Design Criteria for Carbon Capture
Ready Power Stations and
Technological Options under
Development by Power Plant Suppliers

IZEC CCR Symposium, Tokyo, November 19th, 2009

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Content

- Technology steps towards the CO₂ free power station
- Political background, Technology overview for Carbon Capture and Storage (CCS) and development/demonstration issues
- Strategy and definitions for Carbon Capture Ready (CCR)
- Feasibility study results, ongoing development work and implications for the power plant design (CCR and future new build)
  - Oxyfuel / Combustion
  - Post Combustion Capture
- Summary
Power plant supply by HITACHI

Today, tomorrow and in future

Boiler
Turbine/Generator
DeNOx
FGD
Engineering
BOP
I & C System
Civil works
Infrastructure
BOP others

More than 65% of a high efficient power station can be supplied by group members

Efficiencies for coal fired PP
Up to >46% for bituminous coal*
Up to 43% for lignite

*depending on fuel characteristics and location
Increase of efficiency will be a key for future commercial success of CCS implementation

Increased efficiencies to allow CCS in future

- 700°C for bituminous coal: >50 % efficiency
- Dry lignite fired boilers: >47 % efficiency
- 700°C dry lignite fired: >50 % efficiency

Boiler Technologies available and to be demonstrated in first Prototype plants
Power plant supply by HITACHI
Today, tomorrow and in future

CO₂ Separation

CO₂ Compression

Transport & Storage

Unminable Coal beds

Depleted Oil or Gas Reservoirs

Deep Saline Aquifer

Power Station with CO₂ Capture

Pipeline
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Carbon capture and storage: Capture Technologies considered

Pre-combustion
(Gasification & CO₂-capture)

Post-combustion
(capture added downstream)

Oxyfuel
(combustion with oxygen)

CCS retrofit only possible after major equipment changes

Processes most probably capable for retrofits on actual new build and existing coal fired power stations

source: Vattenfall
Why and how considering CO₂ capture readiness?

Regulatory Background – EU


Article 33 / Amendment of Directive 2001/80/EC:

(1) for getting construction / operation licence operators of all combustion plants with a rated electrical output of 300 megawatts or more have to assess whether:
   • suitable storage sites are available,
   • transport facilities are technically and economically feasible,
   • it is technically and economically feasible to retrofit for CO₂ capture.

(2) … the competent authority shall ensure that suitable space on the installation site for the equipment necessary to capture and compress CO₂ is set aside. The competent authority shall determine whether the conditions are met on the basis of the assessment referred to in (1) and other available information, particularly concerning the protection of the environment and human health.
**Development of Coal Gasification**

**Actual step:** Testing of CO₂ scrubbing in IGCC process

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Plant size</th>
<th>Duration</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYCOL</td>
<td>50t/d</td>
<td>'90 ~ '93</td>
<td>Gasifier basic concept Ash treatment method</td>
</tr>
<tr>
<td>EAGLE I</td>
<td>150t/d</td>
<td>'02 ~ '06</td>
<td>Scale-up technology Reliability improvement</td>
</tr>
</tbody>
</table>

HYCOL: Hydrogen from Coal  
EAGLE: Energy Application for Gas, Liquid and Electricity

**EAGLE project**

- CO₂ Recovery
- Gasification
- Air Separation
- GT
- Gas Clean-up
- 60m
- 100m
- 200m
# CO₂ Capture Facilities

<table>
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</table>
| EAGLE II     | 150t/d     | ‘06〜     | Scale-up technology  
Reliability improvement with CO₂ recovery test |

**CO₂ Capture unit**
Status of Pre-combustion Capture in EU according to ETP-ZEP

- Gasification (coal)
- Gasification (Lignite)
- Reforming (gas)
- Dust removal
- CO$_2$ capture and desulphurization
- CO$_2$ purification & compression
- H$_2$ coproduction
- Overall process integration
- Fuel handling (Lignite/Biomass)
- ASU
- CO shift
- H$_2$ gas turbine

Source: Vattenfall & ETP-ZEP

But:
- high availability always requires cold gas cleaning and several temperature cycles and so reduces the efficiency!
- CCR design difficult regarding gas use (GT/Combustor design either flexible or high efficient!)
Capture Processes
Post Combustion CO₂ Capture (PCC)

General Opinions
"CO₂ scrubbing development most advanced"
"Integration simple as downstream arrangement"
"Only process available for retrofits" … BUT
Capture Processes
Integration of post combustion capture to power plants

Process engineering, design and chemistry:
dynamic behaviour of a “chemical plant”
Absorbent: corrosion, degradation, emissions….

Advanced flue gas treatment (dust, NOx, SOx)

Amine scrubbing

Heat recovery / cooling demand

Compression: buffer compressor drive waste heat

Heat (and cooling) demand up to 1/3 of the thermal PP heat without heat integration (95% for desorber)

Flue gas w/o CO₂

Product CO₂

NaOH

Cooler

Reflux Drum

Condenser

Desorber

Absorber

Rich Solvent

Lean Solvent

Advanced flue gas treatment (dust, NOx, SOx)
Capture Processes
Oxyfuel Combustion with a CO$_2$/O$_2$ mixture instead of air

**Advantages**
- Firing design for operation with oxyfuel & air firing possible
- Plant design for retrofits and new build plants
- All technologies basically exist in adequate size

**Challenges**
- Reduction of energy consumption, especially by optimized ASU and heat integration
- Air tightness whole system
- Specific components to be re-designed (AQCS, firing) and materials to be checked
- Some new components to be proven, design basis needed (FG cooling, CO$_2$ purification)

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**Diagram Details**
- **ASU**: Air Separation Unit
- **CPU**: CO$_2$ Processing Unit
- **DeNOx**: Denitration
- **DeSOx**: Desulfurization
- **FG cooling**: Flue Gas Cooling
- **FG**: Flue Gas
- **ESP**: Electrostatic Precipitator
- **Steam cycle**: Boiler
- **Cooling**
- **Air tightness**
- **Flue gas recycle**: Mostly CO$_2$ and H$_2$O

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Roadmap for CCS & power plant business

- Capture, transportation and storage expected to be technically available
- CCS will have to be acceptable by politics and public within a clear regulatory framework for demos and full scale plants (permits)
- Most old plants may be not CCR due to efficiency and commercial reasons
- Most recently built or currently being built plants are CCR
- New build plants will have to be CCR (regulatory issue)
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Strategies for the prove of capture readiness

- CCR check always based on the base of individual project
- CCR may require some design work in advance to ensure maximum efficiency and profitability of retrofit
- CCR prove e.g. can be done by
  - Certification by TÜV according to TÜV NORD Standard: TN-CC 006 Voluntary examination of conventional power plants and CO₂ emitting plants, in respect to the readiness to retrofit CO₂ capture systems (CC-systems) in future
  - Joint study of plant supplier, utility and companies involved in the CO₂ transportation and storage to develop specific ideas for an individual project
  - ..........

Up to now there are no official standards for CCR!
Carbon Capture Readiness
Selection of criteria, based on TÜV TN-CC 006

- Site specific **basic technical concept** (e.g. feasibility study of plant manufacturer for capture)

- There shall not be any site specific items or conditions that could hinder the retrofit by 2020 at the latest (e.g. proof, that there is **sufficient space**)

- Checking of e.g. **official regulations/restrictions, environmental issues** (i.e. emissions, cooling water, noise)

- The plant operator should show **active contribution to CCS R&D**

- Preparatory measures for a retrofit shall not have a significant negative effect on the efficiency of the plant, i.e. **no waste of energy in advance**

- A **site-specific concept for CO2 transportation** must be presented

- A **site-specific long-term storage concept** must be presented

- More details at http://www.tuev-nord.de/en/
CCS effect on efficiency

- In the worst case, CCS may decrease the efficiency of coal-fired power stations from 46% to less than 32% (based on LHV).

- Efficiency increase will support the commercial CCS implementation for all new power stations. Development work for those measures and demonstration have to be done in parallel.

- Optimization of the CCS integration has to be done in addition by suppliers:
  - Optimized energy supply for CCS
  - Waste heat recovery systems
  - Optimized components and processes for PCC unit, ASU and CPU for Oxyfuel
  - Solvent improvement for PCC
Potentials for efficiency increase
Recent high efficient steam generators

SH Outlet Temperature [°C]

SH Outlet Pressure [bar]

180 220 240 260 280 300 380

Japan since 1995
South Africa
China since 2002
USA, Canada since 2005
Germany, lignite
Germany, bituminous

700 ◦C demonstration

-efficiency increase

-Boxberg R
-Boxberg F

Germany, lignite
Germany, bituminous

South Africa
USA, Canada since 2005
Japan since 1995

Germany, bituminous

South Africa
USA, Canada since 2005
Japan since 1995

-efficiency increase

Boxberg R
Boxberg F

Niederaußem K

Germany, lignite
Germany, bituminous

South Africa
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Germany, lignite
Germany, bituminous

South Africa
USA, Canada since 2005
Japan since 1995
CO₂ Emissions of Power Plants with different Fuels

Besides saving of energy CO₂ Emissions can be effectively lower by increasing efficiency using coal for electricity production.

Source: Marheineke T., Krewitt W., Neubarth J., Friedrich R., Voß A. IER-Bd. 74, IER, University of Stuttgart, Germany, 2000
700°C technology: HPE’s steam generator for 500 MW\textsubscript{el} (PP > 50% efficiency)

HP-Part:
Life steam pressure 365 bar
Life steam temperature 705 °C

RH-Part:
Inlet pressure 74 bar
Outlet temperature 720 °C

Bituminous coal
Benson® steam generator
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- Summary
Recycled flue gas: shall be cold, cleaned and partially dried
- minimise changes in the boiler house
- avoid corrosion and erosion
- keep reliability of ductwork / components designed for air operation

Selection of hot gas recycle:
- avoid gas gas heat exchanger in flue gas path where the space is limited
- heat recovery is not possible without major changes in the steam cycle (in retrofit case)
Oxyfuel Process: required measures for retrofit

Exhaust gas

Ambient $O_2$

ID fan

ASU

$O_2$-preheater

$CO_2$

DeNOx catalyst

Steam generator

Burner system

Over fire air

$CO_2$

Mills

Fuel

PA fan

Hot gas recirculation

FD fan

Air preheater

Dryer

FGD

ESP

Flue gas preheater

$CO_2$-Compression

Over fire air

( red components from retrofit )
Oxyfuel component re-design
MPS 245 Operation with sealing gas CO₂

- Replace air as sealing gas by CO₂
- Retrofit sealing design to avoid CO₂ leakage to boiler house
Oxyfuel component re-design
Oxygen preheating arrangement in parallel to „air“ preheater
Oxyfuel component re-design

Burner

**Burner operation targets**
- air mode and oxyfuel mode
- similar flame shape
- similar flame temperature / adiabatic combustion temperature
- burnout progress

**Burner operation measures**
- same volume flow of primary gas in both modes (requirement from mill)
- same momentum flow of secondary and tertiary gas in both modes
- variable oxygen content of primary, secondary and tertiary gas
Design of Water-/Steam System

Heat transfer in the convective path adjusted by means of recycled flue gas mass flow

- Steam parameters match the air combustion case
- Water / steam temperatures do not exceed design values
- Boiler efficiency drops slightly
  - Flue gas mass flow increases
  - Flue gas exit temp. increases
- RH-Spray increases
Oxyfuel component re-design
Improved SOx removal and FG drying

flue gas to CPU

SOx < 5 mg/Nm³
PM < 1 mg/Nm³

30°C

20°C

57.5°C

flue gas from FGD

SOx > 100 mg/Nm³
PM > 10 mg/Nm³

ΔT 27.5°C

NaOH

condensation
PM & SO₃

condensate
c. 185 m³/h

153 MW
26,500 m³/h

reduction of moisture from ca. 8%wt to < 2%wt

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Oxyfuel overall arrangement (partially optimized) and actual/future development work

- Combustion testing in small scale and CFD model validation
- $4-30\text{MW}_\text{th}$ burner / combustion testing
- AQCS testing for all components
- In parallel: materials testing for all components
- Overall process optimization
4 MW<sub>th</sub> combustion test facility, Hitachi Japan

Test items
- Burner, Combustion
- Ash properties
- Heat transfer properties
- Safety

Diagram showing various components of the test facility:
- Air Heater
- Cyclone
- Spray tower (remove dust)
- Primary gas pipe
- Over fire air ports (OFA)
- Combustion air
- Fuel pipe
- Horizontal furnace
- IDD
- PAF, GRF
- Oxygen supply equipment
Simultaneous evaluation for Oxy-Combustion at furnace and flue gas behavior (NOx, SOx, dust, trace elements)

GOALS
- High Performance DeNOx/Hg oxidation catalyst at high conc. H₂O and SO₂
- High efficiency SO₂ removal by wet FGD (SO₂ < 5 ppm for CO₂ compression)
- Trace pollutants (Hg, SO₃, HF etc.) removal
- Optimization of AQCS process
Vattenfall 30 MWth Oxyfuel Plant
HPE’s DS® Oxyfuel Burner and Combustion test in 2010

\[ 34 \]

source: Vattenfall
Future optimization potential for commercial size implementation of oxyfuel

Decrease specific energy requirement of ASU and improve load change behaviour (process design and investment)

Develop new optimized process design

- Checking of SCR requirement depending on CPU capability
- \( \text{SO}_2/\text{SO}_3 \) removal options and way of fg reciculation
- \( \text{CO}_2 \) compression and purification (depending on legislation) design
- Waste water treatment (from FGD, flue gas condenser and CPU)

Improve heat integration project dependent
### Change of Power Station Capacity

**Retrofit oxyfuel „state of the art“ 2009 vs. 2020**

<table>
<thead>
<tr>
<th></th>
<th>Air Mode</th>
<th>Oxyfuel 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal Input (fuel)</strong></td>
<td>1669 MW</td>
<td>1674 MW</td>
</tr>
<tr>
<td><strong>Gross capacity air mode</strong></td>
<td>829 MW&lt;sub&gt;el&lt;/sub&gt;</td>
<td>829 MW&lt;sub&gt;el&lt;/sub&gt;</td>
</tr>
<tr>
<td><strong>Own consumption</strong></td>
<td>61 MW&lt;sub&gt;el&lt;/sub&gt;</td>
<td>63 MW&lt;sub&gt;el&lt;/sub&gt;</td>
</tr>
<tr>
<td><strong>Power consumption for ASU + CO₂ compression</strong></td>
<td>- MW&lt;sub&gt;el&lt;/sub&gt;</td>
<td>192 MW&lt;sub&gt;el&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

**Net capacity**

|                      | 768 MW<sub>el</sub> | 576 MW<sub>el</sub> |

**2009 retrofit:**
- Overall efficiency drop from 46 to 34.3 % (11.7%points)

**2020 expected:**
- New build power station with 50% efficiency
- Reduced consumption by ASU + heat recovery for new builds
- Waste heat recovery from CPU in power station
- Overall efficiency drop from 50 to 40-42 % (8-10%points)
Examples for retrofits and new build PP design

Retrofit studies for actual new builds finished

\[ \Delta \eta = 8\text{–}12\% \text{ points} \]
depending on \(\text{O}_2\) production process details, \(\text{CO}_2\) compression and heat integration/process design, retrofit or new build

Optimization for pure oxyfuel plants ongoing

Air Separation Unit
app. 26,000 \(m^2\)
4 trains

CO\(_2\) Compression
app. 2,000 \(m^2\)

Recirculation Line

500 MWel
Two pass boiler
(New build)
Summary of main Oxyfuel Capture Ready Requirements

**Boiler & Firing**
- design heat absorption the same for oxyfuel/air combustion
- design firing / burner capable for reduced oxygen excess and capability for both modes

**Mill**
- check mill drying and outlet temperature
- check replacement of sealing system (retrofit to CO₂ as sealing gas)

**AQCS**
- check SCR, ESP, FGD performance and retrofit options
- leave place for installation of gas cooler/condenser and additional fan for FGC Δp
- check possible SO₃ sinks

**Cooling System/Cooling tower**
Sufficient space for:
- Additional circulation pumps
- Service water system
Sufficient cooling capacity of cooling tower/other sources

**Electrical self consumption**
Sufficient space for:
- Additional transformer(s)
- Switchyard
- Cable routes

**Condensate System and LP/HP preheaters**
Sufficient space for:
- Heat exchangers for heat recovery
- Additional piping routes with supporting structure

**Mill**
- check mill drying and outlet temperature
- check replacement of sealing system (retrofit to CO₂ as sealing gas)

**ASU and Oxygen**
- leave place for ASU (not necessarily at power station), oxygen pipes and O₂ injection to combustion air

**Cooling System/Cooling tower**
Sufficient space for:
- Additional circulation pumps
- Service water system
Sufficient cooling capacity of cooling tower/other sources

**CPU**
leave place for CPU near power plant

**Raw Water, Cooling Water Supply, Waste Water Treatment**
- space for upgrade
- check water availability, permit possibilities

**Flue gas ducts, recirculation, O₂**
- leave space for ductwork (fg and O₂)
- leave space for recirculation fan or upgradable design of air fan
- consider O₂ heating

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Challenge for retrofits and new design: heat supply and waste heat recovery, component design adjustment, interfaces

development tasks PCC unit: solvent and internal process and component design
Hitachi’s Experiences in CO$_2$ removal from Coal-fired Power Plants

Pilot Plant  Yokosuka, Japan

- Flue Gas Volume: 1000 Nm$^3$/h
- CO$_2$ removal: 4.5 ton/d
- CO$_2$ Recovery: 90%
HPE´s mobile Pilot Plant

- 5000 Nm³/h flue gas
- CO₂ removal > 90 %
- Removal of 1 ton CO₂/h
- CO₂ purity > 95 %
- Two train design for highest testing flexibility
- Operation on different sites due to installation in containers
- Optimized process design for a reduced energy demand

Partners for solvent development:

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Maximum Flexibility in the Choice of Location

Tests supported and at locations of:
Scale up and integration of Full Size CCS-Plant

Absorber diameter of 12 m is state-of-the art in chemical industry

Pilot plant
5 MW<sub>th</sub>
Diameter ~ 1 m

Demo plant
~ 350 MW<sub>el</sub>
Diameter ~ 12 m

Full size plant
~ 800 MW<sub>el</sub>
Diameter ~ 19 m
Interfaces of the Post Combustion Capturing Plant and the Power Plant in detail

- Optimized flue gas cleaning (dust, NO_x, SO_x)
- Process cooling and heat recovery (CO_2-Compressor, Amine-cycle, fluegas cooling)
- Process heat for Desorber and Amine regeneration by steam extraction
- Electrical power for CO_2-Capture process (pumps, fan) and integration of measurement and control
- Energy supply of CO_2-Compressor

**Diagram:**
- Stack
- Flue gas
- Clean Gas
- Scrubber
- Absorber 40°C
- Process steam
- CO_2 Compressor
- CO_2
- Desorber 120°C
- Process cooling and heat recovery
Integration in a Full Size Plant (I) without optimization
Influences on Plant Efficiency

Comparison of efficiency with and without CCS for different CO2 capture methods:
- MEA 3600 kJ/kg CO2:
  - Without CCS: 46.9% (820 MW)
  - With CCS: 31.0% (541 MW)
  - Compression at 200 bar: -13.1%
- Hitachi H3 2800 kJ/kg CO2:
  - Without CCS: 46.9% (820 MW)
  - With CCS: 31.0% (541 MW)
  - Compression at 200 bar: -9.1%

Plant with CCS
The Interfaces between the Power Plant and CO₂ Capture Equipment

- **Air-/ Flue gas system**
  - Fuel
  - Air
  - Flue gas
  - Heat

- **CO₂ Compression**
  - CO₂

- **Water-/steam-circulation, Turbine, Generator**
  - Flue gas
  - Heat
  - Steam
  - Condensate
  - El. Power

- **Cooling**
  - CO₂
  - El. Power

- **Flue gas Cleaning & CO₂-Capture**
  - Depleted Flue gas
  - Flue gas

Heat integration
Main disciplines working together at Hitachi on optimized process design for PCC

- boiler
- turbine & water steam cycle
- AQCS
- PCC process & solvent
- compressor
Integration in a Full Size Plant (II) with optimization

Primary air

DeNOx

FGD

Stack

Absorber

Desorber

Reboiler

Additional component or flow in water steam cycle for CCS operation

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Modifications of the Steam Turbine

Steam Extraction (Reheat Steam Line)

Re-Design of casted outer casing of the IP-Turbine

Cross over valve for pressure adjustment

Modified last stage HP blades due to increased enthalpy drop

Smaller LP blades due to modified steam flow

Steam Extraction (Crossover Pipe)
Loss of efficiency by optimized integration

**Basis no CCS**

- **MEA 3600 kJ/kg CO₂**: 46.9% 820 MW
- **Hitachi H3 2800 kJ/kg CO₂**: 31.0% 541 MW
- **Optimized Hitachi H3 2800 kJ/kg CO₂**: 2.8% 611 MW
- **Optimized Aim: NGS 2500 kJ/kg CO₂**: 2.8% 688 MW

Efficiency [%] vs Compression

**Compression**

- 46.9 %
- 31.0 %
- 2.8 %
- 2.8 %

**CO₂ Emissions**

- 3600 kJ/kg CO₂
- 2800 kJ/kg CO₂

**Output Power**

- 820 MW
- 541 MW
- 611 MW
- 688 MW

**NGS 2500 kJ/kg CO₂**

- 2.8% compression
Plant cycle without CCS

- Cooling tower
- Flue gas with less CO₂
- Cooling water
- Steam generator
- Coal
- Steam lines
- Cooling water
- Coal mills
- Ash removal
- PA fan
- Feed pump
- Feed water tank
- HP Pre-heater
- LP Pre-heater
- Turbine
- Generator
- Condenser
- Gypsum
- ESP
- Draught fan
- FD fan
- Fly ash
- FGD
- Flue gas injection
- De NOx
- De

η 46.9
Plant cycle with CO₂ scrubbing

- CO₂ scrubbing, solvent MEA
- Steam extraction: connection pipe to LP-turbine and cold/hot reheat line
Plant cycle with CO₂ scrubbing

- CO₂ scrubbing, improved solvent, i.e. H3
- Steam extraction: connection pipe to LP-turbine and cold reheat line, no extraction from hot reheat
Plant cycle with CO₂ scrubbing

- CO₂ scrubbing
- Turbine modification
- Steam extraction: connection pipe to LP-turbine
Process integration

- CO₂ scrubbing
- Turbine modification
- Steam extraction connection pipe to LP-turbine
- Transfer of waste heat into FD-air resulting in air heater bypass for HP pre-heater
- CO₂ scrubbing
- Turbine modification
- Steam extraction connection pipe to LP-turbine
- Transfer of waste heat into FD-air resulting in air heater bypass for HP pre-heater
- CCS waste heat shifted to LP pre-heater
Process integration

- CO₂ scrubbing
- Turbine modification
- Steam extraction connection pipe to LP-turbine
- Transfer of waste heat into FD-air resulting in air heater bypass for HP pre-heater
- CCS waste heat shifted to LP pre-heater
- Flue gas heat to LP pre-heater
Summary of main PCC Capture Ready Requirements

**Arrangement planning and space**
Consider additional equipment and minimize distances for heat supply, heat recovery and cooling water

**Cooling System/Cooling tower**
- Sufficient space for:
  - Additional circulation pumps
  - Service water system
  - Sufficient cooling capacity of cooling tower/other sources

**Steam Turbine and Steam Turbine Building**
- Consider steam extraction from cross over system
- Consider internal modifications

**Sufficient space & foundation for:**
- Modification of turbines
- Steam and condensate pipes
- Installation of heat exchangers

**FGD**
Consider space for internal retrofit measures or provide space for additional FGD/FGC unit

**PCC UNIT & CPU**
- Consider space
- Routes for heat supply and heat recovery

**Electrical self consumption**
Sufficient space for:
- Additional transformer(s)
- Switchyard
- Cable routes

**Condensate System and LP/HP preheaters**
Sufficient space for:
- Heat exchangers for low grade heat utilization
- Additional piping routes with supporting structure

**Air Preheating**
Space for heat exchangers for heat utilization

**Raw Water, Cooling Water Supply, Waste Water Treatment**
- Space for upgrade
- Check water availability, permit possibilities

**Cooling System/Cooling tower**
- Sufficient space for:
  - Additional circulation pumps
  - Service water system
  - Sufficient cooling capacity of cooling tower/other sources
For power generation Hitachi today provides cutting edge technologies with highest available efficiencies
- Actually build power stations are “carbon capture ready”
- CCR design continuously updated by new development results

For tomorrow’s demonstrations all processes for CCS are prepared

Hitachi’s mobile pilot plant for PCC CO₂ scrubbing is manufactured, tests will start 2010 in EU. Solvent improvement activities are ongoing at BHK, HPE and in cooperation with Uhde

Oxyfuel development at HPT, BHK and HPE is ongoing in different experimental scale for all components

Hitachi will deliver all components required and power trains including carbon capture in future

Hitachi will play an vital role in the global CCS demonstration programs
Thank you for your attention.
Carbon Capture Readiness
Most important criteria, based on TÜV TN-CC 006

- Site specific basic concept (e.g. feasibility study of plant manufacturer) for a CC system, which is considered a suitable option for retrofit according to the current state of knowledge

- There shall not be any site specific items or conditions that could hinder the integration of a CC system into the main plant by 2020 at the latest. E.g. it should be proofed, that there is sufficient space for the retrofit of a CC system at the plant site

- Proof of extended / additional investigation must be provided on items which actually can not completely assessed

- Furthermore, proof must be provided that no significant obstacles to implementation will arise from these items, e.g. official regulations and restrictions (i.e. emissions, cooling water, noise)

- The operating company at a reasonable amount contributes to R&D in the field of CCS
Carbon Capture Readiness
Most important criteria, based on TÜV TN-CC 006

- The design of the installation must ensure that there will not be any significant negative effects on safety, environment or human health which could be later obstacles for the retrofit.

- The plant operator must ensure eventual preparatory measures for a retrofit do not have a significant negative effect on the efficiency of the main plant, i.e. no waste of energy in advance.

- The plant design should allow to implement future developments in the field of CO₂ capture technology, i.e. flexibility for the integration of future technologies to minimize e.g. the efficiency penalty.

- Possible pre-investments should be identified and be subject to a technical and economic assessment. Positively assessed measures should be taken into account in the planning and implementation phase of the main power plant. These could be related to e.g. control systems, power supply, steam and cooling water supply and other interconnections to future equipment.
A site-specific concept must be presented for the transportation of the produced CO₂ (e.g. technical feasibility, cost estimates and evaluation, influence on efficiency)

A site-specific long-term storage concept must be presented (possible storage options and locations, capacities, cost estimates and evaluation)
For oxyfuel firing of any fuel the same or higher NOx concentrations (but lower NOx freights) is expected depending on process design.

DeNOx can be done in different ways.
Interaction between process design and SOx

High potential of corrosion in flue gas paths and boiler due to higher SO₃ concentration

Moderate/low corrosion potential

High potential of corrosion in flue gas path and boiler, flue gas cooling and compression

Air Products will demonstrate process at Schwarze Pumpe

IZEC Symposium, Tokyo, November 19th, 2009
SO$_3$ removal options to reduce risk of corrosion

**pH controlled FGC**

```
O$_2$  coal

ESP  FGD  FGC

NaOH  Sweep gas

SO$_2$  SO$_3$

CO$_2$
```

**GGH + ESP**

```
O$_2$  coal

GGH  ESP

NaOH  Sweep gas

SO$_3$  SO$_2$

CO$_2$
```

**additional dry DeSOx + fabric filter**

```
O$_2$  coal

ESP  FF  FGD  FGC

CaCO$_3$  Sweep gas

SO$_3$  SO$_2$

CO$_2$
```