Advanced cryogenic technologies (WP3.3):
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 PhD candidate started his work in June. Work description for the PhD has been established and presently 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.

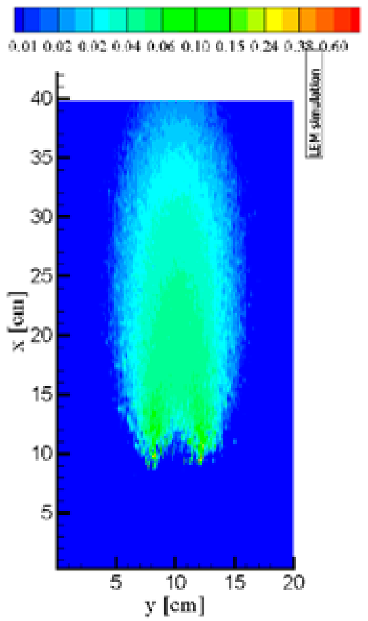
If the investigation of process integration reveal possibilities for reduced energy consumption this will lead to improved overall cycle efficiency. Improvement of unit operations will have its main focus on novel distillation column concepts. If one succeeds in improving the overall efficiency, the energy demand for distillation will decrease. Specifically for DECARBit, the cryogenic ASU unit energy consumption will decrease. Development of compact heat exchangers will lead to improved performance and reduced foot-print of the main heat exchanger in the cryogenic ASU. Compact heat exchangers will as well have many potential application areas.

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.

SP4 Enabling technologies for pre-combustion

The objective of SP4 is to develop safe and optimized premixed hydrogen burners and H2 fuel systems for gas turbine conditions.

Hydrogen combustion (WP4.1):
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 H2-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. During the first year of the project, ENEL started a feasibility analysis for the test of the syngas fuelled Alstom combustors in the Sesta facility.

Fuel systems design (WP4.2):
The aim is to come up with an 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. Furthermore 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. By the demand of the German technical inspection agency the test devices for the ignition limit investigations (mixing and ignition vessels) had to be rebuilt, this has lead to a four month delay for this particular activity.

During the first year of the project, ENEL started a study about safety issues for hydrogen pipelines, starting from a bibliography research about existing regulations in Europe and other countries. As soon as 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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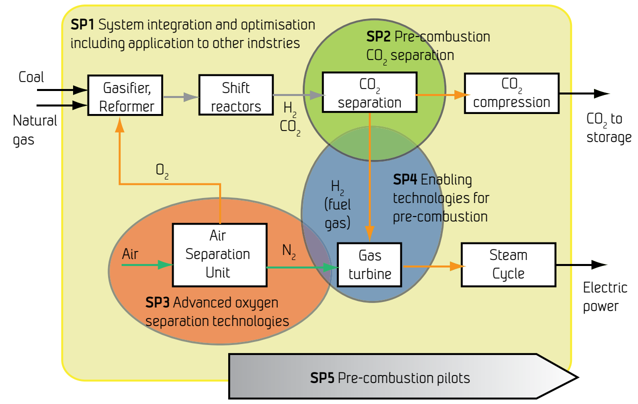
Public Report 2008

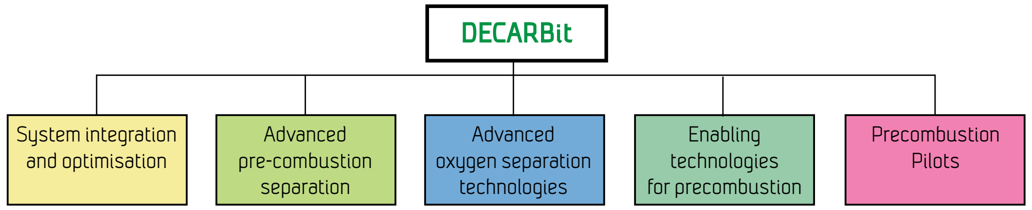
Project Overview

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 that can meet the cost target of 15€/ton CO_2 captured as stated in the Work Programme. 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

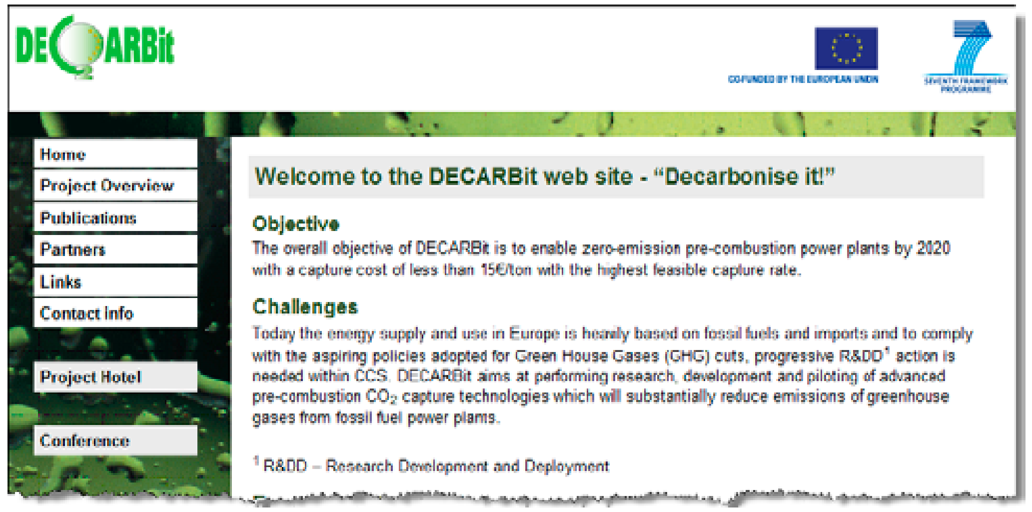


The overall objective of DECARBit is to enable zero-emission pre-combustion power plants by 2020 with a capture cost of less than 15€/ton with the highest feasible capture rate.



DECARBit Project structure

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



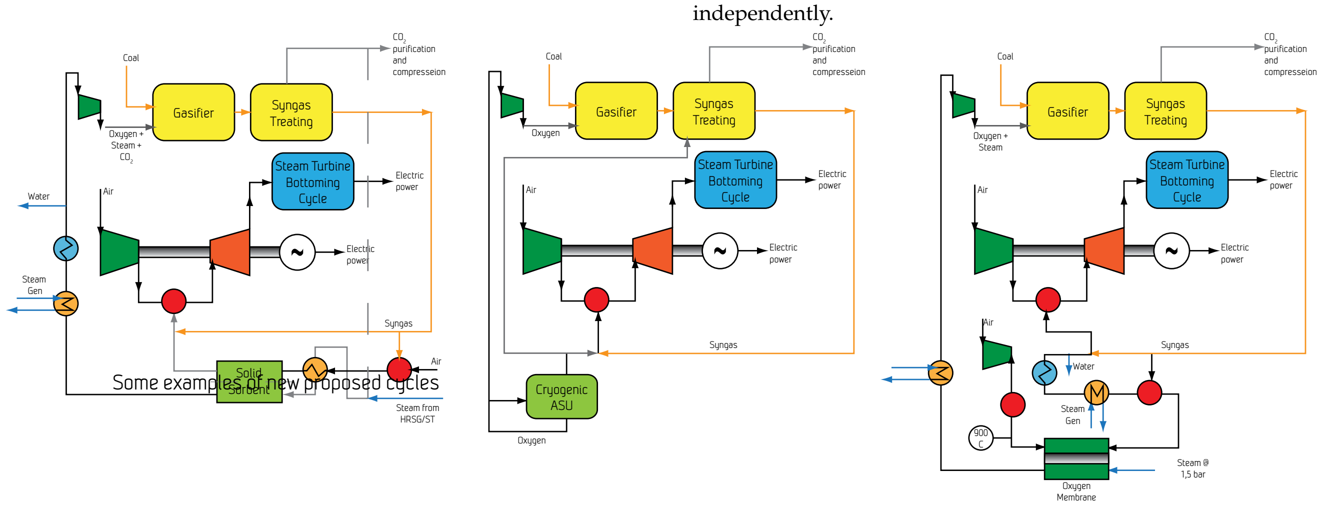
SP1 System integration and optimisation

Operational Requirements (WP1.1): Followed three steps; 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. They are described in a draft report. Other new cycles are being studied now, using novel technologies for CO_2 separation.

Techno-Economic Analysis (WP1.2):
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 (WP1.3):
The main topic was the communication between SP1 and the other SPs dedicated to CO_2 separation and oxygen production. Application of innovative technologies to other industries was not considered in the first year. Communication between SP1 and the other SPs was more difficult than initially thought. Progress has been made and a more structured procedure has now been agreed among the other three SPs. SP1 members have been participating in SP2 and SP3 meetings. Members of SP2 have also participated in a SP1 meeting. A draft 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 (WP1.4):
Was initiated in the first months - collection of parameters defined in WP1.1 and WP1.2 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. SP1 has held two meetings, in Trondheim and Amsterdam, and nine teleconferences. The integration and optimization work carried out in SP1 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.



Some examples of new proposed cycles

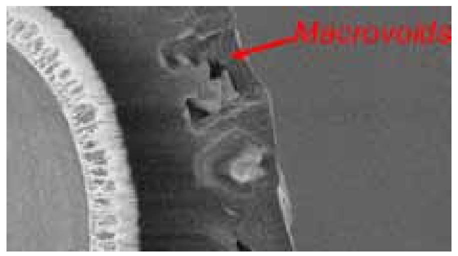
SP2 Advanced pre-combustion CO_2 separation

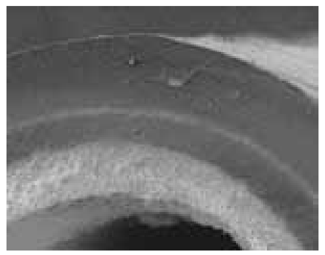
SP2 aims for a set of advanced (CO_2/H_2) separation technologies. Three routes are explored; **Selective membranes** (WP2.1), **Sorbents** (WP2.2) and **Novel solvent systems** (WP2.3). The ultimate aim is to develop CO_2 capture systems that can operate at high temperature and pressure avoiding a large temperature / pressure swing in the treatment of syngas. The expectations are that some of the above-mentioned systems will be proposed to be evaluated for pilot testing.

Selective membranes (WP2.1):
Within this WP different routes for the development of selective gas membranes are being explored. First, ceramic hollow fiber support have been synthesized, and are 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 is on carbon membranes (self supporting hollow fiber 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 fiber membranes consisting of an alumina support with polymeric layer containing nanoparticles have been prepared successfully.

CO_2 Sorbents (WP2.2):
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 (WP2.3):
This WP focusing 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.





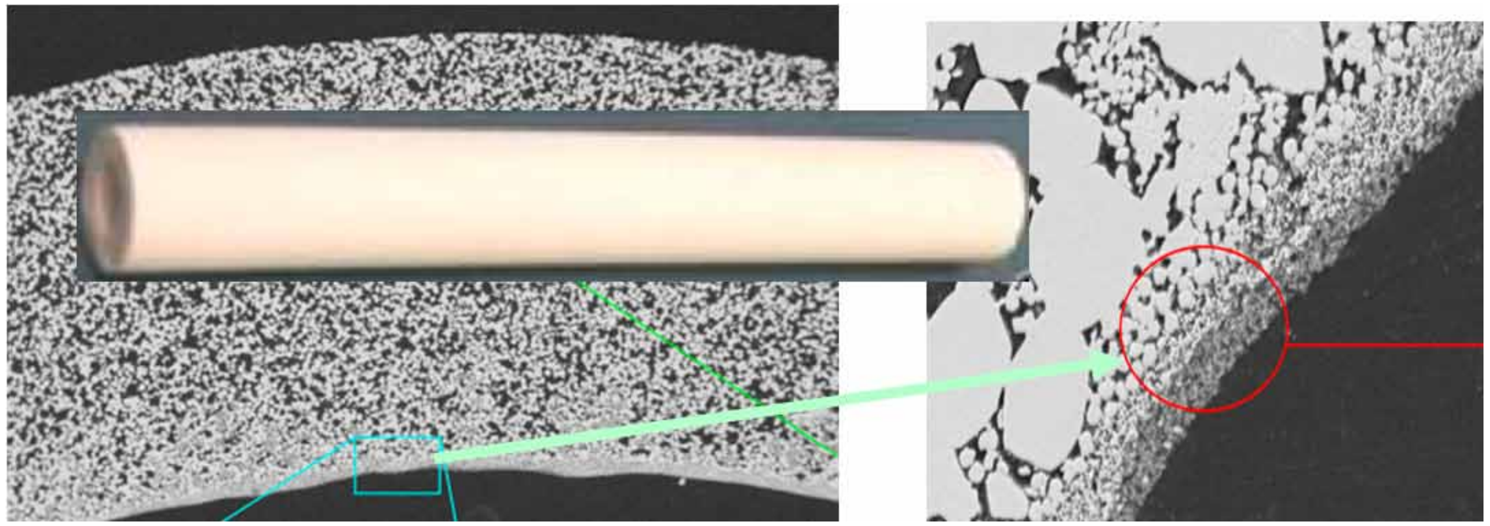
Left:
SEM image of cellulose acetate hollow fibre with macrovoid formations,

Right:
SEM images of cellulose acetate hollow fibres spun in to a water coagulation bath

SP3 Advanced oxygen separation technologies

This DECARBit SP3 subproject proposes to pursue the development of advanced oxygen separation technologies that could allow significant reduction in energy consumption for oxygen production from air. Oxygen Transport Membranes (WP3.1): Membrane operating conditions have been defined in collaboration with SP1, WP1.1. 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.

The compatibility (chemical, thermal, mechanical) of membrane material towards support material has been investigated. More work is needed for compatibility optimization, e.g. by applying different intermediate layers between bare support and dense membrane layer. 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. This work is to be started in 2009.



SEM pictures of one 100nm coated support

Sorbent based technologies (WP3.2):
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. During this first year, the effort in DECARBIT WP3.2 focused on the development of new materials that will outperform existing ones identified in the literature. 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. 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. This will be done in Y2. Until a final material is selected, 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.