A bird’s eye view on Carbon Capture and Storage R&D in France

Bernard Frois
2008 Strong EU French Presidency

EU Set-Plan

20% 20% 20%

France has decided to be in the top EU countries for New Energy Technologies

For 1€ spent on nuclear energy there should be 1€ for renewable energies
CCS R&D has significantly increased in France

• Powerful Public and Private Research

• World collaborations (IEA, CSLF, ZEP, Australia Global Institute)

... and many others ...
33 Public-private projects funded in 2005-07
27 M€ public part

- New processes
  - oxy-combustion
  - adsorption materials
    - NOMAC
  - absorption
    - CICADI
  - thermodynamics
    - CICADI
- monitoring
  - GAZANNEXES
  - GAZCOGNE
  - TACOMA
  - CRISCO2
  - IMCAT
- risks
  - CRISCO2
  - SOCECO2
- acceptance
  - CRISCO2
  - CAP-CO2
  - MECAFI
- storage
  - GASCOGNE
  - MECAFI
  - OXYBAC
  - OXYBAC
  - HETEROGENEITES-CO2
  - CHARCO
  - GEOCARBONE-INTEGRITE
  - GEOCARBONE-PICOREF
  - GEOCARBONE-CARBONATATION
  - GEOCARBONE-INJECTIVITE
  - HPPP-CO2
  - PROCHEPUITS
  - SECOHYA
  - CO2SUBLIM
  - SEC0HYA
  - CLCMA1
  - PUITSCO2
  - wells
    - HETEROGENEITES-CO2
  - Cap Rock
    - coal
    - aquifer
    - HETEROGENEITES-CO2
    - GEOCARBONE-CARBONATATION

2005
2006
2007

Délégation ANR/NTE
## PROPOSED PILOT PROJECTS CCS 1/2

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<thead>
<tr>
<th>Acronyme</th>
<th>Partenaires</th>
<th>Titre</th>
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<tbody>
<tr>
<td>Pil AnSU</td>
<td>ALSTOM EDF Armines GDF SUEZ</td>
<td>Capture</td>
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<tr>
<td>C2A2</td>
<td>EDF ALSTOM</td>
<td>Capture</td>
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<td>TGR-BF</td>
<td>ARCELOR Air Liquide BRGM</td>
<td>Capture, Storage, Transport</td>
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## PROPOSED PILOT PROJECTS CCS 2/2

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<tr>
<td>CICO2</td>
<td>Veolia, BRGM, CGG Veritas, CIRED, Geogreen, IFP, INERIS, IPGP, INPL, PROSERNAT, Solexperts, Technip, TNO</td>
<td>Capture, Transport on short distance and storage</td>
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<tr>
<td>France Nord</td>
<td>TOTAL, GDF Suez, BRGM, IFP</td>
<td>Storage in aquifer</td>
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IFP's strategy is to develop a consistent approach from basic research to industrial development covering the whole chain from capture to storage using both experimental and numerical modeling tools.

In transport, IFP is fully involved in thermodynamic modeling of mixture of different CO2 streams.

In storage, IFP has developed a 3D modeling tool integrating the full range of physico-chemical phenomena.

IFP is coordinating European projects (CASTOR, COACH, ...)

IFP is fully involved in international working groups (IEA, CSLF, ...).
Technical challenges for storage

- **Technologies for well completions**
  - New formulations for cements
  - Tests on long-term behaviour of materials (steels, cements)
  - Specific study of interfaces

- **Predictive modelling of storage**
  - from basin to reservoir and well scale
  - multiphase fluid flow, transfers, coupling with geochemistry and geomechanics, thermodynamics

- **Monitoring & Surveillance**
  - Seismic tracking of the injected CO$_2$
  - Leakage detection

- **Risk assessment**
BRGM Earth sciences CCS program

• recognize, characterize and qualify the deep aquifers favorable for storage and to assess their storage capacity

• characterize potential impacts on the environment and risks related to storage, and propose the safety criteria.

• reference for the evaluation of the storage capacities and the behavior simulation of the injected CO2 in deep aquifer

• build and develop the capacity of public expertise on the environmental impact and the safety criteria for geological storage

• Ensure, in compliance with the rules of quality and deontology, a scientific support to the private sector.
Global impact assessment of the CCS chain (2006, CIRED, ALSTOM, APESA, BRGM, GDF, IFP, INERIS, TOTAL)

> Simulation of capture scenarios, transport and CO₂ storage implementation at national scale for years 2050
> Results: Energy and environmental impact assessment

Significant greenhouse gases emissions reduction achieved (exple: - 62% / same emitters without CCS)
But significant additional energy required and other pollutant emissions increased (such as NOx).

SOCECO2: Project supported by the French Research Agency (ANR)
Cap rock integrity

Identification of:

- Principal geochemical reactions
- Amount of CO₂ permanently sequestered
- Key physicochemical parameters
- Petrophysical properties (k, kr, Pc, IFT, ...)
- Possibility of biofilm development, ...

Diffusion of dissolved CO₂ affecting cap rock mineralogy through geochemical interactions and mass exchanges

Intégrité: project supported by the French Research Agency (ANR)
Potential leakage pathways
Hands-on experience in pilots:

- CASTOR and CESAR: pilot in Esbjerg (Denmark)
- Pre-feasability study of the conversion to oxy-fuel of an 800 MW SC coal power plant
- Mobile pilot plant with E.ON Kraftwerke and Hitachi Power Europe (post-combustion capture)
- Other pilot/demonstration projects with different technologies are under consideration
Project CLEAN: R&D on CO$_2$ injection for EGR in Altmark; the second largest European natural gas field

- R&D project, involving advanced monitoring techniques and process modeling for risk assessment of (abundant) old wells

- Pilot project on a geological and geodynamical closed reservoir to study technical and geological processes linked to EGR, allowing to
  - Support the definition of standards
  - Development of best practices
  - Build up experience

Partners: German Ministry of Education and Research, involving 16 Universities and Institutes; Vattenfall
A first CCS pilot project at Lacq in France
Total Exploration & Production France
**CO₂ pilot in Lacq main objectives**

- Demonstrate the technical feasibility and reliability of an integrated CO₂ capture, transportation, injection and storage onshore scheme for steam production at a **reduced industrial scale** (1/10th of future facilities)

- Design and operate a 30MWth oxycombustion boiler for CO₂ capture
  - improvement of CO₂ capture energy efficiency
  - reduction of capture cost compared to classical post capture technologies

- Develop and apply geological storage qualification methodologies, **monitoring and verification techniques** on a real case to prepare future larger scale long term storage projects
A complete integrated project of CCS at Lacq

1. Natural gas inlet
2. Lacq gas treatment plant
3. Commercial gas
4. Utilities (Boiler oxycombustion, Steam)
5. Oxygen production unit
6. Compression
7. CO₂ transportation
8. CO₂ capture
9. CO₂ injection
10. CO₂ storage

- Compression
- Purification / CO₂ dehydration
- Compression
- CO₂ injection
- 4500 m
- 4000 m
- Rousse reservoir
- Lacq deep gas reservoir
- Lacq gas production
- Natural gas inlet
Boiler revamping

- Existing boiler revamping with CO2 recycling
- 40 t/h of steam 60b/450°C (30MWth) to HP steam network

- ALSTOM in charge of boiler revamping works
- Cryogenic Air Separation Unit
  240t/day oxygen required
Schlumberger R&D Activities in Europe

Participation to collaborative R&D projects:

**European (FP 5/6/7)**
- SACS/ CO2STORE: Sleipner
- CO2ReMoVe: In-Salah, Sleipner, Snøhvit
- CO2SINK: Ketzin
- MoveCBM: Kaniow
- DYNAMIS
- COACH
- GRASP
- CO2EuroPipe

**Transnational (Eureka)**
- COSMOS-1/2
- CO2FieldLab (in preparation)

**National**
- ANR projects (France)
- BERR projects: CASSEM (UK)

**JIP’s**
- CO2QUALSTORE (DNV)
- COUGAR (IFP)

Activities include technology demonstration and studies

Engineering group located in Clamart (Fr)

Plus … many proprietary pre-feasibility studies for private clients
CONCLUSIONS

• France strongly support CCS in France and internationally.
• 2005-2007 National research agency has funded 33 projects in basic research.
• A new demonstration program for 4 years is being implemented by ADEME 400 M€ in New Energy Technologies.
• Air Liquide, Arcelor, GdfSuez, Total, Veolia, etc.) have considerable interest in CCS. All are preparing large scale world projects.
• Lacq project funded by Total has a special interest in terms of complete integration and public acceptance