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

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Alstom Power, Windsor, CT

NETL CO_2 Capture Technology Conference
Pittsburgh, PA
July 11, 2012

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The Alstom Group:
A Worldwide Leader in Power Generation

Clean Power

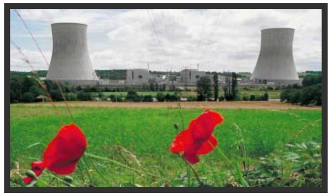
N°1 in integrated power plants

N°1 in air quality control systems

N°1 in services for electric utilities

CO2-Free & Renewables

N°1 in hydro power



N°1 in conventional nuclear power island

Recent acquisition of solar and wind

Carbon Capture

- Post Combustion
- Oxy Combustion

12 CCS Pilots

5 Large Demo Projects

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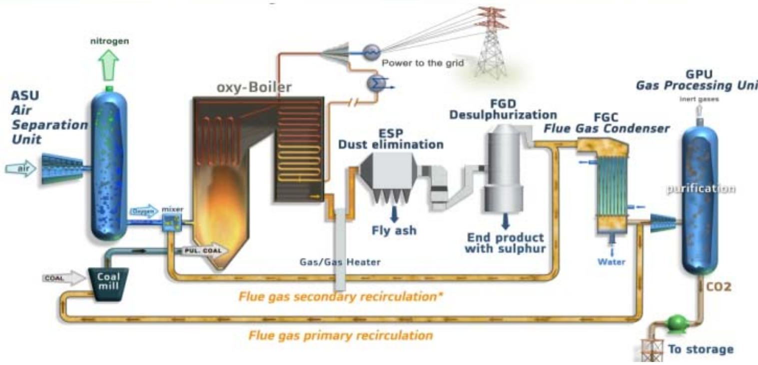
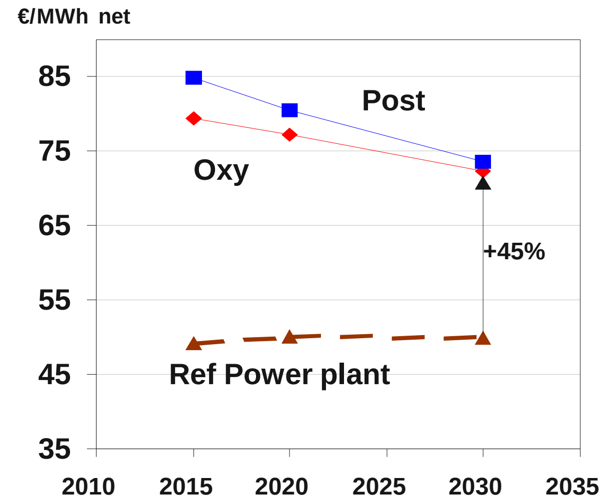
Oxy-Combustion: Benefits and Issues

- **Cost competitive** with other CCS, wind, solar, biomass, nuclear
- **Reliable** - main components only need to be adapted and scaled-up, plant operation demonstrated in large pilots
- **Environmentally friendly** - low emissions, no large chemical feedstocks or new emission sources
- **Retrofit** and "**CCS Ready**" Applications
- **Rapid scale-up** to large commercial (1000 MWe) sizes & high efficiency steam cycles
- **Flexible** operation and power production options
- High CO2 capture rates (>90%)

- Must use the entire boiler island for demonstration requiring substantial funding





Source : Alstom analysis – 2011 – PC power plants with CCS – transport and storage included

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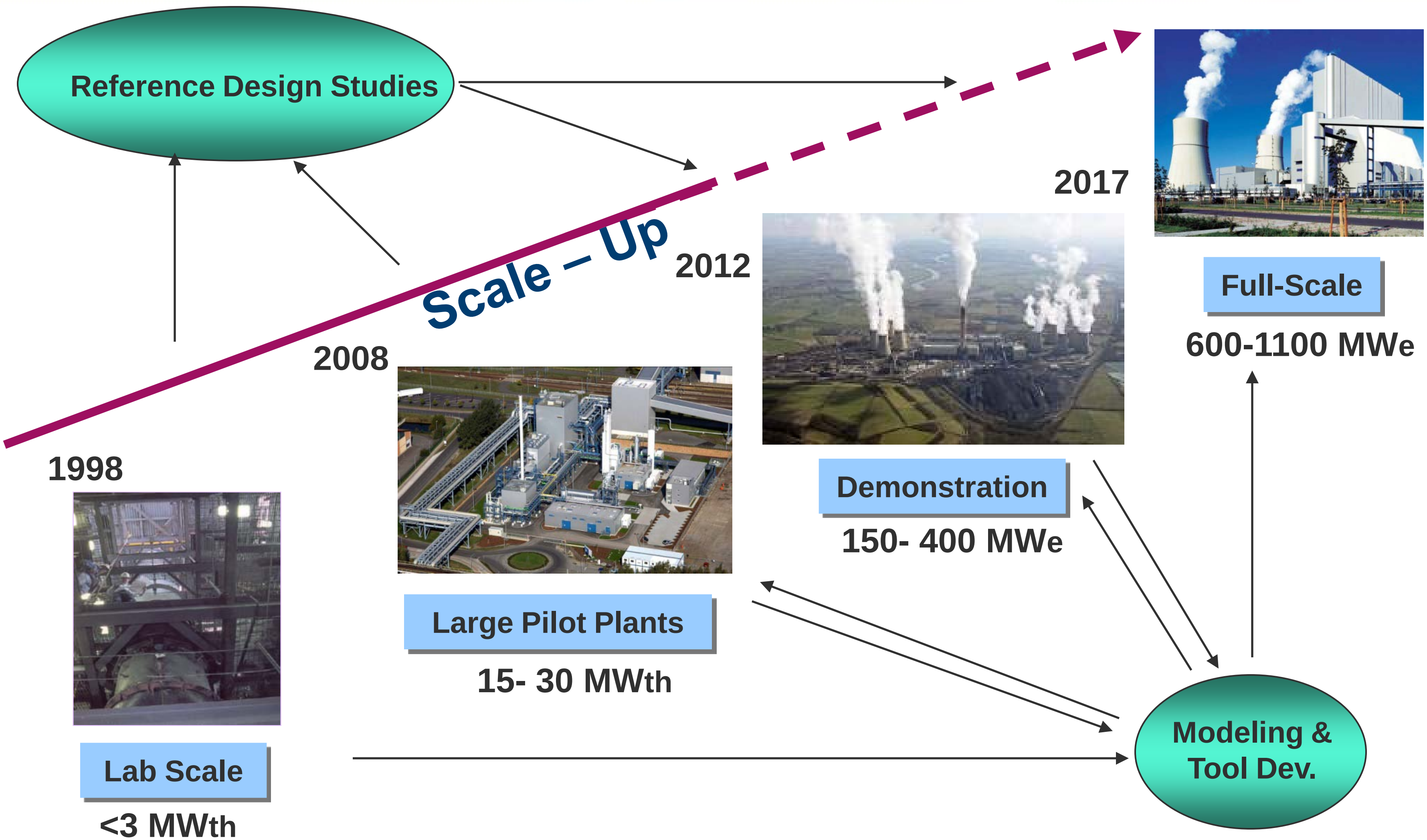
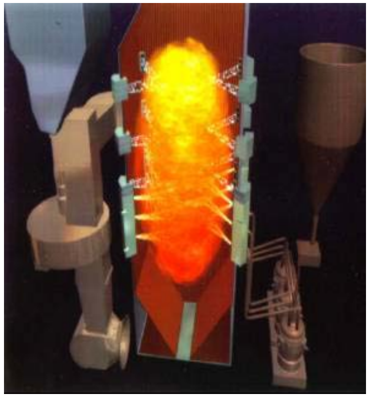
Alstom Oxy-Combustion Technology Development Steps

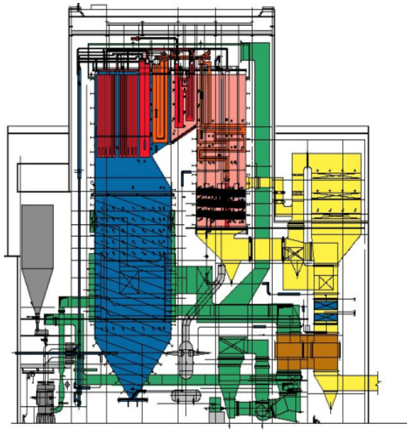


Oxy T-Fired Boiler Development
Project Objectives

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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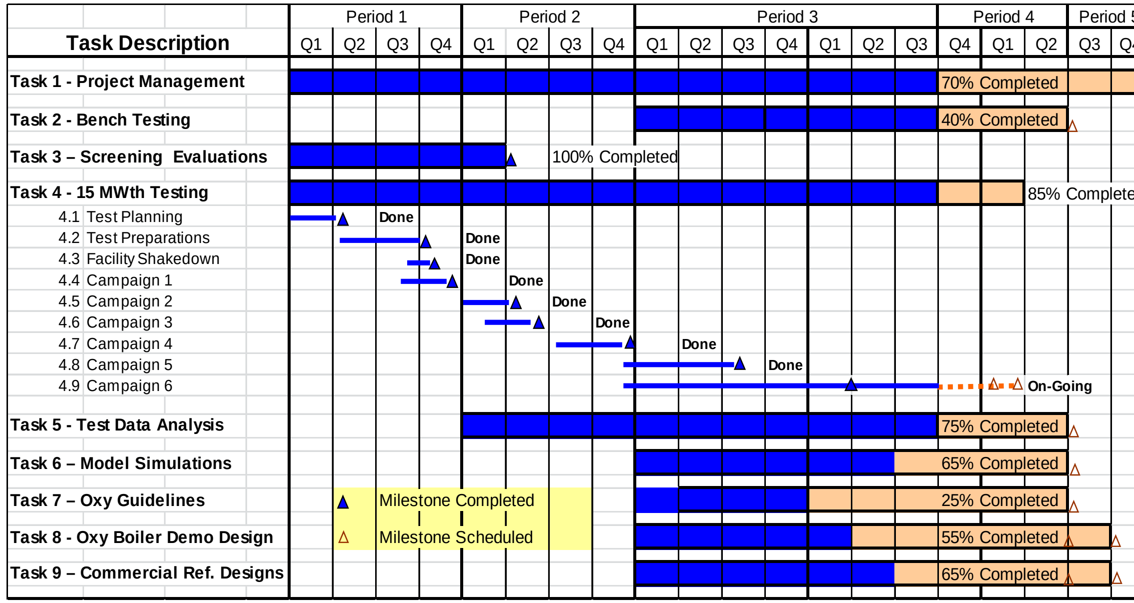
Oxy T-Fired Boiler Development Budget & Schedule

Total Budget: $21.5 M

Project Team:

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

Project Start: Oct 2008 Duration: 5 Yrs



Utility Advisory Group

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

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

15 MWth Boiler Simulation Facility

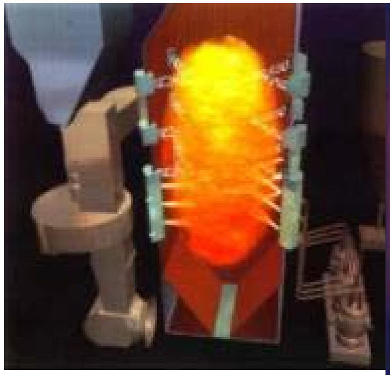
Multi-burner, Tangentially-fired

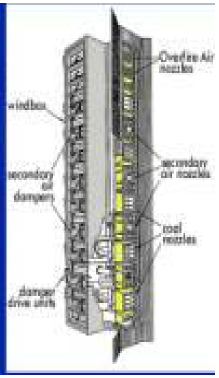
Flexible operating conditions

- 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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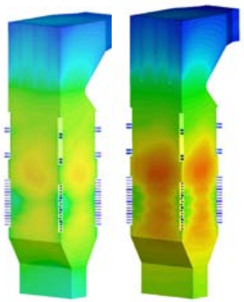
Oxy T-Fired Boiler Development Project Status

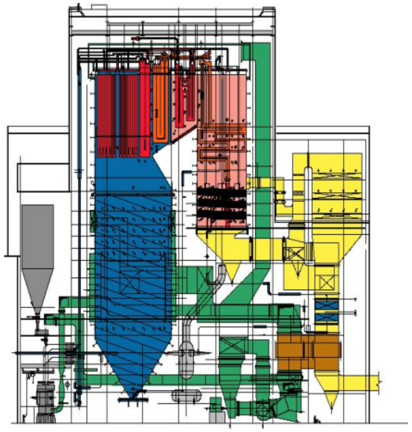
Accomplished

- 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 **Completed**
  Dec. 2011 – Advanced Concepts

On-Going

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





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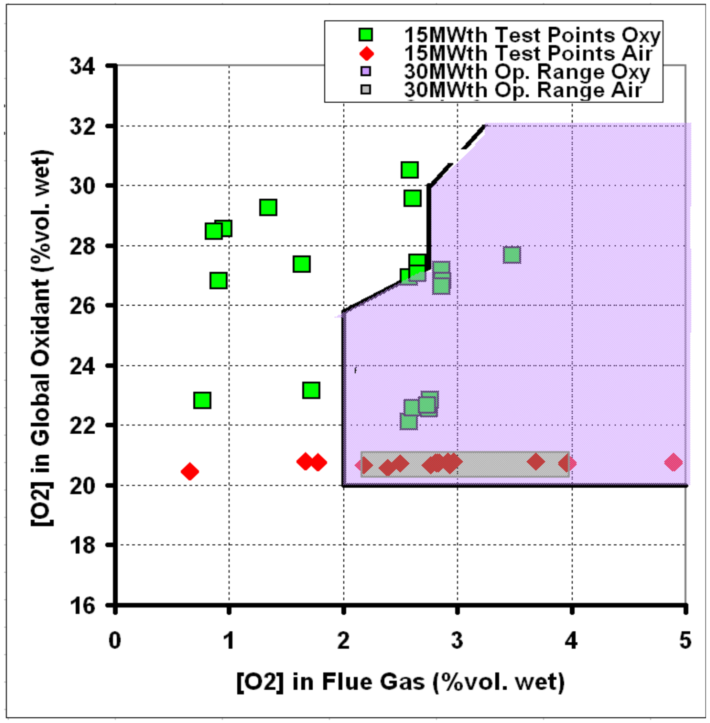
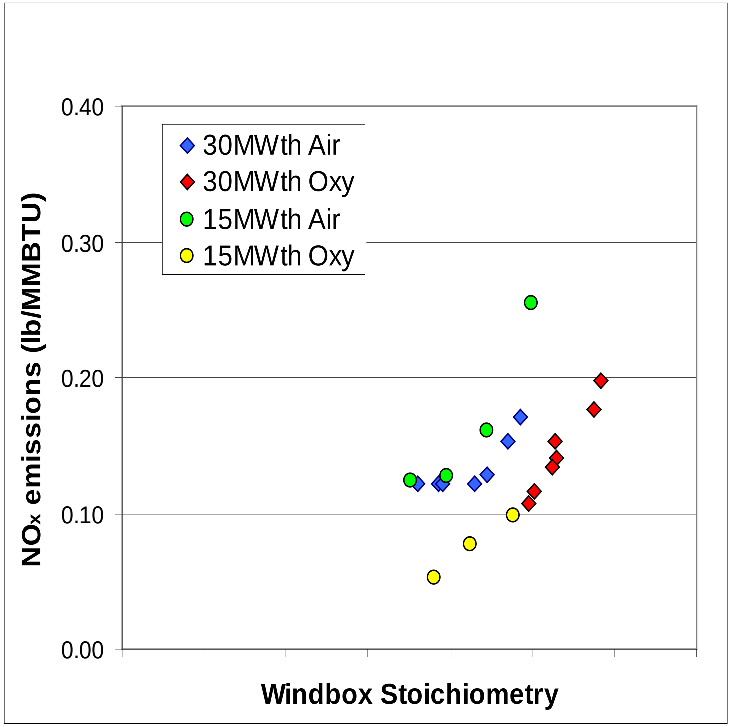
Comparsion of 15 and 30 MWth Schwarze Pumpe Lignite Results

Tested over conditions overlapping both 30 MW and previous 15 MW tests



Similar NOx Behavior in Both Pilots



Established link between 15 and 30 MW_{th} Test Programs

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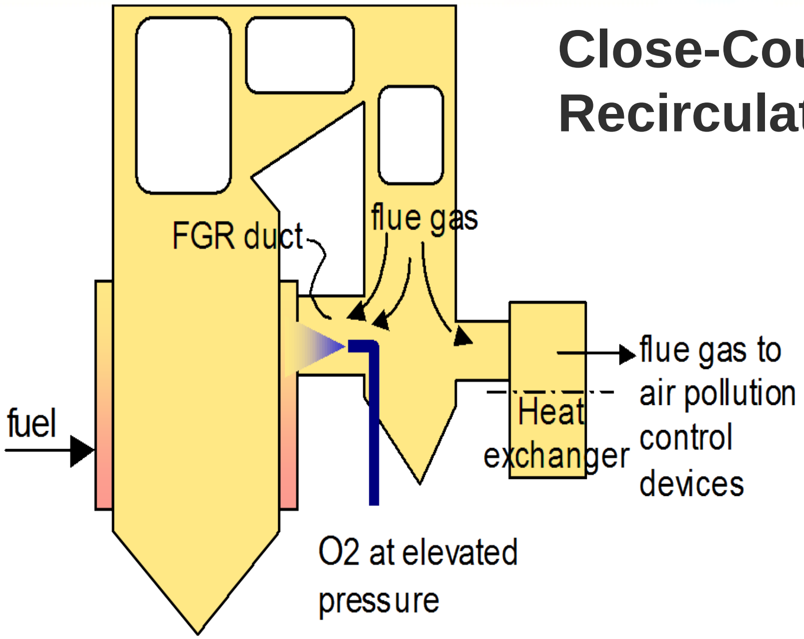
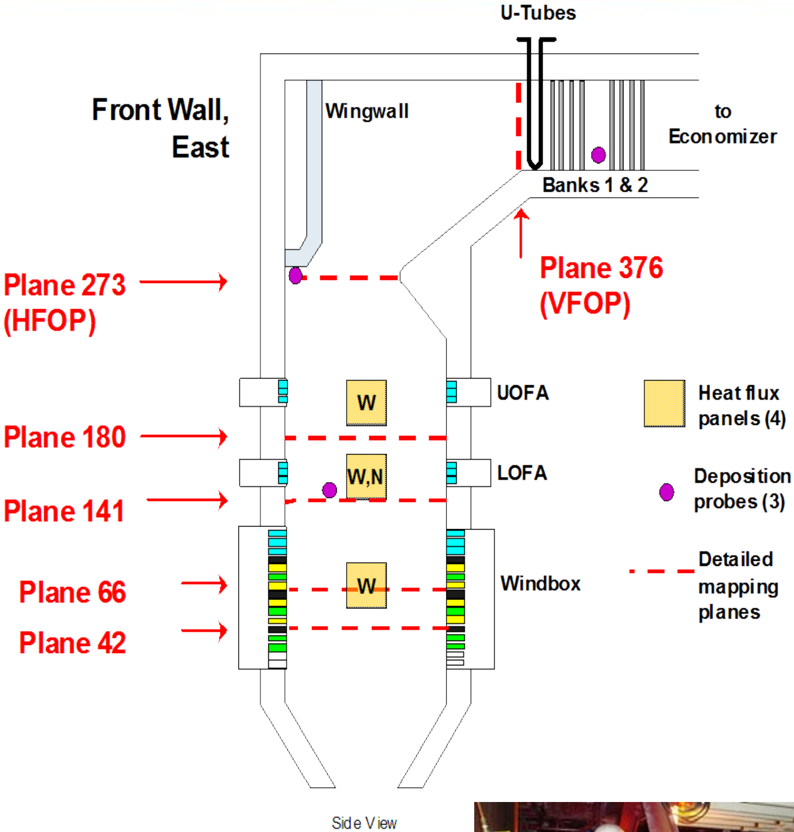
2nd Generation Boiler Concepts: Close-Couple FGR with Eductor

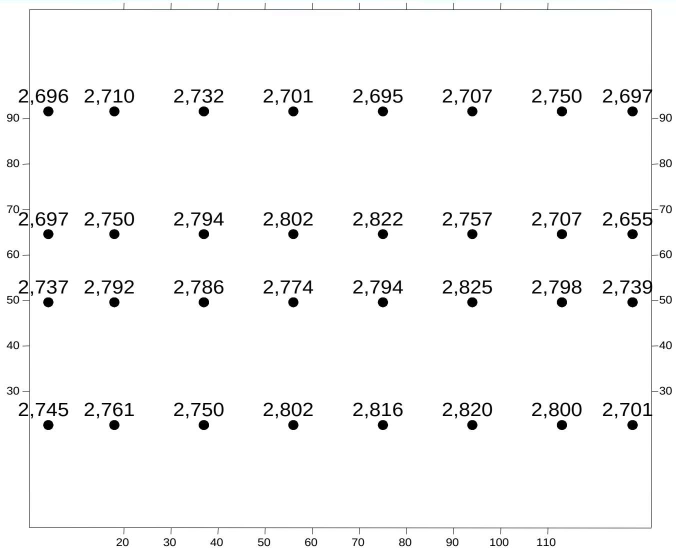


Close-Coupled Recirculation System.

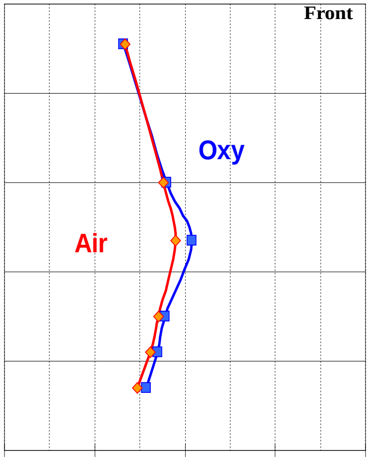
- **Demonstrated Close-Coupled (High Temp) gas recycle for low S coal**
- **Savings in downstream equipment CAPEX (SCR, gas-gas heater, ESP) and fan power – Overall economics evaluated in FY13**
- **Able to achieve 100% secondary gas recycle with single eductor and O2 motive gas (Replaces FD fan in oxy mode)**

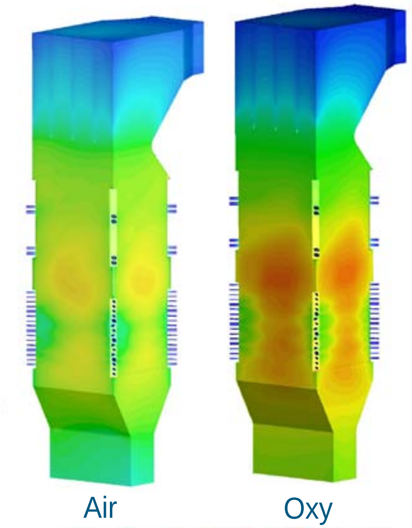
15 MWth Oxy-Combustion Pilot Plant: Detailed Mapping Data For CFD Validations





oxyfired heat flux profile can be controlled to match air fired





Probe Measurements

- Gas Temperatures
- Gas Composition
- Heat Flux

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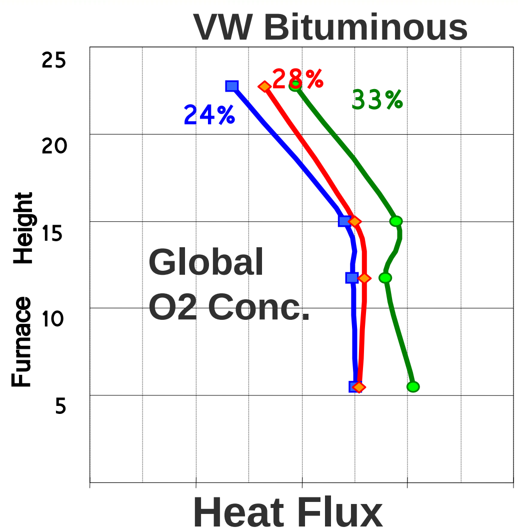
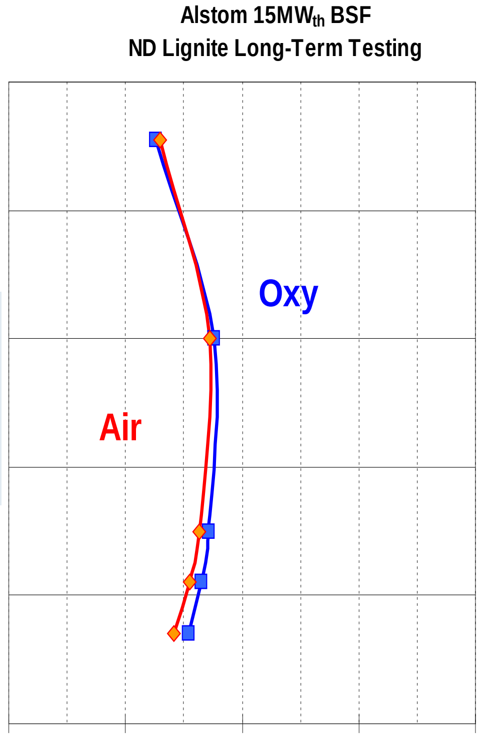
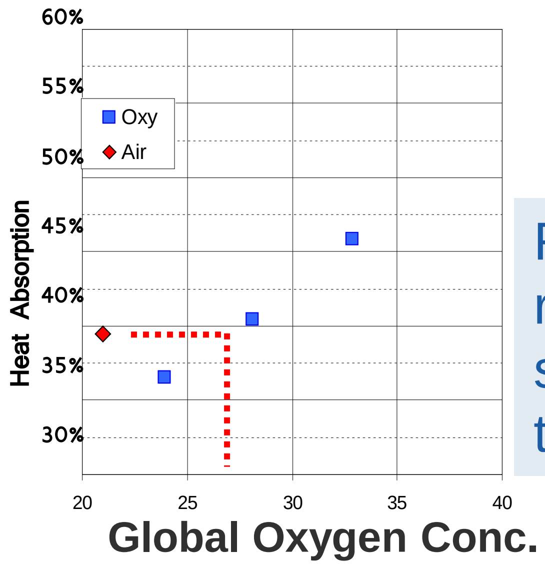
Furnace Waterwall Heat Flux – Can Be Control During Oxy-Firing



Ability to control heat flux magnitude with recycle rate



Able to closely match air firing heat flux



Reduced recycle rate shifts heat duty to furnace

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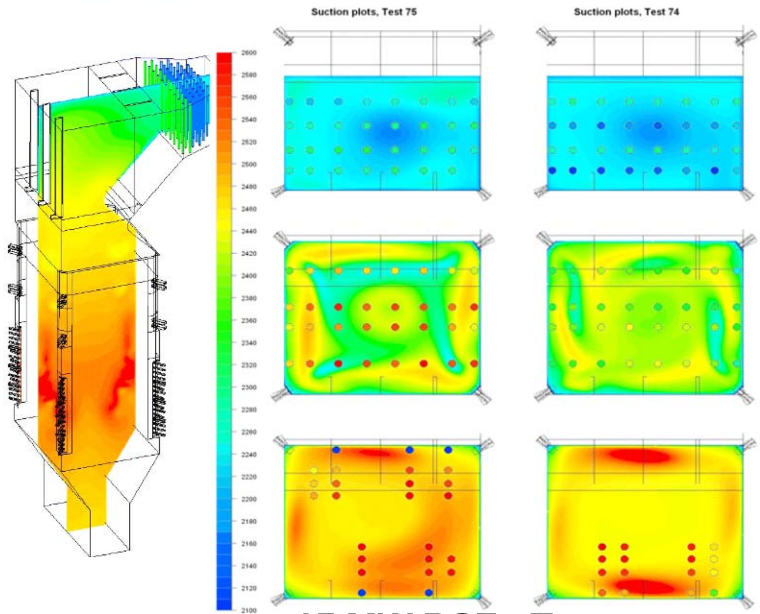
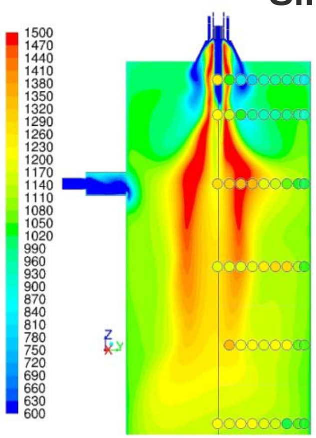
CFD Model Development
Oxy-PC Boiler Model Refinement and Validation

- ANSY FLUENT code: Submodel improvements for radiation, soot, NOx
- Detail comparisons with 15 MW BSF tests, 30 MW OxPP, and 0.5 MW IFK oxy combustor
  - refinement
  - validation
- Joint effort with ICSE at U of Utah
  - Systematic evaluation of experimental data and simulations
  - Uncertainty analysis
  - Large Eddy Simulations

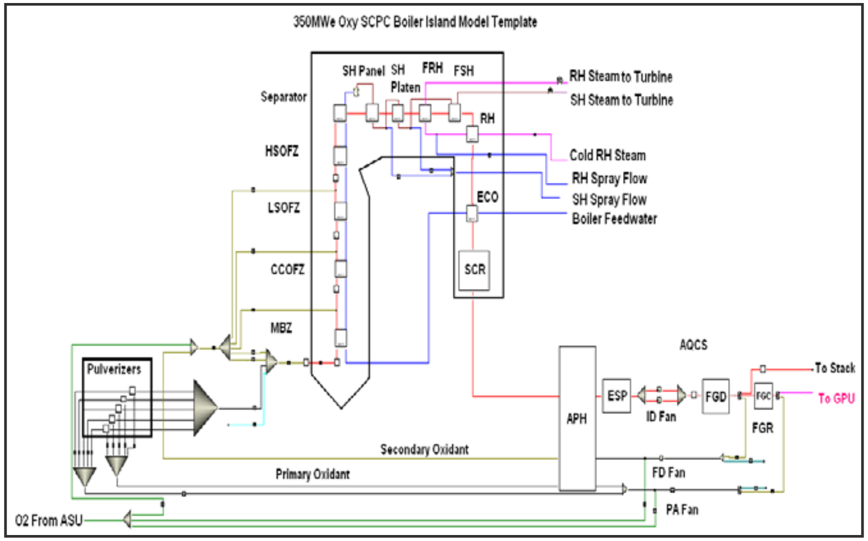


15 MW BSF - Temperature Simulation & Measurements



0.5 MW IFK - Temperature Simulation & Measurements

Dynamic Model Development
Oxy-PC Boiler Island Model

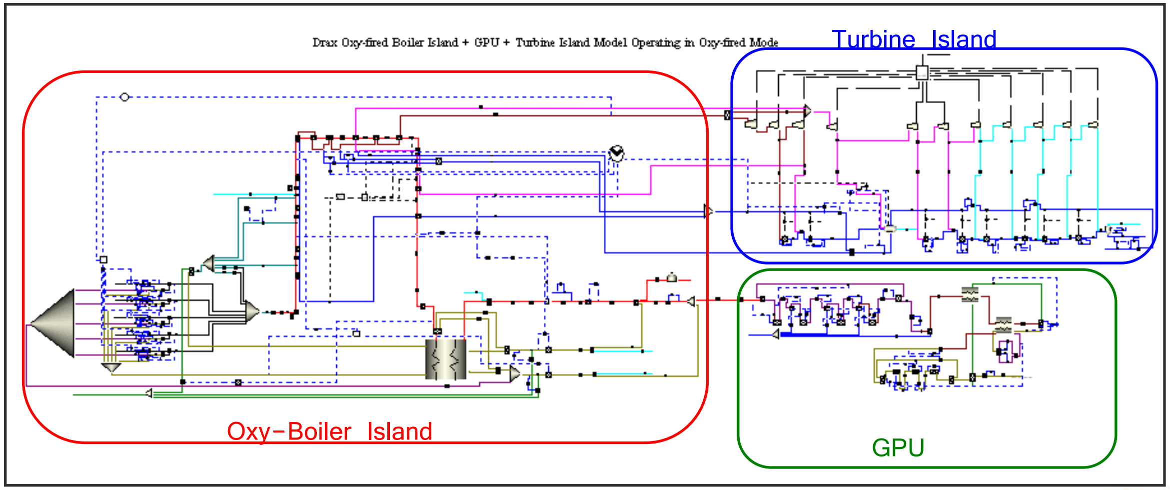


Aspen Dynamics Platform

- Detailed boiler model
- Overall oxy capture plant model

Dynamic Simulation

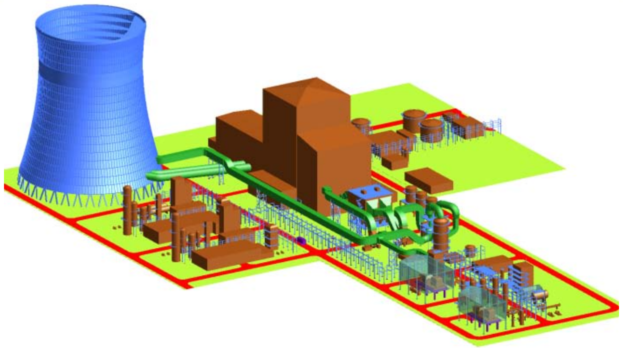
- Assess transient response
  - Operating modes
  - Load changes
  - Failure behavior
- Design advanced controls

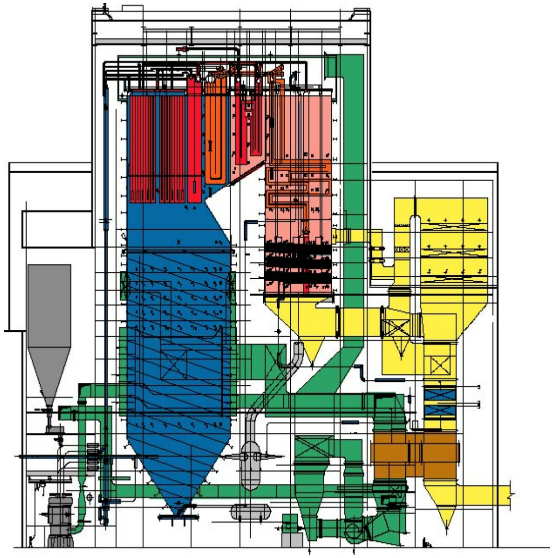


Oxy T-Fired Boiler Designs

Oxy Reference Plant and Demonstration Boiler Designs

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





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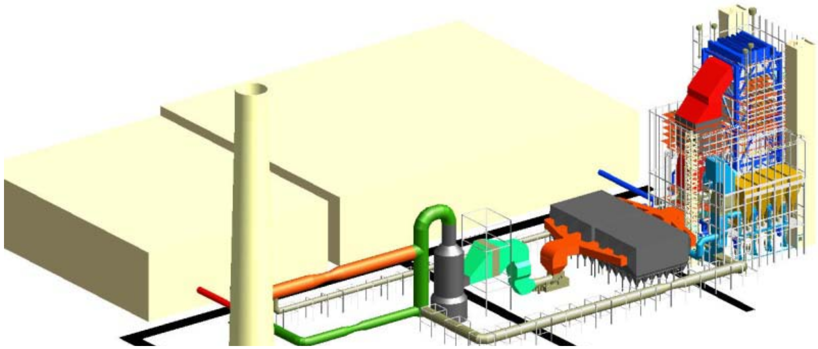
Large Commercial Reference Boiler Design

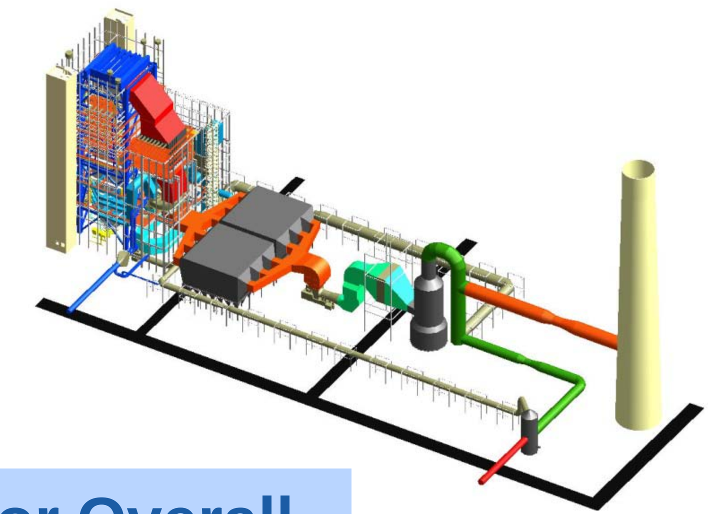
Boiler Specifications

- 900 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

- Optimized for Oxy
- Base load operation
- Min. Load 40%

Boiler Design Optimized for Overall Plant Performance and Cost

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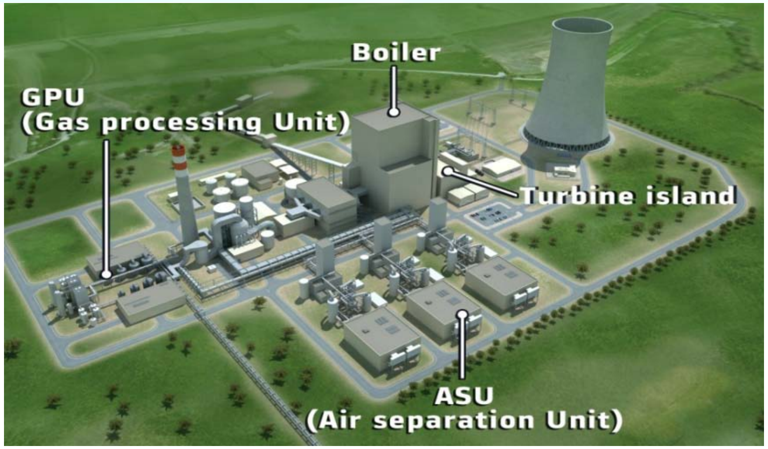
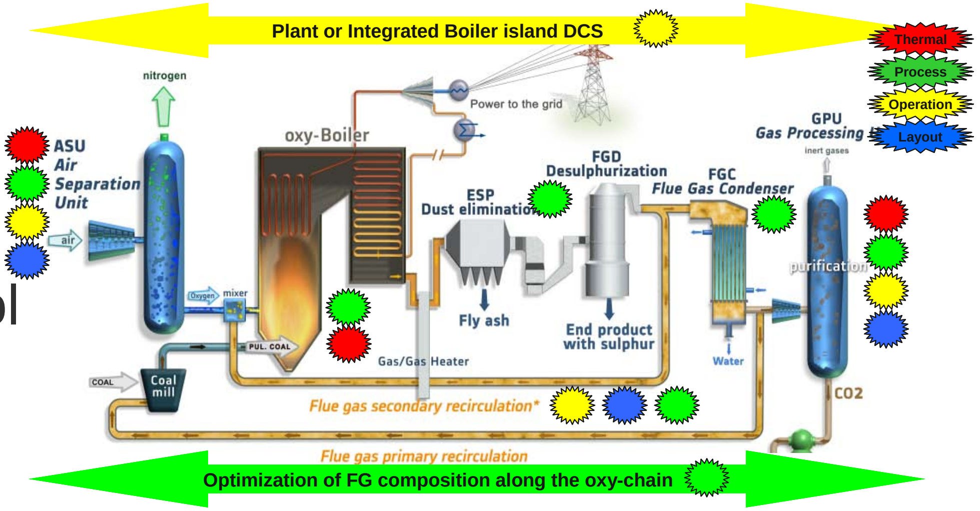
Oxy-firing Integrated Approach: For entire capture plant

- Numerous parameters impacting performance and cost – **Integration is key** (process, thermal, operation, arrangement)
- Globally optimize cost of electricity
- Balance trade-offs between main subsystems (performance and costs)
- Optimize pollutant removal
- Power plant operation and control
- Optimize arrangement and minimize footprint





An integrated approach minimizes the cost of electricity

Demonstration Unit Design

Boiler Specifications

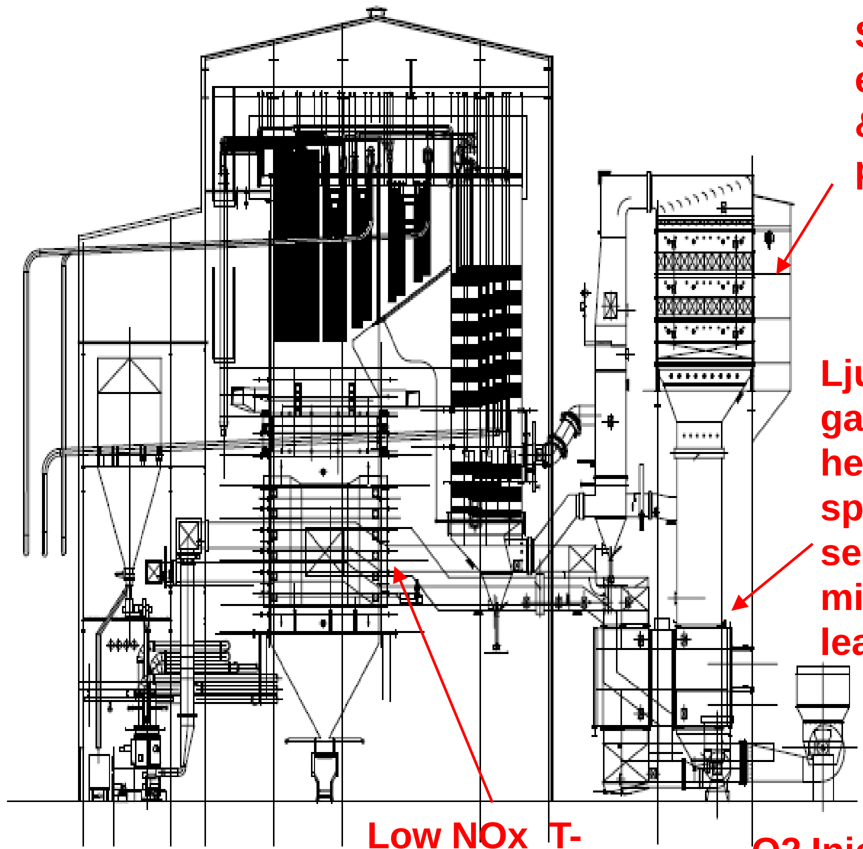
- 400 MWe Gross
- Supercritical, sliding pressure with spiral wall evaporator
- USC – 279/52 bar, 600/620 C
- Direct pulverized coal firing, Tilting-tangential firing system

Design Fuel

- Range of Bituminous Coals

Operation

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



Boiler Design Optimized for Overall Plant Performance and Cost

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The White Rose CCS Project in the UK

Project: New 426 MWe Plant
Ultra Supercritical Steam
Entire Gas Stream Processed
Pipeline Transport & Offshore Storage
Applied for UK & EU Funding
Pre-FEED Nearly Completed

Location: Drax Power Station, North Yorkshire, UK

Project Promoters

- **Oxy-fuel Power Plant**
  - ALSTOM
  - DRAX
  - BOC-Linde
- **CO_2 Transportation & Storage**
  - NATIONAL GRID

Drax
BOC
A Member of The Linde Group
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Concluding Remarks

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

- Detailed test data from this project and other Alstom R&D programs is being applied to
  - refine and validate design tools and design procedures
  - support overall oxy plant integration and optimization efforts
  - develop and optimize designs for demonstration opportunities and future commercial plants

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Acknowledgements and Disclaimer

Acknowledgement

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