Recovery Act: Oxy-Combustion Technology Development For Industrial-Scale Boiler Applications
DE NT-0005290

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Alstom Power, Windsor, CT

NETL CO2 Capture Technology Conference
Pittsburgh, PA
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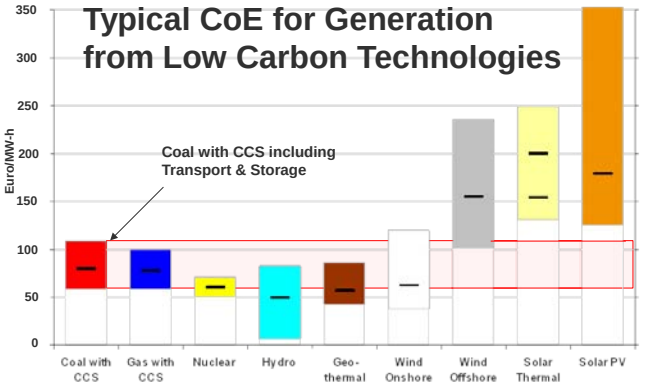
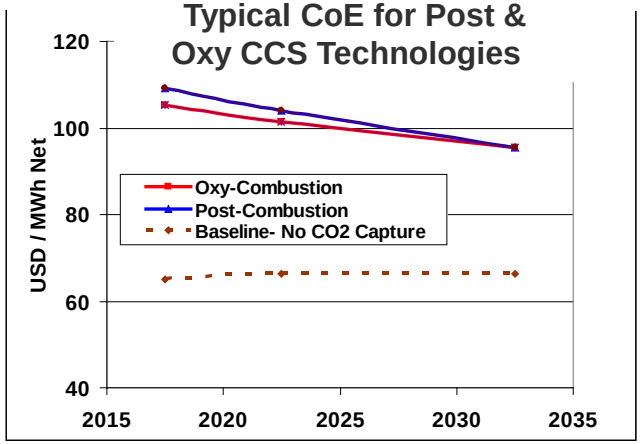
Why Oxy-Combustion:

- Robust - developed from existing components
- Environmentally friendly - near zero emissions
- Options for operational flexibility
- Rapid scale-up to 1000 MWe
- Retrofit and “Oxy-Ready” can be addressed
- High efficiency with supercritical/ultra-supercritical cycles
- High CO_2 capture rates (>90%)
- Cost competitive with other CCS as well as other low carbon technologies





Source : Alstom analysis – 2012 – New PC power plants with CCS including transport and storage . N. American & European Scenarios

A robust and competitive solution

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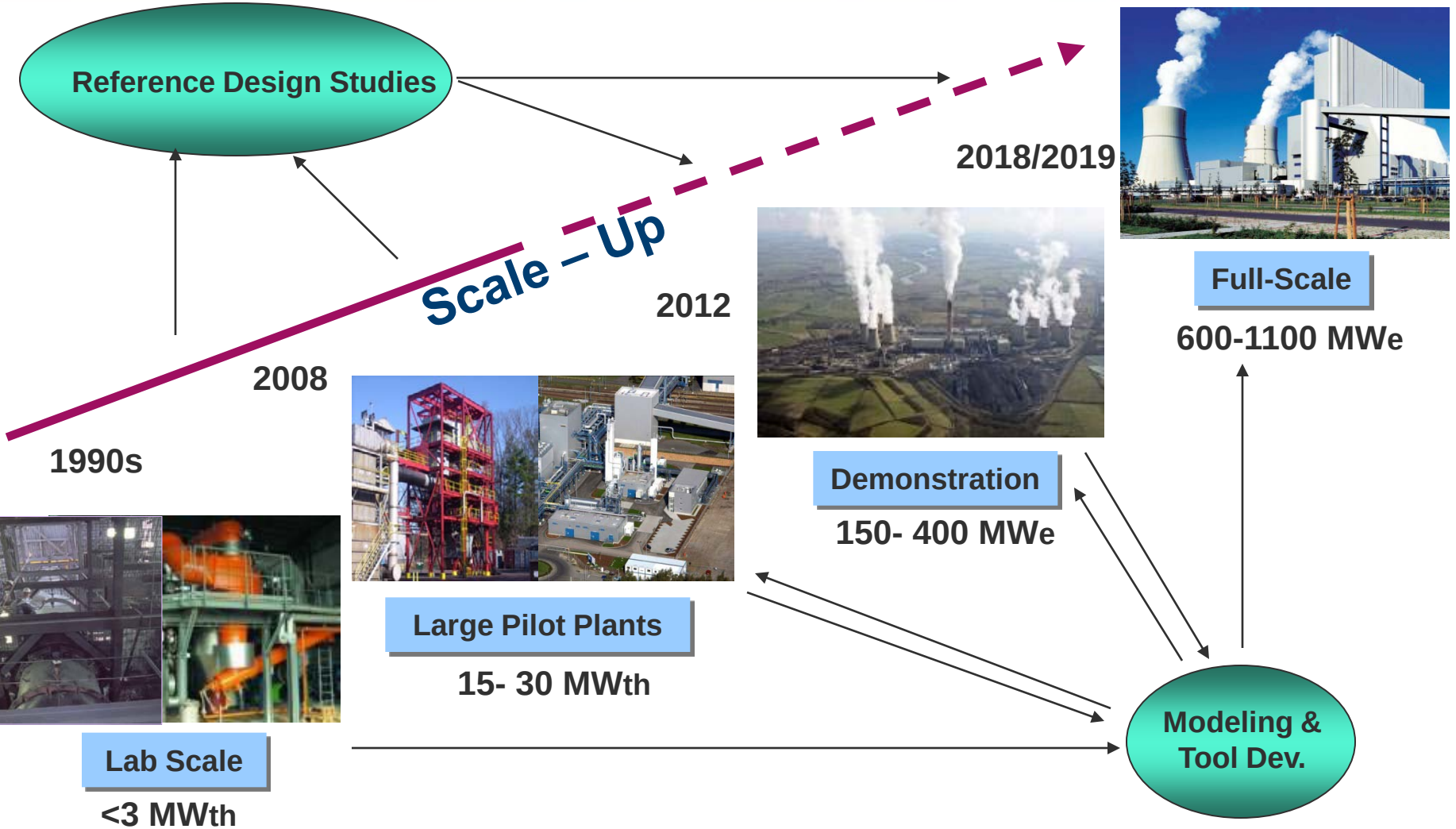
Alstom Oxy-Combustion Technology Development Steps



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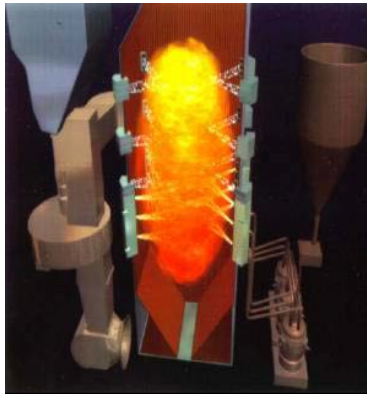
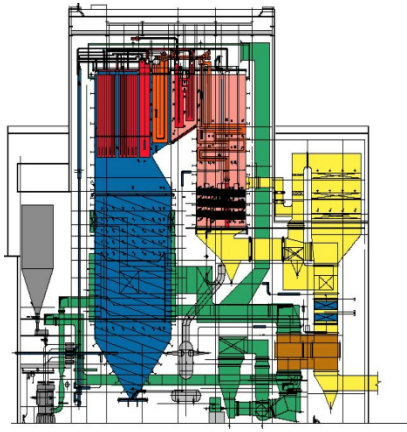
Oxy T-Fired Boiler Development
Project Objectives

Develop and validate an oxyfuel T-fired boiler system as part of commercially attractive CO_2 capture solutions.

- Design and develop an oxyfuel firing system for T- fired boilers
- Evaluate the performance in pilot scale tests at 15 MW_{th} testing
  - operation, combustion, heat transfer, pollutants, ash deposition and corrosion
- Evaluate and improve engineering and simulation tools for oxy-combustion by applying detailed test data obtained
- Develop design guidelines
- Develop the design, performance and costs for a demonstration-scale oxyfuel boiler and auxiliary systems.
- Develop the design and costs for both industrial and utility commercial-scale reference oxyfuel boilers





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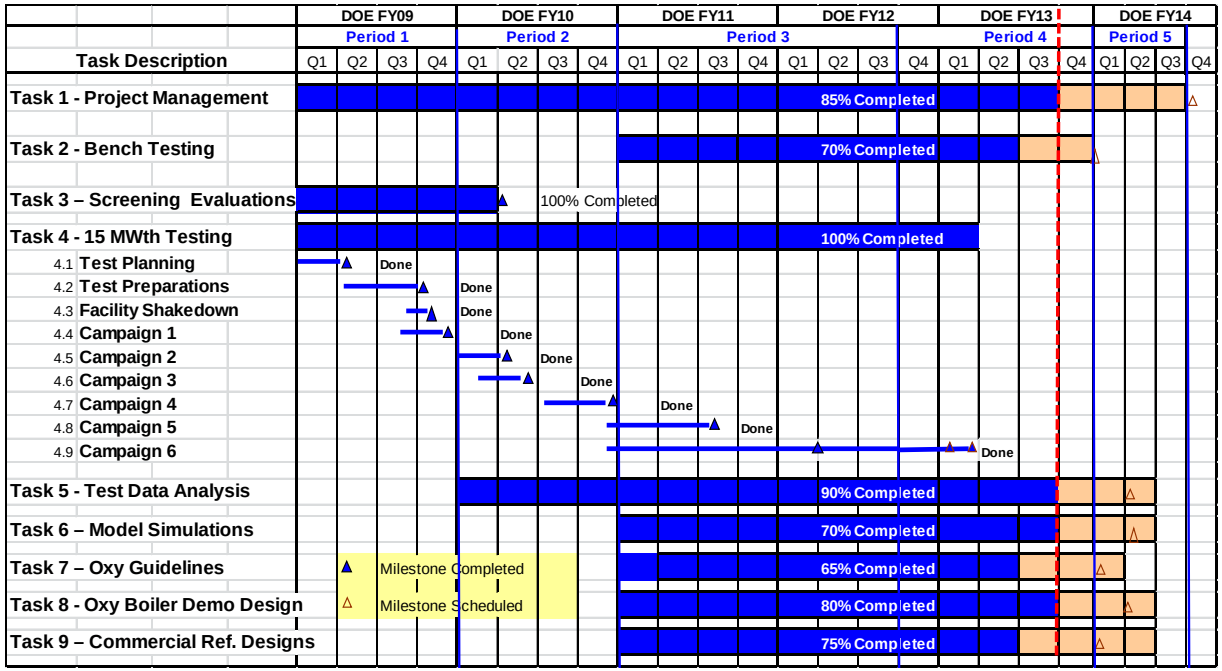
Oxy T-Fired Boiler Development Budget & Schedule

Total Budget: $21.5 M

Project Team:

- Alstom
- DOE–NETL
- ICCI
- NDIC
- Utilities

Project Start: Oct 2008 Duration: 5.75 Yrs



Utility Advisory Group

- Ameren
- ATCO
- Dominion Energy
- Great River Energy
- Luminant (TXU)
- LCRA and Austin Energy
- MidWest Generation
- NB Power
- OG&E
- Vattenfall

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15 MWth Oxyfuel Pilot Plant: Alstom Boiler Laboratories, Windsor, CT

15 MWth Boiler Simulation Facility

- Multi-burner, Tangentially-fired

Flexible operating conditions

- air & oxy-firing, gas recycle configuration, oxygen injection, firing system design

Generation of detailed design and performance data

- combustion, emissions, heat transfer, deposition, corrosion

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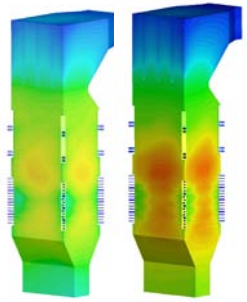
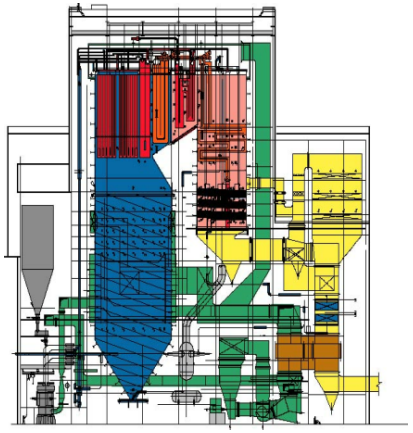
Oxy T-Fired Boiler Development Project Status

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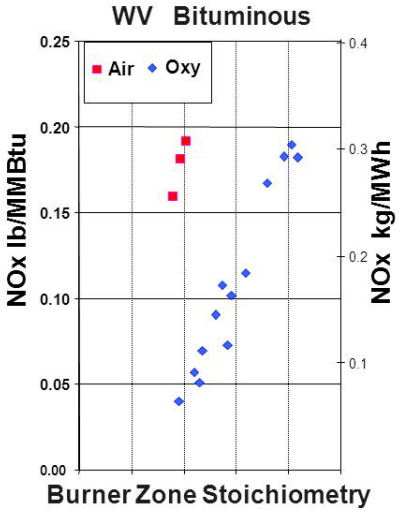
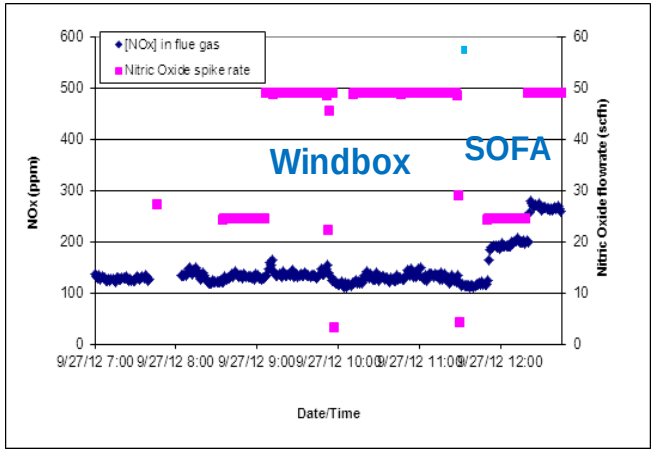
Oxy 15 MW T-fired Testing in BSF
Example of Results: Combustion and Emissions



Lower NOx During Oxy-firing

NOx SpikingTests

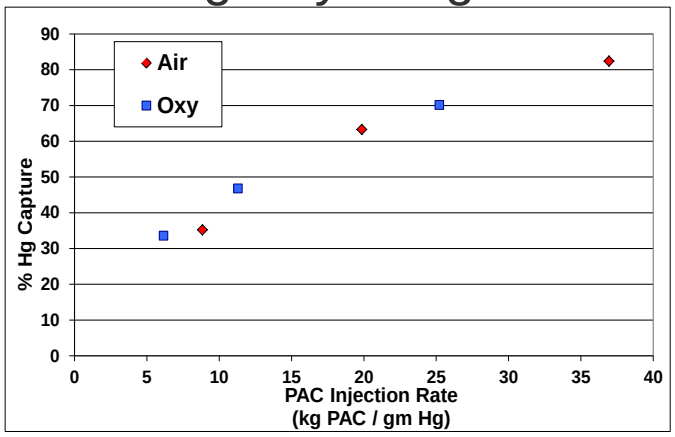
- NOx returned to windbox reburned
- NOx returned to SOFA not destroyed

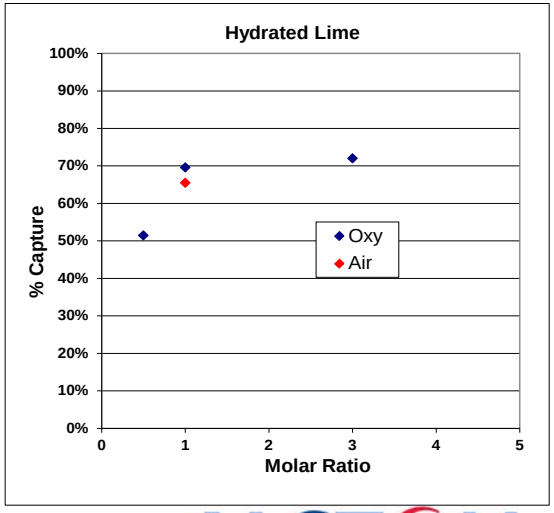


Pollutant Control

- Hg control injection of PAC Optimize between Boiler and GPU
- SO_3 control injection of Na-based and Ca- based additives

Sorbents Behavior Similar During Oxy-firing





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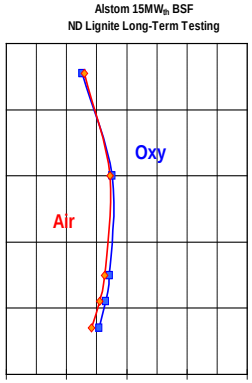
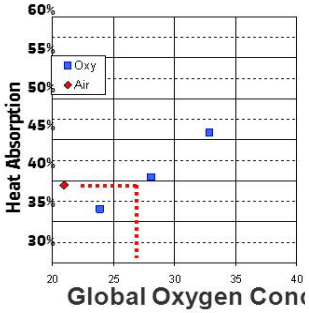
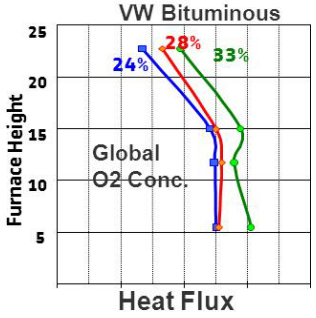
Oxy 15 MW T-fired Testing in BSF Example of Results

Optimize Thermal Performance

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



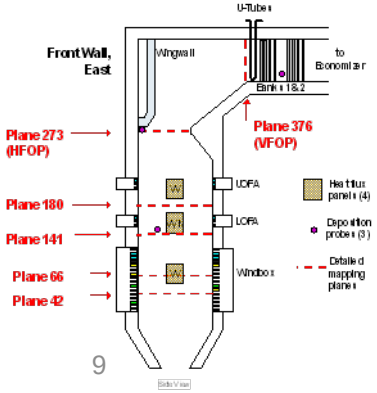




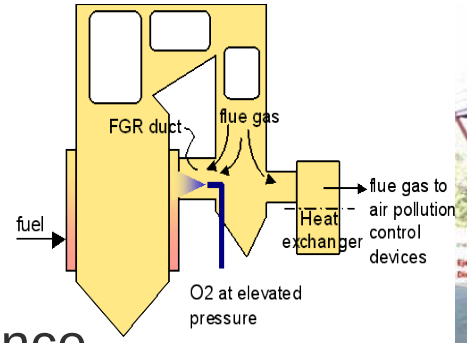
Minimize difference between average and peak values enables lower recycle rates

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 O_2 motive gas. Ideal for high temp recycle applications.

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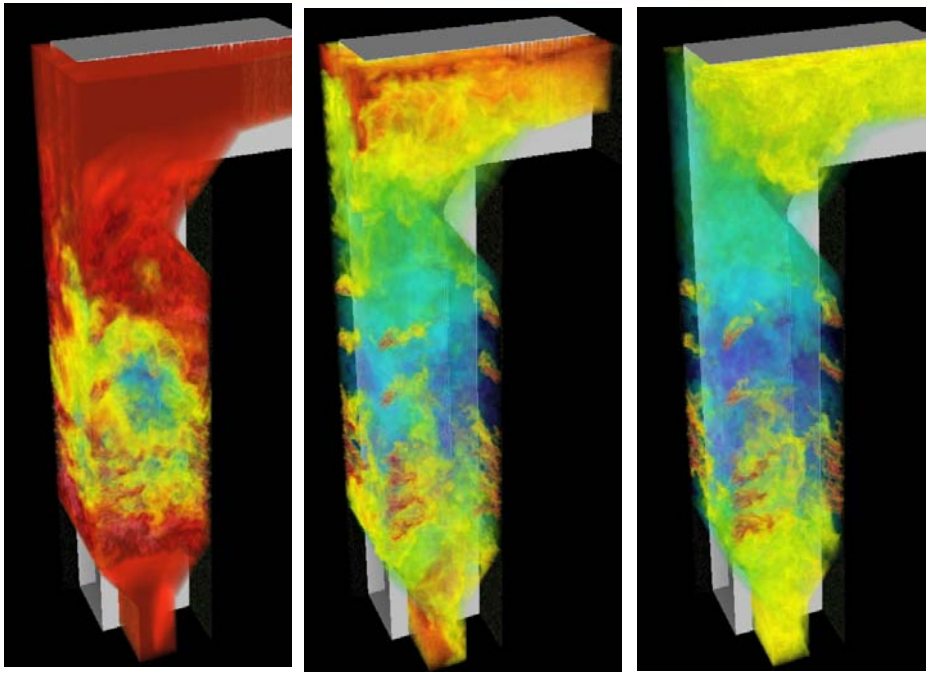
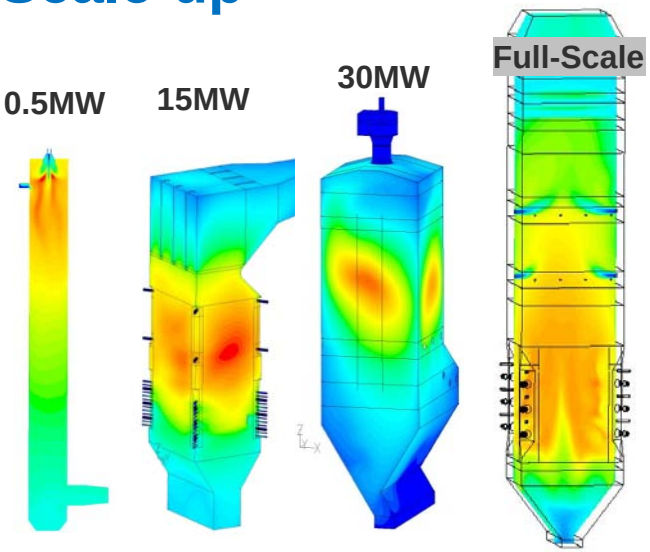
CFD Model Development



LES Modeling Evaluation

U of Utah Results and Animations of Unsteady Combustion (O_2 conc.)

FLUENT - Validation and Scale-up



- **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

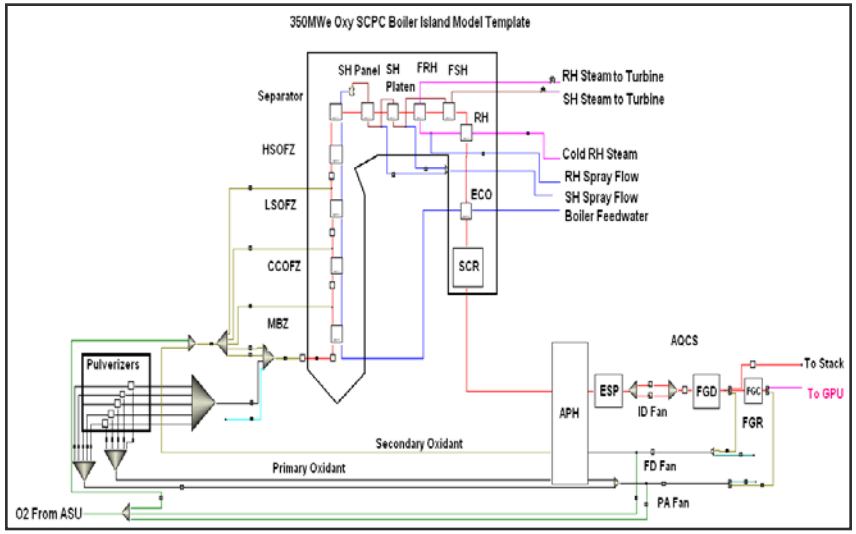
- Detailed boiler model
- Overall oxy capture plant model

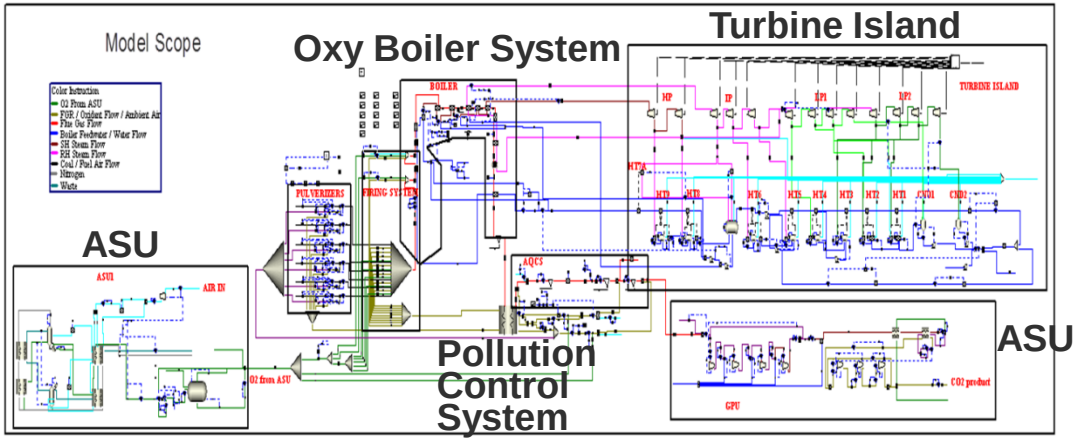
Dynamic Simulation

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

Total Oxy Capture Plant Model

Detailed Oxy Boiler Model





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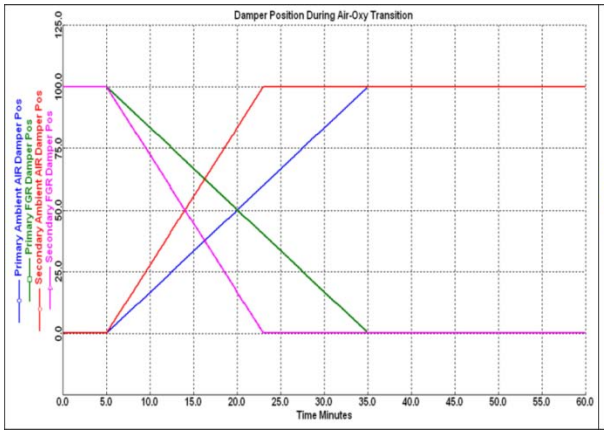
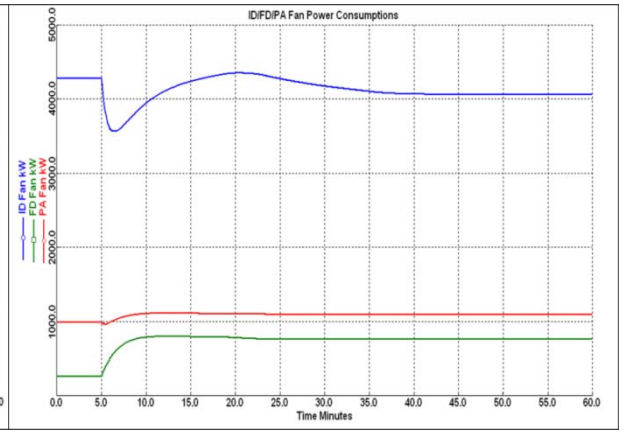
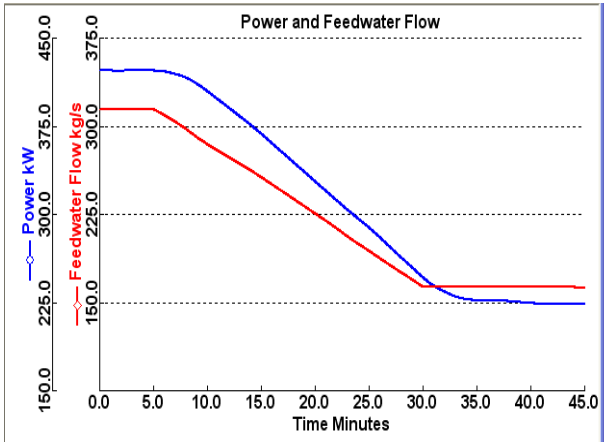
Dynamic Modeling
Example of Results

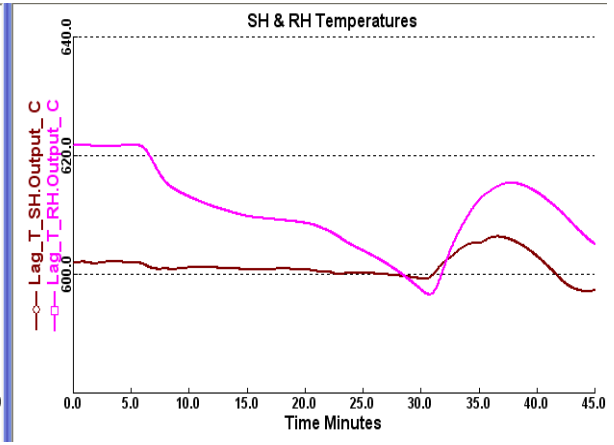
Oxy Boiler Simulation During Transition from Air to Oxy-Firing





Oxy Plant Simulation During Load Change (2% per Minute)





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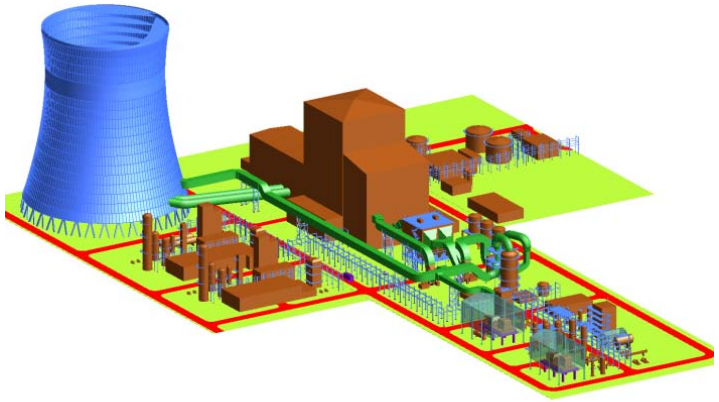
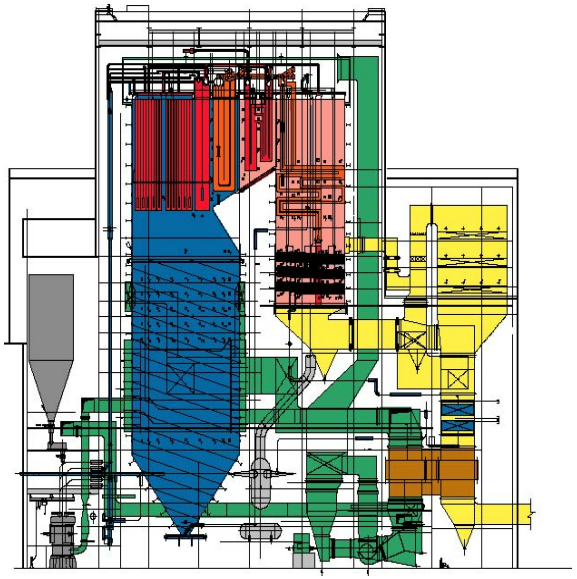
Oxy T-Fired Boiler Designs

Oxy Reference Plant and Demonstration Designs

- Application of test results and design tools
- Development of reference oxy-fired design – 900 MWe gross USC bituminous coal
- Development of oxy-fired designs for demonstration – 400 MWe gross – Dual Air/Oxy - USC
- Optimization, detailed design, performance assessment and costing





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Large Commercial Reference Boiler Design

Boiler Specifications

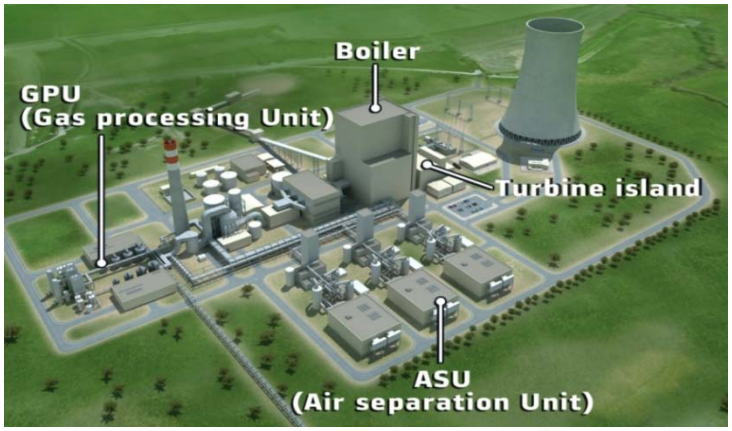
- Supercritical, sliding pressure with spiral wall evaporator
- USC – 279/52 bar, 600/620°C
- Direct pulverized coal firing, Tilting-tangential firing system

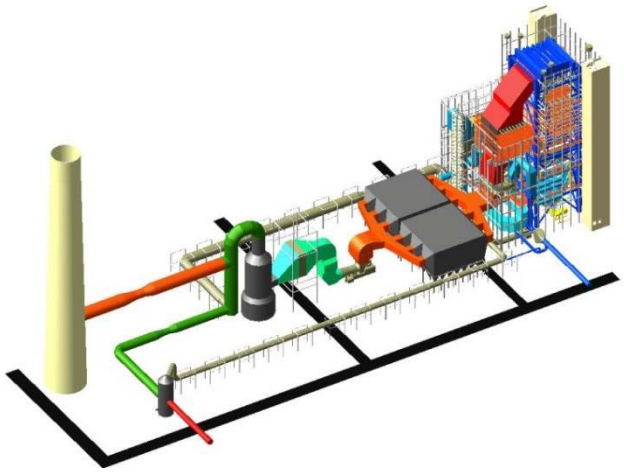
Design Fuel

- Range of Bituminous Coals

Operation

- Optimized for Oxy
- Base load operation
- Minimium Load 40%





Boiler Design Optimized for Overall Plant Performance and Cost

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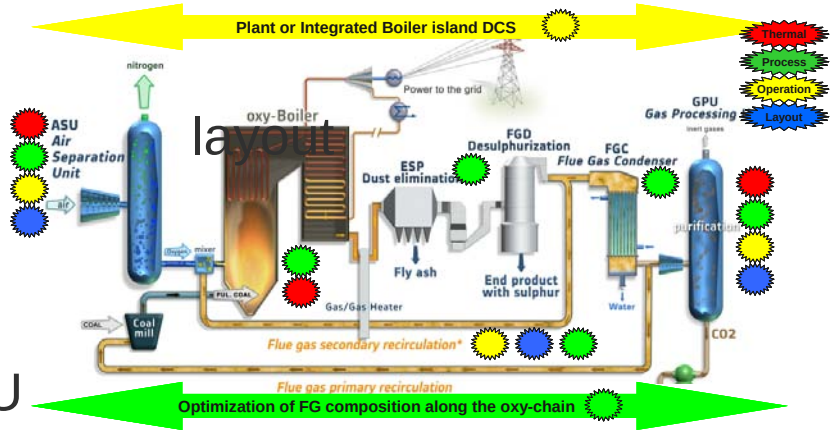
Oxy-firing Integrated Approach: For entire capture plant

A global approach to design of an oxy capture plant is necessary to optimize Performance and Cost of Electricity

- Integration of flue gas cleaning strategy
- Optimization of the arrangement and layout
- Minimize overall energy consumption by
  - Optimize heat integration
  - Optimize O_2 concentration from ASU
  - Balance O_2 concentration in oxidant to burner
- Optimize safety margins on each component to improve power plant performance
- Minimize air ingress/leakage



An integrated approach minimizes the cost of electricity

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Oxy-firing Integrated Approach
Reference concept with integration

DESIGN BASIS

- Oxy-Combustion Power Plant 900 MW (90% CO_2 capture)
- Steam Cycle : 600°C / 620°C / 275 bar
- Bituminous Coal
- Direct cooling (power plant, ASU, GPU)
- CO_2 Specification for Storage (CO_2 > 95% vol, O_2 < 3% vol)
- Base load operating regime
- Flexibility in oxy-mode down to 40%
- Grid code compliance: 5% primary response in 30s at 90% load

ESTIMATED PERFORMANCE

	Net Plant Efficiency (LHV)
Conventional Air-Fired Plant (No Capture)	**46.2%**
Oxy Capture Plant - Not Integated	**34.5%**
Oxy Capture Plant – Integated	**37.1%**

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Demonstration Unit Design

Boiler Specifications

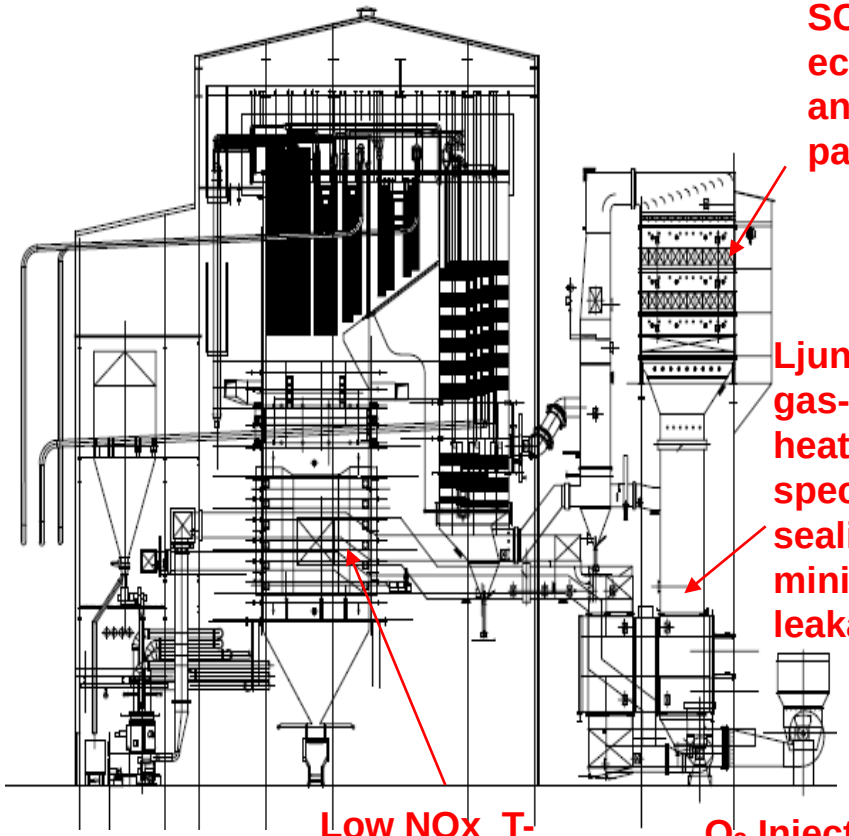
- Supercritical, sliding pressure with spiral wall evaporator
- USC – 279/52 bar, 600/620°C
- Direct pulverized coal firing, Tilting-tangential firing system

Design Fuel

- Range of Bituminous Coals

Operation

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



Boiler Design Optimized for Overall Plant Performance and Cost

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White Rose Large Scale Oxy-Demo Project

Largest Oxyfuel CCS Demo

Project Promoters

Oxy-fuel Power Plant

CO_2 Transport & Storage

ALSTOM DRAX BOC-Linde NATIONAL GRID

WHITE ROSE CARBON CAPTURE & STORAGE PROJECT

- New ultra-supercritical 426 MWe Gross Oxy-fuel Power Plant
- Clean power with entire flue gas treated to capture 2 Mt/y CO_2
- Biomass co-firing option leading to zero (or negative!) CO_2 emissions
- Anchor project for National Grid's regional CO_2 transport & offshore storage network
- Project development on-going
  - Selected for award of FEED under the UK CCS competition (1 B£)

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Concluding Remarks

Program has been very successful – Wealth of detailed information and know-how obtained.

- No technical barriers restrict the continued development and commercialization of oxy-combustion
- Combustion performance, emissions, and thermal behavior (temperature, heat flux intensity, heat flux profile) controlled to similar levels or better as air firing
- Oxy boiler design concepts to improve overall plant performance and cost are being investigated

Results from this project and other Alstom R&D programs have:

- Refined and validated design tools and design procedures
- Supported overall oxy plant integration and optimization efforts
- Developed and optimized designs for demonstration opportunities and future commercial plants

Ready for next step of large-scale demonstration – White Rose Oxy Demonstration Project is a promising opportunity

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Acknowledgements and Disclaimer

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