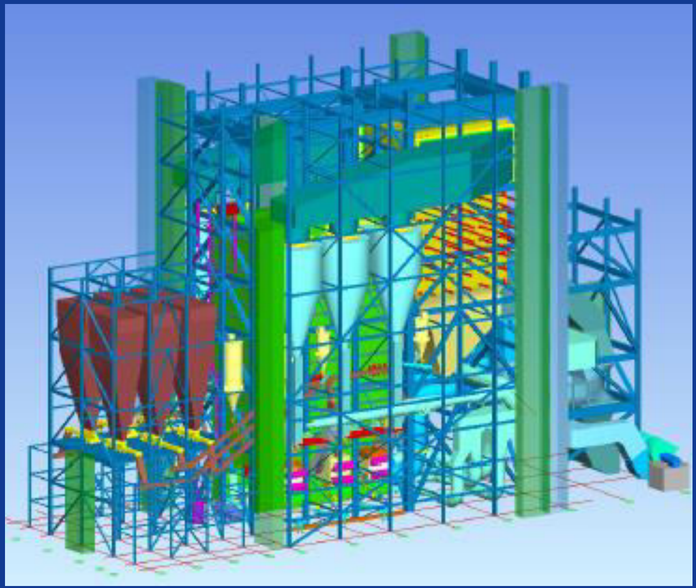
Adoption of USC CFB Technology to Achieving Lower Cost Generation and Environmental Sustainability.

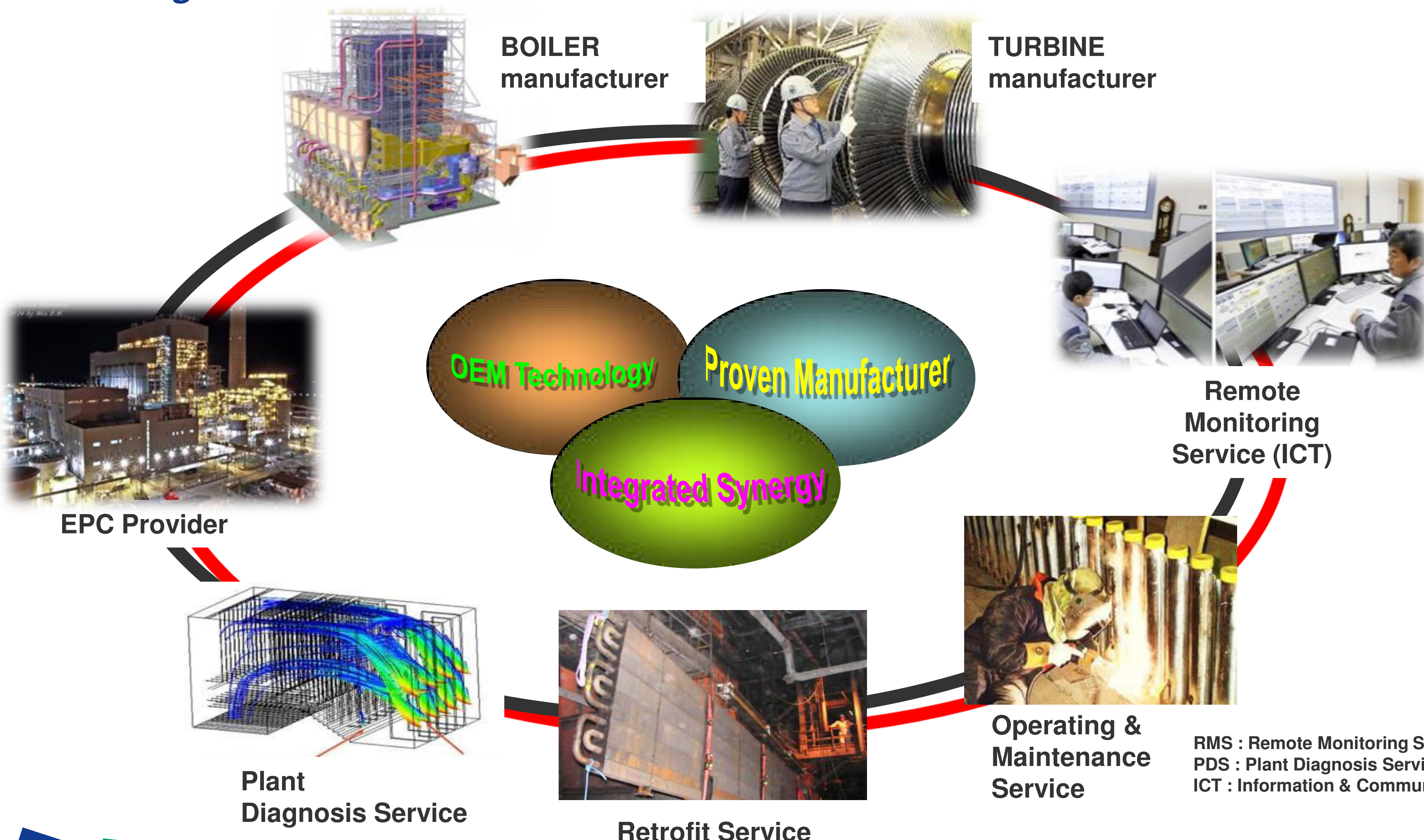


Gerd Heiermann & Douglas Spalding

14 November 2014 – EEC Conference Delhil

Doosan and India – a Total Solution Provider

Doosan returns more benefit and value to clients in India as a total solution provider integrating 'state-of-the-art' OEM technology and aftermarket retrofit & service with proven & professional manufacturing.



RMS : Remote Monitoring Service
PDS : Plant Diagnosis Service
ICT : Information & Communication Technology

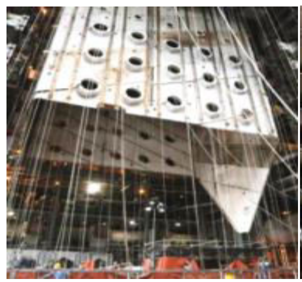
DOOSAN

Part of the Doosan Group

Doosan Group

Doosan Heavy Industries & Construction

Business Groups

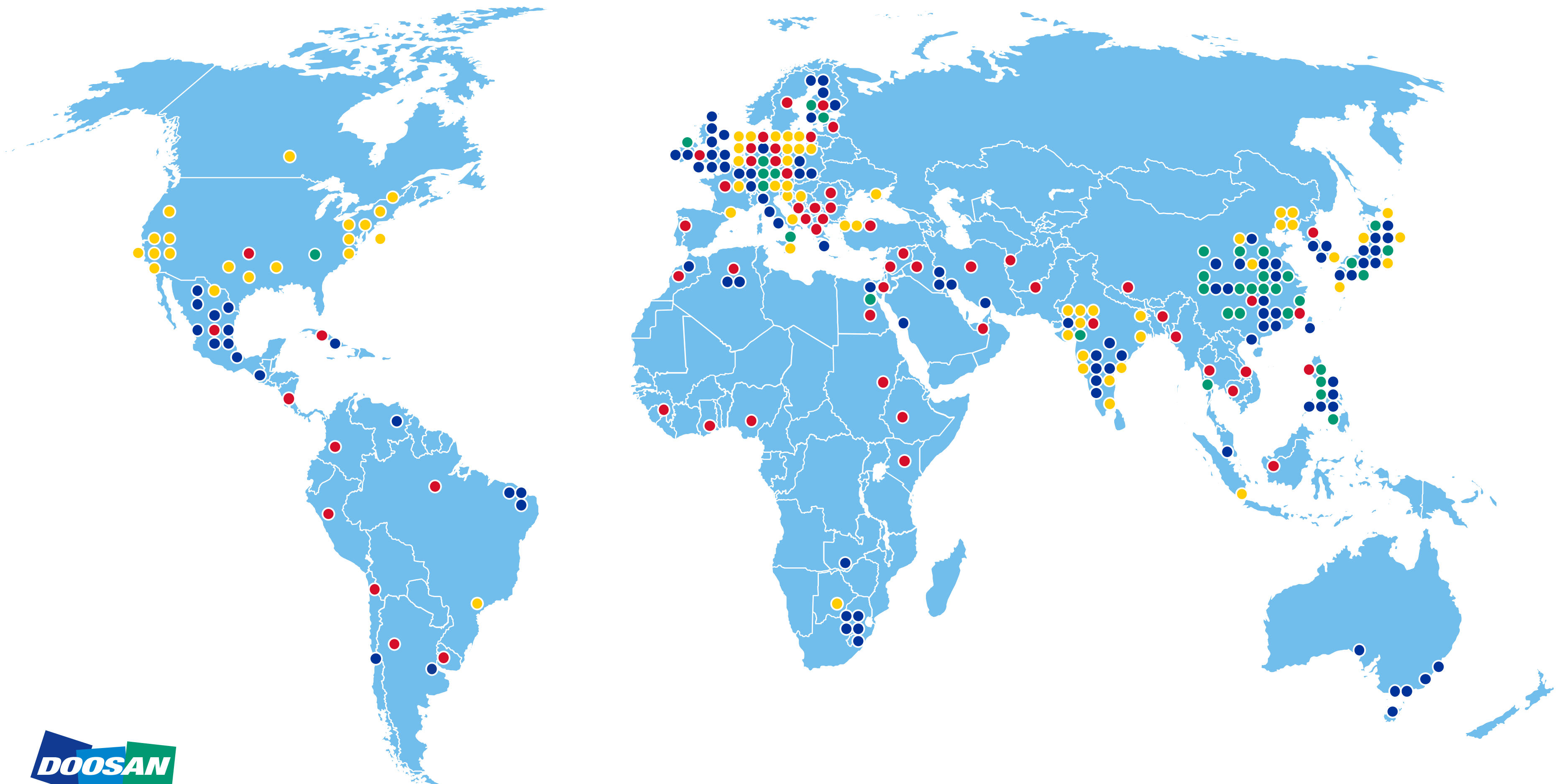
Casting and Forging	Nuclear	Boiler	Turbine	EPC	Water
					

	Turnover (2013)	Employees (2013)
Doosan Group	14.4 Billion €	43 000
Doosan Heavy Industries & Construction	12.8 Billion €	7300

References

References to date

■Supercritical PC boilers	52,321MWe	■Subcritical CFB	21,528MWth
■Subcritical PC boilers	123,086MWe	■Turbines	60,000MWe



Doosan Lentjes Product Lines

Tisova, 100MWe
Czech Republic

CFB

Circulating Fluidised Bed

REC Harlingen, NL,
280.000 t/a; 1 line

WtE

Waste-to-Energy

Oroszlany, Hungary
240MWe Wet Stack

APC

Air Pollution Control

Doosan Lentjes is the global center of excellence for engineering, procurement and construction for CFB, WtE and APC having its own R&D center:

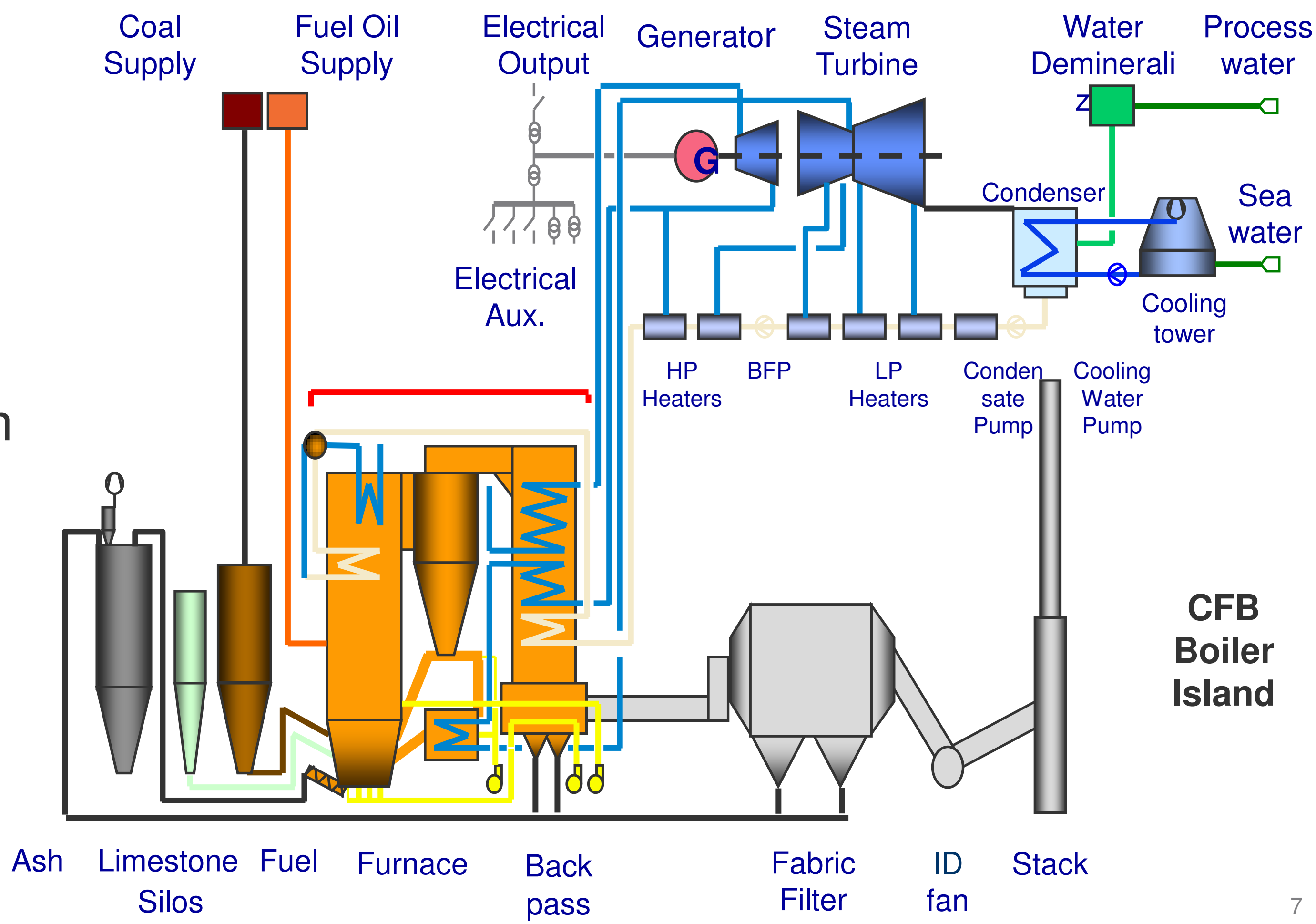
- ***Top tier level CFB OEM technology***
- *References : 113 units (22 GWth, max. 280 MWe)*

- ***Top tier WtE OEM technology***
- *References **:** 77 units (9 mill t/a, max. 35 t/h)*
- *Chute-to-stack or full turnkey supply solutions*

- **Various FGD portfolio OEM technology**
- **R***eferences :*
  - *Wet FGD : 205 units (71 GWe, max. 1,000 MWe)*
  - *Seawater FGD : 10 units (6 GWe, max. 700 MWe)*
  - *CFB FGD : 87 units (13 GWe, max. 305 MWe)*
  - *SCR DeNO$_x$*
  - *Fabric Filters and Electrostatic Precipitators*

CFB Similarities – Subcritical to USC CFB

- USC CFB Cycle primary difference from the Subcritical cycle shown is the introduction of ‘once-through’ technology
- Adopting ’Once Through’ Posiflow vertical combustor tube technology from PC boilers for the water/steam circuit allows the USC CFB design to benefit from higher efficiency
- Design of solid loop similar to subcrit CFB boiler



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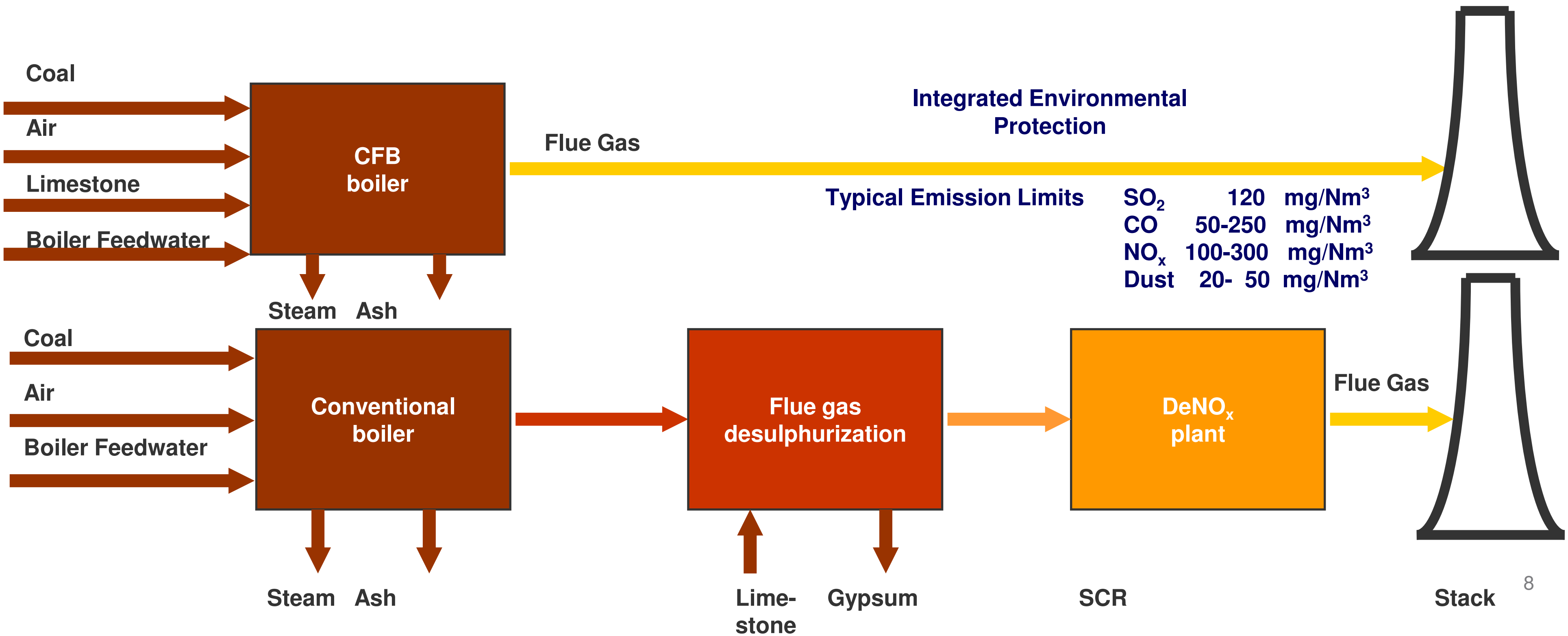
USC CFB Lower Cost Than USC PC Where APC is Needed

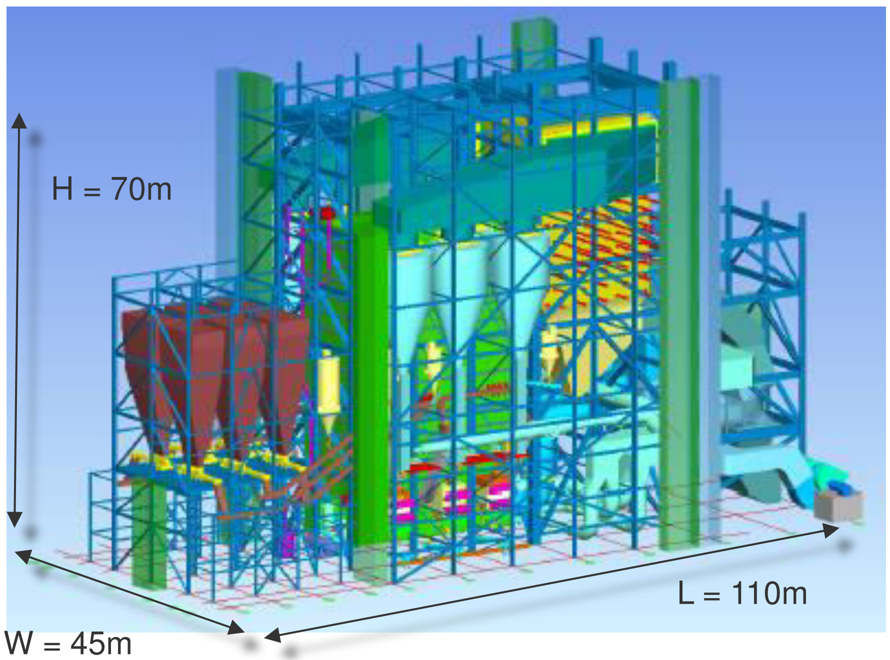
- Integrated Environmental Protection resulting in lower cost generation with less APC.



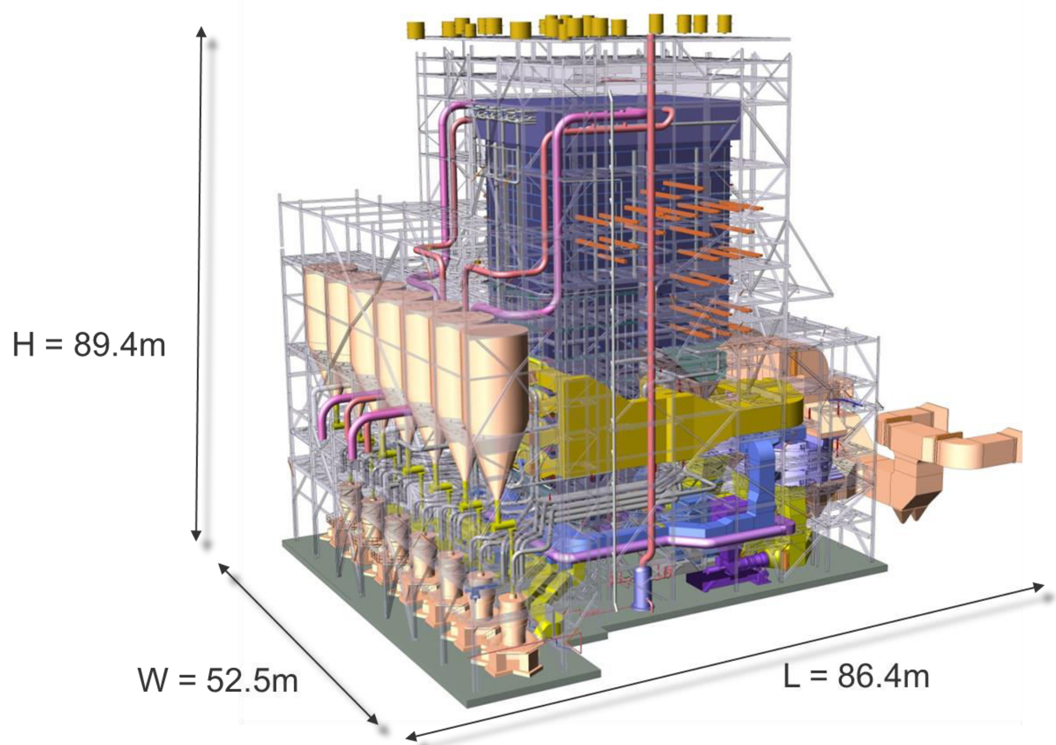
USC CFB More Compact Than USC PC

USC CFB is more compact than PC (with FGD)

600MW USC CFB Reference (Indonesian Sub-bituminous)
Design Footprint = 4950m²



600MW USC PC Boiler (Indonesian Sub-bituminous)
Footprint = 5440m² includes FGD@ 900m²
(Based on Dongbu Green 2x580MW)



CFB More Suited to a Wide Array of Fuels and Fuel Switching.

- Where fuel switching covers a wide range from high CV world traded bituminous to low cost high ash, high moisture or high slagging coals, CFB offers capex, reliability and fuel saving advantages over PC fired units

Fuel Experience	Carb-on %	Sulp-hur %	Ash %	Moist-ure %	H.V. MJ/kg
Biomass	20	0.03	2	40	15
Oil Shale	13,8	0,4	73,7	5,0	4,95
Anthracite Culm	44,8	0,8	45,1	15,0	6,85
German Brown Coal	27,2	1,7	7,0	52,8	9,17
Gujarat Lignite	43,3	< 2,5	19,0	24,0	16,50
Kentucky Coal	63,7	4,0	12,9	4,7	20,05
Anthracite	59,6	1,8	25,2	10,0	20,70
Petcoke / Texas	82,0	4,5	2,7	7,3	31,80

USC CFB Concept Development - Economics

- 600 MW gross is targeted for USC CFB development and Korean demonstration
- Demonstration plant economic modelling by 3rd party confirmed 2 year payback advantage dominated by CFBC fuel flexibility advantage

	NPV $m*	IRR* %	LCOE* $/MWh	Payback* Years
USC PC	153	5.6	46.54	15
USC CFB	431	6.5	42.48	13

- Analysis assumed,
  - 30 years operation from COD
  - Financing based on Gov't funded not project financed model. (No interest during construction, NPV calculated from COD and not from NTP)
  - Similar plant efficiencies/utilisation of PC and CFB assumed
  - NPV difference based on fuel savings for USC-CFB comparing USC-PC-6000kcal@97$/t vs USC-CFB-4250kcal/kg@59$/t (i.e.-15%$/Gcal basis)
- Analysis needs to be qualified for Indian market requirements/conditions

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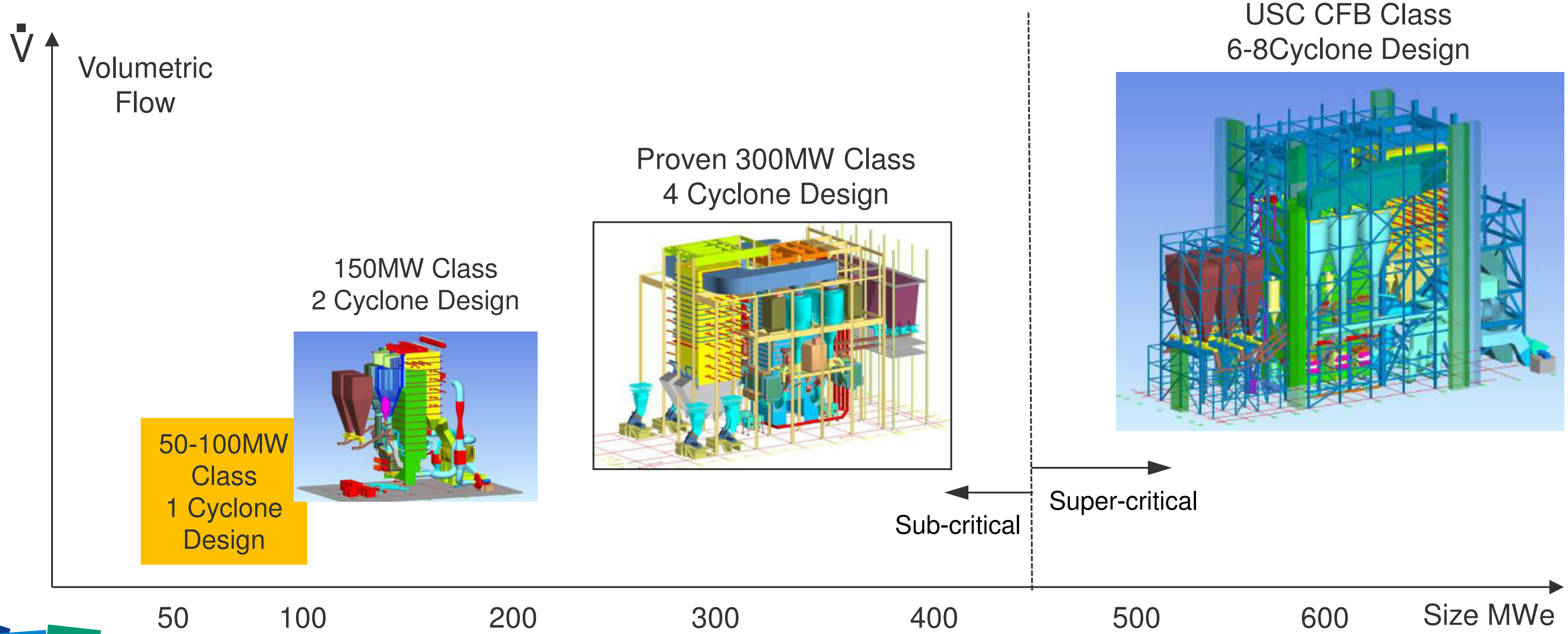
USC CFB Concept Development

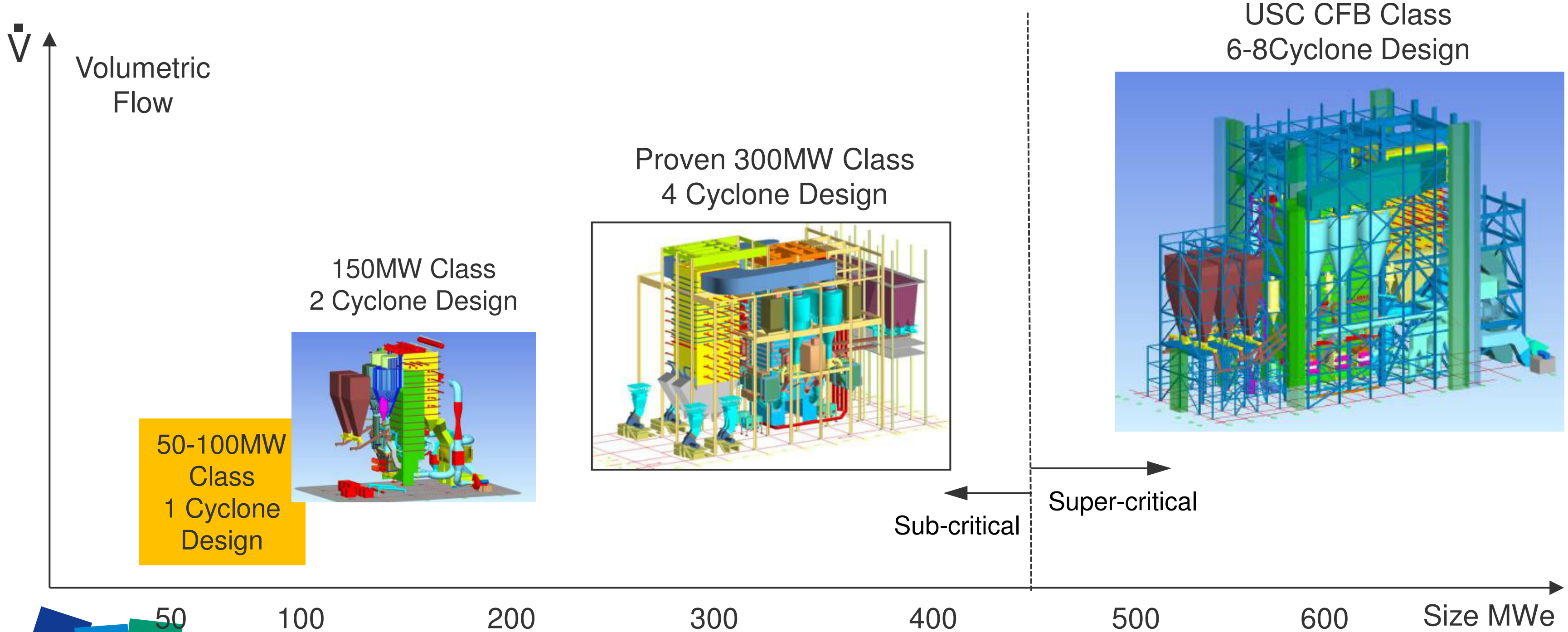
- Doosan has been developing a USC CFB product since 2012 in response to an emerging need for fuel flexible lower cost generation
- USC CFB builds on the modular design available for Subcrit CFB from 50-300MWe
- Concept study of modular design for USC/SC units up to 600MW and over completed in 2013
- 6 to 8 cyclone design foreseen dependent on output, fuel and site conditions.



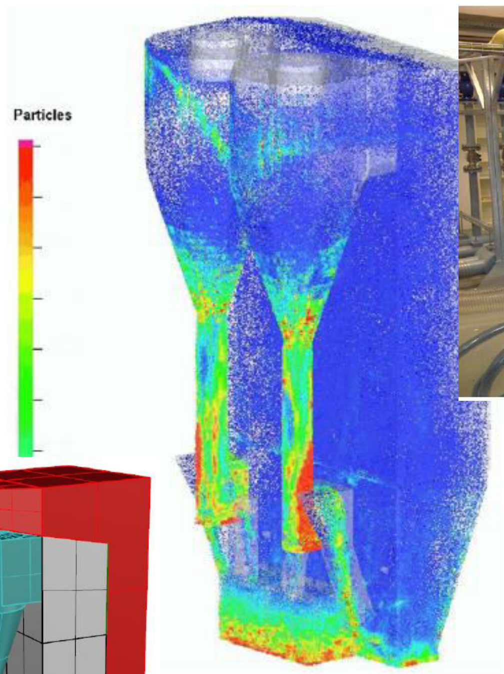
USC CFB Development Plan 1

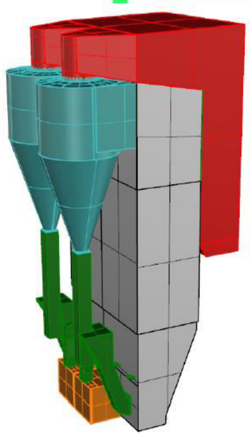
Doosan development plan go-ahead given August 2014. This will comprise,

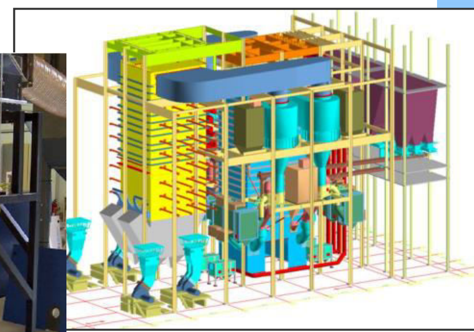
- Integration of USC PC and CFB technologies for better performance and emissions control
- Scale up of the combustor and introduction of ‘once through’ vertical furnace tube technology based on Doosan Babcock’s Posiflow design
- Value assessment of Fuel flexibility to Capex and whole life cost

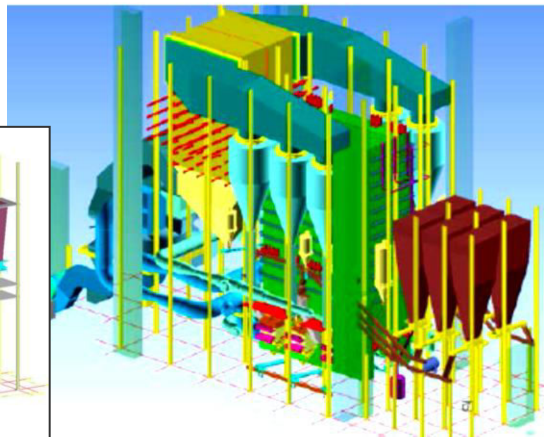


USC CFB Development Plan 2





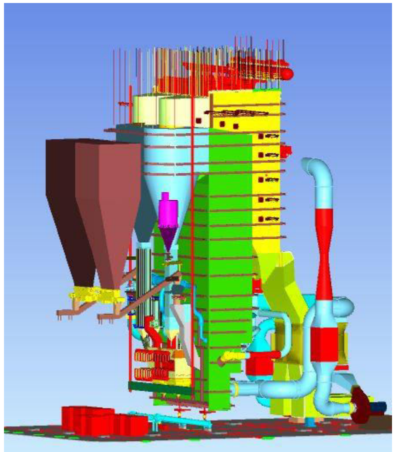




Development plan will also include,

- Validation of analytical results of heat transfer and gas/solid flow pattern
- Adoption of compact design approach from 150MW class.
- Design optimization for maximized fuel flexibility value and reliability

4 CYCLONE RPM → USC CFB



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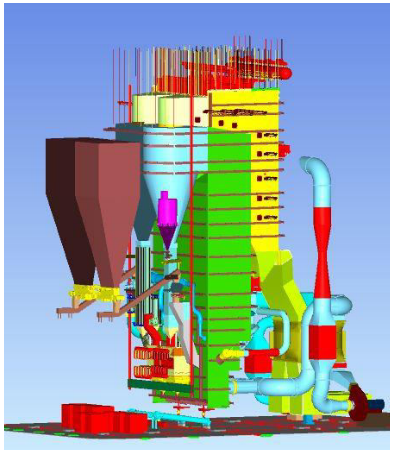

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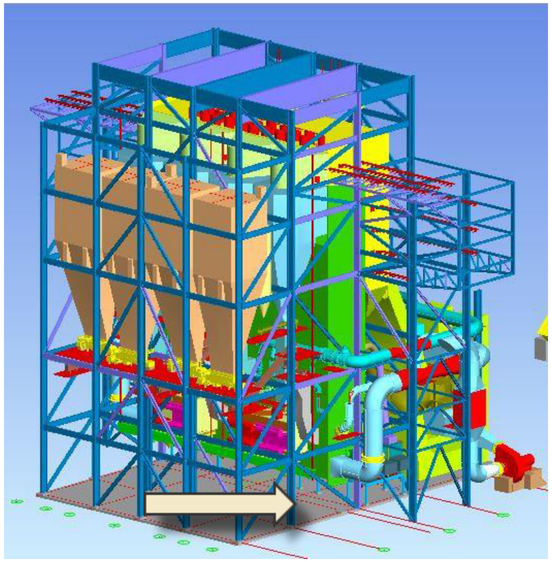
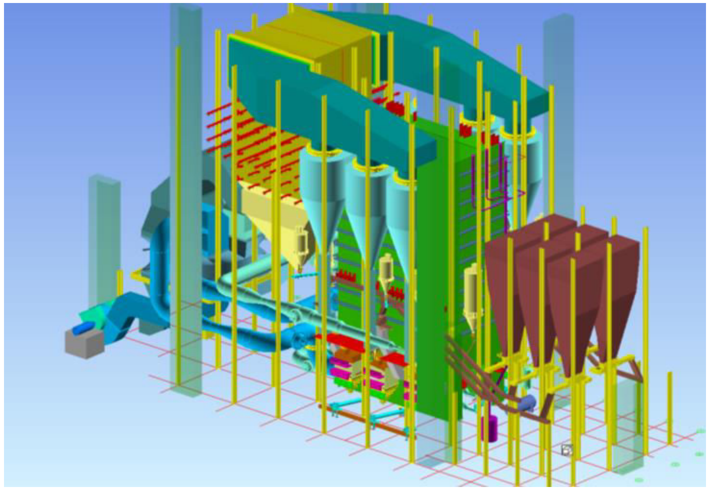


- Modularized 2 cyclone model to be adapted to 4 cyclone model



- USC CFB requires different platform however utilizes key modules of 4 cyclone CFB

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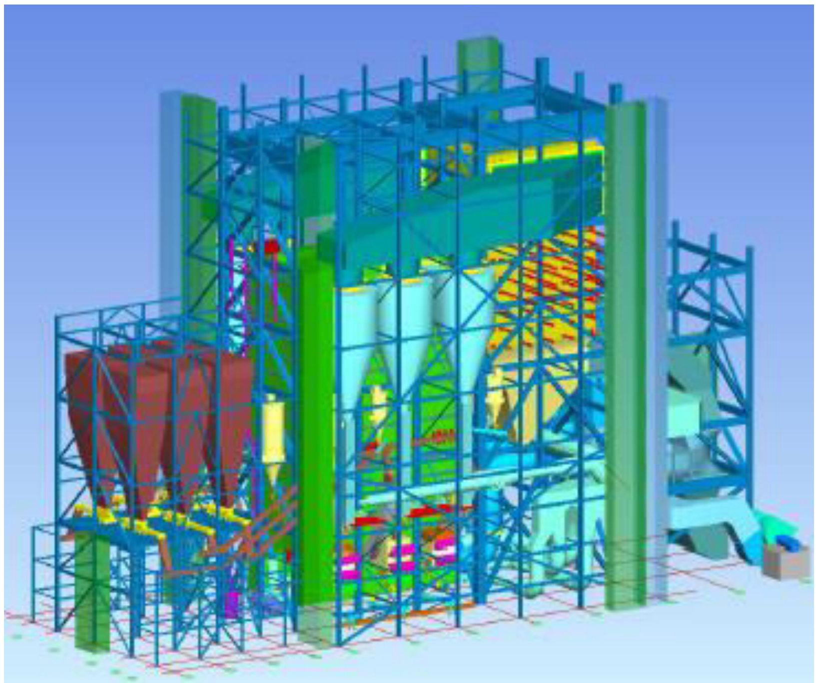
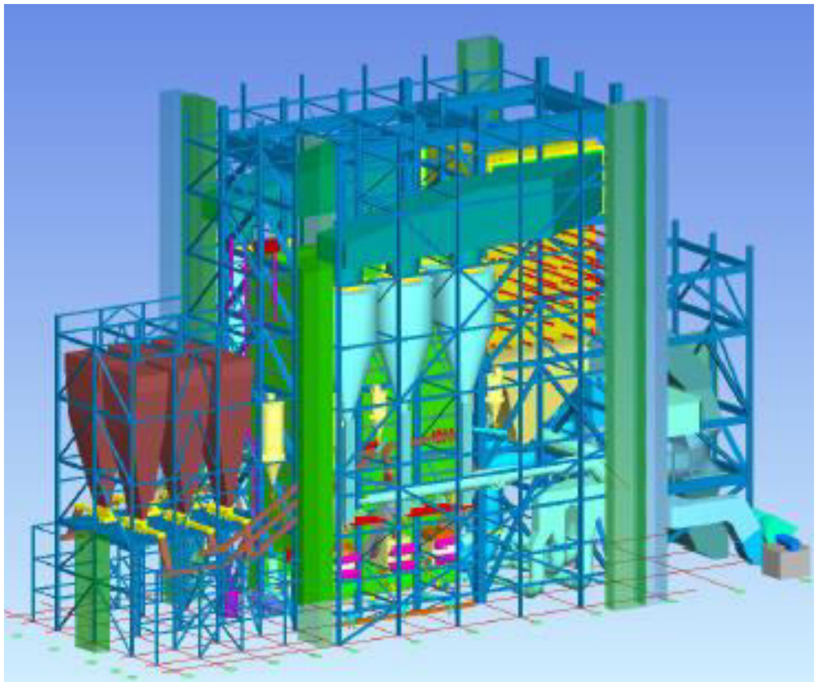
600MWe USC CFB Demonstration Project



Requirement	Target Value
Unit Size (MWe gross)	600
Location / Cooling / Arrangement	Coastal / Sea Water cooled, 6 Cyclones
Fuel – Indonesian LRC – GCV (kCal/kg)	4250
Main Steam Temperature (°C)	610
Main Steam Pressure (Barg)	280
Reheat Steam Temperature (°C)	621
Boiler Thermal Efficiency (%HHV)	>85
Boiler Availability (%)	>90
Outlet SOx (ppm@6%O2)	<50
Outlet NOx (ppm@6%O2)	<50
Outlet Dust (ppm@6%O2)	<15

660MWe USC CFB Concept Design for India



Requirement	Target Value
Unit Size (MWe gross)	660
Location / Cooling / Arrangement	Coastal / Sea Water cooled, 6-8 Cyclones
Indonesian Coal GCV (kcal/kg)	4250
Local Sourced Biomass GCV	3600
Main Steam Temperature	600ºC
Main Steam Pressure (Barg)	280
Reheat Steam Temperature	600ºC
Boiler Thermal Efficiency	>85 (%HHV)
Boiler Target Availability (%)	>90
Outlet SOx (ppm@6%O2) **	<120
Outlet NOx (ppm@6%O2)**	<100
Outlet Dust (ppm@6%O2)**	<50

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Conclusions

- Doosan Lentjes is currently scaling up its CFB boiler capability to 600MWe class for demonstration in South Korea with target steam conditions at Ultra-Supercritical levels. The plant design will couple CFB combustion design with proven supercritical boiler design.

- The USC CFB concept evaluated for demonstration will operate at 'state of the art efficiency levels and fuel flexibility that delivers a better payback than USC PC, resulting in lower cost generation.

- The Indian USC CFB design concept would target 660MWe unit sizes with application to coastal locations where whole life cost savings from fuel arbitrage and APC avoidance will deliver lower cost generation.

- The design concept for India may also accommodate locally sourced biomass for co-firing, supporting a more environmentally sustainable power plant solution.

Thank you

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