THE EU TECHNOLOGY PLATFORM FOR
ZERO EMISSION FOSSIL FUEL POWER PLANTS

RECOMMENDATIONS FOR RTD, SUPPORT ACTIONS AND INTERNATIONAL COLLABORATION ACTIVITIESWITHIN FP7 ENERGY WORK PROGRAMMES AND NATIONAL RTD PROGRAMMES

IN SUPPORT OF DEPLOYMENT OF CCS IN EUROPE

ZEP TASK FORCE ON TECHNOLOGY

18TH APRIL 2008

Recommendations for RTD, Support Actions and International Collaboration activities within FP7 Energy Work Programmes and National RTD Programmes, in support of deployment of CCS in Europe

The scope of this note is to formulate specific topics for RTD, Support Actions and International Collaboration, **for all Areas covering CCS in FP7 Energy Work Programmes and National RTD Programmes.** This input is based on the ZEP Technology Task Force expert recommendations, using the ZEP SRA (Strategic Research Agenda, year 2006) and the underlying WG1 and WG2 reports as a starting point. The proposed RTD topics reflect the need for parallel RD&D routes to support the RD&D Key Recommendations in the SRA, covering power plant and CO_2 capture technologies as well as CO_2 use and storage.

Topics that the Technology Task Force considers **prioritised and which should be addressed immediately by EC FP 7** (and possibly also National Programmes, but links to those remain to be established), are highlighted in grey shadow in this note, and are summarised below:

R&D to enable urgently 10-12 integrated, large-scale demonstration projects across Europe

- For CO_2 capture, develop and validate:
  - Improved solvents and system integration for post-combustion capture
  - H_2 gas turbine combined cycles with high efficiency and low emissions, competitive availability and load-following characteristics for pre-combustion capture
  - Firm basis for design of oxy-fuel boilers, and processes for separation, compression and conditioning of CO_2 adapted for oxy-fuel combustion.
  - o Generic steam power plant efficiency improvements, gas turbines with improved efficiencies for various CCS processes.
- For transport, use and geologic storage of CO_2, ensure safe operation and clarify quality requirements on the CO_2 stream:
  - Develop a common science-based protocol for safe operation of saline aquifers, improve knowledge on natural CO_2 leakage mechanisms, and further develop methods to assess and improve well-bore integrity.
  - Investigate impacts of small quantities of components other than CO_2
  - Adapt and develop safety assessments and standards for large-scale CO_2 transport in densely populated areas and cities.

R&D in support of new concepts already identified, but not validated, for implementation beyond 2020

- For CO_2 capture, accelerate the development of:
  - Chemical Looping Combustion (CLC) for gaseous fuels, coal and heavy fuel oils
  - Post-combustion Carbonate Looping Cycles
- For storage of CO_2, increase confidence and to prove that sufficient storage capacity exists by:
  - Develop and validate long-term modelling of storage in deep saline aquifers
  - Comprehensive assessment of Europe's storage capacity in deep saline aquifers.

Support long-term exploratory R&D into advanced, innovative concepts for implementation of next-generation technology

- For CO_2 capture, perform initial validations of novel and breakthrough concepts that could be developed in the period up to 2050

In addition, this note identifies the RTD topics that the Task Force considers prioritised, but not necessarily to be addressed immediately.

Support actions and international collaboration

The Taskforce has identified the following topics as important:

- Improve awareness and increase knowledge in Europe of CCS as a climate change mitigation option, by information and communication activities
- International collaboration activities to establish and maintain CCS collaborations between EU and emerging economies with a view to the role of CCS in a post-Kyoto era, and to better co-ordinate the EC and the European countries in global CCS activities

Table of Contents:

1. Introduction

During 2006, the Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP), outlined technology RD&D needed to implement CCS on a massive scale in Europe, and this was documented in an SRA (Strategic Research Agenda) based on expert recommendations provided by five Working Groups (WG1 – WG5)

The Key Recommendations that were formulated in the SRA (year 2006) were:

1. ***Urgently implementing 10-12 integrated, large-scale CCS demonstration projects Europe-wide. These projects shall combine CO_2 capture technologies with transportation and storage technologies***
   - Improve the cost-effectiveness and availability of current CO_2 capture technologies; optimise energy conversion efficiency when integrated into a power plant; and bring to commercial readiness by 2020
   - Assess the full potential for CO_2 geological storage, demonstrate its safety to the public and understand/respond to their concerns
   - Resolve all technological uncertainties and establish a critical mass of data for exploitation in parallel R&D projects
2. ***Developing new concepts already identified, but not validated, for demonstration by 2010-2015 and implementation beyond 2020, e.g.***
   - Advanced new materials and combustion systems
   - Storage in onshore, deep saline aquifers and CO_2 for Enhanced Oil Recovery in the North Sea
3. ***Supporting long-term exploratory R&D into advanced, innovative concepts for implementation of next-generation technology, e.g.***
   - Innovative CO_2 capture technologies (membranes, adsorption etc.)
   - Innovative concepts for CO_2 storage
   - Simple, reliable tools for long-term modelling and monitoring of CO_2 storage
4. ***Maximising cooperation at national, European and international level***
   - Mobilize national and European funding and explore new options for launching large integrated projects, such as Joint Technology Initiatives
   - Further promote international cooperation, especially with emerging countries such as China and India.
5. ***Strengthening and accelerating R&D priorities to support the Strategic Deployment Document, informed by experience from demonstration projects and parallel R&D projects on advanced, innovative concepts.***

To fulfil these recommendations, the ongoing CCS projects within FP6 need to be built upon and followed by several years of a wide range of RD&D activities. The SRA describes a collaborative programme of technology development for reducing the costs and risks of deployment.

Since the SRA was elaborated, the ongoing CCS projects within FP6 as well as other worldwide projects have generated more knowledge, and in the FP7 Energy Work Programme 2007 some continued RD&D actions are requested.

In addition to the ongoing FP6 projects and the RD&D actions addressed in the Energy Work Programme 2007, a range of RD&D actions on CO_2 capture technologies as well as geologic storage need to be given priority during the next few years.

The scope of this note is to formulate **specific topics for RTD, Support Actions and International Collaboration for all Areas covering CCS within FP7 Energy Work Programmes and National RTD Programmes**, based on Technology Task Force expert recommendations, using the ZEP SRA (year 2006) and the underlying WG1 and WG2 reports as a starting point.

This note reflects the current view of the Technology Task Force expert group. Since CCS during the latest years has expanded into a broad and very dynamic area, with several new findings, projects and ideas arising continuously, updates are anticipated on a regular basis.

The RTD recommendations reflect the need for parallel RD&D routes to support the Key Recommendations nr 1 – 3 above,

It is the view of the Task Force that both CO_2 Capture and CO_2 Storage need similar levels of RTD support. The economy of the integrated chain is heavily dependent of the cost for capture, which stands for more than 75% of the total cost. On the other hand, it is an absolute need that there is storage available, legally permissible and publicly accepted. This means that the storage technology must be verified and proven, with respect to capacity, safety and long-term performance. Thus both areas need public support, otherwise there will be no CCS.

The Task Force have prioritised the topics into two categories:

1. Topics that the Task Force consider **prioritised and should be addressed immediately by EC FP 7** (and possibly also National Programmes, but links to those remain to be established) **are highlighted in grey shadow**
2. Topics that are **prioritised, but not necessarily addressed immediately are described in plain text without any shadowing**.

Within each Chapter and Key Recommendation, the R&D areas are ranked according to the agreed priority order, with the topic of highest priority being listed first.

The number of grey shaded R&D areas within a chapter does not necessarily reflect the amount of financial support needed.

It may also be the case that **one/a few high priority topic(s) has been and/or will become fully covered by project(s) approved in the first and second FP7 calls.**

The note has the following structure, with one lead author appointed for each chapter:

- CO_2 Capture
  - Post-combustion capture: Hallvard F. Svendsen, NTNU
  - Pre-combustion capture: Hans Jensen, RWE Power
  - Oxy-fuel combustion: Clas Ekström, Vattenfall Research and Development
  - Emerging and new technologies: John Chamberlain, Unión Fenosa
  - Generic research areas to improve CCS efficiency: Guenter Scheffknecht, University Stuttgart
- CO_2 Storage and transport
  - Storage in saline aquifers: Isabelle Czernichowski-Lauriol, BRGM
  - R&D common to CO_2 use and storage: Niels Peter Christensen, Vattenfall
  - CO_2 use and transport: Tore A. Torp, STATOIL
- Support Actions and International Collaboration: Niels Peter Christensen, Vattenfall

Overall Editor: Clas Ekström, Vattenfall Research and Development

Co-leads of the Technology Task Force are:

Lars Strömberg, Vattenfall
Dirk Goldschmidt, Siemens
Niels Peter Christensen, Vattenfall (Previously GEUS)

A complete list of the Technology Task Force members and co-authors can be found at:

http://www.zero-emissionplatform.eu/website/taskforces/index.html

It contains members from 21 European countries, Canada and India, and from 5 different types of organizations; Universities and research institutes, gas and oil business, power industry, equipment manufacturers and non government organizations.

2. Post-combustion CO_2 capture

Expected impact:

The post combustion solvent processes should be brought to a stage where we have:
- Full insight into the advantages and limitations of both organic and inorganic non-precipitating absorption systems, and have pilot scale data (2-4 MW) for a selection of the most promising ones.
- Identified advantages and limitations of precipitating systems (e.g. carbonates)
- Identified optimal capture process designs and the most robust and flexible ways of integrating the capture systems with the power plant with respect to energy loss and environmental impact.
- Created a solid experimental and model fundament for building an improved fully integrated capture plant for demonstration at small industrial scale (40-50 MW)

R&D to enable integrated, large-scale CCS demonstration projects Europe-wide and bring these technologies and concepts to commercial readiness by 2020.

Currently, the highest overall RTD priority for post-combustion CO_2 capture is to reduce energy consumption and costs. Within the proposed R&D areas, RTD projects that are likely to contribute to this overall priority should therefore be favoured.

Collaborative RTD projects covering the R&D areas below should be considered.

1. **R&D area: New solvents for CO_2 capture**

R&D actions (content/scope)

Demonstrate the improvements achievable with the full range of solvent systems and evaluate the environmental impact of the capture process systems.

- Continue and expand work on potential solvent systems including inorganic and precipitating systems, and identification of new improved ones
- Characterization of systems related to energy requirements; equilibrium, kinetics and thermal properties
- Determination of solvent stability and degradation rates in presence of oxygen and other pollutants and the maximum pollutant and flue gas characteristics at CO_2 scrubber inlet.
- Demonstrate energy requirement reduction and degradation rates of new systems in laboratory scale pilot plant.
- Determine potential energy savings from using precipitating systems and regeneration under elevated pressure in laboratory scale pilot plant
- Demonstrate stability, operability and performance under long term process conditions on industrial pilot scale
- Identify the environmental and HES impact of the new capture solvents

Funding Scheme

One collaborative large scale RTD project.

Expected impact

Develop a set of significantly improved solvent systems and develop the database necessary for demonstration on industrial scale. Demonstrate one system on an industrial pilot plant scale such that small scale industrial units (40-50MW) can be set in operation as soon as possible after 2010.

2. **R&D area CO_2 Capture plant integration and optimisation with power plant**

R&D actions (content/scope)

Demonstrate the availability, efficiency loss and environmental impacts of a fully integrated CO_2 capture process:

- Determine scale-up criteria and the most cost effective design for large scale capture units

- Determine the costs to fulfil inlet gas criteria and general considerations for future power plant modifications to include post-combustion CO_2 capture
- Studies of energy losses for different integration schemes; steam extraction, heat recuperation
- Determination of integration scheme consequences on power plant side; flue gas path, cooling water
- Demonstration of full integration with plant and measurement of energy losses
- Determine and if possible monitor the environmental impact

Funding Scheme
One to two collaborative large scale RTD projects
Expected impact
The project(s) will show the energy impact of different integration schemes including retrofit situations. It will demonstrate the effect of a fully integrated industrial size pilot plant with regard to efficiency losses and environmental impact, and thus pave the way for small industrial size (40-50MW) demonstration in 2010(-2015).

3. **R&D area: Development of CO_2 capture plant design and operation**

R&D actions (content/scope)

Demonstrate the improvements achievable with a range of process modifications

- Evaluate possible post combustion processes and quantify and compare the effect of a range of process improvements
- Establish operating procedures and determine possible energy requirement reductions in laboratory scale pilot plants (0.02-0.04 MW).
- Show the production of CO_2 at elevated pressure to reduce compression costs
- Optimize the process and equipment modifications them and demonstrate their operability and effects at industrial pilot plant scale (2-4 MW)
- Determine energy and solvent replacement costs and plant capital cost
- Operational optimisation, intermittent stripper operation, and economic plant shut downs

Funding Scheme

One collaborative large scale RTD project.

Expected impact

Identify the impact of a range of process modifications, and test the most promising ones in industrial pilot plants with a CO_2 capture capacity of 2-4 MW. Develop the data base necessary for demonstration of these modifications by 2010-2012 and to evaluate the environmental impact of the capture processes.

3. Pre-combustion CO_2 capture

Optimise concepts as well as process components for power plants with pre-combustion CO_2 capture, and create a validated solid basis for design of integrated and large scale pre-combustion capture CCS demonstration projects with sufficient reliability to achieve market competitiveness (after allowance for EEC support of early projects).

R&D to enable integrated, large-scale CCS demonstration projects Europe-wide and bring these technologies and concepts to commercial readiness by 2020.

Collaborative RTD projects covering several of the R&D areas below should be considered.

1. **<u>R&D area "High efficiency, low emission H_2 gas turbines and combined cycles"</u>**

R&D actions (content/scope)

- Hydrogen-burning gas turbines (both diluted with nitrogen, steam, exhaust gas or natural gas and up to almost 100% hydrogen content). The key areas of fuel flexibility, load flexibility, load response, reliability, burner stability and emissions should be developed with theoretical studies, laboratory tests and full condition demonstrations. Catalytic, flameless and other novel GT combustion approaches should also be examined and heat recovery steam generators developed to match the gas turbines.
- High temperature material behaviour, heat transfer and advanced cooling approaches with various gas compositions.
- Start-up and load following of advanced gas turbines and combined cycles for syngases and H_2 rich gases.
- Instrumentation and diagnostic tools

Expected impact

Safe reliable gas turbines burning the low carbon content gas. Prepare the ground for zero emission technologies with fuel flexibility such as for syngas and H_2-rich gases

Funding Scheme

Medium to large collaborative RDT projects

2. **<u>R&D area "Full process integration and optimisation for power"</u>**

R&D actions (content/scope)

- Start-up, flexibility, load following, reliability, availability and safe operation of the complex systems are important for early demonstration plants. Efficiency improvements through heat integration, process integration within units and integration across the entire power plant are important developments but not at the expense of reliability.
- Scale-up of equipment, technologies and codes taken from other processes.
- It would be helpful for all large facilities to be able to test novel technologies at smaller scales on side-streams and to incorporate basic understanding (theoretical and bench scale) in demonstration plants building on the knowledge that already exists but may not be widely known or used. Build on projects being developed for side-stream shift reaction evaluation at IGCC plants in operation, as well as on a flagship optimised IGCC of a size to match a gas turbine with the highest currently available efficiency (400+ MWe from the IGCC).

Expected impact

Establish a firm basis for demonstration of pre-combustion CO_2 capture power plants with availability and load following characteristics which are better than current IGCC (Integrated Gasification Combined Cycle) power plants.

Funding Scheme

Large collaborative RTD project which by its nature has opportunities for “exchange” fellowships.

3. **<u>R&D area "Syngas processing, CO_2 capture and CO_2 processing"</u>**

R&D actions (content/scope)

- Catalyst development including resistance to inhibition by syngas composition
- Optimisation of the shift stage or stages, the catalysts and process and thermal integration of the water gas shift with CO_2 separation and other gas (e.g. sulphur compound) removal. Separation of sulphur compounds and CO_2 removal processes (under pressure) should be characterised for various solvents to reduce contaminants (H_2, CO, N_2 +Ar, CH_4 etc) and associated further purification.
- Separation and Purification; adaptation and optimisation of existing and novel processes for pre-combustion capture (CO_2 streams separated from syngases)
- Pre-combustion CO_2 capture may provide opportunities to produce useful by-products other than electricity, for example hydrogen or high grade transport fuels but these are not our current priority.
- Pre-combustion specific aspects of CO_2 compression and purification.

Expected impact

Pre-combustion capture of CO_2 with minimum impact on plant efficiency, minimal reagent use and a product acceptable to the CO_2 transmission and storage infrastructure.

Funding Scheme

Medium collaborative RTD project, possibly including side-stream work on an IGCC.

4. **<u>R&D area "Coal gasification, natural gas reformer and syngas cooler"</u>**

R&D actions (content/scope)

- Modelling, of gasification and natural gas reformer. Validation and verification including materials and coatings.
- Basic information to allow scale-up to a single train of 1200 to 1500 MWth, including gasifier and heat recovery or quench, and gas processing. The train should be optimised for cost and operability, which may or may not mean that some components (even gasifiers) consist of multiple units in parallel.
- Improved coal feeding, ash control and ash removal
- Safety, especially with that related to hydrogen containment at high temperatures and pressures. Appropriate development of compliance codes from related processes.
- This part of the package covers gasification or fuel reforming coupled to water gas shift modification of gas composition. It is applicable to a wide range of solid, liquid and gaseous fuels.
- Priority issues for development of the gasifier or partial oxidation equipment include fuel feeding to required stability and properties for the "burners" or reactor. Reactor scale-up, raw gas cooling, the cost and operability of raw gas coolers and ash issues within and on extraction from this stage are key to the economic performance of the first fuel conversion stage in the plant. Novel gasification and syngas cleaning concepts capable of improving reliability even during variations in process conditions.

Expected impact

Reliable gasifiers and reformers as part of a lower cost pre-combustion CO_2 capture power plant.

Funding Scheme

Medium collaborative RTD projects

4. Oxy-fuel combustion

Expected impact:

The RTD actions add to ongoing projects in order to optimise the complete power plant concepts as well as process components, and create validated firm basis for design of large scale demonstrations (100s of MW_{th}) of complete oxy-fuel boiler power plants, including compression and conditioning of captured CO_2. Construction and operation of such large scale demonstration plants can then form the basis for commercial readiness by 2020.

R&D to enable integrated, large-scale CCS demonstration projects Europe-wide and bring these technologies and concepts to commercial readiness by 2020.

Collaborative RTD projects covering several of the R&D areas below should be considered.

1. **R&D area: Developing and implementing oxy-fuel combustion for boilers**

R&D actions (content/scope)

- Intensify laboratory research into combustion, heat transfer, formation of pollutants, excess oxygen, ash compositions and properties, slagging, fouling and corrosivity of flue gases. It is important to investigate the implications of oxy-fuel combustion for a large spectrum of solid fuels covering ranges of fuel properties, such as high contents of sulphur, high contents of chlorine, calcium-oxide rich ashes, etc.
- For circulating fluidised bed (CFB), in addition to above, verify also minimisation of flue gas recycle, bed material behaviour and in-situ sulphur removal
- Develop, based on research results, and adapt engineering and design tools for scale-up, such as CFD and other advanced tools. Validate developed tools against laboratory and pilot plant testing.
- Pilot plant tests (10s of MW_{th}) of full oxy-fuel pulverised fuel (PF) process, to validate results from scale-up based on laboratory tests.
- Development of PF burner designs and piloting in 10s of MW_{th} scale
- Pilot plant tests (10s of MW_{th}) of full oxy-fuel CFB
- Oxy-fuel combustion for CFB boilers: specific design and scale-up issues include strong heat extraction to solid bed material circulation loop. Perform process investigations addressing alternative schemes for fluidisation of i.a. external bed heat exchanger. A wide spectrum of solid fuel qualities of relevance for the European market should be taken into account.
- Investigations of start-up and shut-down procedures, transient conditions and performance during part-load operation, to be performed as combinations of dynamic simulations and verifications in pilot plants for PF and CFB:s
- Investigations of possibilities to operate oxy-fuel boilers also with air-firing, to be able to maintain power production in case of unavailability of ASU or downstream CCS equipments (i.a. compression and conditioning, transport and/or storage of CO_2)
- Develop design basis for future modifications of boilers to oxy-fuel

Expected impact

These R&D actions will create a validated, firm basis for design of oxy-fuel boilers to be used in large scale demonstrations (100s of MW_{th}) of oxy-fuel power plants.

Funding scheme

2 large collaborative RTD projects covering PF and CFB technologies

2. **R&D area: CO_2 capture, compression and conditioning process specific for oxy-fuel combustion**

High concentrations of other components than CO_2 at entrance of CO_2 compression and conditioning

R&D actions (content/scope)

- Validate, adapt and improve existing technologies (Particle separation, $deSO_x$, $deNO_x$, flue gas condensation etc.) for flue gas treatment, to utilization in oxy-fuel conditions.
- Develop flue gas cleaning/ polishing technologies for implementation in the CO_2-compression train.

- Optimise CO_2 processing and compression system to remove inert gases from the CO_2-product, while minimising CO_2-losses.
- Integrate CO_2 compression process with the power plant in order to minimise the energy penalty
- Establish thermo-physical properties of high concentration CO_2-mixtures, including model development and validation by experimental data.
- Investigate possible reactions (for i.a. sulphur and nitrogen compounds, mercury) induced under the operating conditions in the CO_2 compression/processing train, and their possible influence on the process conditions and material selection.
- Identification of distribution and options for removal of minor and trace components

Several of these R&D actions require investigations in laboratory and in pilot plants (10s of MW_{th})

Expected impact

These R&D actions aim at developing/adapting technologies for flue gas treatment, to utilisation for CO_2 rich flue gases, and to optimise and create basis for design of large compression and conditioning systems for high concentration CO_2-mixtures.

Funding scheme

Medium collaborative RTD project

3. R&D area: Material selection and R&D for oxy-fuel

This R&D area address issues that are specific for oxy-fuel combustion, in addition to the material R&D for steam power plants that are addressed in Chapter 6.

R&D actions (content/scope)

- Investigate long-term operational properties of high temperature materials, for oxy-fuel boilers, for flue gas environment in oxy-fuel processes, also including testing new advanced materials expected to be used in future Ultra Critical Code (USC) 700°C power plants.
- Investigate low temperature corrosion potential, especially for high ash, high sulphur and high chlorine coals.
- Investigate oxygen heater materials

Expected impact

These R&D actions will create a validated, firm basis for proper selections of construction materials when designing oxy-fuel boilers. This is essential to ensure safe and reliable operation of such boilers, since oxy-fuel flue gas compositions will differ from flue gases from conventional air-firing.

Funding scheme

Medium collaborative RTD project

4. R&D area: Adaption of cryogenic air separation unit (ASU) to oxy-fuel power plants

Very large quantities of oxygen delivered at low pressures

R&D actions (content/scope)

- Develop very large air compressor trains, potentially of the adiabatic type, to lower the cost of these units and develop new integration possibilities within the heat system of oxy-fuel power plants
- Optimise cycles for cryogenic ASU, for reduced power consumption, when used in large oxy-fuel power plants.
- Efficiency and load following advances through development of unit internals.
- Air separation unit compressor development, in size and responsiveness.
- Contaminant control.
- Oxygen production at the optimum conditions for the integrated power plant.
- Investigate the operability of ASU/oxy-fuel boiler combination (load following, minimum load, auxiliaries consumptions) theoretically (modelling) and validation of these models in plants

scheffknecht
Comment: moved from generic topic

Expected impact

These R&D actions aim at adapt and optimise the cryogenic air separation process for more energy efficient utilisation, and to investigate its operability, for use in large oxy-fuel power plants.

Funding scheme

Small to medium collaborative RTD project

5. Emerging and new CO_2 capture technologies

Expected impact:

To promote the development of new and emerging technologies that are yet to be validated for the capture of CO_2, which can be cost competitive with the technologies currently identified as front-runners, and brought to the market in the period post 2020. This area will also contemplate R&D activities that can complement and optimise the current front-running technologies. This long-term exploratory R&D in advanced and innovative concepts for the next-generation of CO_2 capture technologies will enable Europe to maintain the position of leadership in the area of environmentally acceptable fossil fuel power generation.

Develop novel underpinning concepts for implementation beyond 2020

1. **R&D area: Chemical Looping**

Chemical looping combustion is a promising concept demonstrated in several laboratory prototypes operating with clean fuel gases at atmospheric pressure. Further development is required to demonstrate the concept at the pilot scale on two fronts: the first for gaseous fuels, and the second for direct application of coal and in chemical looping reformers.

R&D actions

- Demonstration of chemical looping combustion for gaseous fuels employing interconnected high pressure fluidised beds at the next scale to optimise the operating parameters (for example circulation rates, temperatures, etc) and to develop optimal new carrier materials
- Investigation of the direct application of Chemical Looping Combustion of coal and heavy fuel oil in long term pilot tests to verify concepts such as ash and oxygen carrier separation, test possible oxygen carriers in order to characterise them with regard to de-fragmentation and attrition

Expected impact:

Accelerate the development and implementation of Chemical Looping Combustion (CLC) for both gaseous and solid fuels. These projects should result in the demonstration of Chemical Looping Combustion in the first small-scale pilot plants designed specifically for integrated chemical looping combustion.

Funding scheme

RTD Collaborative Project (Medium or large-scale focused project).

1. **R&D area: Post-Combustion Carbonate looping cycles**

Carbonate looping cycles in post-combustion applications is an emerging technology that is being promoted by an increasing number of groups in Europe, which currently leads the development in this area. A number of carbonate looping pilot plants of around 1 MW thermal input are currently being considered, and such pilot plants can provide critical information towards the validation of this concept. Larger scale facilities in the range of a few MWs will be required to validate the technology in real process conditions and to enable further development of the cycle.

R&D actions (content/scope)

- Development of carbonate looping pilot plants of the scale of a few MWs to evaluate and optimise the concept in operating conditions equivalent to large-scale industrial units and to address the key issues facing this technology (impurities in the gas and solid phases, chemical and mechanical performance of the sorbent, deposit formation, erosion and corrosion issues, start up and control issues, model simulation and scaling up tools, etc).

Expected impact

To accelerate the development of CO_2 capture based on carbonate looping cycles to determine if this technology can be cost competitive at the industrial scale in the timeframe of 2020 to 2030.

Funding scheme

RTD Collaborative Project (Medium or large scale focused project)

3. R&D area: Develop novel underpinning concepts for Oxy-fuel power plants

The main R&D needs to improve and further develop hard coal and lignite fired oxy-fuel processes are general measures to increase power plant efficiency and to increase the oxygen concentration in the oxidant flow to the boiler.

R&D actions (content/scope)

Development and tests in laboratory and in pilot plants of:

- Combustion characteristics in high O_2 concentration.
- Heat managing schemes for high O_2 concentration boilers.
- Novel pressurized combustion concepts (with dry or wet coal feed) able to produce a concentrated, pressurized CO_2 stream.
- Slagging oxyfuel boilers
- Low cost technologies for gas cleaning and CO_2 purification

Expected impact

These actions aim at improve efficiency, costs and reliability of coal oxy-fired units.

Funding scheme

Three to four small or one medium collaborative RTD project

Support long-term exploratory R&D in advanced, innovative concepts for implementation of next-generation technology

1. **R&D area: Next Generation Concepts for CO_2 Capture**

Initial validation of novel and breakthrough concepts that could be developed in the period up to 2050 for both new build and retrofit applications. Concepts to be investigated could contemplate the following possibilities:

- New concept materials, sorbents and separation technologies in post-combustion systems to improve the overall efficiency of the process, for example systems based on ionic liquids that can potentially simplify and reduce the energy penalty of the desorption stage, and/or processes using pressure swing, pH swing or the like,
- Novel chemical looping concepts for the production of H_2 (chemical looping reforming, pre-combustion carbonate looping, etc).
- New developments in new Oxy-fuel based concepts/cycles for gaseous fuels

R&D actions

Theoretical work and conceptual designs of completely new ways of separating CO_2 in both post and pre combustion systems up to small –lab-scale screening tests of novel and breakthrough concepts should be considered to validate each concept. ,

Expected impact

Screening of novel concepts to determine if they justify further development at a larger scale.

Funding scheme

Several collaborative small scale RTD Projects.

2. **R&D area: Ion-Transport Membranes for O_2 Separation**

With respect to O_2 separation there is a clear need to develop new large scale, economic oxygen separation techniques for both pre-combustion and oxy-fuel processes. It is believed that improvements can be made if more selective and efficient membranes, such as ceramic ion transport membranes or PSA/TSA technology, are developed and scaled up to capacities needed for large pre-combustion and oxy-fuel power plants.

Ceramic ITM (Ion-Transport Membranes) offer a potential route to achieve significant cost savings in the air separation unit, a key issue for both oxy-combustion and gasification technologies. It has been stated that an ITM Oxygen plant integrated with an IGCC facility could reduce the air separation plant capital and power requirement by over a third when compared to IGCC-cryogenic facilities, predicted that the composition of the ITM that operate in the region of 700-900ºC are tailored to the particular environment and can be fabricated in tubular or planar configuration. These materials can allow for a rapid transfer of Oxygen and could lead to compact and efficient gas separator equipment designs. There is a clear need to build on the work carried out to date, mainly in the US where the concept has been tested at 5T/day small prototype scale, and demonstrate the concept at the next scale.

R&D actions (content/scope)

- Realisation of pilot trials (minimum 100T/day) to further develop ITM for Oxygen Separation in power plant applications
- Investigation of energy efficient integration schemes with power plants for O_2 separation membranes operating in-situ as well as externally, with respect to i.a. required operating temperatures. For membranes operating externally, also identification of sweep gas options
- Material development and selection for ITM, especially to handle the flue gas atmosphere in large solid fuel fired oxy-fuel boilers in order to directly integrate the membranes in the furnace.

Expected impact

The results obtained will provide scale-up data to allow the design and construction of large scale facilities and promote the development of this technology in Europe.

Funding scheme

Collaborative RTD Projects (Medium/Large scale focused project)

3. **<u>R&D area: Gas Separation Membranes and Adsorption Processes for CO_2</u>**

To be a possible option for the separation of CO_2, membranes have to fulfil the challenging demands of high selectivity, mechanical strength, gas permeability and chemical stability in the flue gas environment. The removal of CO_2 using commercially available polymeric gas separation membranes currently results in large efficiency penalties, compared to a standard solvent process Additionally, the maximum percentage removal is lower than for standard chemical solvent processes. The following two options should be considered:

- Membranes operating between two gaseous environments where CO_2 is selectively transferred from a high to a low pressure region (the driving force being achieved with high efficiency compressors operating on the flue gas side or with vacuum pumps on the separated CO_2 side).
- CO_2 selective membrane operating between the flue gas to be treated and a liquid solvent (this option allows the direct treating of flue gas without pre-treatment).

Hydrogen (H_2) selective membranes to produce H_2 directly from natural gas, synthesis gas or after water gas shift, as fuel for subsequent combustion, should also be considered. Operation at 40-50 bars feed pressure allows sufficient driving force for the separation process to fuel gas turbines at 20-25 bars without compression.

Adsorption processes are used commercially in other sectors, however in low CO_2 partial pressures atmospheres the current processes are very costly, both in capital and operating costs. Some improvements can be foreseen to the process and the materials.

R&D actions (content/scope)

- Realisation of small-scale laboratory research experiments to continue the development of membranes and adsorbing materials to improve separation efficiency of CO_2/H_2, reliability and resistance to agents and conditions that currently limits the process.
- Material development and selection for membranes

Expected impact

The results should identify technical developments that simplify the process, and improve the efficiency of CO_2/H_2 separation using membranes.

Funding scheme

Collaborative RTD Projects (Small scale focused project)

6. Generic research areas to improve efficiency of power plants with CO_2 capture

Expected impact:

Highly efficient power plants (steam plants as well as combined cycle plants) to offset the energy cost of CO_2 capture, and to serve as a prerequisite for development of affordable Zero Emissions concepts. Develop framework depending on technology, so that power stations, built before CCS is fully demonstrated, easily can be modified to include CO_2 capture technology. Demonstrate the operability and achievable efficiency gain using ultra super critical boilers and high temperature gas turbines. Show how the CO_2 compression process should be designed and integrated with the power plant in order to minimise the energy penalty from the process.

R&D to enable integrated, large-scale CCS demonstration projects Europe-wide and bring these technologies and concepts to commercial readiness by 2020.

Collaborative RTD projects covering the R&D areas below should be considered.

1. **<u>R&D area: Steam power plant efficiency improvements</u>**

R&D actions (content/scope)

Develop materials and determine how ultra supercritical steam cycles can reach above 50% efficiency in steam power plants, be operated and how power processes can be designed to facilitate future modifications to include CO_2 capture, depending on the chosen CO_2 capture technology.

- Testing of materials and components for +700°C boilers, pipe work and turbines (i.e. beyond the COMTES 700 project); design of ultra high-strength materials and associated production technology for (large) components as well as the compilation of assessment methods for material properties and new materials.
- Development of novel steam turbine designs with steam cooling, improved clearance control, new seals and improved aerodynamics
- High temperature (ceramic) coatings for boiler components, pipes and valves need to be taken into account.
- Development of thermo-mechanical models and simulation tools for evaluating material properties as well as enhanced lifetime modelling.
- Improved combustion systems with low-emission technology to ensure increased efficiencies while meeting environmental needs.
- Research low pressure steam turbine for improved flexibility when integrating with post-combustion capture plant.
- For fuels with high moisture contents, such as lignite, develop, optimise and demonstrate fuel-drying technologies, that could be efficiently integrated into power plants.

Expected impact

Highly efficient power plants to offset the energy cost of CO_2 capture. Develop framework for being capture ready depending on capture technology, and so that power stations built before 2020 can easily retrofit capture technology.

Funding Scheme

Two collaborative/demonstration large scale RTD projects.

2. **<u>R&D area: Gas Turbine development for CCS processes (High efficiency >63% and New Cycle Concepts)</u>**

R&D actions (content/scope)

Promote the development of modelling tools (particularly heat transfer, chemical kinetics and flow) and the materials required for the next generation of Combined Cycle Gas turbines with electrical efficiencies of 63% and probably including high hydrogen content fuels. Develop gas turbine based oxy-fuel cycles

- Development of ultra high-strength materials and coating systems for gas turbine rotors, and the production technology to employ them in large components in conjunction with new thermo-mechanical models and simulation tools for evaluating material properties.
- Development of new sealing systems for high temperature/pressure gas turbines
- Development of new combustion systems for high temperature/pressure gas turbines
- Development of plants with fuel flexibility (different natural gas compositions, syngases, H_2-rich gases and low heating value fuels, such as bio-fuels and industrial gases)
- Basic Research and Development into the oxy-fuel gas turbines cycles to establish a sound engineering basis for these designs
- Investigation of new cycles for gas turbine based processes integrated with pre- or post-combustion CO_2 capture technologies, including recirculation and closed cycles.

Expected impact

Provide the bases for the design and development of the reliable next generation gas turbine plants. With regard to oxy-fuel gas turbines, the research and development should be the forerunner to future pilot designs that could be tested within the next 5 to 10 years

Funding scheme

Collaborative RTD Projects (Small, Medium and Large Scale focused projects)

3. **R&D area: Reduction of turbo-machinery energy consumption in CCS technology**

Optimising Carbon Capture and Storage (CCS) processes is key to promoting zero emission power plants. Turbo-machinery used for air separation in IGCC and in Oxy-fuel plants and CO_2 compression units are energy intensive and further development of air- and CO_2-compression trains is required.

R&D actions

- Projects focussed on improving efficiency of compressor turbine trains in air separation and CO_2 compression and their related components as well as their integration into the power plant design with possible recovery of compressor waste heat.

Expected impact

Optimisation of the design of Turbo-machinery and it's integration into the plant design to minimise the energy penalty from the process.

Funding scheme

Collaborative RTD Projects (Small and Medium scale focused projects)

7. CO_2 storage in saline aquifers

Expected impact:
If in fact CCS is to be widely available for industrial-scale deployment by 2020, considerable urgency exists towards further developing research on CO_2 storage in deep saline aquifers, which is by far the storage option with the largest capacity and the more widespread geographical distribution. This research needs to demonstrate to the public, the regulators, industry and national authorities that there is sufficient aquifer storage capacity available for large-scale CO_2 projects in various parts of Europe and that very large CO_2 quantities (1-10 Mt/y of injected CO_2 per project) can be stored safely for a very long time. This research must be well underway several years (i.e. by 2015) before full-scale deployment of ZEP becomes viable.

R&D to enable integrated, large-scale CCS demonstration projects Europe-wide and bring to CCS commercial readiness by 2020.

1. **<u>R&D area: Scientific and technical protocol for safe operation of large-scale saline aquifer storage sites</u>**

R&D actions (content/scope)

- Develop a common generic protocol to ensure that storage operations will not have adverse local impacts on populated areas, ground waters and ecosystems, neither short- term nor long- term. This protocol must include the scientific and technical basis for site selection and characterisation, design of the injection operations, monitoring, remediation and abandonment phase.
- Build on previous EC and national best practise and research work and further develop and integrate them
- Investigate new methodologies for scenario analysis coupling subsurface evolution with expected Health, Safety and Environmental impacts in case of leakage or ground deformation. Explore how to evaluate and handle uncertainties.

Expected impact
This project will deliver a common science-based protocol which will ensure that large-scale CO_2 storage in deep saline aquifers can be operated safely. This protocol needs to be generic with some flexibility to fit site-specific contexts. It will form the scientific and technical basis for regulatory, legal and economical frameworks and for building confidence in the CCS technology.
Funding scheme: large collaborative RTD project

2. **<u>R&D area: Leakage through natural pathways</u>**

R&D actions (content/scope)

- Develop a comprehensive understanding of the behaviour and impact of CO_2 and associated substances (co-injected impurities or co-mobilised chemicals, such as trace heavy metals, CH_4, ^{222}Rn, He, H_2, H_2S, etc) when migrating up to the surface through the establishment of natural field laboratories in a number of reservoir depths, geological settings, and terrestrial/marine environments.
- Assess the role of faults and the possible links between leakage and seismicity
- Further develop and integrate geological, geochemical, geophysical, geomechanical, biological and toxicological studies in these natural field laboratories to understand leakage pathways, rates, fluxes and mechanisms as well as possible impacts on populated areas, groundwaters and ecosystems.
- Develop a package of robust methods for visualisation, modelling and monitoring of CO_2 migration and leakage in these settings
- Integrate information from different disciplines and different site contexts to give simple, direct and clear answers to the most frequent concerns about risks of leakage and associated Health, Safety and Environmental (HSE) impacts.
- Equip permanently a selection of natural field labs for allowing visits by stakeholders at large for further research, guided field tours and permanent scientific exhibitions.

Expected impact

For CCS to become widely accepted the aspects related to the risk of the CO_2 escaping from the storage must be addressed in a scientifically comprehensive and credible manner. By their very nature, various industry pilot and demo projects are designed NOT to leak and the above project initiative (which could be seen as the European leakage laboratory) is thus best conducted in purpose made RTD project.
This project will deliver the clear scientific messages needed about leakage detection, quantification, variation in space and time, and HSE impacts. This is crucial for helping the set-up of storage regulations and for increasing stakeholders' confidence on CCS.
Funding scheme: large collaborative RTD project

R&D to develop novel underpinning concepts and tools for implementation beyond 2020

1. <u>R&D area: Long-term modelling of CO_2 storage in deep saline aquifers</u>

- Develop methodologies and tools for building 3D detailed, static geological model of the entire aquifer storage sites. Develop up-scaling tools for architectural systems of different depositional systems. Use geostatistics for distribution of key characteristics. Address sandstone reservoir types as well as carbonates with complex porosity systems(matrix and fractures).
- Develop dynamic modelling tools to predict CO_2 fate and site behaviour during the injection period up to long-term storage periods. Couple processes such as fluid flow, geochemical and microbiological reactions, thermal processes, geomechanical processes. Address in great detail the behaviour of the reservoir and cap rocks as well as faults.
- Undertake modelling on selected test cases, quantify over time the various physical and chemical trapping mechanisms, the changes of monitorable physical properties, as well as potential migration in the surrounding areas and ground deformation at surface.
- Benchmark modelling codes and approaches. Calibrate parameters from dedicated laboratory and field test data or history matching.
- Develop tools for quantifying uncertainties and visualizing modelling results.
- Make recommendations for the design of injection operations (position of injection wells and injection flowrates) and monitoring strategies.
- Propose a EU Best Practice Manual for the modelling of CO_2 storage sites, including recommendations for the good characterisation of key input data such as site-specific properties

Expected impact
Modelling is used to characterise both short-term and long-term storage performance in terms of injectivity, capacity, containment, and quantitative estimation of potential leakage. A dedicated project is needed to develop and demonstrate the capacity of models to adequately predict the storage behaviour and CO_2 fate. This will increase confidence in the safe implementation of storage sites and will be useful for optimising the injection operations and the short/long term monitoring strategies.
Type of project: large collaborative RTD project

2. <u>R&D area: Comprehensive assessment of Europe's capacity for CO_2 storage in deep saline aquifers</u>

- Compile, collate, and integrate existing aquifer capacity data from EU and national projects
- Further investigate the key reservoir and cap rocks characteristics of aquifers relevant to storage injectivity, capacity and integrity (geometry, structure, mineralogy, fluid chemistry, petrophysics, hydrodynamics, geomechanics, seismicity…)
- Develop a tool for predicting spatial reservoir and cap rock characteristics, with assessment of uncertainties
- Develop robust storage capacity classification system and provide input for legal end of storage licensing procedures (national or EU-wide)
- Map the whole Europe with respect to potential aquifer storage regions, without straightaway rejecting seismic areas
- Construct electronic EU-wide database and maps of potential storage sites using a GIS platform, with possibility of 3D visualisation
- Make scenarios of source-to-sink matching to relate storage sites with CO2 emission sources

- Initiate collaboration with the countries neighbouring the EU (Mediterranean countries, Western Balkan region, Eastern European and Western Asian states) and further collaborate with CSLF countries (China, Russia, India)

Expected impact

It is becoming increasingly clear that for CCS to become widely deployed by industry, sufficient high quality aquifer storage capacity must be made available. The geology of Europe is very variable and the deep saline aquifers are poorly known, except when they have been explored locally for hydrocarbon or geothermal purposes. To help industry and governments to plan CCS projects, it is imperative that considerable aquifer storage capacity is proven across Europe, and that an orderly system for licensing is instigated for the exploration and use of the storage sites.

Funding scheme: large collaborative RTD project

Support long-term exploratory R&D in advanced, innovative concepts for implementation of next-generation technology

3. R&D area: Mineral carbonation/solution trapping of CO_2 in unconfined aquifers

- Build on pioneer studies to further investigate the possibilities of enhancing mineral trapping of CO_2 and impurities in specific types of aquifers (basaltic and ultramafic aquifers, highly saline aquifers, geothermal reservoirs, etc.)
- Study thermodynamics and kinetics of chemical and microbiological reactions, as well as impacts on fluid flow, injectivity, geomechanics.
- Map potential storage sites in Europe, assess potential worldwide
- Carry out a techno-economical feasibility study

Expected impact

In this storage option, the dominant CO_2 trapping mechanism would be mineral trapping under various carbonates forms. Then the long-term stability of storage is increased. Also, for those countries (such as India and the Baltic countries) or regions that do not have significant deep sedimentary basins with high “structural trapping” storage potential, this option might provide additional potential for CCS implementation.

Funding scheme: small to medium collaborative RTD project

8. R&D common to CO_2 use and storage

1. **R&D area: Impact of the quality of CO_2 on transport and storage behaviour**

R&D actions (content/scope)

- Assess the impact of impurities injected with the CO_2 (*i.e.* O_2, N_2, NOx, SOx, CO, H_2S, etc) on fluid properties and geochemical reactions in the transport system (truck, ship, pipeline), injection wells and storage system (reservoir and cap rock).
- Develop relevant physical-chemical characteristics of most important mixtures at relevant conditions (i.e. phase diagrams at a range of relevant P and T). Develop algorithms for behaviour predictions.
- Investigate to what extent can impurities modify predictive modelling of the transport and storage system (flow, thermal, chemical, mechanical processes)
- Investigate the impact of impurities on subsurface monitoring
- Analyse and review importance of impurities on legal and economical conditions for geological storage permits
- Link with projects on capture processes and related impurities

Expected impact

CO_2 purity is a key issue within the entire CCS value chain from CO_2 source through the transport system and onto the storage site. The purity has implications of profound technical character as well on economic and legal issues (e.g. the London Convention). Clarity is needed in this area for a valuable contribution to the future planning and deployment of CCS.

Funding scheme: Large collaborative RTD project

2. **R&D area: Wellbore integrity**

R&D actions (content/scope)

- Develop novel concepts for well completions and supervision (i.e. new cements, cement free elements, logging and sampling).
- Develop new, advanced methods for modelling and prediction of i) corrosion, ii) cement degradation by geo-chemical and geo-mechanical processes, and iii) near-well migration. Use information from all possible levels: labs, field pilots, archeological analogues, etc.
- Assess risk for scenarios of sudden or slow CO_2 escape through wellbores or near-wellbore pathways and develop risk management procedures.
- Develop material and intervention procedures for repairing wells and restoring integrity
- Investigate also the impact of impurities co-injected with CO_2 or any other chemicals co-migrating with the CO_2.
- Optimise the monitoring system with regard to storage performance, local HSE issues and monitoring cost.
- Develop plugging & abandonment procedures for site closure

Expected impact

The vicinity of the wellbore is the most risky area for potential escape of CO_2 to the surface during and after operations.

Funding scheme: medium to large collaborative project

3. **R&D area: Combining use of CO_2 in EOR with subsequent storage of CO_2**

R&D actions (content/scope)

- Commercial use of CO_2 in EOR, EGR or ECBM may lead to outright subsequent geological storage of CO_2 in the same settings but with different technical and legal/financial drivers. How to plan and operate such set-ups? Can this approach provide long-term CO_2 price stability and a basis to kick-off demos?
- Use of geological storage as buffer facilities in larger systems, ensuring supply and providing match between CO_2 generation profile and CO_2 sink use/storage profile.

Expected impact

Currently planned EOR and ECBM projects are relatively short term and financially dubious. If a longer term perspective was to be applied combining USE and STORAGE a different perspective is likely to merge, possibly providing many new CCS deployment opportunities.
Funding scheme: large collaboration RTD project

9. CO_2 use and transport

Expected impact:

Large scale use of CO_2 with the benefit of climate mitigation, is above all use of CO_2 in EOR - Enhanced Oil Recovery, EGR - Enhanced Gas Recovery and ECBM – Enhanced Coal Bed Methane. In addition to the climate effect it can have a significant economic and resource management effect. These are firstly dependent on the improved recovery of oil/gas/methane.

Transport in pipelines and ships are ongoing, but needs a better scientific basis for design and safe operations in far larger scales. Impurities following the CO_2 are of vital importance.

R&D to enable integrated, large-scale CCS demonstration projects Europe-wide and bring these technologies and concepts to commercial readiness by 2020.

1. R&D area: Safety for large-scale transport in densely populated areas and cities, with CO_2 pipelines and through harbours (shipping)

Implementation of CCS in Europe will emphasize topics connected with large scale CO_2 transport in densely populated areas, and – if CCS will be applied to large combined heat and power (CHP) plants – even urban areas. The population density in general is higher throughout Continental Europe, than in typical oil field districts in the USA, e.g. Texas, where pipeline transport and injection of CO_2 for EOR is established technology. These issues have lately been given higher attention also in the USA, since implementation of CCS to reduce CO_2 emissions will push the CO_2 operations closer to urban areas.

R&D actions (content/scope)

1. Improved dispersion modelling and safety analysis for incidental release of larger quantities of CO_2 from the transport system (e.g. CO_2 pipeline, CO_2 ship or intermediate storage tank at harbour).
2. Investigation of proper mitigation measures and design, to ensure safe establishment and operation of CO_2 pipelines through urban areas.
3. Identification and definition of proper safety distances to protect a CO_2 pipeline from damage (e.g. from digging) to eliminate reasons for incidents.
4. Identification of regulations and standards (mainly the existing for natural gas pipelines, in each nation needed) that need addition or update of CO_2 regulations and standards.
5. Preparation of such updates based on adequate conclusions from 1, 2, and 3 above.
6. Similar as 2, 3 and 4 above but for ship transport.

Expected impact

Ensure proper establishment of CCS, including basis for acceptance, throughout Europe and especially for urban areas to enable establishment of high efficiency CHP plants with CO_2 capture.

Funding scheme: Medium collaborative RTD project

2. **R&D area: Develop cost efficient and safe equipment modifications on existing installations to accept CO_2**

R&D actions (content/scope)

- Precise corrosion prediction tools for high CO_2 contaminated fluids
- Evaluation of remaining safe operation life for process equipment
- Specific monitoring techniques for extended operation life
- Develop low cost steels more tolerant to high CO_2 levels
- Verify cracking behaviour of pipeline materials for CO_2 (safety and cost)
- Evaluate leak before break criteria
- Adapted equipment for CO_2 leak detection in a variety of environments.

Expected impact

The existing oil and gas field installations – on land or offshore – are often not prepared for CO_2 rich fluids. Low cost rebuild will depend on precise prediction and monitoring of its safe performance. This is often the second largest cost factor the resource reclaim is depending on. Future oil & gas prices are less controllable. Pipelines and terminal equipment for handling of CO_2 before/after shipping is mostly dependent on the same materials, design and monitoring techniques as for process installations.

Funding scheme: small size collaborative RTD project

3. **R&D area: EOR/EGR/ECBM with improved recovery of resources**

R&D actions (content/scope)

- To be able to assess potential contributions for economic use of CO_2 to Europe's aspirations for CO_2 emission reductions, it is important to develop strategies for first European movers for EOR/EGR/ECBM in a variety of geological settings. (Prior to final decision points on large scale investment in power plants with capture)
- Evaluation of EOR/EGR/ECBM potential over Europe;.
- Systematic mapping of properties of CO_2 with a variety of impurities.
- Improved reservoir simulation models with field case verifications.
- Fundamental research into the interaction between CO_2 (as well as N_2 and impurities) and coal and its effects on reservoir injectivity, ECBM recovery and CO_2 storage characteristics in situ.

Expected impact

The most critical factor for an economic viable EOR/EGR/ECBM is the recovery factor of oil/gas/methane. Little scientific basis and field experience for the CO_2 behaviour in the reservoirs, necessitate low estimates and poor economy. Better basis and models reduces risk. There are untapped resources in hundreds of potential small and large fields in most European countries from on land in the Balkans, through Central Europe to offshore the Norwegian Sea.

Funding scheme: Large demo and medium size collaborative RTD projects

10. Support Actions and International Collaboration

The Technology Taskforce has identified the following TOPICS as important, but the group don't have the relevant expertise to conclude which of them that should be prioritised and addressed immediately.

TOPIC: Public communication and public perception of CCS

It is a mistake to say that we need support action for public acceptance, because the public get sceptic by the wording "public acceptance". When researchers talk about public acceptance, the public easily get the impression that the scientists have a crazy idea that they will force the public to accept. We are going to provide information on CCS, because studies show that the public becomes more positive to CCS when they get good information on CCS.

Actions:

- Ensure that complete and relevant information about CCS reaches the public, NGOs and national decision makers and regulators
- Promotion of the ETP ZEP, the EU CCS Flagship Programme and the EU 10-12 CCS demos
- CCS information and communication facility and interactive website with blog.
- Particular emphasis on involving all member countries
- Links to relevant European activities (projects and programmes, national activities etc)
- Dialogue with emerging economies on CCS promotion and mechanisms for deployment.

Expected impact

Much improved awareness on CCS throughout European and increased knowledge of the CCS as a climate change mitigating option.

Funding Scheme

Support actions (one or more projects)

TOPIC: Preparing for the post-Kyoto Era – international CCS cooperation

Actions:

- Establish and maintain technical and other collaboration with emerging economies (China, India, Brazil, South Africa, etc) linking to ongoing or planned activities within the EU.
- Initiate collaborative activities with neighbouring countries (Russia, Ukraine, Turkey, North Africa, Moldova, Serbia, etc) with a view to promoting CCS.
- Create a forum or mechanism for international collaboration on technical and other activities with a view to building a partnership promoting CCS at the UN COP meeting in 2009 in Copenhagen. Follow-on activities would be expected also for the COP meetings in 2010 and 2011.

Expected impact:

The EU and its member countries need to have a strong and fruitful presence in some of the most important emerging economies. This work was successfully commenced in FP6 (e.g. with China) and it should be continued and further strengthened. The likelihood of a widely accepted global agreement to succeed the Kyoto Protocol after 2012, but without CCS (i.e. without provisions for continued use of coal) is not very high, but this appears to be poorly recognised by the COP parties. A concerted effort on behalf of CCS is needed.

Funding scheme

International collaboration activity (2 – 3 projects)

TOPIC: EU and the global CCS activities (CSLF)

Actions:

- Strengthen EU profile within CCS, particularly within CSLF Technical Group
- Support and coordinate EC with European CSLF member states
- Provide coordinated European input to selected CSLF activities (e.g. PIRT committee)
- Contribute to global collaboration on the establishment of common technical standards
- Assess potential for joint activities on global atlas of storage capacity

Expected impact:

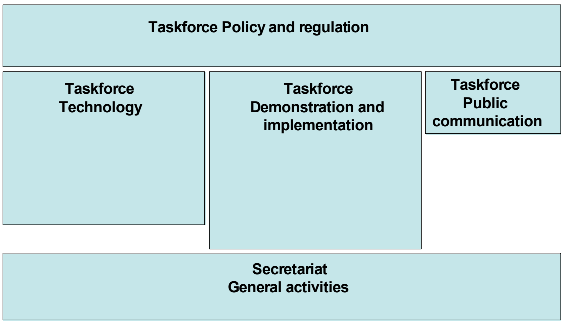
By better coordination and closer collaboration, the EC and those European countries who are members of the CSLF would be come much better recognised for their work within CSS and could become much more efficient in contribution to the global development of CCS.

Funding scheme:

International collaboration activity

ETP ZEP Task Forces

The following task forces have been formed:



Terms of reference for the **Task Force on Technology**

1 Organise R&D
    - 1.1 Map R&D needs&R&D landscape. Identify and specify the gaps and priorities
    - 1.2 Induce a higher level of activities&expertise from R&D-side
    - 1.3 Improve coordination between national programmes and FP7
    - 1.4 Maintain SRA&working group papers, possibly through a technol. Assessment group

2 Ensure public funding
    - 2.1 By mapping the need for additional finance for R&D
    - 2.2 Through public bodies (EC, member states), jointly with taskforce policy&regulation
    - 2.3 By initiating public-private-partnership(s)

3 Network and disseminate
    - 3.1 Organise technical days aimed at networking researchers and industry

The taskforce Technology will closely work together with the Taskforce Policy&Regulations regarding task 2 (ensure public funding)

Co-leads of TF Technology :

Lars Strømberg, Vattenfall
Dirk Goldsmidth, Siemens
Niels Peter Christensen, Vattenfall (Previously GEUS)