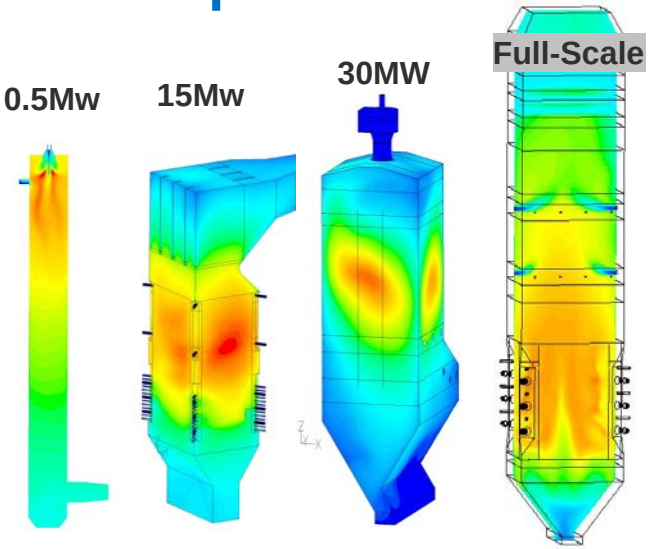
# CFD Model Development



## FLUENT - Validation and Scale-up




## LES Modeling Evaluation

**U of Utah Results and Animations of Unsteady Combustion (O2 conc.)**

- **Upgrade of Model Subroutines**
- **Evaluation and Refinement Using Experimental Data**
- **Verification and Uncertainty Analysis with U of Utah**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# Dynamic Model Development

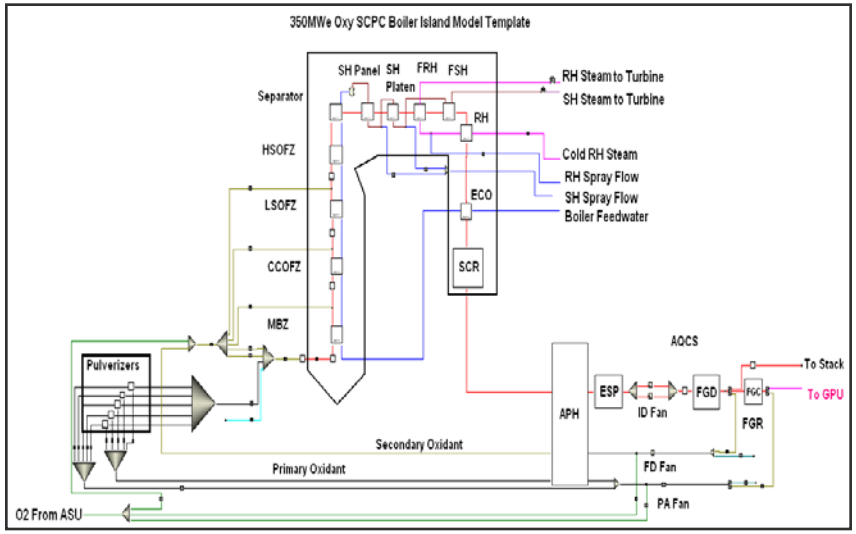
## Aspen Dynamics Platform

- Detailed boiler model
- Overall oxy capture plant model

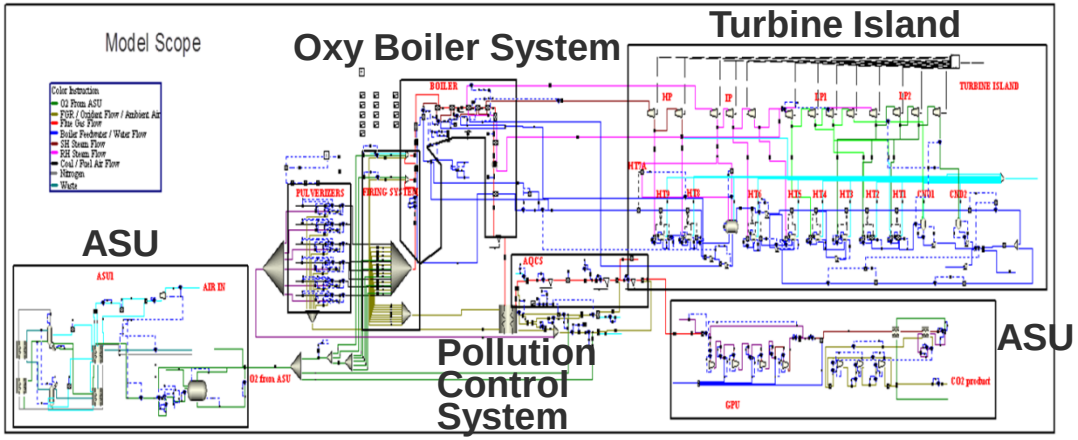
## Dynamic Simulation

- Assess transient response
  - Operating modes
  - Load changes
  - Failure behavior
- Design advanced controls

## Detailed Oxy Boiler Model




## Total Oxy Capture Plant Model



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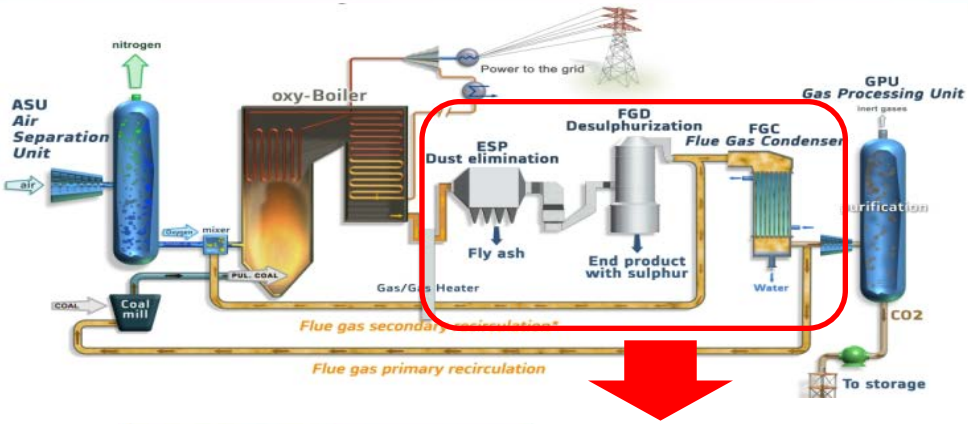
# Oxy-PC Pilot Testing - Optimized Integration with Boiler, **AQCS, FGC**, and GPU



ESP at Oxy Schwarze Pumpe

Alstom NID™ Dry FGD

Alstom Wet FGD

Alstom FGC



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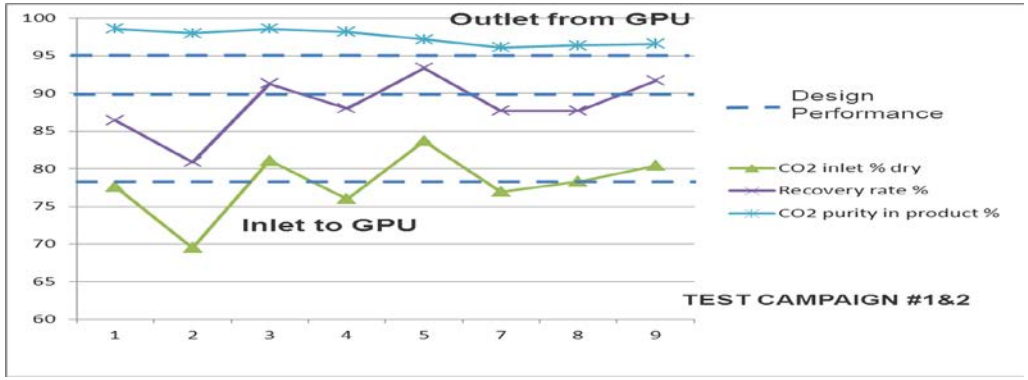
# GPU Pilot Tests in Alstom's CCS test centers
## Sweden (Vaxjo) and USA (Windsor)

- Evaluation of Drying, Compression and Cryogenic-Purification
- Behavior of SOx and NOx during each process step
- Behavior of SOx in Direct Contact Condenser
- Behavior of Ash, Hg and other heavy metals, VOC during each process step

**Tested under actual oxy coal-fired conditions**

**GPU Pilot Container Arrangement –15 MW BSF**




**Wuyin Wang – Session 4b Thursday (09:30) and Olaf Stallmann – Session 5b Thursday (12:10)**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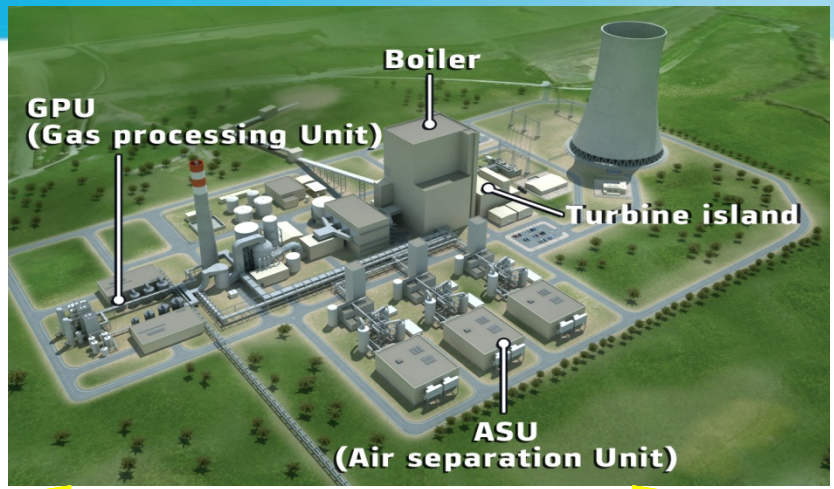
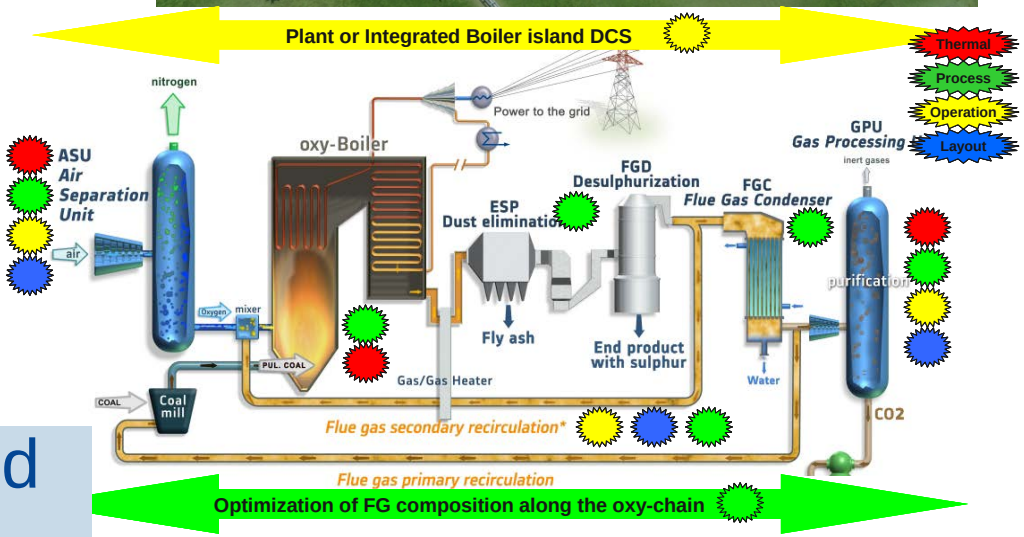
# Oxy-firing Integrated Approach Reference Plant work

- Globally optimize cost of electricity
- Balance trade-offs between main subsystems (performance and costs)
- Determine specification for the new subsystems
- Optimize power plant operation behaviour
- Optimize arrangement and minimize footprint




## Guides the oxy-program and defines future commercial

**Thierry Pourchot – Session 4a Thursday (09:50)**



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# Demonstration Unit Boiler Design

## Specifications

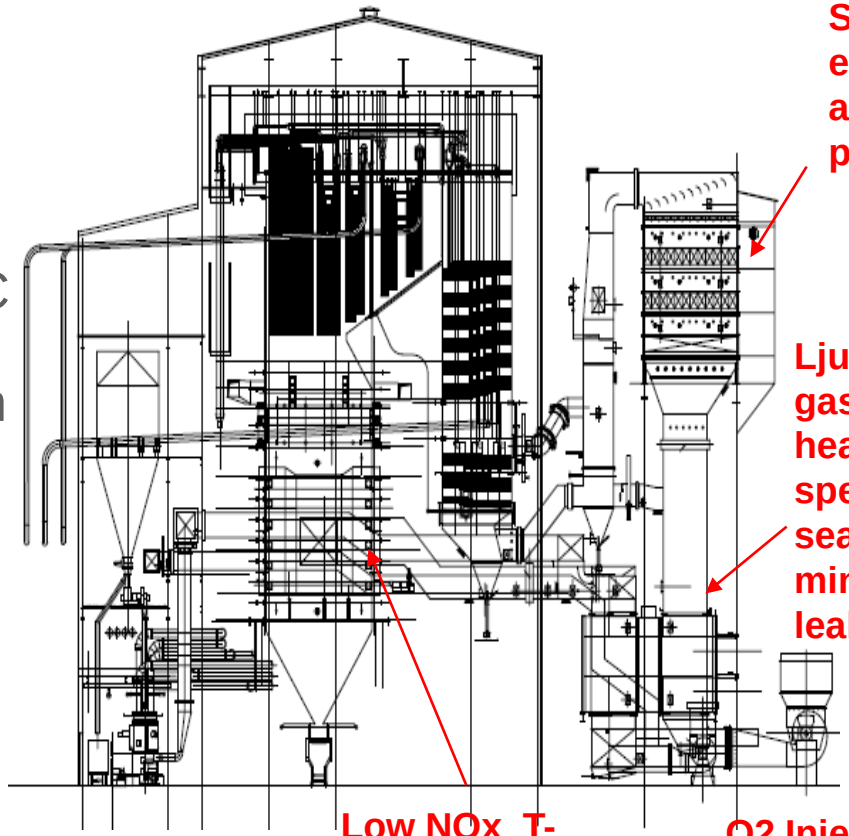
- 425 MWe gross
- Supercritical, sliding pressure with spiral wall evaporator
- USC – 279/52 bar, 600/620 C
- Direct pulverized coal firing, Tilting-tangential firing system

## Design Fuel

- Range of Bituminous Coals

## Operation

- Dual 100% Air / 100% Oxy
- Cycling load operation
- Min. Load 25%




**Materials & Corrosion – Bettina Bordenet – Workshop 1 Wednesday 14:00**



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# About the White Rose project

- The White Rose partners – Alstom, Drax and BOC – are planning to build a 426MW oxy-combustion carbon capture and storage (CCS) demonstration project
- The project will comprise a state-of-the-art new build coal-fired power station that will be fully equipped with CCS technology
- It will be built at the existing Drax power station site, near Selby, North Yorkshire, and will capture around 90% of emissions
- Around two million tonnes of $CO_2$ will be transported through the proposed National Grid pipeline for permanent storage under the North Sea
- On March 20th 2013, the project was selected as one of two preferred bidders remaining in the UK Government's CCS Commercialisation programme
- The Project has now entered a risk reduction phase for which a Front End Engineering and Design (FEED) contract will be concluded with DECC

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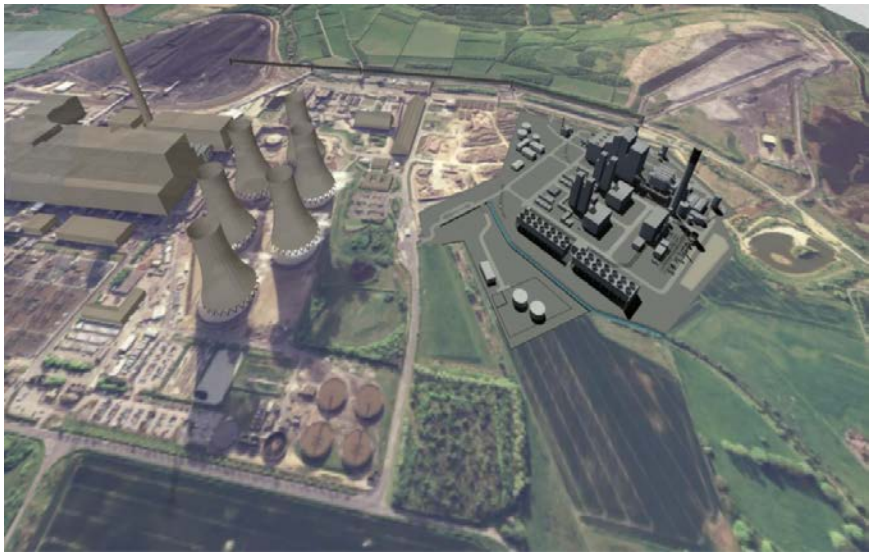
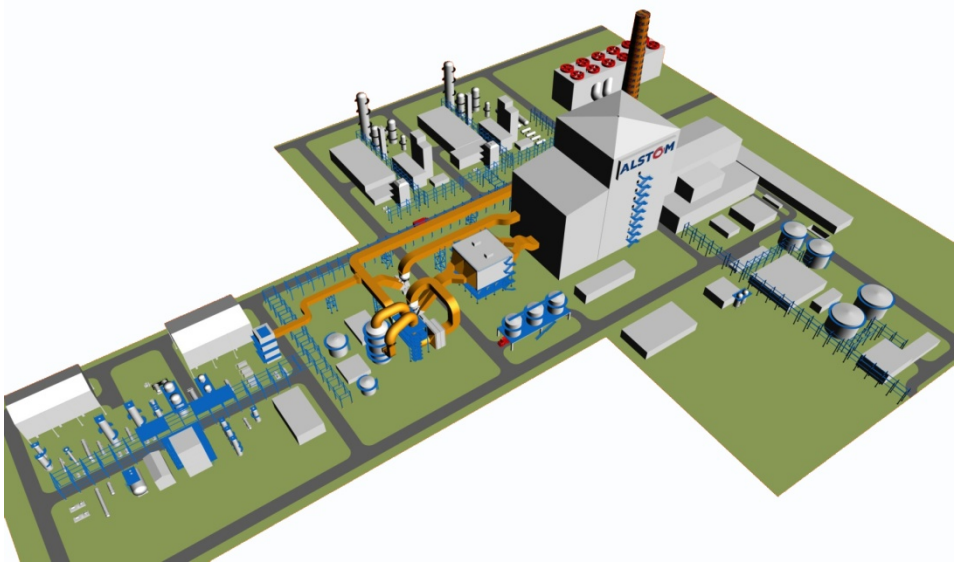
# Power plant appearance



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# Project's Objectives

- To demonstrate Oxy-combustion CCS technology as a reliable, flexible and affordable low-carbon technology
- To help reduce $CO_2$ emissions in order to meet future environmental legislation and to help combat climate change
- To improve the UK's security of electricity supply by providing a coal-based low-carbon electricity generation option
- To generate enough low-carbon electricity to meet the energy needs of more than 630,000 homes
- To act as an anchor project for the development of a $CO_2$ transportation and storage network in the UK's most energy intensive region

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# Project participants

- A global leader in the world of power generation, power transmission and rail infrastructure
- A pioneer in large-scale and efficient CCS technologies

- Owner and operator of the UK's largest, cleanest, most efficient coal-fired power station; meets 7% of the UK's electricity needs
- Committed to reducing Drax & UK power generation carbon footprint

- The largest provider of industrial gases in UK, and a leader in clean energy technologies
- A member of the Linde Group, a world leading gases and engineering company

- An international electricity and gas company and one of the largest investor-owned energy companies in the world.
- Expert in running high pressure natural gas system in a safe, reliably and efficient manner.

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# Participants' roles

Location: Drax Power Station, Selby, North Yorkshire, UK

**Project Promoters**

Oxy-combustion Power Plant & $CO_2$ Capture

- Alstom
- Drax
- BOC

$CO_2$ Transportation & Storage

- National Grid

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# $CO_2$ Transportation and Storage

## Transport Development

- **R&D programme**
  - Vapour phase programme completed
  - Dense phase programme underway
- **Onshore route planning**
  - Public consultation underway
- **Offshore route planning on-going**

Source: National Grid

## Storage Development

- **Regional assessment completed**
- **257 wells assessed in target area**
- **Key sites shortlisted**
- **Technical programme to identify prime target (two front runners) developed**
- **Developing appraisal plan (to include drilling)**

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# Project Development Status

- **Bid submitted for funding under UK CCS Commercialisation programme**
- **Selected as preferred bidder for the risk reduction phase of the programme (FEED Contract)**
  - Permitting process for the Oxy-combustion power plant on-going
  - Engaged with National Grid Carbon on project $CO_2$ transportation and storage solution development, and on development of Humber cluster
- **Competition winner will be selected after FEED and awarded Project Contracts:**
  - Final Investment Decision (FID) and construction start expected in 2015
  - Project completion and commencement of operation in 2019
- **Application for funding under Phase II of the European NER-300 programme submitted by the UK government**

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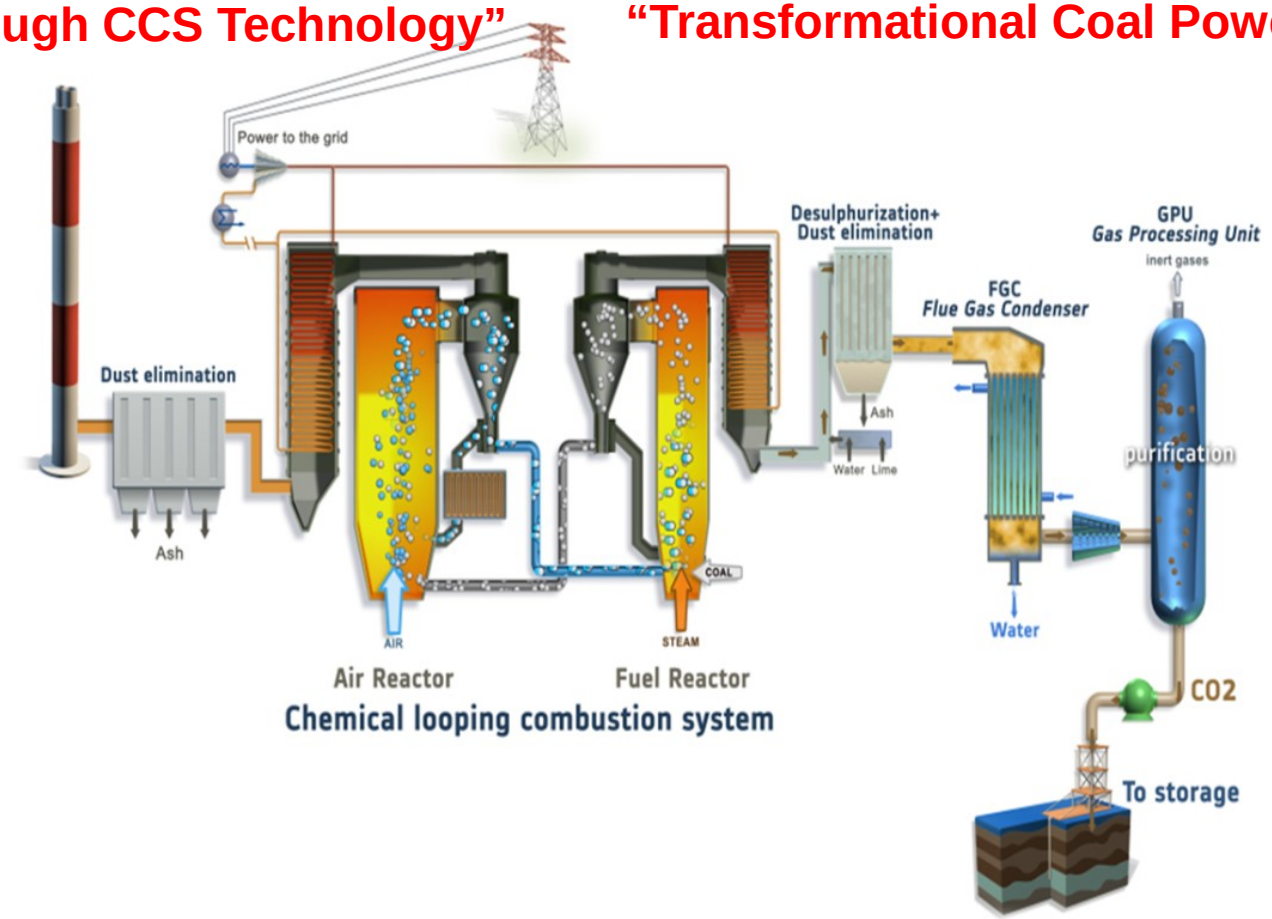
# Chemical Looping

## Fossil fuel Power with CCS at lower cost than alternates

**"Breakthrough CCS Technology"** **"Transformational Coal Power Technology"**




**CO2 capture process in oxy-combustion using solid oxygen carriers rather than an ASU (cryogenic O2 production), avoiding related cost & energy penalty**



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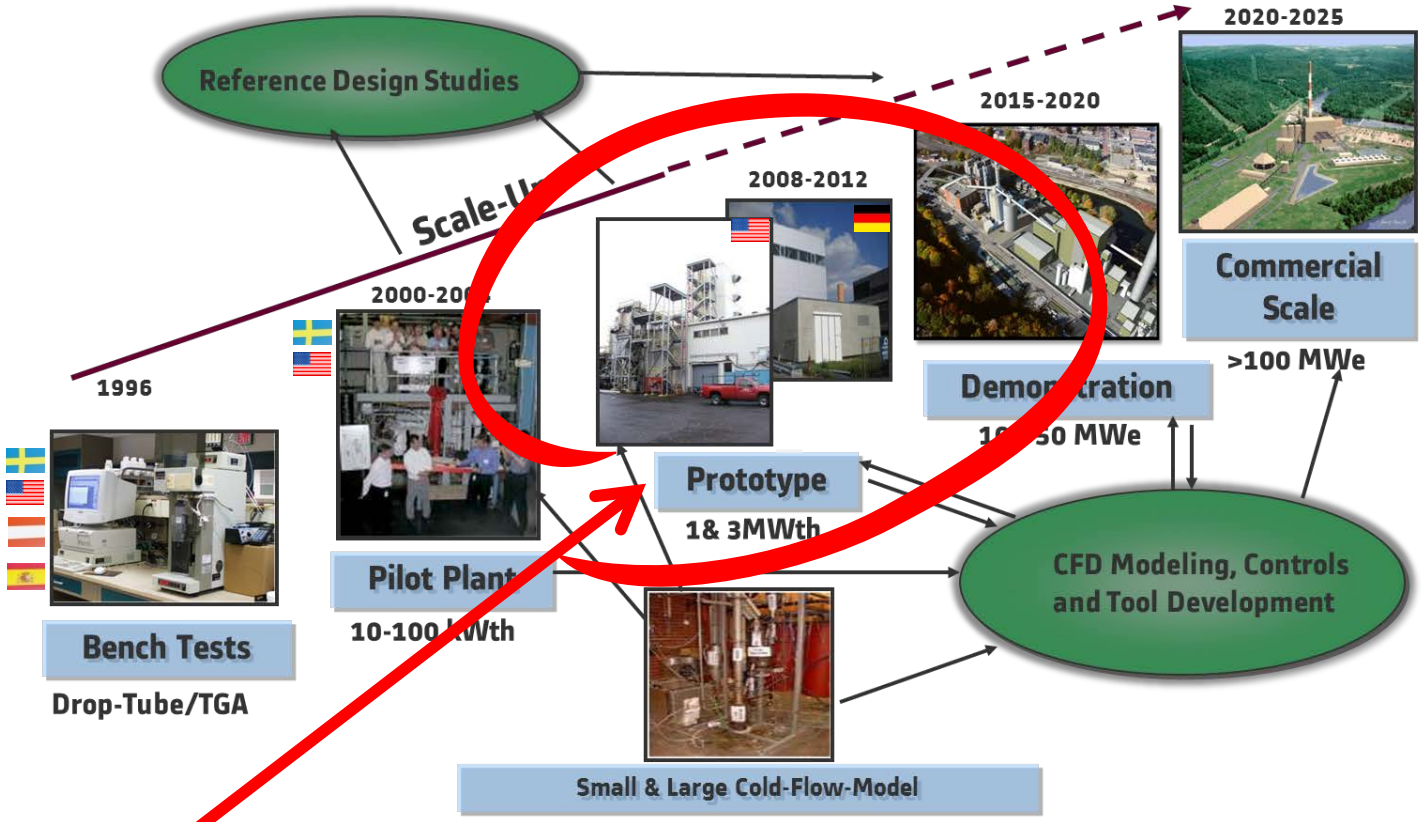
# Alstom - Chemical Looping Process
## Managed Development and Scale-up Steps




**We are here, Significant progress made**

**1st Worldwide to achieve "Auto Thermal Operation"**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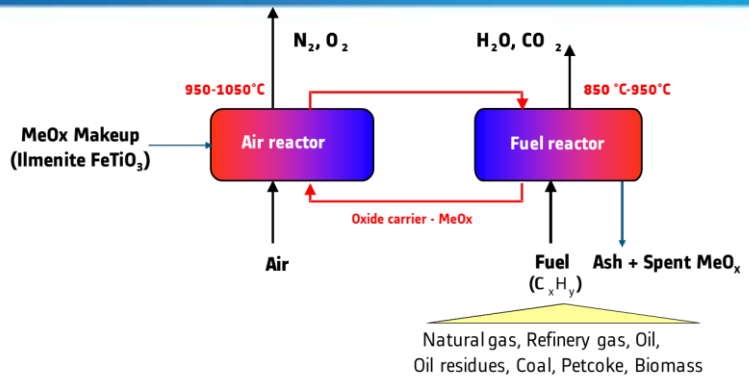
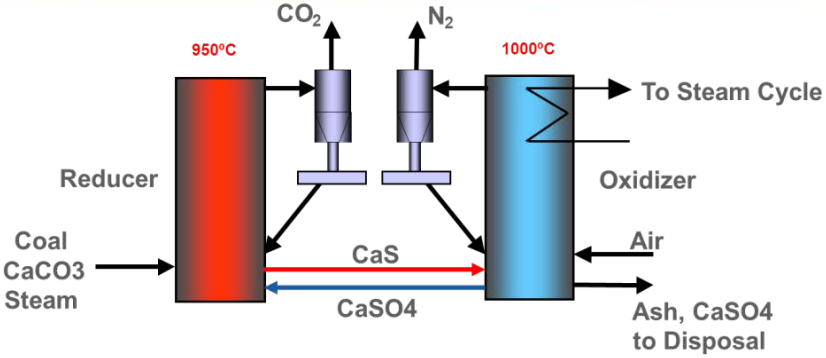
# Alstom's Chemical Looping Development
## Since ~ year 2000




## Metal Oxide Based (MeOx)

**ECLAIR Program – EU RFCS co-funded**

**Main Features:**

- Metal Based Oxygen Carriers ilmenite ($FeTiO_3$) – iron-titanium ore
- Process based on CFB solids transport
- Carbon stripper for minimizing UBC

## Limestone Based (LCL™)

**US-DOE co-funded**

**Main Features:**

- Limestone based oxygen carrier – CaS, $CaSO_4$
- "Fast" CFB solids transport
- Sorbent reactivation for increased limestone utilization
- Same materials in commercial CFBs

**Corinne Beal – Session 5d, John Marion – Session 5d Thursday 14:00 – 15:20**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# Concluding Remarks

- **Oxy-combustion successfully developed over the past ten years**
- **Alstom and other oxy pilots across the world provide design data and confirm the robustness of the process**
- **Alstom has addressed all major components and their integration**
- **Total plant integration is needed to optimize performance and minimize the CoE of oxy power plants**
- **Alstom is ready to demonstrate oxy-combustion at large-scale under real commercial conditions**
- **The White Rose project in UK is a promising opportunity providing a key step for commercialization**
- **Long term, advanced technologies like Chemical Looping may offer improved performance and cost**

**Please attend Alstom presentations and speak with Alstom representatives at OCC3**


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