

Carbon Abatement Technologies for Coal Fired Power Plant

Mike Farley
25 May 2005

Director of Technology
Policy Liaison



Chairman



Member



Key Messages

- Carbon abatement of existing coal-fired fleet is possible now and can complement renewables and energy efficiency measures to reduce CO₂ emissions
- A Staged approach to Carbon Abatement is possible using Mitsui Babcock BAT Advanced Supercritical Boiler Turbine designed for Biomass-cofiring and CO₂ Capture ready
- Advanced Supercritical Boiler/Turbine technology is the Clean Coal technology preferred by the majority of customers
- Government may now be much more sympathetic to supporting Clean Coal with Carbon Abatement than previously
- Major large scale opportunities for industry

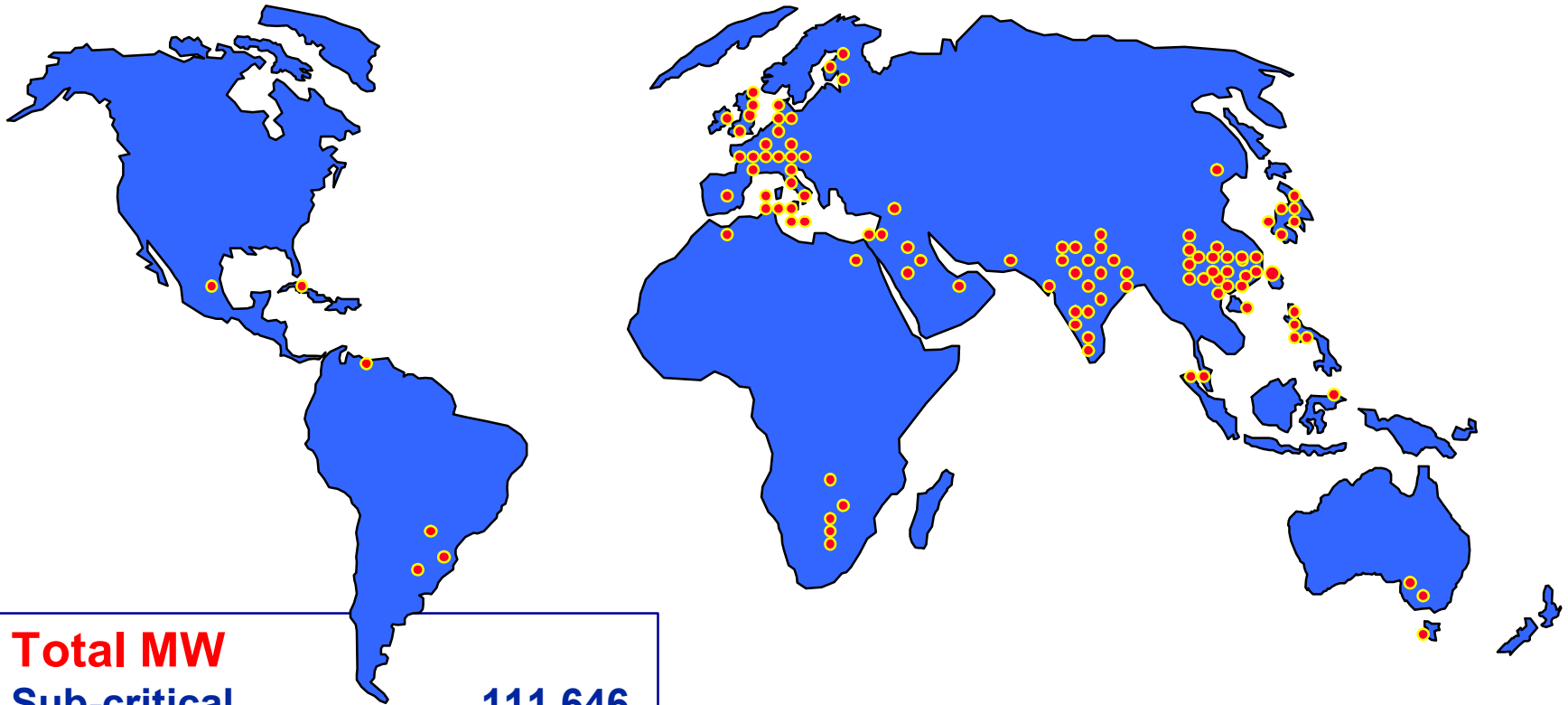
Content

- Mitsui Babcock update
- Challenges for Coal fired Generation
- Technologies available
 - Clean coal
 - Carbon abatement / CCS
- Mitsui Babcock staged approach to Carbon Abatement
 - Keeping options open
 - Futureproofing
- UK government position on Coal
 - Carbon Abatement Technologies Strategy

About Mitsui Babcock

- Established in the UK in 1891 as Babcock & Wilcox, Mitsui Babcock has over 110 years of experience serving the energy industry
- Active across Power Generation, Petrochemical, Oil & Gas, Nuclear and Pharmaceutical markets
- Headquartered in UK, offices in Atlanta, Beijing, Shanghai, Wuhan, Tokyo, Chennai, Hanoi, Taipei
- Annual turnover of £397 million (2004/05), profitable and sustainable
- 4000 Employees (UK, Europe, USA, Asia Pacific)
- Mitsui Babcock is owned by Mitsui Engineering & Shipbuilding (MES) – one of the world's largest and most successful engineering firms

World Distribution of Mitsui Babcock Power Plants

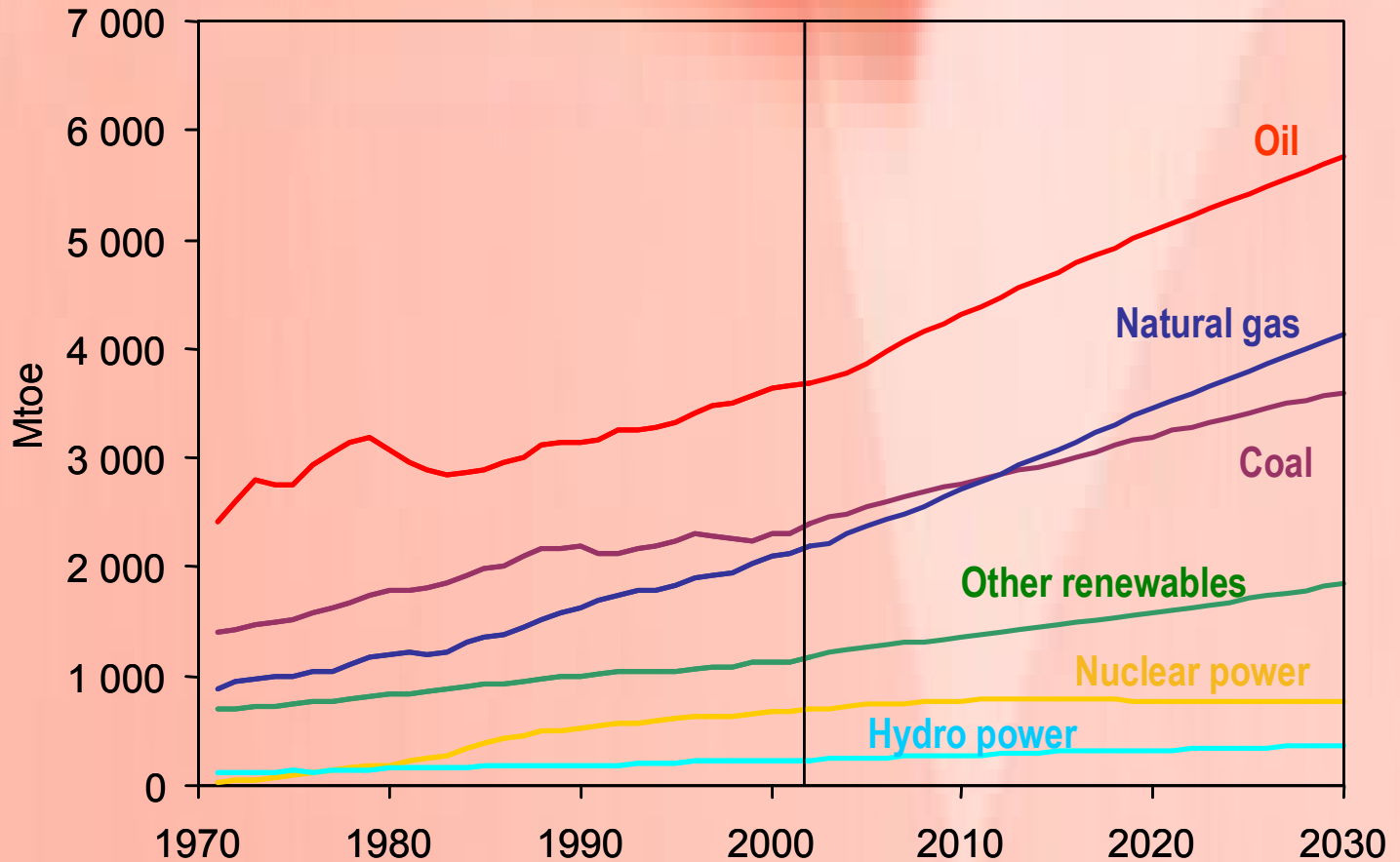


Total MW	
Sub-critical	111,646
Supercritical	33,475
Total Fossil Fired	145,121
Nuclear	6,054
Grand Total	151,175

Total MW after 1987 in Asia Pacific	
Subcritical	15,424MW
Supercritical	24,000MW
Total	39,424MW

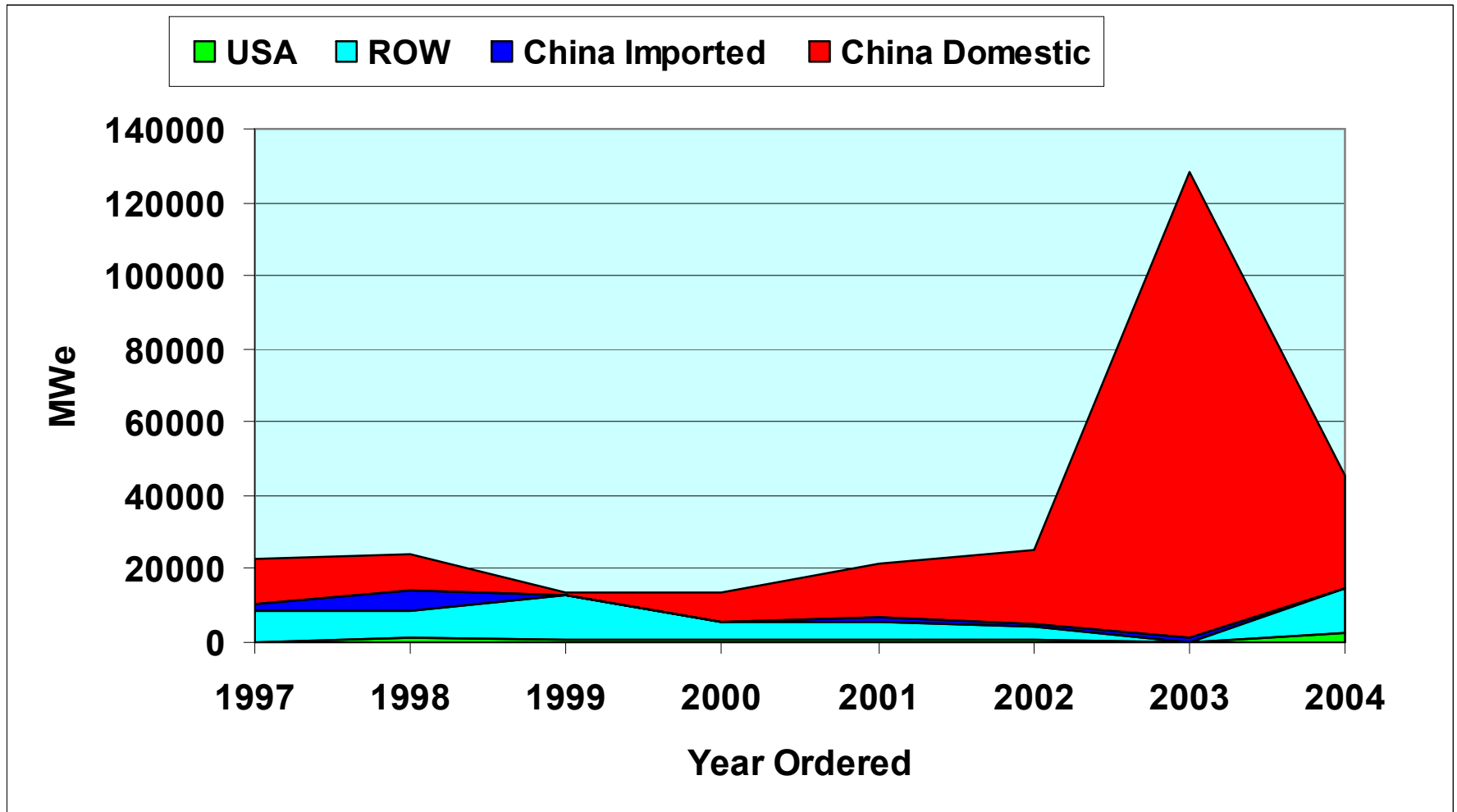
World Primary Energy Demand

(Source: IEA – World Energy Outlook 2004)



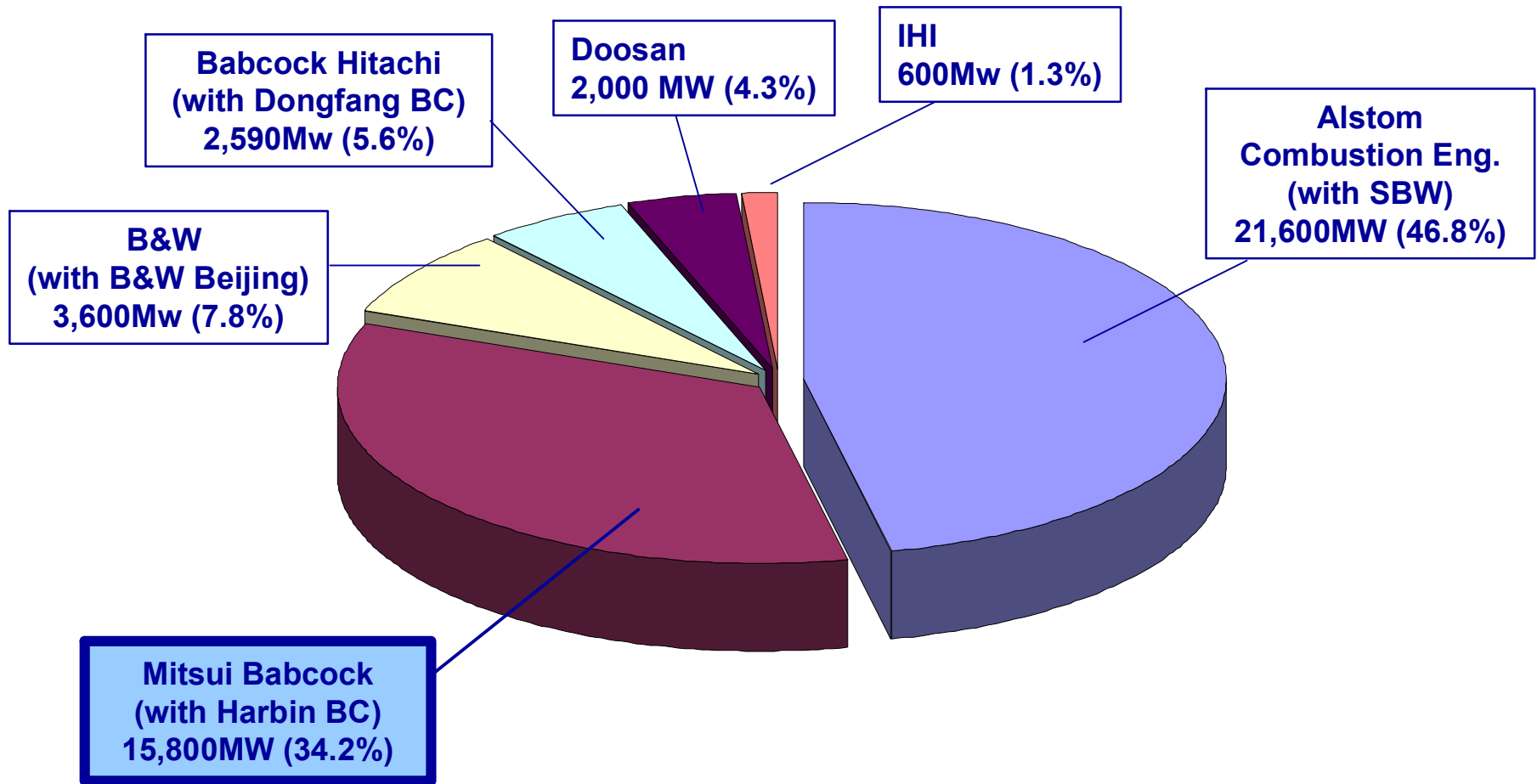
Fossil fuels account for almost 90% of the growth in energy demand between now and 2030

Trend in Coal-Fired Boiler Orders



World-Wide Once Through Supercritical Boilers

Distribution of orders by Technology Provider 2003 (McCoy)



Current R+D in Mitsui Babcock

- Designs for Advanced Supercritical Boilers (Posiflow)
- Materials for 700deg Ultrasupercritical boilers
- Biomass cofiring
- Carbon Dioxide Capture and Storage
 - Amine Scrubbing
 - Oxyfuel firing
- Advanced Supercritical Boiler Retrofit with Carbon Dioxide Capture
- In-furnace NOx control to 2016 levels (NOXSTAR)

Content

- Mitsui Babcock update
- **Challenges for Coal fired Generation**
- Technologies available
 - Clean coal
 - Carbon abatement
- Mitsui Babcock staged approach to CATs
 - Keeping options open
 - Futureproofing
- UK government position on Coal
 - Carbon Abatement Technologies Strategy

Technical Challenges for Fossil Power Generation

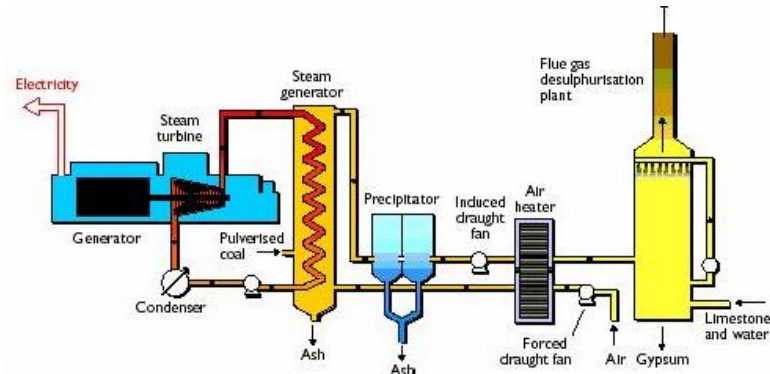
	NOx	SOx	Particulates	Other Pollutants (incl. Hg, VOCs)	Carbon Dioxide
Gas	✓	X	X	X	✓
Coal	✓	✓	✓	✓	✓ ✓
Oil	✓	✓	✓	✓	✓
	Limits set by LCPD, USA and similar legislation elsewhere Technologies available to meet legislation at relatively low cost (FGD £66/KW, DENOX £30-80/KW)			Various limits being proposed	Abatement essential if Climate Change targets are to be met

Content

- Mitsui Babcock update
- Challenges for Coal fired Generation
- **Clean Coal Technologies available**
 - **Clean coal power generation**
 - Carbon abatement
- Mitsui Babcock staged approach to CATs
 - Keeping options open
 - Futureproofing
- UK government position on Coal
 - Carbon Abatement Technologies Strategy

New Build Clean Coal Power Plant

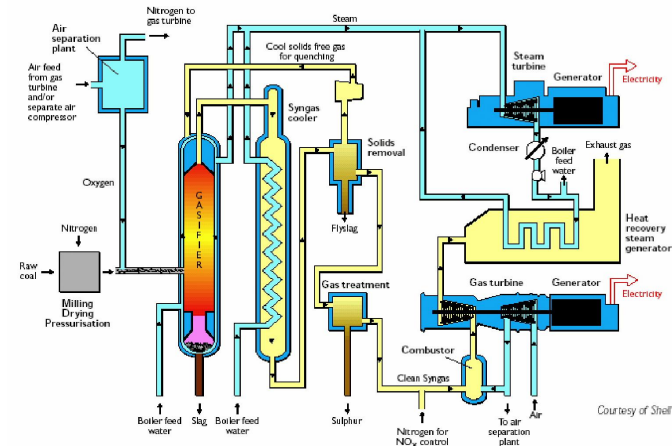
**Advanced Supercritical
Pulverised Coal Boiler
/Steam Turbine
400-1000MW**



- Technology of choice for vast majority of new build orders (China, Germany, Japan, Korea, Australia, Italy, USA, India, Taiwan)
- Best available Technology now 46/47% efficient
- Advantages are proven Availability, Flexibility and Fuel Range
- Continuous evolutionary development
- Matches IGCC for emissions/MWh
- Can be fitted with CO2 capture

New Build Clean Coal Power Plant

Integrated Gasification Combined Cycle 500MW+



- New technology for power generation attractive because of its low emissions and potential for hydrogen generation and CO₂ capture
- Currently, 3 units in operation on coal and 3 further orders for DOE supported demonstration plant in the US
- Challenges are poor availability, high cost, lack of flexibility and limited acceptance by the market
- Several competing technologies, Chevron Texaco/GE, Shell PreNFLO, E-Gas each suitable for a different type of coal
- Latest designs attempt to improve availability by parallel streaming and reduced integration with consequences on efficiency

Advanced Supercritical Boiler/Turbine

- **Best Available Technology**
 - **Steam conditions 300bar, 585°C S/H, 600°C R/H**
 - **Mitsui Babcock Posiflow™ Vertical tube Boiler**
 - **Net Efficiency 46-47% (UK)**
 - **NO_x <200mg/Nm³ (37.5 lowest currently offered)**
 - **SO_x < 200mg/Nm³ (100 lowest currently offered)**
 - **Particulates/PM10 <(20 lowest currently offered)**
 - **Designed for Biomass cofiring (up to 20%)**
 - **Designed to be “CO₂ Capture ready”**

Emission levels achievable in best practice Advanced supercritical boiler/turbine plant

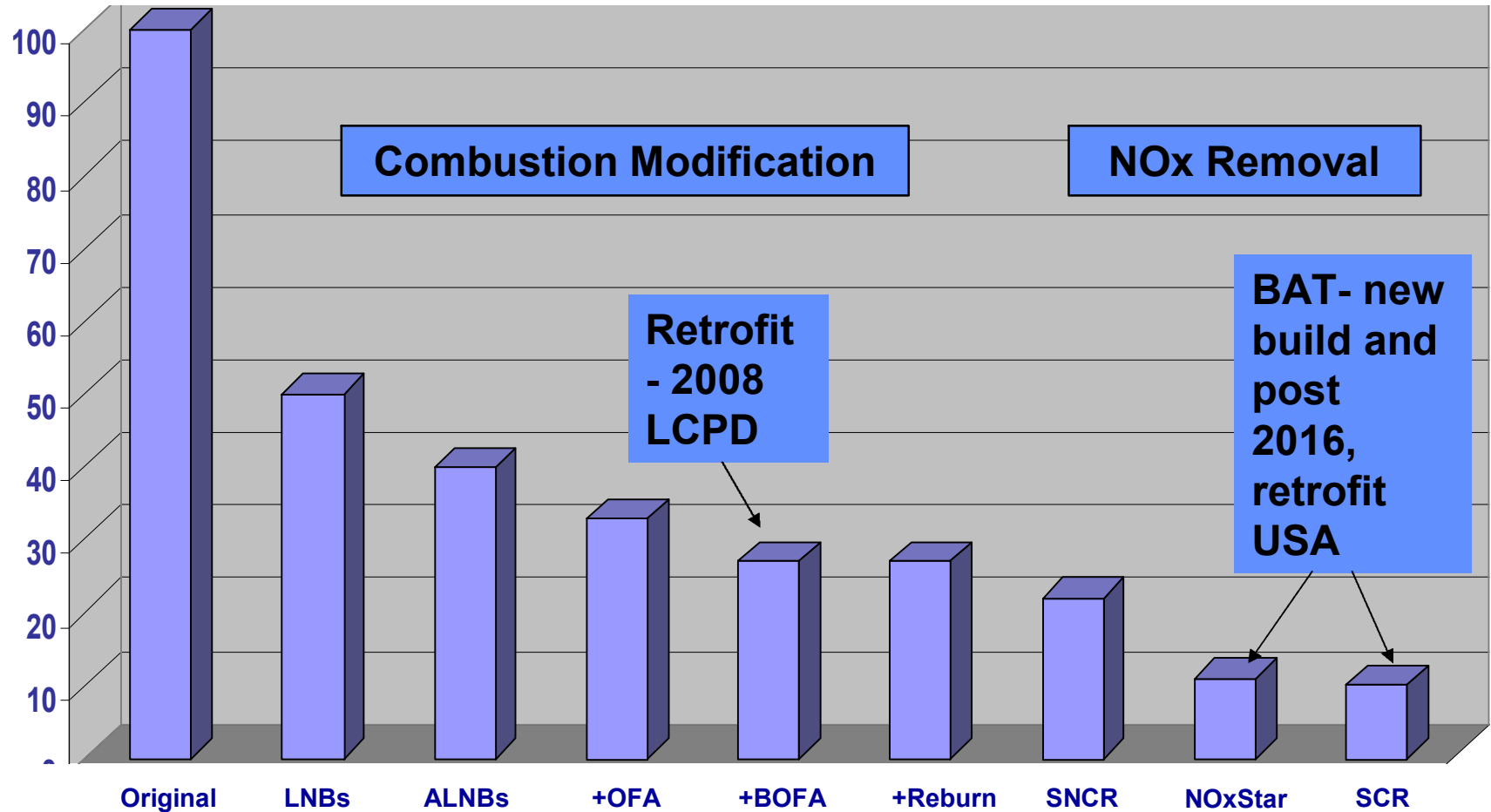
Emission Levels (@6% oxygen dry vol basis) Units are mg/Nm³ (lb/10 ⁶ BTU)	EU LCPD Limit – Existing Plant (from 2008)	EU LCPD Limit – New Plant (from 2008)	Levels Achievable[†]	Uncontrolled Levels
NO_x	500 (0.40)	200 (0.16)	37.5~(0.03)	1200+
SO₂	400 (0.32)	200 (0.16)	100 (0.083)	4000
Particulates	<50 (0.04)	30 (0.024)	30 (0.024)	25000
PM₁₀			20 (0.015)	
Mercury			10 x 10⁻⁶ lb/MWh	
VOC			37.5 (0.03)	
CO			11 (0.09)	
H₂SO₄			3.75 (0.003)	

† = Derived from recent Mitsui Babcock guarantees; exact figures depend on coal composition.

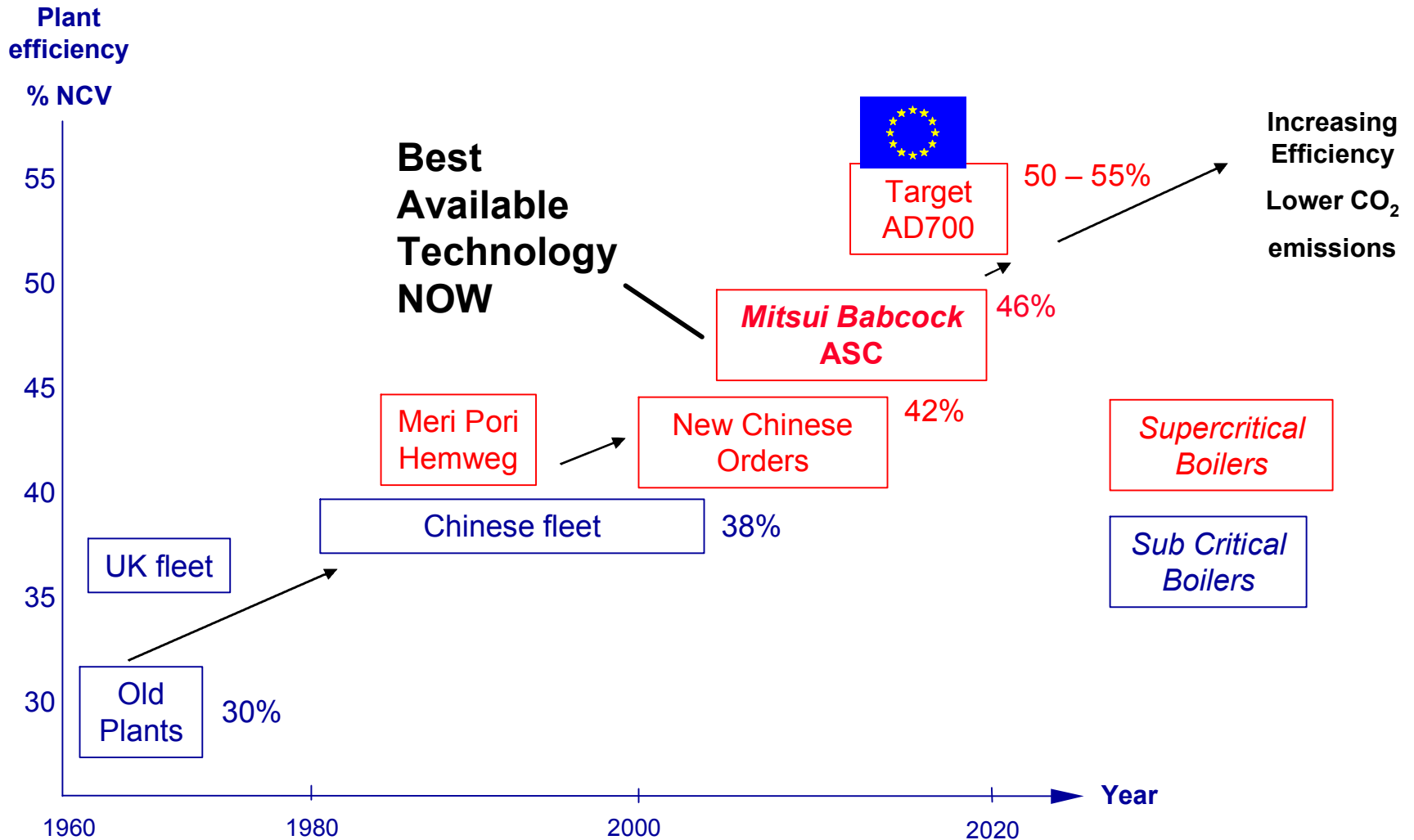
Mitsui Babcock NOx Reduction Technologies

-for new build and retrofit

NOx
percentage
reduction



Progressive improvement of Efficiency



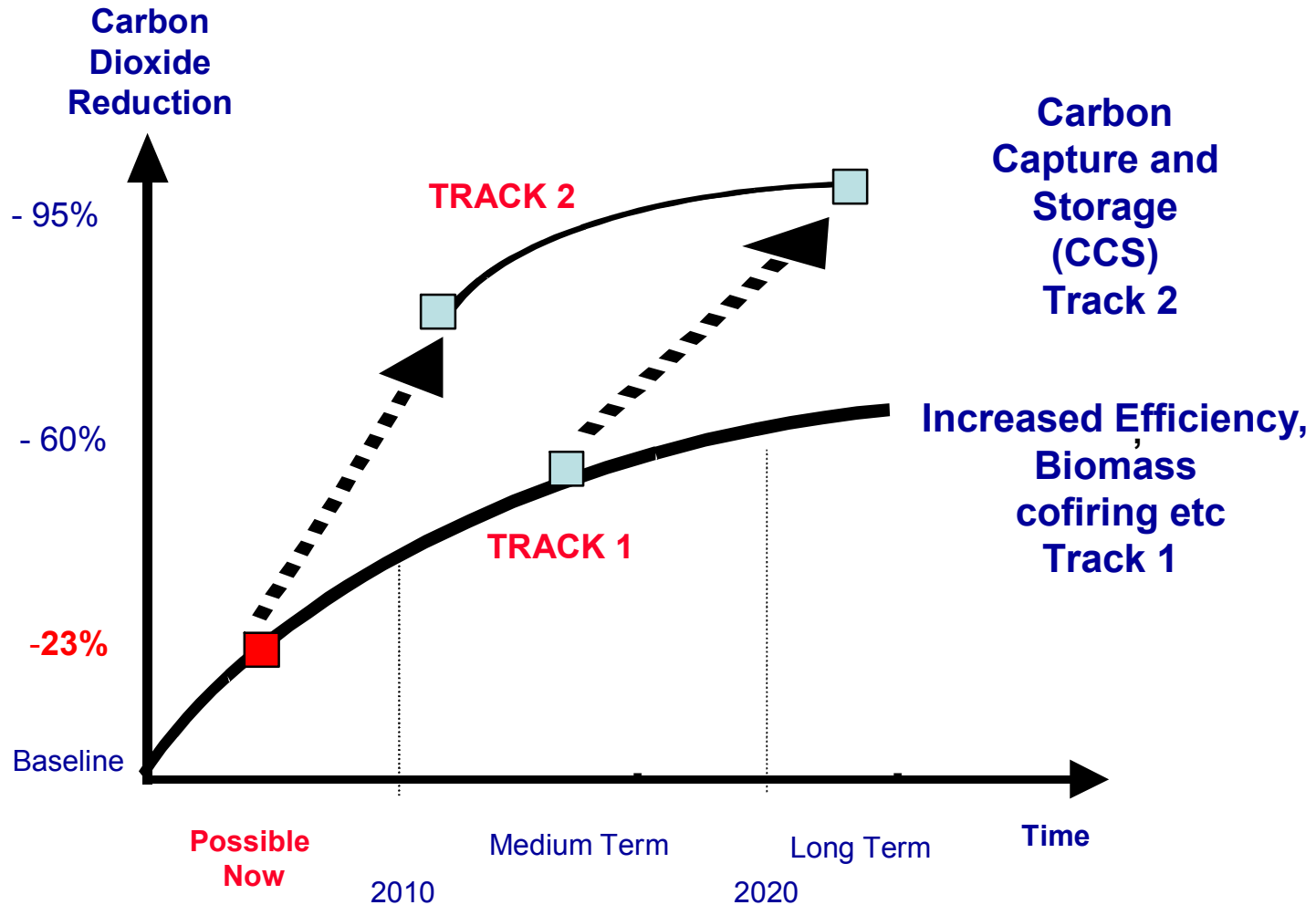
Content

- Mitsui Babcock update
- Challenges for Coal fired Generation
- **Technologies available**
 - Clean coal
 - **Carbon abatement**
- Mitsui Babcock staged approach to CATs
 - Keeping options open
 - Futureproofing
- UK government position on Coal
 - Carbon Abatement Technologies Strategy

Abatement of carbon dioxide from fossil power generation

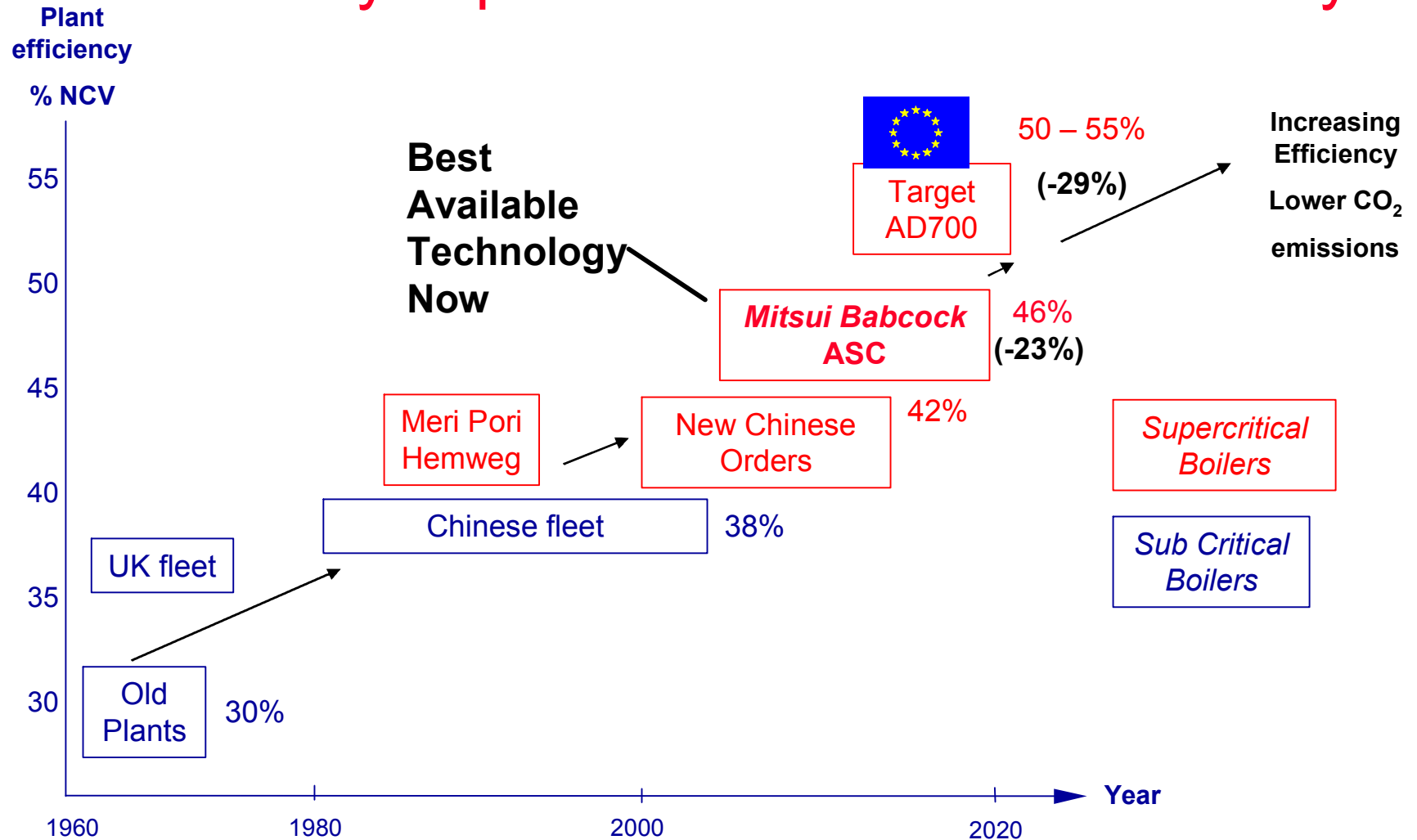
- CO₂ abatement will be *necessary*
 - For coal and gas
 - For existing plant (by retrofit) and new plant
- CO₂ abatement also necessary in Hydrogen economy scenario if hydrogen generated from fossil fuels
- CO₂ abatement possible by two tracks:
 - 1. Efficiency improvement, biomass cofiring, feedwater heating
 - 2. Carbon dioxide capture and storage

CO₂ abatement from fossil fuels – twin track approach



Source: IEA

Progressive lowering of Carbon Dioxide emissions by improvements in Plant Efficiency



Track 1: CO₂ Abatement by Biomass Cofiring

- Biomass is CO₂-neutral and qualifies as a renewable fuel
- Typically, 5%-7% can be cofired in existing coal-fired plant (blended with coal)
- Up to 20% can be cofired by direct injection (separate injectors/burners)
- Cofiring in advanced supercritical plant is much more efficient and cost effective than in small-scale dedicated plant

Track 2: CO₂ Abatement by Capture and Storage

- Huge capacity for storage in saline aquifers and scope for use for Enhanced Oil Recovery (EOR) in North Sea
- Technology demonstrated on gas platforms (Sleipner) and for EOR (Weyburn)
- Issues are cost (efficiency penalty), legality (subsea), eligibility for ETS, value of EOR

But no showstoppers!

1st EU Conference on CO₂ Capture and Storage, Brussels 20-22 April 2005:

**“CCS is practical, safe and will be economic for coal
at a CO₂ price of 20 Euro /tonne”**

CO₂ capture & storage: summary

CO₂ Capture & Storage (CCS) is an emerging technology suited to large stationary point sources of CO₂ from power generation, industry and H₂ production.

CO₂ Capture

- √ Post-Combustion
- Pre-Combustion
- Oxyfuels
- \$40-100+/Tonne CO₂

Transport

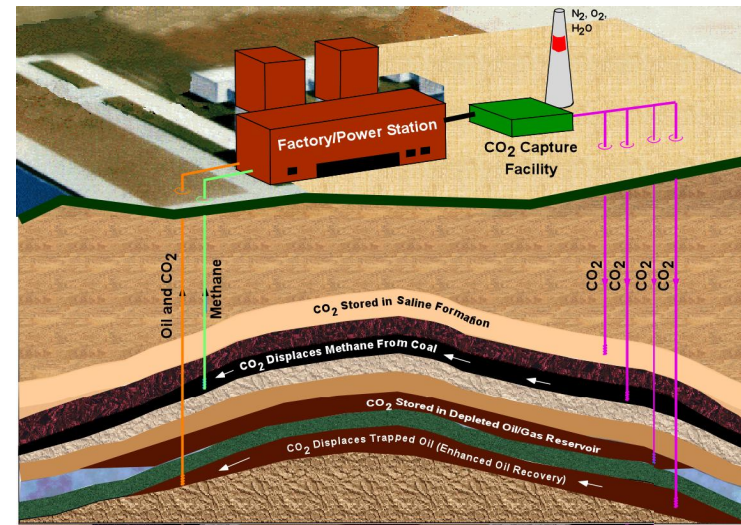
- √ Pipelines
- Ships
- Depends distance

Geological Storage

- √ Enhanced Oil Recovery
- √ Saline Aquifer Formations
- √ Depleted Oil/Gas Reservoirs
- Enhanced Coal Bed Methane
- \$1-10/t CO₂

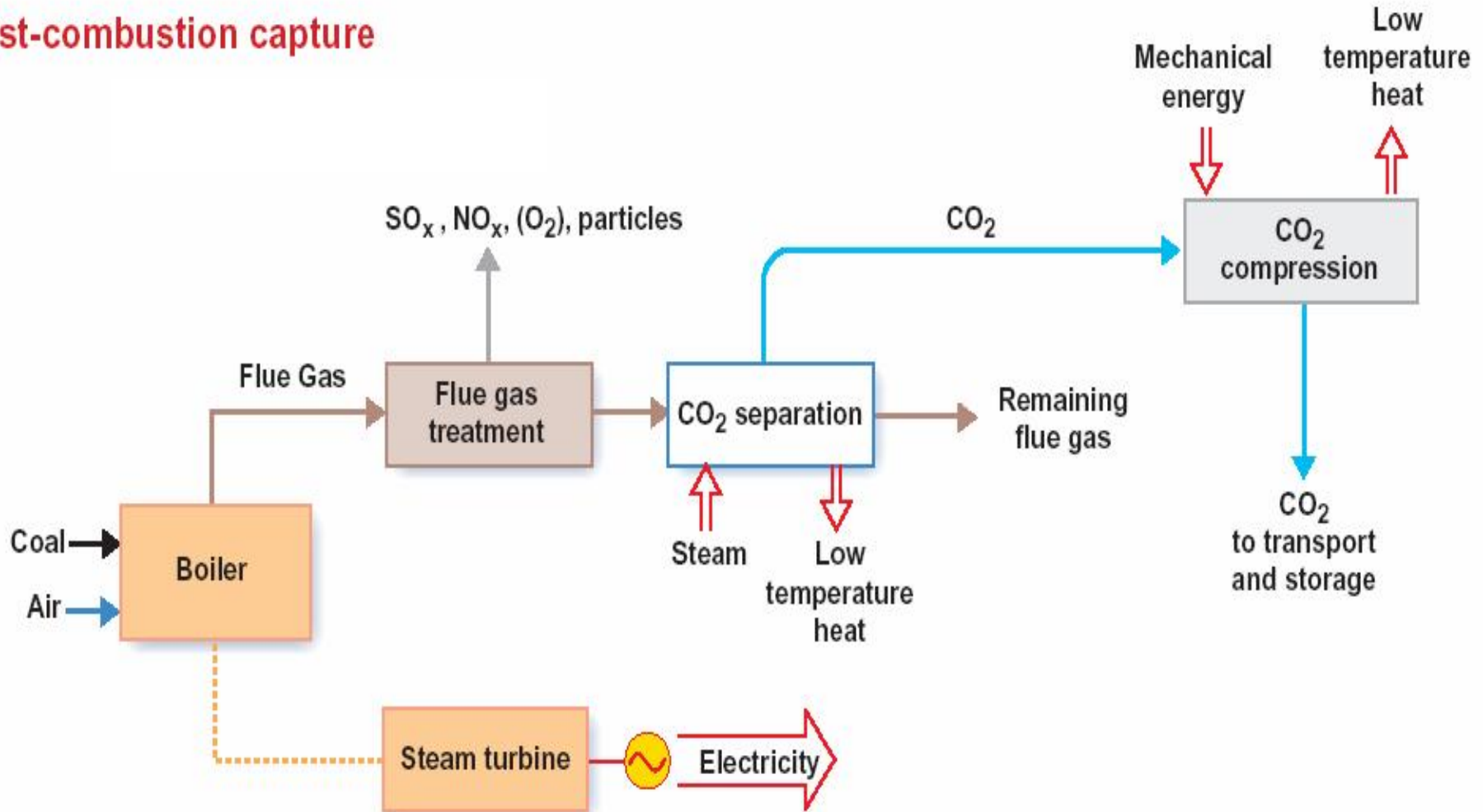
High Purity Sources

- Already separated
- Hi Concentration
- √ Amines, Membranes, H₂
- \$0-10/t CO₂



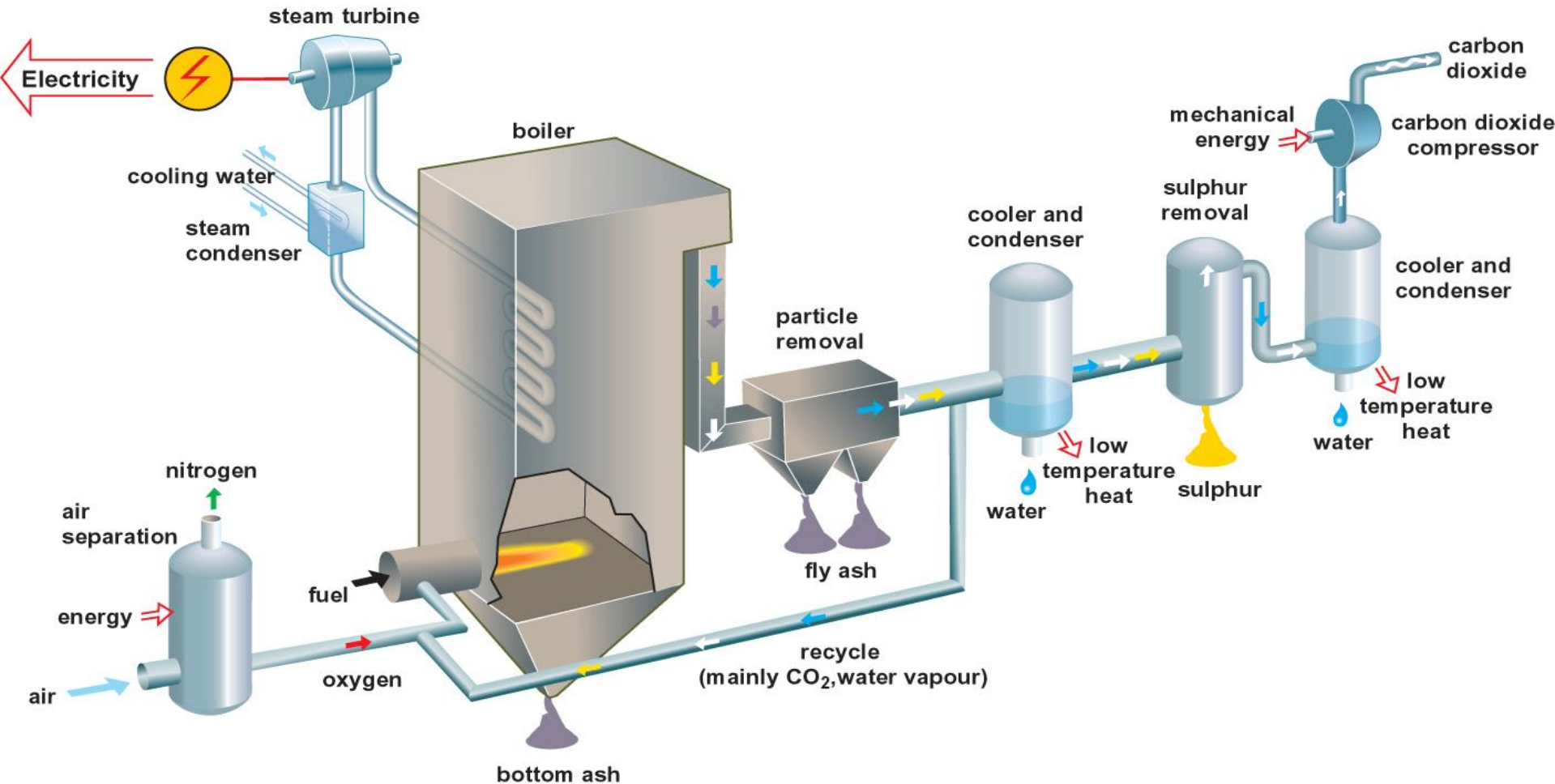
Post-combustion capture – amine scrubbing absorption process on Pulverised Coal Plant

Post-combustion capture

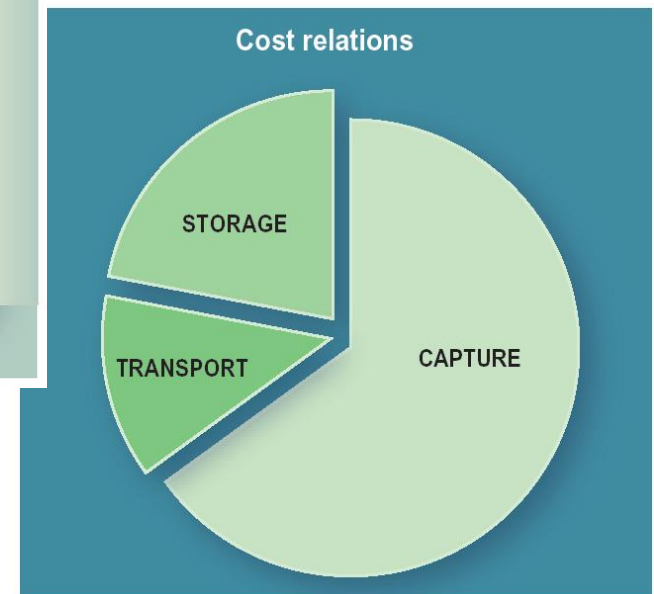
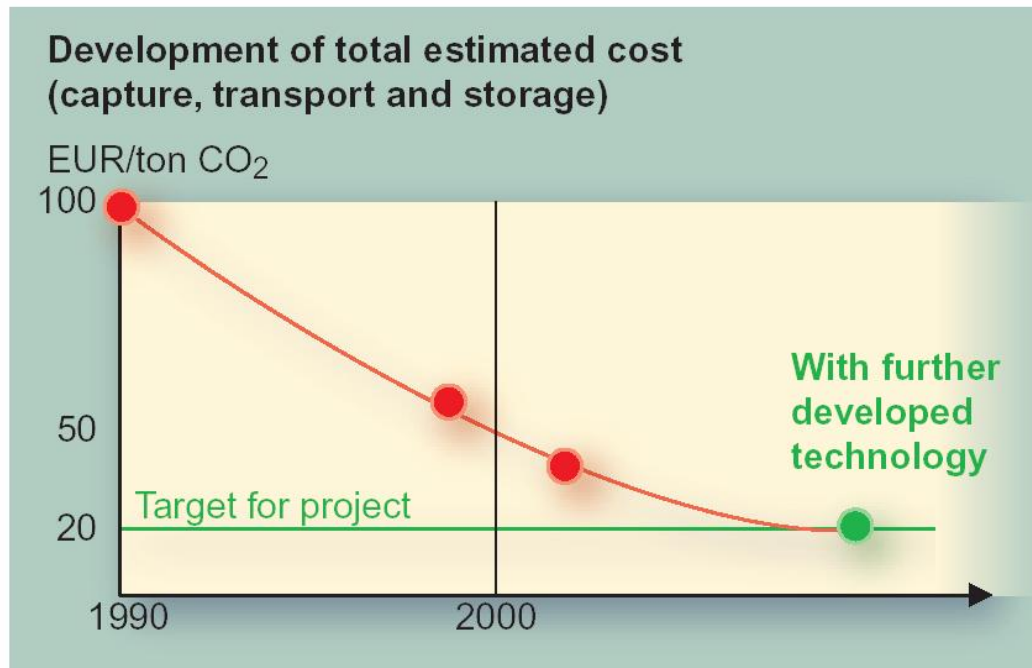


Carbon Capture by Oxyfuel firing on Pulverised Coal Plant

O₂/CO₂ recycle (oxyfuel) combustion capture



CO₂ capture and storage – cost estimates



Source: Vattenfall

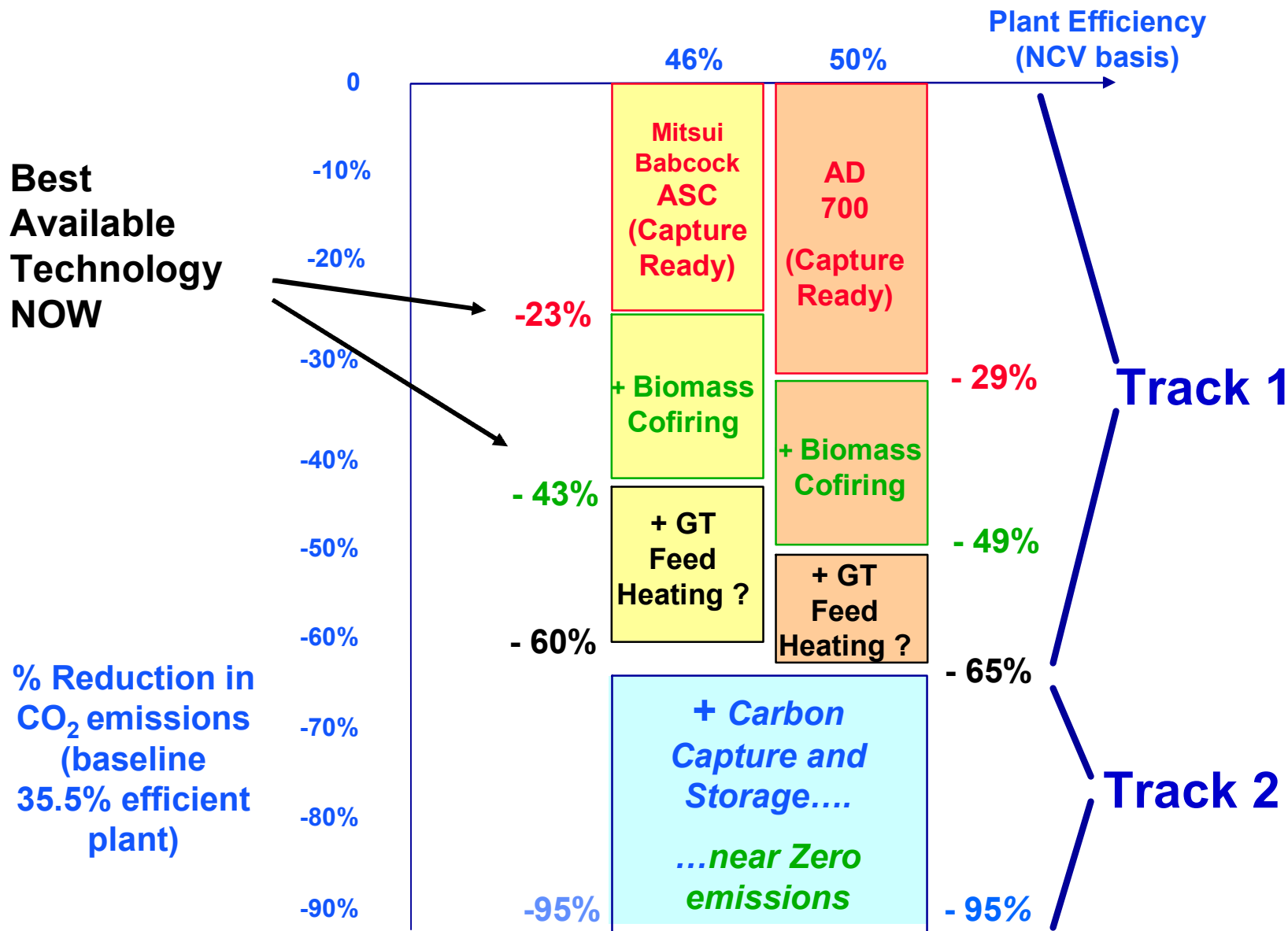
Content

- Mitsui Babcock update
- Challenges for Coal fired Generation
- Technologies available
 - Clean coal
 - Carbon abatement
- **Mitsui Babcock *staged* approach to CATs**
 - **Keeping options open**
 - **Futureproofing**
- UK government position on Coal
 - Carbon Abatement Technologies Strategy

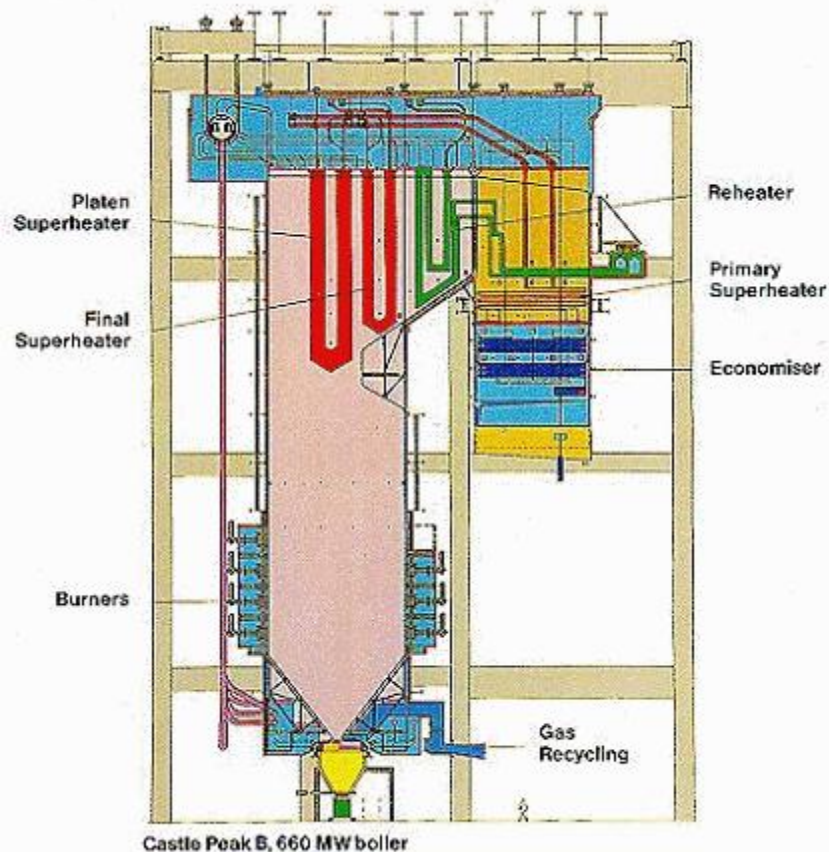
Staged approach to Carbon Abatement Technologies for Coal Fired Plant

- CATs can be used for New Build *and can be retrofitted to existing power plant*
- Basic building block is the Advanced Supercritical Boiler/Turbine Retrofit
- *Uses existing valuable infrastructure* (coal handling, ash handling, buildings, skills)
- Can be designed for biomass cofiring and can be designed to be “*capture ready*”
- More *flexible* in operation than existing sub-critical plant or IGCC
- NOx post 2016 ($< 200 \text{ mg/Nm}^3$) compliant

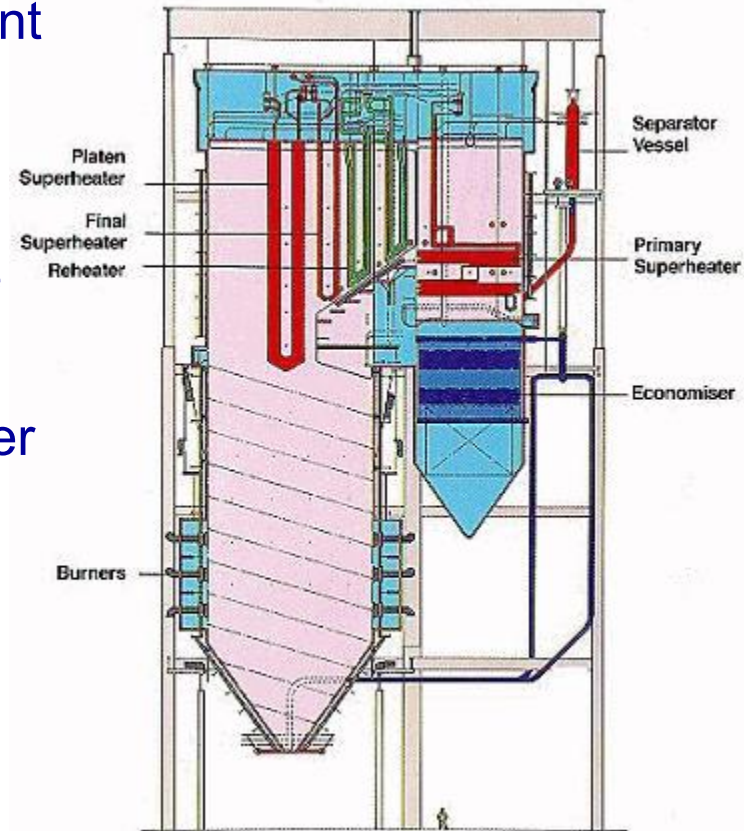
CO₂ Abatement by Twin Track Approach



Sub-critical to Supercritical Boiler *Retrofit*



- Replacement of boiler pressure parts, within boilerhouse envelope
- Lighter boiler weight
- Re use of bulk of ancillary equipment
- Turbine modifications



Advanced Supercritical *Retrofit with CO₂ Capture* - status

- Design study on Advanced Supercritical Retrofit *completed* for Scottish Power
 - No technical showstoppers
- New DTI contract “TechnoEconomic studies on Advanced Supercritical Retrofit with Carbon Capture”
 - Mitsui Babcock, Alstom, EonUK, Air Products, Fluor, Imperial College, Drax Power, EDF Energy
 - Will demonstrate how to make ASC Retrofits “*capture ready*”
- Several overseas study contracts (IEA, Canada Clean Power Coalition...)

Comparison of Costs of Electricity

		CO ₂ versus Existing Coal	
New build coal	2.6 p/kWh	-20%	£30.5/te = 2 USD/GJ
New build coal & CO₂ capture	3.2 - 3.6 p/kWh	-85 to -90%	
New CCGT	1.9 - 3.0 p/kWh	-60%	3 to 5 USD/GJ (=17.5 to 30p/Therm)
New CCGT & CO₂ capture	2.8 - 3.9 p/kWh	-90%	
Onshore Wind	3.68 p/kWh	?	Excludes back-up costs, 25% capacity factor
Offshore Wind	5.52 p/kWh	?	
Coal-fired ASC Retrofit	1.8 p/kWh	-16%	£30.5/te = 2 USD/GJ
Coal-fired ASC Retrofit & CO₂ capture	3.4 p/kWh	-85 to -90%	

Conclusions

- Carbon abatement of existing coal-fired fleet is possible now and will complement renewables and energy efficiency measures to reduce CO₂ emissions
- Staged approach to Carbon Abatement possible using BAT Advanced Supercritical Boiler Turbine designed for Biomass-cofiring and CO₂ Capture ready
- Carbon Abatement Technologies for fossil fuels more economic than many alternatives
- Government needs
 - to support Research, Development *and* Demonstration
 - *Incentivise* the implementation of CATs
 - Recognise the *opportunities* for UK industry

Mitsui Babcock - Vision

- A balanced portfolio of power generation to ensure security of supplies ie Renewables, Coal, Gas, and Nuclear
- Carbon Abatement of Fossil fuels used to complement End-use Energy Efficiency, Renewables and Nuclear to reduce Carbon Dioxide emissions with CO₂ EOR used to extend the life of North Sea Assets
- Government support and policies to maximise environmental and trade benefits -globally
- Scottish industry at the heart of new energy investment in all these technologies

“Mitsui Babcock is committed to development and global implementation of Carbon Abatement Technologies as rapidly as the market allows”

Thank you for your attention

mfarley@mitsuibabcock.com



Content

- Mitsui Babcock update
- Challenges for Coal fired Generation
- Technologies available
 - Clean coal
 - Carbon abatement
- Mitsui Babcock staged approach to Clean coal
 - Keeping options open
 - Futureproofing
- **UK government position on Coal**
 - **Carbon Abatement Technologies Strategy**

Energy policy- 2005 reality check

- Emissions targets not being met, more needs to be done
- Renewables Obligation working but proving to be expensive
- UK heading for 80% gas ,80% imported, many other countries increasing their reliance on gas
- Gas prices increasing dramatically
- CO₂ emissions will go up if more nuclear closes and replaced by gas
- Recognition that Emerging economies' emissions increasing much faster than the West can make reductions

Government Actions 2005

- UK Climate Change Programme Review
- Strategy for Carbon Abatement for Fossil Fuels (coal and gas) about to be announced
- Put Climate Change at the top of the Agenda for G8 and EU Presidency
 - Including how to encourage Carbon Abatement for fossil fuels
- Look at Incentives for Carbon Abatement for fossil fuels

Government CAT Strategy (as summarised by Mike O'Brien)

- Cover coal and gas
- Recognise global importance of CATs and benefits of exports and technology transfer
- Recognise both routes to carbon dioxide abatement, ie, 'the twin track approach'
- Support a substantial programme of industry-led research, development and demonstration
- Establish legal frameworks for CCS
- Devise further market incentives to encourage full-scale deployment

Gordon Brown's Budget statement

- *Carbon capture and storage (CCS) is a process by which the carbon in fossil fuels is captured as carbon dioxide and committed to long-term storage in geological formations. It has the potential to significantly reduce carbon emissions from fossil fuel power generation. It is likely to prove a critical technology in global carbon reduction strategies, particularly for countries with fast growing economies and rapidly growing fossil fuel consumption.*
- *The Government is therefore examining how it might support the development of CCS in the Climate Change Programme Review, including the potential for new economic incentives.*

Climate Change Programme Review

- **Consultations complete (UK and Scotland)**
 - **Report due July**
- **Key points from our response are**
 - **Implementation of CATs can start now, is cost effective and gives CO2 reductions which are additional to those achieved via Renewables and Energy Efficiency. (ie Don't wait for CCS).**
 - **CAT Strategy is good, needs support, *needs a substantial R, D and D programme.***
 - ***Incentives equivalent to ROCs will be necessary to stimulate investment. ROCs are working for Renewables. (A separate "Obligation"/"Incentive" can be priced at the appropriate level and won't interfere with ROCs' prices)***
 - **Restrictions on Cofiring should be removed**