HELE coal-fired power generation: current technology and future prospects

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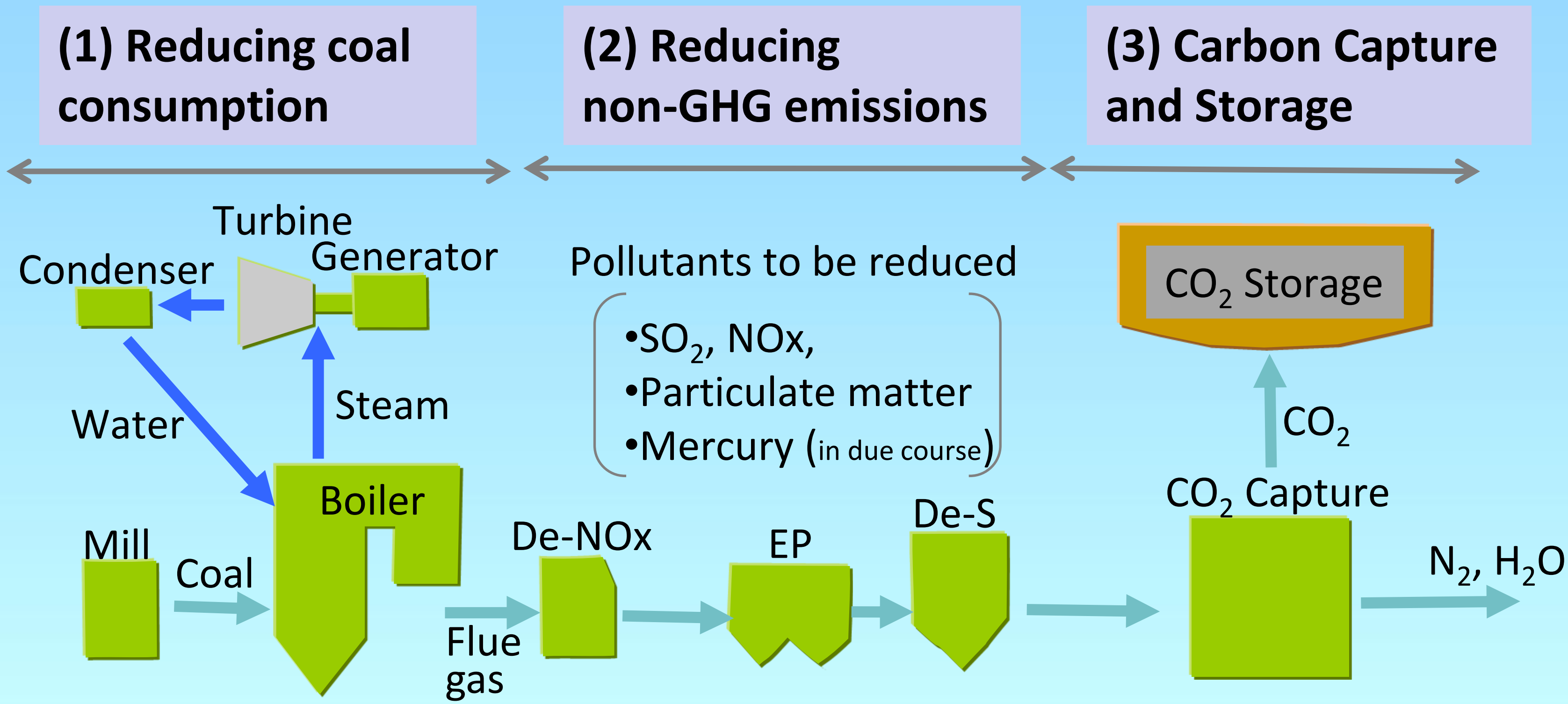
Scope of presentation

- HELE clean coal technology development and deployment (pulverised coal)
- Power sector issues with renewables integration (Germany case study)
- Means to implement HELE (China case study)
- Future technology developments
- Final thoughts

HELE clean coal technologies are a key step towards near zero emissions from coal

Focus on technologies to reduce both GHG and non-GHG (NOx, SO_2, PM) emissions.

Technologies for cleaner coal generation

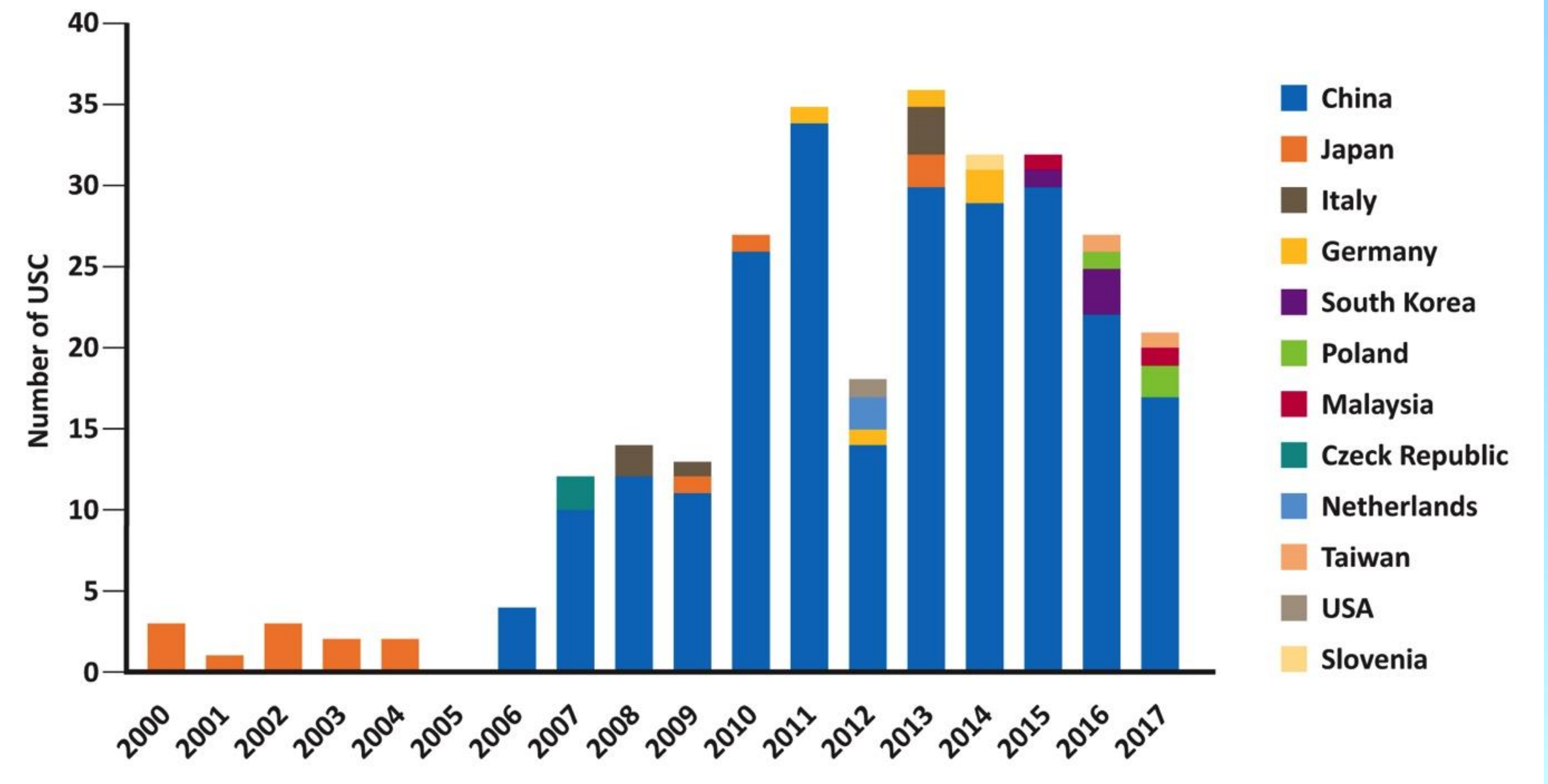


Strategic importance of HELE technologies

- Reality is that developing countries are going to use coal, as their driver is security of supply and economic competitiveness
- Many OECD countries will continue to use coal although they will likely have more balanced energy portfolios
- It is essential to support the use of more efficient coal-fired power, as it's the only realistic way to bring down CO_2 emissions in the near term
- HELE clean coal technology is commercially available now and being deployed commercially, such as in Germany, Japan, Korea, USA but more especially in China
- Development work is underway to establish advanced systems that will provide a step change improvement to over 50% cycle efficiency

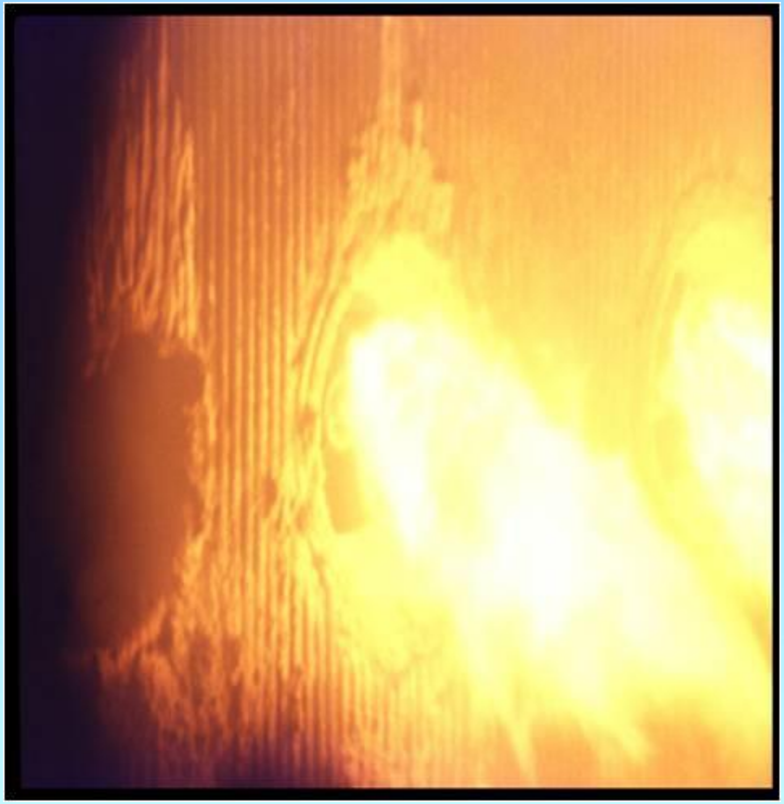
Global USC coal power plants (*JCOAL* 2015)

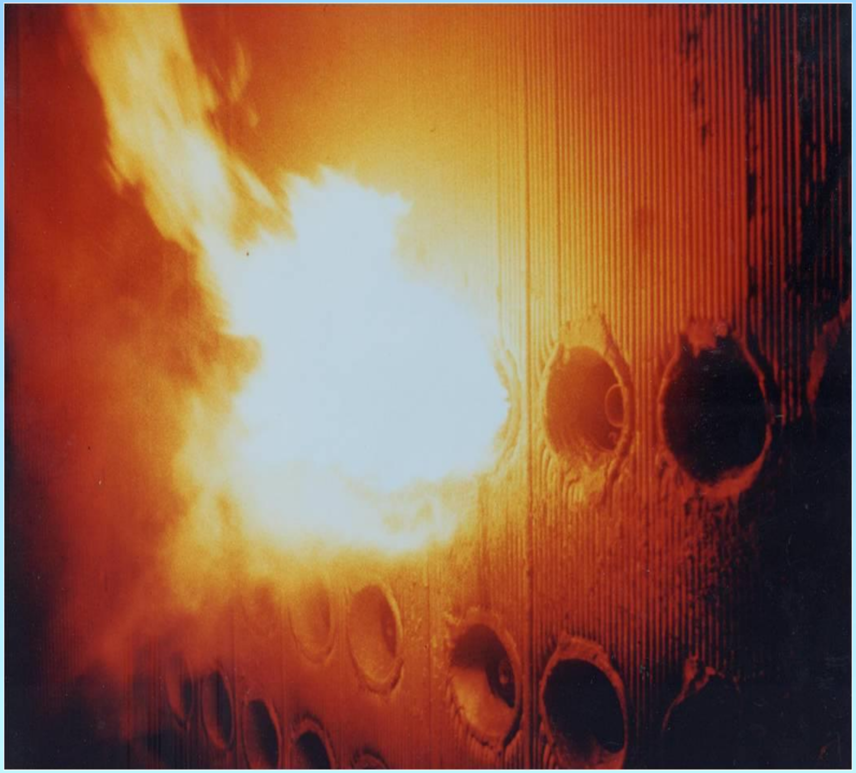
- In 1993, Japan installed first USC unit and has continued with this technology for all new units
- In 2006, first USC unit was put into operation in China. By 2017, its USC capacity will be over 208,000 MWe, with the 1000 MWe unit now the technology of choice
- USC are operated in more than ten countries in the world, with first units under construction in Malaysia (2015) and Taiwan (2016).



First step for NOx emissions control

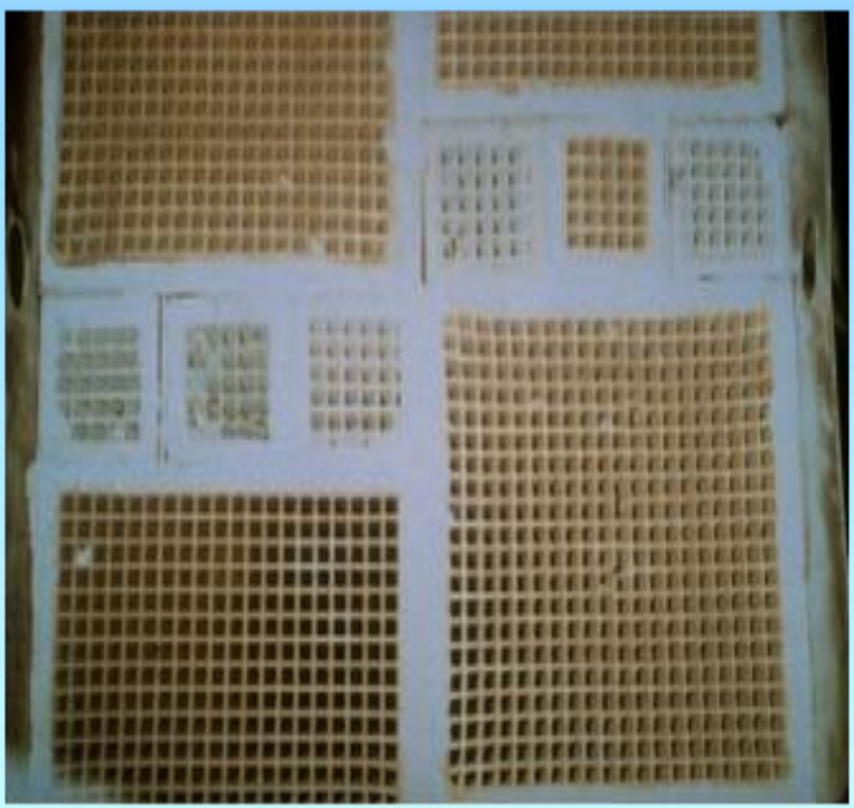
The first option technologies to be installed are Low-NOx Burners and Over-Fire Air systems. Effective for bituminous coals and lignites, much less so for lower volatile coals.

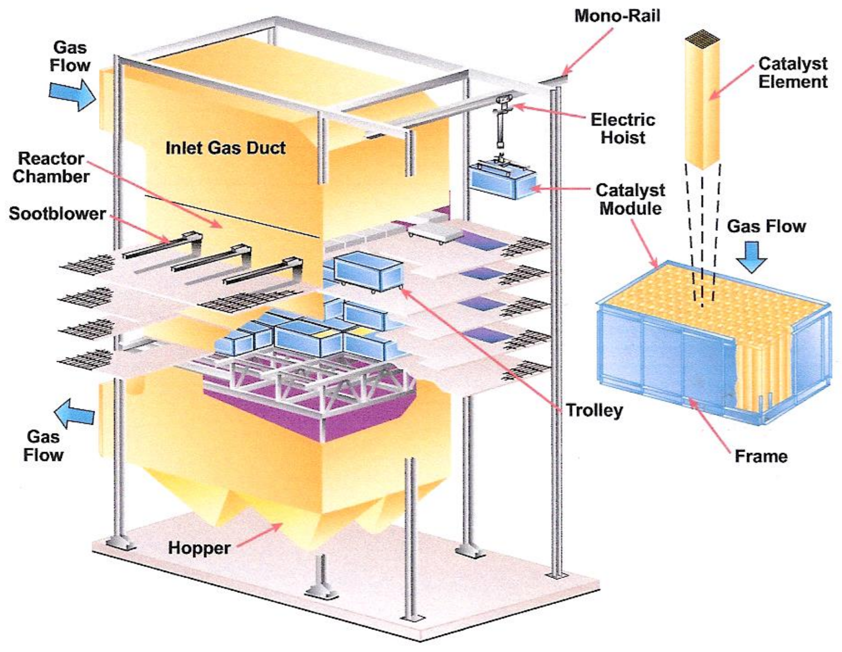




Second step for NOx emissions control

If the combustion modification approach should not prove adequate, flue gas de-NOx technology should be installed, such as Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction (SNCR), and SNCR-SCR systems



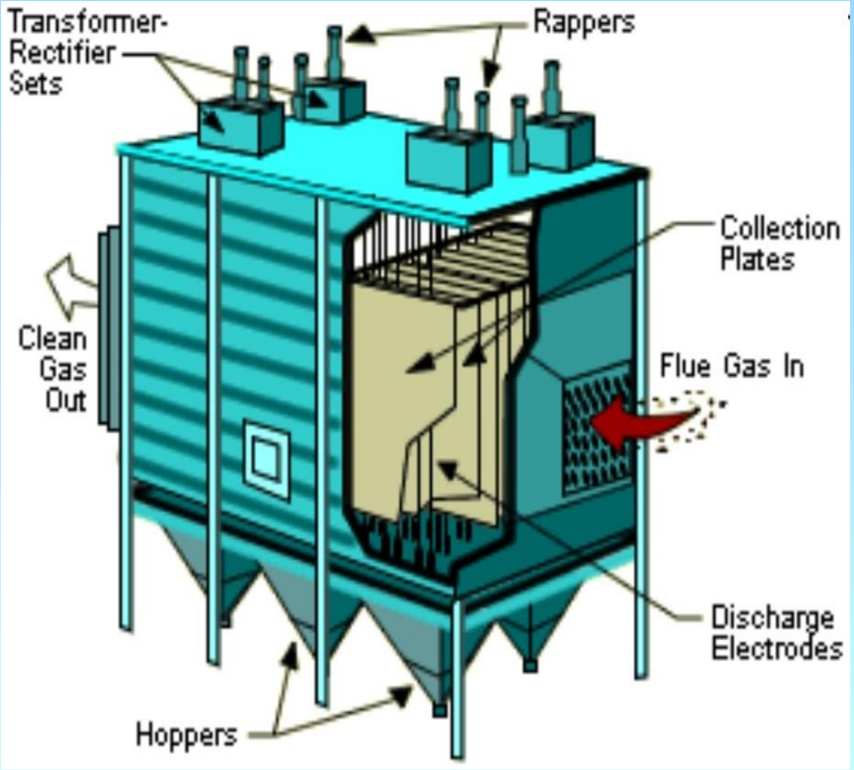


Vertical-flow fixed-bed type reactor chamber

source: Southern Company 1995

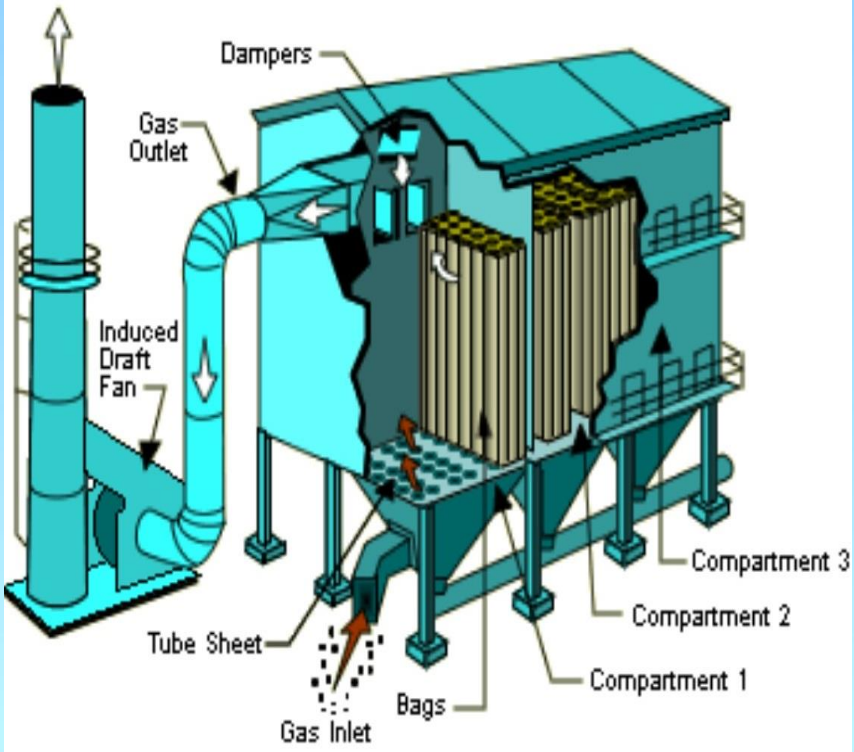
Use of ESPs for particulates emissions control requirements

For fine particulates (dust), the usual approach is to use ESPs. This is proven technology but if emissions standards are very strict, there is scope to use a combination of ESP plus part bag filter. For coals that have difficult ash characteristics, there can be a need to introduce full bag filter systems.

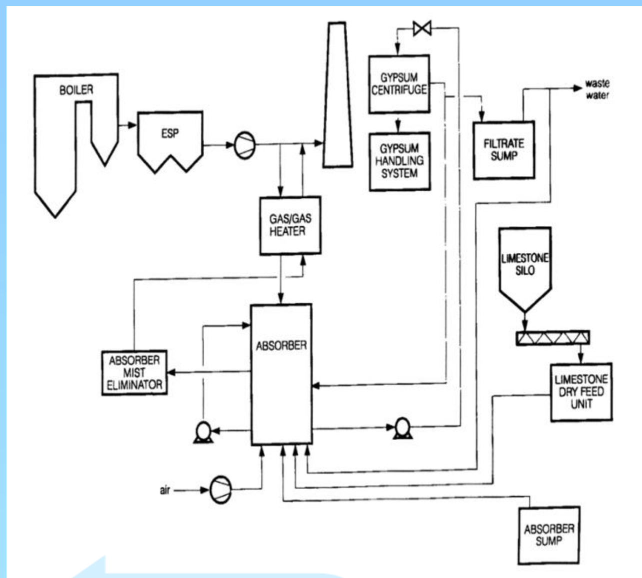


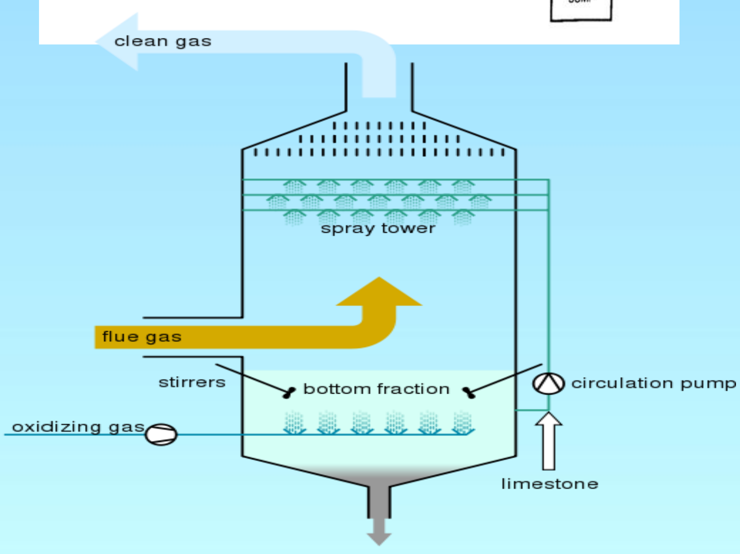
Use of bag filters for particulates emissions control requirements

Bag filters are a more expensive option than ESPs but can achieve higher dust collection efficiencies, especially for the smaller diameter particles



Wet flue gas scrubber system





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High efficiency clean coal units are the norm in parts of Asia

Isogo SC power plant near Tokyo

Waigaoqiao No. 3 USC power plant in Shanghai

Waigaoqiao No.3
1 GWe power plant in China

Emissions (mg/m^3)

Dust: 0.7

SO_2: 15.1

NOx: 17.2

Year	2008	2009	2010	2011	2012	2013	2014	2015 to date
Net efficiency (%)	42.7	43.5	44.0	44.5	44.4	44.4		44.9
Specific coal consumption (gce/kWh)	287.4	282.2	279.4	276.0	276.1	276.8		272.9
Annual load rate (%)	75	75	74	81	77	78		76

HELE current and future challenges

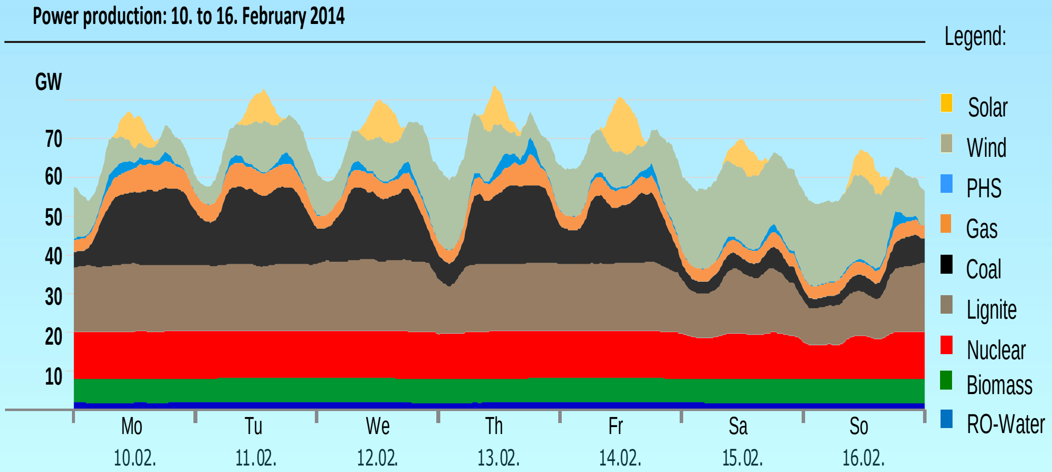
- Capital costs are higher than for subcritical units, while operating costs should be lower, depending on capital investment costs and coal costs
- Plant size needs to be some 400MWe upwards, which can impact on local grids
- Increasing need to accommodate intermittent power generation on the grid where renewables are introduced
- Further advances in steam conditions will increase costs and will require careful design consideration to ensure flexibility on the grid.

Cost and performance comparison between various Chinese coal power units (Tsinghuha 2010)

Type of unit	Specific capital investment (US$/kW)	Steam parameters	Design efficiency (% net LHV basis))
Sub-critical 2×600MWe	495.88	16.7MPa/ 538/538°C	39
SC 2×600MWe	551.47	24.5MPa/ 566/566°C	42
USC units 2×1000MWe	514.26	27.5MPa/ 600/600°C	45

HELE coal power has been extensively deployed in Germany

- **Operating net efficiency 43.2% LHV**
- **High steam conditions 27.5 MPa/580°C/600°C at turbine; initial difficulties solved using 27% Cr materials in critical areas**
- **Unique heat recovery arrangements with heat extraction to low temperatures – complex feed-water circuit**
- **Lignite drying plant installed to enable even higher efficiency**
- **HELE units are having to stabilise the grid due to renewables 'overload'**



Design standards for existing and new pulverised coal power plants in China

- Since 2006, new plants must be SC or USC of at least 600MWe capacity

- From 2015, for new coal power projects, unit capacity must be at least 600MWe USC and mostly 1000MWe USC, with net coal consumption lower than 285gce/kWh and 282gce/kWh respectively

- By 2020, average net coal consumption for all existing coal power plants must be lower than 310gce/kWh, with all such units of 600MWe and above having a specific net coal consumption of less than 300gce/kWh

Towards ≥50% cycle efficiency with advanced USC technology

National programme	Steam temperature	Efficiency (LHV, net)	Programme start date	Demonstration plant operational by (size)	Also includes:
EU	700ºC	>50%	1998	2021 (500 MWe)	Coatings, biomass co-firing, cycling
USA	760ºC	45-47% (HHV, net)	2000	2021 (600 MWe)	Oxyfuel, coatings, high sulphur coal
Japan	700ºC	>50%	2008	2021 (600 MW)	Biomass co-firing
China	700ºC	46-50%	2011	2021 (660 MWe)	-
India	700ºC	>50%	2011	2017 (800 MWe)	-

Metals used in boiler and turbine hot spots:

- **Steels well proven in USC at 600ºC**
- **Nickel based alloys proving capable in A-USC at 700ºC**

HELE coal power plant as a stepping stone for CCS introduction

- HELE plant is a precursor for the addition of CCS, since CO2 capture unit can be better integrated with a modern coal power plant

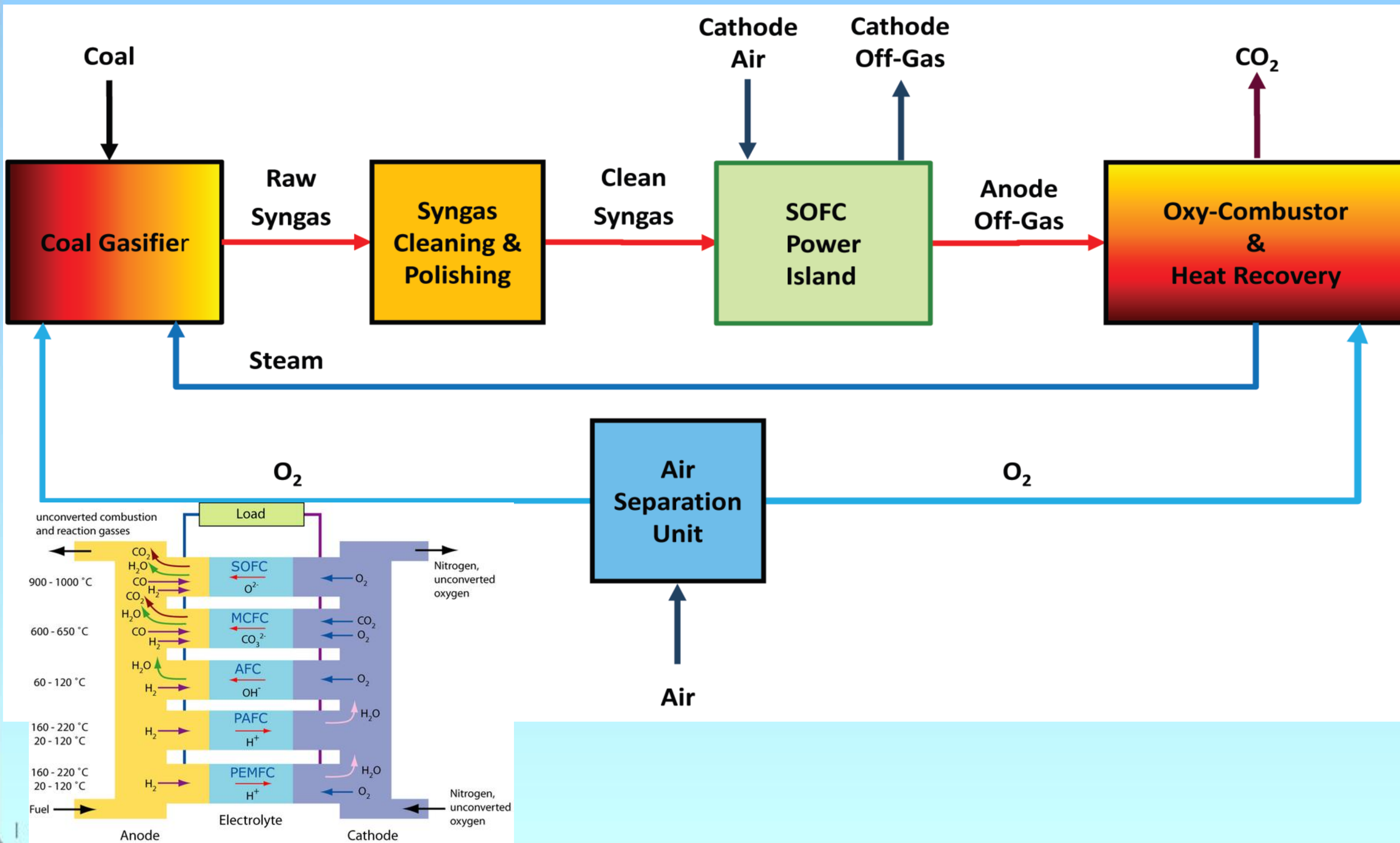
- HELE with CCS represents the ultimate clean coal power plant, at comparable cost to most alternative low and zero carbon technologies

Other advanced systems being developed but some way from the market

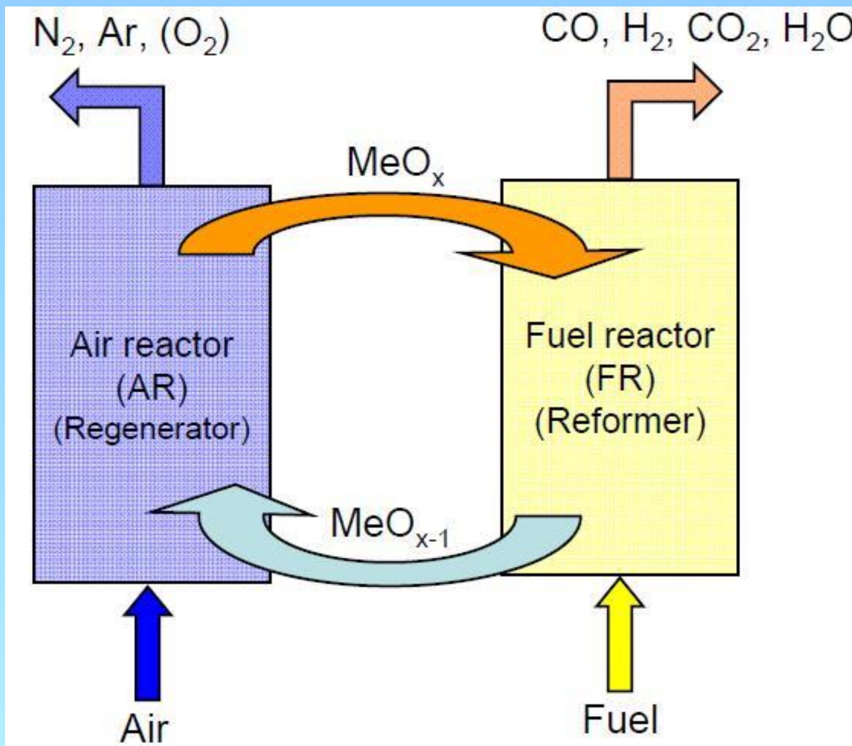
Developers are considering alternative innovative coal power cycle concepts that may be attractive especially when the need to include integrated CCS is included.

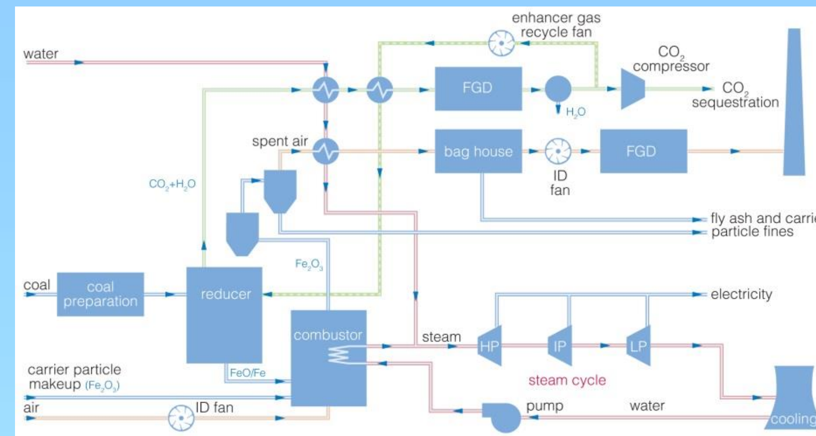
- Fuel cells integrated with a coal gasification system, with a net plant efficiency towards 56% and CO_2 capture rates up to 99%. Japan plans demonstration from 2021
- Chemical looping combustion (CLC) may also offer significant advantages in the longer term
- Various cycles that use supercritical CO_2 as the working fluid. Although very complex, they offer the longer term prospect of lower capital costs combined with effective CO_2 capture.

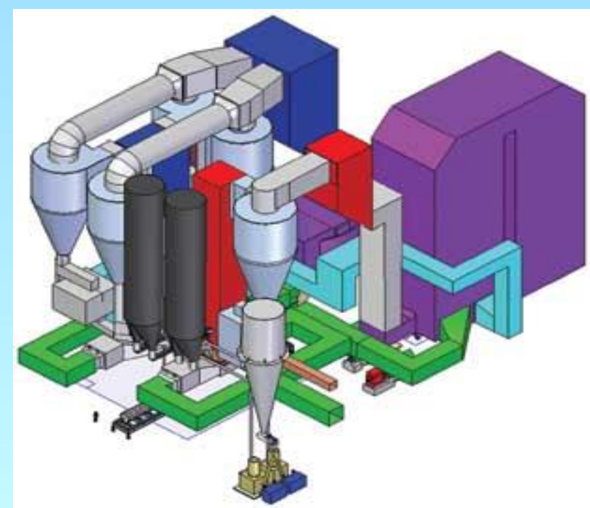
Integrated gasification fuel cell (IGFC) system



Chemical looping combustion (CLC)



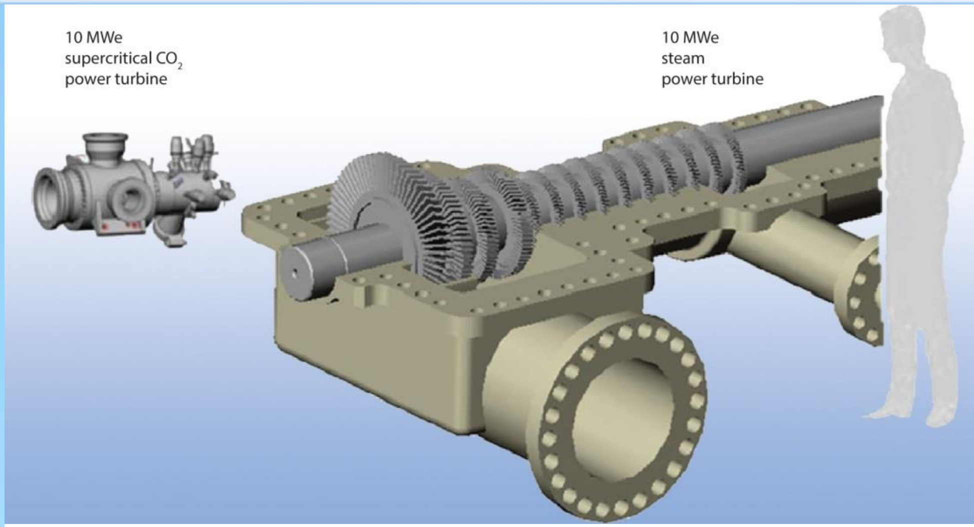




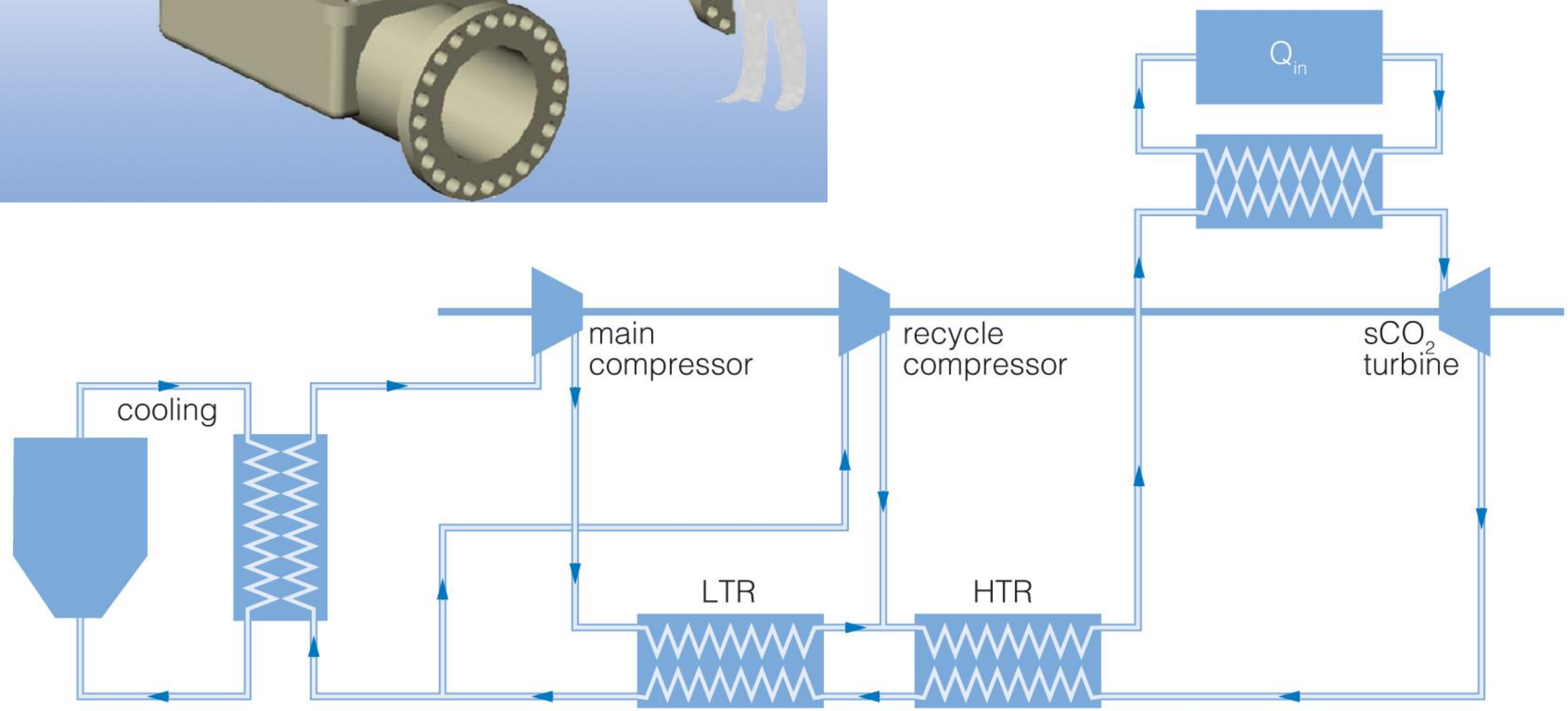
Chemical looping combustion/gasification

Drawing of Alstom's 550 MWe CLC power plant concept →

Alternatives to steam Rankine cycles



A 10 MWe sCO_2 power turbine and a 10 MWe steam turbine



Closed Loop sCO_2 recompression Brayton cycle

Global reality

- The IEA and others have emphasized that a diverse energy mix is still needed and that a renewables-only future is not viable
- It is also clear that such a mix will have very distinct regional characteristics and that any attempt to force a ‘one size fits all approach’ will not work
- For coal, the near term drivers must be to support both demand side energy efficiency measures and supply side introduction of HELE technologies
- This can result in a major reduction in global CO_2 emissions while also providing the necessary precursor for subsequent introduction of CCS techniques
- It will also improve overall air quality compared to the use of non-HELE systems
- There has to be a concerted effort to push CCS to the demonstration and deployment stage

Thank you for listening!

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