# ENCAP Integrated Project

Large CCS Projects meeting, Brussels
5 September 2006

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Vattenfall AB, Coordinator

# Enhanced $CO_2$ Capture - ENCAP

**A Research Project for the development of**
**Pre-combustion technologies for**
**ENhanced CAPture of $CO_2$**
**in Large Power Plants**

**A five year Integrated Project within the EC FP6**
**Total budget 22.2 MEuro**
**EC support 10.7 MEuro**

**Project period 2004 March - 2009 February**

# ENCAP – a powerful consortium

**The ENCAP Consortium gathers:**

- **5 large European energy companies**
- **11 leading European technology providers**
- **12 high ranked research providers**

| | |
|---|---|
| Energi E2 | |
| PPC | |
| RWE Power | |
| Statoil | |
| Vattenfall | |
| +Total | |

| | |
|---|---|
| Air Liquide | BOC |
| ALSTOM Power Boiler (Fr)(GE) | Linde |
| ALSTOM Power Centrales | Lurgi |
| ALSTOM Power Ltd (UK) | Mitsui Babcock |
| ALSTOM Ltd (CH) | Siemens |

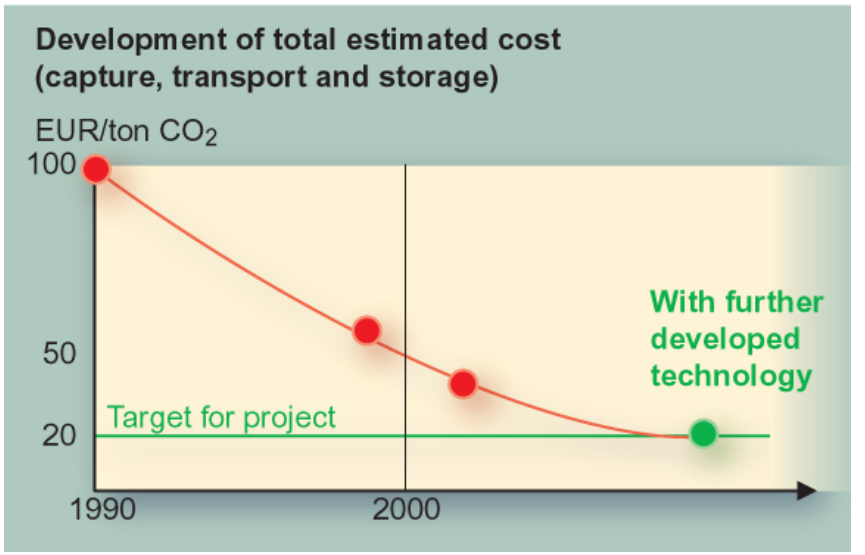
| | |
|---|---|
| DLR | SINTEF |
| IFP | TNO |
| ISFTA | |

| | |
|---|---|
| Chalmers | University of Twente |
| NTNU | University of Stuttgart |
| University of Paderborn | University of Ulster |

# ENCAP Target

**Develop pre-combustion technologies that in large Power Plants meets the target:**

- 90% CO2 capture rate and
- a cost of 20 €/ton stored $CO_2$



# ENCAP Concept development

## Development and verification of technologies to reach a capture rate higher than 90% at a cost lower than 20 €/ton $CO_2$

- Pre-combustion decarbonisation
  - IGCC for hard coal and lignite
  - IRCC for natural gas

- $CO_2/O_2$ combustion technologies (oxyfuel)
  - PFC for hard coal and lignite
  - CFB for hard coal, lignite and pet coke

- Chemical Looping Combustion

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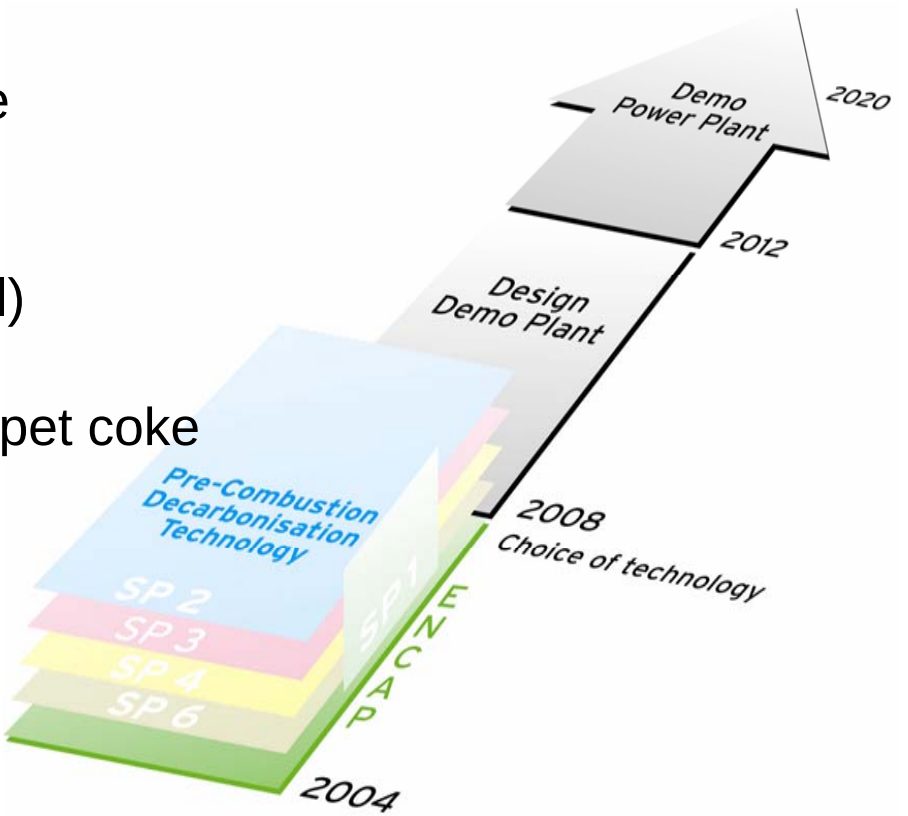

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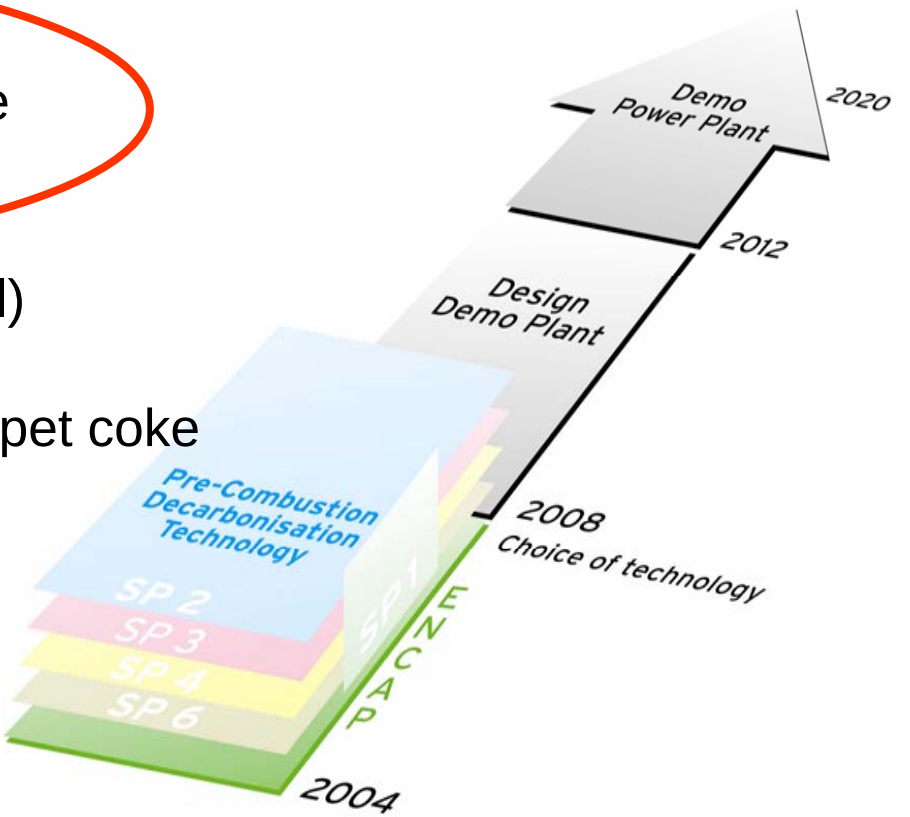
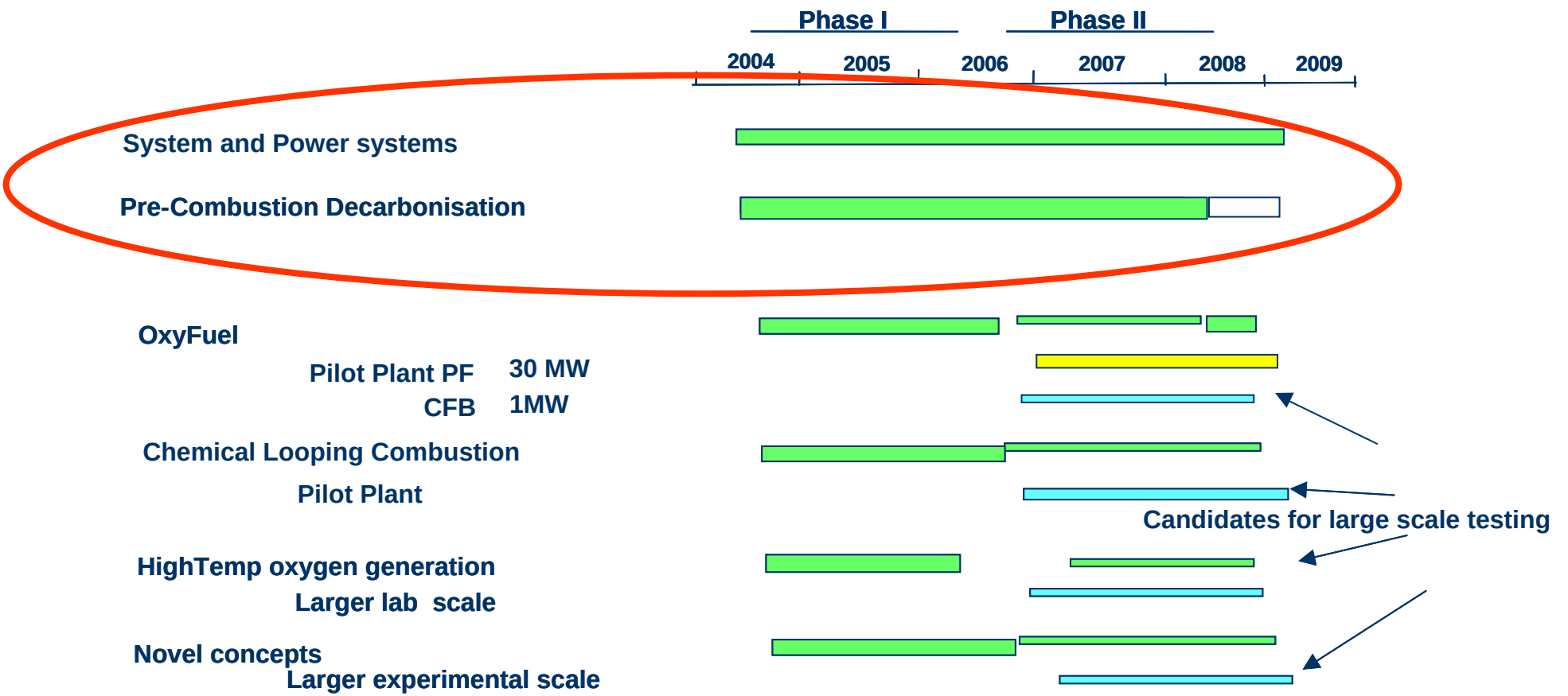


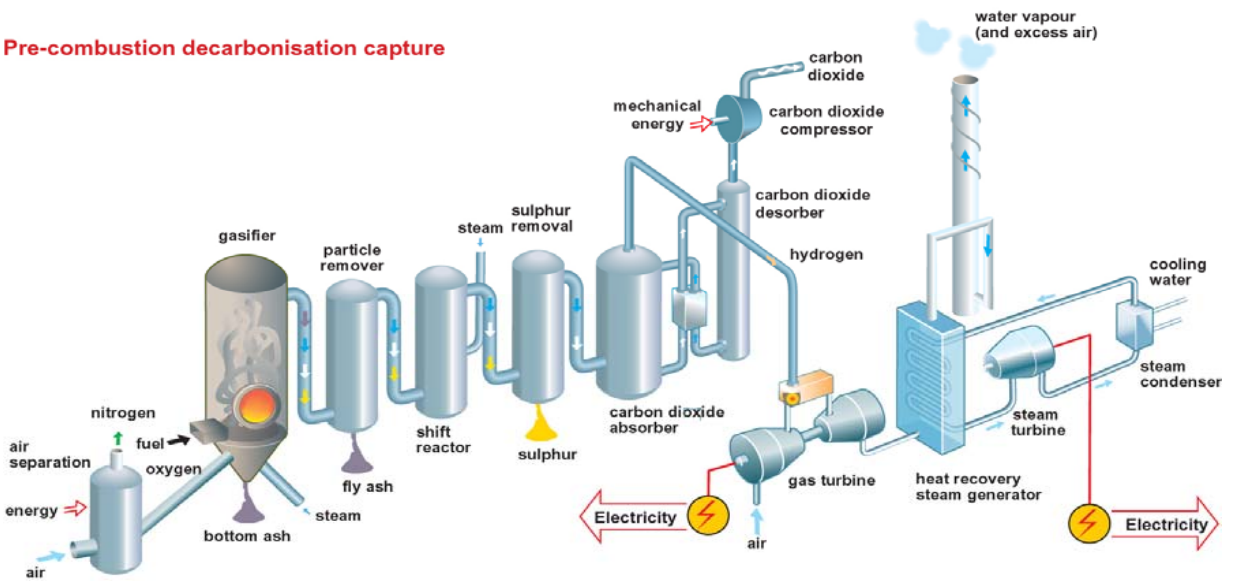
# ENCAP – Planned in two phases



# Pre-Combustion Decarbonisation Technologies

## Key items

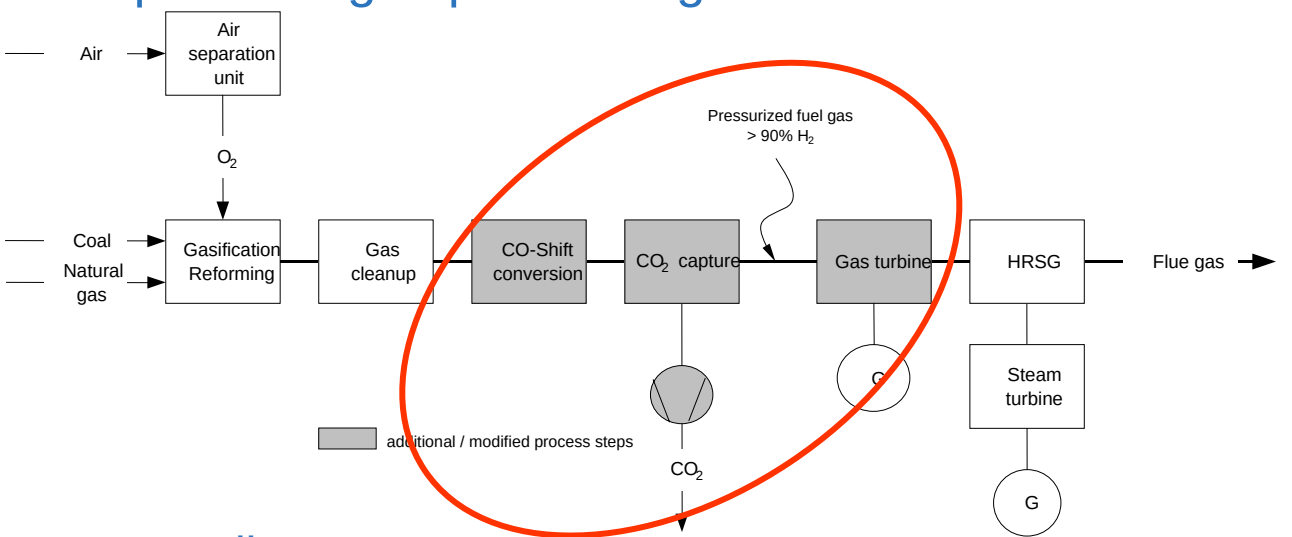
- Definition & analysis of plant concepts
- Optimising of CO-shift conversion
- $H_2$-rich combustion
- Development of capture unit integration with plant
- Development of overall plant outline specification



# Pre-combustion decarbonisation development

## Bituminous coal and lignite

### Optimised gas processing

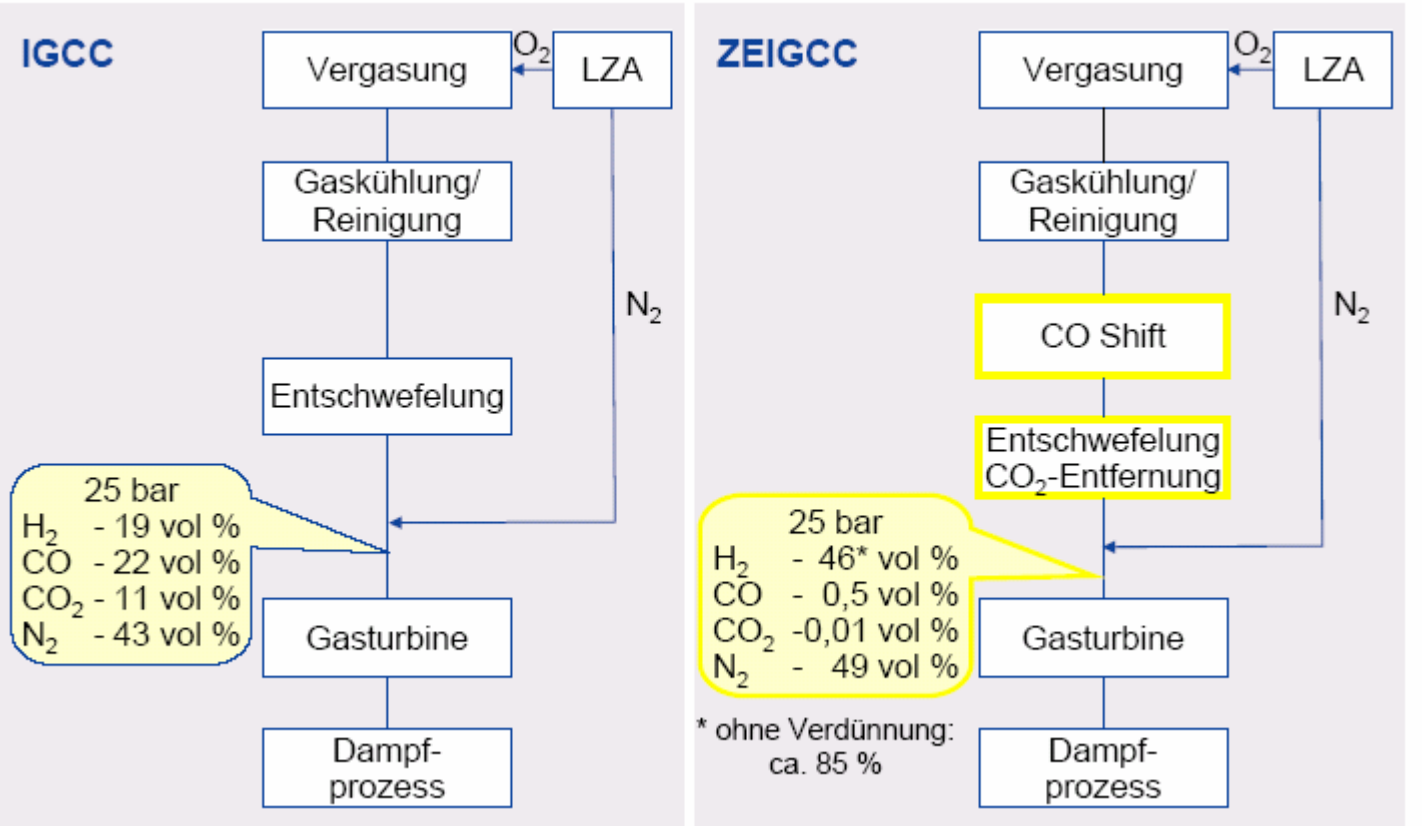



### Process outline

Integration of cryogenic oxygen production, $CO_2$ capture, gas and steam turbines into functioning power plants

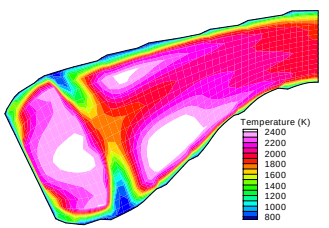
# ENCAP IGCC process verifications

**Bituminous coal and lignite**

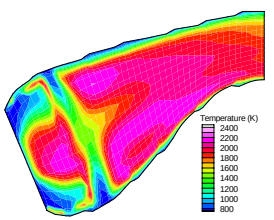


# Pre-combustion decarbonisation

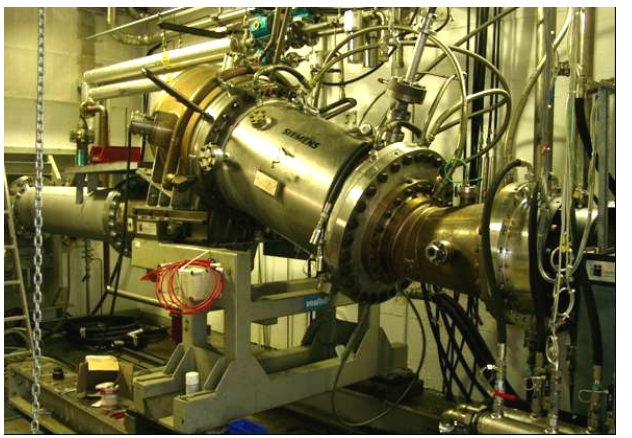
## Lean-Premixed Combustion of $H_2$-rich fuels simulations and tests




Hydrogen




Natural gas



High pressure test rig DLR

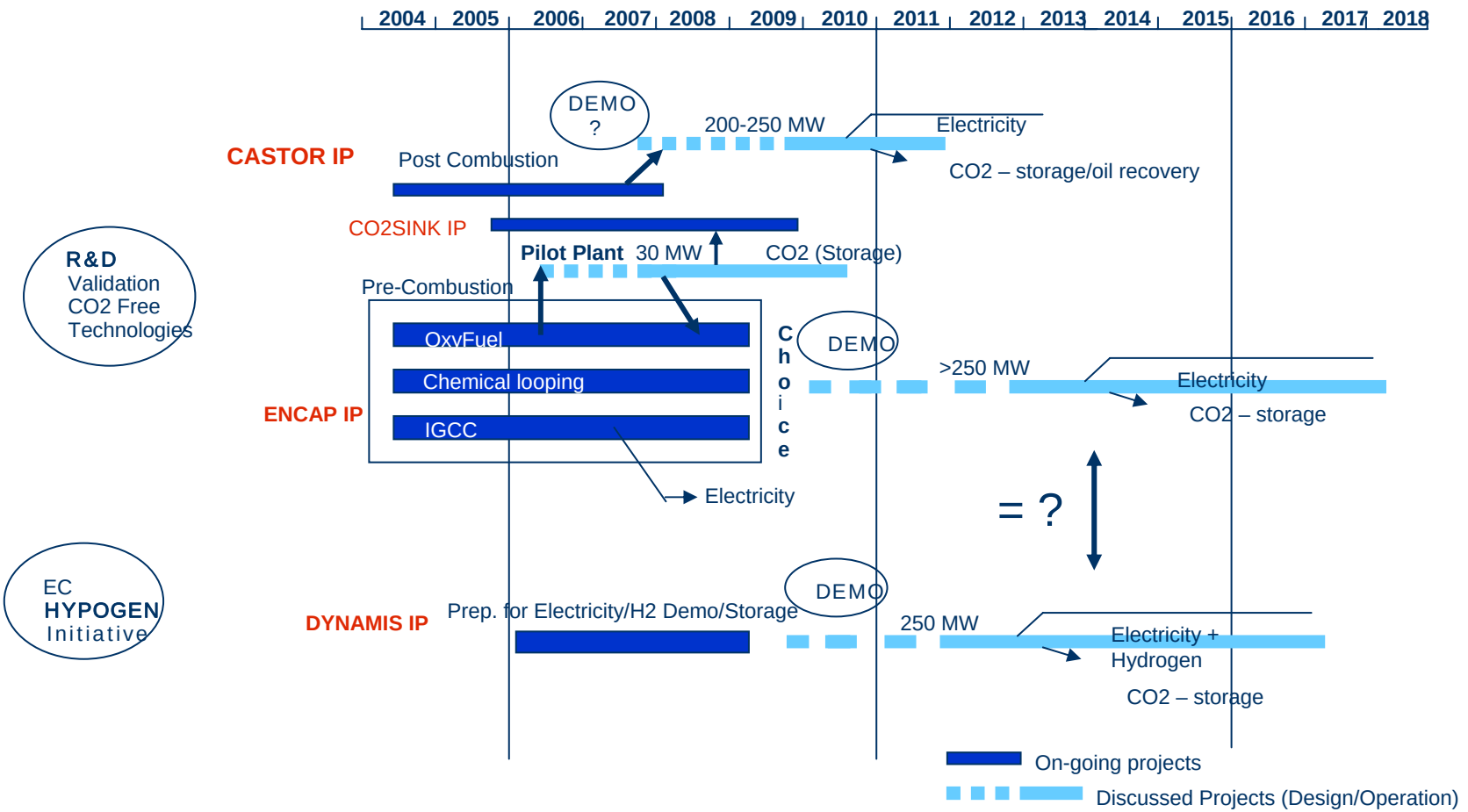
# Reference cases and guidelines for ENCAP technology concepts

## A common framework is established to define:

- State of the art reference power plants without $CO_2$ capture
  - **Natural gas-fired 400 MWe Combined Cycle Gas Turbine (Statoil / Siemens)**
  - **Hard coal / pet coke-fired 445 MWe Circulating Fluidised Bed (Alstom)**
  - **Hard coal-fired 600 MWe PF (Mitsui Babcock)**
  - **Lignite-fired 1000 MWe IGCC/PF (RWE / Vattenfall)**
  - **Lignite fired 380 MWe PF (PPC).**
- Boundaries for economic analysis
- Procedure to evaluate power plants with $CO_2$ capture
- Design scenarios for $CO_2$ purity

- **This will enable consistency in the benchmarking of $CO_2$ capture alternatives**

# ENCAP in relation to other IPs



# Thanks for the attention

## ENCAP - Deliverables Month 13-24

**Dissemination levels:**
PU=Public
PP=restricted to other programme participants (including the Commission Services)
RE=restricted to group specified by the consortium (including the Commission Services)
CO= confidential, only for members of the consortium (including the Commission Services)

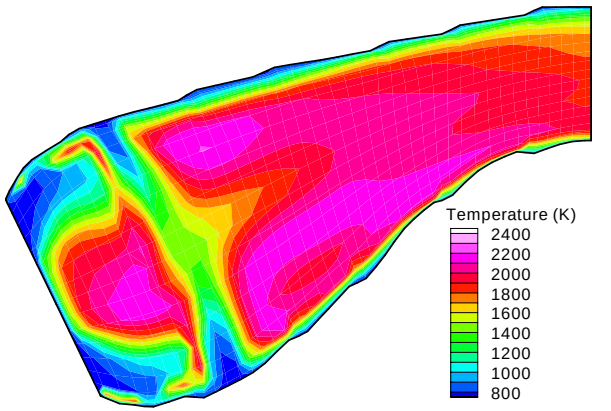
Approved PMt
Minor delay, delay under control
Major delay

| Delivery no. | Deliverable name | WP no. | Due date | Actual/ forecast delivery date | Lead participant (codes from Annex 1) | Status | Dissemi-nation level |
|---|---|---|---|---|---|---|---|
| D-1.1.2b | If needed, an issue 2 of Guidelines and boundaries for technical and economical evaluations | 1,1 | 20 | 17 | 3 | Approved PMt | RE |
| D-1.2.1 | Technical and economical comparison, evaluation and benchmarking of CO2 capture concepts | 1,2 | 24 | 24 | 5 | Approved PMt | RE |
| D-1.3.3 | A model which is able to calculate cost effective solutions for $CO_2$ free electricity production with respect to present and | 1,3 | 18 | 21 | 20 | Approved PMt | RE |
| D-2.1.4 | Mass end Energy balances of all processes | 2,1 | 15 | 18 | 5 | Approved PMt | PP |
| D-2.1.5 | Investment costs, technical and economic key figures | 2,1 | 18 | 24 | 5 | Approved PMt | PP |
| D-2.2.3 | Detailed mass balance and energy consumption of the gas conditioning section | 2,2 | 15 | 18 | 16 | Approved PMt | PP |
| D-2.2.4 | Process Flow diagrams of the gas conditioning | 2,2 | 18 | 20 | 16 | Approved PMt | PP |
| D-2.3.3 | Report on limits of current burners using $H_2$-rich fuel mixtures | 2,3 | 9 | 22 | | Approved PMt | PP |
| D-2.3.4 | Analysis and reduction of the validated final reaction mechanism | 2,3 | 15 | 16 | 18 | Approved PMt M16 | PP |
| D-2.3.5 | EDC or assumed joint probability density function combustion model | 2,3 | 18 | 26 | 18 | | PP |
| D-2.3.8 | Report on flame structure data (at high pressure) | 2,3 | 19 | 25 | 18 | | PP |
| D-2.3.6 | Interim risk analysis and FMEA report | 2,3 | 22 | 28 | 18 | | PP |
| D-2.3.7 | Preliminary assessment of effects of H2-rich combustion on other components of the combustion system | 2,3 | 22 | 28 | 18 | | PP |
| D-2.4.3 | Heat flow diagrams of main concept variants (based on current concept) | 2,4 | 15 | 18 | 18 | Approved M18 | PP |
| D-2.4.2 | Final selection of steam integration in overall plant | 2,4 | 16 | 20 | 18 | Approved PMt | PP |
| D-2.4.5 | Preliminary systems design schematics of syngas fuel system | 2,4 | 18 | 19 | 18 | Approved PMt | PP |
| D-2.4.6 | Report about plant concept for variation of dilution parameters | 2,4 | 22 | 30 | 18 | Will be rewritten to D | PP |
| D-2.5.1 | Preliminary documentation of complete plant for all cases | 2,5 | 24 | 28 | 5 | | PP |
| D-3.1.2 | Data set on NOx/SO2-formation and burnout for process layout, operation and validation of process simulation. | 3,1 | 18 | 19 | 20 | Approved PMt | CO |
| D-3.1.3 | First report on identification and evaluation of oxyfuel flue gas parameters for various conditions. | 3,1 | 21 | 25 | 20 | | CO |

# Hydrogen combustion

- Hydrogen as fuel behaves very different from natural gas
- Hydrogen is extremely reactive, a safe design of the combustion chamber for a stable flame with low nitrogen oxide emissions is a genuine challenge
- Hydrogen is known as gas turbine fuel in cases without severe restrictions on nitrogen oxide emissions or high demands on power plant efficiency

Simulation of temperature in combustion chamber

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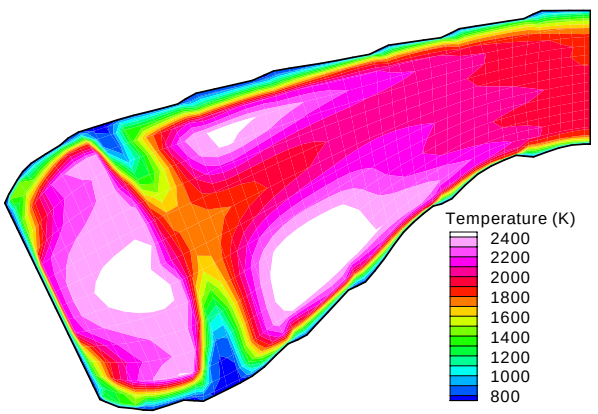
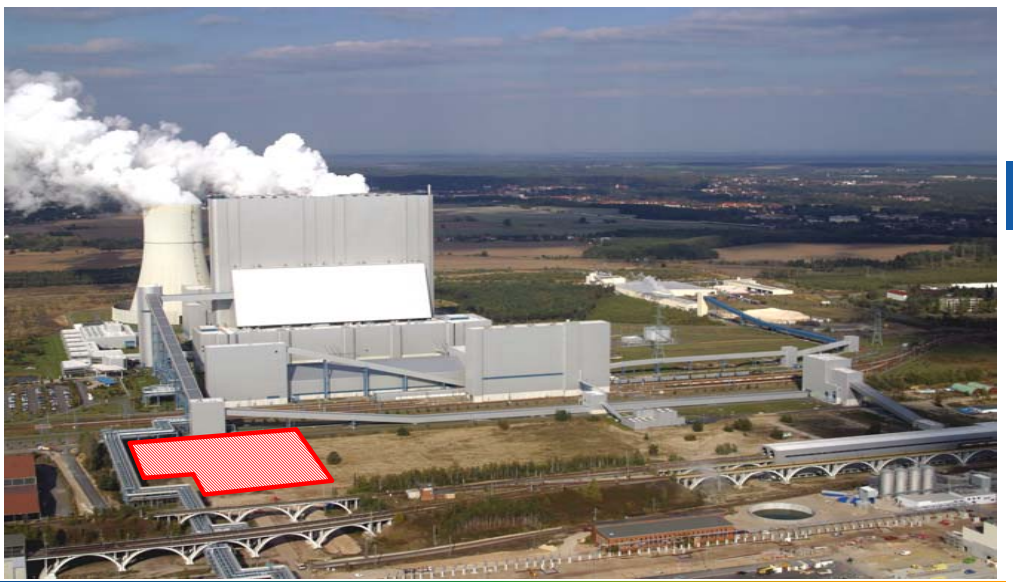



Hydrogen

# Vattenfall 30 MW PF Oxyfuel Pilot

## Location of the pilot plant

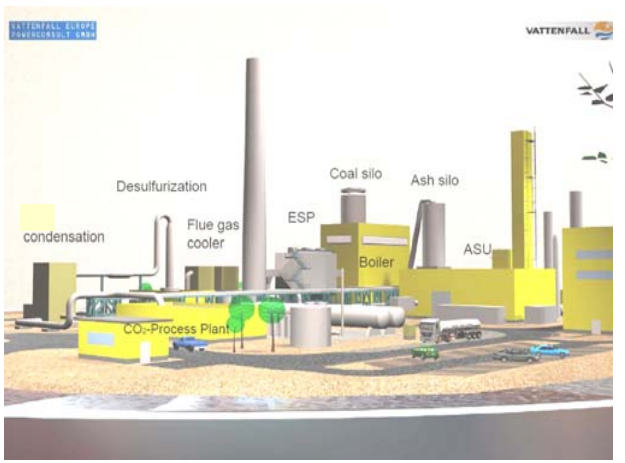






VATTENFALL

## 30 MW oxyfuel pilot – preliminary layout





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