Lacq CCS Integrated Pilot

A First

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Lacq pilot project overview

CCS pilot, Lacq, France

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..)

Lacq Field Test Compressor

Flue gases treatment package

Acquire expertise and reduce costs for future industrial deployment

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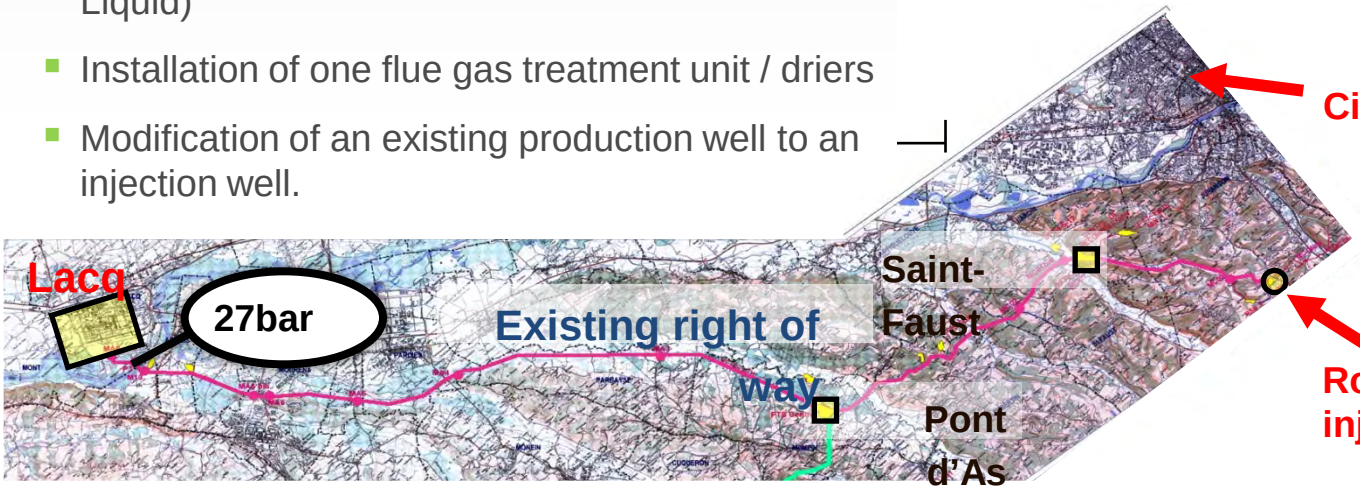
Project description

- Budget : CAPEX 60 M Euros
- Up to 90000 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.



This industrial operation is planned to capture and trap ~ 90,000 tonnes of CO_2 over a 3 1/2-year period (eq to the exhaust emissions of 30,000 cars)

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Project phasing

	2006	2007	2008	2009	2010	2011	2012	2013
Site screening and conceptual studies								
Basic engineering studies								
Detailed engineering and procurement								
Construction works								
Injection well work over								
Facilities running (capture)								
Injection								
Environemental & seismic base line surveys								
Monitoring								
Information to stakeholders								
Public inquiry								
Permitting process / regulatory agencies					Official authorization 05/2009		Official authorization for 18 month prolongation 11/2011	
Injection schedule					Start of injection 8th Jan. 2010		End of injection July 2013	
Reporting to regulatory agencies								

Start-up of operational phase: July 3rd, 2009
First CO_2 injection in Rousse reservoir: January 8th, 2010
End of injection: 8th July 2013

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Permitting and public acceptance

- 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

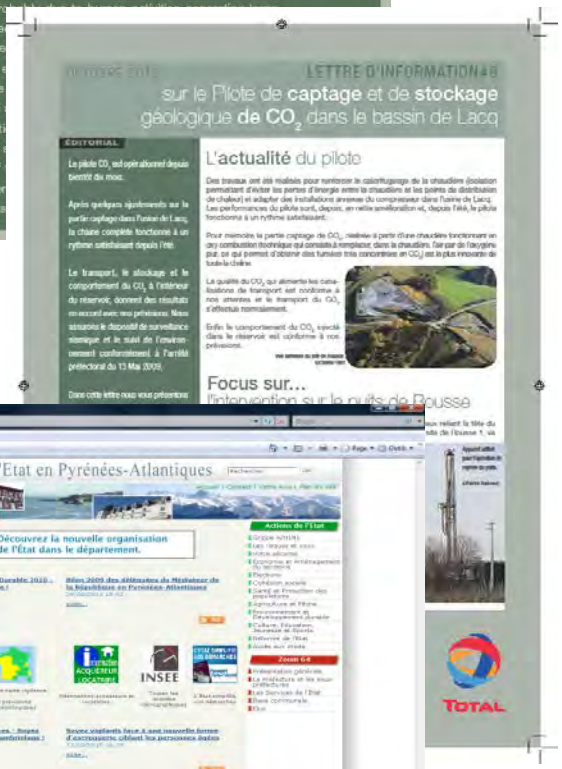
- Public dialogue – transparency policy
  - Identification of Stakeholders (ONG, mayors…)
  - Early public meetings in 2007 (4 public meetings)
  - Follow up information committee (7 meetings)
  - Information letter every quarter (14)
  - Hot line

- 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



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Lacq pilot project technical description

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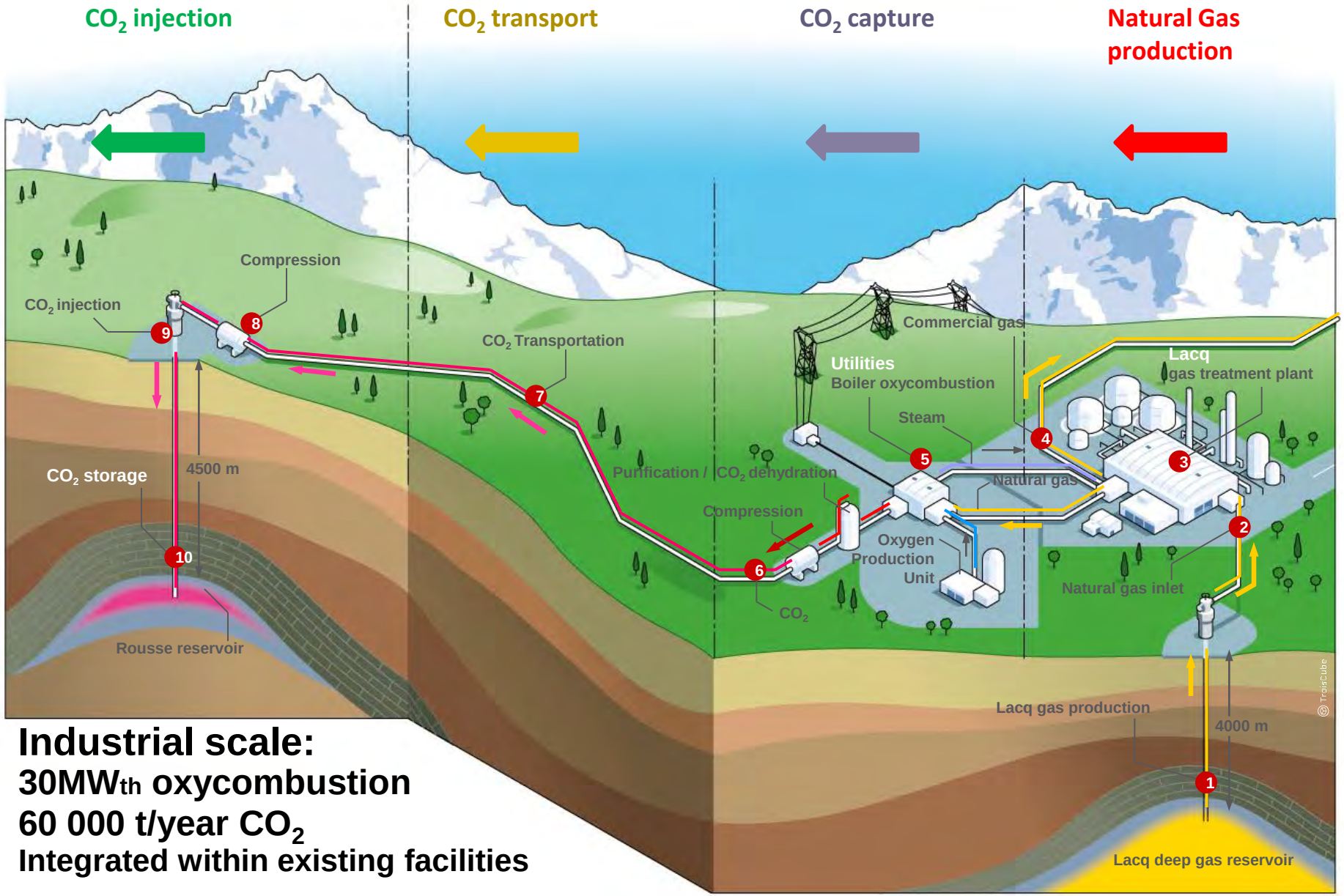
A complete industrial chain



Industrial scale:

30MW$_{th}$ oxycombustion

60 000 t/year CO_2

Integrated within existing facilities

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Capture description

Air separation unit

Cryogenic unit
(Air Liquide)
O_2 : 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

Wet CO_2 compressor

From 1barg to 27 barg

Dehydration Unit

Outlet : < 20 ppm of water

Transport

CO_2 composition
(@98% O_2 purity)
CO_2 : 92.0 %
O_2: 4.0%
Ar: 3.7%
N_2: 0.3%

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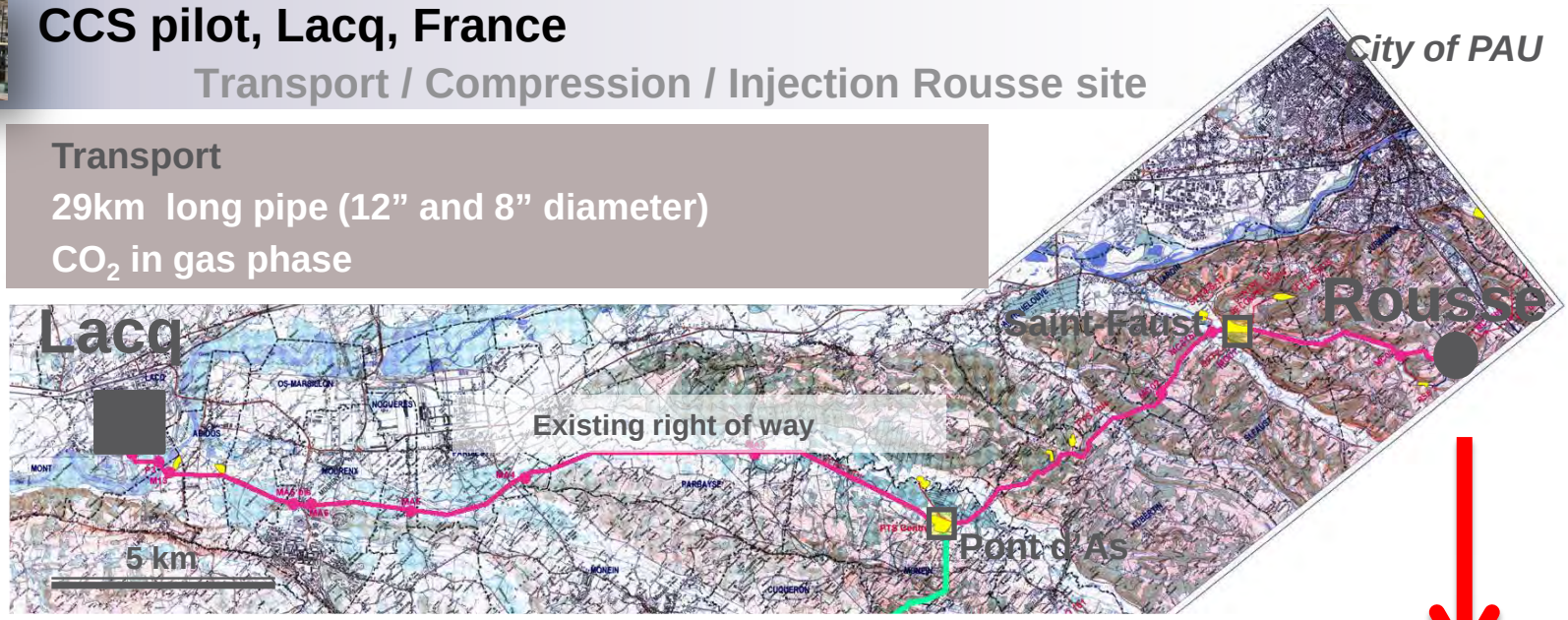
Transport / Compression / Injection Rousse site

Transport

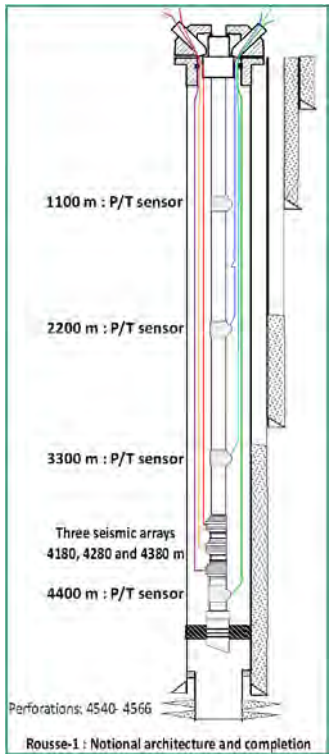
29km long pipe (12” and 8” diameter)

CO_2 in gas phase

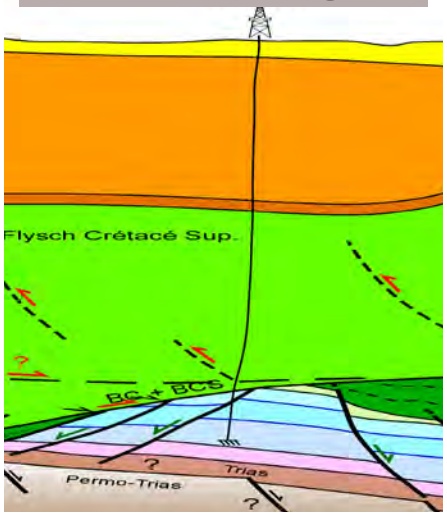


Rousse compressor

Pinlet: 27bar Poutlet: 51bar



Rousse storage



Depleted gas reservoir @ 4500m/GL

Surface Operational Feedback

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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%O_2 dry)
    - Ÿ Even when operating at 99.5% vol O_2 purity (no N_2 from ASU)
    - Ÿ Source of N2 is from the commercial gas (~0.4% vol N_2)
- **Cools down the flue gas from 220 C to 30 C (design was 50 C)**
  - ☺ No issue

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Lacq compressor 1/4

- **Wet CO_2 stream compressor**
  - Ÿ LMF 3 stage reciprocating non lubricated / Max discharge P=27bar
  - Ÿ Cylinders in cast iron / all other parts made of acid resistant materials
  - ☹ Corrosion problems (now resolved)

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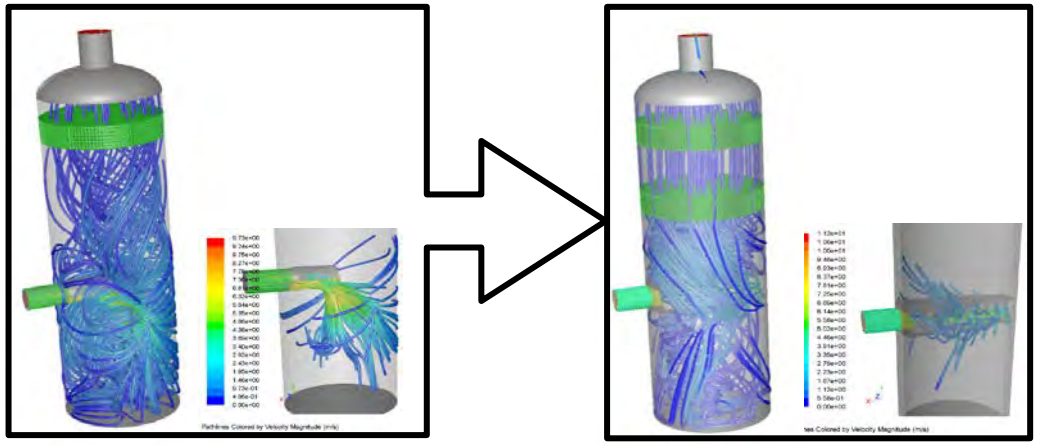
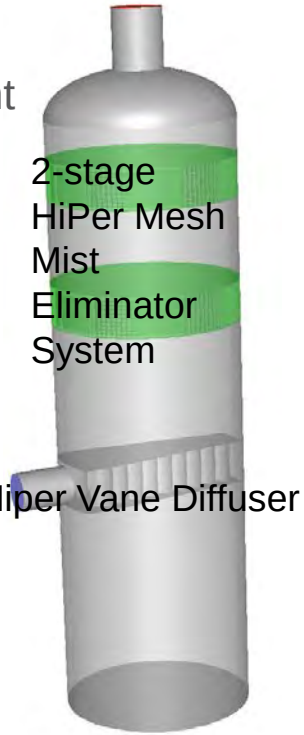
Lacq compressor: Corrosion remediation 4/4

- **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 CO_2 stream before compression
- **Slight increase of compressor suction temperatures**
  - To minimize condensation in the compressor
- **Recycling of dry CO_2 (downstream dryers) to compressor inlet**
  - To dry the CO_2 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**

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Lacq Industrial chain

- **“Air Liquide’ Molecular sieve technology : Measured [H_2O] < 10 ppm vol. compare to a design value of 30 ppm (= water due point around -50 C)**

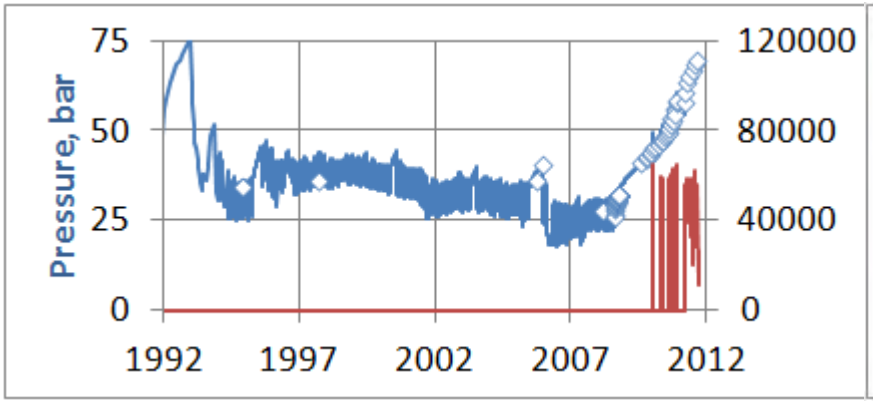
☺ **No issue**

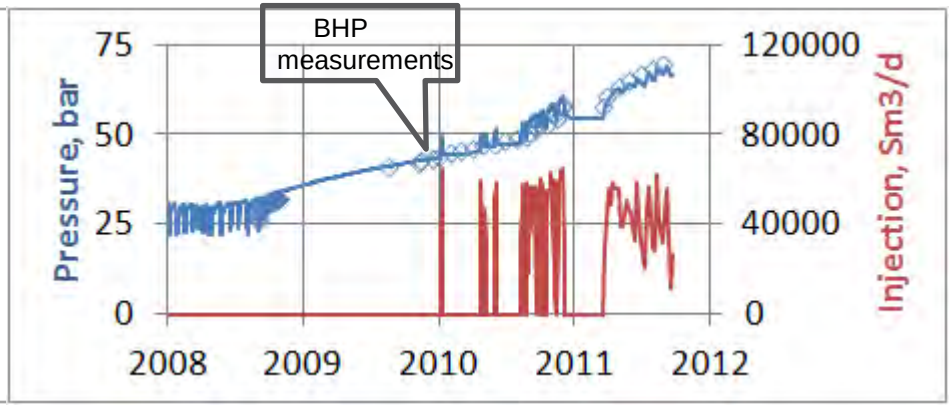
- **CO_2 is transported in gas phase at 27bar max**
  - Ÿ 29 km long existing carbon steel pipe (Ø 8" / 12")
  - Ÿ Dry CO_2 rich stream avoids corrosion
  - ☺ No issue
- **Rouse Dry Compressor**
  - ☺ **No issue – Works on design**
- **Well head and well**
  - **Standard gas production technology and 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**

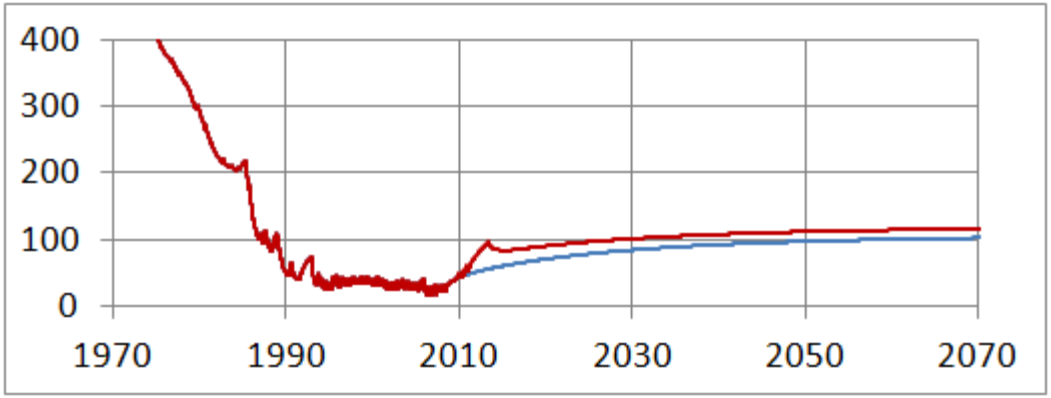
Sub- Surface Operational Feedback

Sub-surface Feedback monitoring
Bottom hole P measurement

- **Static reservoir pressure is increasing due to CO_2 injection. The reservoir pressure increase is as per the predictive model. (Eclipse 300 compositional modeling)**

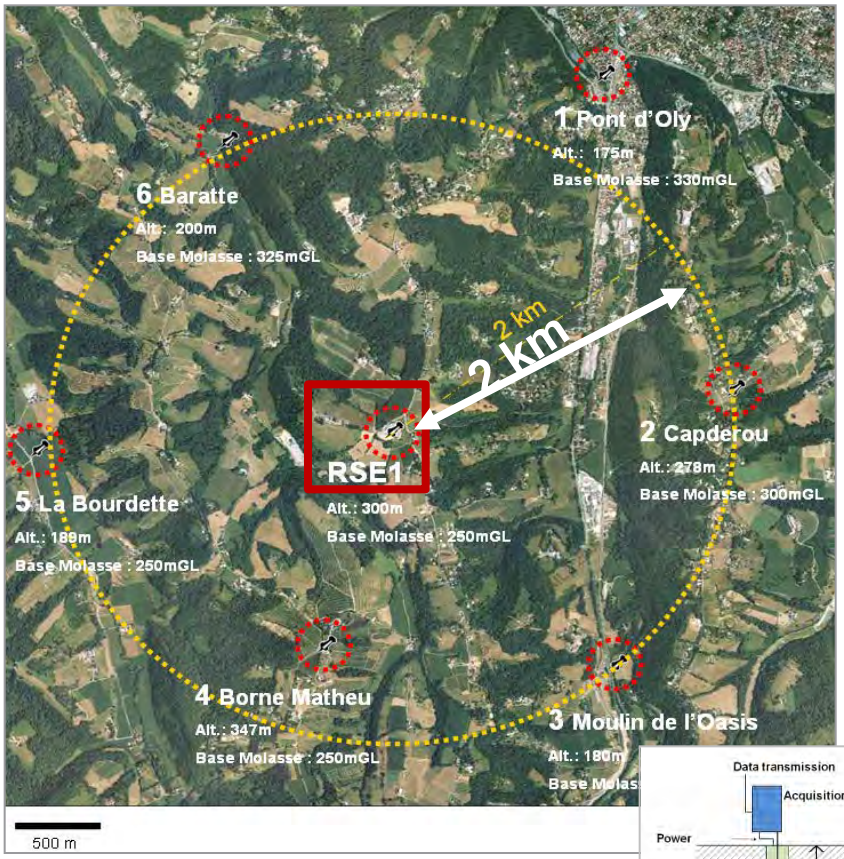


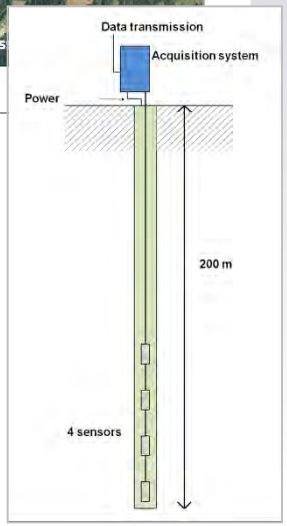




Long term pressure impact (bar) of CO_2 injection
- No injection
- 100 kT CO_2 injection

Sub-surface Feedback monitoring
Microseismic monitoring





- **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 sismicity**
- **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**

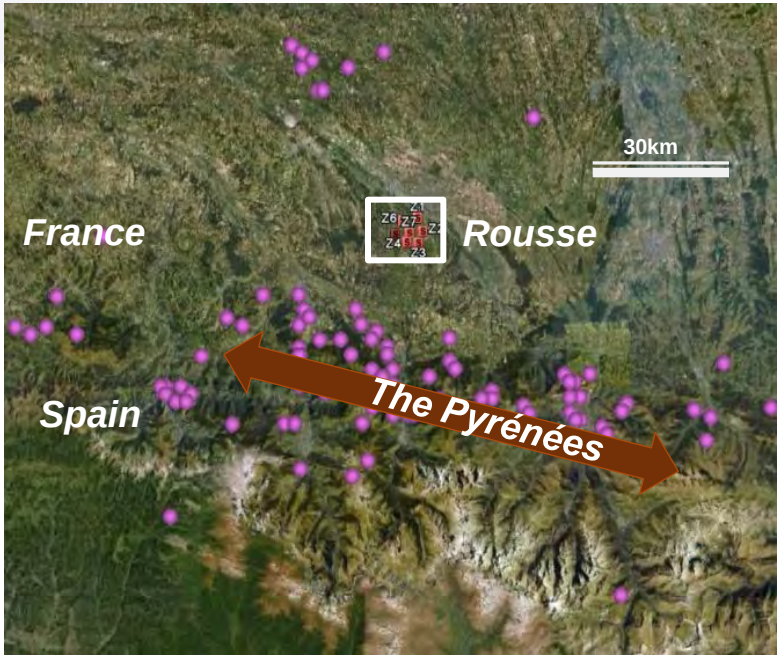
Sub-surface Feedback monitoring

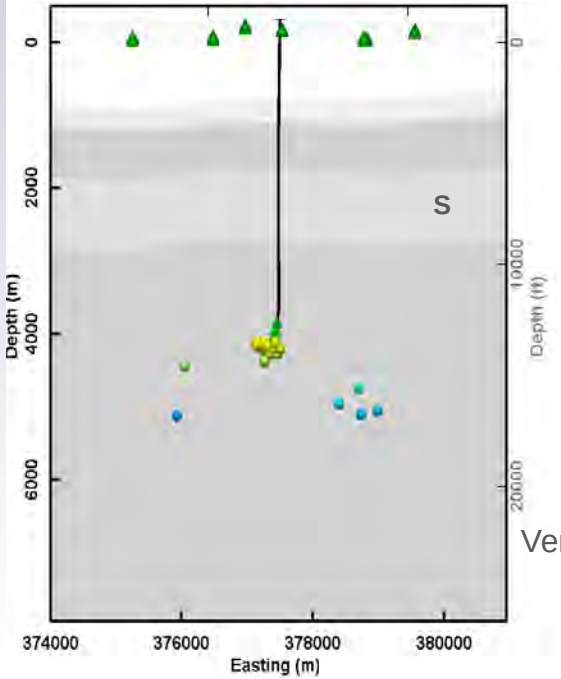
Microseismic monitoring

- Calibration by real shots
- Mainly natural seismic activity linked to northern front accident of Pyrenées 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**

Magnitude	faille (en m)	Déplacement (en mm)
-3	0.31	0.015
-2	1	0.05
-1	3.1	0.15
0	10	0.50
1	31.6	1.58
2	100	5.00
3	316.2	15.81
4	1000	50.0





Vertical cross-section

Environmental Plan Monitoring and feedback

Environmental monitoring
Soil gas, Water, Fauna & flora

				Winter	Spring	Summer	Autumn
Environment	Water quality	Surface water (rivers)	Chemistry				
			Bio-indicators				
		Phreatic aquifer (springs)	Chemistry				
		Grounwater	Chemistry				
	Ecosystems	Fauna					
		Flora					
	Soil gas						
Site	Res. & Caprock	Microseismic + P&T		Permanent			
	Injection well	CO2 sensors at injection pad		Permanent			
		Well annulii		Permanent			
		P & T		Permanent			
		Flowrate, Composition		Permanent			
Additional R&D (French National Research Agency, Paris & Nancy Univ., INERIS, IFPEN, BRGM, IPGP etc.)	Soil gas	C isotopy, Inert gas, radon					
	Phreatic aquifer	6 m deep shallow well	Chemistry	Permanent			
		80 m deep shallow well	Chemistry, water level	Permanent			
		Springs	Chemistry,	Permanent			
	Atmospheric CO2 concentration	Flux tower		Permanent			
		Infra red and lidar		In test			

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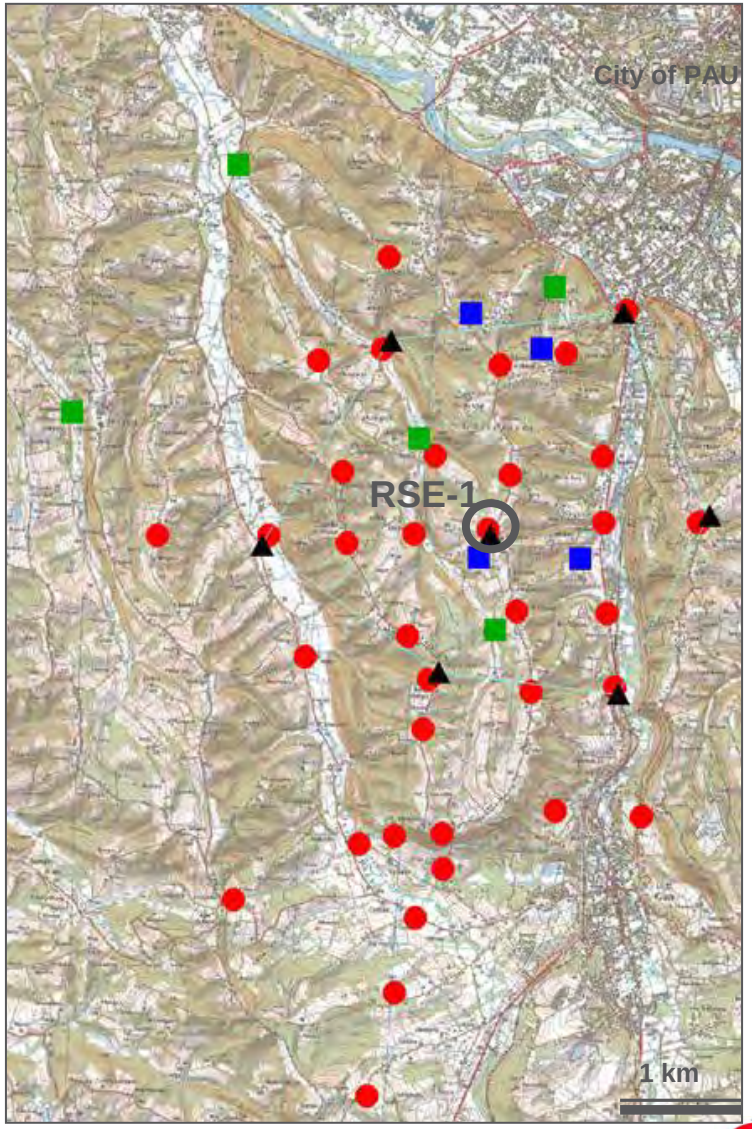
Environmental monitoring
Soil gas, Water, Fauna & flora

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).



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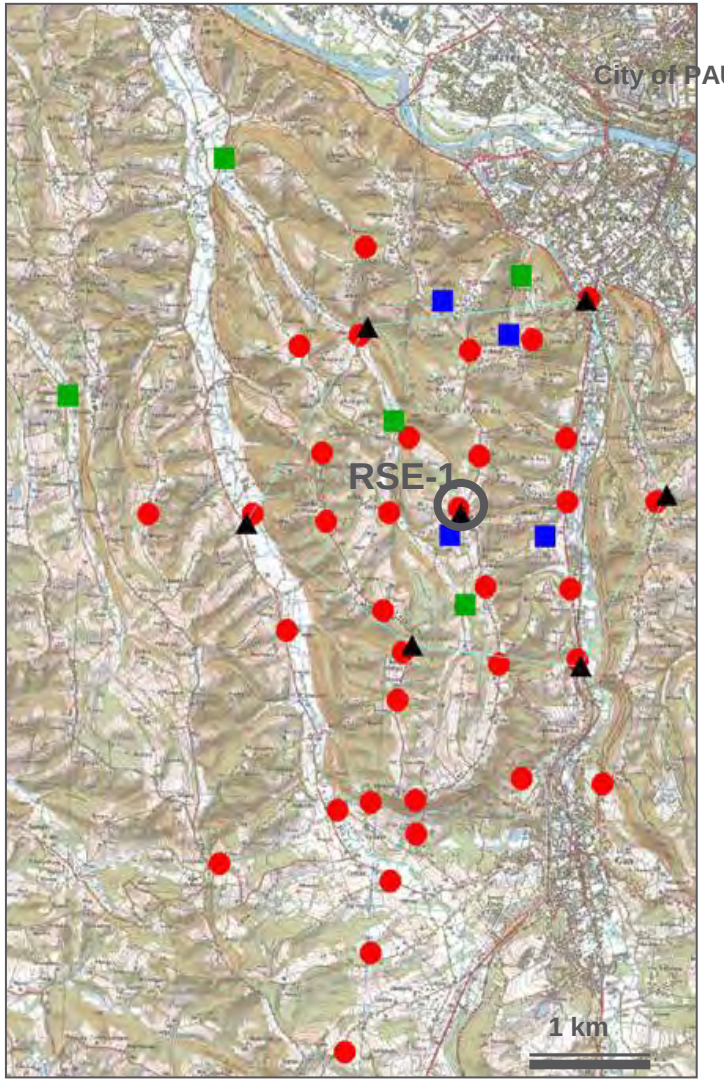
Environmental monitoring
Soil gas, Water, Fauna & flora

No deviation from Baseline surveys in 2009 have been recorded..



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Conclusion/ Way forward

- At this stage of the pilot (43000 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 CO_2 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 CO_2 capture technologies** which are required to cut down costs (CLC, Membranes, Cryogenics techno..)
- **The long term CO_2 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..

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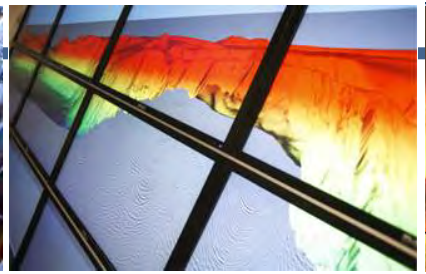


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