Lacq CCS Integrated Pilot
A First

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TOTAL EP – R&D Division
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Lacq pilot project overview
Objectives

- To Demonstrate the technical feasibility and reliability of an integrated onshore Carbone Capture and Storage scheme for steam production at a reduced scale (1/10th of future facilities).
- To acquire operational experience and data to up-scale with cost reduction the oxy-combustion technology from pilot (30MWth) to industrial scale (200MWth).
- To develop geological storage qualification methodologies
- To develop monitoring methodologies on site to prepare future larger scale long term onshore storage projects. (Micro seismic monitoring, Environmental monitoring..)

Acquire expertise and reduce costs for future industrial deployment
This industrial operation is planned to capture and trap ~ 90,000 tonnes of CO₂ over a 3 1/2-year period (eq to the exhaust emissions of 30,000 cars).

- Budget: CAPEX 60 M Euros
- Up to 90,000 tonnes of CO₂ injected
- Main technical's features
  - Revamping of one existing air combustion boiler to an oxy-combustion boiler (Air Liquid / Alstom)
  - Installation of 2 new CO₂ compressors (Lacq and Rousse)
  - Installation of one Air Separation Unit (Air Liquid)
  - Installation of one flue gas treatment unit / driers
  - Modification of an existing production well to an injection well.

Lacq site

City of PAU

Rousse-1 injection well

Transport: 27 km long pipe from Lacq to Rousse-1
## CCS pilot, Lacq, France

### Project phasing

<table>
<thead>
<tr>
<th>Event</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
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**Start-up of operational phase:** July 3rd, 2009  
**First CO₂ injection in Rousse reservoir:** January 8th, 2010  
**End of injection:** 8th July 2013
Permit obtained in May 2009 for capture, transportation and storage based on:
- A « Regulatory » pilot, 1st in Europe
- Specific risk and impact analysis
- Permit extension obtained in November 2011
- Injection until July 2013

Public dialogue — transparency policy:
- Identification of Stakeholders (ONG, mayors…)
- Early public meetings in 2007 (4 public meetings)
- Follow up information committee (7 meetings)
- Information letter every quarter (14)
- Hot line

Scientific Advisory Committee since 2007

Scientific collaboration program with National Institutes and Universities on Rousse storage

Project endorsed by the Carbon Sequestration Leadership Forum (CSLF)

Project information also available on www.total.com/corporate-social-responsibility
Lacq pilot project technical description
CCS pilot, Lacq, France
A complete industrial chain

Industrial scale:
30MW\text{th} oxycombustion
60 000 t/year CO\textsubscript{2}
Integrated within existing facilities
CCS pilot, Lacq, France

Capture description

Air separation unit

Cryogenic unit (Air Liquide)
O₂ : 240 t/d

Oxy-combustion Boiler

Existing 1957 boiler revamped by Alstom to oxy-combustion boiler.
Oxyburners developed by Air Liquide
(30 MWth, 40 t/h steam @ 60b, 450 C)

Flue gas cooling tower

Cooling of flue gases
From to 200 C to 30 C

Dehydration Unit

Outlet : < 20 ppm of water

Wet CO₂ compressor

Transport

CO₂ composition (@98% O₂ purity)
CO₂ : 92.0 %
O₂ : 4.0%
Ar: 3.7%
N₂: 0.3%

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O₂ : 4.0%
Ar: 3.7%
N₂: 0.3%
CCS pilot, Lacq, France
Transport / Compression / Injection Rousse site

Transport
29km long pipe (12” and 8” diameter)
CO₂ in gas phase

Lacq

Existing right of way

Rousse storage
Depleted gas reservoir @ 4500m/GL

Rousse compressor
Pinlet: 27bar  Poutlet: 51bar
Surface Operational Feedback
 CCS pilot, Lacq, France
Lacq Industrial chain

- **Air Liquide ASU**
  - 😊 No operating issue

- **Air boiler retrofitted to Oxy-combustion**
  - 😊 Start-up on air up to 30% load: no issue – on design
  - 😊 Transition from air to oxy-mode: no issue – on design
  - 😊 Steady state and transients in oxy-mode: no issue – on design
  - 😊 Recently added: an automatic transition from oxy to air-mode – no issue
  - 😊 Overall, smooth operation of oxy-burners / Oxy-boiler

- **NOx produced is in the 400 ppm range (@3%O₂ dry)**
  - ✢ Even when operating at 99.5% vol O₂ purity (no N₂ from ASU)
  - ✢ Source of N₂ is from the commercial gas (~0.4% vol N₂)

- **Cools down the flue gas from 220 C to 30 C (design was 50 C)**
  - 😊 No issue
Wet CO₂ stream compressor

- LMF 3 stage reciprocating non-lubricated / Max discharge P=27 bar
- Cylinders in cast iron / all other parts made of acid resistant materials
- 😞 Corrosion problems (now resolved)
- Lower cooling at the cooling tower: set point initially at 50°C lowered to 30°C
  - To condense more water & decrease the dew point of the CO₂ stream before compression
- Slight increase of compressor suction temperatures
  - To minimize condensation in the compressor
- Recycling of dry CO₂ (downstream dryers) to compressor inlet
  - To dry the CO₂ stream feeding the compressor and decrease the dew point
- Gas / liquid separators internals have been improved
  - To minimize liquid carry-over to suction chambers

These technical solutions have proven to be effective: no more corrosion has been observed on the compressor since restart
“Air Liquide’ Molecular sieve technology: Measured [H₂O] < 10 ppm vol. compare to a design value of 30 ppm (= water due point around -50 °C)  

😊 No issue

- CO₂ is transported in gas phase at 27bar max  
  ✅ 29 km long existing carbon steel pipe (Ø 8" / 12")  
  ✅ Dry CO₂ rich stream avoids corrosion

😊 No issue

- Rouse Dry Compressor
  😊 No issue – Works on design

- Well head and well
  ▶ Standard gas production technology and materials
  ▶ A work-over of the well was achieved in winter 2010/2011 to install new sensors down hole (micro-seismic arrays)

- Tubing was inspected: no corrosion

😊 No issue
Sub- Surface Operational Feedback
- Static reservoir pressure is increasing due to CO$_2$ injection. The reservoir pressure increase is as per the predictive model. (Eclipse 300 compositional modeling)

Long term pressure impact (bar) of CO$_2$ injection

- No injection
- 100 kT CO$_2$ injection
Objective: To monitor caprock integrity

Seven subsurface arrays with 4 triaxial sensors in 7 shallow wells (TD: 200m/GL):
- 6 wells on a 2km radius circle around the injection well;
- 1 well on the injection site.

One sismometer for natural seismicity

Online and continuous information

Minimum detection: magnitude -2.5
Localization: +/- 250m

9 month baseline survey before injection

In addition, one deep array (3 triaxial sensors) in injection well for R&D objectives
Calibration by real shots

Mainly natural seismic activity linked to northern front accident of Pyrenees mountain range (between Iberic and Eurasian plates)

Good sensitivity of data acquired for R&D with deep arrays, data analysis on-going: many micro-seismic events located around RSE-1, since March 2011 (yellow dots) Magnitude : - 2.5

Very few micro-seismic events recorded by surface installation

→ No incidence on Caprock integrity
Environmental Plan Monitoring and feedback
# Environmental monitoring

## Soil gas, Water, Fauna & flora

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<tr>
<th>Environment</th>
<th>Water quality</th>
<th>Surface water (rivers)</th>
<th>Chemistry</th>
<th>Bio-indicators</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
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<tr>
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<td>Phreatic aquifer (springs)</td>
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<td>Winter</td>
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<tr>
<th>Site</th>
<th>Res. &amp; Caprock</th>
<th>Microseismic + P&amp;T</th>
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<tr>
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<td>Well annulii</td>
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<td>P &amp; T</td>
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<td>Flowrate, Composition</td>
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<tr>
<th>Additional R&amp;D</th>
<th>Soil gas</th>
<th>C isotopy, Inert gas, radon</th>
<th>Winter</th>
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<tr>
<td>(French National Research Agency, Paris &amp; Nancy Univ., INERIS, IFPEN, BRGM, IPGP etc.)</td>
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*Note: Six test phases include Winter, Spring, Summer, Autumn.*
Environmental monitoring
Soil gas, Water, Fauna & flora

To detect changes that could be linked to the effect of a CO2 leakage
Baseline surveys in 2009.

- **Soil gas (35):** CO$_2$ and CH$_4$ concentration and flux. C isotopy. Inert gas. Autumn and winter.

- **Perched aquifer (4 springs):** Chemical and mineral content, every 6 months. Indicators: pH, conductivity, carbonates, bicarbonates.

- **Shallow and deep saline aquifers** sampled at selected existing water wells (drinking water supply of Pau). Monitoring idem perched aquifer.

- **Surface water (5 small rivers):** Standardized bio-indicators (diatoms and benthic macro invertebrates) and chemical and mineral content. Every 6 months.

- **Fauna and Flora:** Annual inventory of:
  - Flora of representative ecosystems (33 sites)
  - Several amphibians and insects species (50 sites).
No deviation from Baseline surveys in 2009 have been recorded.
Conclusion/ Way forward

- At this stage of the pilot (43,000 t injected), the demonstration of the technical feasibility and reliability of an integrated onshore Carbon Capture and Storage scheme for steam production has been proved. (Obj.1)

- For CO₂ contained in combustion flue gases (GT, Furnaces, Boilers), current cost evaluations for capture units of industrial size are still high, even for oxycombustion. More R&D and demonstration projects are needed before up-scaling and streamlining Capture installations.

- The design of 200 MWth oxyboiler should be finalized in 2013, thank to the Lacq pilot plant. (Obj.2)

- The Lacq pilot is part of the larger Total CCS technological roadmap. CCS is considered as a valuable contribution to GHG reduction. The Lacq pilot demonstration project is an example of what kind of project contributes to the deployment of this technology by 2030.

- The main TOTAL’s CCS R&D surface activities are to participate in the development of breakthrough CO₂ capture technologies which are required to cut down costs (CLC, Membranes, Cryogenics techno..)

- The long term CO₂ storage monitoring program economically and technically viable is still to be developed. (Obj.3)

- ‘Transparency’ in communication with the stakeholders is one of the key factor to reach the public acceptance. It remains a permanent “concern” to be taken into account during the whole life of a CCS experimentation and for the future industrial deployment of CCS.
“Innovation is one of the main drivers of sustainable growth in our production”

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