Newsletter 1-2009

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SIXTH FRAMEWORK PROGRAMME

SEVENTH FRAMEWORK PROGRAMME

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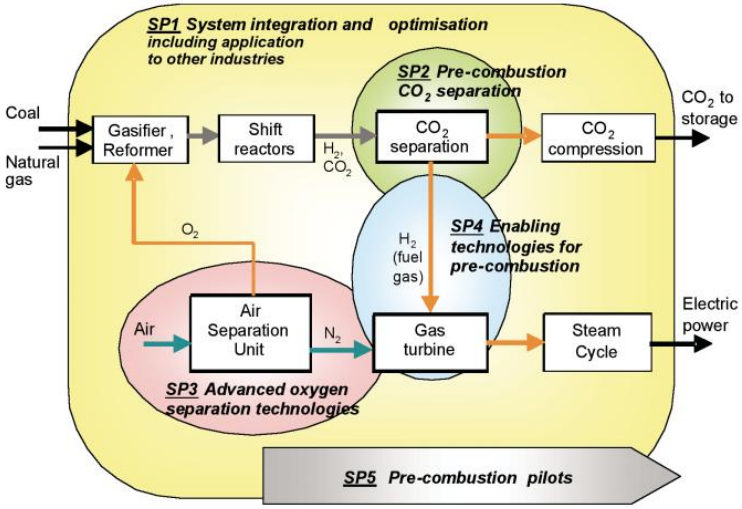
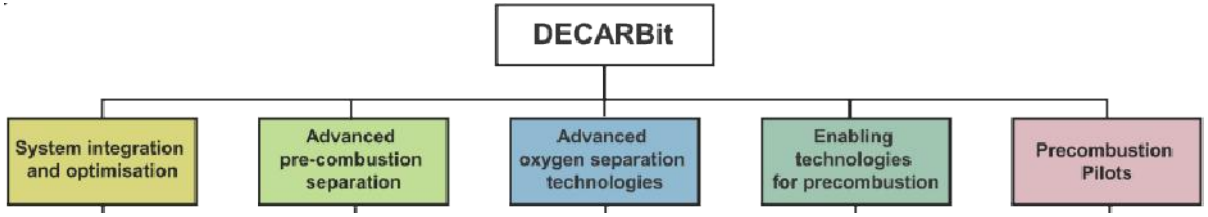
DECARBIT progress medio 2009

DECARBit responds to the urgent need for further research and development in **advanced pre-combustion capture techniques** to substantially reduce emissions of greenhouse gases from fossil fuel power plants. The project will accelerate the technology development and contribute to the deployment of large-scale carbon capture and storage (CCS) plants, in line with the adopted European policies for emission reductions. The project focus is to pursue the search for improved and new pre-combustion technologies. DECARBit is designed as a Collaborative Large-scale Integrating Project. The RTD activities are structured in 5 sub-projects directly responding to the objectives of the Work Programme:



- SP1 System integration and optimisation
- SP2 Advanced pre-combustion CO_2 separation
- SP3 Advanced oxygen separation technologies
- SP4 Enabling technologies for pre-combustion
- SP5 Pre-combustion pilots

The overall **objective** of DECARBit is to enable zero-emission pre-combustion power plants by 2020 with a capture cost of less than **15€/ton** with the highest feasible capture rate.



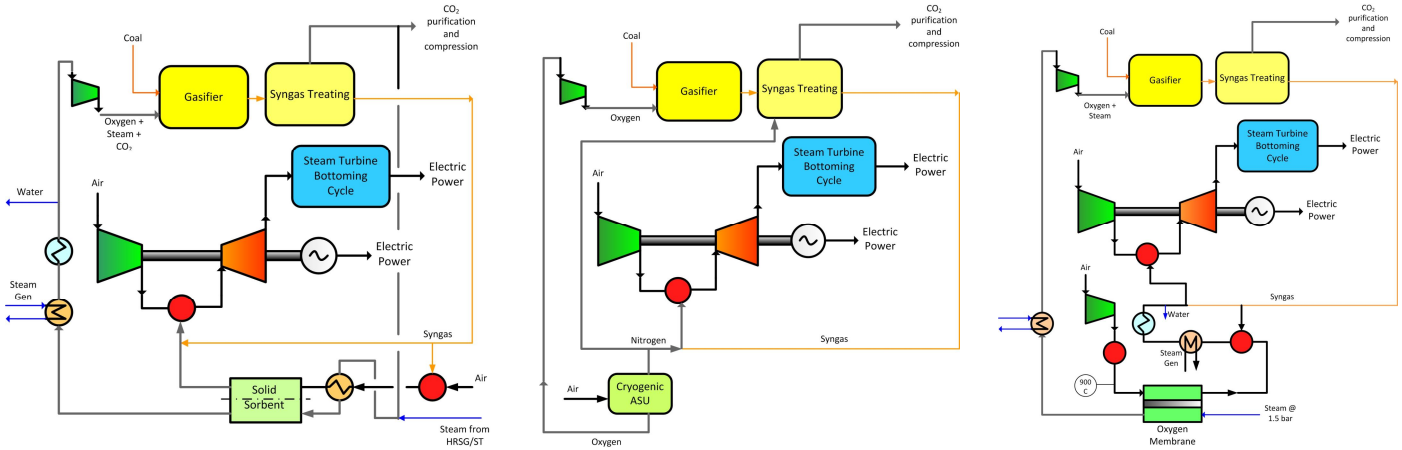
DECARBit Project structure

Welcome to the DECARBit web site - "Decarbonise it!" http://www.decarbit.com/

CESAR Enhanced Separation & Recovery

Progress in System integration and optimisation

Operational Requirements: Definition of operating conditions for a base cycle, construction of this base cycle and creation of new cycle propositions, based on new technologies investigated in DECARBit. Main parameter definitions have been decided and a base cycle was designed. Six new cycles were then proposed, based on novel technologies for oxygen production. Other new cycles are being studied now, using novel technologies for CO_2 separation.



Some examples of new proposed cycles

Techno-Economic Analysis: A collection of basic economic assumptions has been established for the economic assessments of the new cycles to be carried out later. This first report has established a framework for the economic study.

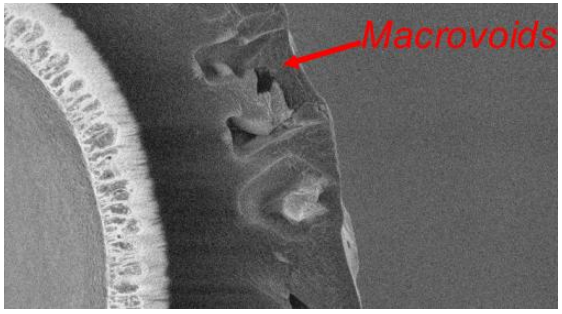
Coordination and Application to Other Industries: The main topic is dedicated to CO_2 separation and oxygen production. Progress has been made and a more structured procedure has now been agreed upon. A report summarizing the boundary conditions for the other SPs has been made available, were the boundary conditions have been taken from work done in earlier projects as e.g. ENCAP and DYNAMIS.

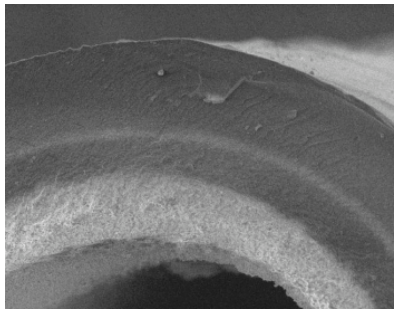
European Benchmarking Task Force: Was initiated in the first months for the writing of the Common Framework Definition Document - CFDD. Meetings of the Task Force were held in Amsterdam, in October 2008, and in Washington, in November 2008, with representatives from the three projects. The CFDD, still in draft form, builds on ENCAP, DYNAMIS and CASTOR FP6 projects, including new topics related to the FP7 projects. The integration and optimization work carried out is expected to make possible a broad view of the technical and economic applicability of novel separation technologies, not possible in the investigation of each one independently.

Progress in Advanced pre-combustion CO_2 separation

Exploration of advanced (CO_2/H_2) separation technologies. Three routes are investigated; **Selective membranes**, **Sorbents** and **Novel solvent systems**. The ultimate aim is to develop CO_2 capture systems that can operate at high temperature and pressure avoiding a large temperature / pressure swing in the treatment of syngas. The expectations are that some of the above-mentioned systems will be proposed evaluated for pilot testing.

Selective membranes: Different routes for the development of selective gas membranes are being explored. Ceramic hollow fibre support have been synthesized, and made available to the different partners. These supports have been used for the deposition of a selective layer. With respect to the membrane development the focus has been on carbon membranes (self supporting hollow fibre and ceramic supported), polymeric membranes with inorganic nanomaterials and dual phase membranes. For the selective layer different types of nanoparticles (e.g. hydrotalcites and zeolites) with high selectivity CO_2 have been selected. Hybrid hollow fibre membranes consisting of an alumina support with polymeric layer containing nanoparticles have been successfully prepared.

a) 

b) 

a) SEM image of cellulose acetate hollow fibre with macrovoid formations, b) SEM images of cellulose acetate hollow fibres spun in to a water coagulation bath

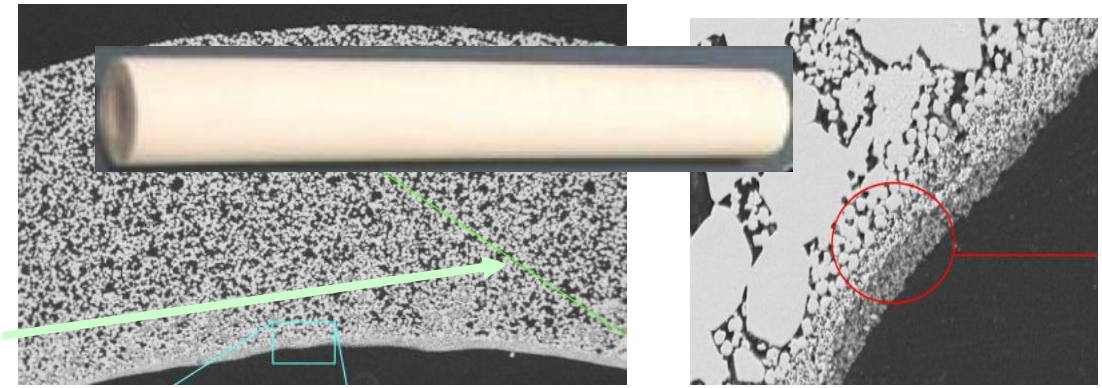
CO_2 Sorbents: The scope of CO_2 sorbents focuses on solid adsorbents: carbon based, silica-based, zeolites, polymer-based or MOF-based (Metal Organic Frameworks). To find promising materials, characterization by determining adsorption isotherms for several of the (new) materials is in progress. Furthermore, these materials, in particular zeolites and MOF-based adsorbents are used in a dual-reflux PSA process. This approach allows for a high purity separation step, and the dual phase aspect assures a heavy and a light product, making it most suitable for IGCC.

Novel Solvent Systems: Ongoing work on a system suited to combine an absorption and desorption step at elevated pressures where the solvent (or liquid loop) is kept at constant pressure. For this membranes and solvents are being developed, and the integration of the solvent with a membrane in single process is studied. A solvent screening has been performed, as the most promising candidates amines, ionic liquids and physical solvents have identified. In parallel, suitable membranes that are stable in the presence of one of the solvents at elevated temperatures are being synthesized.

Progress in Advanced oxygen separation technologies

Concerns the development of advanced oxygen separation technologies that could allow significant reduction in energy consumption for oxygen production from air.

Oxygen Transport Membranes: Membrane operating conditions have been defined. Membrane module design as well as membrane material system, suitable for given conditions, have been carefully selected. Porous supports of alumina have been provided to SINTEF by Corning, either bare or coated with a thin intermediate layer for surface optimization. SINTEF has also been working on extruding alumina porous tubes to contribute to optimize support's microstructure. Supports have been coated with membrane material by dip-coating in ceramic-based slurries developed by SINTEF.



SEM pictures of one 100nm coated support

The compatibility (chemical, thermal, mechanical) of membrane material towards support material has been investigated. Novel membrane materials synthesis for optimization of the selected membrane material system by cation substitution is performed at SINTEF. So far 5 different compositions have been synthesized and are ready to be tested with respect to oxygen flux. Sealing technology for assembly of membrane units in housings will be developed by Corning and SINTEF.

Sorbent based technologies: The main goal is to develop a technology for air separation units (ASU) using solid sorbent materials implemented in a configuration where the adsorption and desorption streams are cycled by rotating a fixed bed. From screening in thermogravimetric devices, IFP has found a class of materials demonstrating oxygen transfer capacities reaching 1.8 wt % at 500°C and good stability when cycling from air to humid nitrogen. In parallel, SINTEF has identified a material that reaches 4.9% oxygen transfer capacity but only at a higher operating temperature of 800°C. These results represent a 2 to 6-fold gain compared to the best known materials. Further testing will confirm the high potential of these materials and their potential for promoting sorbent based ASU technologies. Application of these materials in a honeycomb structure is under development by Corning.

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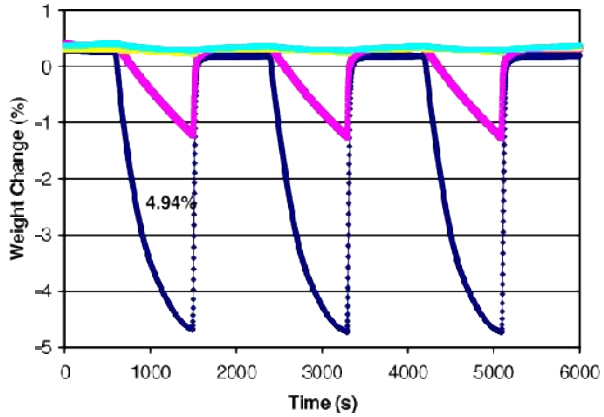
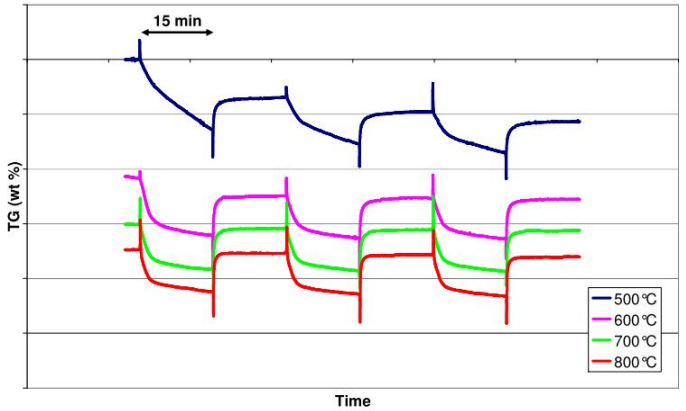
A simulator for the process is under development where the first step has been to model a fixed bed system in a new approach that combines the description of 3 physical dimensions: the crystal, the grain and a bulk phase. The physical and chemical properties of the developed materials need yet to be measured to feed the model. Various preparatory work is being performed using LSFC perovskites. This includes, adsorption isotherm modelling by ETHZ, shaping these materials in a honeycomb structure form by CORNING and setting up various experimental tools that will be used for testing larger quantities of material under more realistic operating conditions, including a lab-scale rotating bed system.





Advanced cryogenic technologies: Has the ambition to development advanced cryogenic oxygen separation technologies to reduce overall energy consumption. The performed work and main results are so far:

- Concept studies with focus on process integration: The main work has focused on suitable designs for the Air Separation Unit (ASU) based on the stream specification given for the overall cycle. An ASU scheme has been proposed, taking into account the consequence on its integration, especially with the gas turbine.
- Improved unit operation concepts: The focus is on development of a model for state-of-the-art distillation columns with a suitable thermodynamic model.
- Compact heat exchanger basis: Initial experiments for tubes with small diameters have been performed (heat transfer and pressure drop characteristics). Investigations for design of prototype heat exchanger were begun.

In total, the focus of the work is to achieve a cryogenic air separation unit optimized and best possibly integrated to reveal the full potential of this air separation technology. This should make a basis for a best possible comparison to alternative concepts.

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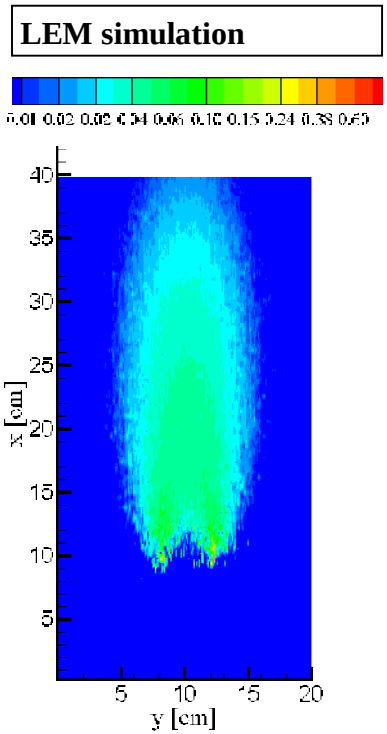
Progress in Enabling technologies for pre-combustion

The objective of this work is to develop safe and optimized premixed hydrogen burners and H_2 fuel systems for gas turbine conditions.



Hydrogen combustion: Covers both a numerical part and an experimental part. The numerical part has focused on three different issues related to numerical simulations of hydrogen combustion; to (1) find the best available chemical kinetic mechanism for high pressure high temperature hydrogen combustion. This is important when we want to simulate combustion at second stage combustor conditions. Work performed on this subject is now finished and is available as a final report, presenting the recommended mechanism. (2) Direct Numerical Simulations (DNS) simulations demonstrating how hydrogen mix and combust under gas turbine conditions. (3) The third issue is the verification of how a Linear Eddy Model (LEM) can simulate mixing of hydrogen with significantly less CPU resources than with DNS.

The experimental part the work is focused on the combustion of H_2-rich fuel in a reheat combustor as used in Alstom's GT24/26 family. A gas turbine burner must fulfil various performance criteria, which are influenced by the type of fuel being combusted. As a result, the efficiency of the gas turbine, emissions, fuel capability and operability margins for various fuel compositions are of particular interest. Various investigations on a generic level were carried out, mainly regarding the injection angle of the fuel and the reactivity of the fuel air mixture depending upon fuel composition, temperature and pressure. Preliminary designs have been established and combustion test will be conducted in the near future.

Fuel systems design: to achieve optimized design for H_2 fuel systems for gas turbines. The work performed since the beginning of the project consist of construction, verification and first results from the test rig for the auto-oxidation investigations for different compositions/temperatures of H_2-rich syngases. Literature and numerical investigations to evaluate the minimum expected energy to ignite the H_2-rich syngas compositions as well as to predict the range of expected H_2-rich syngas ignitions for the later calibration of the calculation tool has been performed. Also the piping and sealing material evaluation in manner of a literature study as basis for the piping material decision for the auto-oxidation investigations has been started. During the first year of the project, ENEL started a study on safety issues for hydrogen pipelines. As soon as the hydrogen economy will start to impose itself, pipelines will be a common system for hydrogen transportation, and the safety of it will have to be granted through the application of shared rules.

The main results so far are pre-evaluation of piping material for the auto-oxidation investigations and the running of the auto-oxidation test rig under the specified requirements, first results are available. The expected final results of this work is an optimized H_2-rich gas turbine combustor and fuel system to enable safe, reliable, highly available, fuel flexible and cost-effective operation of a H_2-rich gas turbine within a pre-combustion CCS power plant.

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SEWGS technology demonstrated on PDU scale

The CACHET project, which finished in April 2009, demonstrated the continuous operation of the SEWGS process development unit under various pressure swing cycles.

CAESAR achievements in 2009

- ***Testing of novel sorbents***
  The CAESAR consortium has identified a new sorbent, which has been tested in the single column rig for 1200 cycles. In contrast to the old sorbent used up to now, this new sorbent retained its mechanical integrity. As such, a major potential showstopper for the SEWGS process was removed.
- ***Calculation of efficiency of SEWGS system integrated in NGCC power plant and comparison with conventional capture technologies.***
  For the NGCC case, it was shown that a net electrical efficiency (LHV) of 49 to 50% is possible. This is 5 percentage points higher than the final CACHET figures and is partly the result of a different syn-gas generation technology (compared to the CACHET NGCC case) and partly of a more ambitious integration scheme which has in it self a higher risk of operational difficulties.
- ***Identification of integration scheme's for the SEWGS process in the IGCC power plant***
  For the IGCC case, preliminary calculations showed net electrical efficiencies (LHV) above 37%. Further optimisation of the SEWGS integration will show the potential of the SEWGS process in IGCC applications.

Old sorbent — Before | After test

New sorbent — After test

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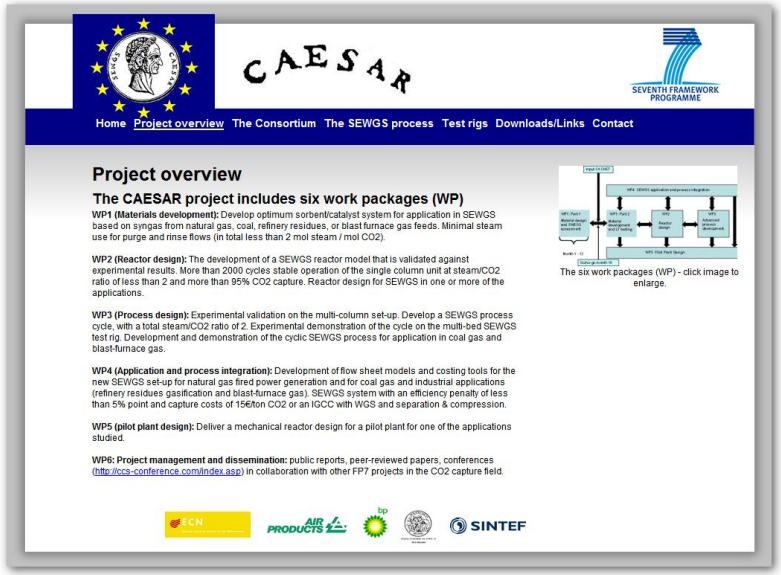
Process optimisation

The preliminary process optimisation calculations, based on process modelling and validation with multi column test results, showed that the SEWGS technology could well be a competitive technology. Combining the CACHET results and the CAESAR results so far, all partners agreed at a scheduled go/no-go point in June to continue the CAESAR project on the basis of pre-set criteria, reflecting the expected favourable performance of the SEWGS technology. The Description of Work was modified to incorporate the learning's from the CACHET project and address the remaining research questions from that project

CAESAR website launched

In July 2009, the CAESAR website (http://caesar.ecn.nl) was launched. The website provides the latest information on the CAESAR project.



Dissemination activities

During the European CCS meeting in February 2009 in Oslo, three CAESAR oral presentations were given (http://caesar.ecn.nl/downloadslinks)

1. Carbon Free Electricity Production by SEWGS (Daan Jansen, ECN)
2. Sorbent Development by ECN and Sintef (Paul Cobden, ECN)
3. SEWGS applications and process integration (Giampaolo Manzolini, PTM).

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CESAR
Enhanced Separation & Recovery

CESAR NEWS LETTER SEPTEMBER 2009

CESAR is ongoing and on track. The achievements in the first half of 2009 are described below.

Advanced separation processes

Solvent testing is ongoing to determine the potential of new solvent systems. Tests where done for different temperatures. Much attention is being paid to the energy consumption of the different systems. The results are being compared with a MEA system.
The chemical process simulation tool CHEMCAD is used to perform proof of concept calculations and simulations for carbonate systems. Modeling work has been started.
Small hollow fiber modules have been characterised at lab scale as membrane contactors for CO_2 capture with amines. Parameters have been determined of PTFE and Polysulfone microporous membranes.
The semi-industrial hollow fiber module (10 m^2) has been designed (see Figure 1) and is being built. Experimentation on this semi-industrial module is planned to start in December 2009.

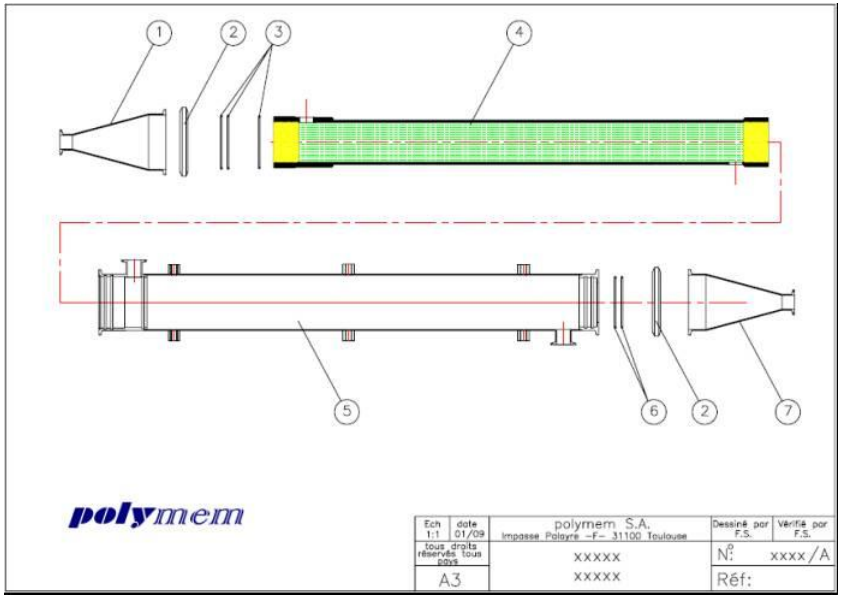

Figure: Sketch of the semi-industrial module

Capture process modeling and integration

The overall goal of this work is to optimise process integration between all elements of a power plant equipped with CO2 capture - boiler, steam generation, CO2 capture
& CO2 compression.
Modeling of new solvents is performed with the in-house developed tool of SINTEF and NTNU named CO2SIM.
An Aspen capture plant model has been made. In the coming period an extension will be made to implement new solvents in the Aspen model. European Benchmark Task Force activities are ongoing in cooperation with CAESAR and DECARBit concentrating on defining a common framework for technical and economic assessment of IGCC and post combustion CCS plants.

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Solvent process validation studies

Our pilot plant is Esbjerg was successfully upgraded and is operational for the testing of the CESAR solvents. A MEA test run has been performed with the upgraded plant. The results will become available in the coming period.
Laboratory pilot plant tests of various solvents have been performed and reported and are ongoing. CESAR 1 is chosen for the next campaign.
Environmental impact assessment measurements will be performed during the test campaigns.

Figure: Laboratory Pilot Plant at SINTEF

CESAR Website

CESAR website is alive and continuously update with the latest news and facts (www.co2cesar.eu)

Dissemination

At the CCS conference in Olso, three CESAR presentations where given: CESAR Overview by Peter van Os (TNO), Pilot Scale Testing in CESAR by Jacob Nygaard Knudsen (DONG Energy Generation), Solvent developments in CESAR by Eirik Falck da Silva (SINTEF)

CESAR has started preparations for the 2010 CCS conference, to be held April 20th – 21nd of 2010 in Rotterdam, the Netherlands. The conference will be organized in cooperation with CAESAR, DECARBit and CO2NET.

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News from the European Benchmarking Task Force (EBTF)

The European Benchmarking Task Force is a group of representatives of three CO_2 Capture and Storage FP7 projects – DECARBit, CAESAR and CESAR – dedicated to seeking the establishment of standards and guidelines for consistency in benchmarking assessments among European CCS R&D projects. Experiences and relevant reports from FP6 projects – CASTOR, CACHET, ENCAP and DYNAMIS – were to be considered as sources of information and ideas to be used in the work of the task force.

The inaugural meeting of the task force was held at TNO, Amsterdam, in October of 2008. The task force was then formed with five members from DECARBit, two members from CAESAR and two members from CESAR Other face to face meetings were held in London (March 2009), Amsterdam (May 2009) and London (June 2009). Three teleconferences were also held in January and February 2009. So far the team has been very homogeneous, cooperative and committed to its mission. Nevertheless the mission has proved to be more difficult than expected: long discussions and many adjustments have been necessary to guarantee agreement of all members in the definition of standards, test cases and guidelines.

Three deliverables are responsibility of the EBTF: a Common Framework Definition Document – CFDD (Dec. 2008), Test Cases and Preliminary Benchmarking Results from the Three Projects (June 2009) and European Best Practice Guidelines for CCS Plants (Dec. 2010). A first version of the CFDD was issued in December of 2008, followed by other two versions in February and May of 2009, the latter probably final. It covers a broad number of issues, from fuel composition to exit conditions of CO_2. The Test Cases report is being elaborated. The delay with respect to its deadline has been caused mainly by the holiday season and by the change of a member of the EBTF. The expectation is that its delivery will be possible by the end of October.