european cement research academy

Carbon Capture Technology
ECRA's approach towards CCS:

Communication Bulletin

29 August 2012

ECRA – European Cement Research Academy

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1 ECRA's approach towards CCS

Due to the long term growth of the global economy and the development in many markets of the world, the demand for cement and concrete construction materials will continue to increase significantly. Within this context, the technical potential to reduce the overall CO_2 emissions from cement manufacturing with today's technology is limited and certainly less than what abatement strategies currently being discussed demand. The capture of carbon dioxide and its geological storage, often referred to as "carbon capture and storage" (CCS), is seen today as an emerging technology capable of reducing CO_2 emissions significantly, however with many aspects of this technology still open.

According to different abatement scenarios and the International Energy Agency's roadmaps, the cement industry is expected to contribute to CO_2 mitigation globally by a set of different measures among which CCS is seen to play a key role. After 2020, a commercial application of CCS technologies is anticipated to be available at least in the OECD countries, but to a significant extent also in emerging countries like China and India.

It is obvious that any CCS pilot or even a demonstration plant can only be initiated on the basis of sound facts and figures on technical and economical feasibility. Against this background, ECRA, the European Cement Research Academy, has decided to examine the capture of carbon dioxide as a prerequisite for the safe geological storage of CO_2 (or for utilisation of the captured CO_2). ECRA's goal is to examine the technical and economical feasibility of this technology as a potential application in the cement industry. ECRA puts strong emphasis on the global perspective of its research and also on its sustainability aspect. This implies that not only CO_2 emissions as such, but also the huge energy demand for operating CCS plants will be taken into account.

ECRA's CCS research will focus on the capture process only. The transport and storage of CO_2 is regarded as a technology to be used by other industries also, and which as a consequence requires a much broader focus in addition to a political framework which still needs to be worked out. ECRA anticipates that governments and policymakers will join forces and strive for sound storage technologies supported by good public acceptance.

In its project, ECRA will concentrate on establishing facts by providing information on the technical and economical feasibility of CCS. As CCS is without doubt a technology which – due to its expected cost - might have a strong impact on the cement industry as such, ECRA will however also communicate the current state of the project via institutions such as CSI, CEMBUREAU or PCA in order to allow the cement industry to anticipate future developments and be in a position to discuss potential impacts with its stakeholders.

In its CCS project ECRA has established the structure for a long-term project which comprises five phases. Each phase requires the deliverables of the previous phase. The start, of every new phase is to be initiated by ECRA's Technical Advisory Board (TAB) and based upon the input from ECRA's members. The phases of ECRA's CCS project are as follows:

Phase I: Literature and scoping study (January - June 2007) - finalised
Phase II: Study on the technical and financial aspects of CCS projects, concentrating on oxyfuel and post-combustion technology (summer 2007 – summer 2009) - finalised
Phase III: Laboratory-scale / small-scale research activities (autumn 2009 – beginning of 2012) - finalised
Phase IV: Pilot-scale research activities (time-frame: 2-3 years)
Phase V: Demonstration plant (time-frame: 3-5 years)

2 Project outline

Phase I was finalised in spring 2007 and provided a first overview of CCS and the potential implications which can be foreseen for the cement industry. It includes an evaluation of the pros and cons of the potential application of carbon capture technologies in the cement industry. In the end, four options to capture CO_2 were investigated, which are currently being discussed: pre-combustion, post-combustion, oxyfuel technology and carbonate looping. Although a full and detailed technical understanding of CCS is still pending, the study concluded that all capture technologies are today far from being applicable to the cement industry due to technical and cost reasons. Nevertheless, some capture technologies seem to be more appropriate for the potential application at cement kilns than others. This applies to oxyfuel and post-combustion (chemical absorption) technologies. Consequently the ECRA Technical Advisory Board decided to continue the project and launch phase II in order to examine these technologies in more detail in a feasibility study. The report summarising the results of Phase I is available on the ECRA website (**www.ecra-online.org**).

Phase II started at the end of 2007 and was completed in summer 2009. The main objective in this phase was to perform a more detailed study for CO_2 capture at the clinker burning process which focused on oxyfuel and post-combustion measures (chemical absorption). The budget for phase II was supplied by the ECRA members and industrial project partners such as technology manufacturers and gas suppliers. The report on phase II can also be downloaded from the ECRA website (**www.ecra-online.org**).

In October 2009 after the completion of phase II the TAB decided to continue the ECRA CCS project and to undertake phase III. The main research tasks were running laboratory-scale tests with different absorbents with typical cement kiln exhaust gas mixtures, extended process modelling, the development of more detailed plant layouts, and the modification of process technology. In this project phase several work packages were assigned to external project partners like technology providers, engineering companies and research organisations / institutes. Two work packages were assigned to a Norwegian cement plant for a feasibility study and a concept study for the erection of a test site and for the carrying out of post-combustion pilot trials. The budget for phase III was provided by ECRA members, industrial partners, and cement organisations.

At the beginning of 2012, the Technical Advisory Board concluded to continue the CCS project into Phase IV with a dedicated focus on oxyfuel technology. ECRA will remain

involved in the Norwegian project on post-combustion technology as a member of the project consortium, however without contributing financially to the corresponding budget.

Regarding oxyfuel research, the ECRA CCS Steering Committee recommended to split phase IV into two sub-phases, namely IV.A und IV.B. Phase IV.A should focus on the optimisation of the hitherto existing findings for a hypothetical medium-sized plant and the preparation of technical concepts for an oxyfuel pilot plant. Within the framework of the subsequent phase IV.B, a pre-engineering study on the retrofit of a full-scale existing plant with oxyfuel technology should be carried out. The final decision on whether to carry out phase IV.B will be taken after completion of phase IV.A.

The following project phases are still to be decided upon. They could involve small-scale trials with an oxyfuel pilot plant to gain real-case experience. These pilot tests should demonstrate the reliability and effectiveness of the capture processes. Phase V is even more subject to the final decisions of the ECRA members, funding opportunities, and the political and technical framework for CO_2 storage.

3 Research objectives for Phase IV

3.1 Work packages phase IV

As in phase III, several work packages have been defined which comprise different research tasks. After a tendering procedure, the work packages will be assigned to different project partners. The scope of the individual work packages is specified below.

WP A1: Simulation study

This work package includes a supplementary simulation study on the basis of the results obtained from phase III. The findings on e.g. air intrusion, flame formation and cooler design will be implemented into the overall process model. Furthermore, simulation studies will be carried out for different plant sizes, for kilns with bypass system, and for different fuel scenarios, including alternative fuels. In addition, the impacts of process fluctuations on plant operation, energy demand and flue gas composition will also be considered.

WP A2: CFD modelling

As the gas properties during oxyfuel operation are significantly different from those in conventional operation, gas streams perform differently in the kiln. Regarding the overall design of the plant, this issue has already been taken into account in the current process modeling. However, up to now it has not been possible to implement a detailed illustration of the gas flows into the current model and the accuracy of the existing simulation cannot be completely verified.

Therefore, the objective of this work package is to establish a reference case and to simulate specific oxyfuel-related issues based on the findings from other work packages. Due to the complexity of creating a CFD model of a complete kiln plant, this work package has to be sub-divided into individual models for specific plant components, in particular for the calciner.

The results from the CFD modeling are seen as a necessary prerequisite for the layout of a full-scale retrofitted oxyfuel kiln. Work package A2 will therefore only be assigned in phase IV.B in the context of the pre-engineering study.

WP A3: Advanced cooler design

Within the framework of phase III a new cooler concept was developed for an oxyfuel cement kiln. The most promising approach seemed to be a concept using two heat shields which would facilitate an operation of the clinker cooler with different gas atmospheres. However, it is not clear to what extent the mechanical parts in the new cooler type would be affected by high thermal stress. Therefore it is essential to further refine the new cooler concept, avoiding dynamic parts for the gas separation and ensuring acceptable gas-tightness. Furthermore, the work package should deliver an energy balance of the optimised cooler and an evaluation of all relevant safety aspects.

WP A4: Future air separation systems

Power-intensive air separation is one of the main factors which have a strong impact on operating costs. Up to now, cryogenic air separation is the most suitable system and the only one fulfilling the requirements with respect to the capacity and purity of an oxyfuel cement plant. However, current developments show that other emerging technologies for oxy-combustion might be more efficient. One example are O_2-transport membranes, which could be used for the oxygen enrichment of the flue gas, which is provided to the cooler. As the efficiency strongly depends on how the membranes are integrated into the process, options for implementation should be examined.

The objective of this work package is to analyse the current state-of-the-art technology with regard to O_2-separation and its potential integration into the kiln plant - taking into account suitability, availability, efficiency, and costs. The use of “waste nitrogen” from the air separation will also be analysed and potential synergies between the air separation unit (ASU) and the CO_2 processing unit (CPU) examined.

WP A5: Experimental verification of sealing potential

An important finding of phase III was that an improved maintenance of the major points of false air ingress, namely inspection doors, flaps etc., is sufficient to keep the reference of 6% false air in the flue gas. Under these conditions the CO_2 purification could be operated satisfactorily. The experimental testing of the sealing potential by optimised maintenance at an existing plant is essential for further development, especially regarding the concept of a pilot kiln. The scope of this work package covers the preparation and set-up of maintenance measures, O_2 measurements in the raw gas, and an evaluation of the experimental data resulting in an oxygen balance of the plant.

WP B: concept of a pilot kiln

If at any time a CCS plant is to be built in the cement industry, a demonstration plant can only be built based on the experience from a pilot plant. How such a pilot plant has to be dimensioned and where and how it could best be built and operated has to be examined in this work package. Furthermore, a time schedule for the preparation and carrying out of the pilot trials has to be prepared. The study will also include cost calculations (investment and

operating costs) and a concept for the re-use or re-selling of the pilot plant after the operating period.

Based on the outcome of this work package the objectives of phase IV.B (concerning WP C, WP A2) can be defined in more detail.

WP C: Pre-engineering study

A pre-engineering study on the application of oxyfuel technology to an existing plant is necessary for a full technical and economic analysis. Such a study will implement the findings of all work packages from previous phases, including phase IV.A and, as a result, deliver a full concept of how an existing cement kiln can be adapted to oxyfuel operation.

It will provide the first cost figures for a retrofitted plant, whereas so far all cost figures have been derived for new plants only. In this sense this work package is seen as essential since it will for the first time produce cost figures for a plant retrofit. Finally, a concept for the usage of the captured CO_2 (onshore / offshore storage, EOR, etc.) has to be included.

Besides a detailed plant layout, necessary measures for the re-dimensioning of the kiln will be given. Practical questions which were not answered in phase III will be answered, such as kiln operation under switching mode conditions as well as optimised maintenance instructions for minimum air-intake. Most importantly, cost figures will be developed giving the first estimates for a plant retrofitted to oxyfuel conditions.

WP D: General topics

WP D1 - CO_2 overall balance

As a basis for the evaluation of CO_2 abatement costs, the identification of the overall capture rate is essential. Although oxyfuel technology envisages the full capture of CO_2 emissions, leakages of CO_2 to the environment occur in different forms and intensity. Therefore, this work package will reveal the impact of flue gas leakages on the capture rate as a basis for an economic analysis.

WP D2 - Economic sensitivity analysis

The identification of costs and an analysis including economic and legal impacts is the key factor in many respects. Although cost figures are available for CCS technology in the cement industry, so far no cost estimates could be given for an existing plant to be retrofitted for oxyfuel operation.

Therefore, the objective of this work package is to carry out an economic sensitivity analysis based especially on the deliverables from work packages B and C, namely the elaborated cost estimation (capital and operational costs) for the industrial application. A first comparison will be made with abatement costs in other sectors (industry and power generation) making use of existing CO_2 abatement cost curves. A recommendation will be given if a broader cross-sector study should be conducted.

3.2 Project coordination

The project coordination is carried out by ECRA. It comprises

- preparing the tendering process for the various work packages
- organisation of meetings of the Steering Committee
- cooperation with external project partners and coordination of their activities
- budget follow-up and reporting
- issuing of progress reports
- issuing of the final report on phase IV

3.3 Proposed schedule

Work items	Phase IV.A																					Phase IV.B																								
	2012												2013												2014												2015						Mon
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Work package A: Further optimization/ detailing of the 3,000 t/d plant																																											
A1: Simulation study																																											15
A2: CFD modelling																																											10
A3: Advanced cooler design																																											12
A4: Future air separation systems																																											6
A5: Experimental verfication of sealing potential																																											6
Work package B: Concept study for pilot plant																																											15
Work package C: Pre-engineering study																																											18
Work package D: General topics																																											
D1: CO_2 overall balance																																											6
D2: Economic sensitivity analysis																																											4
Work package E: Project coordination																																											33

4 Project management

The research project is managed by ECRA. A Steering Committee will be responsible for conducting the project in detail. Consequently ECRA is also in charge of the financial administration of the project.

The Steering Committee will be comprised of representatives from ECRA member companies and the relevant equipment manufacturers who are involved in the ECRA project. In addition every partner has the right to nominate a representative for the Steering Committee.

The Steering Committee will set up a work plan to conduct phase IV.A. This will include the installation of working groups if necessary or the nomination of experts to conduct certain sub-tasks. The Steering Committee also has the task of guiding the research project and making a proposal for its further proceedings to the ECRA Technical Advisory Board. Progress reports will be issued every 3 months and a final report at the end of phase IV.A (at the end of 2014).

5 ECRA – the European Cement Research Academy

The European Cement Research Academy (ECRA) was founded in 2003 as a platform on which the European cement industry supports, organises and undertakes research activities within the context of the production of cement and its application in concrete.

By creating and disseminating knowledge from research findings, ECRA's mission is to advance innovation in the cement industry within the context of sustainable development and to communicate the latest knowledge and research findings in cement and concrete technology.

The Academy is steered by a Technical Advisory Board staffed with representatives from major European cement producers under the chairmanship of Daniel Gauthier of HeidelbergCement. The Board is responsible for defining the focus and scope of ECRA’s seminar programmes and research projects and monitors the Academy's finances.

ECRA’s activities are pre-competitive and comprise seminars, workshops and dedicated research projects. Its seminars and workshops cover the issues of major importance to the cement industry today and provide a platform for teaching the latest knowledge on cement and concrete technology and for communicating and discussing the latest research findings. Its research projects focus on issues which due to their more general importance for the industry as a whole might not be tackled by single companies themselves.

With a membership of almost 50 leading cement producers and equipment suppliers worldwide, ECRA understands itself as part of a network which comprises various research facilities such as universities, federal institutes and the research centres of cement companies or equipment suppliers. In this context it is able to develop a knowledge centre which benefits from cooperation with the best institutes in the respective areas of research, acting as a core competence centre for top researchers in each field.