Staff Subcommittee on Electricity and Electric Reliability

NARUC Summer Policy Summit

Staff Subcommittee on Electricity & Electric Reliability and Staff Subcommittee on Clean Coal & Carbon Management

Chinese Clean Coal Technology

NARUC Summer Policy Summit

Chinese Clean Coal Technology

Moderator: Hon Jeremy Oden, Alabama

Presenter: Dr. Peter Chen, Forest Power & Energy Holdings

Chinese Clean Coal Technology

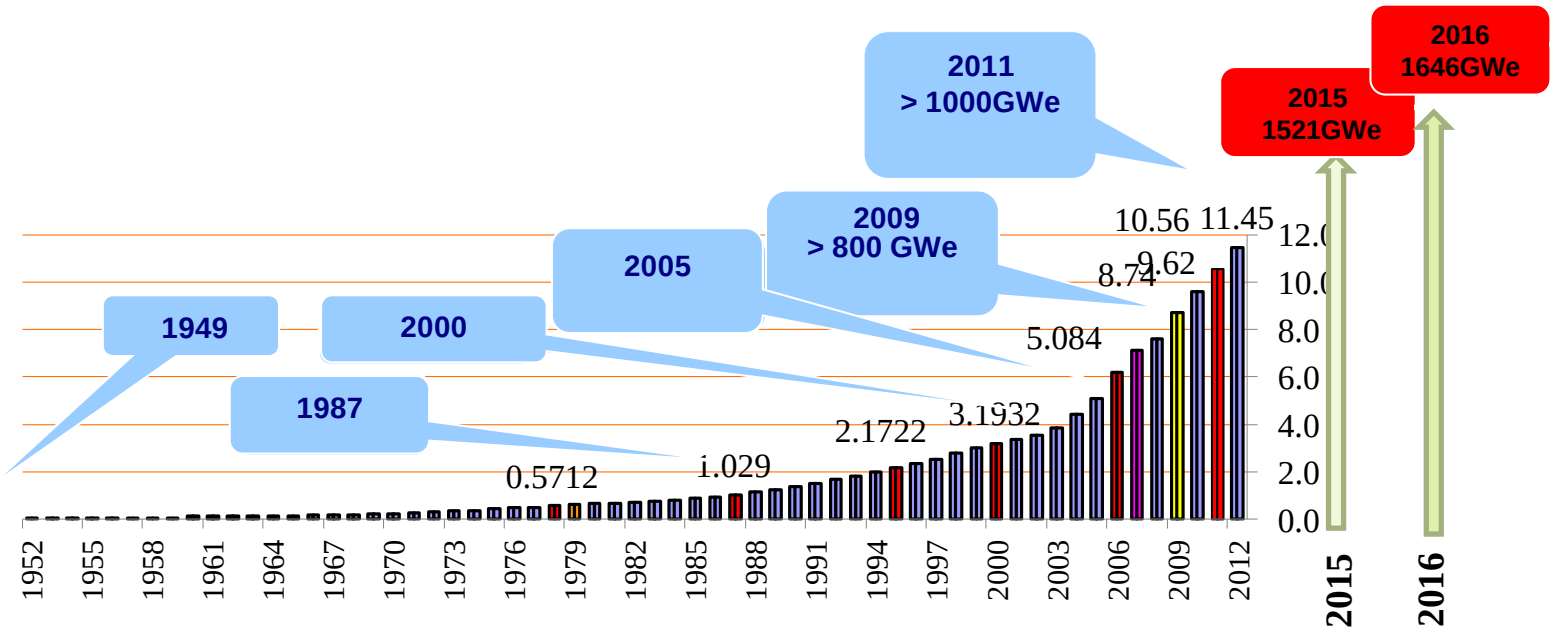
Peter Chen, PhD
Forest Power & Energy Holdings

NARUC Summer Policy Summit

July 16, 2017
San Diego

FOREST HOLDINGS

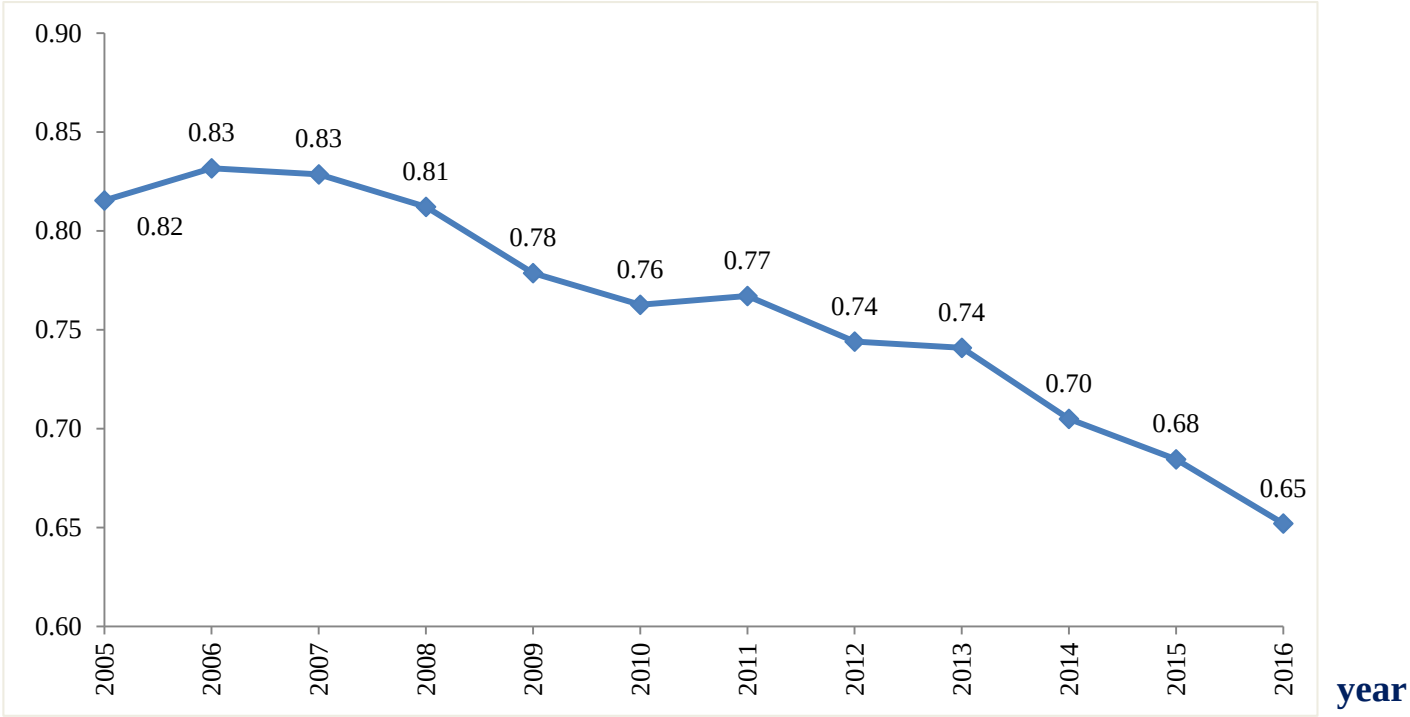
Growth of Total Installed Electric Power Capacity in China



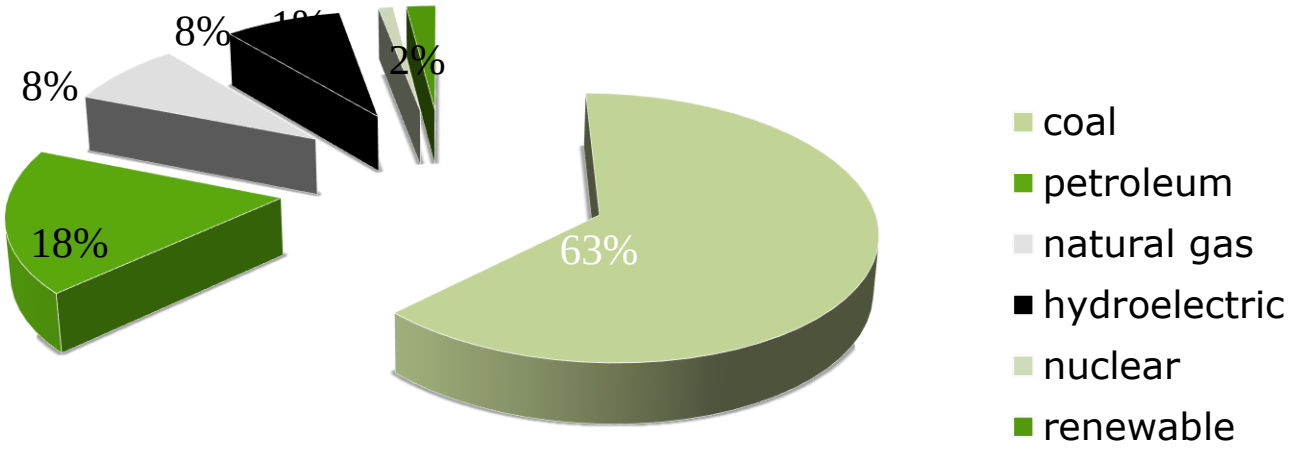
Ranking of Electricity Generation Capacity of China in the World

No.21 in 1949; No.8 in 1978; No.2 in 1996; No.1 in 2011

China coal power generation share by power source (2005-2016)



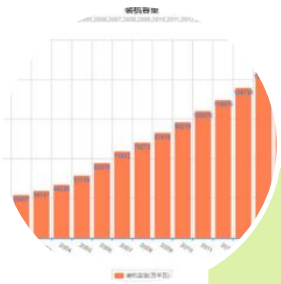
Energy Structure of China in 2015



Policy of “developing large units and suppressing small ones”

Qualitative Change

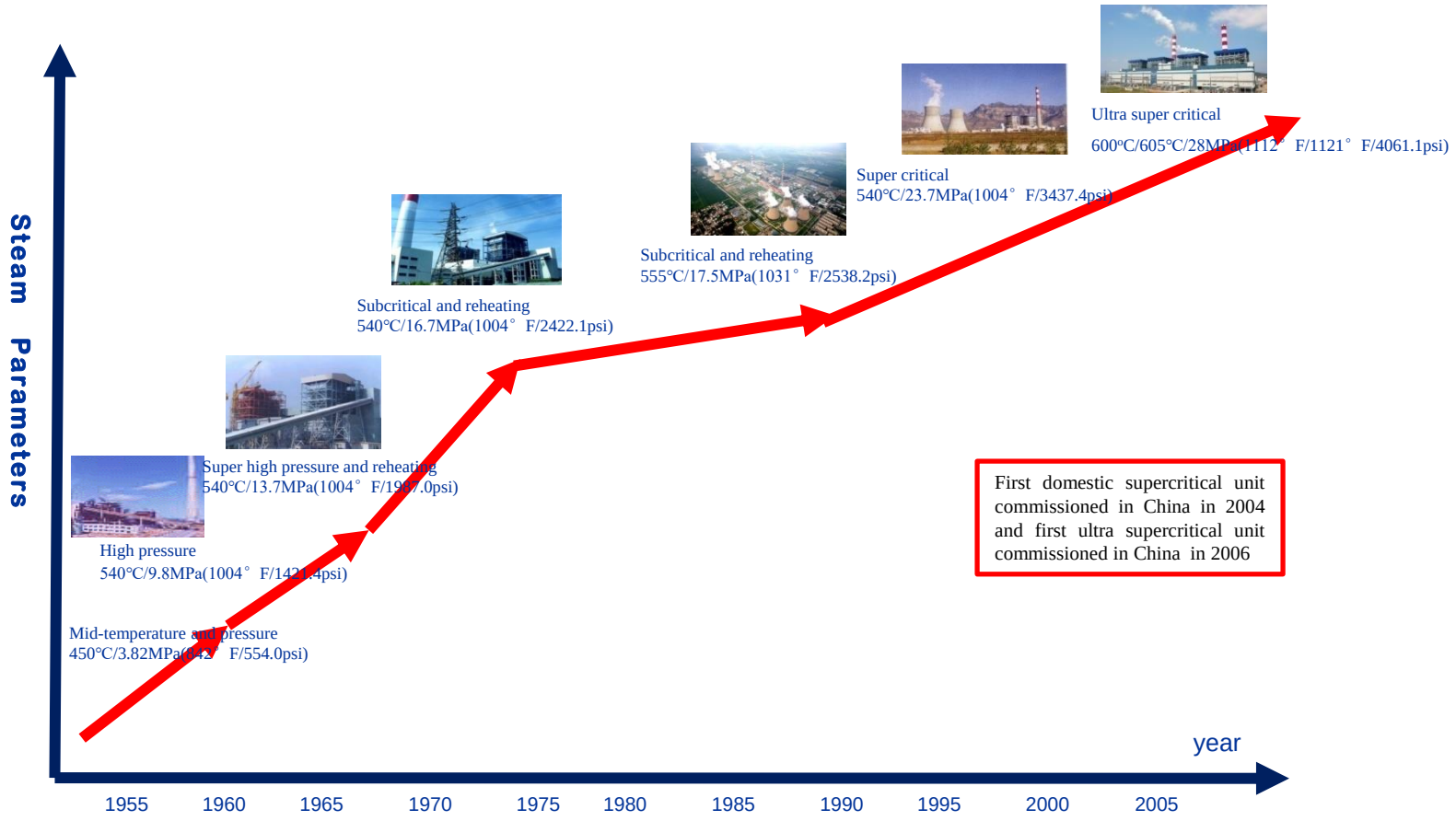
Compared with large units, the coal consumption and pollutant emissions of small units are larger



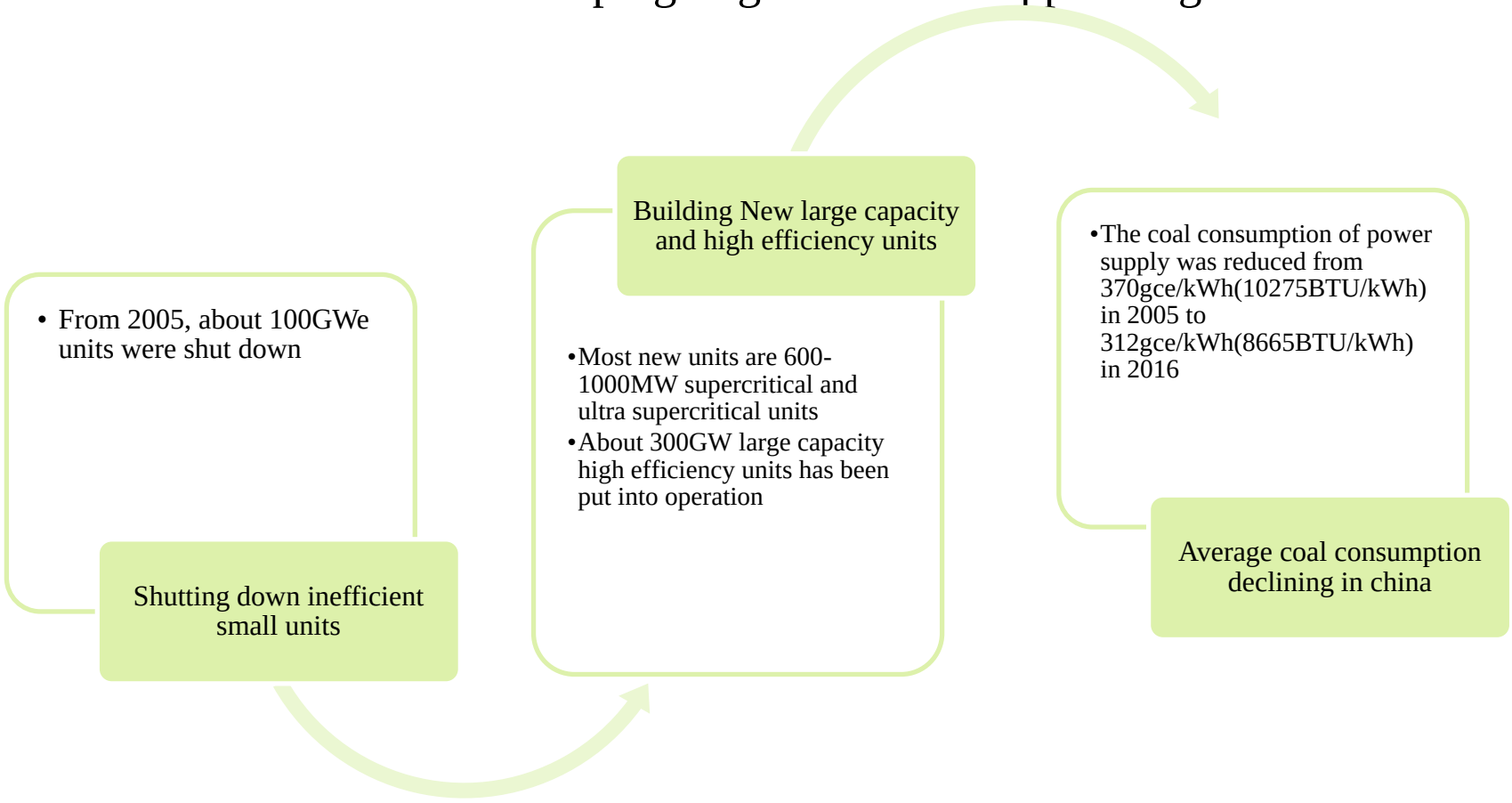
Quantitative Change

Total capacity of less than 100 thousand kW CFPP was more than 115 million kW, and more than 400 million tons of coal was consumed every year, and 5 million 400 thousand tons of CO2 was discharged

Development of Steam Parameters of CFPP units in China

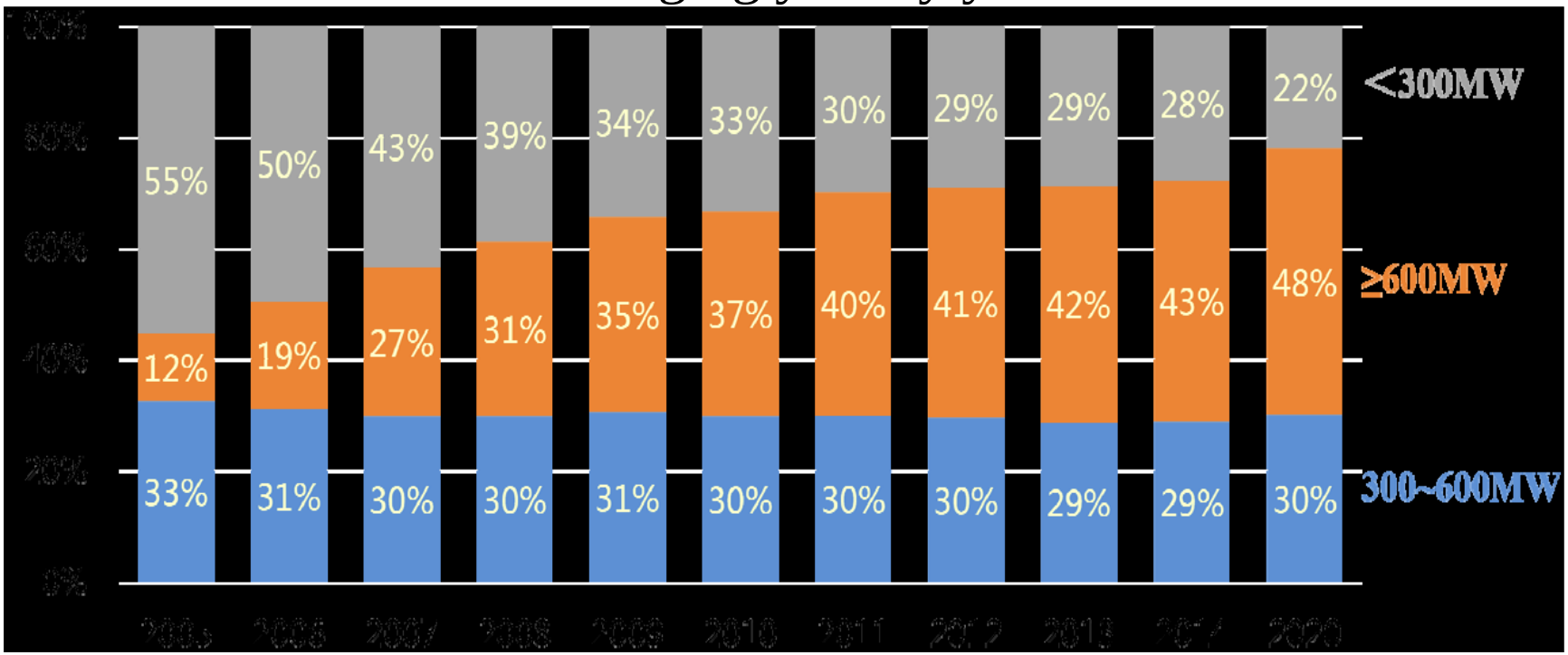


Results of “developing large units and suppressing small ones”



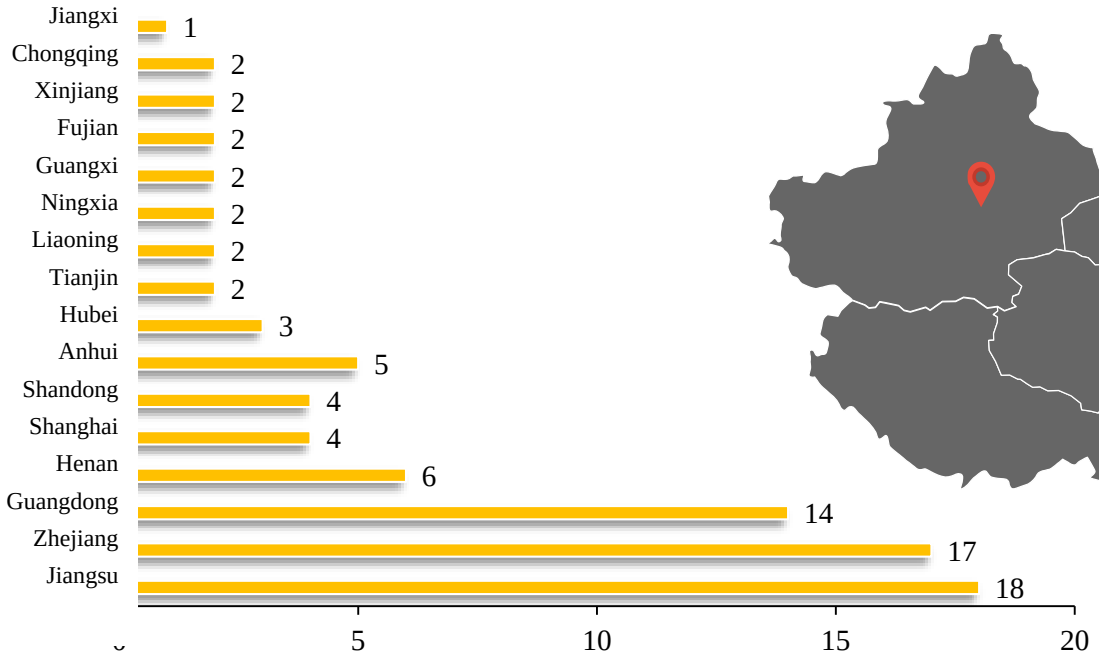
Results of “developing large units and suppressing small ones”

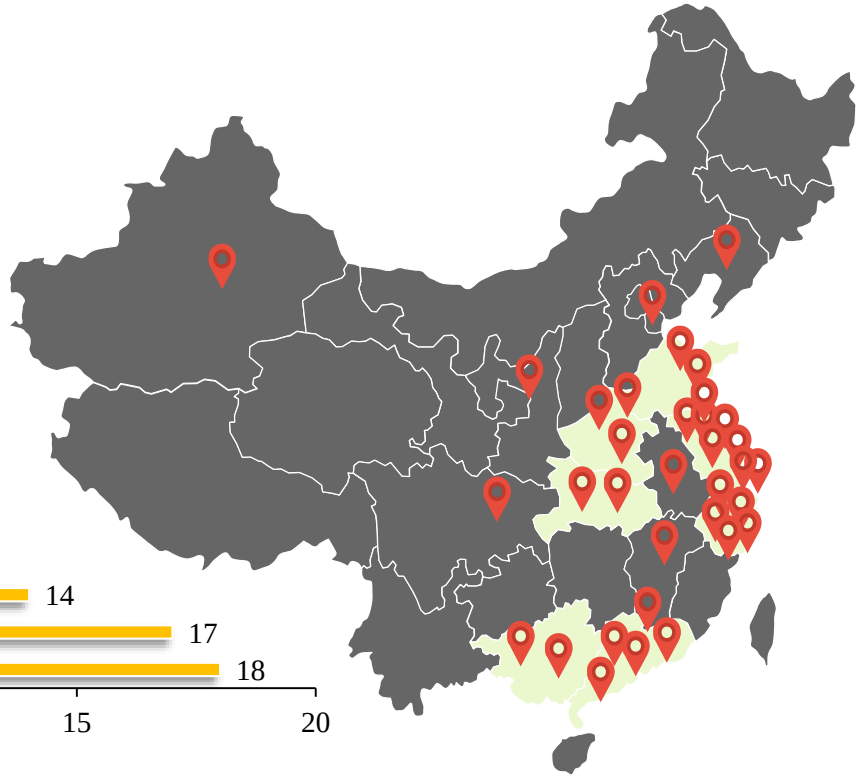
Structure of CFPP changing year by year from 2005 to 2016



Ultra Supercritical is the Direction of CFPP Development in China

Distribution of 1000MWe Ultra Supercritical Units in China

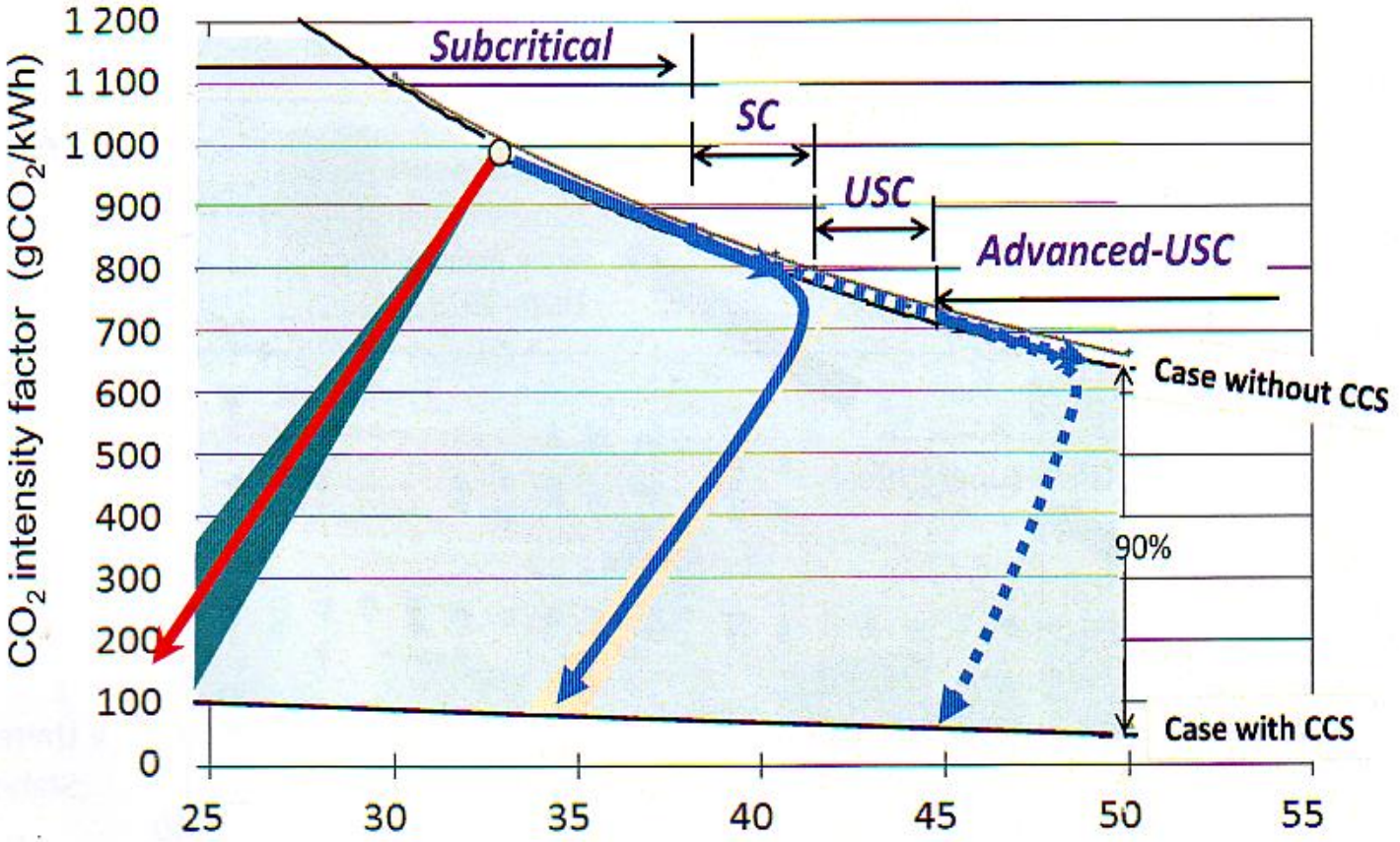




Results of “developing large units and suppressing small ones”

Year	Total capacity of CFPP （MWe)	Average coal consumption of CFPP in China (gce/kWh)	BTU/kWh
2005	384,130	370	10275
2006	484,050	367	10192
2007	554,420	356	9887
2008	601,320	345	9581
2009	652,050	340	9442
2010	706,630	333	9248
2011	765,460	330	9164
2012	819,170	326	9054
2013	862,380	321	8914
2014	915,690	318	8831
2015	1022,740	315	8748
2016	1053,880	312	8665

Highly efficient coal power is the foundation of adopting CCS



Shanghai Waigaoqiao No. 3 Power Plant (WGQ3)
2×1000MWe USC 600℃ (1112°F)
Construction 9/2005 ~ 6/2008


POWER
BUSINESS & TECHNOLOGY FOR THE GLOBAL GENERATION INDUSTRY SINCE 1882
www.powermag.com
Vol. 159 • No. 10 • October 2015
Coal-Fired Top Plants
Shanghai Waigaoqiao No. 3

APQO

ASIA PACIFIC QUALITY ORGANIZATION
WALTER L. HURD FOUNDATION

Global Performance Excellence Award

SHANGHAI WAIGAOQIAO NO.3 POWER GENERATION CO., LTD.

Shanghai, P.R.C.

Global Performance Excellence Award

WORLD CLASS

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DR. CHARLES A. AUBREY II
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DR. H. JAMES HARRINGTON
APQO Adviser & WLHF Chairman

ASIAN POWER AWARDS 2009

GOLD Award for

Best Environmental Performance Power Plant of the Year

PHASE III OF WAIGAOQIAO POWER PLANT (2X1000 MW USC)
WAIGAOQIAO NO.3 POWER GENERATION COMPANY
SIEMENS ENERGY

Hosted by Publisher Timothy Charlton

ASIANPOWER

The
Prime Movers Award
for outstanding contributions
to technical literature on
Thermal Electric Generating Station
Equipment and Practice
This Testimonial established by
The Prime Movers Committee of
Edison Electric Institute
to be administered by
The American Society of
Mechanical Engineers
was awarded to
Weizhong Feng
2016
The American Society of
Mechanical Engineers
PRESIDENT
EXECUTIVE DIRECTOR
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

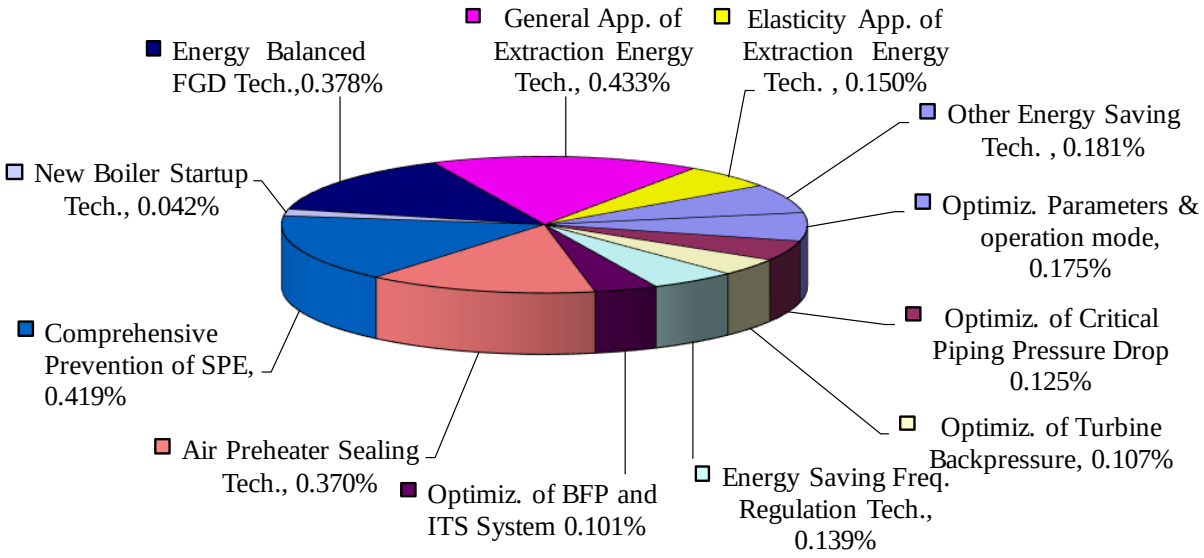
WGQ3 Boilers (GE-Alstom)

Boilers:
Alstom licensed, tower type, USC, single reheat, single furnace, corner tangential firing and open arrangement, balanced draft, solid slag disposal, built-in separator, spiral water wall with sliding operation.

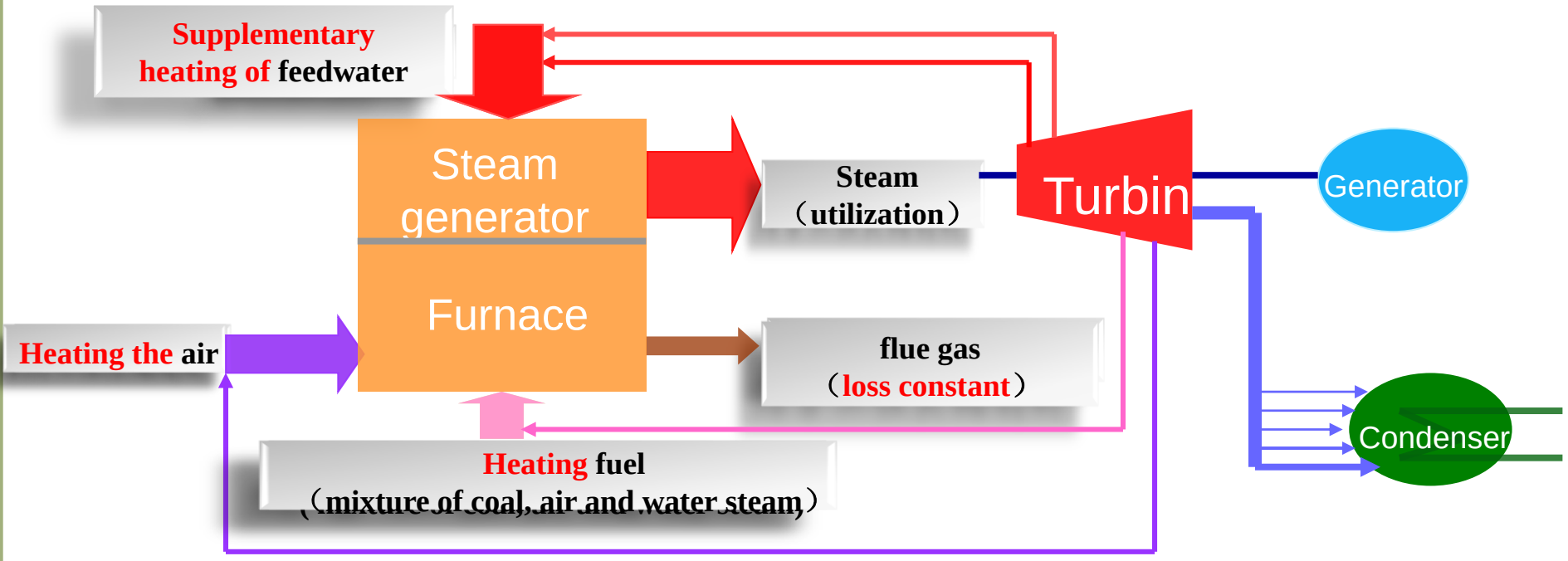
WGQ3 Turbines (Siemens)

Turbines;
Siemens licensed,
1000MW,
single shaft, four casings &
four exhausts, double backpressures.

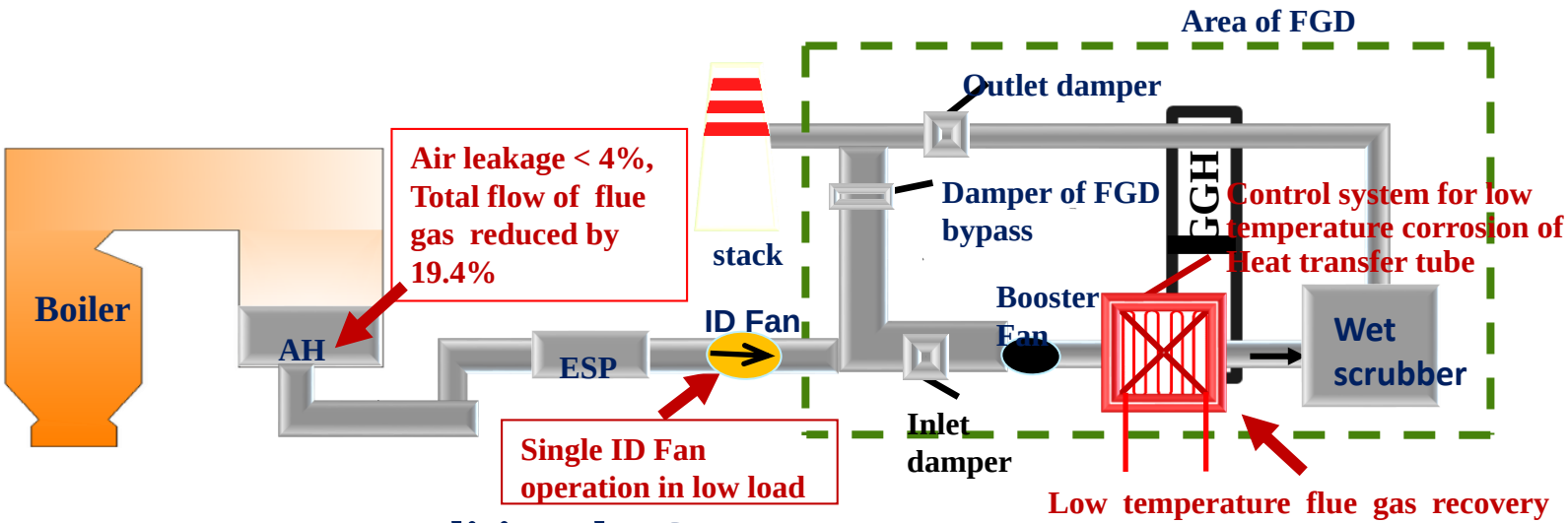
Advanced Energy Saving and Emission Reduction Technologies



Generalized Regeneration Technology



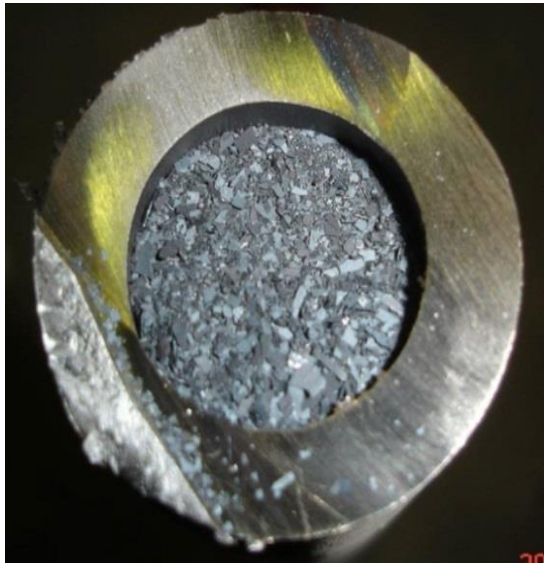
Energy balanced FGD technology



Traditional FGD system

Energy balanced FGD system

SPE (Solid Particle Erosion)



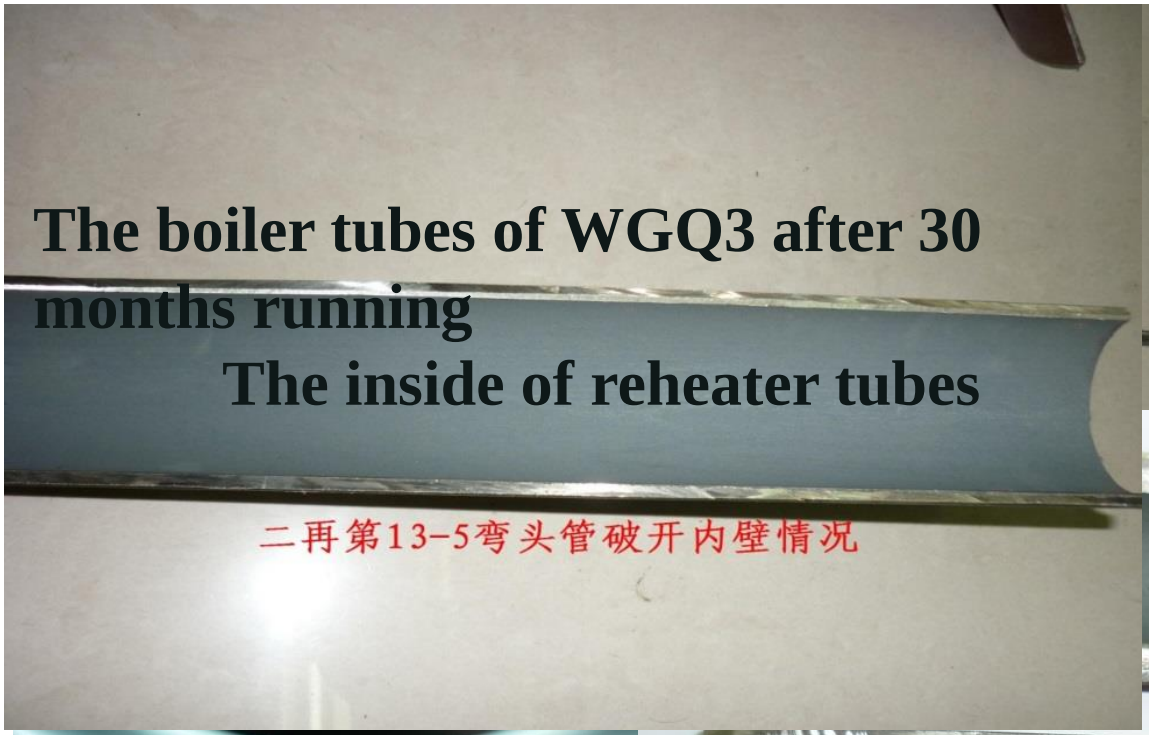
Tube Blocked by Oxide Scales

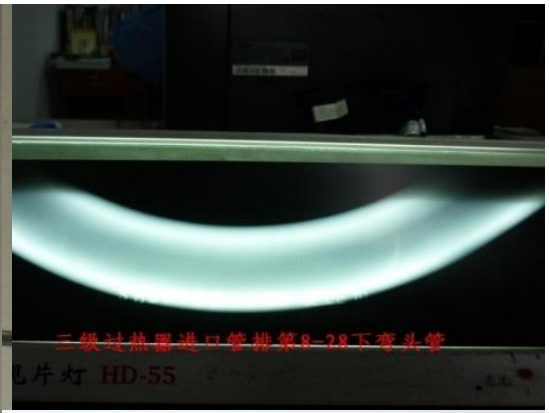
Turbine Blades Eroded by Solid Particles

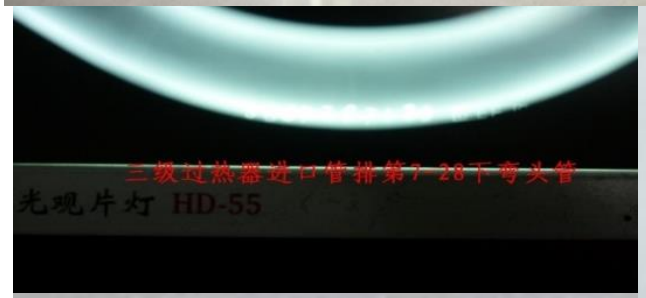
Bypass Valve Plug Eroded by Solid Particles

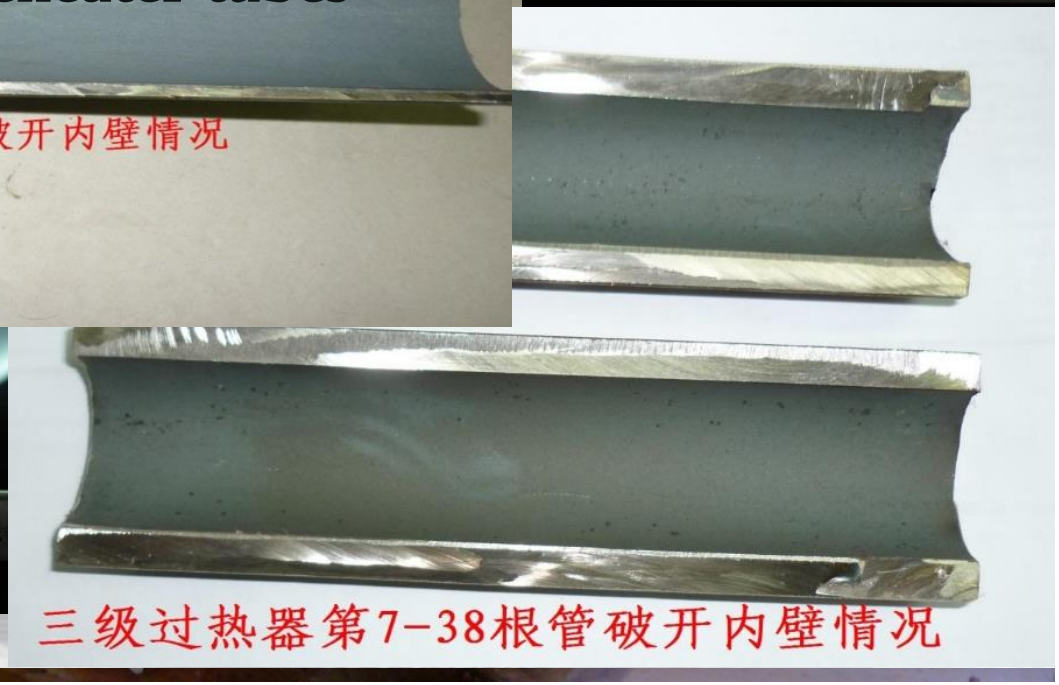
The boiler tubes of WGQ3 after 30 months running

The inside of reheater tubes







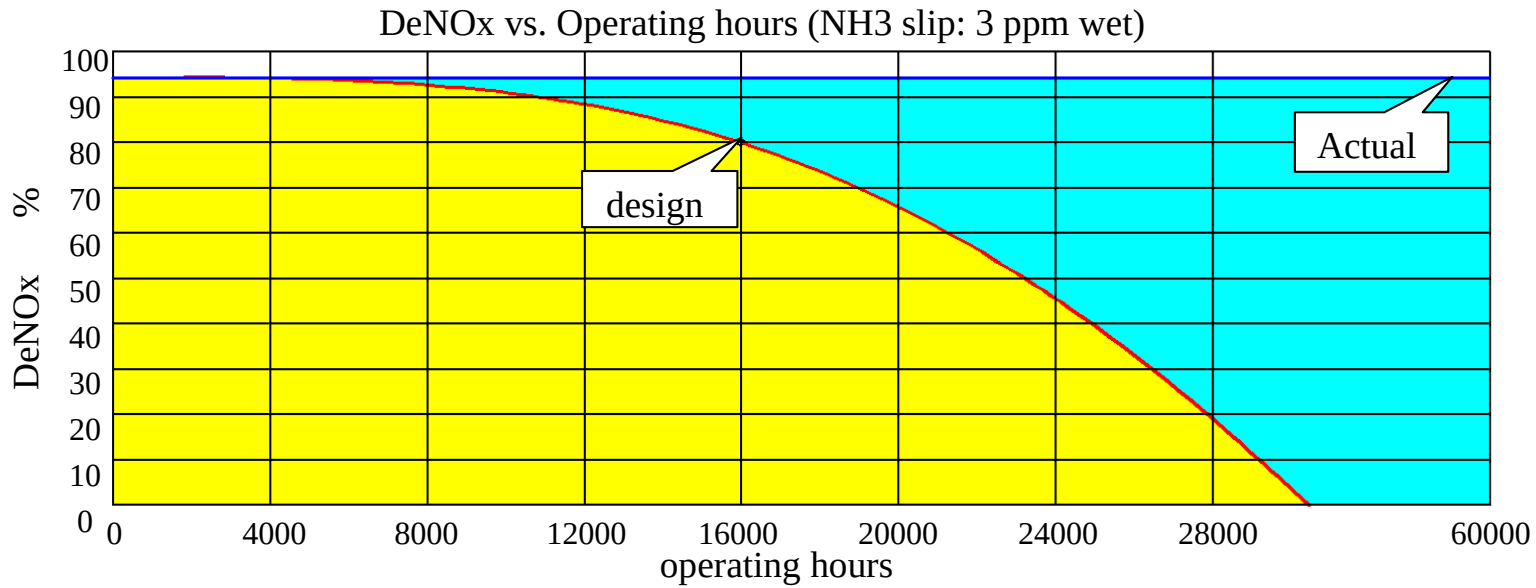



WGQ3 turbine blading after 8 years operation

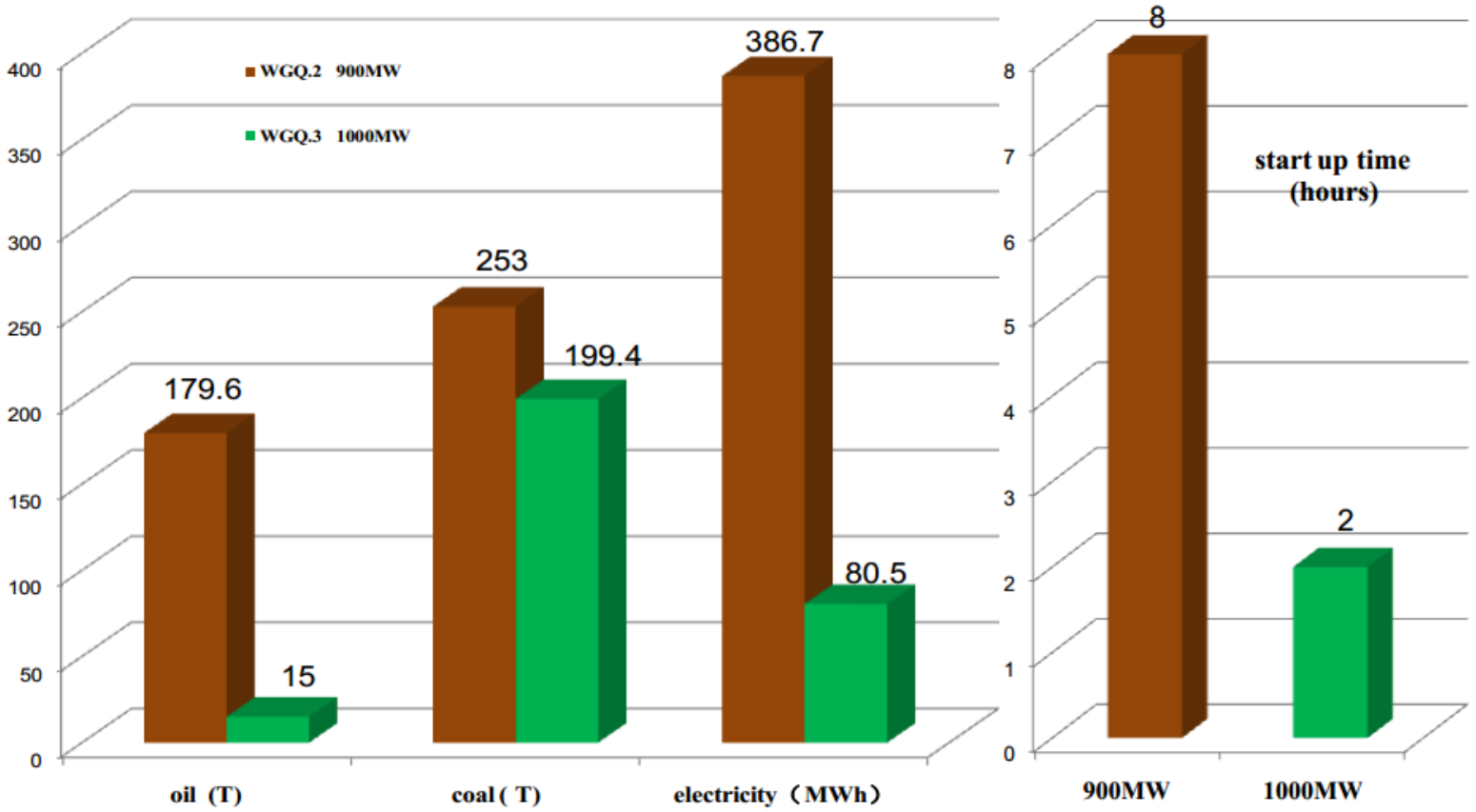
Extending life time of SCR catalyst

Design life time of catalyst is 16,000 hours, actual operation time is more than 60,000 hours.

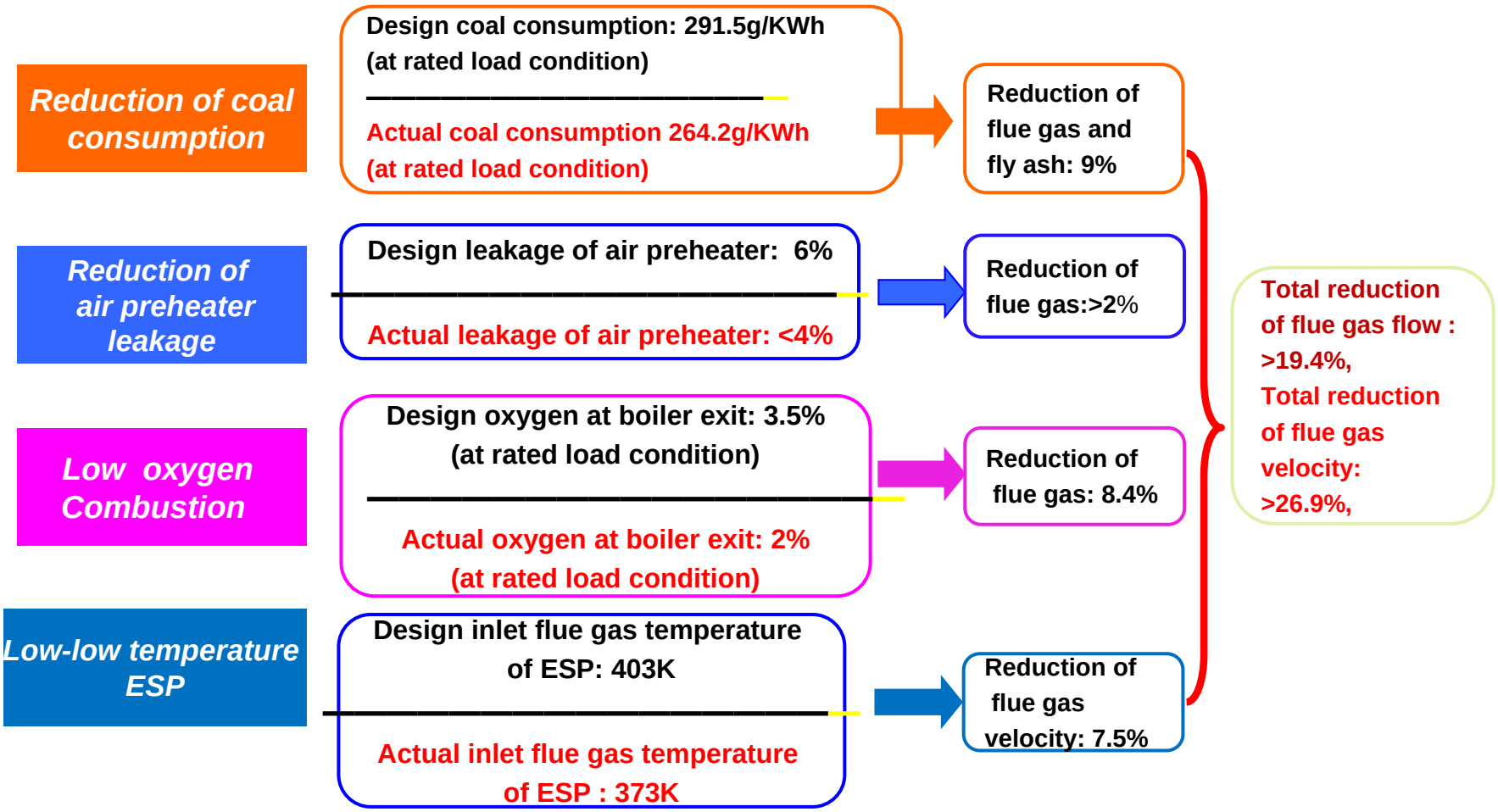
efficiency stays at >90%, with insignificant efficiency decline.



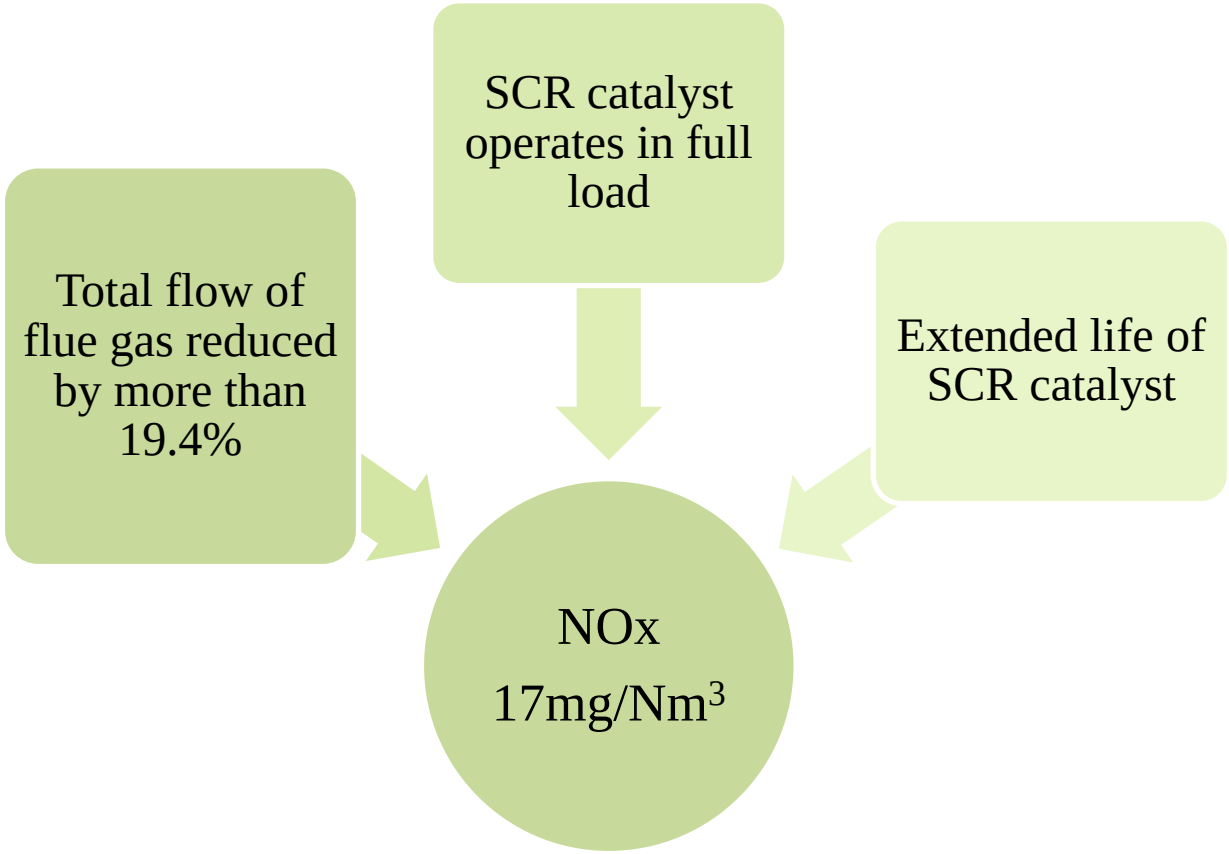
Comparison of cold startup between WGQ2 900MW unit and WGQ3



The effect of generalized regeneration technology



High efficiency and full load SCR system



Energy balanced FGD technology

Effect：

Metallographic analysis shows that the sulfur corrosion can be neglected

Improve efficiency by 0.378%, saving 30000 tons of specific coal each year

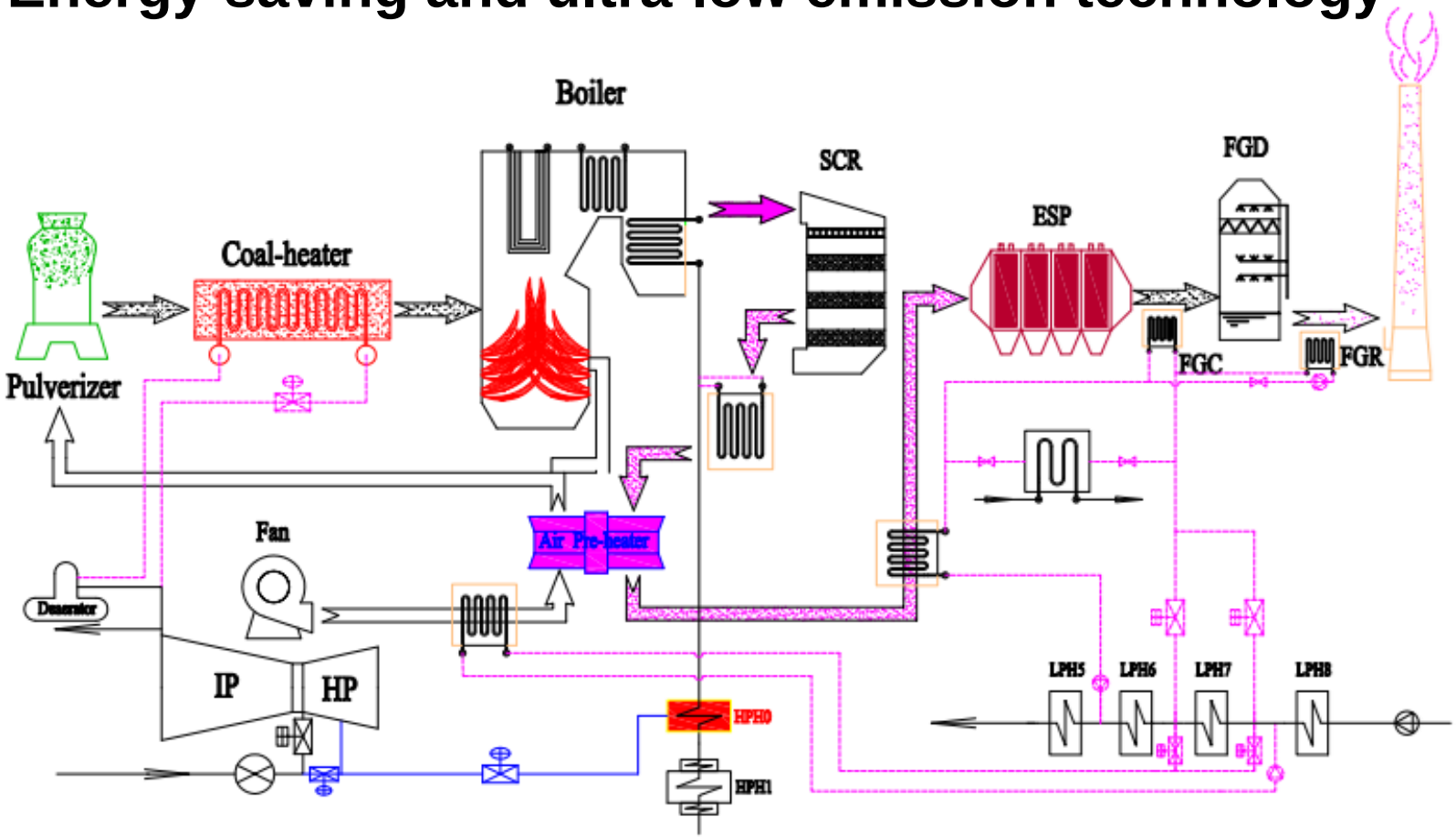
Reduce water consumption of FGD scrubber by more than 45t/h

One year later

Two years later

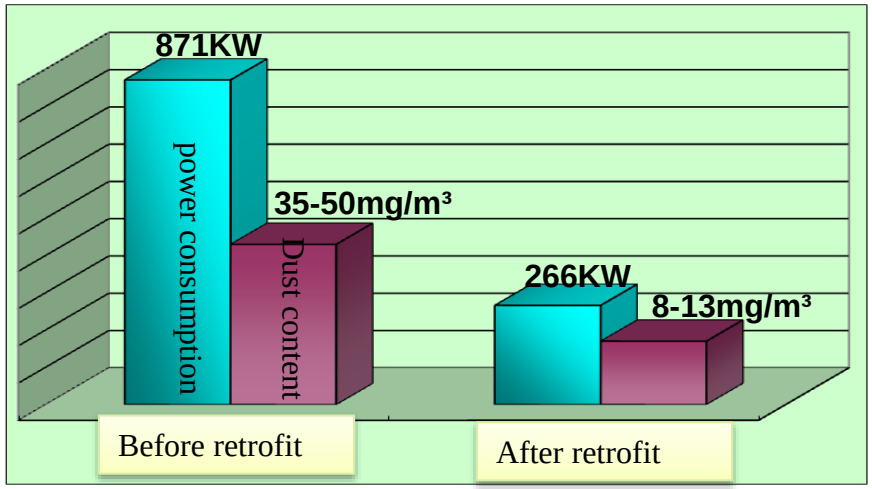
After the cleaning

Energy-saving and ultra-low emission technology



A series of high-efficiency and energy-saving de-dust technologies

High frequency power supply is adopted, not only improve ESP efficiency, but also reduce power consumption

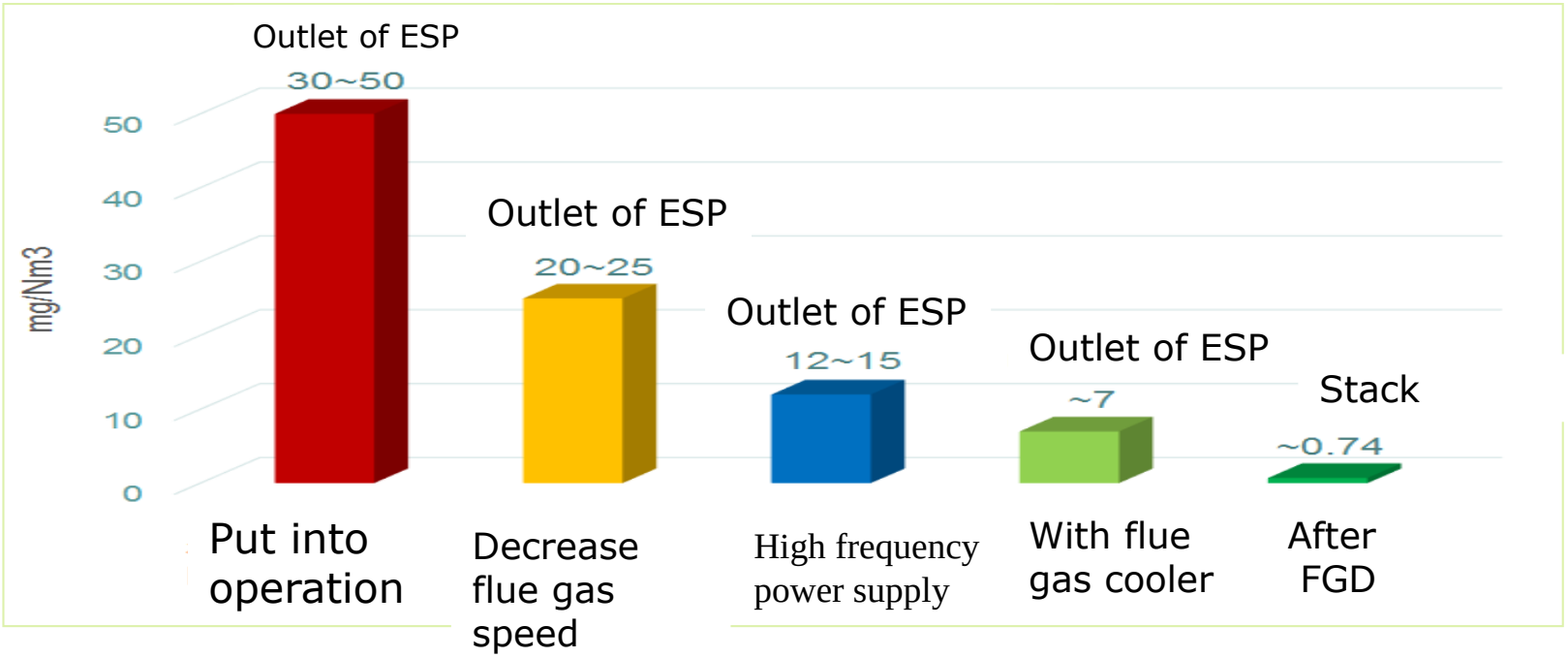


Effect:

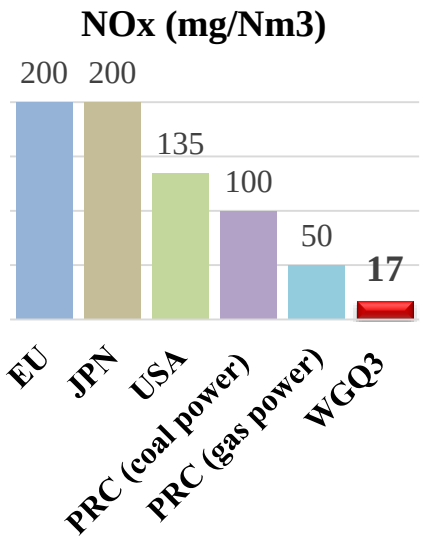
- Power consumption of the ESP reduces by 70%, saving 9.07 GWh power annually.

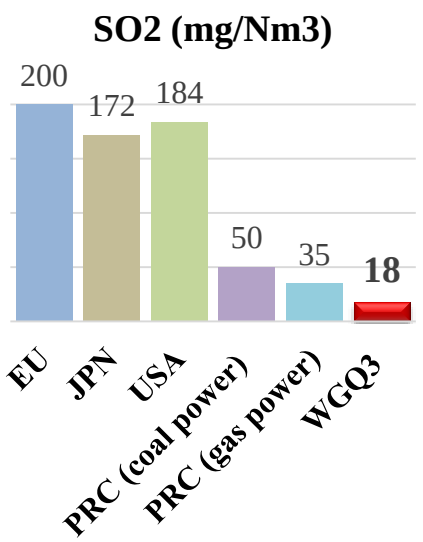
A series of high-efficiency and energy-saving de-dust technologies

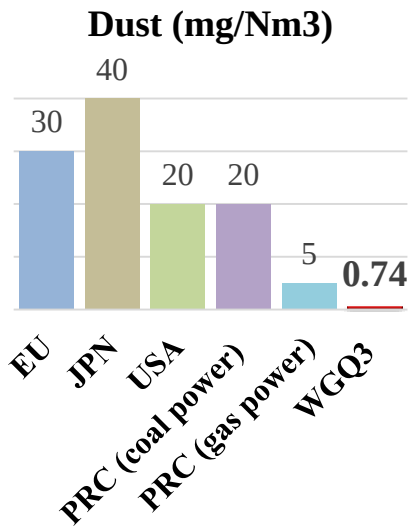
The low dust emission of Shanghai WGQ NO.3 CFPP



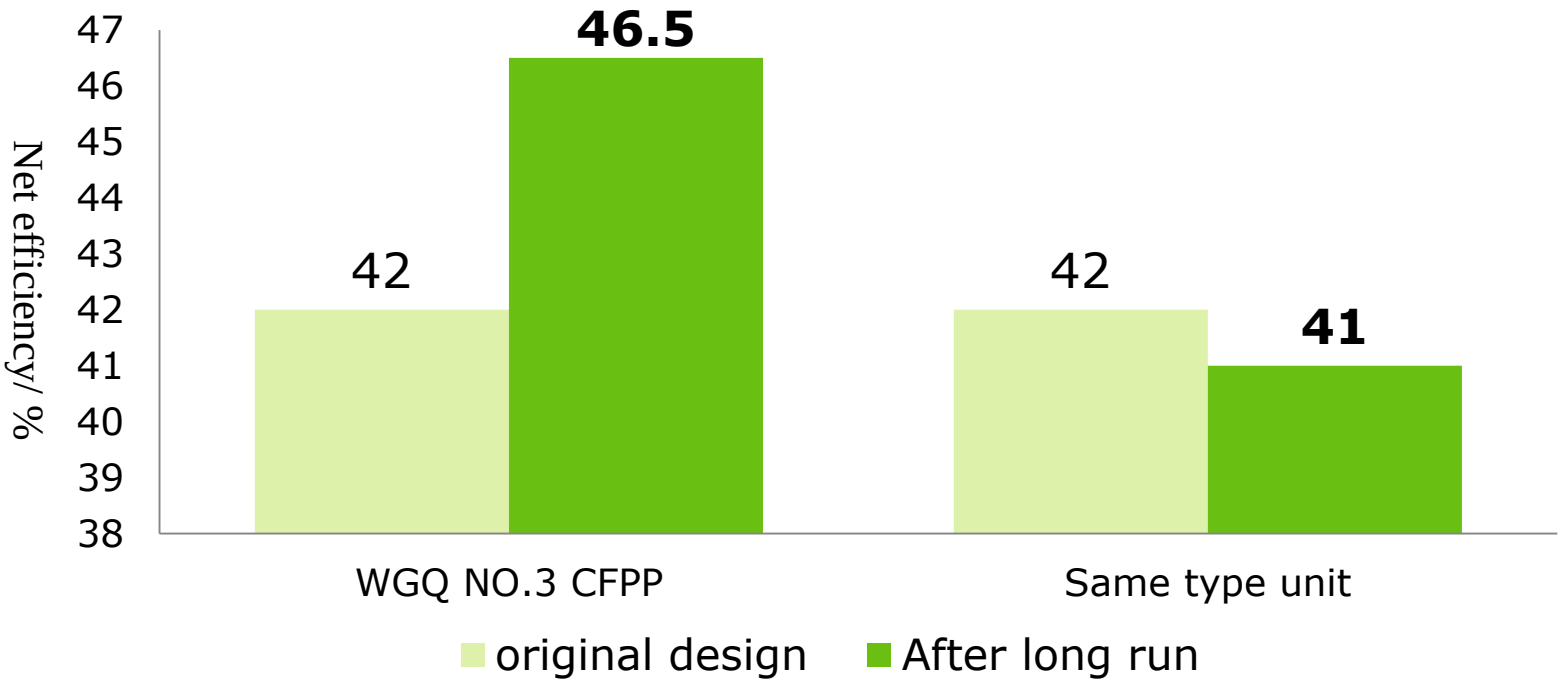
Emissions of Shanghai WGQ NO.3 clean CFPP







Rated Efficiency



Energy Saving	A series of energy-saving technologies, including: innovative boiler start up, generalized regeneration technology, centralized frequency variable power system, and energy-saving emission reduction technology.
	Improve the existing unit efficiency from 42% to 46.5% in full load.
	House power rate has been reduced from 3.5% to less than 2% (SCR and FGD included)

Efficiency Preservation	Prevent the formation of oxide skin and solve the problem of solid particle erosion on turbine blades.
	Solve the problem of blocking and corrosion in cool end of air preheater.
	Net efficiency is 5.5% higher than that of the same type unit and does not decline after long operation.

Ensuring Safety	FCB safety technology
	Avoid boiler tube explosion due to the steam side oxidization
	Water pump optimization, eliminate the disconnection and juxtaposition between multiple pumps

Environmental Protection	Low oxygen combustion, high efficiency combustion, reduce the total amount of flue gas
	Dust, NOX and SO2 emission：0.74mg/Nm^3,17mg/Nm^3 and 18mg/Nm^3

Ensuring Elasticity

The minimum boiler load is 8.24% with stable combustion under oil breaking conditions

For retrofitting units, the stable load of the unit can be lower than 20%.

Development and Application of Advanced CFPP Technology

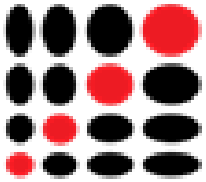
Ultra Supercritical Units

華潤電力 CR Power

Tongshan

Cao Feidian

Fuyang



Anhui Pingshan Phase II

Subcritical Units

華潤電力 CR Power

Xuzhou

Tongshan Project **(2*1000MW USC)**

Technology implementation in existing Tongshan HuaRun Power Plant (2*1000MW USC).

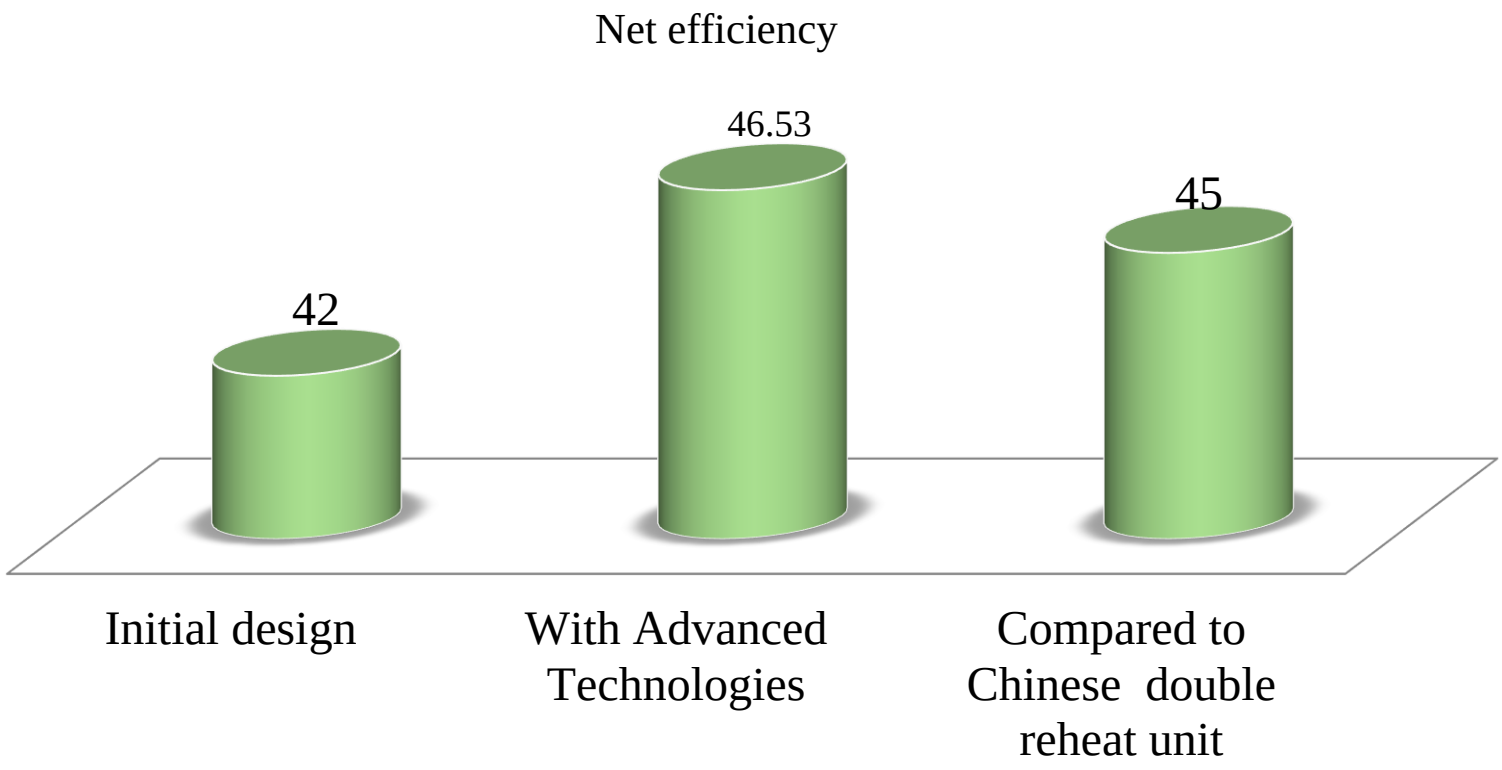
Siemens and GE commissioned to conduct the performance test for the unit.

Heat rate improved from 7970BTU/kWh to 7665BTU/kWh.

Coal consumption of power supply reaches to 276 g/kWh based on original design parameter of 287 g/kWh

Performance test load rate	100%	80%	50%
Performance test number	1	2	3
Boiler efficiency	95.52 %	95.68 %	95.88 %
Performance test fuel quantity	99.42 kg/s	83.78 kg/s	51.95 kg/s
Total load during performance test	1007.4 MWe	804.1 MWe	542.7 MWe
Power consumption of auxiliary machine during performance test;	34.18 MWe	28.87 MWe	24.07 MWe
Net load during performance test	973.2 MWe	775.2 MWe	518.6 MWe
Coal consumption of power supply during Performance test	273.2 g/kWh	274.5 g/kWh	280.4 g/kWh
power supply efficiency during performance test	45.0 %	44.8%	43.9 %
Power supply efficiency before reformation (2013)）	43.5 %	42.5 %	40.7 %
Improvement of the power supply efficiency after the reformation,	1.5%	2.3%	3.2%

Caofeidian Project (2*1000MW)



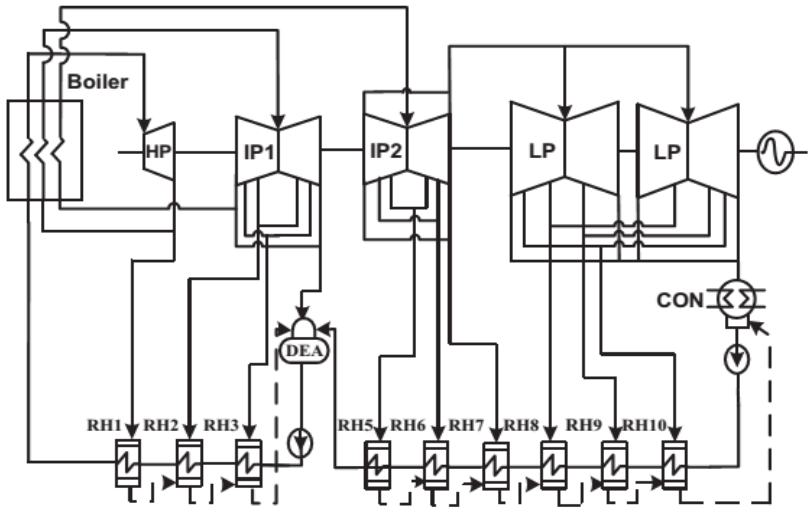
Caofeidian project plans to build two units of single-shaft arrangement with single reheat cycle;

With Advanced Technologies, the efficiency will reach 46.53%, exceeding the level of China's double reheat units in 1000MW.

Why is China developing double reheating Technology?

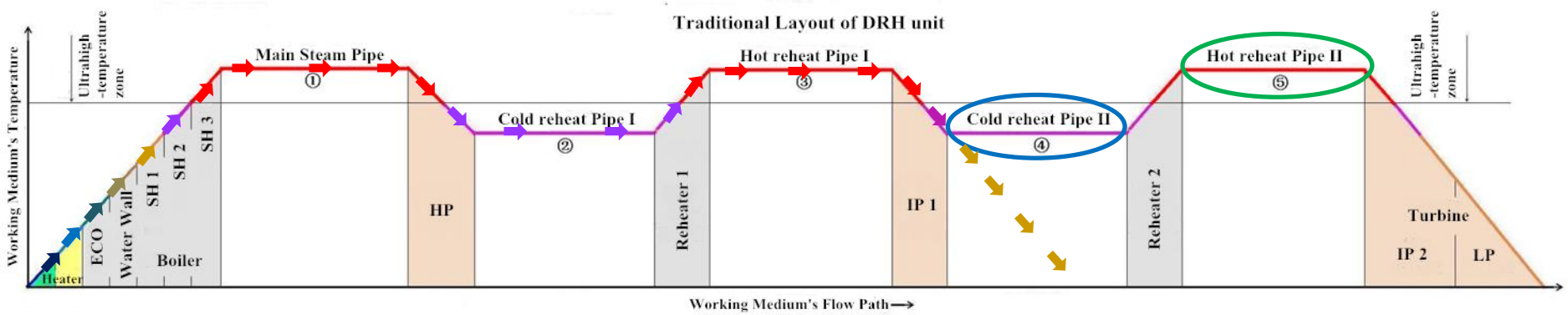
- Compared with the primary reheating technology, the efficient of the double reheating technology is higher by 2% and the CO2 emission reduces by about 4%.

- It is expected that the 700° C （1292° F） ultra supercritical technology will take about 10 years to demonstrate and fully commercialize.



Challenge of conventional double reheat design

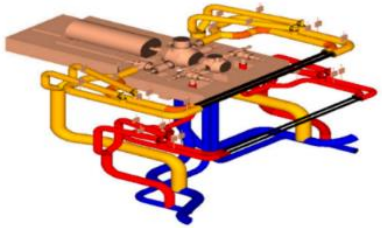
For conventional double reheat technology, the main steam and reheat steam piping would be routed long distance between the boiler and turbine ~ 200m for a single pipe (1000MW unit).



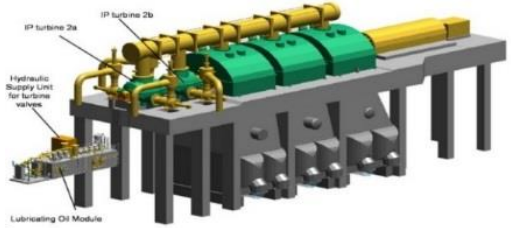
Working medium’s flow path of double reheat unit with conventional layout

Pingshan Phase II Project(1*1350MW)

- Double reheat +Elevated T-G layout

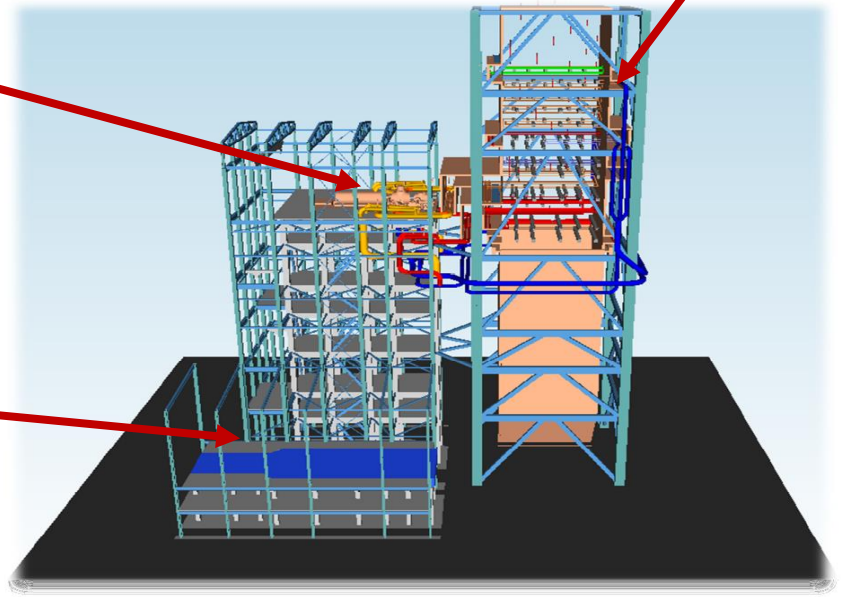


High positioned turbine generator train (the platform is about 85 meters high)

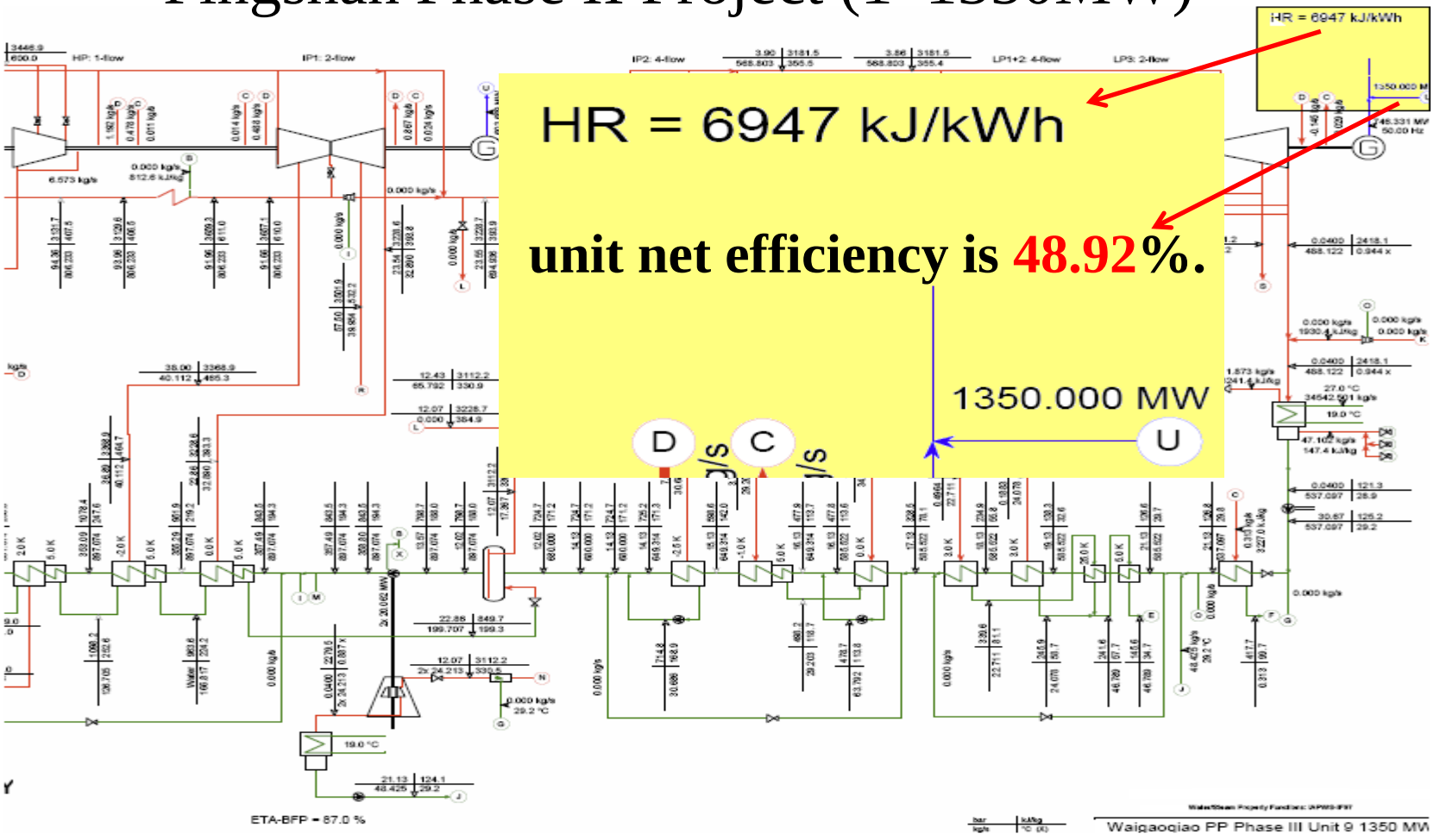


The platform for conventional turbine generator train

Tower type of boiler



Pingshan Phase II Project (1*1350MW)



Pingshan Phase II Project (1*1350MW)

- Some optimization was made, and the results calculated by Siemens list as follows.

Item	Result	Impact on Δheat rate kJ/kWh
LP inlet pressure	3.9 bar -> 3bar	+10
Main steam pressure	300bar -> 330bar	-20
Main steam temperature	600ºC -> 610ºC	-13
2nd HRH temperature	620ºC -> 630ºC	-9
1st HRH temperature	610ºC -> 620ºC	-10
Feed water temperature	317ºC -> 320ºC	-4
optimized LP extraction and use 2LSB design		~-10
Optimization on Cycle**		~-10
Sum		**-65**

Remarks:

the design net efficiency can be improved to **49.8**%

Pingshan Phase II Project (1*1350MW)

Efficiency related indicators and CO2 emission levels (design condition)

Project	WGQ3 power plant	Pingshan phase II 1350 MW unit (latest research)	Elevated T-G unit with 700°C.
The design coal consumption rate g/kWh	264.16	**246.66**	231.76
The design net efficiency	46.50%	**49.80%**	53.00%
Heat rate BTU/kWh	7338	**6852**	6438
The design CO2 emission (gross) g/kWh	666.87	**622.69**	588.21
The design CO2 emission (net) g/kWh	713.23	**665.98**	625.75

Notes:

1. **The design CO2 emission (gross)**--namely kg CO2/MWh of gross power output at design condition;
2. **The design CO2 emission (net)** --namely kg CO2/MWh of net power output at design condition;
3. The coal consumption rate and net efficiency above are calculated with the calorific value of **standard coal 29307.6 kJ/kg**.

Pingshan Phase II Project (1*1350MW)

Efficiency related indicators and CO2 emission levels (annual average load rate of 80%)

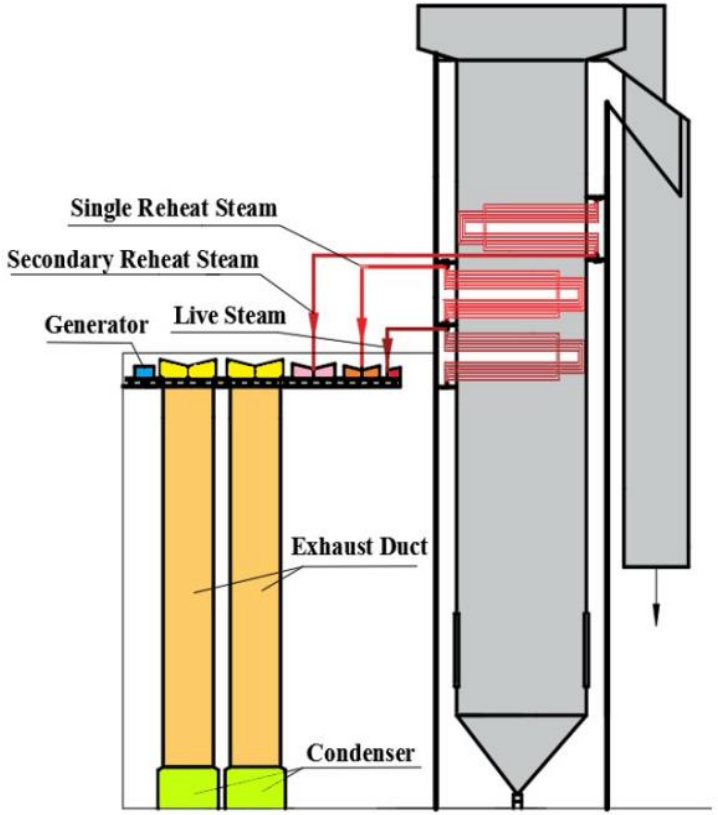
project	WGQ3 power plant	Pingshan phase II 1350 MW unit (latest research)	Elevated T-G unit with 700°C.
The annual average coal consumption rate g/kWh	276.02	**251.71**	236.22
The annual average net efficiency	44.50%	**48.80%**	52.00%
Heat rate BTU/kWh	7667	6992	6562
The annual average CO2 emission (gross) g/kWh	696.81	**635.44**	599.53
The annual average CO2 emission (net) g/kWh	745.25	**679.62**	637.79

Notes:

1. **The annual average CO2 emission (gross)**--according to the definition of CO2 emission standard by American EPRI, namely kg CO2/MWh of gross power output at annual average load rate of 80%;
2. **The annual average CO2 emission (net)** --namely kg CO2/MWh of net power output at annual average load rate of 80%;
3. The coal consumption rate and net efficiency above are calculated with the calorific value of **standard coal 29307.6 kJ/kg**.

Fuyang Project (2×660MW)

- Principle: The whole single shaft turbine is elevated and the condenser is at conventional level.
- Effect: The unit efficiency is expected to be about 50%.

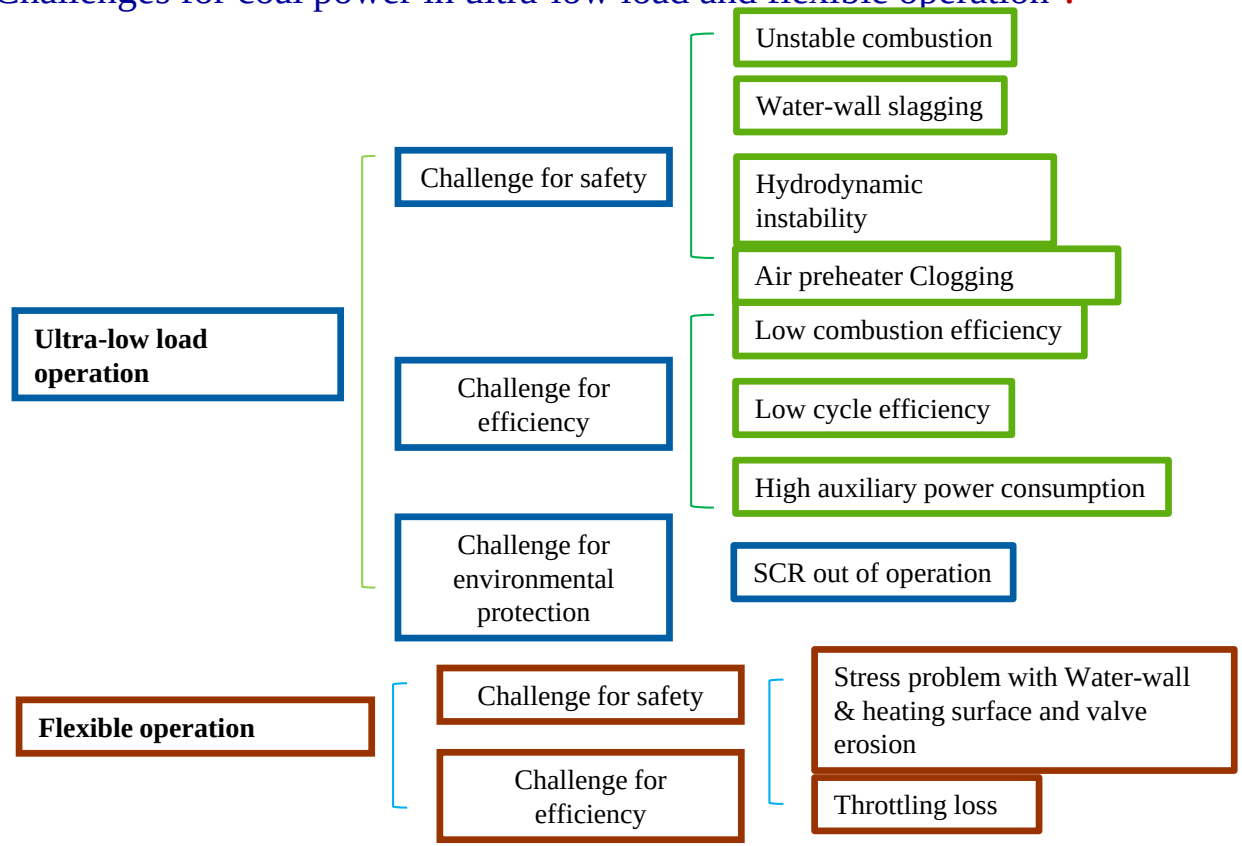


Xuzhou Power Plant——
Reformation of high temperature subcritical unit

- The reformation technology of the high temperature sub critical unit is to keep the unit pressure at the sub critical level (about 17MPa) but improving the temperature of the main steam and reheat steam to about 600℃（1112°F）
- Reform content

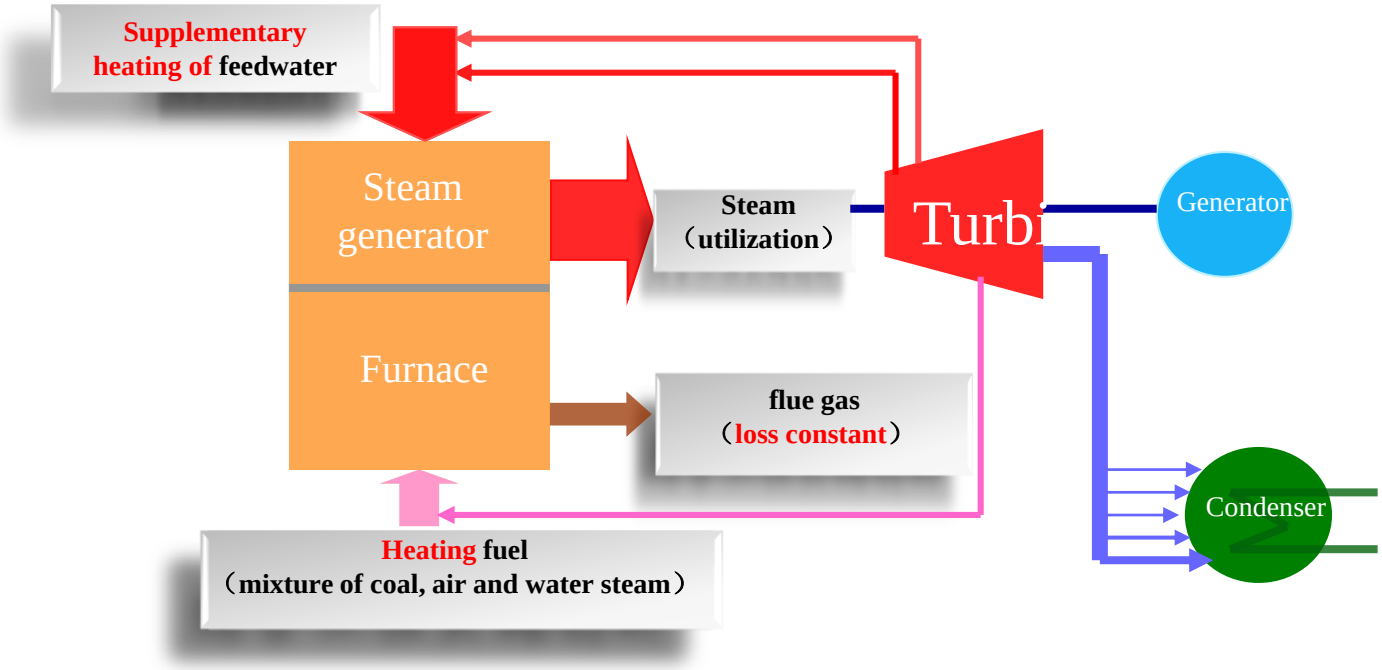
- Super heater and reheater, HP and IP pressure cylinders, and other main steam pipes and valves, hot steam pipes and valves, high and medium pressure by-pass valves.
- Extent of reform is relatively small: the wall thickness of the pipe can be controlled and the pressure is unchanged.

- Challenges for coal power in ultra-low load and flexible operation：

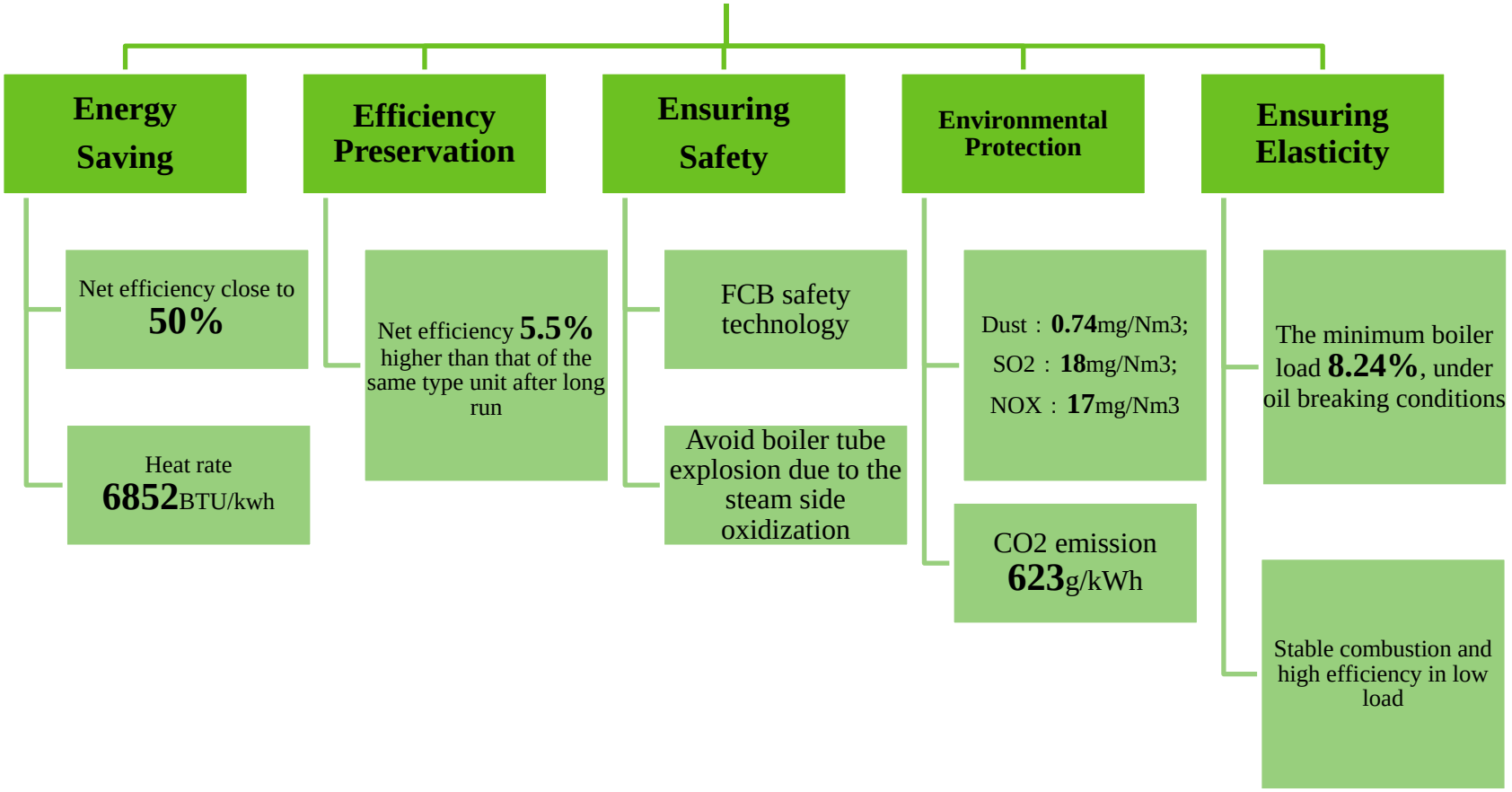


Ensuring the elasticity of CFPP

---Ultra low load stable operation technology



Ultra High Efficiency and Low Emission CFPP Technologies



THANK YOU!

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Staff Subcommittee on Electricity and Electric Reliability

NARUC Summer Policy Summit