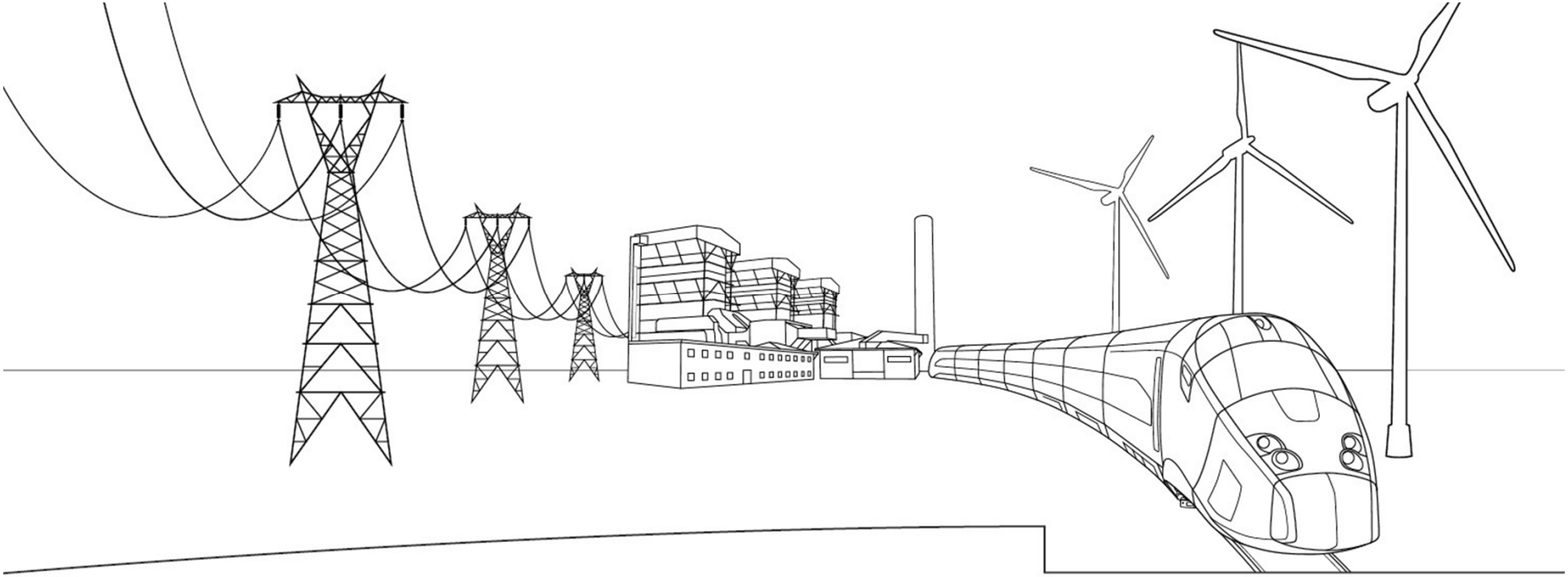

Understanding the boiler operation under oxyfuel combustion conditions – Impact to Material Selection

B. Bordenet, F. Kluger, P. Mönckert,
J. Marion, A. Levasseur

4th Meeting of the oxy-corrosion working group

London, June 18th, 2014

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Shaping the future

Why oxy-combustion:

Robust:

- ✓ developed from existing components

Flexible :

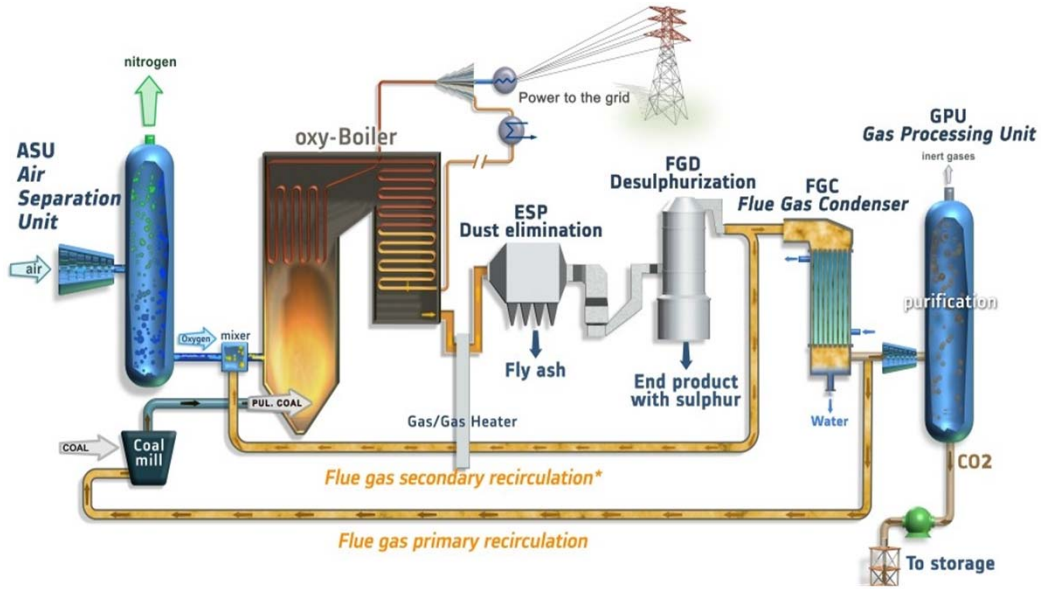
- ✓ All types boilers, firing systems, fuels
- ✓ Options for operational flexibility
- ✓ Retrofit and “Oxy-Ready” can be addressed

Scale-up:

- ✓ No constraints anticipated for large commercial units up to 1000 MWe, high efficiency with ultra-supercritical steam cycles

Cost competitive:

- ✓ With other CCS & other low carbon generation



Environmentally-friendly:

- ✓ Near Zero Emissions
- ✓ No new chemicals introduced to plant
- ✓ High CO_2 capture rates (>90%)

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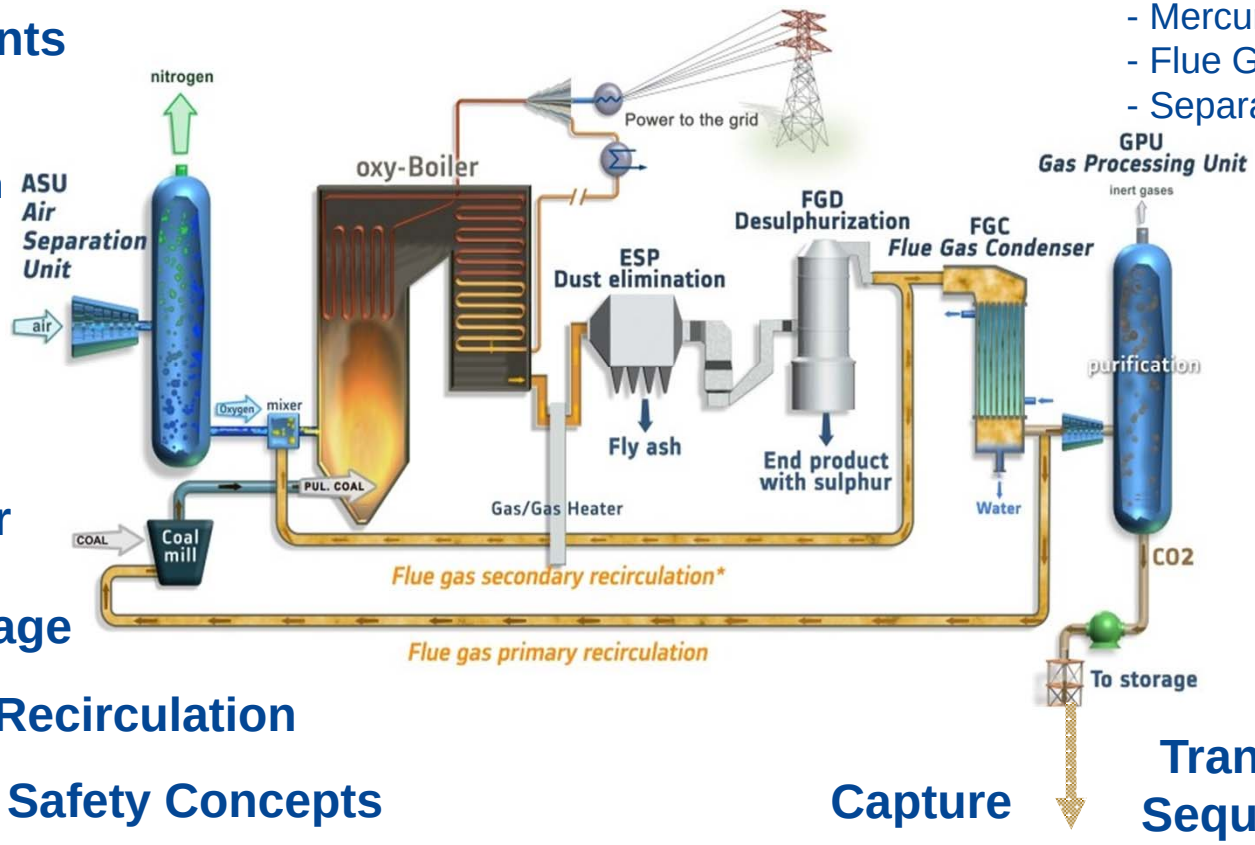
Oxy-Combustion Plant - Areas of Focus

Air Separation Options
- Cryogenic
- Membranes
- Oxide Carrier Materials

Steam Generator
- Oxyfuel PF Firing
- Oxy CFB
- Chemical Looping

Flue Gas Cleaning
- Particle Removal
- NOx-Removal
- Desulphurisation
- Mercury Removal
- Flue Gas Drying
- Separation of N_2, O_2, ...

Components
- Scaling
- Integration
- Optimisation



Materials

Dynamic Behaviour

Air Inleakage

Flue Gas Recirculation

Control & Safety Concepts

Capture

Vent Gases

Quality & Efficiency of CO_2-Separation

Transport & Sequestration

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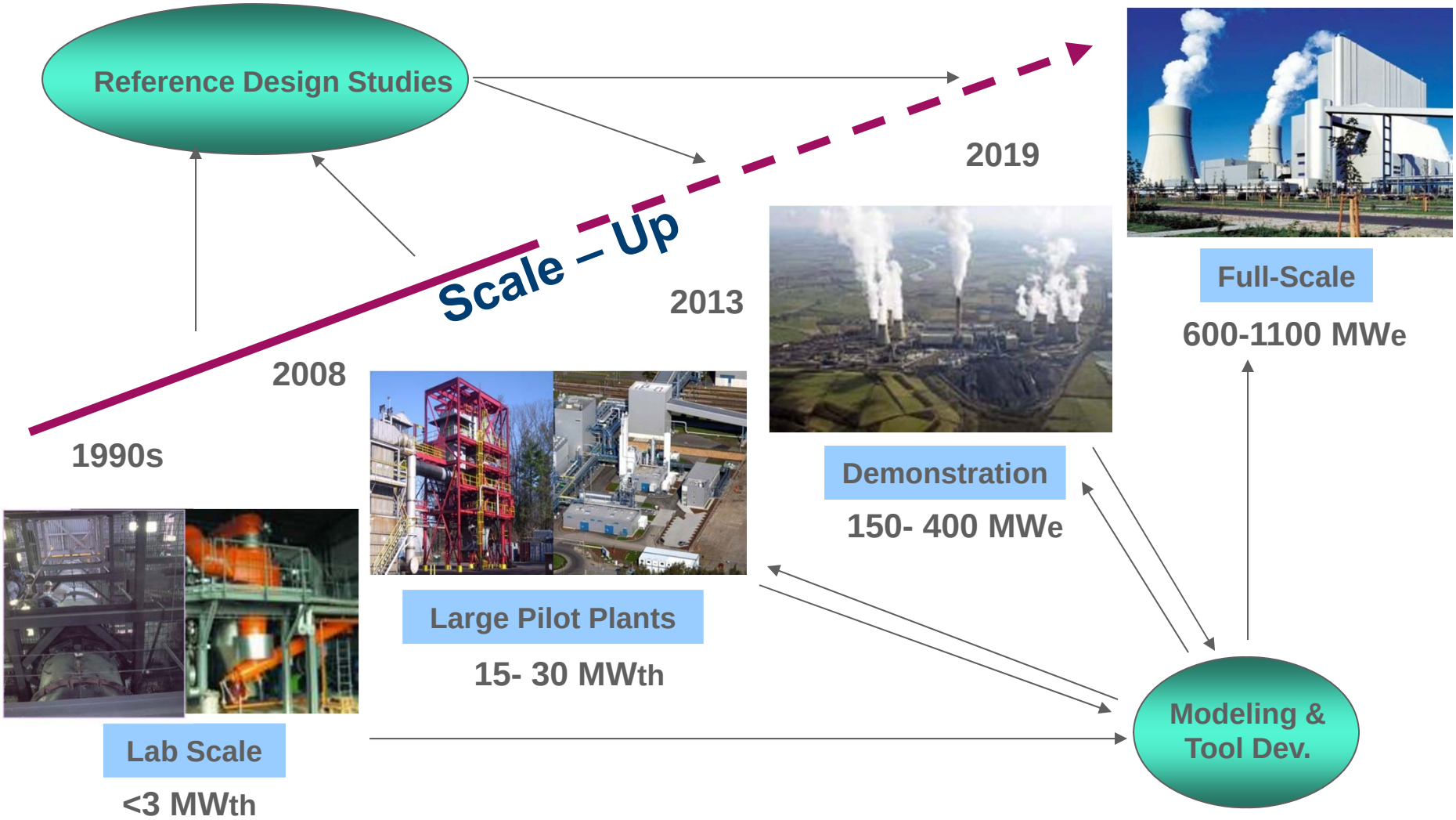
Alstom oxy-combustion technology
Development steps



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30MW$_{th}$ Oxy-combustion pilot plant at Vattenfall's Schwarze Pumpe, Germany

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

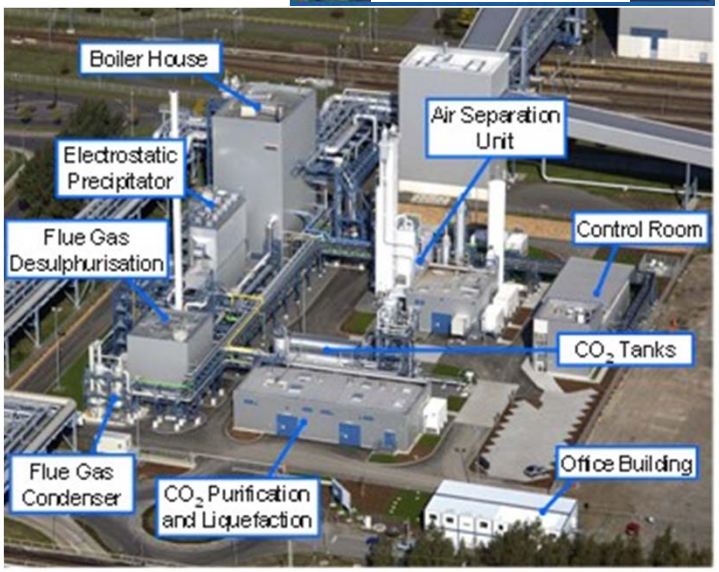
- Alstom supplied the Boiler, ESP and other components of the flue gas path
- Single Burner down-fired furnace
- Technology partnership with Vattenfall to advance oxyfuel technology

Operation started September 2008

- More than 11,700 operation hours and >10,600 tons of CO_2
- Tests with two lignites (low/high sulfur)
- Test phases with Alstom Burners (Design A+B) finished
- Data on combustion and boiler performance, and component interactions

Alstom Oxy-burner

Alstom Oxy-boiler



30 MWth Oxy Plant

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15MW$_{th}$ Oxyfuel pilot plant (BSF)
Alstom Boiler Laboratories, Windsor, CT

Multi-burner, Tangential Fired facility to develop oxy boiler system and generate detailed design and performance data.

Comprehensive Test Program with US DOE ($21.5M USD)

- Testing started Sept. 2009 until 2014
- Evaluate the impacts of different oxy process options and boiler design parameters
- Evaluate the performance of different 8 coals: Subbituminous , Low S bituminous, High S Illinois bituminous coal, Noth Dakota Lignite & Lausatian Lignite
  - combustion, heat transfer, pollutant emissions, deposition, corrosion …
- Evaluate, improve, and validate engineering and computational tools
- Development of design guidelines
- Commercial Reference Designs
- Demonstration Design

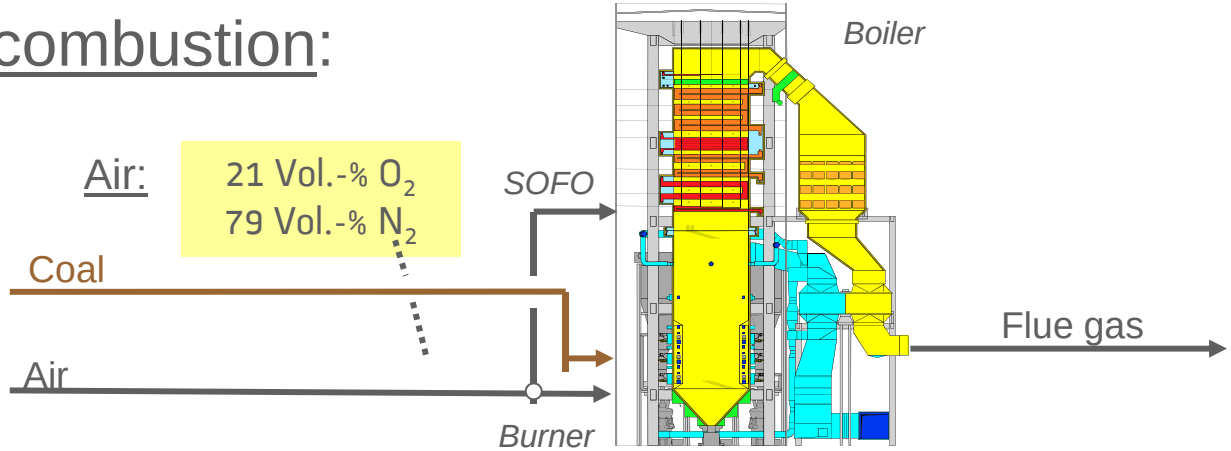
Tangential firing

Alstom Oxy-pilot plant

Oxyfuel Prozess - Air vs. Oxy Combustion
Differences of Flue Gas Qualities

Air combustion:

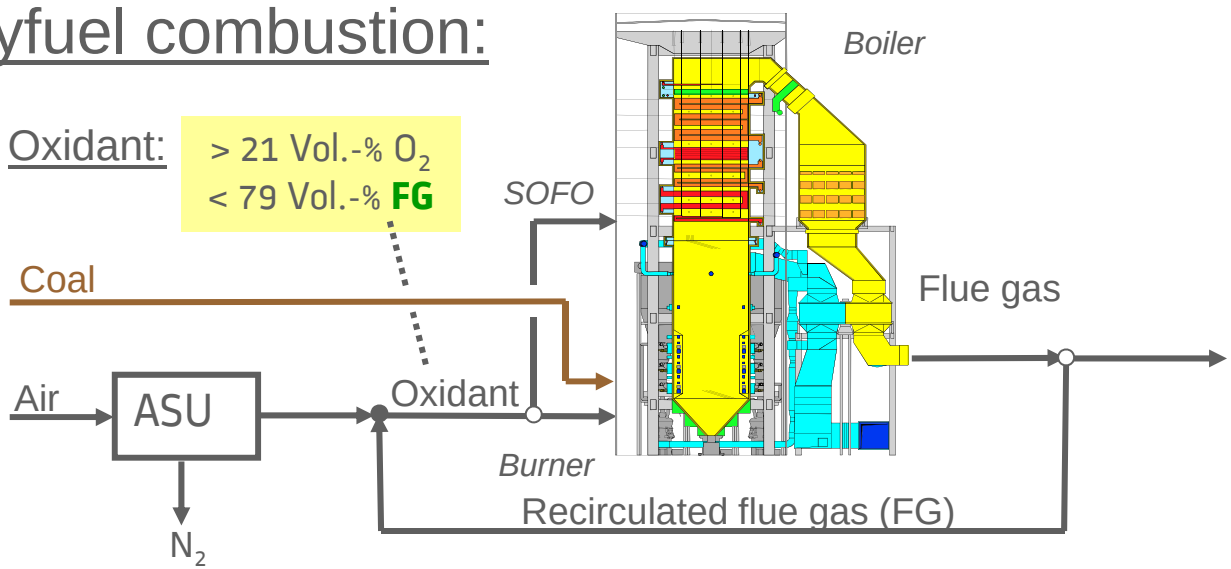
Air: 21 Vol.-% O_2
79 Vol.-% N_2



%	Vol.
N_2	72.3
O_2	4.7
CO_2	13.7
Ar+Inerts	0.9
H_2O	8.3
SO_2	0.1

Oxyfuel combustion:

Oxidant: > 21 Vol.-% O_2
< 79 Vol.-% **FG**



%	Vol.
N_2	7.8
O_2	3.6
CO_2	58.3
Ar+Inerts	2.3
H_2O	27.7
SO_2	0.3

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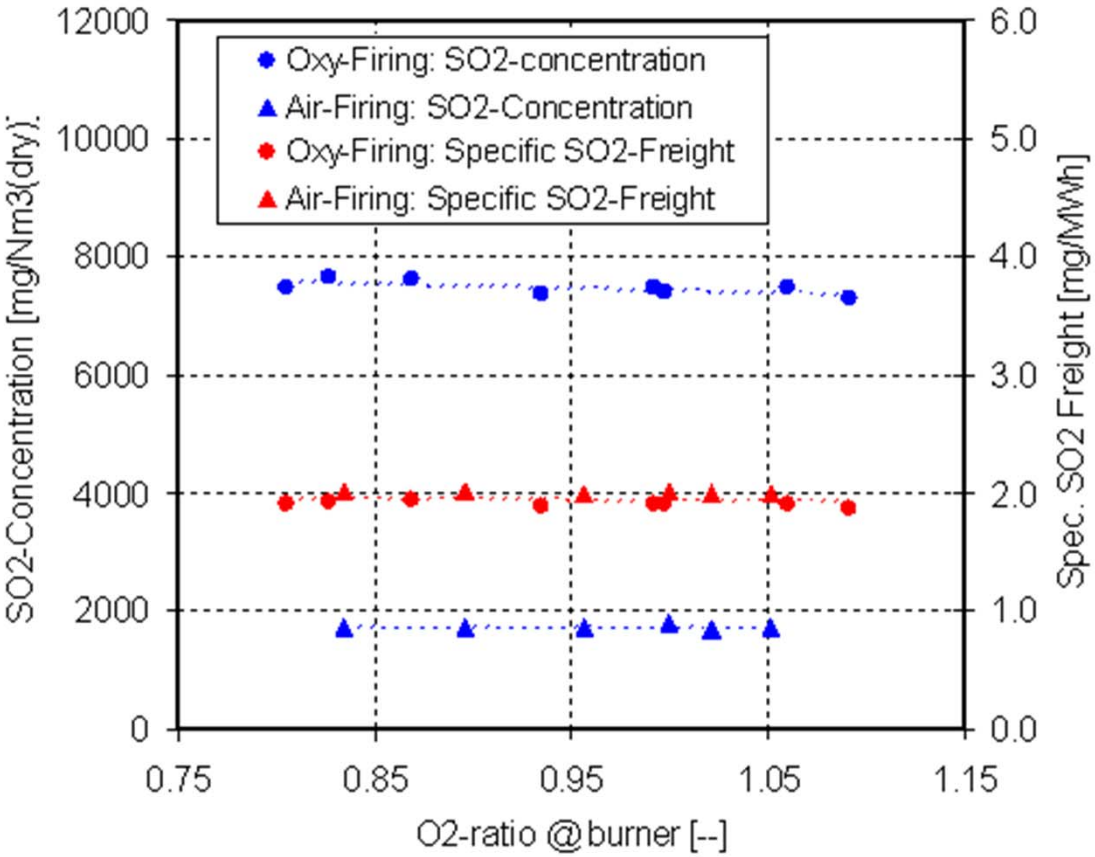
30MW$_{th}$ Oxy-combustion pilot plant (Schwarze Pumpe) SO_2-concentration Air vs. Oxy

German (Lausatian) lignite, w/o sulfur capture in recycle loop



- SO_2 concentration in the flue gas is depending on the availability of sulphur sink in the secondary recycle
- Secondary recycle location in the pilot plant is downstream of ESP, also w/o a sulphur sink
- SO_2 concentration in oxy-combustion is approx. 4 times the value in air combustion
- SO_2 loading [mg/MWh] in oxy-combustion is the same as for air-combustion

Specific SO_2-loading is the same for air and oxy

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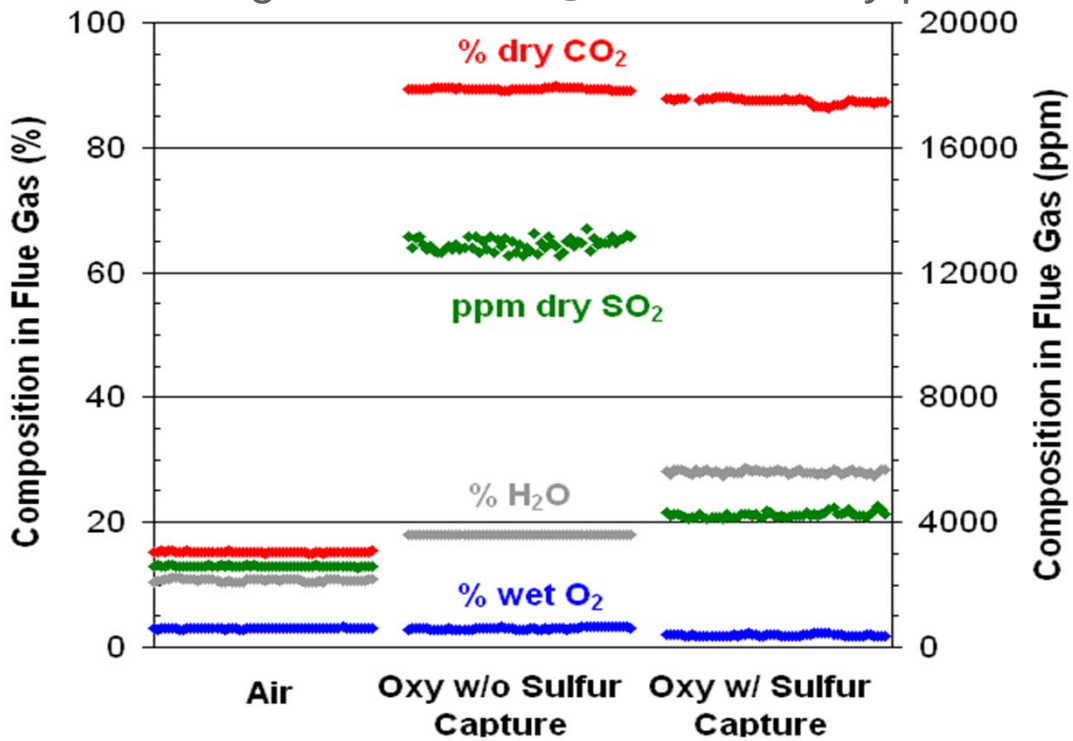
SO_X in the flue gas – impact of oxy-firing

- Absolute SO_X-concentration depends on recycling scheme

Illinois high sulfur coal @ 15MWth Oxy pilot



- Air-firing: reference
- Oxy w/o sulfur capture: increase of factor 3-4 due to flue gas recirculation
- Oxy w/ sulfur capture: small increase as massflow is smaller (= less dilution) in oxy to keep heat input constant

Increase in SO_2 even with sulfur capture from recycle

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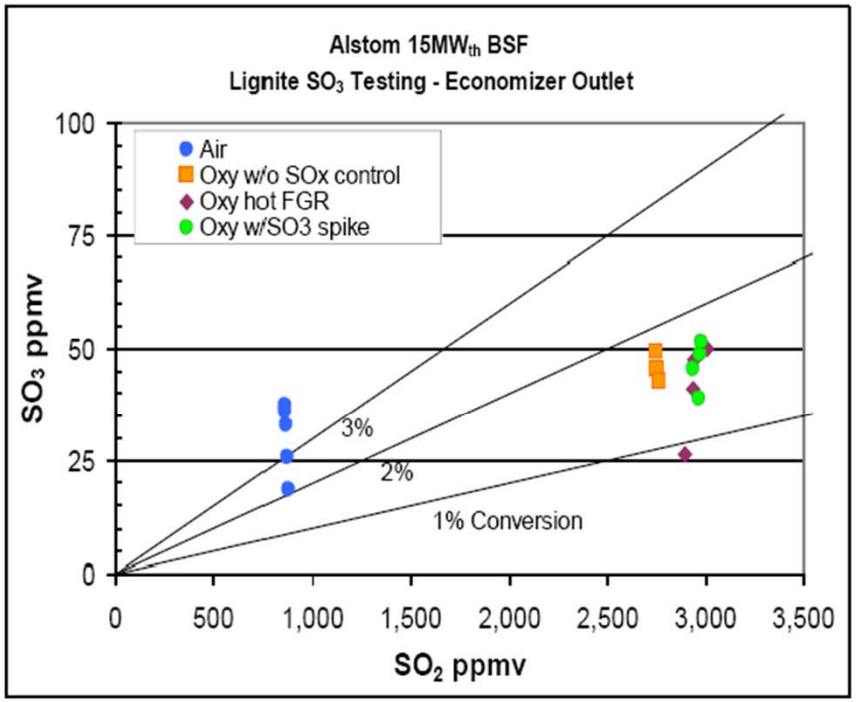
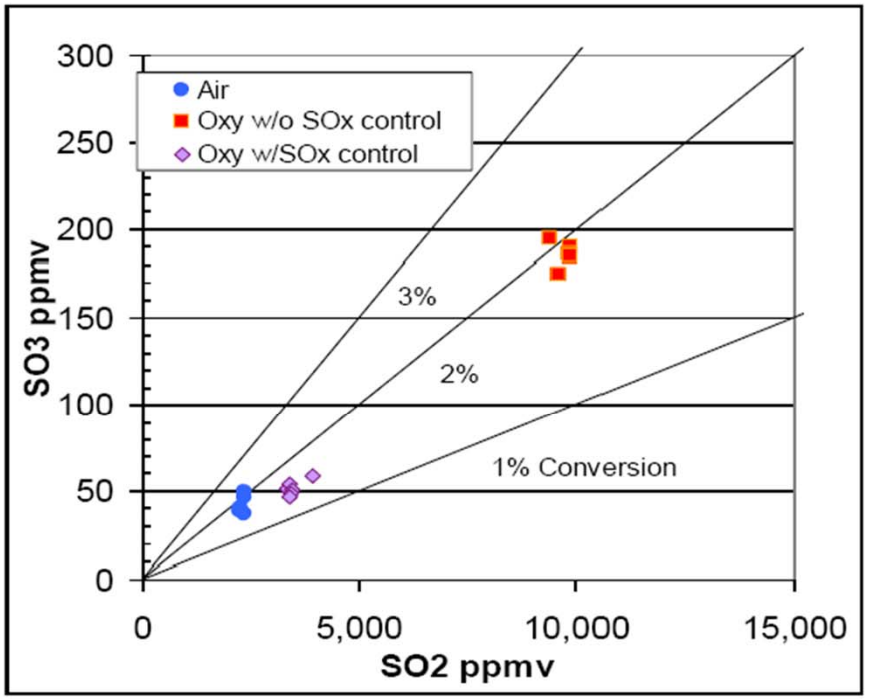
Similar SO_3 Conversion Rate As Air Firing - Economizer Outlet Measurements in 15MWth oxyfuel pilot plant (BSF)

North Dakota
Economizer Outlet SO_3 results



Illinois Bituminous
Economizer Outlet SO_3 results



Similar SO_2 to SO_3 conversion rates

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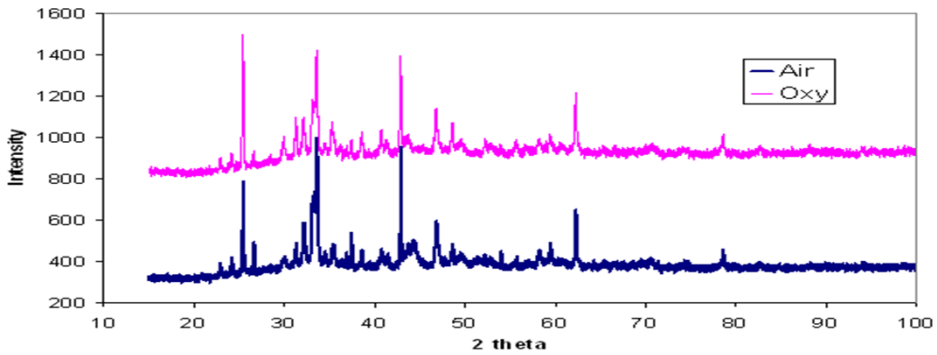
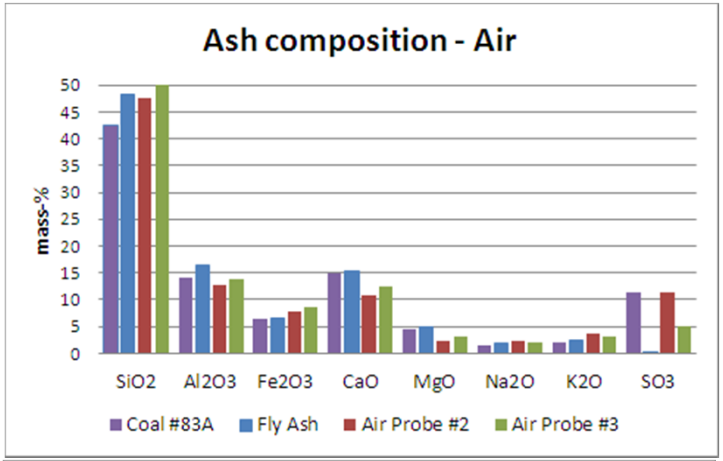
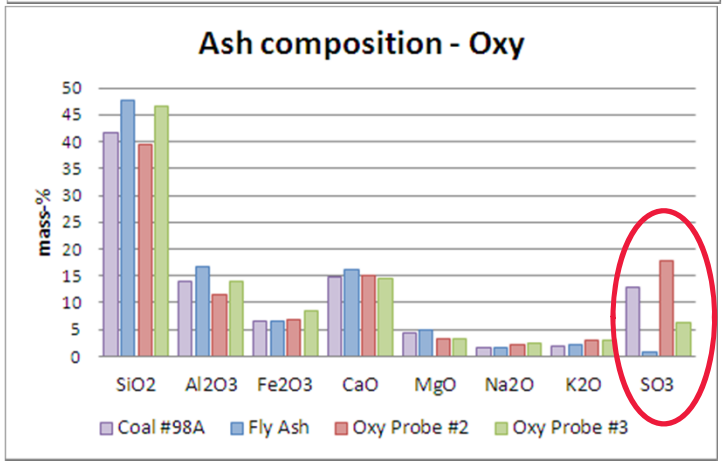
Similar ash composition

- Ash measurement from 15MWth oxy-pilot (BSF) with North Dakota lignite: no S capture in recirculation loop

- Ash samples from 30MWth Schwarze Pumpe with German (Lausatian) lignite from air- and oxy-firing: show comparable X-ray diffraction spectrum (= mineral composition)







Ash composition similar with higher SO_3-content when no S is captured in recycle loop

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Impact on boiler operation

- Heat transfer
  - Comparable to heat transfer experienced in air-combustion
  - Heat transfer profile in the pilot can be adjusted by firing system parameters (e.g. flue gas recycle)
- Burnout
  - Comparable to burnout experienced in air combustion
- Fouling & Slagging:
  - Similar behaviour in air- and oxy-combustion
  - Fly ash and bottom ash do have similar composition in air-and oxy-combustion

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Impact on Furnace corrosion

- Waterwall & Fireside corrosion:
  - Similar ash composition:

  ⇒ Similar corrosion mechanisms expected
  - Absolute SO_X-content in flue gas and ash is dependent on recycling scheme:
    - w/ sulfur capture in recirculation loop: SOX-content in flue gas only slightly higher than in air
  - Corrosion experience from air-fired could be transferred to oxy-fuel, if SO_X-content is maintained within experience range
  - More details in presentation 'Fireside corrosion under oxyfuel combustion conditions ' on June19th

  ⇒ oxy-fuel plant can be equipped with standard materials, with monitoring of metal wastage to confirm statements by long-term experience

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Impact on ESP / Flue gas recirculation

Prevention of cold end corrosion

- Acid dew point vs. cold end of Regenerative-Gas-Heater:
  - Sulfuric acid formation: SO_2 to SO_3 conversion influenced by reactive surfaces (ash compounds, membrane wall, …)
  - High moisture and high SO_2 concentrations impact level of acid dew point temperature

Mitigations:

- Proper selection of location for flue gas recycle:
  - Secondary recycle downstream FGD (reduced SO_2 content),
  - Primary recycle downstream FGC (reduced moisture)
- Adjusting temperature according SO_X-level to be above acid dew point by appropriate insulation

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Concluding remarks

- Material experience from air-firing can be transferred to oxy-firing, when SO_X-content is within experience regime or S capture is installed in the recirculation loop
  - Long term operation and evaluation of material performance in large-scale will be collected to confirm lab / pilot plant results
- Oxy-combustion has successfully achieved development steps over the past ten years.
- Alstom and other oxy pilots across the world provided design data and confirmed robustness of the process.
- We are prepared to demonstrate oxy-combustion at large-scale under real commercial conditions.
- The White Rose project in UK is a promising opportunity and providing a key step for commercialization.

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Outlook: White Rose Large Scale oxy-demo project, UK

Location: Drax Power Station, North Yorkshire, UK

PROJECT DEVELOPERS:

Oxy-Power Plant

CAPTURE POWER

Alstom

Drax

BOC-Linde

&

CO_2 Transport & Storage

National Grid

- Largest Oxy-Combustion CCS project worldwide: 450MW_e (gross)
- New ultra-supercritical coal-fired power plant with full stream treatment
- Biomass co-firing : zero - or negative - CO_2 emissions
- CO_2 Transport and offshore Storage network by National Grid Carbon Limited
- 90% CO_2 capture-rate
- A Front End Engineering and Design (FEED) Contract has been awarded for the White Rose CCS project , signed by the UK Government on 20th December 2013

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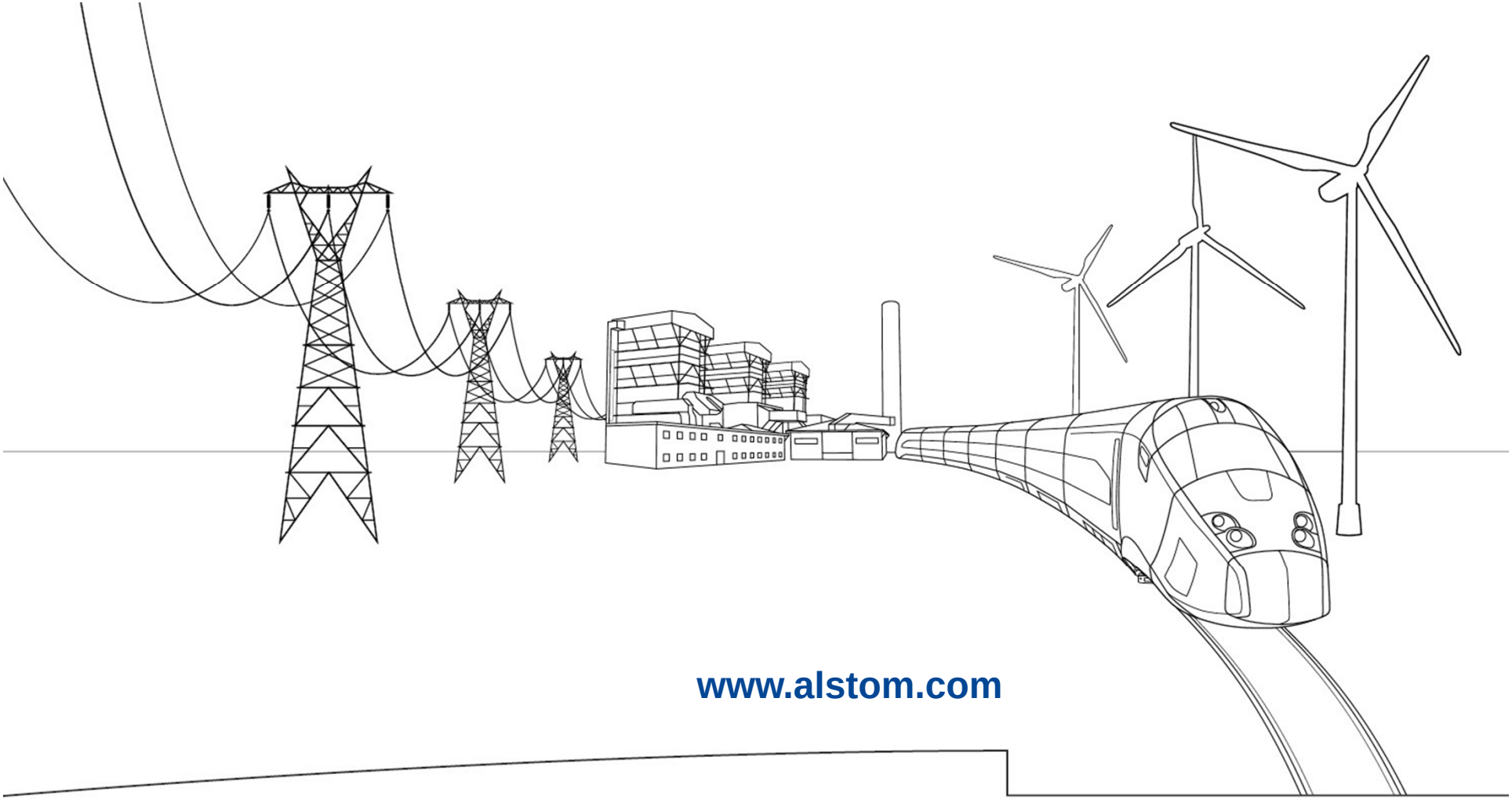

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