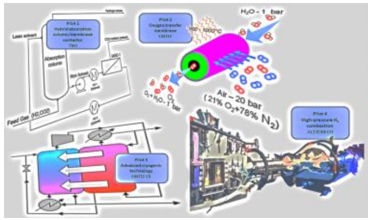
Newsletter
2012

DECARBIT progress ultimo 2012

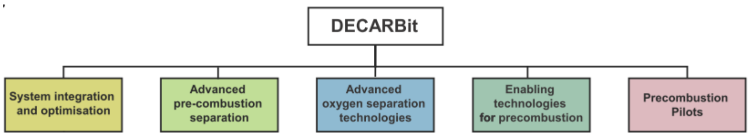
DECARBit responds to the urgent need for further research and development in advanced pre-combustion capture techniques to substantially reduce emissions of greenhouse gases from fossil fuel power plants. The project will accelerate the technology development and contribute to the deployment of large-scale 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.

Prolongation: Due to reduced availability of a suitable test slot for high pressure testing of Pilot 4 at DLR in Cologne, ALSTOM CH has requested a prolongation of the final date of their high-pressure hydrogen combustion activity organized under SP5 – Pilot 4. Based on this the EC granted a prolongation of the full project until month 54 (June 2012).

2010-2012 -> The PILOT phase



DECARBit has now reached the end of Y4 and has already achieved many of its goals. The current newsletter sum up some of the results, of which, DECARBit is proud to give publicity to.



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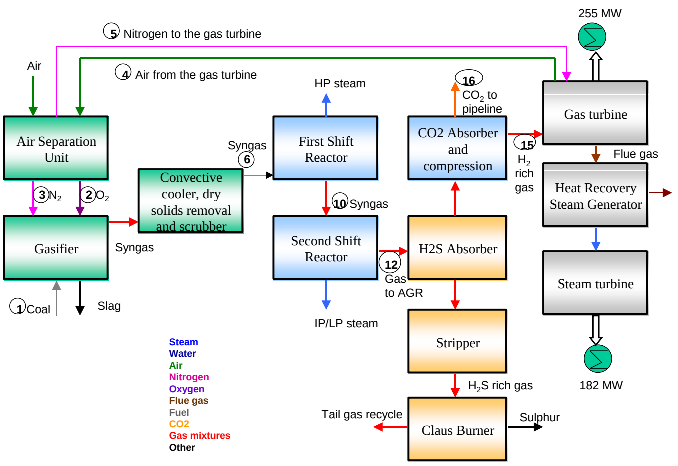
System Integration and Optimization (SP1)

In the first year of the project, boundary conditions and operational requirements were defined by WP1.1 for the research on gas separation processes in SP2 and SP3, such as

- Oxygen, hydrogen and CO_2 purity requirements
- Temperatures for membrane operation
- Fuel supply pressures and temperatures and preliminary heat and mass balances

The definition was made through the construction and analysis of a Base Case cycle, which was also the IGCC cycle provided by DECARBit to the work of the European Benchmarking Task Force. This cycle captures CO_2 with Selexol. It is shown in the figure below.



Four cycles based on the novel processes were derived from the Base Case and the heat and mass balances of these new cycles were calculated. One of them is the case with air separation using a high temperature Oxygen Transfer Membrane (OTM). The other three are the cases with CO_2 separation using the Pressure Swing Adsorption (PSA), Membrane Gas Desorption (MGD) and Low Temperature (LT) processes. In the second and third years of the project, the main activities of SP1 were related to the EBTF and to the operability studies of the cycles with CO_2 capture. A considerable number of teleconferences and face to face meetings were necessary among representatives of DECARBit, CESAR and CAESAR to elaborate the final consolidated report on Best Practice Guidelines for Assessment of CO_2 Capture Technologies. Besides the IGCC example studied by DECARBit, the report contains a super critical pulverized coal case and a natural gas combined cycle case, provided respectively by CESAR and CAESAR. Analyzing the flexibility of a plant, in terms of its ability to adapt to changes in operating conditions, is an important aspect of operability analysis. More specifically, the focus in the project was on part load analysis of the DECARBit IGCC Base Case with CO_2 capture. One of the conclusions of the study: close to the design-point (above 90% GT load) the net plant electrical efficiency showed a slight drop-off but further away from the design-point the drop-off in efficiency was steeper. The CO_2 capture rate was nearly constant for all cases. Due to the lower efficiency at part load, the specific CO_2 emissions increased at lower loads.

In the last year of the project, the main activities of SP1 were related to the cost and economic assessments of the new processes and cycles, to the risk analysis of selected cycles and to the investigation of possible applications of the new gas separation processes to other energy intensive industries, in particular cement, iron and steel, oil and gas and chemical industry. The fact that these industries show multiple sources of CO_2 was taken into consideration, resulting in a substantial and detailed report, where several aspects of each industrial process were studied. In the petro-chemical industry, multiple processes have been analyzed as potential applications of the CO_2 capture techniques: steam methane reforming for H_2 production, ammonia production, ethylene oxide production and gas-to-liquid process (Fischer-Tropsch). The following tables show possible applications in the oil and gas industry and in the chemical industry.

Area of application	CO_2 content	Pressure	Current CO_2 separation	DECARBit options
Fluid Catalytic Cracking	15-20%	1-2 bar	-	-
SGP H_2 production shifted gas	30-35%	50-60 bar	Physical solvent+ PSA	MGD, PSA, LTC
Acid gas removal in Natural gas production	Approx. 6%	70-80 bar	Amine solvent	MGD

Area of application	CO_2 content	Pressure	Current CO_2 separation	DECARBit options
Steam Methane Reforming shifted gas	20-25%	20-30 bar	PSA	PSA, MGD
Ammonia manufact.	15-20%	30-40 bar	Amine solvent	MGD

Gas to Liquids Fischer-Tropsch reactor off gas	20-30%	50-60 bar	-	MGD, PSA, LTC
EO recycle gas	2-3%	20-30 bar	Potassium carb.	-

During the last year-and-a-half, the DECARBit project focused on the establishment of four selected pilots, with the aim of providing more correct figures for the CO2 capture cost analysis for the selected and most promising DECARBit processes (PSA = Pressure Swing Adsorption, MGD = Membrane Gas Desorption, LT = Low Temperature separation, ITM = High temperature membrane air separation). The following table gives the main techno-economic results elaborated by SP1, as based on SP1-SP4 input values. The colors emphasize the comparative situation of each technology regarding each of the investigated parameters, orange fill color being the worst and light blue being the best in the group.

The main techno-economic results obtained in DECARBit

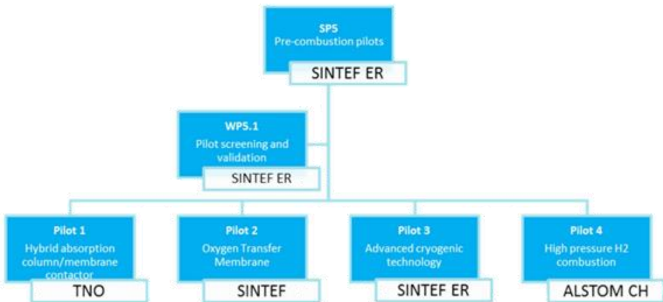
		DECARBit				EBTF	
Parameter	Unit	PSA	MGD	LT	ITM	with CCS	w/o CCS
Net electricity output	MW	370.9	379.1	396.5	365.1	352.7	391.5
Efficiency	%	36.6%	39.0%	40.2%	37.7%	36.7%	46.9%
CO_2 emitted	kg/MWh	136.6	118.8	208.9	90.1	88.9	757.6
CO_2 Captured	kg/MWh	838.0	795.7	678.5	897.0	864.5	0.0
Total plant cost	M€	1147	1187	1096	1264	1134	926
Specific investment	€/kWe net	3095	3129	2763	3463	3213	2371
Annual fuel costs	M€/yr	82.8	78.7	80.0	78.5	78.9	66.6
Fixed O&M costs	M€/yr	27.6	27.5	28.0	26.7	25.6	22.1
Variable O&M costs	M€/yr	11.1	14.7	7.9	15.8	8.57	5.8
BESP	€/MWh	85.7	85.1	77.8	90.6	86.0	64.6
Cost of CO_2 avoided	€/tonne	35.3	33.2	25.1	40.4	32.3	NA
Cost of CO_2 captured	€/tonne	25.1	25.7	19.5	29.0	23.9	NA
Capture rate	%	86.0%	87.0%	76.5%	91.0%	91.0%	NA

The main finding is that the LT technology seems to be the most economic one, able to capture at 19.5 € per ton closely follow by PSA and MGD at 25.1 € and 25.7 €, respectively. ITM achieved the highest capture costs of 29 € per ton. However, it should be noted that the capture rate for the selected cases is inversed regarding capture cost, where the most economic LT technology only has a capture rate of 76.5%. Then again the LT comes out as the best alternative in terms of efficiency, total plant cost, specific investment, net electricity output, variable operation and maintenance costs, break-even electricity selling price as well as cost of CO2 avoided. Variations in capture rate for the different cases are trade-offs and have been selected based on each systems currently known optimum operation. In comparison, the base-case developed by EBTF have a capture cost of 23.9 € per ton and a capture rate of 91%.

One reason that the low temperature technology was able to obtain quite low capture costs is that it has been optimized throughout the DECARBit project. Further optimize station of the competing alternatives might possibly lead to somewhat lower capture costs. Regarding the OTM integrated IGCC technology, it has still room for improvement, especially when it comes to improved power plant configuration, increased flux rates and novel cycles i.e. ITM integration in power generation sector. When it comes to the MGD alternative, improvements could be achieved by increasing significantly the flux rates from the constructed pilot plant. Finally, the PSA alternative needs to improve both efficiency and capture rate to become a viable alternative.

Pre-combustion pilots (SP5)

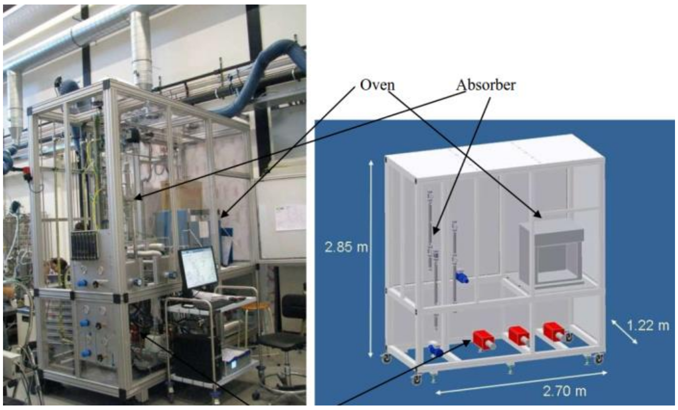
In 2010 the information requirements and evaluation criteria for the assessment of pre-combustion pilots were defined. These pilots form the essential outcome of DECARBit by testing and verification of selected technologies at a sufficient scale towards industry uptake. In the beginning of 2010 all candidates for pilot testing submitted a "Pilot test application" according to a pre-defined format. Six applications were received and discussed during the EB meeting in February 2010. Following this meeting and general comments from the Technical Exploitation and Advisory Committee (TEAC), revised applications were requested with a new deadline as of late February 2010. TEAC then performed a more detailed evaluation of the proposals, mainly focusing on their ability to take the suggested technologies to the next step towards demonstration and industrial relevance. The decision was to fund four of the pilots within SP5 and to reallocate two applications as demonstration units to their respective work packages, as these were more fundamental. The final SP5 structure is illustrated in the figure below.



Pilot 1 results

This pilot follows from the work at WP2.3 in SP2. The development of the absorption process and the membrane module is a joint effort of TNO (Delft), TIPS

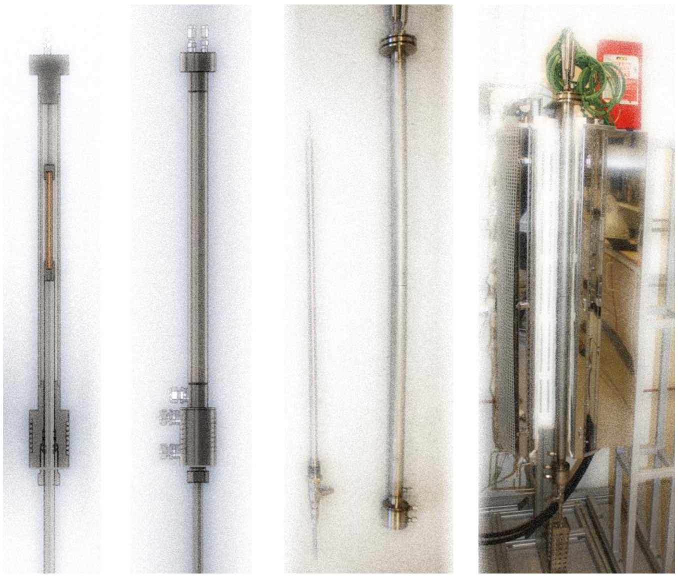
RAS (Moscow), Shell SGS (Amsterdam), TU Delft and SINTEF (Trondheim).



Overall, promising results have been obtained with Pilot 1. On the one hand, stable operation of the pilot within the required operation window could be shown. On the other hand, CO_2 fluxes could be obtained in this integrated system that agree well with data obtained in a dedicated small scale membrane unit. Fluxes up to twice that obtained earlier were measured. However, possible improvements for pilot operation have also been identified. Therefore, a revamp is planned. The main issue to resolve is related to temperature control. The heat exchange and cooling capacity will be increased as well as some other changes in the way equipment is placed to be able to increase temperature in the system without exceeding the maximum temperature the equipment is suited for. Improved control of the solvent flow towards the MGD unit to reduce the problems with membrane rupture as well as smoothening out the unit itself will be also made.

Pilot 2 results

Continued work on OTM within Pilot 2, based on WP3.1 activities, was expected to provide results of significance for evaluating the benefits of OTMs integration in power plants and other potential applications. Hence, this work will assist strengthening the European competitiveness on R&D activities for this technology. Using extrusion processes developed at SINTEF, tubular symmetric (dense) membranes and porous supports of up to 60 cm length are prepared as part of the work in DECARBit WP3.1.



The porous supports are coated using a ceramic suspension and heat treated to obtain the novel asymmetric membranes consisting of thin dense membrane layers on top of mechanically strong porous structures. By tailoring the coating procedure dense membrane layers with thickness of < 10 µm are achieved. The membrane is applied on the mechanically strong porous support by dip-coating. The method consists to dip the support in a ceramic-based suspension and to withdraw it with a constant speed. This process is thus very flexible and can be used on supports with various lengths and shapes.

Membranes with novel asymmetric architecture with tubular geometry were developed using procedures which may be up-scaled for commercial processes. The membranes were built up from mechanically strong porous supports (up to 60 cm length) with thin (~ 10 µm) dense membrane layers of the same material (CTF) on top. Membrane modules (single and multi-tube) are developed for testing of tubular membranes under realistic conditions; high temperature (up to 1000°C) and high pressures (up to 20 bars) and with various gas compositions available for both feed and permeate side of the membrane. Symmetric (dense) and asymmetric tubular membranes (CTF) have been tested at realistic temperatures and high oxygen partial pressures (pO2 up to 6.4 bar), simulating pressurized air (up to 30 bar). Long term stability of oxygen flux for >1600 hours was demonstrated. Degradation of flux in the presence of steam was observed, indicating that the current IGCC process integration must be reconsidered for this membrane material. The preliminary models for predicting oxygen flux for various operating conditions is confirmed by the experimental data and goal flux of 10 mL/cm2min) is within reach for sufficiently thin membranes (~ 10 µm). At current stage the membranes are developed in batches at lab-scale and the real cost after commercialization is difficult to predict, however, an estimated cost for membrane module of approximately 2000 €/m2 makes it interesting to study the technology further as an interesting alternative to cryogenic distillation. In general there is a strong need for further investigations of performance/stability (including creep and effect from pollutants), future cost of the membranes as well as improved integration schemes.

Pilot 3 results

Pilot 3 is a joint effort of the partners participating in WP3.3. One of the aims of this WP is to investigate the feasibility of novel distillation column concepts for air separation. A theoretical study predicts that the use of heat integrated distillation columns as part of a conventional two-column air separation unit can reduce the inefficiencies in the distillation section with 20 to 30%. The overall aim of Pilot 3 is to enable a more detailed feasibility evaluation of such a distillation column configuration. In order to do so, a concentrically heat integrated distillation set-up is constructed. The columns have diameters of 14 and 22 cm and a total height of about 3.5 m. The experimental investigations focus on obtaining more insight in the dependency of the thermal energy transfer and separation efficiency on the column geometry and on operating conditions like the column loadings and the pressure ratio. The development of radial temperature and/or composition gradients and the interdependency of thermal and molar fluxes are also assessed.

The results on heat integrated distillation columns (HIDiC) have been brought forward for Pilot testing in SP5. Parts of the SP3 results, such as construction and P&ID details, have been documented and presented in journal publications and in relevant conferences.

Pilot 4 results

Hydrogen combustion investigations in the DECARBit project started in 2008 as a further development aiming at zero CO_2 gas turbine (GT) technology. Alstom undertook the task to develop a full-scale lean premixed reheat burner, capable of burning hydrogen-rich fuel - 70/30 H_2/N_2 by volume - at conditions applicable to the sequential combustion system used in its GT24 and GT26 gas turbines. This work represents the first study in developing such a technology for a reheat system. A different burner is required to burn the H_2-rich fuel because it has a shorter ignition delay time than natural gas. Because of the shorter ignition delay time, fuel/oxidant mixing quality has to be achieved in a shorter time too. Thus, new burner concepts were investigated from the beginning of the project, through evolving burner designs, analysis, and testing. These steps included chemical kinetics calculations, computational fluid dynamics (CFD) modeling and water-rig testing throughout the period between 2008 and 2011, before high pressure (HP) combustion tests were carried out. Three high pressure test campaigns were conducted. The first achieved successful low NO_x operation on a fuel containing 47% Hydrogen by volume in natural gas. Though this had a significantly lower reactivity than the targeted 70/30 H_2/N_2 mixture, it indicated that the proposed hardware concept was appropriate for more reactive fuels. A second test campaign demonstrated that 70/30 H_2/N_2 combustion was possible at the conditions of the reheat burner. The pilot test – third campaign - was launched in May 2012, at DLR in Cologne, to demonstrate the part load as well as base load performances at real engine conditions. It covered three hydrogen levels: H_2/N_2= 50/50, 60/40 and 70/30. As predicted by the calculations, it was found that the auto-ignition delay time does not always decrease monotonically with an increasing pressure. This trend depends on the inlet temperatures. The part load NO_x level was much lower than the base load level. Contrary to the H_2/N_2 ratio of 70/30, ratios of 50/50 and 60/40 showed no sensitivity of NO_x to burner inlet velocities. No pulsation problem was observed in the pilot test, consistently with the higher stability of the hydrogen flame. However, it must be pointed out that only a single burner was tested, where the combustion dynamics can be different from that of a multi-burner system, not in the scope of the project. The pilot test proves it is feasible to burn hydrogen-rich fuels in a reheat combustor.

Further work is now required to integrate this capability into an engine.

CArbon-free Electricity by SEWGS: Advanced materials, Reactor-, and process design

Starting date	1 January 2008
Duration	48 months
Budget	3.1 million €
EU-contribution	2.3 million €
Coordinator	Energy Research Centre of The Netherlands

CESAR – Enhanced separation & recovery

Starting date	1 February 2008
Duration	48 months
Budget	6 million €
EU-contribution	4 million €
Coordinator	TNO Science and Industry

DECARBit –Enabling advanced pre-combustion capture techniques and plants

Starting date	1 January 2008
Duration	48 months
Budget	15.5 million €
EU-contribution	10.2 million €
Coordinator	SINTEF Energy Research

SIXTH FRAMEWORK PROGRAMME SEVENTH FRAMEWORK PROGRAMME

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