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

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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, 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 were received and notes of the following members of the technical group are included in the present revised version

  - Norway
  - Italy
  - China
  - India
  - The USA and Canada
  - The notes from the previous technology group meetng

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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 technical 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

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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

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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 entirely based on conventional 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.

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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 seems possible, but not yet tested. If it can be done, the economic prospects are very good, since costs for extra energy are reduced to nil.

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

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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.

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Identifying the gaps - Conclusions

The three technologies closest to commercial introduction have in common, that of the R&D necessary, relatively seen, less research is needed. They all however require a large amount of development.

Still needed are:

- A program for scale-up, from pilot plants to several demonstration plants
- Gradually better integration, optimization and improved process layout
- Gradual introduction of improved components, methods and materials

In the near future, they will all probably see their first large-scale pilot/demo plants.

Unfortunately, this is by far the most costly part of the research and development chain.

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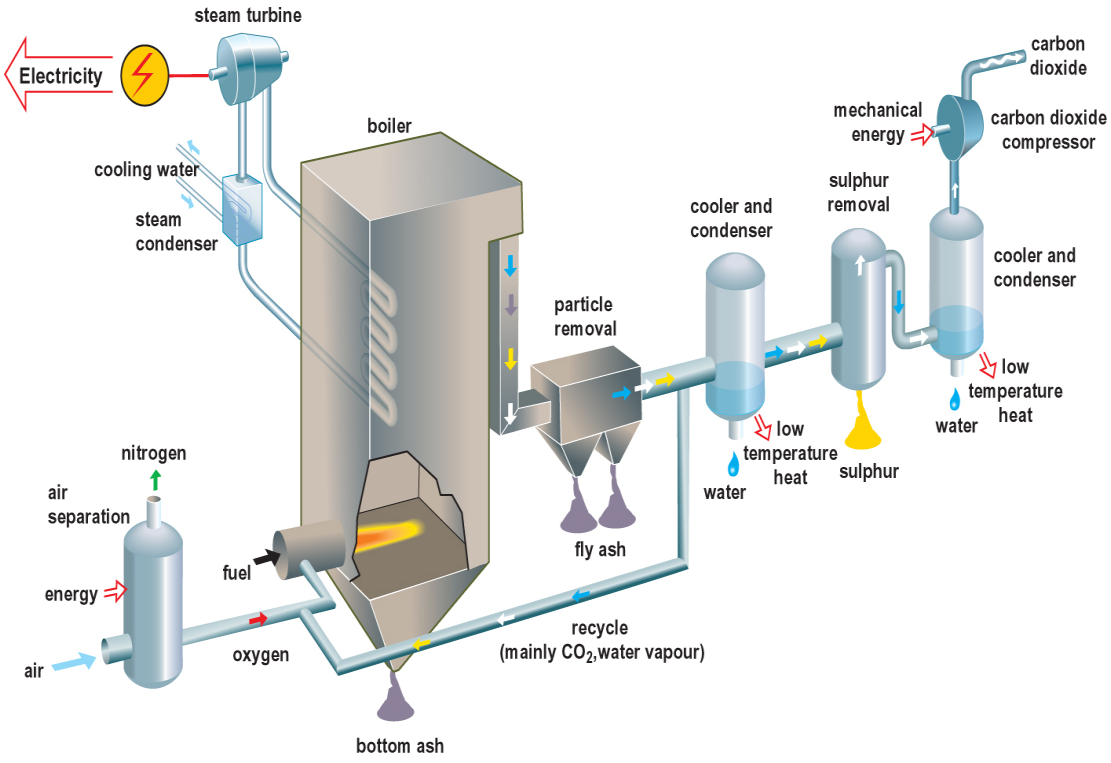
The Vattenfall Pilot Plant

The size of the plant is 30 MWth and the energy will be utilized.



- Technology used is the CO_2/O_2 combustion (Oxyfuel) technology
- The plant is built adjacent to the Schwarze Pumps Power plant and utilize all necessary infrastructure there.
- Fuel used is lignite and hard coal
- Budget including test program is Mio € 57

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Identifying the gaps capture and transport - Outcome of the discussion in the Technical Group

The report was accepted by the Technical Group in consensus, but with some alterations still to be made:

- The changes proposed from the USA received to late to be incorporated in the distributed document
- New considerations received from German industry
- The views from Korea and India presented at the meeting will be considered.

- The points above will be included in the final report

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Identifying the gaps capture and transport - Forward action

The task force agreed to continue its work and provide an analysis of the following issues, as proposed by the Technology Group

- Review the upcoming Special report from the IPCC and
  - Define discrepancies between this and the present GAP analysis
  - Comment on the findings
  - Eventually propose changes in the GAP analysis or motivate not doing so
  - erning both A program for scale-up, from pilot plants to several demonstration plants
- Review existing information on (technical) systems integration
  - To higlight experience in optimization work for improved efficiency and availability in the power business, process industry and elsewhere
  - Discuss findings in relation to the development needs concerning process optimization, found common to all three main technology candidates
- Review the present Technical Roadmap and propose changes related to the findings in the GAP analysis

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