The experience of Lacq industrial CCS reference project

Carbon Sequestration Leadership Forum
Lacq, France - March 17th 2010

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Total Exploration & Production France
Operated Assets (16 mining leases)

- Lacq Profond (100%)
- Meillon, Saint-Faust (100%)
- Hydrocarbon treatment
- South Ouest Oil: VBH (73%), PCE, LAV
- Paris Basin Oil: ITV (78.7%), VLG (90.1%), LCX, VLT

Non Operated Asset: DML (57%) Lundin

Work Force: 780 end 2008

Wells in operation (productors/injectors): 82

Raw Gaz Production 2008 (Mboe/day): 7.6 (4.2 Mm3/j)

Oil Production 2008 (Mbbl): 1.9 (5.2 kbep/j)

Daily global average (in Kbep/day): 25.5

Gasoline & Condensates (in bep/day): 1200

Sulfur Production (in t/day): 834

Investments 2008 (in M€): 72

Total E&P France – ID Card (2008 figures)
Gas production history – Forecast

In billions of m³ of raw gas per year

1961: Reservoir fully developed @ 635 MMSCFD
1971: Max plateau production 1200 MMSCFD
1983: Raw gas compression, 3 units, 8 MW
1987: Turboexpander, 630 MMSCFD
1993: Booster compression, 2 units, 8 MW
2000: HP compressors rewheeling
2004: Booster rewheeling
2005: New mercaptan removal and dew point

1979: Shut Down Lines 1 & 2
1985: Shut Down Line 3
1995: Line 4 & Refinery

97% recovery factor
Lacq Plant – General Flow diagram

- **Raw Gas**
  - Raw Gas
  - Crude Oil
  - Mercaptan Removal (Molecular Sieves)
  - Acid Gas
  - Sulphur Recovery (2 trains Claus) Sulfreen
  - Sulphur For sale
  - Thioorganics
  - Commercial Gas
  - Stabilization
  - Stabilized Crude & Condensates
  - Naphta

- **Désulfurization** (3 trains amines)
  - Sweet Gas
  - Désulfurization
  - Mercaptan Removal (Molecular Sieves)

- **Stabilization**
  - Stabilization
  - Mercaptan Removal
  - Dew Point (Cooling)
  - Thio Chemistry

- **Sulphur Recovery**
  - Sulphur Recovery
  - Sulfreen
  - Sulphur For sale
An integrated carbon capture, transportation and geological storage in a depleted gas field project

Industrial scale:
30MW\textsuperscript{th} oxycombustion
60'000 t/year CO\textsubscript{2}
Integrated within existing facilities
## Project schedule milestones

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**Start up of operational phase : July 3rd, 2009**
Official integrated project inauguration on Jan. 11th, 2010
Oxycombustion as part of a CCS integrated pilot

- Industrial scale 30MWth oxycombustion unit with gas
- Revamping of a conventional boiler
- CO$_2$ transport and injection for 2 years
- 120 kt CO$_2$ storage in a depleted reservoir
- First CO$_2$ injection for storage in France
- Public acceptance with consultation and dialogue
- Upscaling of oxyboilers for high steam/power generation
Principle of oxycombustion

**AIR COMBUSTION**

![Diagram showing the principle of oxycombustion](image)

- **CH₄** (5%)
- **O₂** (22%)
- **N₂** (73%)
- **H₂O** (12%)
- **CO₂** (15%)

**COMBUSTION**
Oxyburner and oxyboiler upscaling program set up

- Upscaling know-how
- CFD modeling using proprietary code
  - Specific to oxycombustion
  - Calibrated with real oxycombustion data

1 MW prototype
AL-CRCD rig

4 x 8 MW demo
Total-Lacq pilot plant

n x 30 MW
first of a kind
industrial
oxy-boiler

2006
2008
> 2010
1 MWth Oxycombustion test rig

- Objectives:
  - Expand scientific knowledge on oxy-flames.
  - Contribute to industrial oxyburner design
  - Test Lacq 1MW prototype burner

- Versatile and functional test rig
  - Variable FGR rate and temperature
  - Liquid / gas fuel feed capability
  - Cold wall configuration
  - Combustion monitoring
Air Liquide Oxy-burner Principle

No external oxygen mixing:

- Intrinsic oxygen flames advantages: flame stability, turndown ratio, uneasy fuels.
- Improved operating safety: dedicated pure oxygen circuit all along distribution system.
- Additional flexibility to adjust FGR rate.
Capture facilities within Lacq existing utilities plant
Construction Phase at Lacq

ASU

Flue Gas Recycle

Boiler

ASU

Oxy-burner quarls

Boiler
Air Separation unit by cryogenic distillation

- 240 t/day of oxygen
- 95% to 99,5% oxygen purity
- Nitrogen for CO2 dehydration molecular sieves regeneration
Air Separation Unit for Lacq pilot

- Standard ASU packaged plant
- 240 tpd O₂
- LP: 1,8 bar abs
- Variable purity (95-99,5% O₂)
- No oxygen storage
Industrial steam boiler in oxycombustion mode

40 t/h of steam 60b/450°C (30MWth) to HP steam network

wet CO₂ recirc.

oxyburners

revamping

Gas
Oxyburner implementation into Lacq CH2 boiler

- Retrofitting of an air-fired boiler
  - Oil & Gas boiler configuration
  - Fixed geometry:
    - four horizontal burners
    - Chamber: L 5 m; W 4.5m; H 6-7m

- Careful sealing at every interface to minimize air in-leakage

- Fluid distribution control and measurement

- Operating mode

- Safe operation Safety analysis

- Tests and measurement plans

Openings for the four existing air-fired natural gas burners

Existing measurement port
Oxyburner implementation into Lacq CH2 boiler
"Oxyfiring" started on July 3rd, 2009

Ø = 1 m
Wet scrubbing of high CO2 content flue gas

- Flue gas (~ 48% H$_2$O, 48% CO$_2$) @ 200°C and atm pressure
- Venturi scrubbing
- Wet scrubbing
  - Water condensed
  - flue gas outlet @ 50°C
CO2 compression, dehydration and export

wet CO₂ compressor
dedration
Transportation and injection into a gas depleted reservoir

**Lacq**

City of PAU

WH 50 barg

ROUSSE-1 Injection well

Existing right of way

**Typical CO₂ composition**

- CO₂: 92.0 %
- O₂: 4.0%
- Ar: 3.7%
- N₂: 0.3%
- Water content # 30ppm
Facilities at Rousse well pad
CO₂ Monitoring plan

Injection phase

- Flowrate & composition of injected gas
- P and T borehole and reservoir pressure (optical fibre)
- Microseismic monitoring of reservoir and caprock
  - baseline before injection
- Gas migration at the surface:
  - soil gas survey (baseline before injection)
  - surface detectors on well pad
- Environmental monitoring
  - Underground aquifers and surface water
  - Fauna and flora

Post injection phase

- P and T bottom hole and reservoir pressure
- Microseismic monitoring of reservoir and caprock
- Gas migration at the surface
- Environmental monitoring
Monitoring system installation during work over
RSE 1 Avant le work-over

Casing 18 5/8"
120m
Casing 13 3/8"
1096m
Casing 9 5/8"
3465m
Top ciment
2270m
Top ciment
4412m
Casing 7"
Top liner 4433m
4539m
Liner 5"
4732m
Top ciment 4790m
Trou ouvert 4 1/8"
5215m

RSE 1 Pendant le work-over

Casing 18 5/8"
120m
Casing 13 3/8"
1096m
Casing 9 5/8"
3465m
Top ciment
2270m
Top ciment
4412m
Casing 7"
Top liner 4433m
4539m
Liner 5"
4732m
Top ciment 4790m
Trou ouvert 4 1/8"
5215m

RSE 1 Complétion installée

Casing 18 5/8"
120m
Casing 13 3/8"
1096m
Casing 9 5/8"
3465m
Top ciment
2270m
Top ciment
4412m
Casing 7"
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Liner 5"
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MEILLON
4919-5145m

OPERATIONAL SEQUENCE
CBL 7” 1967
Bottom cement log

2009
Storage complex:
Overburden, resources, migration paths

Well (injector, observation, others)

Storage site

Caprock
Reservoir
Structure

Trap
Seismic data and wells available

Earth model perimeter

Meillon-Saint Faust

Lacq

Lagrange

Vic Bibi

10 km

3D
2D
Aquifers within the storage complex

Coupe géologique N-S à travers Rousse

- Sables Infra-molassiques
- Calcaires de Lasseube
- Nappe intra-molassique
- Nappe Gave de Pau
- Rousse
Microseismic monitoring and RSE1 well work over

6 Baratte
Alt.: 200m
Base Molasse : 325mGL

1 Pont d’Oly
Alt.: 175m
Base Molasse : 330mGL

2 Capderou
Alt.: 278m
Base Molasse : 300mGL

5 La Bourdette
Alt.: 189m
Base Molasse : 250mGL

4 Borne Matheu
Alt.: 347m
Base Molasse : 250mGL

3 Moulin de l’Oasis
Alt.: 180m
Base Molasse : 90mGL

500 m
A long process for a well known depleted gas field

2006 : Early presentations of the concept
Jan – Oct 2007 : Formal information to the french administration, mayors
March 2007 : Public meeting Rousse
Nov 2007 : press conference and launch of the dialogue phase
Nov – dec 2007 : 3 public meetings (Jurançon, Pau, Mourenx)
Apr – June 2008 : several meetings with small groups
May 2008 : meeting with all mayors from Lacq to Rousse
June – July 2008 : CLIS n°1 et 2
July 2008 : working meetings with Jurançon
July – Sept 2008 : official public hearings
Sept 2008 : CLIS n°3
Dec 2008 : well pad open to the public – information letter to project neighbours
Feb – March 2009 : CLIS n°4, CLIS n°5
May 2009 : Official permit to capture, transport, inject and store 120’000 t of CO2
June 2009 : CLIS n°6
July 2009 : CO2 capture start up - first oxycombustion test
July 2009 : One local NGO taking administrative actions against official permit
Sept. – Oct. 2009 : pre-injection baseline data and detailed monitoring procedures set up
Jan. 8th 2010 : Fully operationnal CCS project
In order to ensure that the consultation process initiated by Total is useful to all concerned, and to guarantee a meaningful dialogue with all stakeholders, the Group undertakes to:

- Provide full, honest and clearly expressed information about the project (characteristics, impact, surveillance and monitoring system, etc.) so as to facilitate the sharing of knowledge and to foster open discussion with all stakeholders.
- Execute and report on the project with advice from a number of independent scientific and technical experts.
- Provide answers to all questions asked by stakeholders or members of the public.
- Publish minutes of all public discussion meetings as well as a summary of the consultation process, and take these into account in deciding final project details.
- Provide stakeholders and general public with regular updates of project progress and timetable.

Project information also available on www.total.com/corporate-social-responsibility
Project public information
http://www.pyrenees-atlantiques.pref.gouv.fr/
Lessons learned from early operations

- **Oxycombustion**
  - No major issue from revamping (but initial boiler status assessment critical)
  - Several weeks of control system tuning
    - Pressure control in the boiler
    - Flame stability
    - Change of load
    - Automatic switch from air to oxy
  - Air and oxygen firing compatibility is essential
  - After adjustments, very smooth operation for plant operators

- **Compression and drying**
  - NOx content in condensed water differs from design
  - Liquid carry over in compression is more critical than classical gas compression

- **Transportation and injection**
  - No problem of pipeline start up
  - No problem of injectivity
  - Microseismic system downhole sensors sensitive to temperature
  - Microseismic passive monitoring is a promising technique
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