Modern Ultra-Supercritical Boiler and Emission Control Technologies

Dr David Smith

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APG TF
cleaner fuels for power and industry

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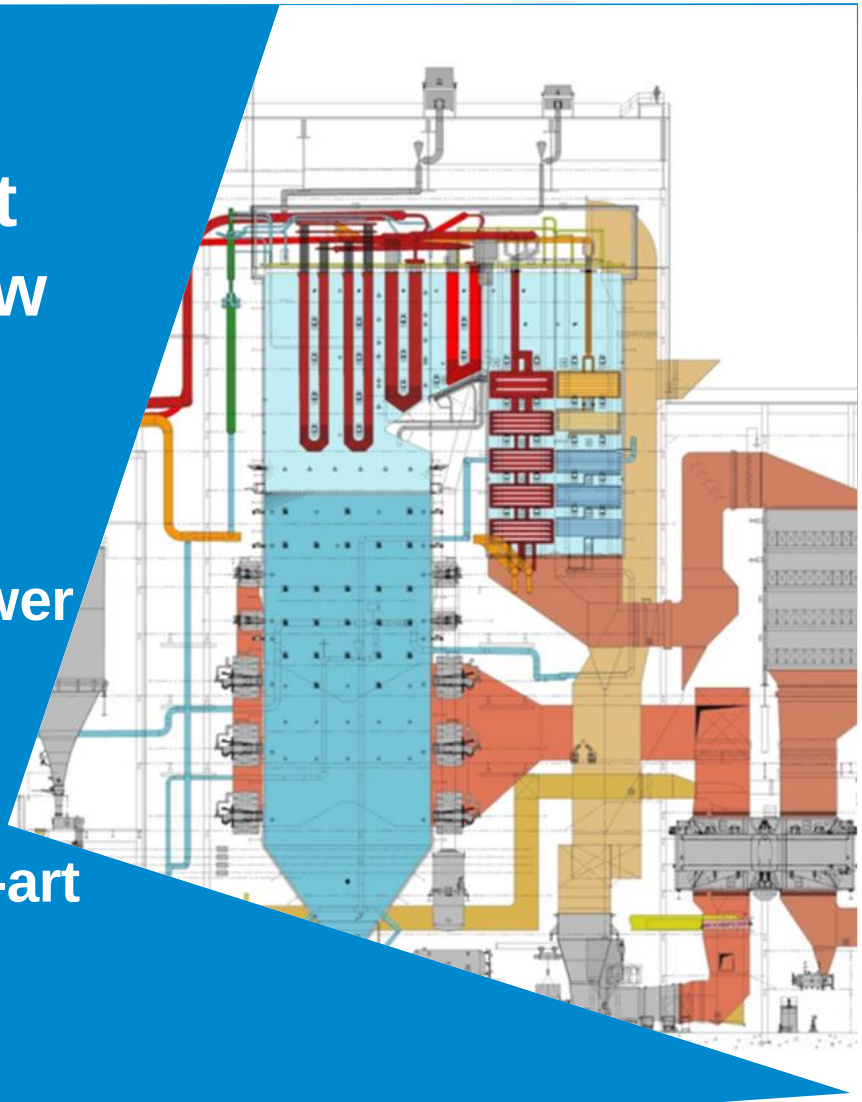
Meeting Increasingly Stringent Emissions Regulations for New Coal Fired Power Plants

- Emissions limits for Coal Fired Power Plants – status and trends
- Boiler and emission controls technologies – current state-of-the-art



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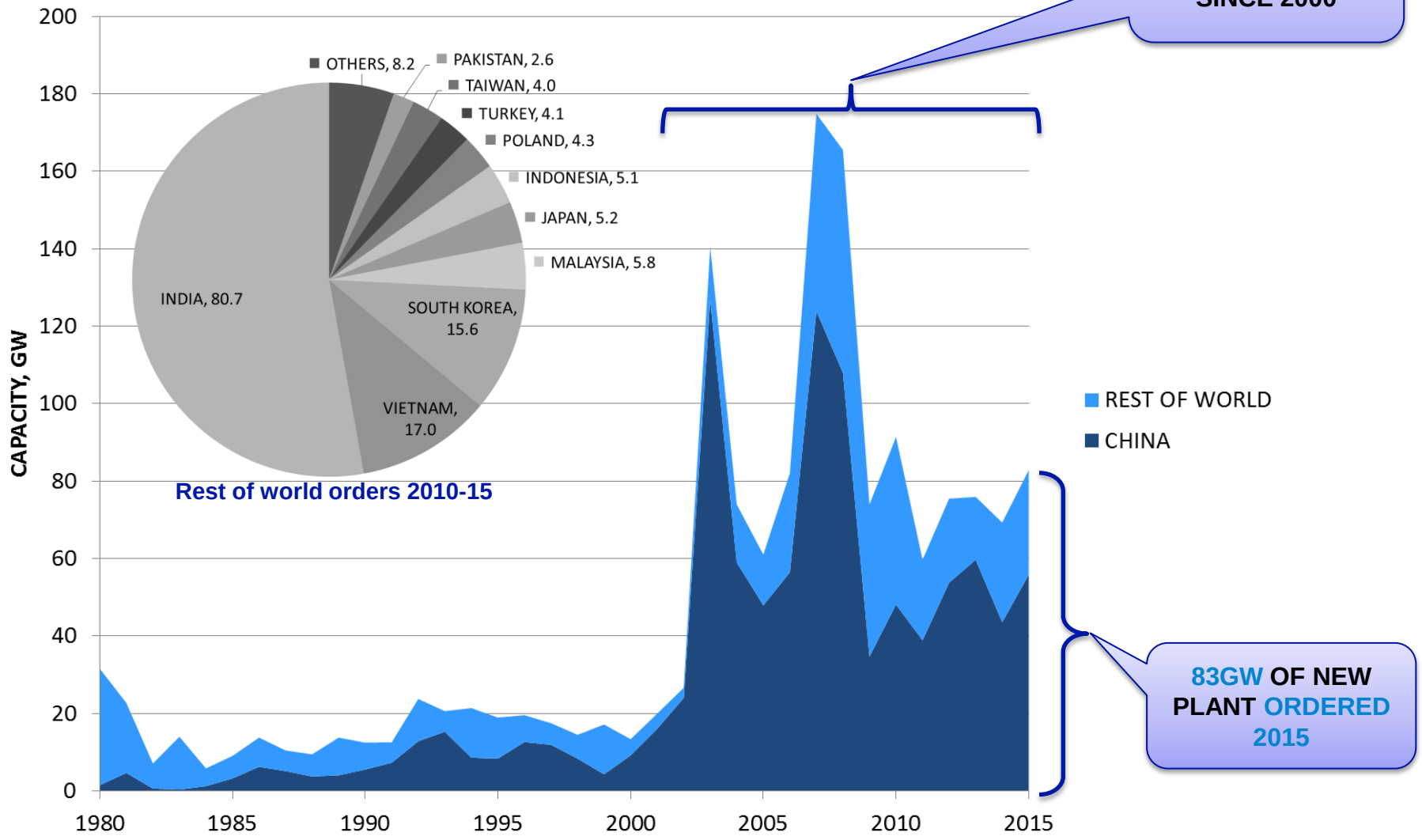
New Build Coal Fired Power Plant Trends
Power Plant Orders > 250MW



All coal fired power plant orders for unit sizes above 250MWe (Gross)
[Raw data from McCoy Power Reports]

New Build Coal Fired Power Plant Trends
Reducing Stack Emissions Limits

Pollutant	IED / European Standard	World Bank (WB) IFC, (1)	CHINA GB 13223-2011	TURKEY	INDONESIA	INDIA[3,4]	SOUTH KOREA[2]
NOx	150 mg/Nm^3	200 mg/Nm^3	100 mg/Nm^3 (6)	200 mg/Nm^3	750 mg/m^3 (10)	(300 mg/Nm^3) **100 mg/Nm^3**	164 mg/Nm^3 (80 ppm)
SO2	150 mg/Nm^3	200 mg/Nm^3	100 mg/Nm^3 (6)(9)	200 mg/Nm^3	750 mg/m^3 (10)	(200 mg/Nm^3) **100 mg/Nm^3**	228.8 mg/Nm^3 (80 ppm)
PM	10 mg/Nm^3	30 mg/Nm^3	30 mg/Nm^3 (8)	30 mg/Nm^3	100 mg/m^3 (10)	(50 mg/Nm^3) **30 mg/Nm^3**	20 mg/Nm^3
HG	Not defined / 0.03 mg/Nm^3 (5)	Not defined	0.03 mg/Nm^3 (7)	Not defined	Not defined	0,03 mg/Nm^3	Not defined

mg/Nm^3 = milligrams per normal cubic meter at 6%O_2 , 273,15°K and 1.013 bar except Indonesia – note 10

1. *Emission guidelines from World Bank IFC, 2008 Environmental, Health, and Safety Guidelines. (for DA areas (DA = Degradated Airshed = poor air quality)).*
2. *Generation capacity > 500MWe, from 1st Jan 2005 to 2016*
3. *Values in brackets 2004 – 2016)*
4. *Bold values for new plant after Jan 01 2017 Plant > 500MWe*
5. *From German Regulation / 13. BimSchV,*
6. *Increased to 200 in certain provinces.*
7. *From 2015*
8. *Reduced to 20 for certain regions.*
9. *Reduced to 50 for certain regions.*
10. *mg/Nm^3 = milligrams per normal cubic meter at 7%O_2 25°C and 1.013 bar.*

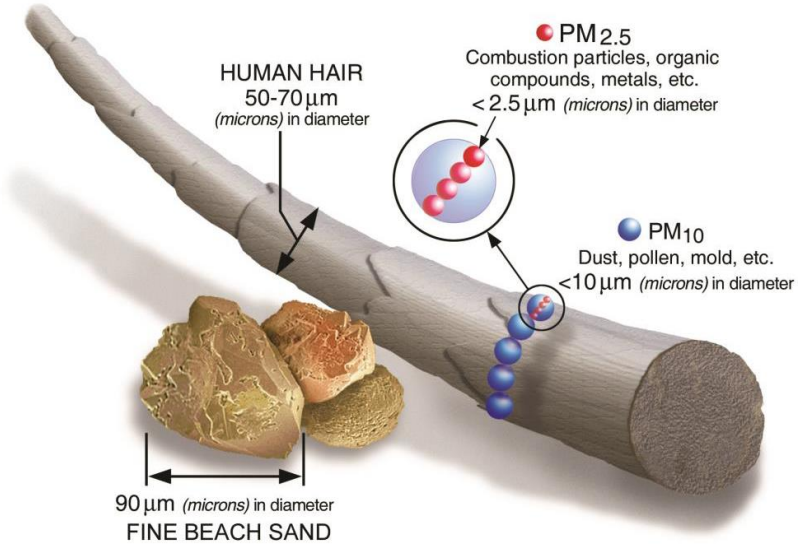
New Build Coal Fired Power Plant Trends Reducing Stack Emissions Limits

Future Ultra-Low Emission Limits

- Drive to even lower emission limits for NOx, SOx and PM – eg new South Korean limits:
  - PM – 5 mg/Nm^3
  - SO_2 – 25ppm (71.5 mg/Nm^3)
  - NO_2 – 15ppm (30.8 mg/Nm^3)

$PM_{2.5}$

- In most countries particulate matter from coal fired power plant is not distinguished by size at the stack, but may be distinguished in ambient air.
- $PM_{2.5}$ concern because of possibility for deep penetration to lungs.
- $PM_{2.5}$ classified as primary and secondary:
  - Primary is filterable fine particulate matter (eg fly-ash)
  - Secondary is formed by reactions of other pollutants (eg SOx, NOx, NH_3)



Source: US Environmental Protection Agency - EPA

Doosan State-of-the-Art Technologies for Boilers and Emission Controls

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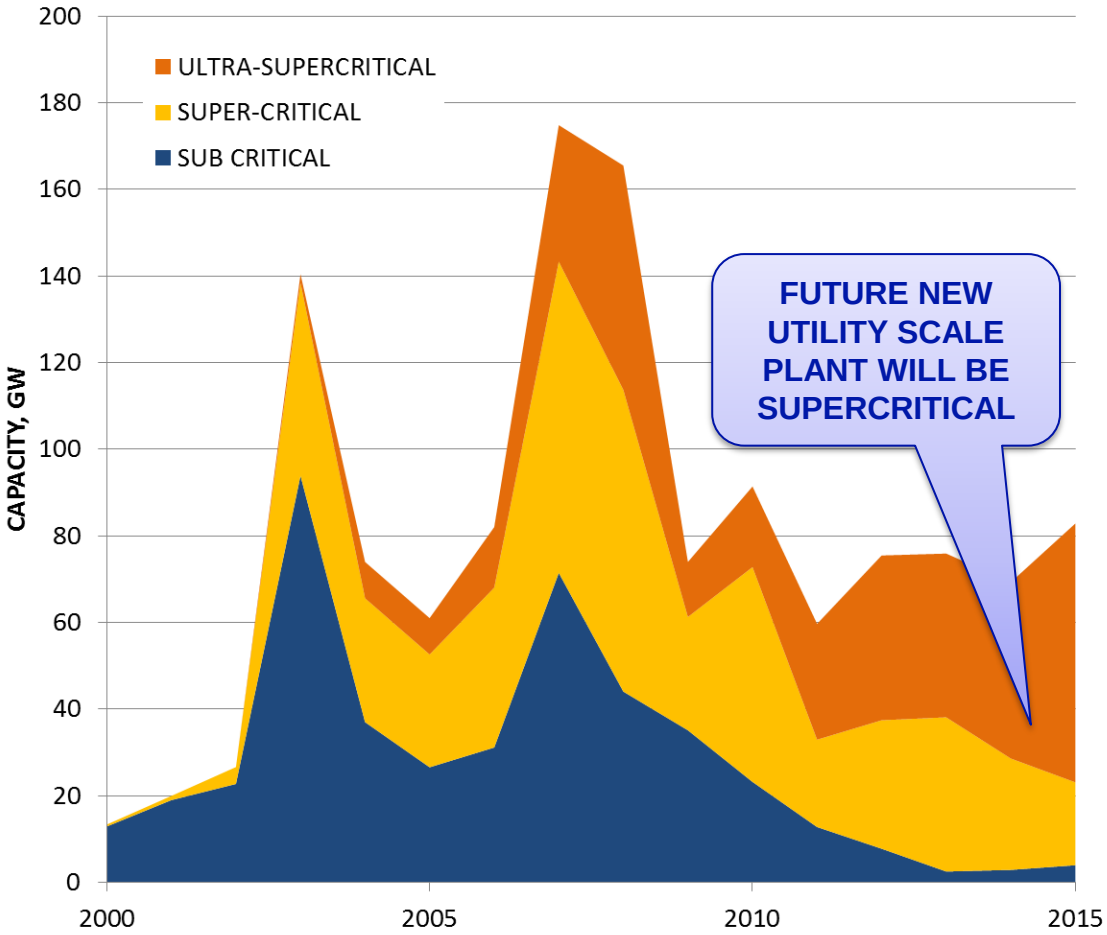
Ultra-Supercritical Boiler Technologies for High Efficiency

- Highest efficiency achieved via steam cycle optimisation by a combination of:
  - USC steam parameters at turbine inlet
  - Regenerative feedwater heating to increase boiler feed water temperature
  - Condenser pressure / LP Turbine last stage blade optimisation
- Emission reduction resulting from higher efficiency is substantial:

Parameter	Supercritical	Ultra-Supercritical
Main Steam Pressure / Temperature	245 bar / 565 C	280 bar / 600 C
Reheat Steam Pressure / Temperature	40 bar / 565 C	60 bar / 610 C
Net Plant Efficiency (% LHV)	41.8	44.0
Emissions (CO_2 SO_2, NOx, PM)	Base	**-5%**



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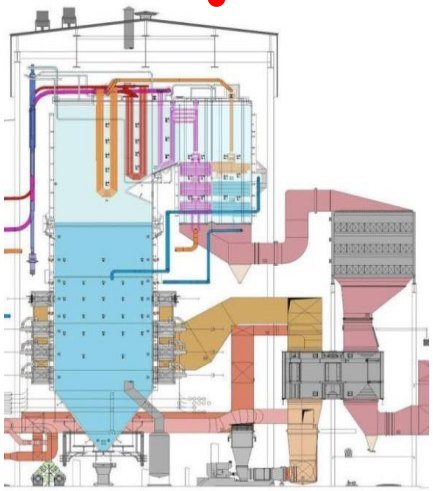
Ultra-Supercritical Boiler Technologies for High Efficiency

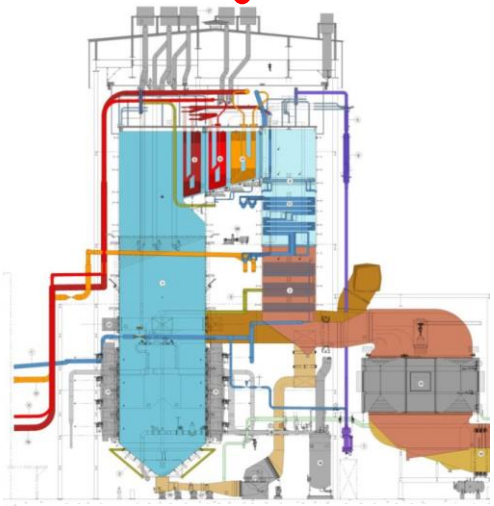
2011



GHECO-ONE, THAILAND

1 x 700MW
SH 569℃/ RH 569℃ 255 atg
Sub-bituminous Coal

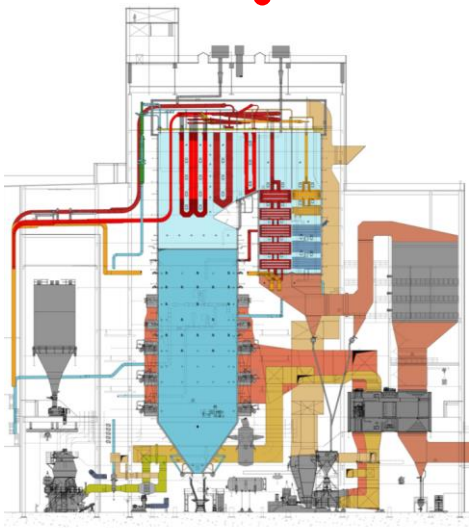
2014



AIN SOKHNA, EGYPT

2 x 650MW
SH 540℃/ RH 540℃ 265 atg
Mazout Oil

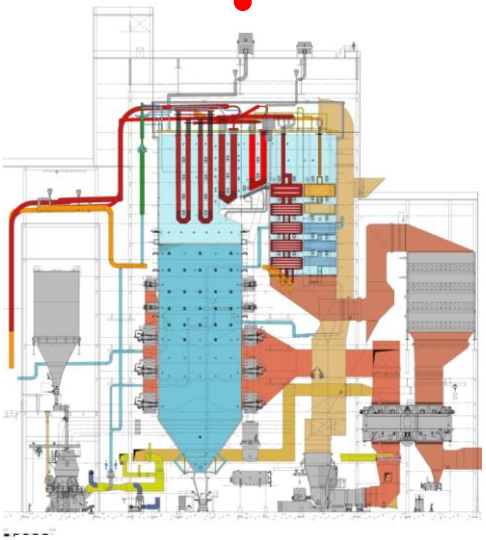
2015



YEONG HEUNG 5,6, S. KOREA

2 x 870MW
SH 569℃/ RH 596℃ 251 atg
Sub-Bituminous and Bituminous Coals

2016



SHINBORYEONG, S. KOREA

2 x 1000MW
SH 613℃/ RH 624℃ 274 atg
Sub-Bituminous and Bituminous Coals

EVOLUTION IN STEAM CONDITIONS

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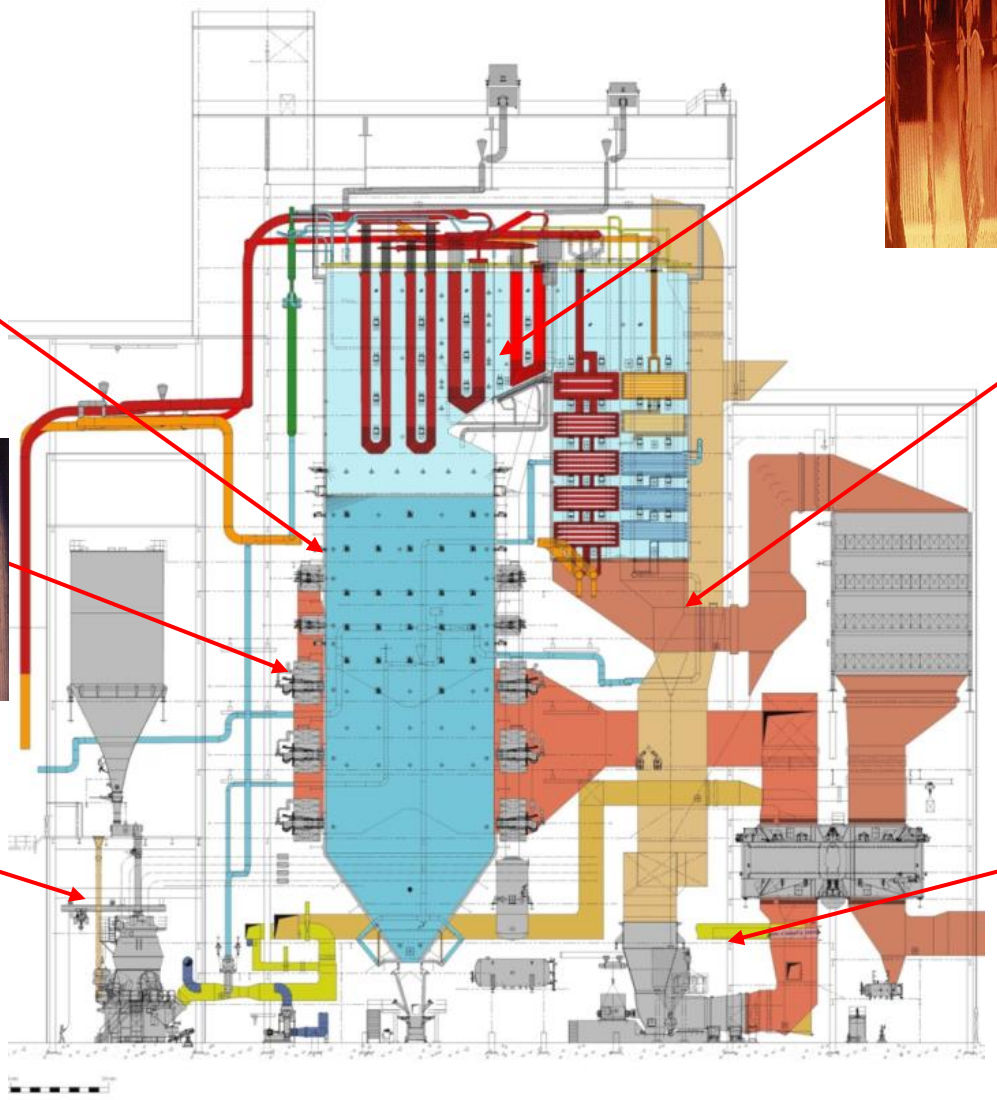
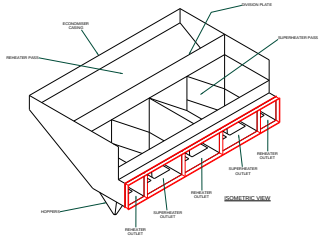
Ultra-Supercritical Boiler Technologies for High Efficiency
Boiler Features – 1000 MW Design

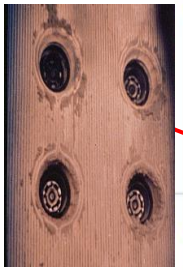


Proven Two pass arrangement (Pendent and Horizontal)

Stable RH steam temperature control for wide range coals with flue gas bias damper – higher efficiency at lower load



Once-Through boiler technology with proven lower spiral wall tube and upper vertical wall tube



High performance Low NOx burner And OFA

Vertical mills with dynamic classifiers

Proven capability for rapid starting with two shift operation
- 2 Axial FD fans
- 2 Axial ID fans
- 2 Axial PA fans
- 2 Trisector AHs

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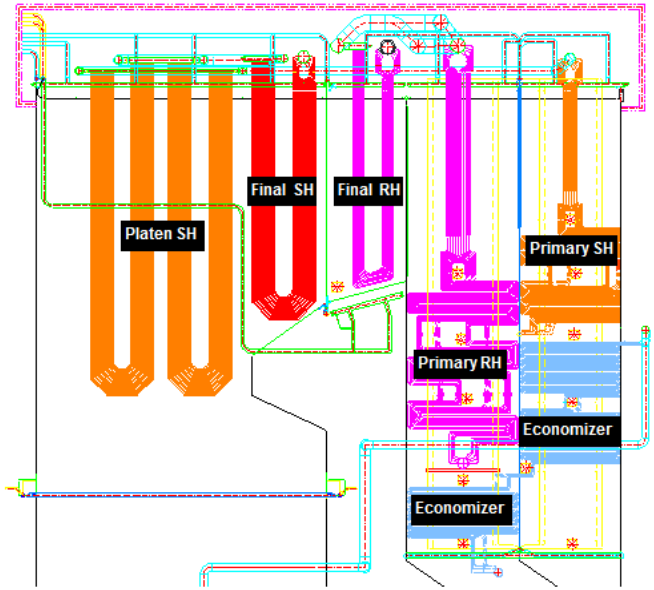
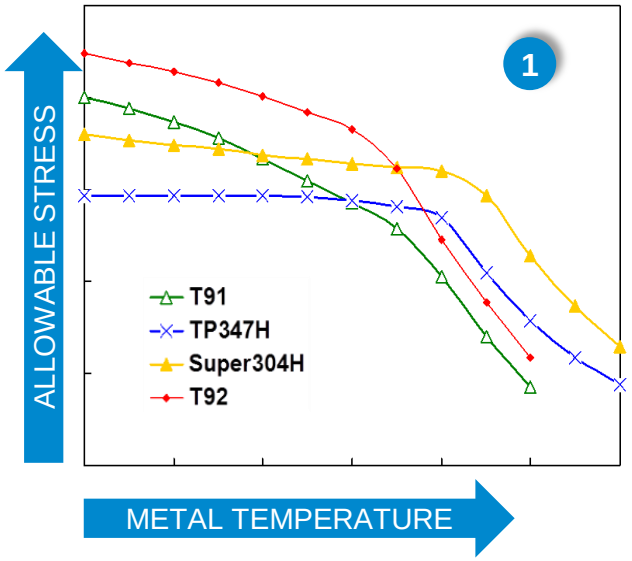
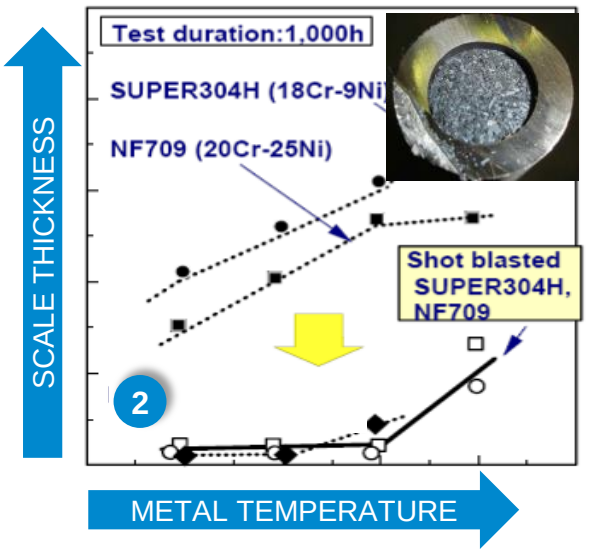
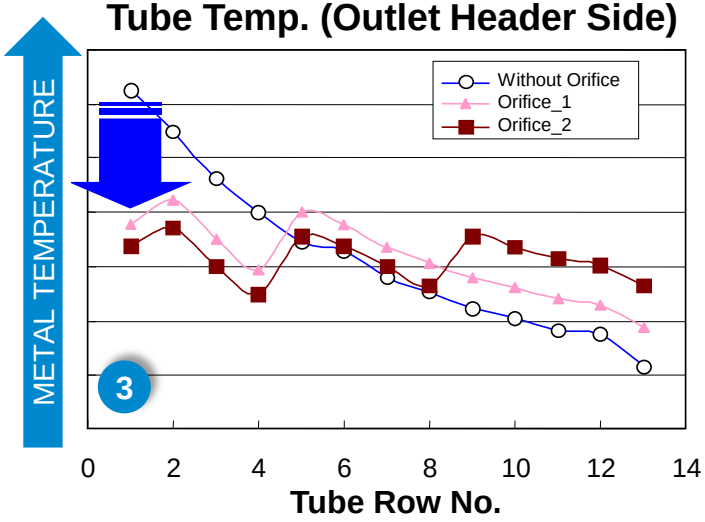
Ultra-Supercritical Boiler Technologies for High Efficiency Materials for USC Conditions



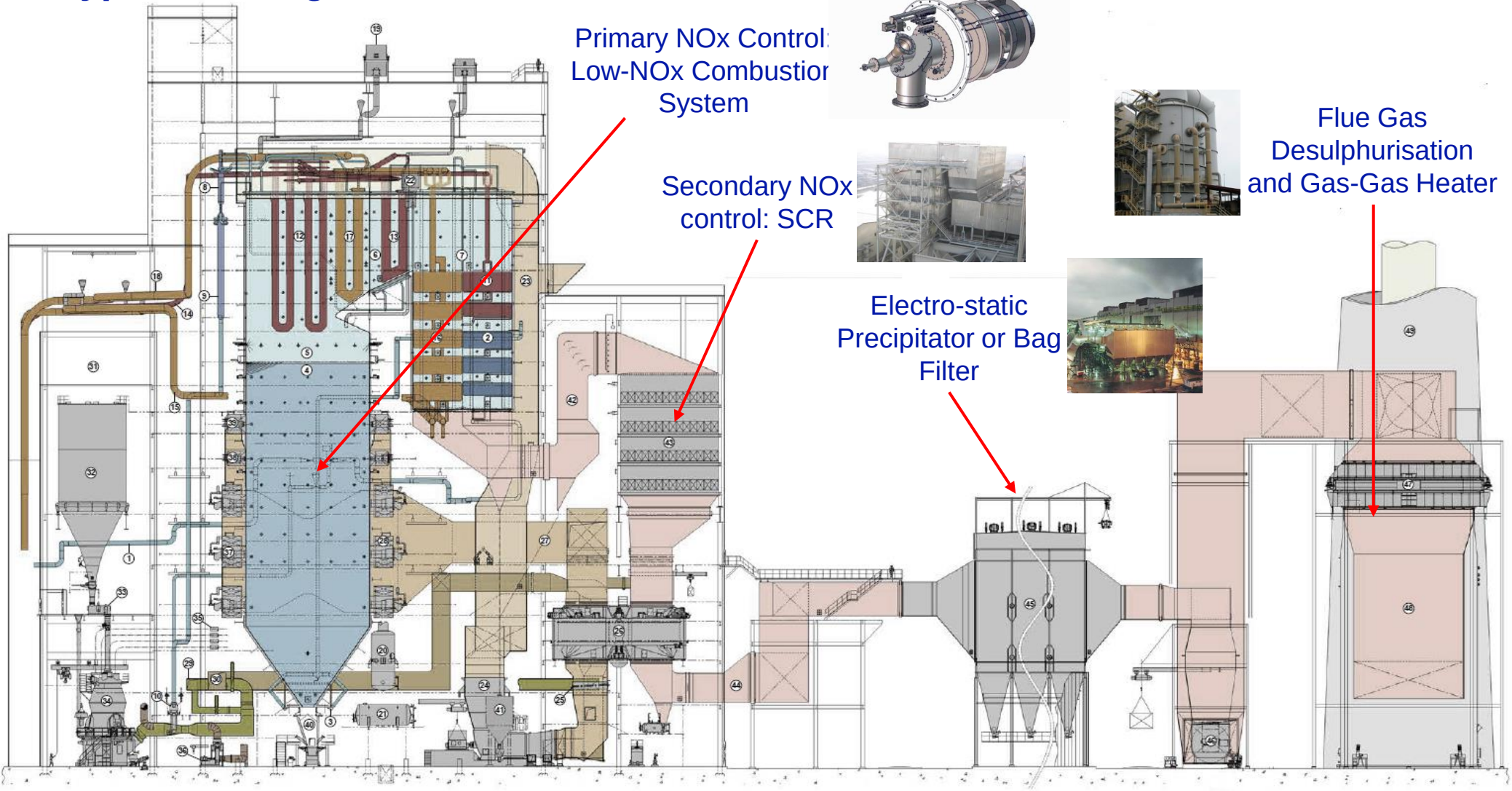




- Current USC steam parameters require a spectrum of ferritic and austenitic alloy steels for highest temperature components.
- Material selection mainly depends on (1) strength as a function of tensile and creep properties and (2) resistance to steam side oxidation.
  - Careful design of flow distribution can reduce operating conditions (3)



State-of-the-Art Emissions Controls Technologies
Typical Arrangement on Modern Plant



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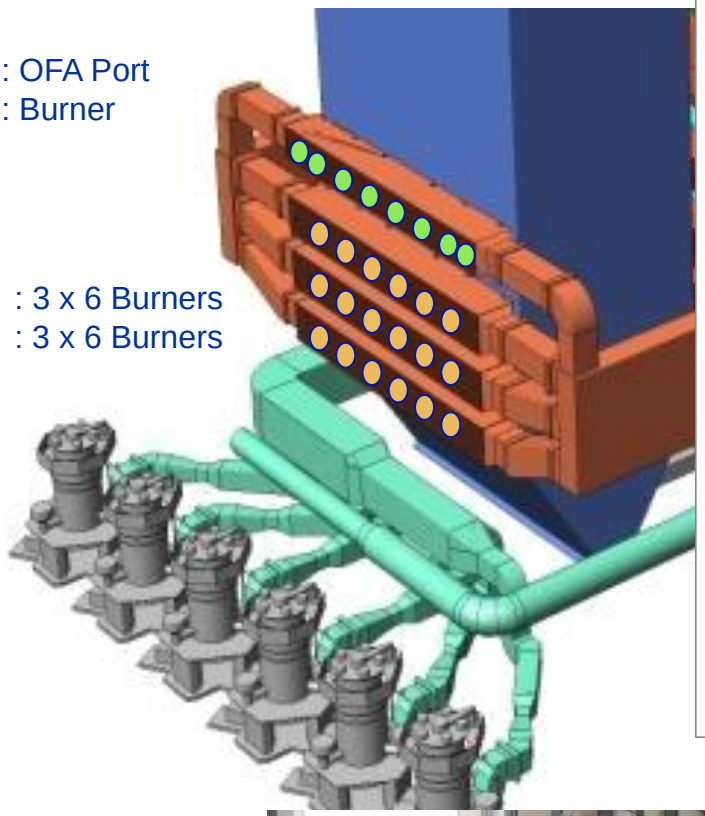
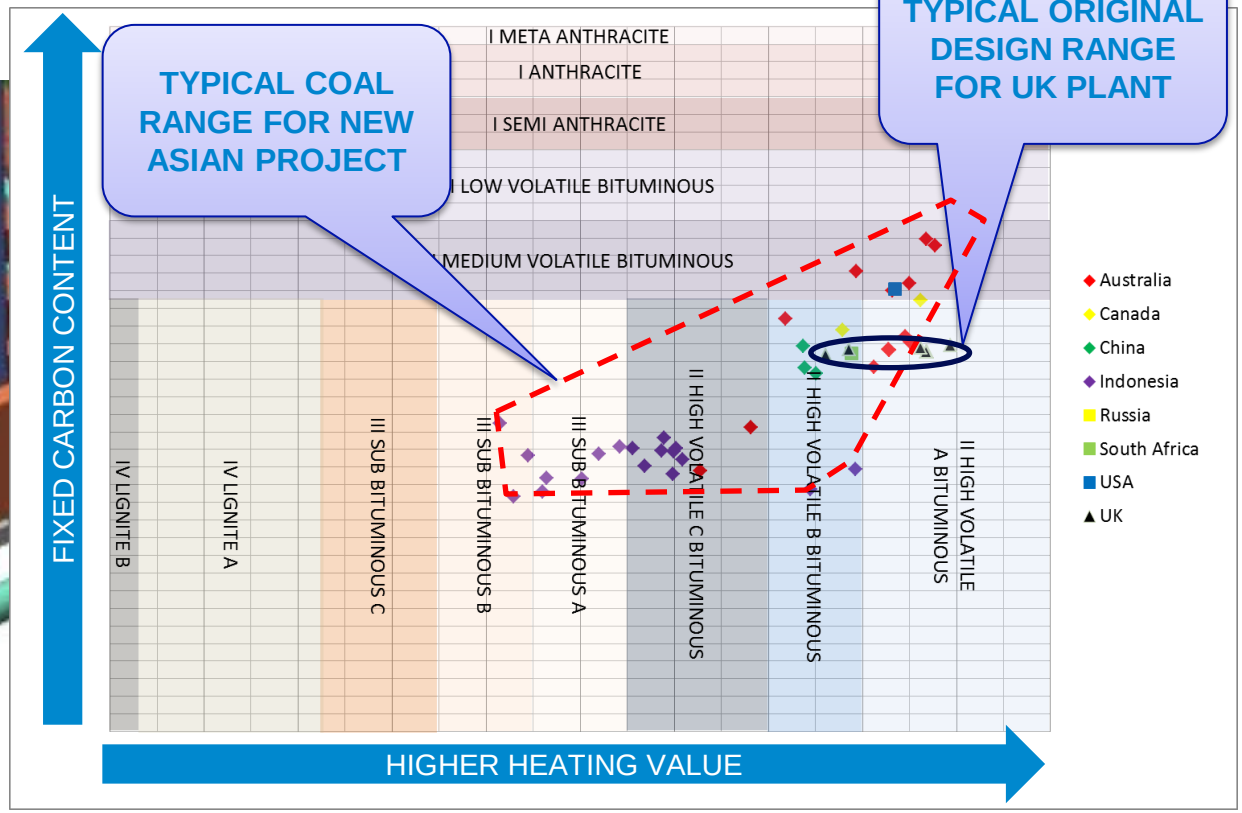
State-of-the-Art Emissions Controls Technologies
Primary NOx Control

: OFA Port
: Burner

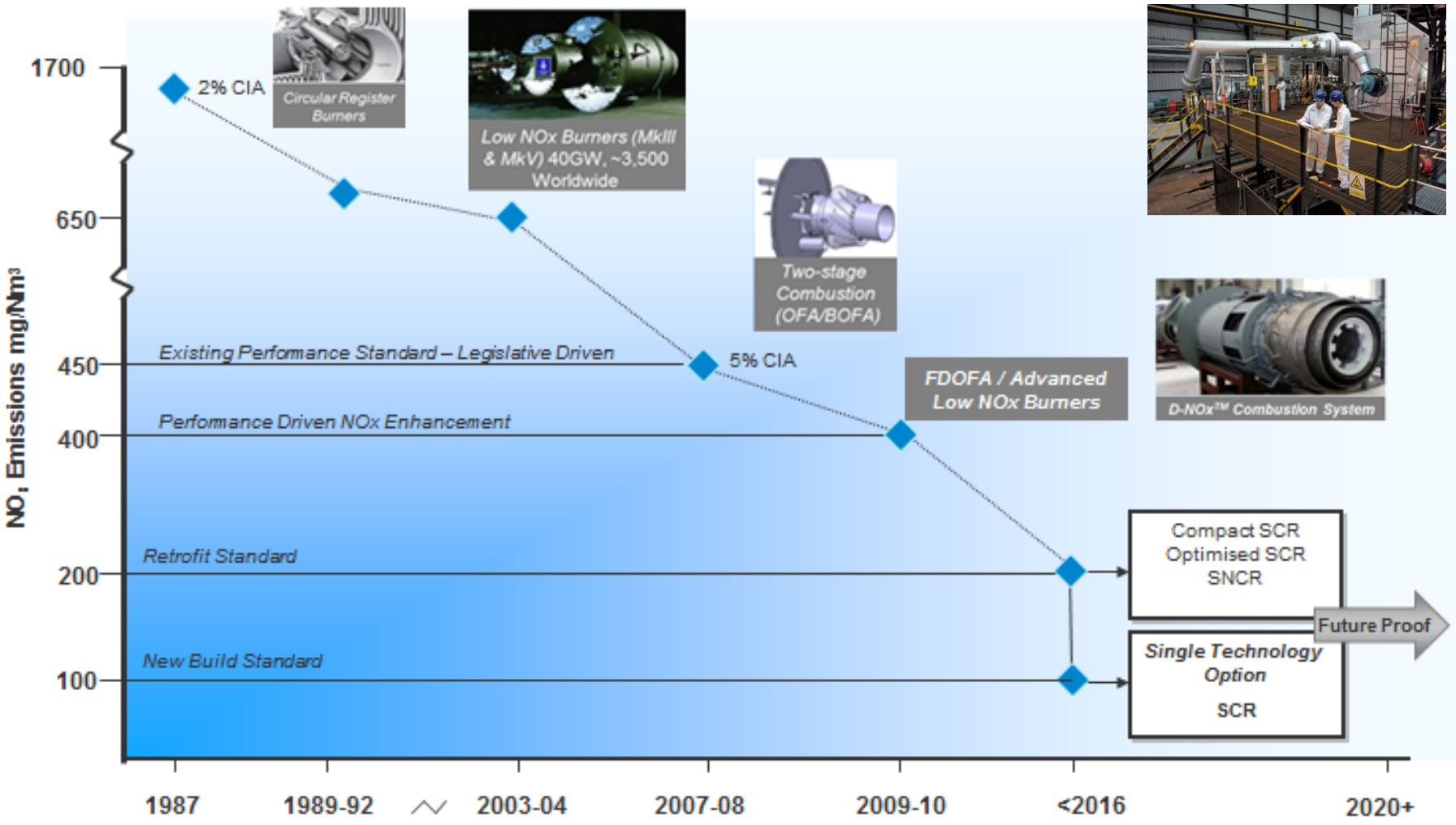
Front : 3 x 6 Burners
Rear : 3 x 6 Burners





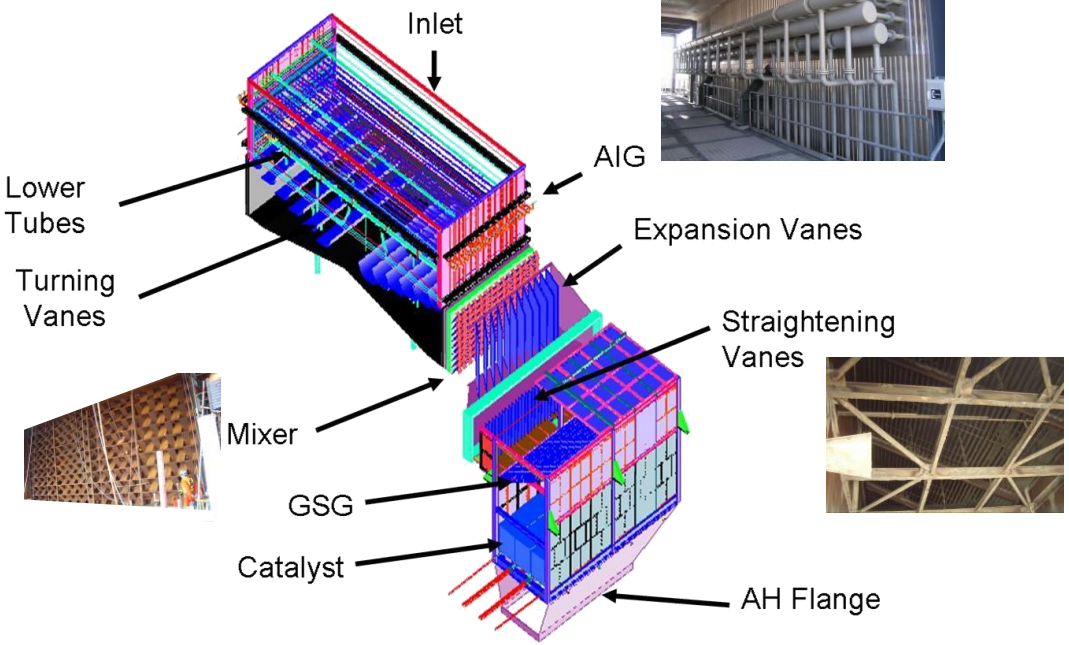
- Project fuel ranges become ever wider to ensure flexibility to accommodate changes in international coal sourcing.
- Mature low NOx combustion systems deliver primary NOx reduction
  - Current performance expectation circa 200 to 300 mg/Nm^3 NOx with <3% Carbon in Ash

State-of-the-Art Emissions Controls Technologies
Primary NOx Control



State-of-the-Art Emissions Controls Technologies
SCR for NOx Control

- Capable of up to 80-90% NOx reduction



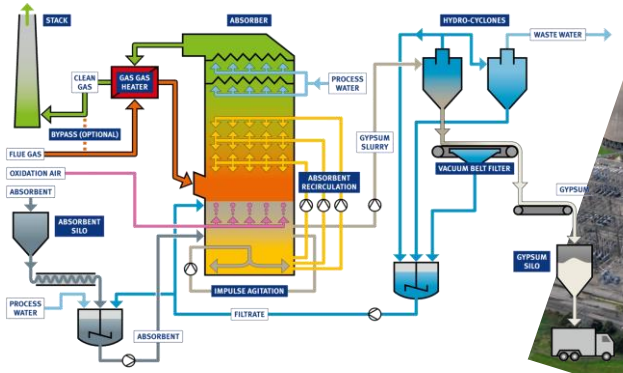
Case Study:
Ratcliffe, United Kingdom
4 x 500 Mwe Units

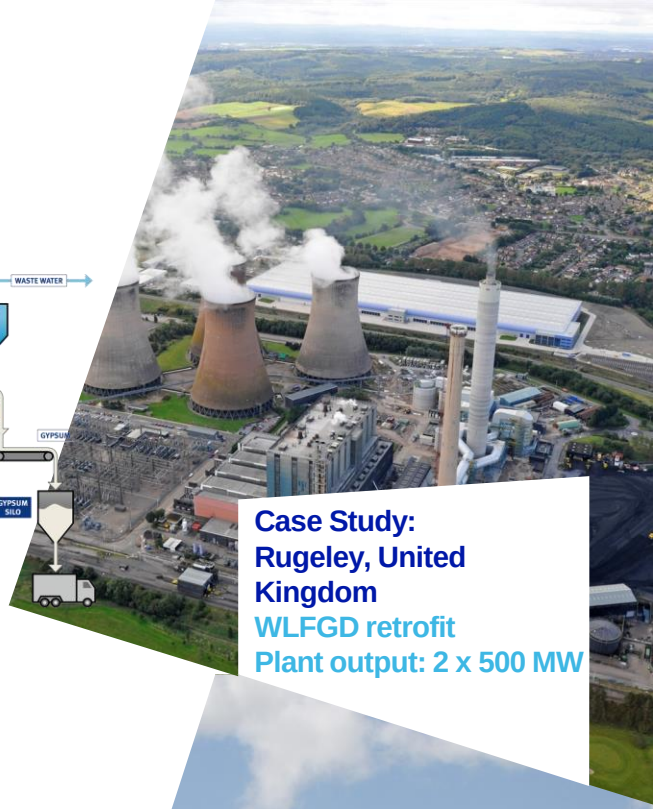
Case Study:
Castle Peak B, Hong Kong
BOFA System for Primary NOx control
Compact "In-Duct" SCR Arrangement

State-of-the-Art Emissions Controls Technologies
Flue Gas Desulphurisation

Wet Lime / Limestone FGD

- 205 absorbers installed (110 absorbers in China)
- 71 GW_e total capacity
- Maximum absorber size: 1,000 MW_e





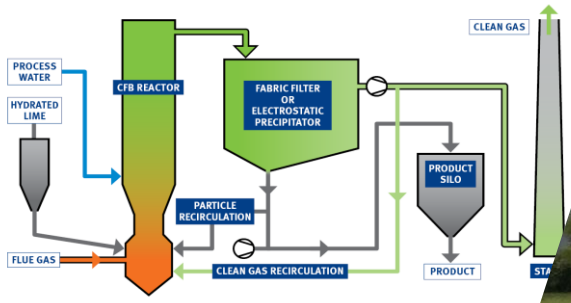
Case Study:
Rugeley, United Kingdom
WLFGD retrofit
Plant output: 2 x 500 MW

Seawater FGD

- 14 absorbers installed
- 8 GW_e total capacity
- Maximum absorber size: 700 MW_e

Circoclean® FGD / FGC

- 90 reactors installed (18 reactors in China, 26 in the USA)
- 13 GW_e total capacity
- Maximum reactor size: 305 MW_e



Case Study:
Lanesborough / Shannonbridge, Ireland
1 x 100 MW / 1 x 150
Circoclean ® FGD units

State-of-the-Art Emissions Controls Technologies
CO_2 Capture and Storage

Oxy-Coal

Full Scale Burner Test

- 40MWt
- Safe and stable operation over a wide operational envelope and smooth transition between air and oxyfuel firing achieved.

Pilot Plant Test – Vattenfall Europe

- 30MWt
- 2500 hrs on Oxy-Firing
- Automatic transition between air and oxy firing

PCC

Pilot Test, 1 t/day

- Ability to test wide range of coals and other fuels
- High degree of flexibility and accuracy to test wide range of solvents and other modifications

Ferrybridge, 100 t/day

- Largest post carbon capture demonstration plant in the UK
- Long-term testing and validation of process and solvent performance
- Evaluate transient conditions and process control
- Extensive monitoring planned

Conclusions

- Energy demand growth in Asia, India and some other regions continues to drive investment in new coal fired power plants.
- Ultra-Supercritical Technology with steam temperature > 600C is now state-of-the-art with unit sizes between 350MW and 1000MW – project developers and financers are implementing this technology with consequent increase in efficiency and reduction in emissions for new coal fired fleet.
- Emissions legislation is rightly becoming increasingly stringent, both in emission limits and in scope albeit with some regional anomalies.
- State-of-the-art emissions control technologies can meet the requirements of the current legislation, project developers and financers. However, the time is never more urgent for R&D efforts for ever greater emissions reduction.

Thank you

Questions?

david.smith2@doosan.com