Clean coal: new global challenges and potential opportunities

Dr Andrew J Minchener OBE

Scope of the presentation

Role of coal in the global energy mix

- Historical and future trends
- Focus on use in China and other developing nations

Coal's efficiency and environmental challenges

Coal and China

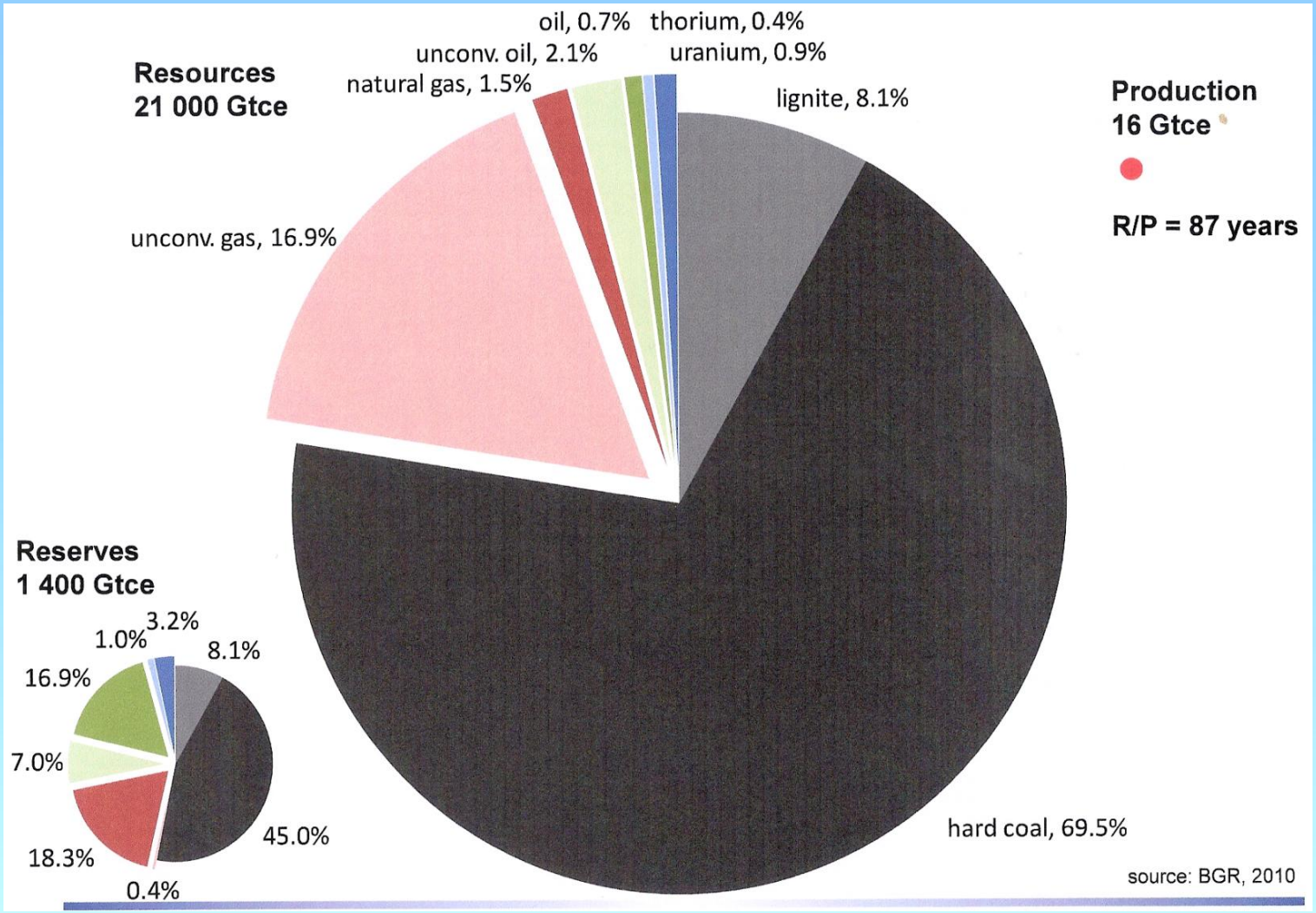
- Market sector and geographical availability analysis
- Imports and exports
- Policy issues and the Five Year Plans
- Coal-fired power generation technology improvement options
- Coal to chemicals
- CCS for China

International cooperation

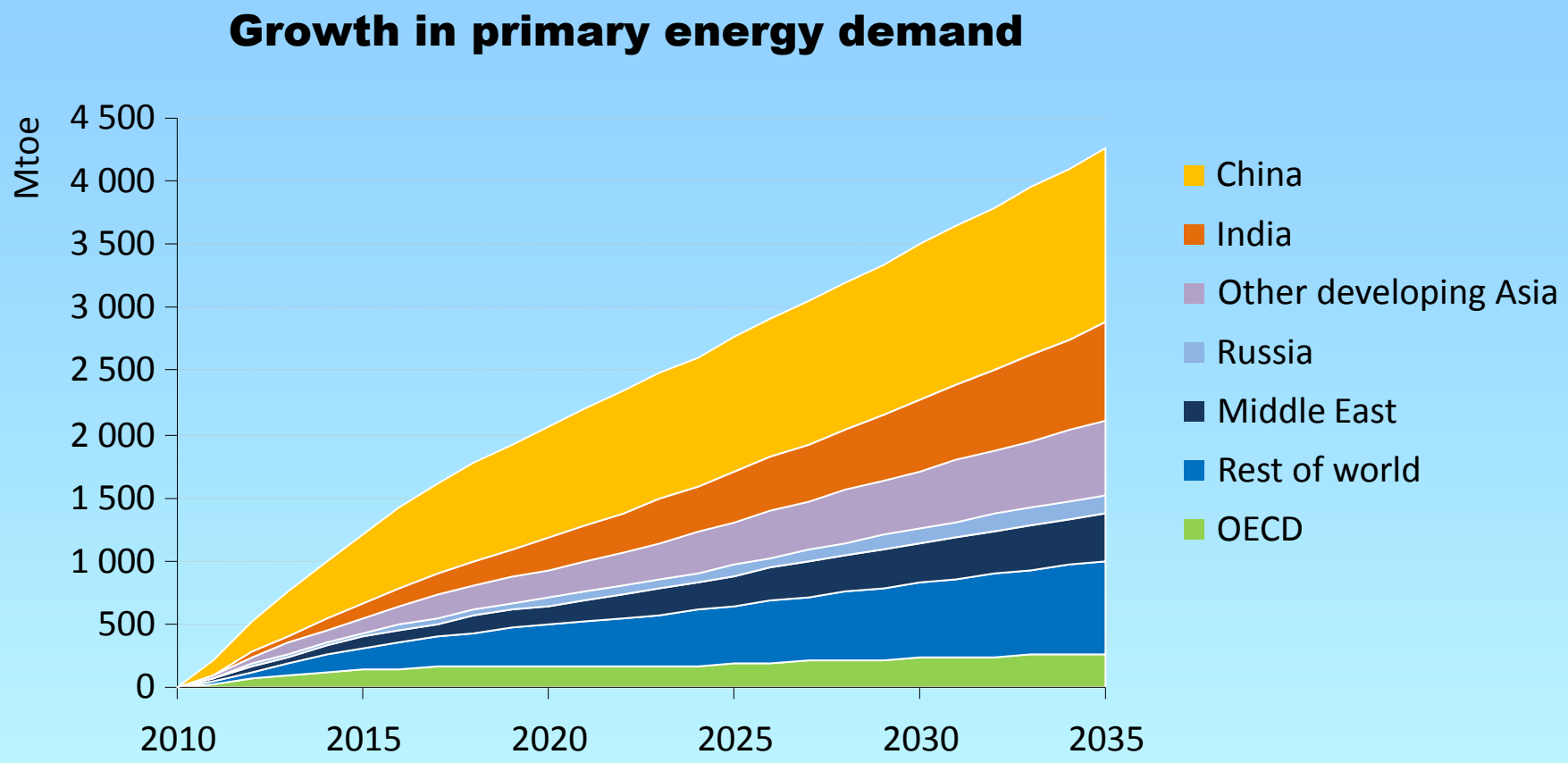
Final thoughts

Acknowledgements

Global energy resources and reserves



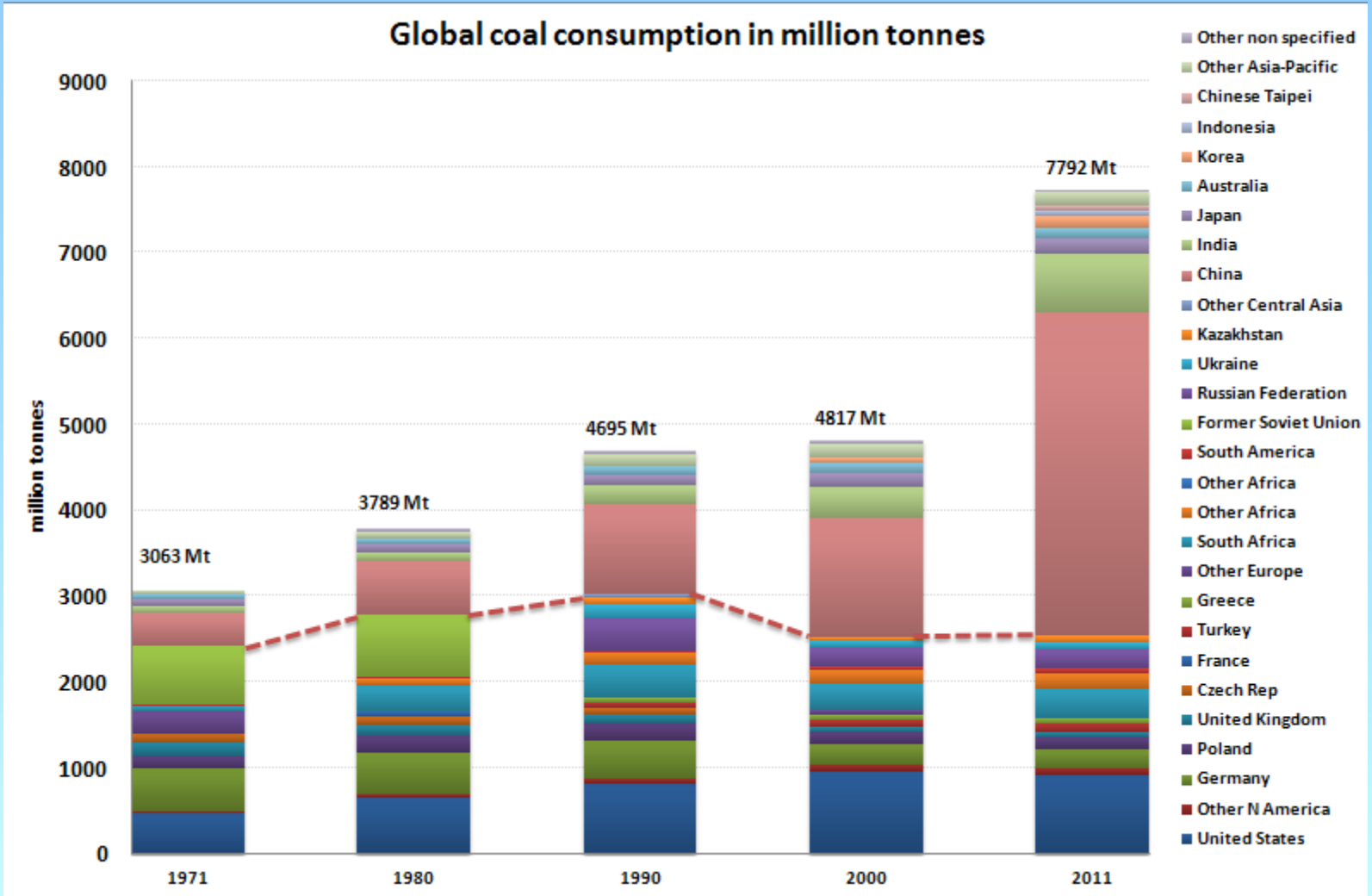
IEA WEO 2011: Emerging economies continue to drive global energy demand



Global energy demand increases by one-third from 2010 to 2035, with China & India accounting for 50% of the growth

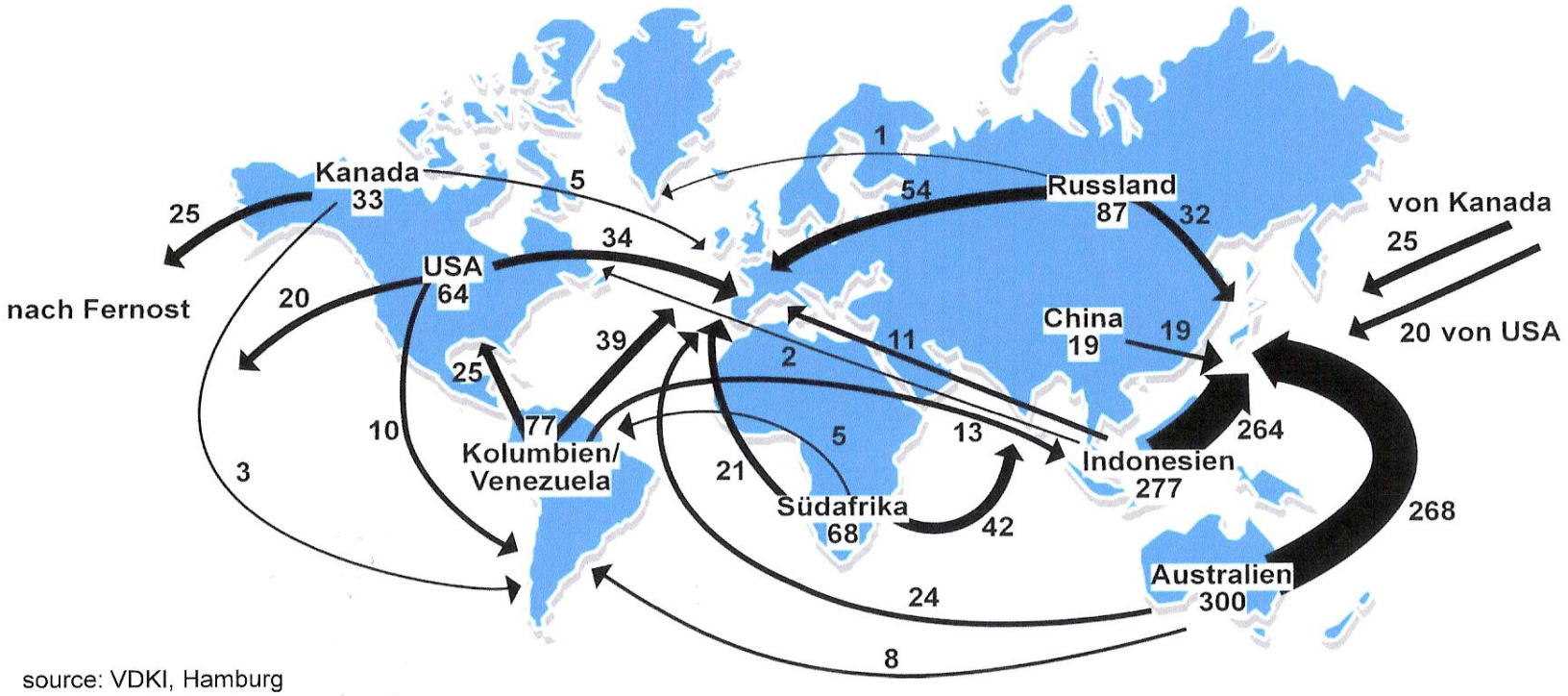
Asia is the growth region for coal use, with China the dominant nation

(Baruya 2012)



World hard coal trade in 2010

(VDKI Hamburg)



source: VDKI, Hamburg

world hard coal production	6 700 million tonnes
steam coal trade	713 million tonnes
coking coal trade	250 million tonnes

Seaborne hard coal trade reached 963 Mt in 2010, 14.4% of total production.

Coal's global efficiency and environmental challenges are epitomised by the situation in China

- Need to maximise use of useful heat from coal combustion and conversion, for power, CHP and other applications
- Need to reduce conventional (non GHG) emissions still further
- Increasing need to address emissions of trace metals
- Expectation of the requirement to limit CO_2 emissions

Geographical spread of Chinese coal resources

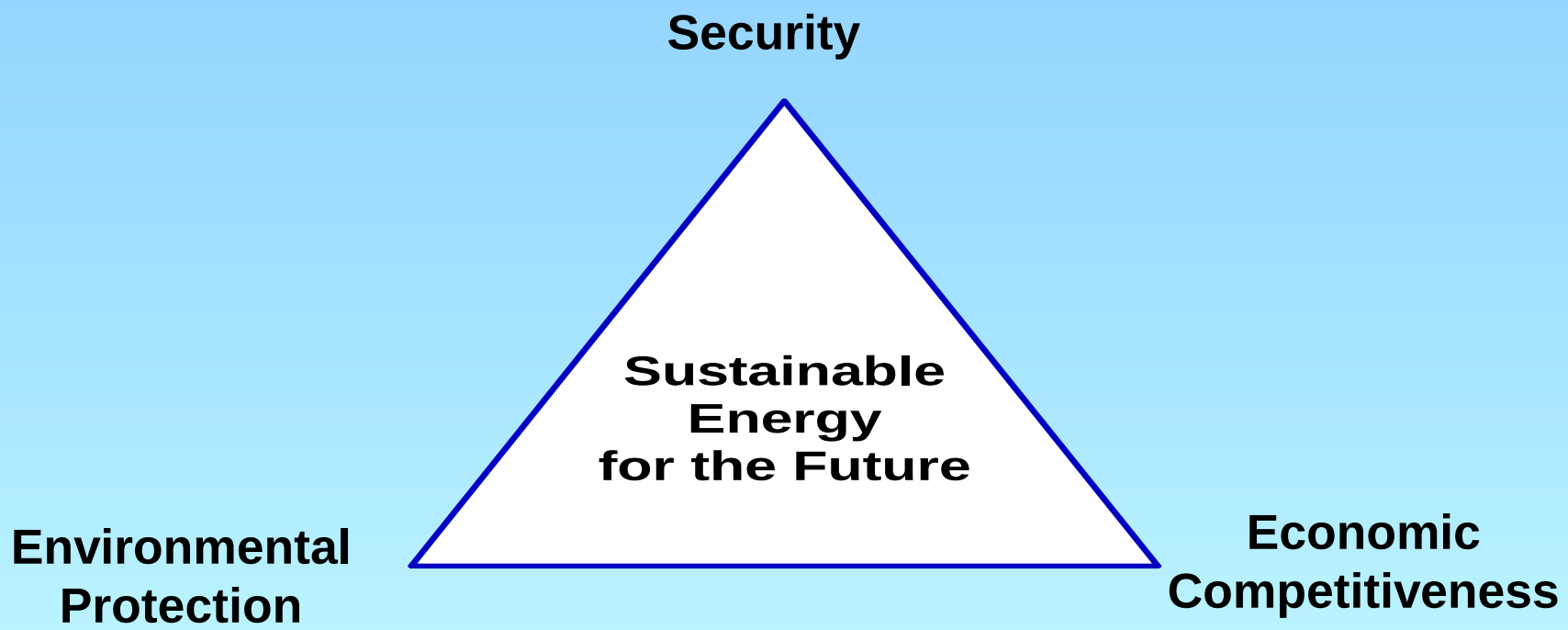
Coal use in China

Unlike OECD countries, coal use in China is spread across many sectors. Coal for power generation is the largest sector and its proportion of a growing total will rise in future.

Sector	Coal use in 2010 (Mt)	Proportion of coal use (%)
Power generation	1765	54.8
Iron & steel	515	16.0
Building materials	515	16.0
Chemicals	171	5.3
Others	245	7.6
Export	10	0.3

China's energy and environmental policy initiatives within the Five Year Plans

11th and 12th Five Year Plans have moved away from production targets towards a much more inclusive approach, with increasing emphasis on energy security and environmental issues



Energy and environment targets in the 12th Five Year Plan (2011- 2015)

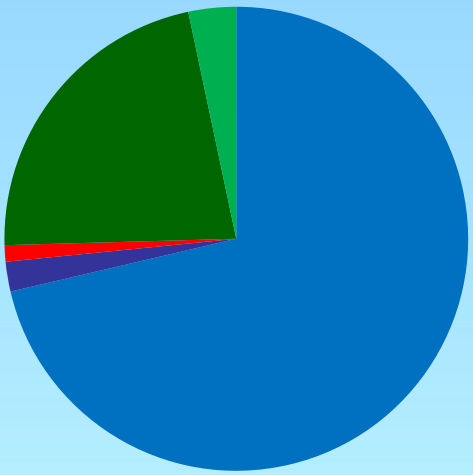
- Energy intensity to be cut by 16% from 2010 levels;
- CO_2 intensity to be cut by 17% from 2010 levels;
- Non-fossil fuel use to account for 11.4% of primary energy consumption, with a target of 15% for 2020;
- SO_2 emissions to be cut by 8% from 2010 levels;
- NOx emissions to be cut by 10% from 2010 levels;
- Heavy metals pollution to be reduced at least to 2007 levels;
- Water consumption per unit of value-added industrial output to be cut by 30%.

12th FYP goals for the power generation sector

- 235 GWe capacity for non-fossil energy sources
  - 40 GWe of nuclear power projects
  - 120 GWe of hydropower stations,
  - At least 70 GWe of wind power capacity
  - 5 -15 GWe of solar power
- 270 GWe of coal fired power plants, comprising 600, 660 or 1000 MWe high efficiency supercritical and ultra-supercritical units.
- Closure of some 50GWe of older less efficient coal power plants

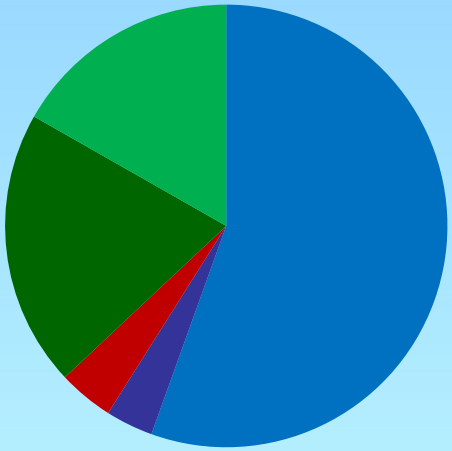
Projected changes in China coal power capacity mix

2010 (963 GWe)



- Coal (71.4%)
- Natural gas (2.0)
- Nuclear (1.1%)
- Hydropower (22.1%)
- Other renewables (3.4%)

2020 (1730 GWe)



- Coal (55.5%)
- Natural gas (3.5%)
- Nuclear (4.0%)
- Hydropower (20.3%)
- Other renewables (16.6%)

China's strategic approach for clean coal integrated technologies development

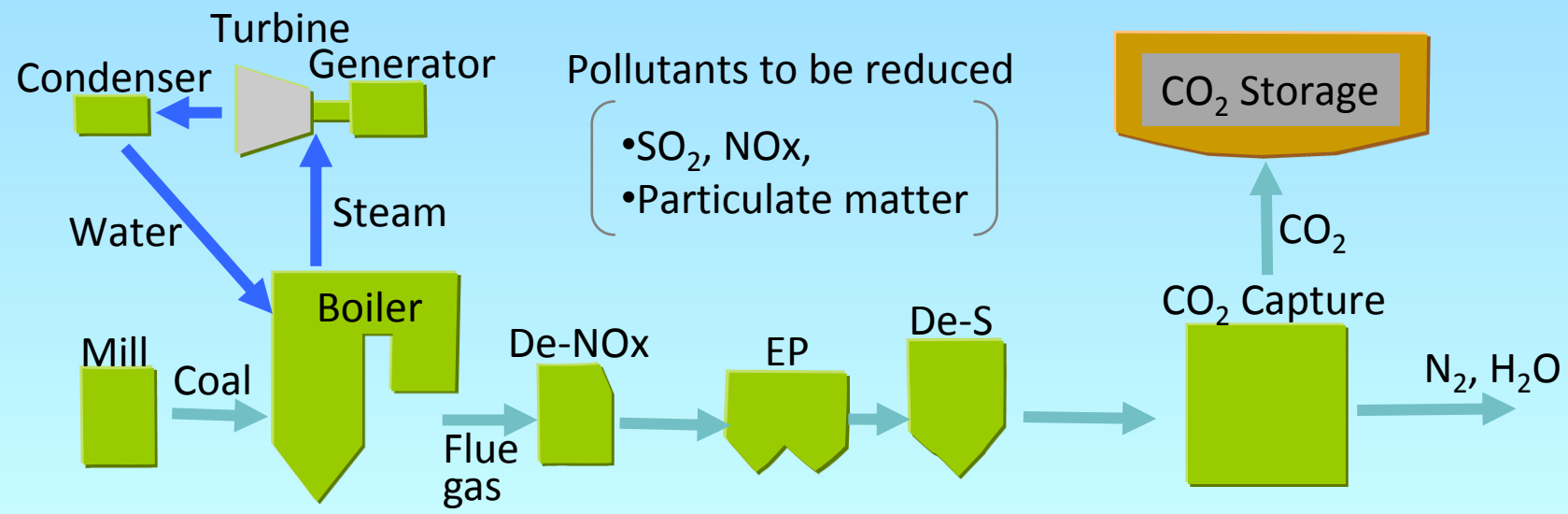
Focus on technologies to reduce both GHG and non-GHG (NOx, SO_2, PM) emissions.

Technologies for cleaner coal generation

(1) Reducing coal consumption

(2) Reducing non-GHG emissions

(3) Carbon Capture and Storage



EP: Electrostatic Precipitator

Coal fired power generation deployment in China

- Coal based power generation is mostly (90%) based on pulverised coal combustion (which is also the primary technique for use in cement manufacture)
- Alternative technology for power generation (10%) is circulating fluidised bed combustion, which is used for low grade and variable quality coals
- Integrated gasification combined cycle is a further longer term possibility but has yet to be demonstrated in China

The past

Obsolete 2x200 MWe plant with minimal emissions control

Low quality coal, often with a high sulphur content

Chinese energy efficiency programme for the coal power sector

- Over 200 GWe of advanced, high efficiency large capacity installed between 2006 and 2010 and over 72 GWe of old, small coal plants decommissioned
- Nationwide average coal consumption for power generation reduced from 370 gce/kWh in 2005 to 335 gce/kWh in 2010. Best new plants are achieving <280 gce/kWh
- Policy will be continued during 2011-2015, including closure of units up to 300 MWe in size

Cost and performance comparison between various Chinese coal power units

Type of unit	Specific capital investment (US$/kW)	Steam parameters	Efficiency (% net LHV basis))	Coal consumption (gce/kWh)
Sub-critical 2×600MWe	495.88	16.7MPa/ 538/538°C	42.0	293
SC 2×600MWe	551.47	24.5MPa/ 566/566°C	43.6	282
USC units 2×1000MWe	514.26	27.5MPa/ 600/600°C	45.0	273

Source: CEC 2008

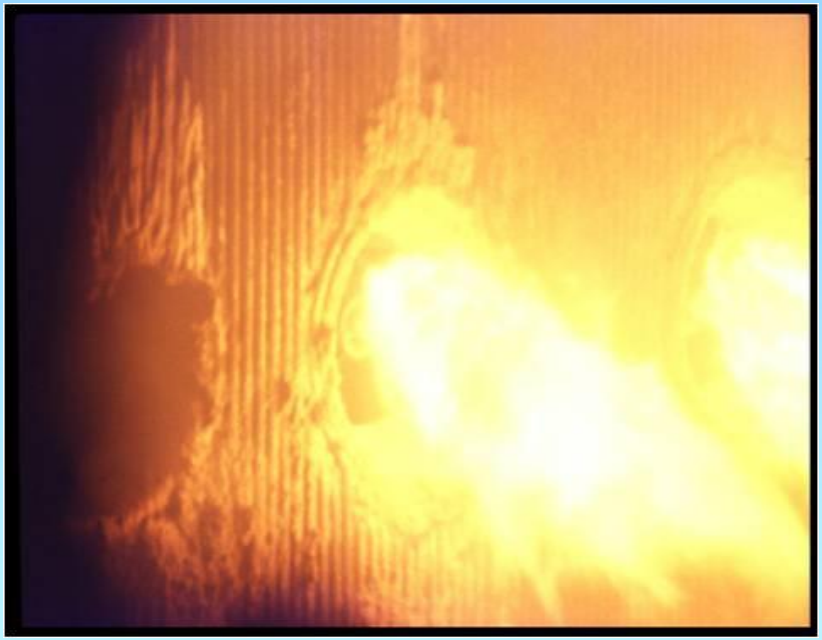
New emission limits for coal power plants in the priority regions of China

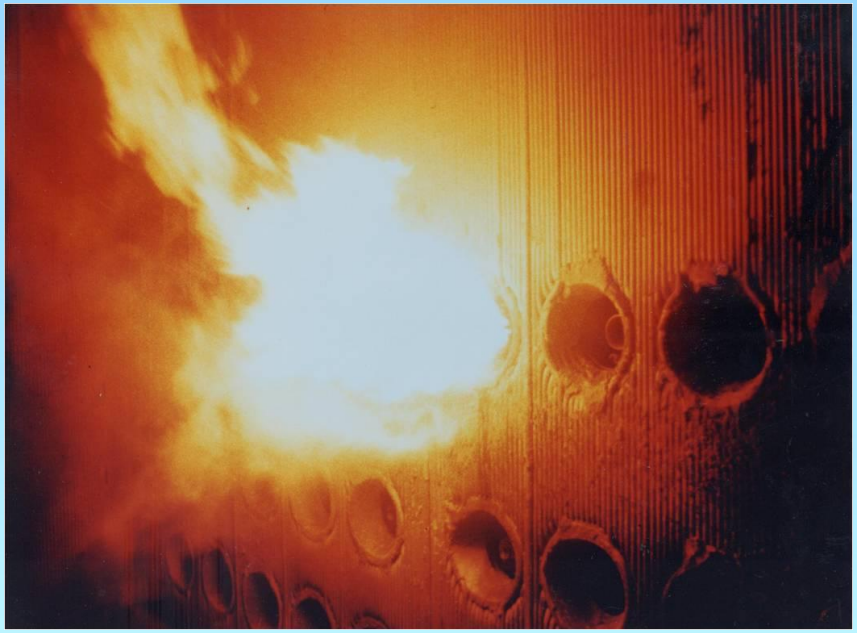
[GB13223-2011]

Pollutant	Conditions for appln.	Permitted emission levels (mg/m^3)	Location for monitoring emissions
Particulates	all	20	Stack or flue duct
SO_2	all	50	
NOx (as NO_2)	all	100	
Hg and compounds	all	0.03	Exit of stack

First step for NOx emissions control

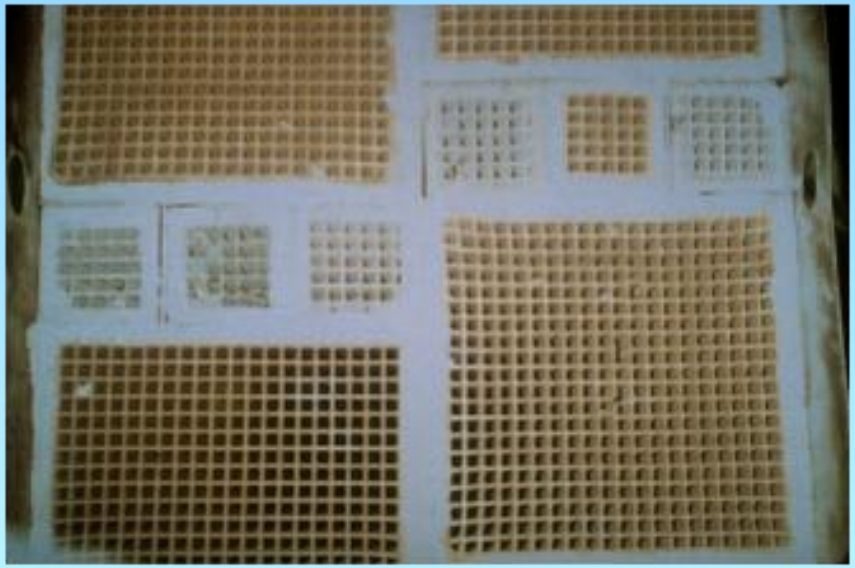
The first option technologies to be installed are Low-NOx Burners and Over-Fire Air systems, which are the technologies that have been introduced previously.

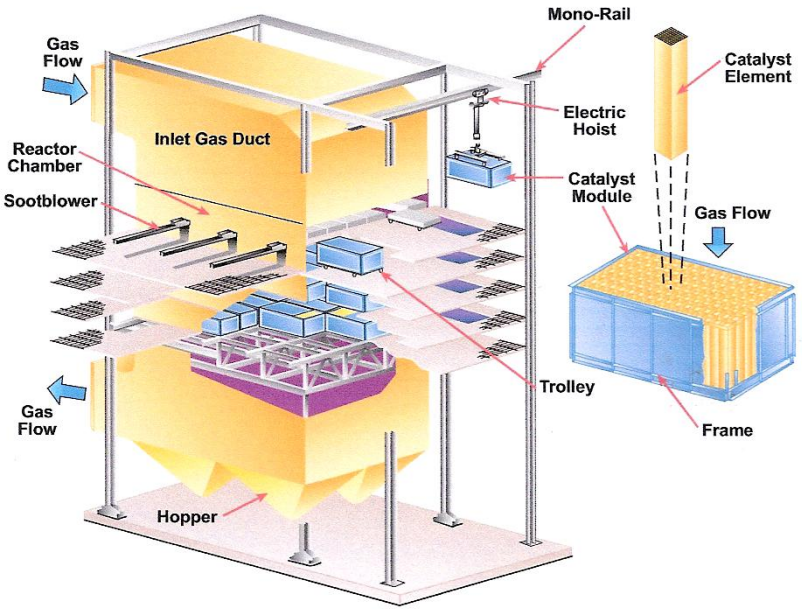




Second step for NOx emissions control

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



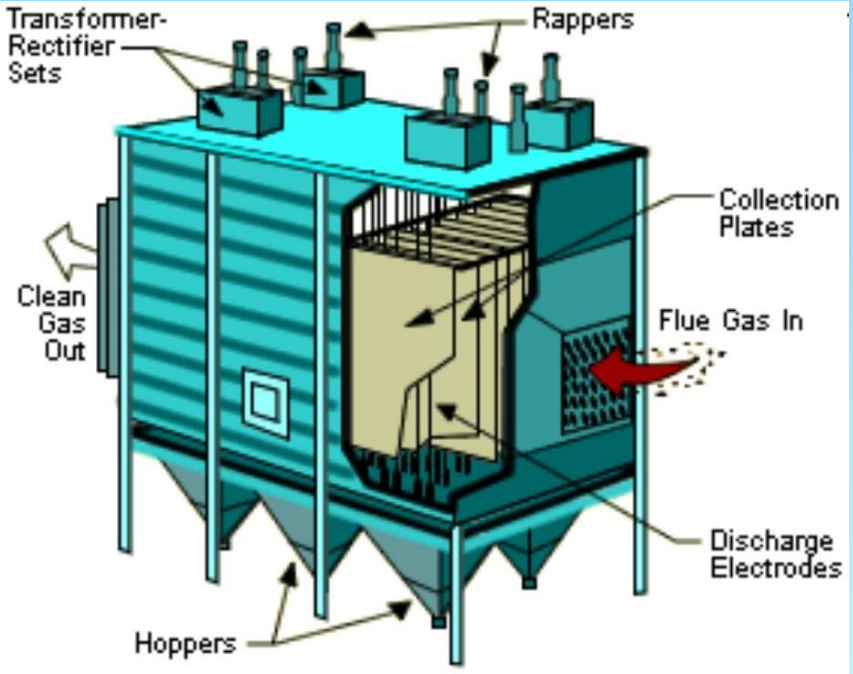


Vertical-flow fixed-bed type reactor chamber

source: Southern Company 1995

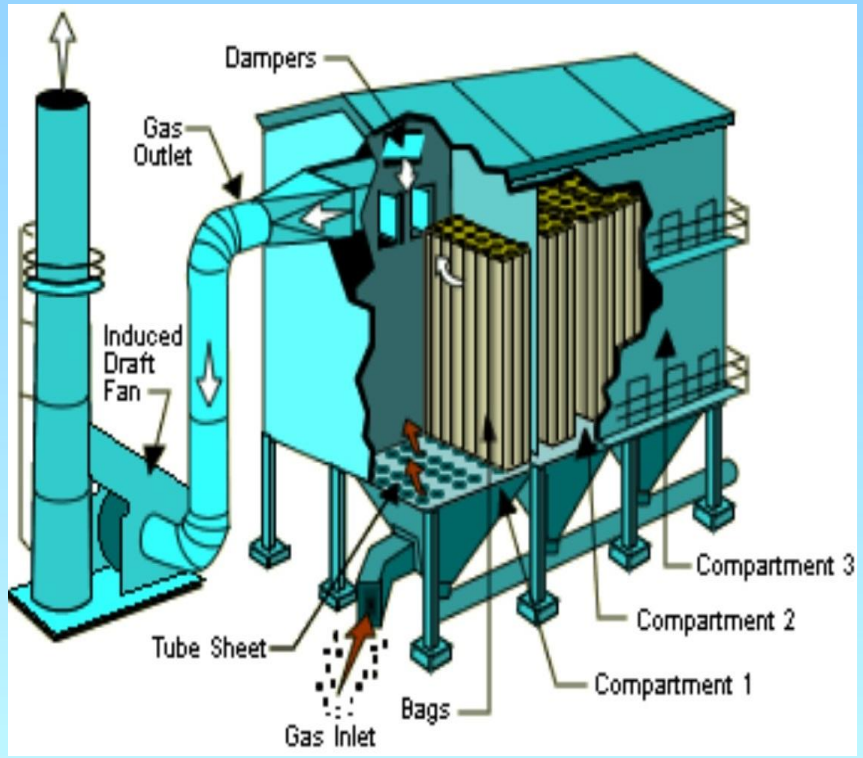
Use of ESPs for particulates emissions control requirements

For fine particulates (dust), the usual approach is to use ESPs. To meet the new standards, the collection efficiency will need to be improved and, if that is not enough, there will be a need for a combination of ESP plus part bag filter. For coals that have difficult ash characteristics, there will be a need to introduce full bag filter systems.



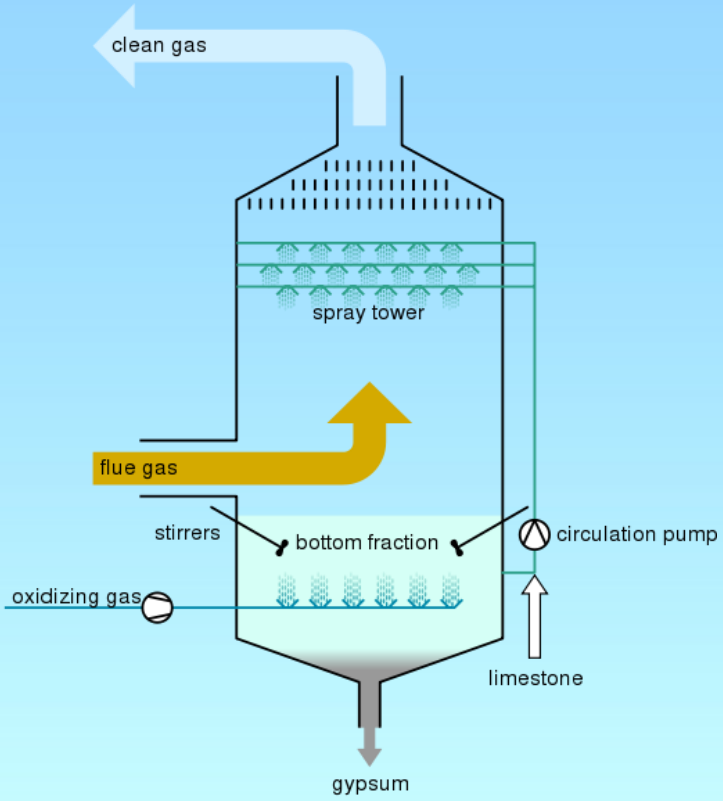
Use of bag filters for particulates emissions control requirements

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



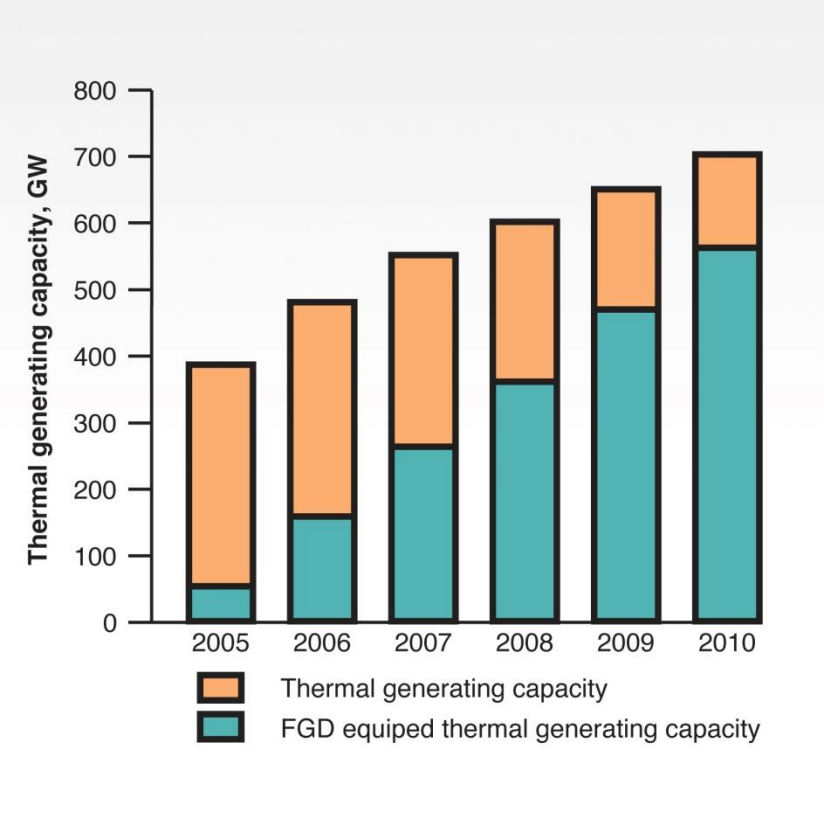
SO_2 emissions control requirements

This will require the installation of advanced FGD equipment on the remaining plants not yet fitted with this equipment and not expected to be closed in the near future as well as on all new plants, while improving and raising the desulphurisation rate to at least 95% on all existing systems, and in some cases to 97% depending on the sulphur content of the coal to be used.



Lessons learned from monitoring and verification

Coal power capacity has increased from 384 GWe in 2005 to 687 GWe in 2010, with FGD being installed on all new plant since about 2006. Combination of incentives and enforcement has led to overall SO_2 levels decreasing.



Year	Coal power SO_2 emissions (Mt)
2000	6.5
2001	6.5
2002	6.7
2003	8.3
2004	9.3
2005	11.1
2006	11.6
2007	10.9
2008	9.3
2009	9.3*
2010	9.5*

Market opportunities through to 2020

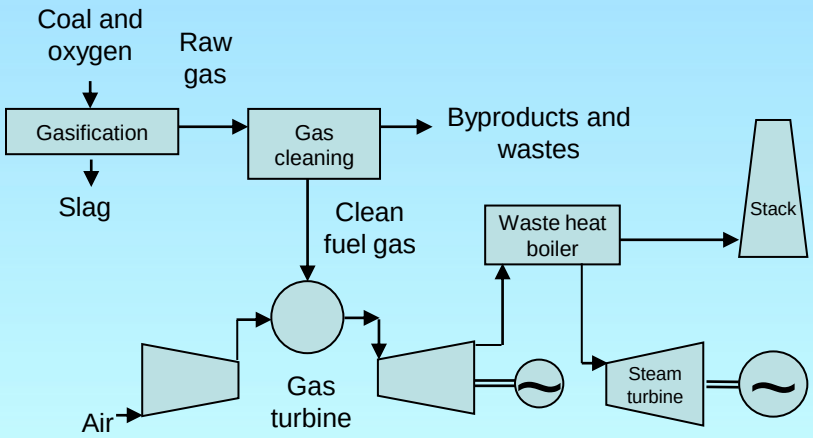
- New thermal power plant emission regulations and standards will further create a rapidly growing and large market demand in China for improved pollutant control devices on coal fired units, both for retrofit and new applications. This includes particulates, SO_2 and NOx emissions control, mercury monitoring devices plus continuous emissions monitoring systems for supervision and verification.

- China's demand will dominate the global markets over the next ten years during which time some major Chinese suppliers will enter that global market from a position of strength

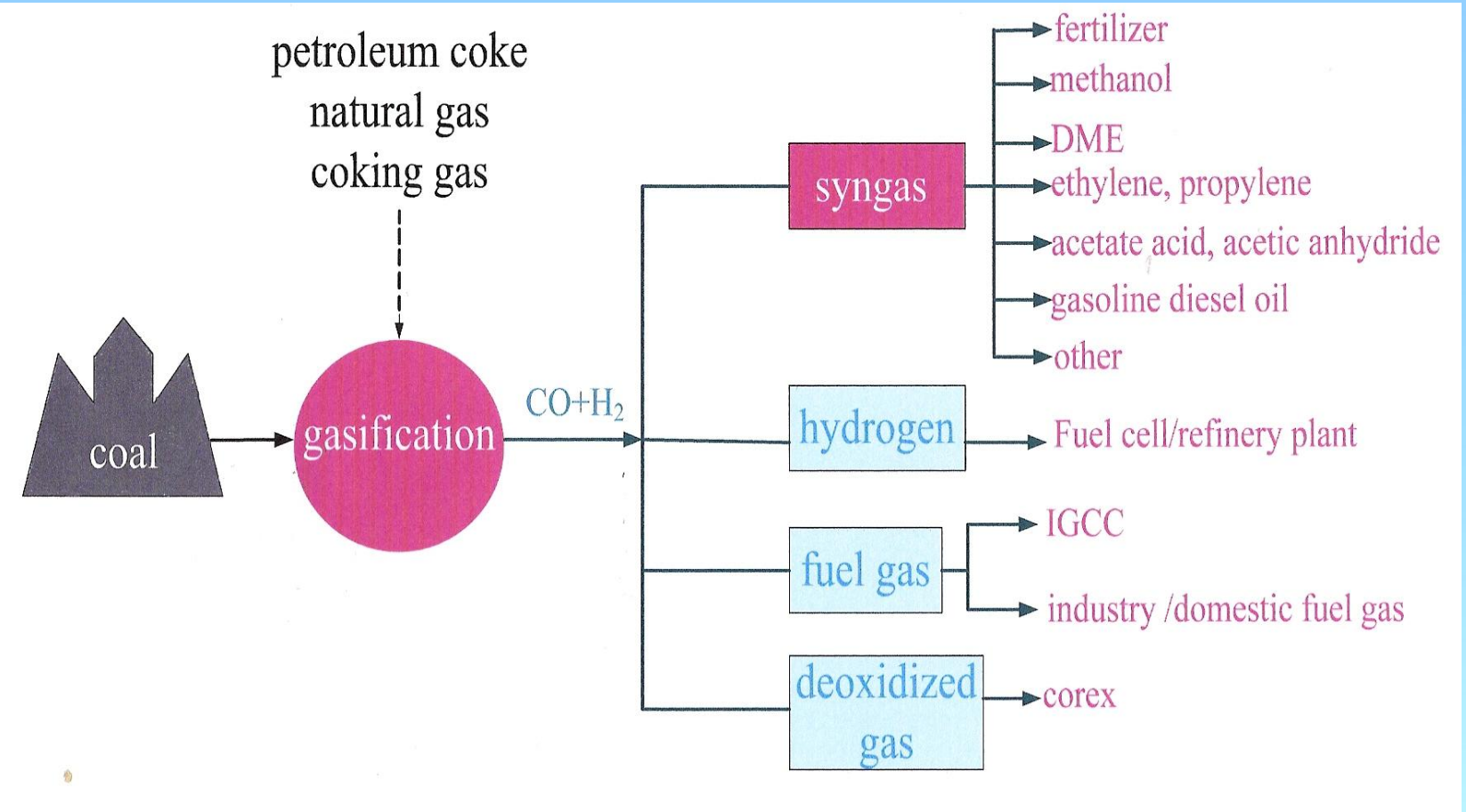
Development and deployment of CFBC in China

- Licence for 300MWe units obtained from Alstom
- Building and operating units to 350 MWe
- Designed and building 600 MWe unit with supercritical steam conditions
- Not yet clear if the boilermakers will push to go to still larger size plant.

IGCC demonstration as Phase 1 of the Greengen project



Non-power gasification options in China

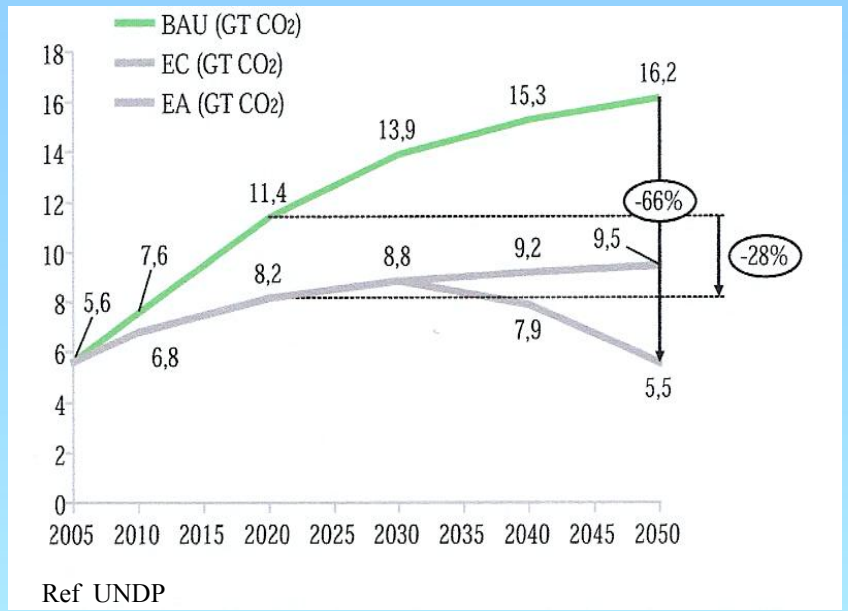


Overview of non-power coal gasifier deployment in China to end 2011

Supplier	Coal gasification projects		
	Operational	Design/ construct	Total
GE	27	10	37
Shell	14	5	19
Siemens	1	2	3
Sasol Lurgi	3	3	6
GTI U-Gas	1	1	2
ECUST	8	9	17
TPRI	-	3	3
CACG	3	15	18
Tsinghua U	3	5	8
ICC-CAS	3	-	3
Total	**63**	**53**	**116**

Consequences for increased coal use

Current and possible future CO_2 emissions for China



In the near term, coal use will continue to dominate power generation sector, with its capacity rising from ~700 GWe (2010) to ~935 GWe (2015)

In 2010, CO_2 emissions were 8.3 Gt with those from coal in excess of 6Gt.

Studies indicate that absolute CO_2 emissions will rise but at decreasing rates.

With further introduction of low/zero carbon technologies, emissions may reach a plateau by about 2030.

CCS will be required if emissions are to subsequently decline.

CCS and China

What does it offer China?

- Fossil energy can be used in a sustainable way.
- Existing infrastructure can continue to be used.
- It enhances security of supply
- It increases the flexibility of emission control
- It is competitive to alternative sustainable options

Issues of concern

- Lack of proven technology maturity
- Increased coal demand
- Increased water requirements
- Adverse impact on power generation costs

Status of CCS for China

- Does not feature in the economic goals of 12th FYP but is included as a high technological priority within the R&D programme
- Mixture of domestic R&D programmes plus larger scale industrial trials and significant international cooperation for capacity building

China's national CCS R&D programme

The aim is to establish Chinese based techniques upon which can be secured independent intellectual property rights.

- The National Basic Research (973) Programme includes work on:
  - CO_2 use for EOR applications and long term storage;
  - Coal based syngas production and conversion for carbon free use in gas turbines.
- The National High-Tech Research and Development (863) Programme includes projects to develop:
  - advanced CO_2 capture technologies based on adsorption and absorption processes
  - applications for CO_2 storage technology.
- There is support for the understanding and development of oxyfuel combustion and chemical looping combustion processes

CO_2 utilisation activities by non-power sector Chinese industries

A series of large scale trials is underway, covering EOR as well as assessing other CO_2 utilisation schemes

- PetroChina CO_2 EOR project at the Jilin Oil Field, Liaoning Province using CO_2 removed from a natural gas deposit
- Sinopec EOR project at the Shengli oilfield of Shandong Province using CO_2 captured from a coal fired power plant
- ENN Resource CO_2 recycling project using algae to absorb CO_2 for subsequent processing to produce biodiesel

CO_2 capture and utilisation trials in the coal fired power sector

In 2008, Huaneng Group established a side stream post-combustion capture unit on the 800MWe Gaobeidian PC CHP plant in Beijing, with an annual CO_2 capture capacity of 3000 tonnes.

Captured CO_2 is sold to the food and beverage industries.

Huaneng post-combustion CO_2 capture unit in Shanghai

In 2010, Huaneng installed a larger unit on the 2x660 MWe Shidongkou No. 2 Power Plant in Shanghai, which can capture 120,000 tonnes of CO_2 each year.

As in Beijing, CO_2 is sold to the food and beverage industries

Cost of CO_2 capture well below OECD projections

Greengen IGCC CCS project

The aim is to establish a high-efficiency, coal-based IGCC polygeneration system and efficient treatment of pollutants with near-zero emissions of CO_2.

Phase 1 is to prove the scale-up of the Chinese gasifier design and to ensure overall reliability and acceptability of the integrated IGCC power plant.

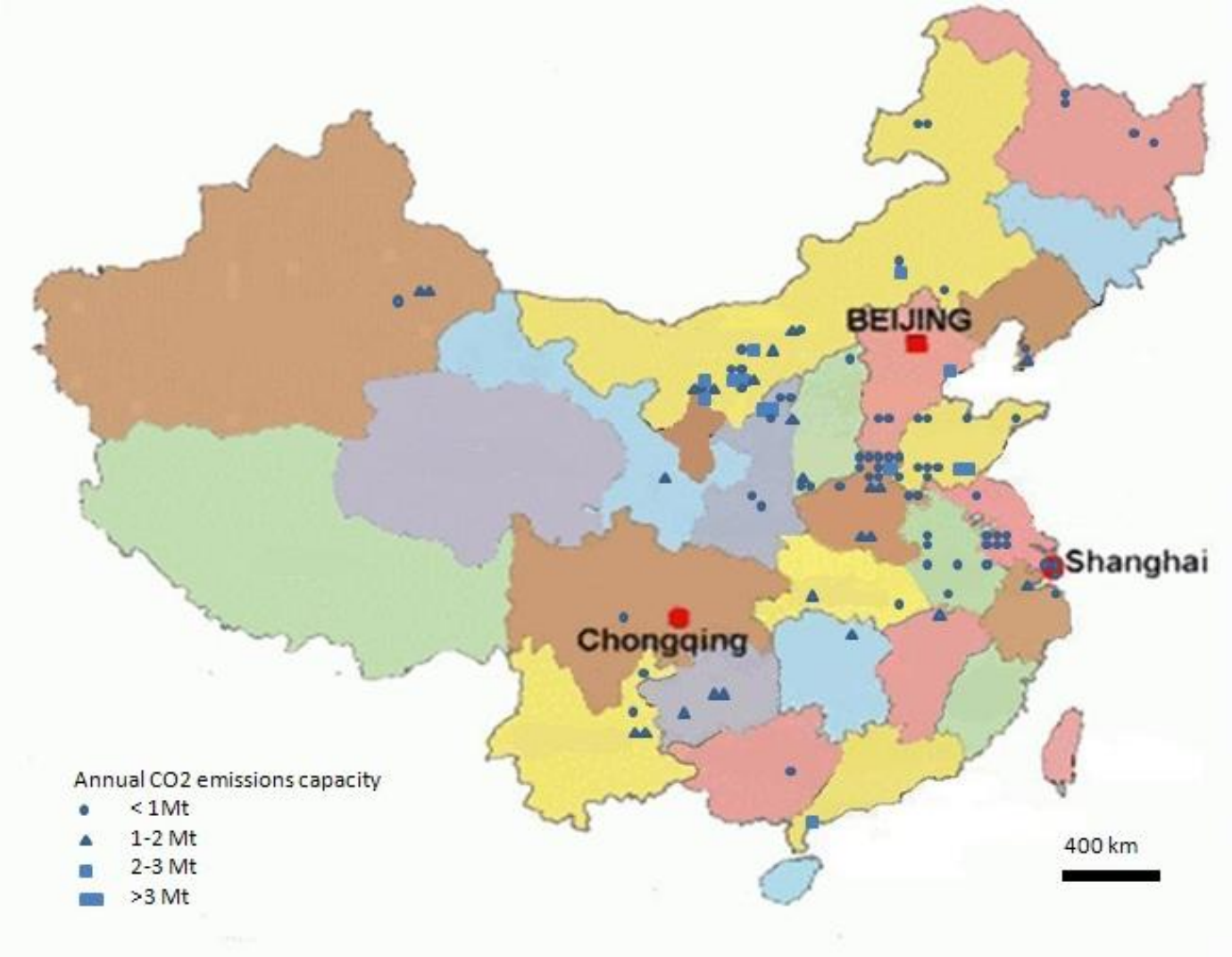
For Phase 2, the aim is to improve the IGCC polygeneration technology, together with a sidestream of syngas to determine how best to take forward the fuel cell power generation technology, and to produce up to 30-60,000 tonnes/year of CO_2 for EOR trials.

Phase 3 will comprise a 400 MWe demonstration of the overall concept.

CCS potential in the coal to chemicals sector

There is a growth in scale and extent of application in the coal to chemicals sector, with the opportunity to capture, at relatively low cost, concentrated streams of CO_2. These developments suggest a valuable potential for some early CCS demonstrations and commercial prototypes, probably for EOR applications.

CCS opportunities for the modern coal to chemicals sector



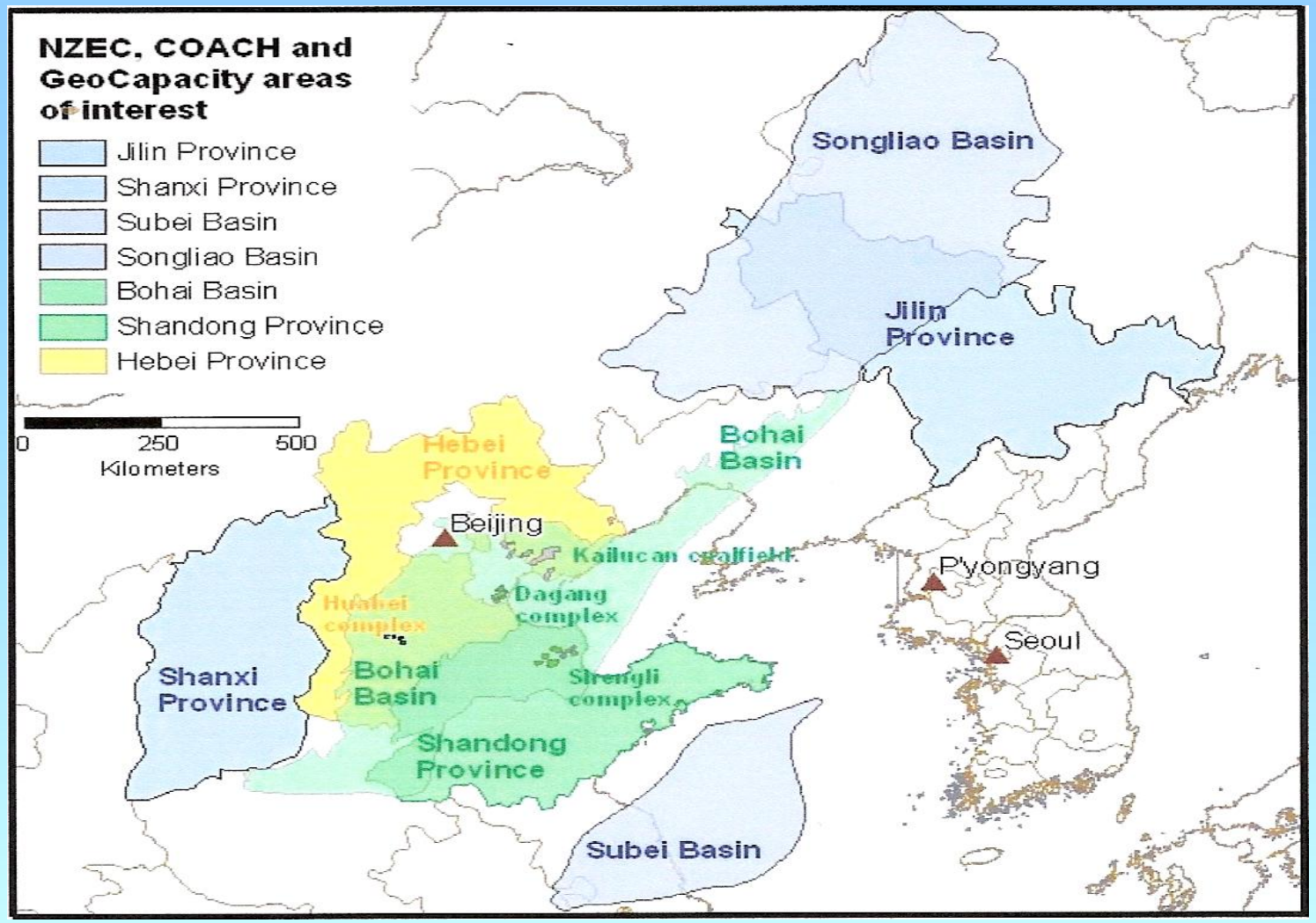
Gasification based CCS trial

The first major coal gasifier CCS trial in China is under way at the Shenhua Direct Coal to Liquids (CTL) Demonstration Plant, close to Erdos, Inner Mongolia Autonomous Region. Aim is to remove up to 100,000 tonnes/year of CO_2 from the waste stream, then compress and transport it for storage in a nearby aquifer.

So far some 40,000 tonnes of CO_2 stored successfully

CO_2 storage capacity assessments

(China-UK NZEC project www.nzec.info)



Possible hurdles for CCS deployment

Technical issues are not the main worry. All three capture routes will work; they will get better and cheaper from learning by doing

Big issues are non-technical

- Regulation – especially long term liability for storage
- Finance – incentives are needed for investment
- Public acceptance of overland transport and underground storage

The way forward?

China needs to balance medium to longer term strategic energy and environmental objectives with finding solutions to short term difficulties. It is pursuing a low carbon development path with Chinese characteristics, with clearly defined targets and priority actions. Major challenges remain.

Recognition that China can fulfil a leadership role in clean coal technology with carbon capture and storage

- Can be the focal point and prime driver for improved clean coal utilisation throughout most of Asia
- China already a growing provider of equipment and know-how in power generation, both domestically and overseas
- Tremendous scope to build on the base to integrate CCS techniques as necessary

UK remains active on CCS international cooperation with China

- DECC supported a ground-breaking near zero emissions from coal capacity building project in Northern China
- FCO is supporting a CCS-ready capacity building initiative in Guangdong Province
- EPSRC is supporting various CCS related cooperative R&D projects

These cooperative activities have increased Chinese capacity and raised awareness of CCS among many stakeholders.

Broader clean coal R&D and knowledge transfer between China, other developing countries and the UK

- Industry has contractual links with Chinese equipment suppliers
- Still a strong clean coal R&D base, including CCS, in UK universities
- IEACCC represents a centre of excellence for coal based knowledge transfer

University of Nottingham initiatives

- **Has established overseas campuses, including one at Ningbo, China**
- **Development of an engineering doctorate school on the lines of the Eng.D. Centre in Efficient Fossil Energy Technologies at Nottingham. Aim is to train 50 PhD students on aspects of:**
  - advanced combustion and gasification leading to cleaner power generation
  - coal-to-liquid transport fuels (petrol, diesel and higher fuel alcohols)
  - non-conventional hydrocarbons, such as shale gas
  - the whole spectrum of carbon capture technologies covering integrated multi-pollutant control
- **A summer school for the Eng.D students is held each year**

Coal based R&D activities involving University of Nottingham in China

Collaboration with Zhejiang University and 5 industrial partners. Focus on the research, development and commercialization of NOx and SOx removal technologies

Technologies to address deposition, erosion and corrosion caused by biomass utilization in coal-fired power stations

Formation of fine particulates (PM2.5, PM10) and its control

Novel technologies for fine particulates control

Carbon capture based on novel solid absorbent

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Some of the products and services offered by the Centre

WEBINARS

Impacts of seaborne trade on coal importing countries

Date: Wed, 08 Aug 2012
Presented By: Paul Baruya
Rating: 4.2 / 5
Duration: 00:27:11

Non-greenhouse gas emissions from coal-fired power plants in China

Date: Wed, 11 Jul 2012
Presented By: Dr Andrew Minchener
Rating: 5 / 5
Duration: 01:41:10

Newsletter

IEA CLEAN COAL CENTRE

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IEA CLEAN COAL CENTRE WORKSHOP

Advanced ultrasupercritical coal-fired power plants
19-20 September 2012

IEA Clean Coal Centre is organising a workshop on Advanced Ultra-Supercritical Coal-fired power plants. It will be held on 19-20 September 2012 in Vienna, Austria.

The workshop is being used by the IEA to launch its High Efficiency Low Emissions roadmap for coal-fired power plant as this depends heavily on perceptions of how advanced coal-fired power technologies will develop. The main part of the workshop will focus on materials testing and plant design for the highest possible plant efficiencies. Development work is ongoing in China, Europe, India, Japan and the USA, where there are plans to design and build demonstration plants over the coming years. Based on registrations received, all of these countries and regions will be represented with multiple abstracts submitted from Europe, USA, Japan and China. The IEA Clean Coal Centre work programme includes writing a review report on this topic. The workshop presentations and outcomes will be used to inform that report which will be published in 2013.

Vienna from the Cathedral roof

Cafe Sperl

The workshop will be hosted by EVN in Vienna, Austria and is being organised by IEA Clean Coal Centre in co-operation with the VGB, Germany. Those wishing to register and attend need to visit the relevant section of the workshop website at http://ussc.coalconferences.org. Abstract submissions closed on 31 July and the provisional programme based on these submissions can also be found on the same workshop website. Late submissions will be considered but cannot be guaranteed an oral presentation as the programme is already full.

The IEA Clean Coal Centre Newsletter is available free from
> http://www.iea-coal.org

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Various dissemination events organised by the Centre

Final thoughts

- Coal extraction and utilisation are set to continue to expand over the next 2 decades
- Increasingly the focus for coal use will be China, India and the rest of Asia
- While China is taking very significant steps to improve efficiency and limit environmental impact, there is considerable scope to do better in many of the other Asian countries by creating conditions to enable the use of advanced, cleaner, more efficient technologies
- UK continues to have valuable expertise and experience that should be utilised for the global greater good, especially in developing countries where economic growth is linked to coal use

Acknowledgements

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UK Foreign & Colonial Office

UK Department for International Development

Asian Development Bank

World Bank

BCURA

Coal Research Forum

European Commission

International Energy Agency

IEA Clean Coal Centre

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Thank you for listening!

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