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ECCO – European value chain for CO₂

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Abstract

This paper presents strategy and structure of “ECCO – European Value Chain for CO₂” project. ECCO is a new collaborating project under the 7th framework programme for research of the EU. It was initiated in 2008, with the main objective to facilitate robust strategic decision making regarding early and future implementation of CO₂ value chains in the face of uncertainty. SINTEF Energy Research is coordinator of the project, which has a total budget of 5.35 M€ over three years. This is the first project funded by EU having a relevance to oil and gas production through the focus on enhanced oil and gas recovery with CO₂ injection (EOR/EGR).

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1. Introduction

Despite the strong focus towards carbon capture and storage (CCS), and the number of assessments and studies that have been published in the recent years, the evaluation of complete CO₂ value chains has not been extensively studied, and lacks a common basis and terminology.

Originally, feasibility studies on EOR potential were triggered by the drive for increased oil recovery from ageing oil fields. Some assessments have been made on the profitability of specific EOR projects in the North Sea, mainly by oil producers or governmental agencies, without paying much attention to the advantages offered by creating a robust CO₂ value chain. Most of them are proprietary works and are not publicly available.

In the recent years however, the concept of CCS has received increasing attention, being regarded as a possible option for mitigating global climate change. Simultaneously, the implementation of the emissions trading scheme (ETS) has posed as an incentive for developing and deploying CO₂ value chains. As a consequence, a limited number of studies that address the complete CO₂ value chain have been published during the last 3 years.

EU has conducted a large number of R&D projects focusing primarily on CO₂ capture and storage. To be able to meet the recommendations set out by EU regarding CO₂ reductions and deployment of large-scale zero-emission fossil fuel power plants, the whole CO₂ value chain needs to be in place. Operators involved along the CO₂ chain are

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the CO2 generators, the CO2 capture operators, the CO2 transporters, and the CO2 storage operators. Focusing on the technologies along the CO2 chain separately is essential for success.

In order to meet the challenges related to CCS a new project was proposed – ECCO. ECCO is a collaborating project under the 7th framework programme for research of the EU. It was initiated in 2008, with the main objective to facilitate robust strategic decision making regarding early and future implementation of CO2 value chains in the face of uncertainty. SINTEF Energy Research is coordinator of the project, which has a total budget of 5.35 M€ over three years. This is the first project funded by EU having a relevance to oil and gas production through the focus on enhanced oil and gas recovery with CO2 injection (EOR/EGR).

ECCO will evaluate the whole CO2 chain and identify the most promising alternatives for the authorities and the industry operating along the CO2 chain. ECCO will produce added and urgently required knowledge related to deployment of the CO2 infrastructure, the effect and applicability of new EC laws under development, cross border regulations, emission trading schemes, financing schemes and regime of incentives, and organization of the supply chain. ECCO is thus paving the road for commercial deployment of CCS and the development of sound regulations and economical incentives.

2. The ECCO project

The scientific and technological objectives for ECCO are:

- Provide the basis for, and the recommendations leading to implementation of the most promising EOR and EGR alternatives, with the basis in the developed methodology - scenario development and case studies - for the future in Europe (2020).
- Prepare for analyses and recommendations through the development of a CO2 value chain analysis tool. This will be a mathematical tool that will include models related to global, economical and technical issues. This also includes reservoir related issues such as CO2 injection, processing of CO2 in the produced oil and the possible integration of aquifers for intermediate CO2 storage in a large scale CO2 infrastructure.
- Assess specific cases (as defined in the first phase of ECCO) with the analysis tool, which then also will include the influence from regulatory issues. The results from the scenario studies will be used to set the frames for the future value chains and the models developed in the project will be used with input from project partners being operators or power producers in separate regions of Europe.
- Quantify the potential for enhanced hydrocarbon recovery (EOR/EGR) and CO2 storage in European petroleum reservoirs and evaluate technological challenge, both onshore and offshore.

The methodology of ECCO comprises:

- Envisaging CCS in Europe by 2020 by development of a set of carefully designed scenarios describing European power generation with carbon capture, EOR/EGR, and CO2 storage.
- Formulation of CCS case studies, analyses, and identification of the most promising CO2 value chains across Europe.
- Development of a tool for economic analysis of CO2 chains. The tool architecture will allow flexibility, i.e. linking multiple CO2 sources and sinks, dynamics in the chain and market behavior.
ECCO will provide the opportunity to define and analyse relevant CCS cases through the development of a robust methodology, with emphasis on securing a transparent and consistent implementation of CO2 value chains. Further, ECCO will provide the required means for analyses through development of a flexible CO2 value-chain tool with capability of linking multiple CO2 sources and sinks, as well as handling dynamics in the chain and market behavior. Sources for CO2 will be fossil fuel power generation plants, as well as other large point sources such as steel, cement or ammonia production plants. Figure 1 gives an overview of the sub-project (SP) structure and the information flow between the work-packages in ECCO.

![ECCO Work structure](image)

Figure 1: ECCO Work structure

To overcome the drawbacks and fill the gaps from the existing knowledge, ECCO will follow a holistic approach to the development and deployment of value chains in Europe addressing technical, economical, financial and organisational issues. More specifically, the project will develop generic but robust methodologies and procedures that can be used for the appraisal of value chains, make recommendations for the development and deployment of specific value chains across Europe, estimate capital costs needed for the development of the required infrastructure and based on them propose an investment plan and review the upcoming regulatory framework and suggest further improvement. More specifically ECCO will assess:

- The technical and economic consequences of operating several CO2 chains simultaneously and as part of the same infrastructure.
- The technical and economic aspects of a European infrastructure that evolves with time.
- Alternatives for cost-effective stepwise building of infrastructure.
- The impact of a large CO2 infrastructure in terms of energy savings, cost reductions, and operability.
- How much of the costs of CCS are due to uncertainties and how much to investments.
- How the regulatory work and policy development being done by EU during 2007 can be “put into practice” and recommend how it can be applied to facilitate CCS early opportunities.

Three main instruments will be used to do this:
- Scenario development
- Formulation of case studies
- Quantification of cases with the tool

3. Value chain assessment through scenario development and case studies
- **Scenarios influence on CCS in 2020**: The scenario building will secure a common understanding of -and ownership to possible CCS alternatives in the future since ECCO partners are invited to contribute to the work. It will bring the project beyond state-of-the-art along two routes:

1. Strategies for developing knowledge and methodology that is required to facilitate decision making regarding EOR/EGR via CO₂ injection. The results will serve as a basis for the long term and short term priorities within ECCO. Also addressed is how case studies can contribute to meet the challenges implicated by the scenarios in a robust manner.
2. A set of principal challenges regarding development and deployment of CCS including EOR/EGR will be pointed out.

In this part of ECCO, all aspects affecting realization of CCS value chains will be addressed, identifying which issues that can be addressed within the project, and in which part of the project. There will certainly be some restrictions with respect to how much can be covered within ECCO – but all aspects will be reported, also including those that should be evaluated outside of the projects.

- **Formulation of CCS case studies**: The method for formulating the cases is robust since questions to be addressed by case studies will based on boundary conditions coming from the defined scenarios.

1. The questions raised by the scenarios will cover not only practical areas including physical connections, volume and temporal compatibility or development, but will also extend to issues such as economic viability, financial incentives, commercial arrangements and regulatory options.
2. Assembly of plausible CO₂ chains for case studies, assembly of chain elements data, and classification by relevant characteristics and grouping to provide sensible clusters and routes. This should include an appreciation of expected timings and required flow rates. Off-shore and on-shore cases will be produced.
3. Develop initial recommendations for case studies building on the questions formulated; a set of proposed case studies will be developed together with appropriate variants. Cases will be chosen to cover relevant issues both around the North Sea and onshore in Eastern/Central Europe.
4. Results will be reviewed to assess the case’s relevance to the formulated questions and a gap analysis will be carried out to highlight any missing elements. Further cases will be developed to address any important omissions or further issues.

### 4. CO₂ value chain assessment tool

The CO₂ value chain assessment tool will be developed in a joint effort between the stakeholders in ECCO, thus pursuing to benefit from requirements identified by the partners. The architecture will consist of a core model linked to sub-models, hence allowing for development of sub-models among the project partners. Following this strategy, the CO₂ value chain assessment tool has the potential for representing simulation technology well beyond state-of-the-art of existing comparable tools.

Input from the scenario study and the case definition will define the general, functional specifications. Inventory of possible high-level functional specifications will be made based on existing value chain knowledge and tools and on possible cases to be studied. During this inventory, existing tools from earlier EU projects will be assessed for their applicability to ECCO. Examples are: GESTCO, GeoCapacity, CASTOR, and CO2ReMoVe. These projects involved several ECCO partners, guaranteeing efficient re-use of concepts and methodologies developed.

**Features**

Based on experiences gained in earlier EU projects and similar activities, a preliminary selection of tool specifications will be agreed upon through the first workshops in ECCO (including scenario definitions). The CO₂ value chain will be defined in a way that allows flexible, demand-driven tailoring to the applicable market dynamics. For CO₂-EOR, however, functionality is required that has not yet been developed in earlier EU projects, in particular:

- The possibility to model infrastructural, regional dependencies between assets that are gradually and increasingly networked
- The multi-scenario modelling of incremental oil recovery as a result of CO₂ injection
- Dynamic network models of the CO₂ market
The ability to test regulatory regime scenarios to understand and overcome market imperfections
- The re-organisation of existing equity shares
- Optimisation of possible decision paths

Main architecture
To model the CO₂ value chain in a transparent and maintainable way, modern software engineering techniques will be applied. The main architecture of the tool will comprise three main elements being developed in parallel:
- A “core-tool” or “kernel” that will link the modules for the chain elements source/capture/transport/storage and the global modules and that will perform the economic calculations
- Component modules containing the calculation routines for the pertinent technical processes, and a database of existing component types
- Global modules, containing the database of economic parameters and models reflecting the plausible market scenarios.

The infrastructure including its anticipated evolution in time, and possible scenarios for linking the sinks and sources will be set and implemented by the user (how the particular chain is designed and how the modules are specified).

The tool should be a flexible object oriented tool designed for the following
- Chain network design from basic modules connecting sources and sinks and matching in capacity and time)
- Techno-economical modelling of each module calculating CAPEX/OPEX/revenues for each component based on characteristic parameters – proxy “Time-2-Business” models
- Reflecting the market/macro-economic effects specifying the external parameters – their time profiles (oil, gas, el, steel prices)
- Performing financial analysis evaluating the key indicators: NPV, cash flows, balancing revenues vs. costs
- Performing: optimization, sensitivity, risk, uncertainty analysis, implementing decision making procedure

5. Reservoir technology for EOR/EGR

CO₂ injection of water flooded reservoirs has proven to be an efficient technique for EOR through numerous injection projects, most of them in the North America. CO₂ based EOR has also been performed in a limited number
of fields in Eastern and Central Europe. Due to CO₂ properties as an effective injection fluid it has a positive economic value in areas where it can be used in petroleum production, even tough pipeline transportation often over hundreds of kilometers often is necessary. In Europe, the largest oil provinces are located offshore, and the characteristic reservoir properties are often different from the onshore reservoirs, especially for the large fractured fields in the North Sea. However, besides the special issues related to EOR in the chalk fields, the main difference between onshore and offshore operations will most likely be related to the larger well spacing used in offshore fields and the restricted topside space for the additional process equipment that is needed to conduct a CO₂ injection process. This will affect the EOR potential and may impose severe limitation for the practical implementation of CO₂ injection projects into offshore petroleum reservoirs. The value of CO₂ will be affected by these factors.

The North Sea oil reservoirs represent large sinks for CO₂ that can be utilized early in a CO₂ deposition era. However, since most of the reservoirs are in the decline phase, the time before EOR measures must be taken is limited and most of the potential reservoirs will need CO₂ in the same time-period. This, combined with the fact that the net amount of CO₂ needed for a specific reservoir will rapidly decline due to break through of injected CO₂ which results in a total storage profile that also decreases with time. CO₂ from power plants and other industries will be produced at a constant rate over long periods. This potential mismatch between sources and sinks can only be balanced by including aquifers into the CO₂ deposition chain.

SP4 will address the most important issues related to CO₂ injection into European oil and gas reservoirs which will include:

- Estimation of EOR and EGR potentials for characteristic reservoir types in Europe including uncertainty analyses
- Different options for handling of break through CO₂
- Effect of recirculation of CO₂/hydrocarbon gas mixtures on the oil recovery potential
- Schemes for use of existing process equipment and wells and need for modifications and their costs
- Integration of aquifers into a CO₂ deposition chain
- Use of CO₂ deposited in aquifers as swing CO₂ supply for the oil and gas recovery processes and their costs

Most issues above will be studied under the constraints of offshore operations which will produce crucial knowledge that presently is scarce. The knowledge gained through this work will also be useful for evaluation of possible onshore based deposition systems in Europe. The valuable experience gained in the already performed and ongoing CO₂ injection projects in Central and East Europe will be fully utilized in the work.

The final outcome of the work will be predictions of EOR and EGR profiles and potentials for CO₂ injection into European oil and gas reservoirs, the corresponding CO₂ storage potential and profiles and cost data both related to CO₂ EOR/EGR and aquifer storage. This new knowledge will be utilized in the modelling of the complete value chain from capture to storage and will demonstrate to what extent CO₂ based EOR/EGR can reduce the cost of CCS early in a deposition era.

6. Strategies for implementation of CO₂ value chains

The strategy work described will in addition to special reports, be summarized in the document; “ECCO Strategies for CO₂ value chain deployment” comprising ECCO’s joint strategies and recommendations regarding deployment of the CO₂ infrastructure, liability issues, cross border regulations, emission trading schemes, financing schemes and regime of incentives, and organization of the supply chain will be given. Based on the total ECCO effort, including the CO₂ value chain tool, the methodology developed, and the joint effort in developing robust strategies, the report will have the potential to become the document referred to when industry, national authorities, and the European Union act towards deployment of CO₂ value chains.

Developing the strategy

- Development of a strategy for the deployment of the CO₂ infrastructure. Building on the expert assessment of the results from the case studies, strategies for deploying the necessary CO₂ infrastructure in the short/medium
term in Europe will be developed, that will take into consideration critical technical and economic issues that may hinder the deployment of CO₂ value chains.

- Recommendations for improving the regulatory framework and for optimizing the organization of the value chains. The new regulatory framework being developed by EC will be addressed in the scenario study and the case study. The impact of the new regime will be analysed in the case study and recommendations for improvements of the regulatory framework that is necessary to facilitate the establishment of CO₂ value chains in the near term will be given. The recommendations will address liability issues, cross border regulations and emission trading schemes (like EU ETS, CDM and JI). Furthermore, it will make recommendations for an overall organization of the supply chain, in terms of access rights, trans-boundary transport and storage of CO₂ and rules for utilization/capacity allocation.

- Recommendations for the facilitation, promotion and financing of the development of the infrastructure. Based on the outcome of the project work and the extrapolation of the results of the case studies, recommendations will be provided on how best to promote and finance the development of the infrastructure to take advantage of the window of opportunity offered by the exploitation of near term EOR opportunities, taking into consideration commercial risks and economic uncertainties. It will explore the opportunities of funding schemes offered by private-public-partnerships, propose a business model for the CO₂ value chains, and make recommendations on a favorable evolution of the carbon market in Europe to provide long term confidence to investors interested in exploiting CO₂ value chains.

- Assessment of the impact of the development of CO₂ value chains on the goals of the European energy and environmental policies. Assessment of the impact of developing and deploying CO₂ value chains in Europe in the short and medium term on the goals of the European energy and environmental policies. More specifically, assess the medium and long term impact of their deployment on
  1. The reduction of CO₂ emissions
  2. The maintenance of the security of energy supply
  3. The enhancement of the competitiveness of the European economy