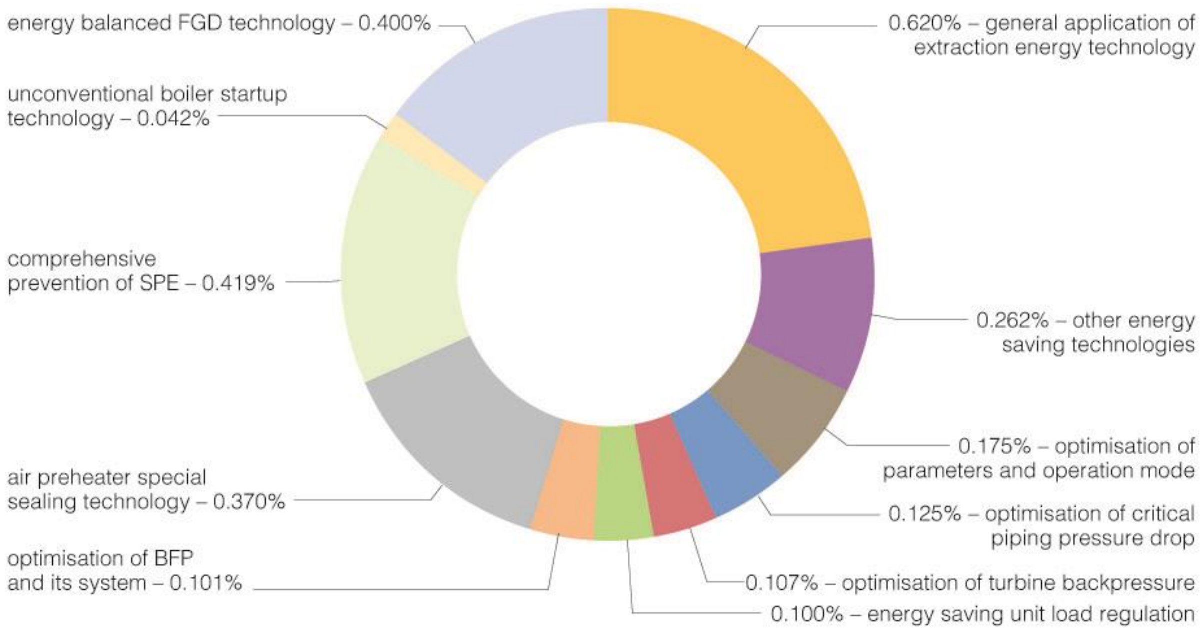
The two 1000MWe units of Shanghai Waigaoqiao Number 3 coal-fired power plant were designed, constructed and commissioned in just over 3 years, from 2005 to March-June 2008, at a cost of 8.5 billion Yuan RMB (1.2 billion US$) - well within time and under budget. A number of improvements were made during the build. The power plant now runs with higher efficiency and lower emissions than designed for. In recognition of this, Shanghai Waigaoqiao Number 3 has won the following awards:

- 2010 Shanghai Science and Technology Award First Class;
- 2011 National Science and technology progress award Second Class;
- 2011 National Gold Medal: Classic Works (30th Anniversary).

Alstom boiler (made in Shanghai)	Tower, single spiral tube furnace, tangential firing	**Siemens turbine/generator (made in Shanghai)**	Tandem compound, 4 x casing and exhausts
Steam output	2955 tonne/hour	**Rated output**	1000 MW
Main steam (at boiler)	605°C / 28 MPa	**Main steam flow**	2738.6 tonne per hour
Reheat steam (at boiler)	603°C / 6.4 MPa	**Output in vales wide open**	1059.97 MW
Feedwater	298°C	**Frequency control**	Control & overload valve
Dimensions	21.5m x 21.5 m x 69m	**Main steam**	600°C / 25.86 MPa
Furnace bottom	Dry bottom	**Reheat steam**	600°C
Combustion efficiency	93.75% (now 95.5%)	**Backpressure**	4.19 kPa /5.26 kPa
Coal	Shenhua bituminous, Russian and Indonesia	**Design heat rate**	7320 kJ/kWh

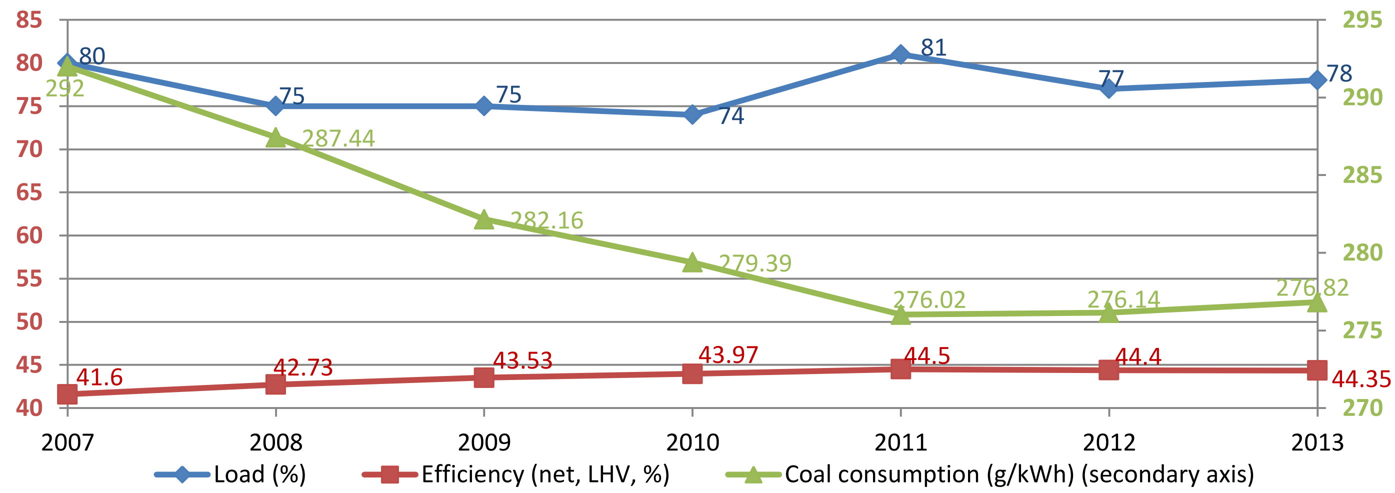
The upgrades and modifications made at Shanghai Waigaoqiao Number 3 include:

- **Flexibility –** cold-start to full load takes ≤2 hours due to the following measures. High pressure steam from an adjacent unit is injected into the economiser to warm-up the boiler, which displaces the amount of oil-fired by ≤15 tonnes and the auxiliary power load is kept to a minimum during start-up. The additional capital expenditure was recovered within 8 cold-starts;
- **Pumps –** the original design for three feedwater pumps was replaced with a single larger feedwater pump;
- **Seals -** new sealing technology for the rotary air pre-heater has minimised air leakage. The payback period for the new seals was 3 years;
- **Heat recovery** – the boiler is pre-heated using waste heat from the FGD, forced draft and induced draft fan. The efficiency has improved by 0.4% and the FGD water consumption reduced by 45 tonnes per hour. The payback period for the additional heat recovery loop was <4 years;
- **Chemical attack -** when significant amounts of SO_3 are detected in the flue gas, the flue gas flow rate is increased slightly to prevent sulphuric acid from condensing on, and corroding, low temperature materials downstream of the air pre-heater. If the flue gas is still not warm enough, steam from the HP steam turbine can be used to heat the flue gas. The steamside oxidation, exfoliation and erosion has been minimised with coatings and advanced feedwater treatment;
- **Selective catalytic reduction (SCR)** – the SCR catalyst had a design life of 16,000 hours and design efficiency of ≥80%. The same catalyst has been operating for 30,000 hours at 89% efficiency due to the following measures. Lower flue gas velocities reduce erosion on the SCR catalysts. The optimum flue gas temperature is maintained by HP steam injection after economiser, which also ensures efficient operation of SCR at low-load. Less oil is fired during start-up and highly efficient combustion prevent catalyst contamination. In 2011, the SCR had an availability of 98.54% and an auxiliary load of <0.75%;
- **Electrostatic precipitator (ESP)** – state-of-the-art high frequency energisation and microprocessors control have been installed on the ESP for optimum operation with all types of fly-ash;
- **Fast cut back -** if the power gird fails, the boiler firing rate will decrease to minimum, with the turbine spinning but disconnected to the main generator. The plant can then re-synchronise and reconnect to the grid, to full-load, within 7 minutes.



Efficiency improvements at Shanghai Waigaoqiao Number 3

In 2014, the average NOx, SO_2 and particulate emissions have been 16.61, 32.96 and 9.92 mg/m^3 respectively, well within the regulated limits of 100, 50 and 20. The graph below shows the average annual efficiency, where 2007 shows the original design values. The average auxiliary load in 2013 was 2.5%. It is important to note that in 2013 the plant at full-load reached 46.7% net efficiency, with only 2% auxiliary load.



The next major efficiency improvement can be achieved with a re-design of the turbine layout to decrease pipe lengths. Known as the cross compound at high/low position arrangement (CCHLPA), or elevated turbine-generator (T-G) unit, the HP and IP turbines are both mounted at the same level as the boiler outlet steam headers, whereas the LP turbine remains at ground level. The CCHLPA reduces the pressure drop, temperature loss and material costs.

For example, a 1350 MWe unit with double reheat and CCHLPA, operating at USC steam parameters (600/620/610/30, 310°C feedwater, 6996 kJ/kWh heat rate and 4000 Pa back pressure), combined the with other efficiency improvements made at Waigaoqiao Number 3, has been independently verified by Siemens, Alstom and Chinese local manufacturers to reach 48.92% net electrical efficiency (LHV).

When such technology is combined with nickel alloys, to reach 700°C steam (AUSC), efficiency could reach 52%, or 236 g_{coal}/kWh; with the advantage of reduced nickel alloy costs on conventional plant arrangements.