Materials for the "AcceptRis" Exercise on Carbon Capture and Storage (CCS)

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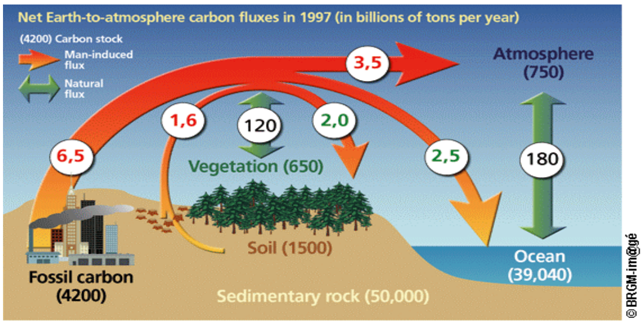
Carbon Capture and Storage in the actual French Context

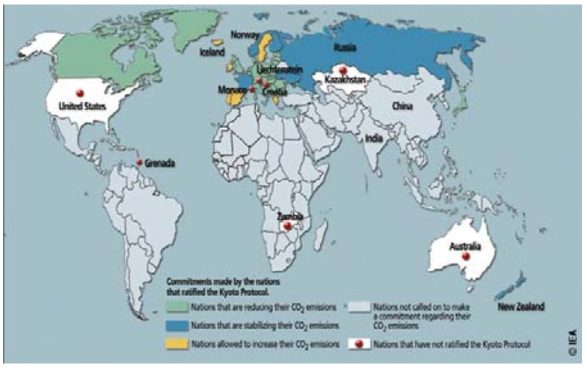
1) Global Warming and the Kyoto Protocol

The actual phenomenon of climate change has consequences that are becoming more and more obvious in everyday life: global warming (+0,5°C in average in the last century, but +0,9°C average in France), sea level rise (+10 to 20 cm in the last century), changes in precipitation (more rain in Northern regions in autumn and spring, but less in dry regions), migration (to the North and in altitude) and/or extinction of species… That the enhanced greenhouse effect, at the origin of our changing climate, is largely due to anthropogenic greenhouse gas emission became in the last two decades a fact that a large majority of scientists admit. CO2 is actually the most "active" of the greenhouse gases. Human activity induces about 30 Gt of CO2 emission per year, which equals 8,1 Gt of carbon: 6,5 Gt by combustion of fossil fuel (petrol, coal and natural gas), 1,6 Gt by deforestation and agricultural techniques. The natural carbon sinks are absorbing about the half of those 8,2 Gt of carbon (sea: 2,5 Gt, vegetation and soil: 2 Gt), the 3,5 Gt stays in the atmosphere and disturbs the carbon cycle – and, as a consequence, the climate.



Net earth-to-atmosphere carbon fluxes in 1997. *Source: BRGM*

According to the Intergovernmental Panel on Climate Change (IPCC), the international cooperating groups of multi-disciplinary scientific experts, global temperatures will continue to rise (as the sea level…): projections for 2100 show a global warming of +2°C to +6°C. If, for +2°C, global impacts (global evaluation of average impacts: in some regions, climate conditions will become worse, in others, better) are still positive or neutral, this is a threshold value. In fact, above +2°C, global average impacts will be negative (for everyone, everywhere). In order to contain global warming to this threshold value, CO2 (greenhouse gas) emissions need to be reduced: that is one of the objectives of the Kyoto Protocol. Developed nations have quantified CO2 emissions reduction objectives for 2012, of globally 5,2% of their level in 1990 (annex A: Changes in GHG emissions – UNFCCC).

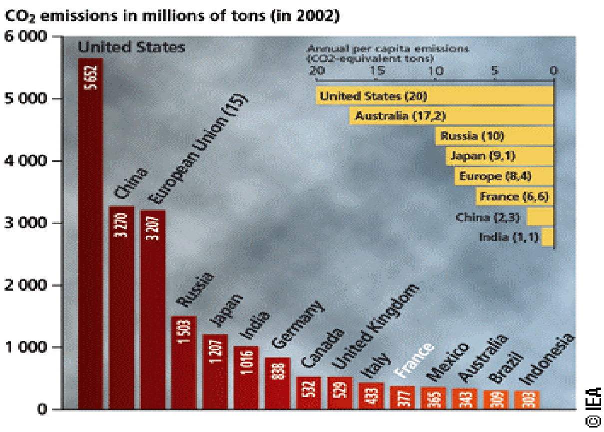


Commitments made by the Nations that ratified the Kyoto Protocol. *Source: IEA.*

Still, this reduction of CO2 emission will not be enough: CO2 emissions need to be reduced by about 50% to match the final objectives of the UNFCCC. It seems that there are two possible options: stop to emit CO2, or capture and retain the CO2 induced by human activity.

2) Anthropogenic CO2 emissions

CO2 emission is a natural fact. Every human being is producing CO2, simply by breathing. But the surplus of CO2 inducing the reinforced greenhouse effect are largely originated by human activity, through combustion of fossil fuels for energy production, industry or transport.



Our actual way of living – especially in the developed world – is only possible by consuming huge quantities of energy. Developing countries will have, by progressing, an exponentially growing demand for energy. In the next decades, the demand – or the need – for energy will therefore not diminish, but increase, even if everyone tries to save it wherever possible. It seems that we have to admit that CO2 liberation through fossil fuels combustion will have to continue for some time – at least as long as there is no competitive substitute.

3) Reducing anthropogenic CO2 emissions

Reducing anthropogenic CO2 emissions is still a necessity. There are several options that may contribute partially and progressively:

- Energy saving by collective and individual efforts means a major change in our actual way of living and acting. Housing, transports and industry hide a large energy saving potential. Ecological conception of products may contribute to those savings.
- Switching to less carbon intensive energy sources is already largely advanced (natural gas, for instance, reduces by 40% CO2 emissions, compared to coal). Only nuclear energy is CO2 free – but is a largely controversial technique. Other renewable energy sources – wind, sun, water – may be used more intensively in the future, but are not yet "operational" and competitive. France pursues the objective of producing 20% of its energy by using "clean" energy sources by2010 (actually 15%).
- In the domain of transports, "clean" or bio-fuels (vegetable oils, wheat…) and less energy consuming motors will contribute – several programs to develop and reinforce those techniques exist in France, Europe and the world. In 1997, a car is emitting about 190g of CO2 per kilometer. The European automobile constructors will reduce this quantity to 140g/km in 2008, and try to reach 120g/km in 2012. The development – and the potential industrial deployment – of the fuel cell using hydrogen as a vector of energy is another option.
- …

Still, even the sum of all those evolutions may not be enough to reach the UNFCCC objectives and assure the satisfaction of the growing demand for energy. Energy production in power plants is one of the most important CO2 releasing human activities (about 40%, i.e. over 7 billions of tons of CO2 per year). It seems to be impossible to reach the objective of "zero CO2 emission", we still need fossil fuels. So, we will have to act, in addition, on the CO2 necessarily released. One partial option is reforestation: forests constitute a natural CO2 sink. But we can not reforest enough for an entire absorption of the surplus of CO2 we release into the atmosphere. Another, supplementary, option is CO2 capture, already largely used in certain industrial processes (use of natural gas, agricultural industry, petrol industry…). The captured CO2 could be compressed and stored – that means it will not be released, and will therefore not contribute to the climate deregulation.

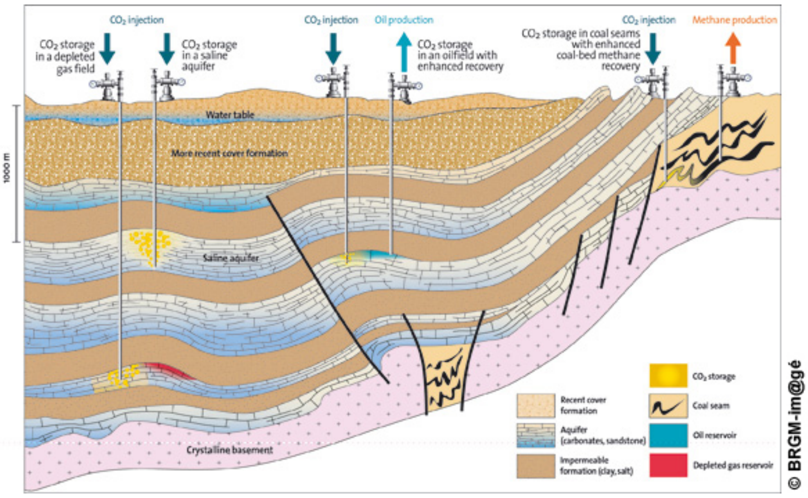
4) Technical options for Carbon Capture and Storage

There are several known techniques for CO2 capture. Each of those has as well advantages as disadvantages when trying to apply it to existing industrial sites (for schemes, see annexes B, C, D).

- Capture post-combustion (Annex B): The CO2 contained in combustion smoke is captured. This option is possible for already existing plants without modifying the installation. In fact, CO2 is captured by using a solvent or using a membrane. The captured CO2 is separated and compressed (ready for being stored) and the solvent reinserted.
- Capture by oxy-fuel combustion (Annex C): This is not a real CO2 capture technique, because the CO2 is separated before the combustion. In fact, using pure oxygen in the combustion process gives a 90% CO2 concentration in smoke that is then retreated. This option is used in industry already (production of glass). It is particularly suitable for retrofit existing installations, but the separation process is highly energy consuming and expensive.
- Capture pre-combustion (Annex D): The objective is to capture CO2 before the combustion process when producing the combustible. The combustible is converted into a synthetic gas, a mix of CO (carbon) and hydrogen (H_2). In a shift reactor, CO is interacting with water (H_2O) to form CO2 (captured), hydrogen (H2) used for energy production and air. This capture option needs special installations and does not fit existing installations.

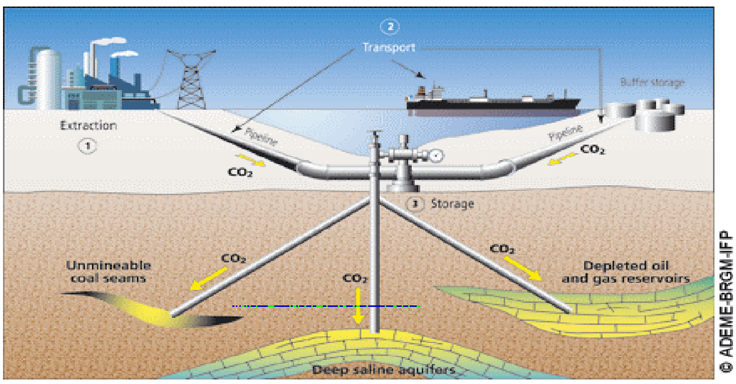
Once captured and compressed, CO2 may be stored. Several storage options are considered actually, most are geological storage options (alternative emerging solutions like mineralogical storage or storage via bacteria and micro-algae treatment are explored, but far from being operational). Geological storage means injecting CO2 in the space offered by permeable and porous rocs deep under the ground. CO2 must be injected deeper than 800 meters in order to reach the conditions of its supercritical state (above 31°C and 74 bars): it is less dense and needs less space.

- The first geological storage option is deep saline aquifers. Deep saline aquifers doe exist all over the world, and could absorb the entire quantity of anthropogenic CO2 emissions for centuries. The cost would be about 2 to 3€ foe a ton (more expensive offshore). The Sleipner installation in the North Sea is an experimental pilot site and operated since 1996.
- A second possibility is CO2 injection into depleted gas or petrol reservoirs. Industry already uses CO2 injection for enhanced oil recovery since the late 1950s. Well known research sites are Weyburn (Canada), or the K12B gas field in the North Sea (Holland). The injected CO2 maintains the pressure in the reservoir, liquefies the oil and facilitates oil recovery. Depleted reservoirs could be used for CO2 storage: it would allow to store about 1000 billions of tons of CO2.
- Finally, CO2 could be injected into non exploited coal veins (too deep). There are several points that are favouring this option: the geographical repartition of those veins (all over the world, near to CO2 emitting sites), economical advantages by exploiting the by-product methane (energy source)… There are disadvantages, too: coal is hardly permeable and does not permit to inject CO2 rapidly, and the quantity of CO2 potentially to be stored in coal veins is only of 40 billions of tons of CO2. Experimental pilots do exist (Allison, New Mexico).



To complete the CCS chain, CO2 transportation from the capturing plant to the storage place is necessary. For security reasons, CO2 transportation is subject to legal regulation. Compressed CO2 may be transported, thinking about the important quantities, by boat or by pipelines, under diverse forms.

- Transportation by pipeline onshore or offshore is rather well known: CO2 is an inert gas and is already being transported by pipeline for industrial activities like assisted fuel retrieving (in the US, since the 1980s, 50 millions of tons of CO2 are transported by pipeline every year – globally, more than 3000km of CO2 transporting pipelines do exist). While in the pipeline, CO2 is in its supercritical state, i.e. under a pressure of more than 74 bars – this means it could be necessary to have intermediate re-pressurisation (for long distance transportation). It could also be liquid, if pressure were about 10 bars and temperatures of -40°C – what means isolating the pipelines. Actually, there is no real network of pipelines that could be used. The cost would be from 0,5 to 10€ every 100km for 1 ton of CO2 (offshore pipelines are more expensive).
- For offshore storage or long distance transportation, cargo boats could be used. CO2 is shipped under conditions near to those of GPL transportation: under light pressure and low temperatures in a liquid state. Since 1989, Hydro Gas and Chemicals uses four cargo boats to transport captured CO2 to ports (where it is used for fertilization). Cargo transportation is less expensive than using pipelines over long distance, but there will be a need for temporary storage sites.



5) CCS Research & Development: The European and international context

As CCS at large is still in the R&D phase, in the last two decades, European and international actors have begun to investigate and cooperate in order to explore and enhance techniques. The objective is the economically viable deployment of CCS techniques at a large scale – and a contribution to the necessary CO2 emissions reduction while continuing to use fossil fuels.

Since the early 1980s, CCS has a R&D frame with an international agreement on Greenhouse Gas avoidance, proposed by the International Energy Agency (IEA). Related activities have given a first evaluation of technological options. Since 2001, there are national relay agencies developing and supporting dedicated R&D projects. Actually, five poles of CCS R&D exist: Australia, USA, Canada, Europe and Japan.

The international dimension is very present: direct cooperation in large demonstrators development (Weyburn, Sleipner) or research programs, and indirect coordination by the IEA GHG program or the Carbon Sequestration Leadership Forum.

December first, 2005, is the birthday of the European “Zero Emission Fossil Fuel Power Plants” technological platform (ZEFFPP). Its objective is to federate R&D activities in the development of power plants using fossil fuels (especially coal) with no CO2 emission. December 23, the European Community agreed on a Memorandum of Understanding with the Chinese Science and Technology Agency on “near zero emissions coal technology” (clean coal technologies).

6) The French actors’ commitment to CCS R&D

In June 2004, a French inter-ministerial work resulted in a common report insisting on the necessity of technological ruptures in the fields of energy production and consumption. CCS is one of those technologies identified, and could be, according to the 2005 “Gagnepain report”, the “safety valve” for global politics on global warming: CCS would “give the necessary laps of time to change for a more economical civilization without CO2 emission”. France has the goal to divide its CO2 by 4 in 2050 – what seems to be impossible without CCS techniques.

Several French actors are engaged in CCS R&D, since the first European research project “The underground disposal of carbon dioxide” (Joule II, 1993-1995) with the BRGM. Since 2001, national research programs exist:

- A network has been created for investigating geological storage options. Industrial companies (Total, Gaz de France, Geostock), research centers (BRGM, IFP, CNRS) and several universities participate.
- In 2002, the ADEME launches a first R&D program on CCS. The industrial partners are Air Liquide, Alstom, Arcelor, EdF, Lafarge, Total…

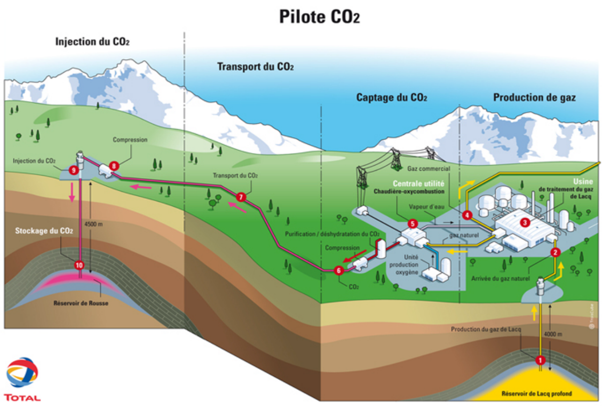
- In 2003, the IPGP (Globe Physics research institute in Paris) became associate with Schlumberger and Total, in order to initiate research on storage and circulation of CO2 underground. 6 research laboratories are participating, sustained by ADEME.
- In 2005, the French research agency (ANR) launched a national CCS research program. Subjects cover capture, transportation and storage techniques, and transverse aspects like a socio-economic evaluation or safety and security.

Furthermore, there are quite a number of “invisible” actors engaged, designing – by resource allocation and calls design for projects – the general shape of the CCS research landscape in France: national agencies (environment: MEDD, finance and industry: MINEFI, transportation: Ministère des Transports), technical administration services (DRIRE, DDE…)…

INERIS is engaged in several technical CCS research projects (PICOREF, METSTOR…), and since 2007 in a transverse socioeconomic project called “SocECO2”, investigating issues of societal acceptability of CCS in France (economical aspects, actors, perception, interest groups, social dynamics, regulatory aspects…). The Lacq project, a CCS demonstrator pilot run by Total, is the field case considered. Partners of the SocECO2 project are: Gaz de France, TOTAL, Alstom, CIRED, CNRS, APESA, BRGM, IFP, INERIS.

7) The Lacq project

February 8, 2007, Total is releasing the following press communiqué (translated by the author), accompanied by the following scheme.



‘Total launches, in France, the first integrated project of capture and geological storage of CO2 in a depleted natural gas field.

Total announces the launching of a pilot project of CCS in the Lacq basin in South-eastern France. This project, based on a technique considered as one of the most promising in the battle against climate change, will permit to inject in two years time from 2008 on, up to 150000 tons of CO2 in a depleted reservoir in Rousse (Atlantique Pyrenees).

"*The project will illustrate the contribution of CCS to the reduction of CO2 emissions in industrial plants, says Christophe de Margerie, DG Exploration-Production of Total. It represents the first integrated chain of CO2 capture by oxy-combustion, associated with storage in an ancient onshore field of hydrocarbon.*"

The first element of this project consists in a vapor production unit in the gas treatment plant in Lacq. Combustion in this unit will be realized using oxygen instead of air, which permits to get a concentrated flow of CO2 easier to capture. After purification, the CO2 will be compressed and transported by pipeline to the ancient gas field of Rousse, 30 km from Lacq, where it will be injected using an existing sink, into a roc formation 4500m deep.

After preliminary studies in 2006, the Rousse field, which presents a geological structure offering solid guarantees for durability, has been chosen as injection site. Today, Total just launched the phase of engineering studies. First CO2 injections are projected for November 2008.

The project, which will cost nearly 60 millions €, will be realized in partnership with Air Liquide, and benefit from several cooperation partners, e.g. IFP and the BRGM.

The Total group participates since a decade in several projects on the re-injection of CO2, especially in the saline aquifer formations of the petrol production sites in the North Sea. Capture and Storage of CO2 is completing the system of GHG emissions reduction already deployed by the group via other actions like the development of renewable energy, the reduction of combustion or gas associated to that production, and the enhancement of energetic efficiency of the production plants.'

'A pilot demonstrator at Lacq

The project aims to convert one of the five existing thermal heaters of the plant to oxy-combustion, used on the site of the gas field, and capture, compress and re-inject CO2 emissions in the depleted gas reservoirs of the Lacq region.

The pilot, which will produce about 40 tons of vapor per hour used by the industries on site, will emit up to 150000 tons of CO2 in 2 years that will be captured and stored.

This pilot that should start working in 2008 after 2 years of studies and preparing, constitutes a project unique in size of oxy-combustion of gas and liquid combustible and, regarding CO2 storage, the first French experience. It needs therefore a constructive dialogue with the competent administration which will precise the applicable regulation, as well as with the stakeholders.

This work will enhance the mastery of the oxy-combustion network – especially concerning the warm production of extra-heavy oil in Athabasca (Canada) – and contribute to evaluate the interest of the Lacq site as durable storage place for CO2.'

In the second, shorter, press release, the group is citing as well regulatory authorities as the general "stakeholders". While the first should, according to the group, enhance the regulatory framework applicable in order to enhance the viability of the CCS network, the second have no assigned role – still, stakeholder involvement seems to be part of the strategy around the pilot demonstrator in Lacq.

8) Main issues for CCS development in France

Developing CCS activities in France is conditioned by a series of diverse aspects, each having a different weight for the different actors or stakeholders in presence. The following gives a non exhaustive overview.

- Cost saving. Economical viability of CCS is one essential aspect. Actually, the average cost of capture, transportation and storage is 60€ per ton of CO2. The objective is to divide it by 2 or 4. Transportation techniques are operational at reasonable cost. Capture techniques are still expensive: about 85% of the 60€/ton, and need enhancement.
- Safety aspects. Guaranteeing security for the overall CCS chain, and that for the long term, is essential. R&D is still necessary in order to fully understand chemical and physical processes going on in the used storage reservoirs. Methodologies need to be developed for site selection, for long term projections of the impact the injected CO2 might have for the reservoir and the environment, for risk evaluation, but also for monitoring and control. Numerous research projects all over the world are engaged in those works.
- Regulatory aspects. Actually, there is no legal or regulatory framework specialized for CCS, nor a legal status for CO2 produced by combustion plants. Some regulatory texts offer first steps towards an answer, but none does address the long term storage of CO2. Future regulatory frameworks need to integrate those aspects, especially long term storage. The actual pilots are referred to other texts, like those regulating underground storage of natural gas or the oil exploitation in the Northern Sea. Still, the regulatory context cannot be the same for onshore and offshore storage…
- Societal aspects. Actually, there are only assumptions about how the French public may react to massive storage of CO2 in France. The first surveys show a large lack of public knowledge regarding those techniques. When the public gets informed, the questions arising concern fears about the durability of storage sites or potential leakage of CO2. Industrial and research groups as well as the competent authorities need to inform, but even more to engage a real dialogue with the public, especially those living near to potential storage sites, and social active actors (NGOs…). Transparency and independent control instances are *sine qua non* conditions for this enterprise. CO2 storage management should be assured under the best available security conditions, and needs to be judged satisfying by the public opinion.

9) The French regulatory context for industrial activities

The European Seveso II directive is the general applicable regulatory framework for industrial activity in Europe. Parts have been integrated in the general regulatory framework for industrial sites ("installations classes"), and in the French 2003 "Risks Act". In fact, after the 2003 AZF accident in Toulouse, the French regulating authority for (dangerous) industrial activity (Environmental and Sustainable Development Agency/Ministère de l'Ecologie et du Développement Durable) elaborated an approach to industrial risk largely inspired by its framework for natural risk and risk prevention.

The general approach is one of a "territorial (shared) management" of industrial risks, integrating all of the stakeholders in a consultative process. The "Risks Act" imposes, for any industrial under the Seveso II conditions, and any community concerned, to elaborate jointly with the elected persons a Technological Risks' Prevention Plan (*"Plan de Prévention des Risques Technologiques", PPRT*). Actions for a safer environment include:

- Risk reduction at its source when feasible (in the industrial installation).
- Better land use planning around the sites, taking into account the industrial sites and related risks.
- Creation of participatory/consultative structures (*CLIC: Comité Local d'Information et de Concertation*/Local Committee for Information and Consultation), accompanying the PPRT elaboration, but staying durably an informational relay for the entire population. Those CLIC are strongly inspired by the Arhus Convention and by existing examples of local committees in other sectors (waste management…), or abroad (US, Northern European States…). The CLIC includes as participating members the competent authority (prefect) and its technical or instructing services, the industrialist(s), the employees of the industrial site, the elected persons of the community, and the concerned population (or NGOs representing them).

While the CLIC is a durable structure, the elaborating phase of the PPRT includes a consultation of the general public (it is a consultative participatory process, with a predetermined timeline for the technical instructions and several stages to be accomplished). The consultation of the general public is not really explained or pre-designed in the regulatory framework: the prefect or its technical services (supposed to make consultation a success) know that they have to do it. They do not know how, nor when, and information, consultation or co-elaboration is nothing less than one of their training objectives or the required skills.

The new process for industrial risk management could be the one applicable to CCS – even if, actually, it is not (but in the case where the industrial site is already a Seveso classified installation: any change must be object of a consultative action, and changes must be integrated in existing PPRTs). In the case of the Lacq pilot, the site is under Seveso II classification – the consultation is therefore necessary (as it seems to be for the industrialist, according to his February statement). Though, its structure and path is not determined by the law…nor is the role of any of the potential participatory process initiators (competent authority, local elected persons, and industrialist) or participants.

10) List of cited documents and statistics

Annex A: UNFCCC list of GHG emissions reductions 1990-2004.
Annex B: scheme CO2 capture by post-combustion.
Annex C: scheme CO2 capture by oxy-fuel combustion.
Annex D: scheme CO2 capture by pre-combustion.

Useful link about CCS: www.clubco2.net
About PPRT (in French only): http://www.prim.net/actu/archives/pprt.html