Discussion Paper from Task Force for Identifying Gaps in CO_2 Capture and Transport

CSLF meeting London
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Discussion on Gaps existing in knowledge of CO_2 Capture and Transport

- It was decided at the September meeting 2004 of the Technical Group of the CSLF that an analysis of the gaps in the knowledge of CO_2 capture and transport should be made by a Task Force.

- Purpose of the Gap analysis:
  - To create an instrument to update the technology roadmap of the CSLF

- Appointment of the Task Force in January 2005:
  - Lars Strömberg, Vattenfall AB Sweden, representing the European Commission (appointed Chairman in January 2005)
  - Chen Wenying, Tsinghua University, representing China
  - Claudio Zeppi, ENEL S.p.A., representing Italy
  - Hubert Höwener and Jürgen-Friederich Hake, Later also Volker Breme, Forschungszentrum Jülich GmbH, representing Germany
  - Lars Ingolf Eide, Norsk Hydro ASA, representing Norway
  - Jean-Xavier Morin, Alstom, representing France

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Discussion on Gaps existing in knowledge of CO_2 Capture and Transport

- A first proposal for ta gap analysis was presented at the spring meeting 2005 of the Technical Group in Oviedo

- Several views on the content have been received, which are included in the present revised version

- Last years discussion has been mostly around the value of words and differing views on valuation of the three main technologies.

The logic of the paper

- The Analysis discuss:
  - The Capture and the Transportation steps in the chain for capture and storage of CO_2.
  - The gaps to be covered in R&D work, to establish a technical knowledge good enough to fulfill the goals set up.
- The paper discuss only the main technology candidates fulfilling the goals set by several countries
  - To avoid CO_2 emissions from power plants and other large scale sources, at a cost of 10 – 20 EUR/ton of CO_2. within a time frame up to 2020.
- Research in processes, principles and technology that might be very important and promising, but probably not will give results enabling large-scale applications within this timeframe, is not discussed.
- Technical options related to energy production or in energy-related industrial processes are discussed. There exist numerous industrial processes not discussed, where CO_2 can be captured, in chemical, petrochemical, food, and in the paper and pulp industry, to mention a few.
- Only technical ways to capture CO_2 are considered, i.e. reforestation and other system- related ways are not included.

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Technologies considered

1. Technologies possible to realize within 15 years, based on existing production technology and reasonably well established technologies, for both coal and gas.
   - Postcombustion capture
   - Precombustion capture
   - Oxyfuel processes

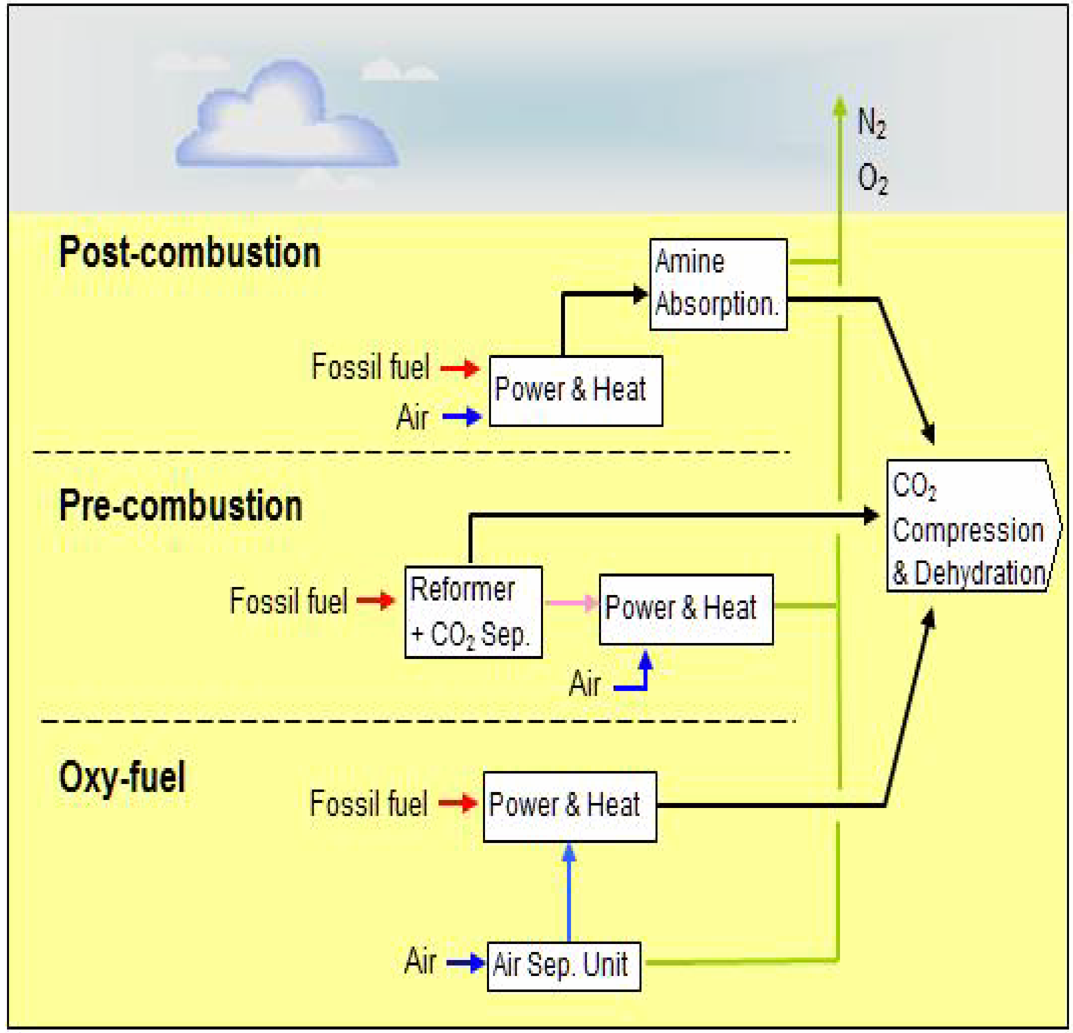
2. Technologies tested in laboratory scale and possible to realize after the three first generation technologies
   - Chemical looping.

3. New technologies not yet available that will be based on next-generation physical, chemical or thermodynamic processes, such as
   - Processes based on membrane technology
   - Solid adsorbers
   - New thermal power processes

Key points - Technology Options

Three technologies seems capable to fulfil the primary target to 2020. No “new” technology can do that.

- All three largely contain known technology and components
- All need optimization, scale up and process integration



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Identifying the gaps - Postcombustion Technology R&D Needs

- Postcombustion tecnology is a technology commercially available, albeit not optimized in the size and for the purposes intended here.
- The main challenge in parallel with reducing investments is to reduce the heat requirements for regeneration of the solvent.

- The general areas to be covered include:
  - Process optimisation for large-scale plants
  - New and less energy-intensive solvents
  - Demonstration of long-term operational availability and reliability on a full-scale power plant using relevant fuels

- More specifically, the needs are:
  - Reduce energy consumption and temperature requirements for regeneration
  - Reduce power consumption by development of amines or other solvents with higher CO_2 loading, applied at a higher concentration to reduce pump requirements and equipment size
  - Reduce degradation of sorbents
  - Develop other types of absorbers

Identifying the gaps
- Precombustion Capture Technology R&D Needs

The overall feasibility of the precombustion process depends on the total performance of the combination gasifier or reformer, CO_2 capture and the power process. This combination still has to show satisfactory performance, both in terms of efficiency and availability.

The main R&D needs thus are:

- To integrate all process steps and to demonstrate that concept
- To build and run, and later demonstrate optimised gas turbines for hydrogen

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Identifying the gaps
- Precombustion Capture Technology R&D Needs II

More specifically, the R&D needs are:

- Improved performance, availability and reliability of the gasifier island.
- Integration and optimisation of CO_2 capture equipment
- Development of the water shift gas reaction, particularly the catalysts
- Integration of the air separation unit
- Improved solvents for physical absorption
- Novel methods for air separation (e.g., high temperature ceramic membranes)
- Verify and test novel methods for CO_2/ H_2 separation in membrane (ceramic and polymer) reformers and water gas shift
- Development of an optimized hydrogen fuelled gas turbine

In addition:

- Development of "polygeneration" technologies (i.e., hydrogen, methanol and synthetic fuels, in combination with electricity)

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Identifying the gaps - CO_2/O_2 (Oxyfuel) Combustion R&D Needs

The technology for coal is based on conventional power processes. Differing is the combustion process, with a CO_2/O_2 mixture instead of air. First generation boilers will be very similar to a process using air.

The main area for improvement is the air separation process. Improving existing and development of new large-scale oxygen production concepts are thus essential.

The logical gaps and consequent R&D needs are:

- Create a thorough knowledge of the combustion process in large scale
- To integrate the processes, to reduce energy consumption and investment costs
- To establish a series of pilot plants and demonstration plants (gas and coal)
- To develop new boilers based on i.e. CFB and other conventional boilers.

Identifying the gaps - CO_2/O_2 (Oxyfuel) Combustion R&D Needs II

More specifically the R&D needs are :

- The boiler has to be developed and optimised for this concept
- Development of CFB technology for this concept
- Combustion chemistry and kinetics to provide design and scale-up data
- Verification of developed flue gas cleaning equipment
- Material selection for new flue gas environment
- The long term operational properties at large scale, such as slagging, fouling and corrosion
- Verification and pilot testing of integrated oxygen transporting membranes with gas turbines
- Finding new integration possibilities within power plants, especially if a new type of ASU is developed

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Identifying the gaps
- Chemical Looping Technology R&D Needs

Chemical looping has been proven functioning well in a lab test rig with natural gas. To burn coal in a similar process is also tested in labscale with good results. The economic prospects seems very promising, since costs for extra energy are reduced to a low value and the physical build-up of the process can be based on fluidized bed technology.

Chemical looping technology depends strongly on finding a suitable oxygen carrier.

This means that the concept may be feasible, but it is still at a laboratory level of knowledge. There is still a long way to go.

The obvious R&D needs are:

- Develop oxygen carriers for gas and coal processes
- Develop a process for coal combustion
- Design and develop a suitable thermal process

Identifying the gaps
- Transport R&D Needs

- Transport of CO_2 is a well-known technology in industry. Technologies exist for all types of transports, for small or large volumes, for long and short distances, on shore and off shore.

- No actual research is needed to arrive at a solution.

- Cost per transported ton is lower for an integrated system than for a line from source to storage.

- What is needed is a good way of initiating a larger system. The challenge is to establish the first large transport lines in a system, and from there to establish a large integrated system.

- Until a market is formed, larger integrated systems, serving several emitters of CO_2 and supplying a system of storages, will not exist.

Identifying the gaps
- Conclusions I

- Generally known technology and components
- Process integration, optimization and scale-up
- The last steps in the development process are long, very expensive and need support

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Identifying the gaps - Conclusions II

- Development of the three main technologies for the 2020 target
  - Several large scale pilot and demonstration plants, optimized, with full process integration
  - Supporting R&D to reach lower costs, increase process efficiency and achieve better availability
- R&D for new and emerging technologies for deployment after 2020
  - Many routes to examine
  - Assessment to prioritize the technologies capable to overtake the leading role from any of the three main candidates.

Identifying the gaps

Discussion Paper:

Comparison of the views expressed in the CSLF document: Gaps Existing in Knowledge of CO_2 Capture and Transport, and the IPCC Special report on Carbon Dioxide Capture and Storage

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What is the ZEP ?

- The Zero Emission Platform is an initiative within the European Union to get a common view on
  - Present status of the CCS technology
  - Examine the GAPs and hinders to develop CCS to a commercially available option in 2020 and beyond
  - Create a strategic research agenda
  - Define a deployment route
- The work has been performed by more than 100 persons nominated from different parts of society
- The result is presented in form of
  - Reports from five different working groups
  - A Strategic Research Agenda
  - A Strategic Deployment Document

ZEP on the web

www.zero-emissionplatform.eu

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CO_2 free power plant

Back up

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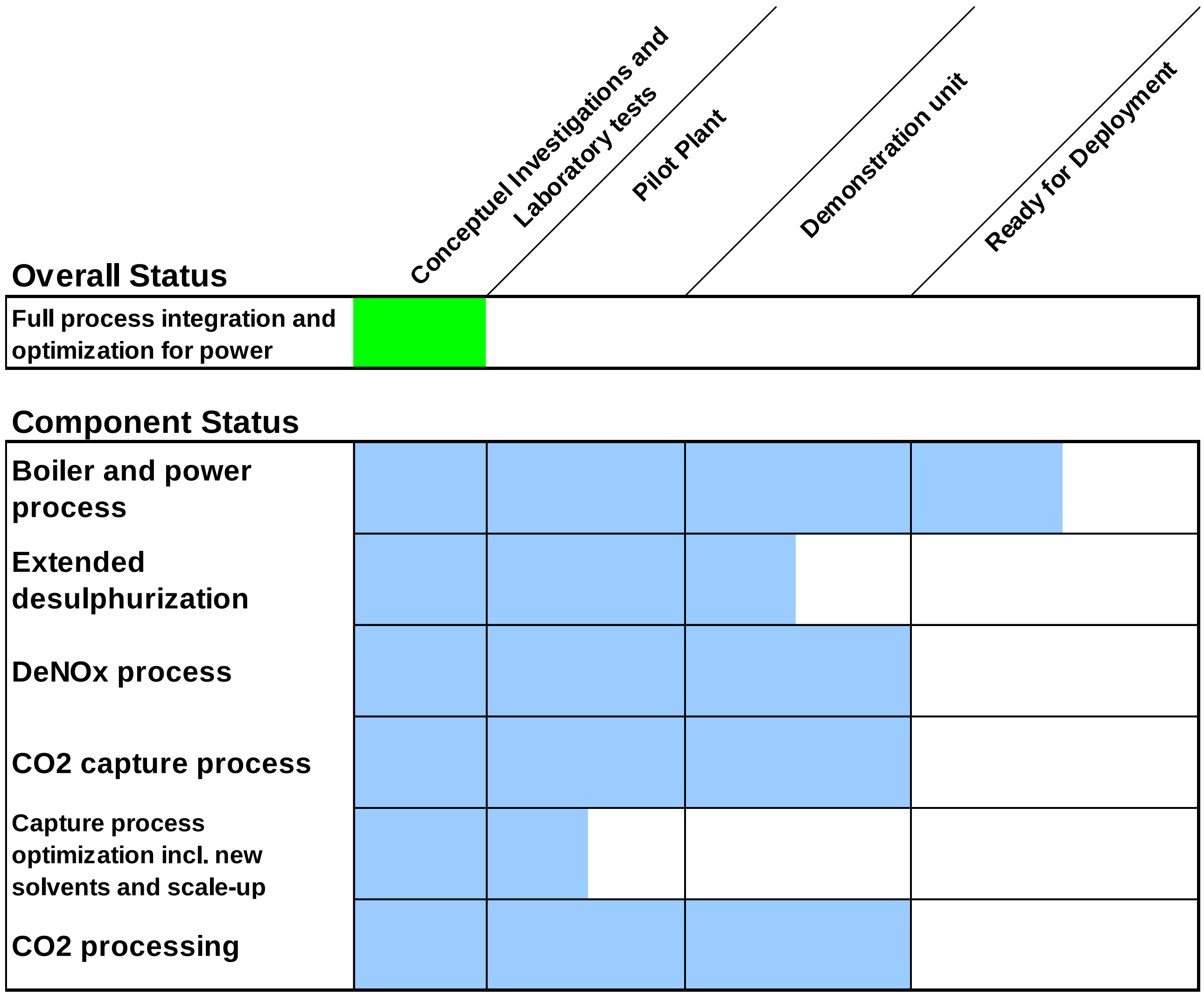
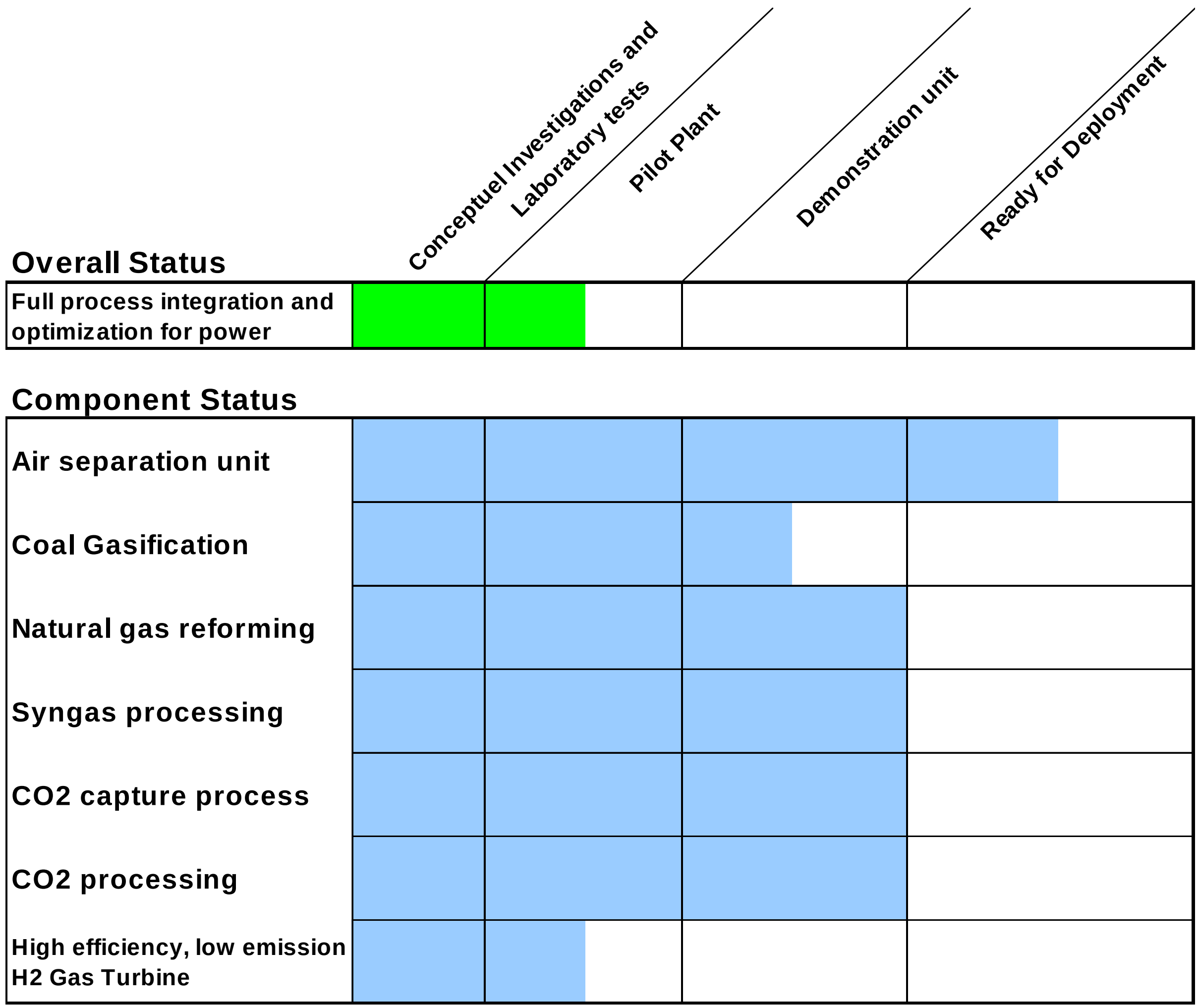
Key Points – Development need

Post-combustion



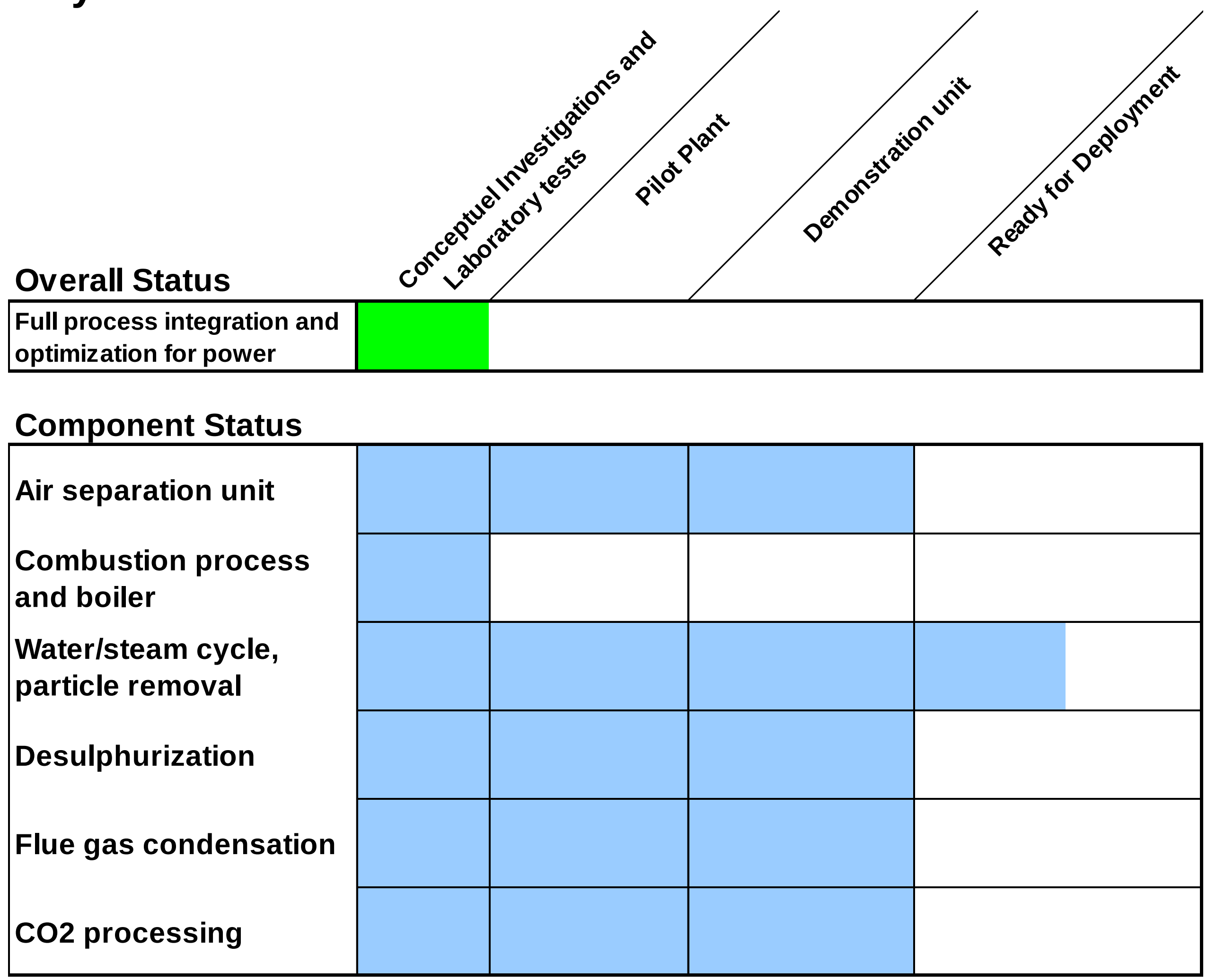
Key Points – Development need

Pre-combustion



Key Points – Development need

Oxy-fuel



Benchmark

Financial and other boundary conditions		Natural gas	Hard coal	Lignite
Fuel price	€/GJ (LHV)	5,8	2,3	1,1
Plant size	MWe (Ref)	420	556	920
Specific investment	€/MWe (Ref)	471	1058	1278
Common input				
Life time	Years	25		
Wacc	%	8		

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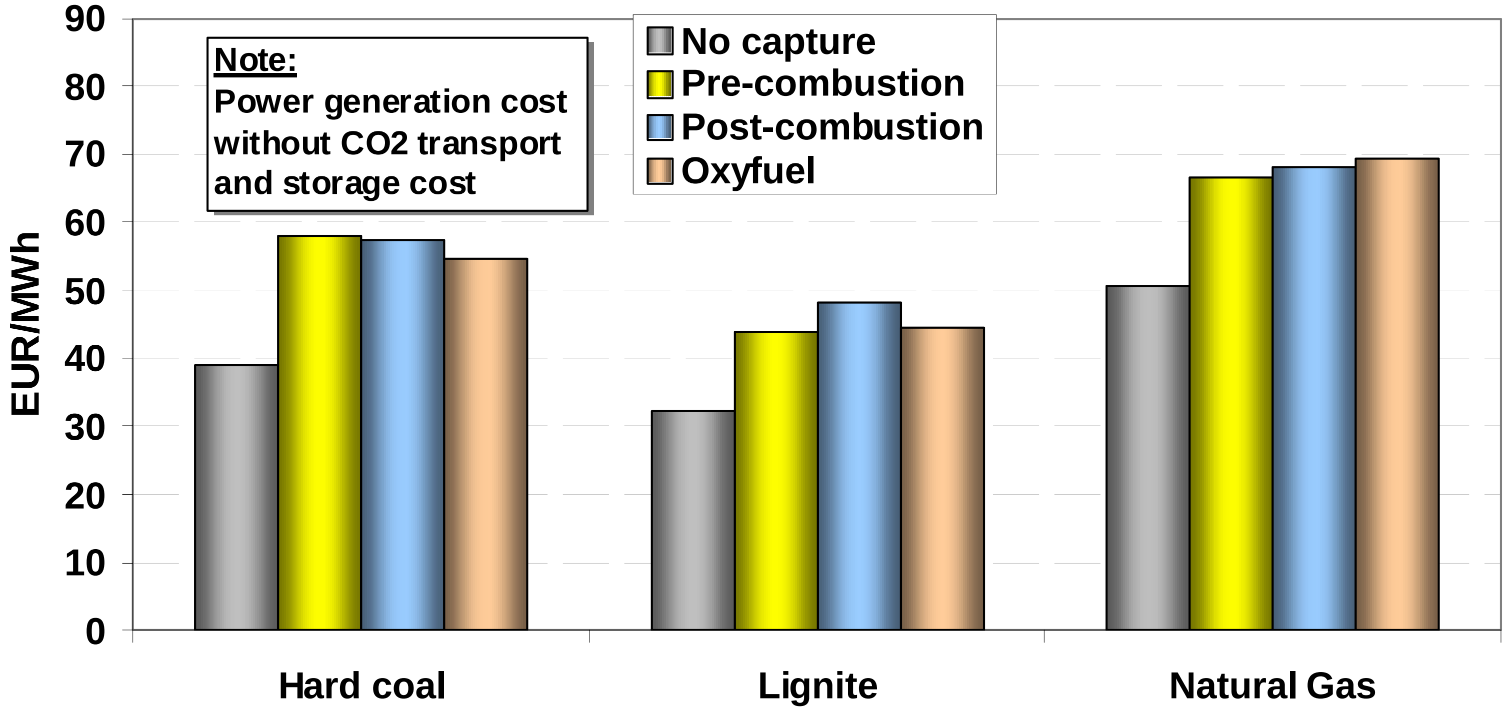
Benchmark

Electricity generation cost for large power plants in operation by 2020 (ZEP WG1)



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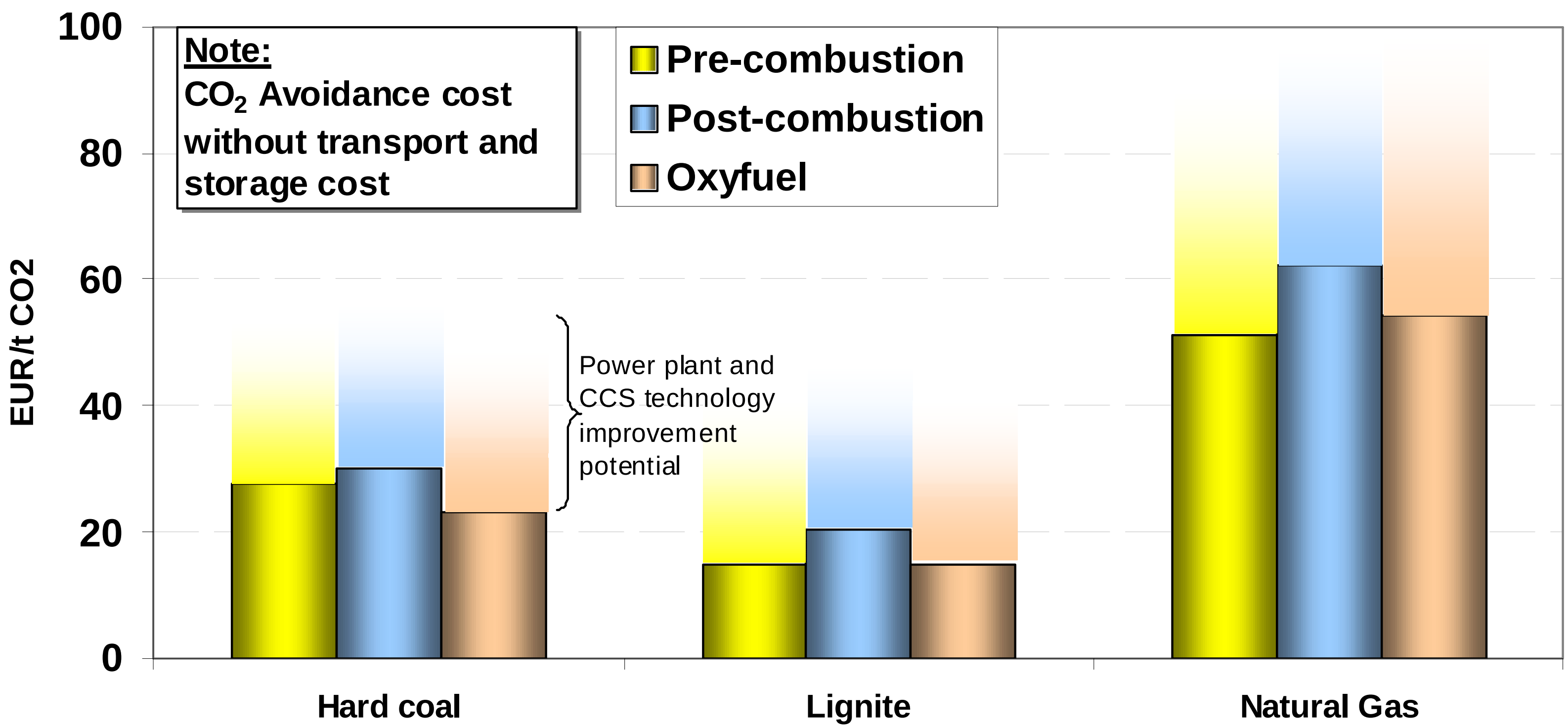
Benchmark

Avoidance cost for large power plants in operation by 2020 (ZEP WG1)



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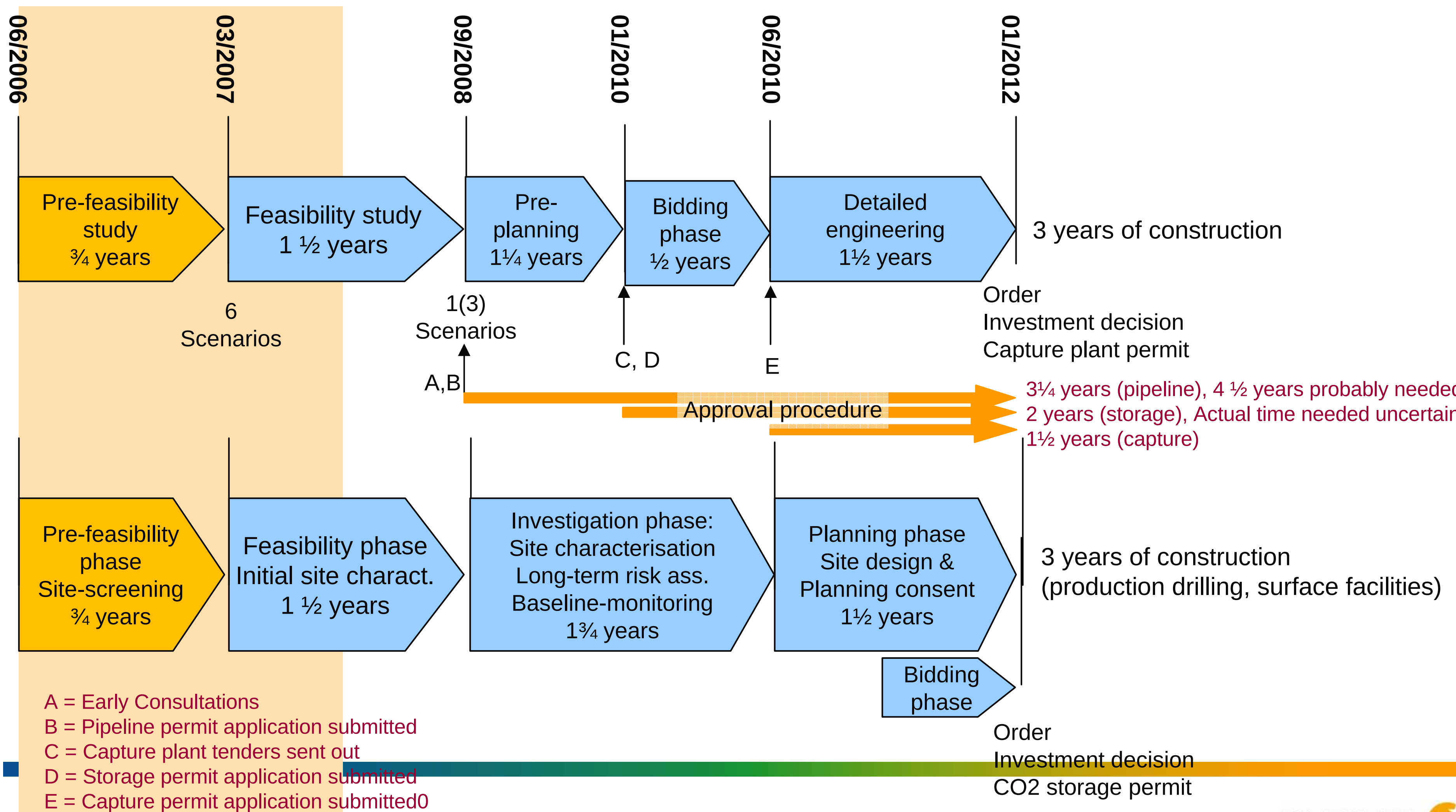
Roadmap to realization -
Pilot Plant and Demo Plant

Vattenfall's Roadmap to realization

2006		2015	2020	
Conceptual investigations	**Laboratory Test**	**Pilot Plant**	**Demo-Plant**	**Commercial Plant**
• Theoretical Research	• Research • Basic principles • Combustion characteristics	• Demonstration of the process chain • Interaction of components • Validation of basic principles and scale-up criteria • Long term charac-teristics • Non-commercial	• Verification and optimization of the component choice, the process and reduction of risks • Commercially viable incl. subsidies	• Competitive in the market at that time • No subsidies

The demonstration project time line: Capture & Storage



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Pilot Plant Lay out

Vattenfall oxyfuel pilot plant at Schwarze Pumpe Power station