The experience of Lacq industrial CCS reference project

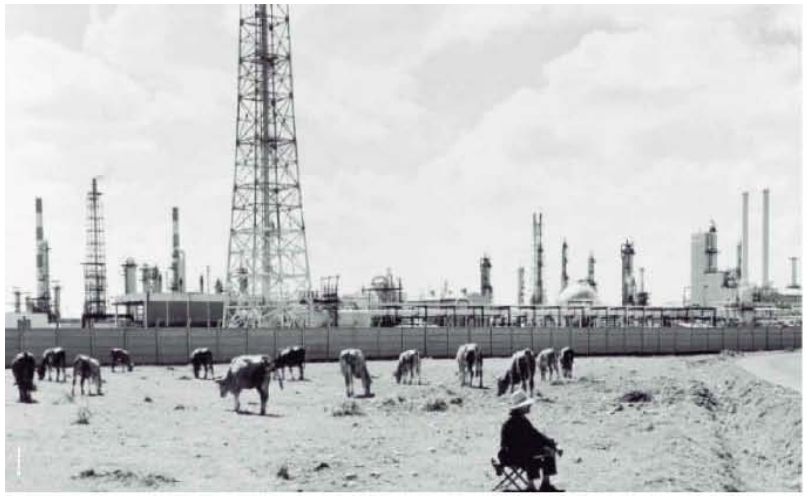
Carbon Sequestration Leadership Forum

Lacq, France - March 17th 2010

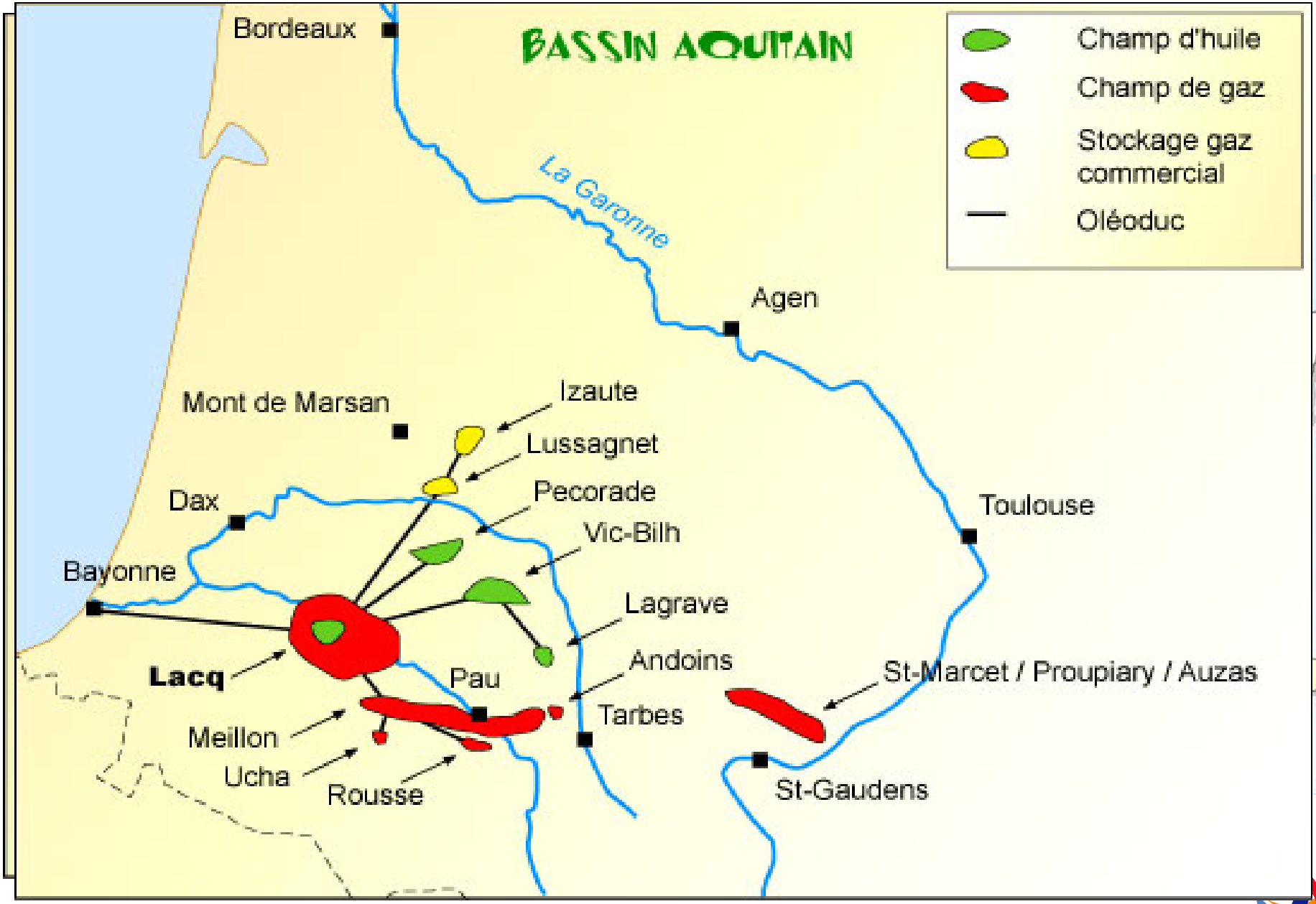
Nicolas AIMARD – Total CCS R&D Program Manager and Lacq CCS Project Manager

TOTAL

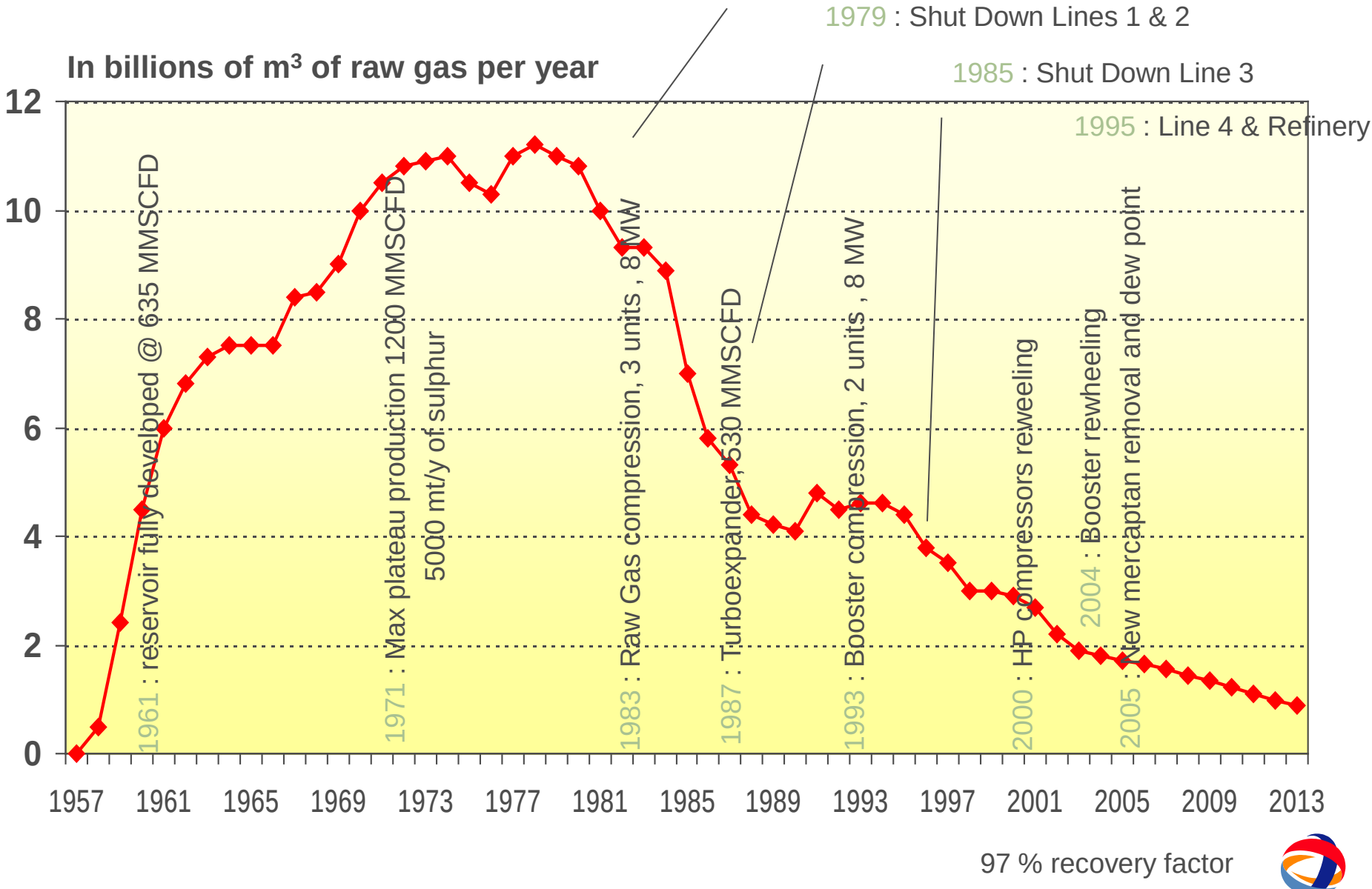
Total Exploration & Production France



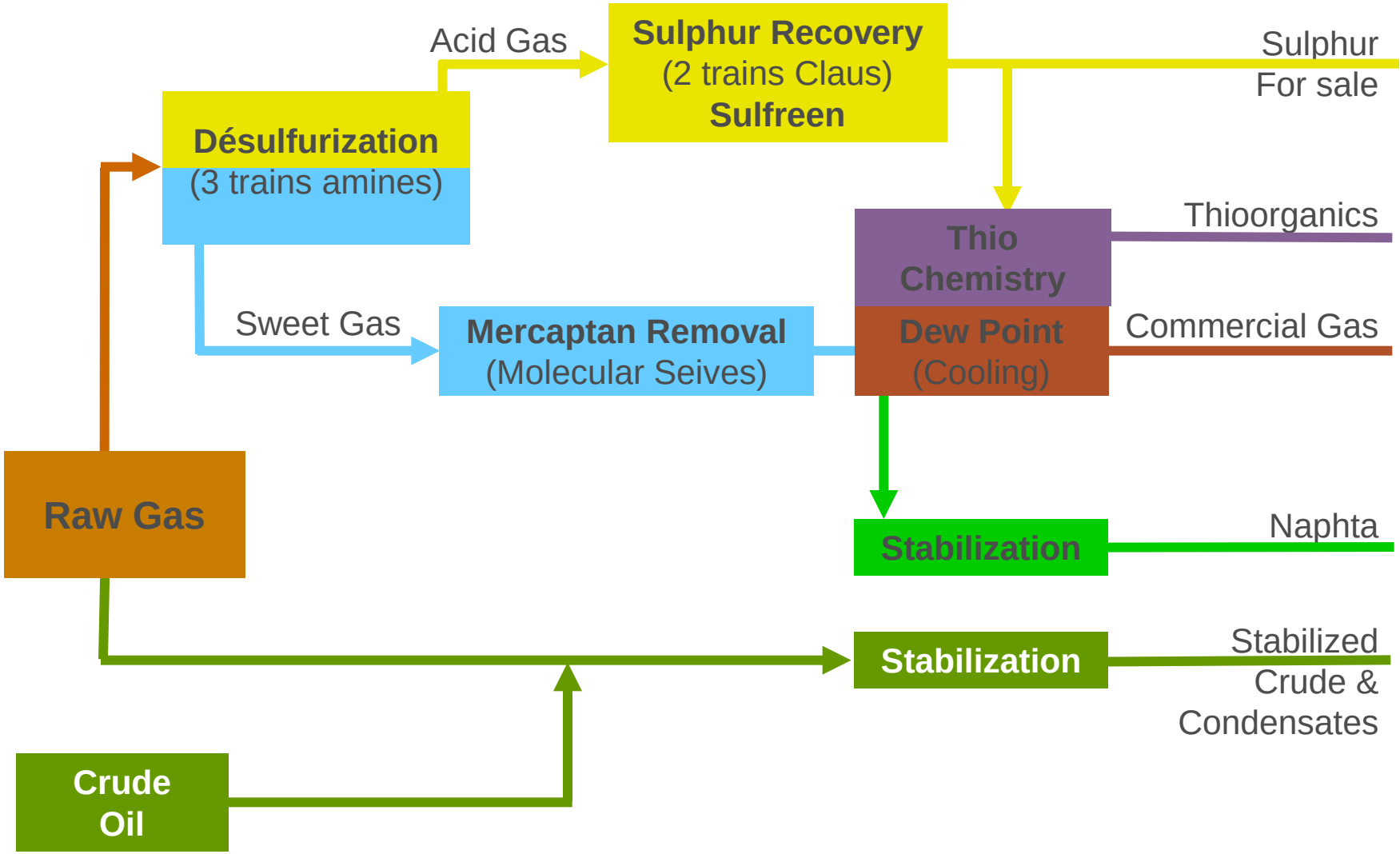
TOTAL


BASSIN AQUITAIN
Champ d'huile
Champ de gaz
Stockage gaz commercial
Oléoduc
La Garonne
Bordeaux
Agen
Toulouse
Mont de Marsan
Izaute
Lussagnet
Pecorade
Dax
Vic-Bilh
Bayonne
Lagrave
Lacq
Andoins
Pau
St-Marcet / Proupiary / Auzas
Tarbes
Meillon
Ucha
Rousse
St-Gaudens

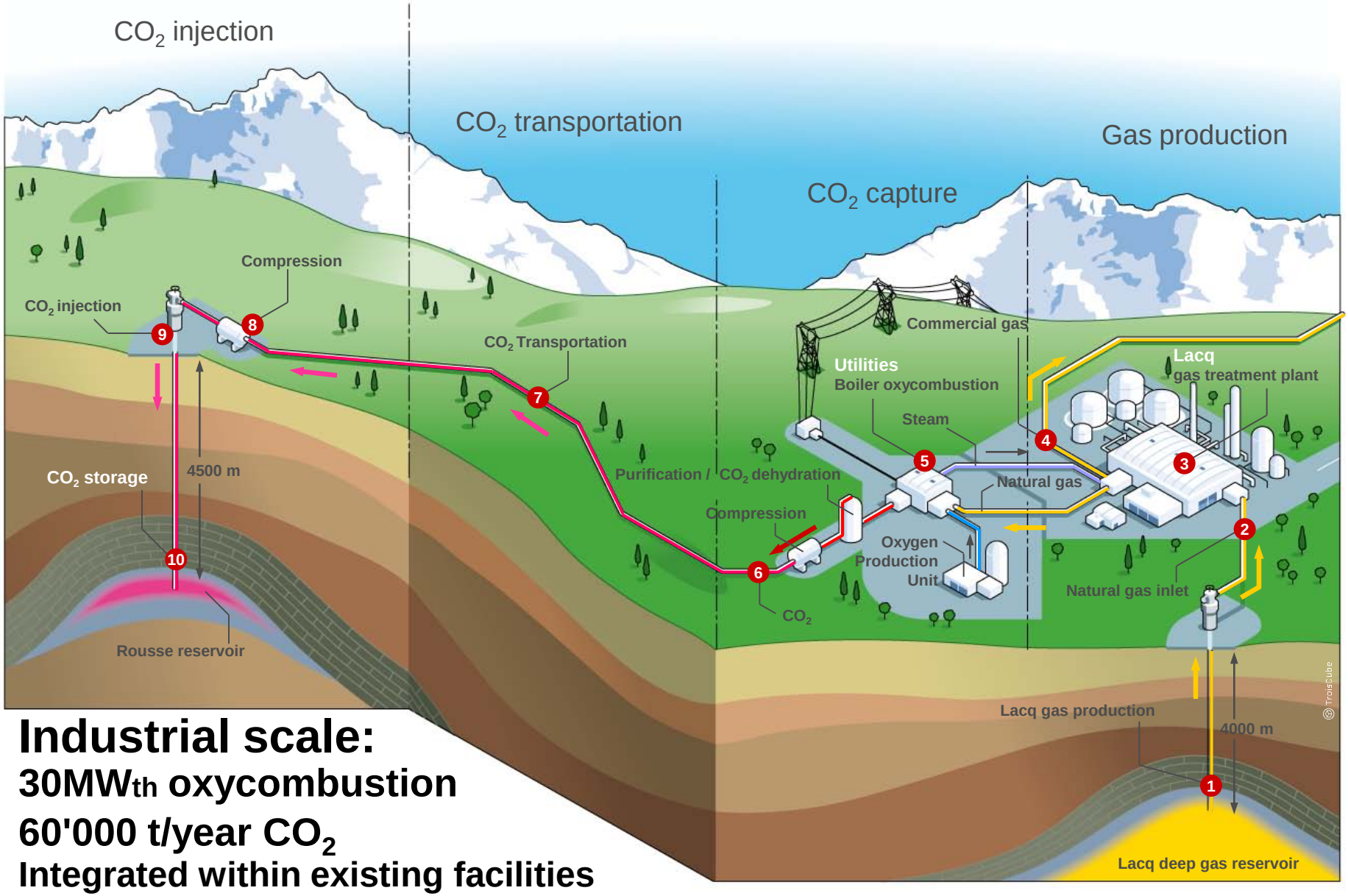
Gas production history – Forecast



Lacq Plant – General Flow diagram



An integrated carbon capture, transportation and geological storage in a depleted gas field project



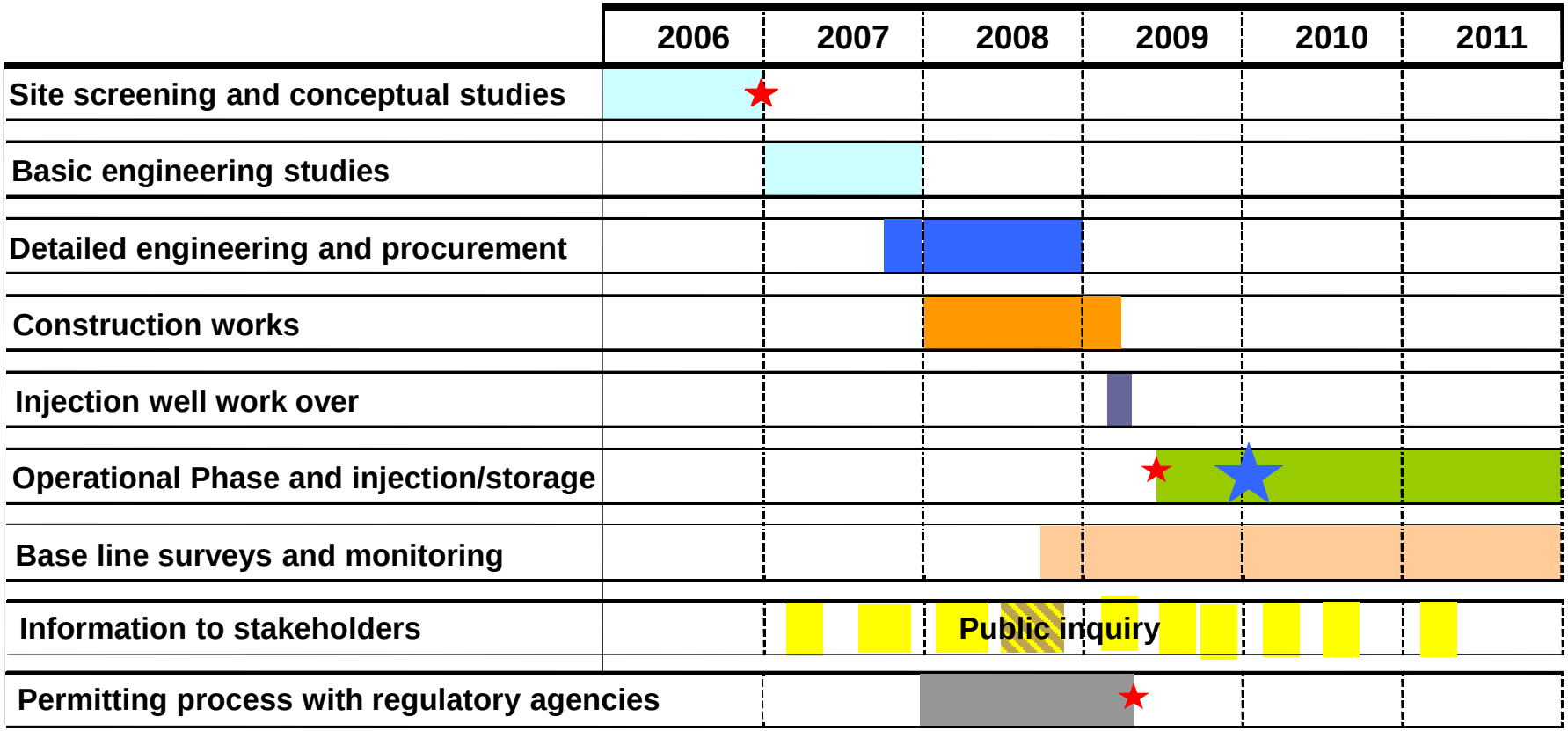
Industrial scale:

30MW$_{th}$ oxycombustion

60'000 t/year CO_2

Integrated within existing facilities

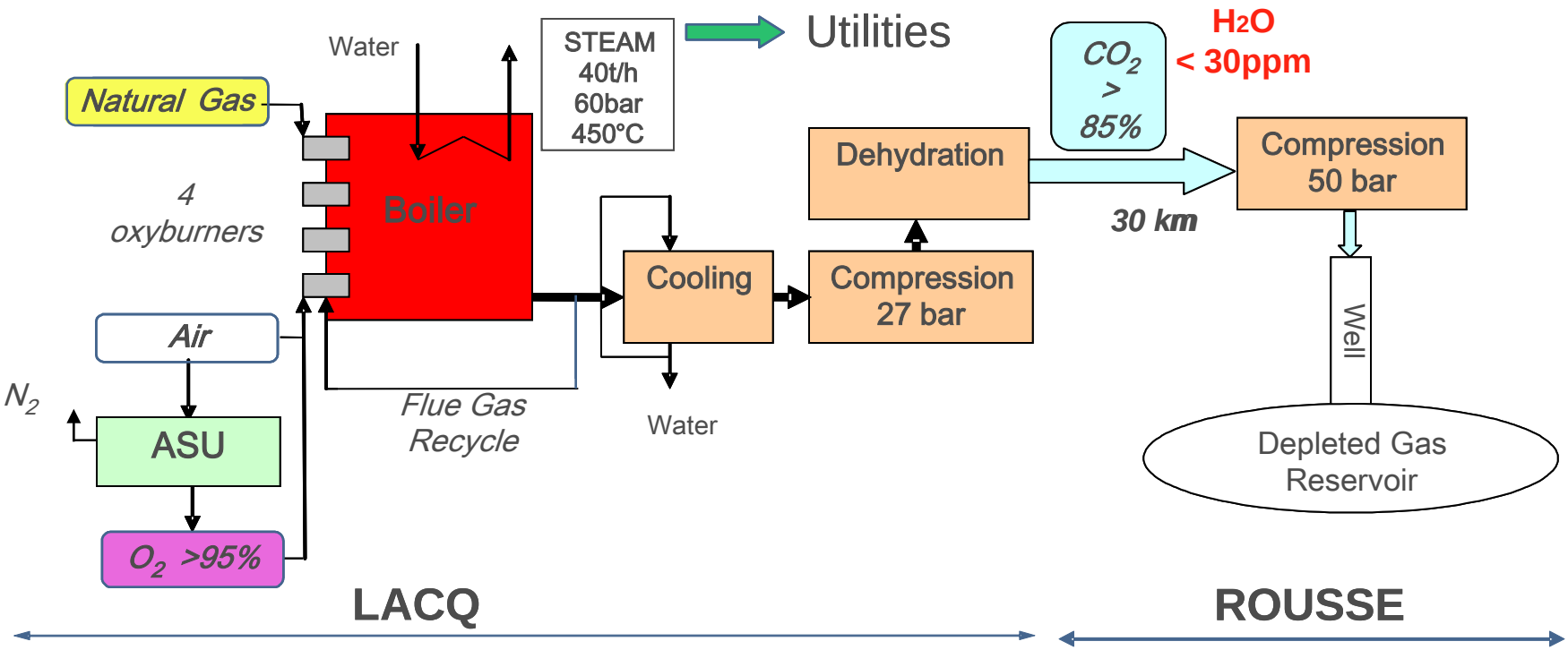
Project schedule milestones



Start up of operational phase : July 3rd, 2009

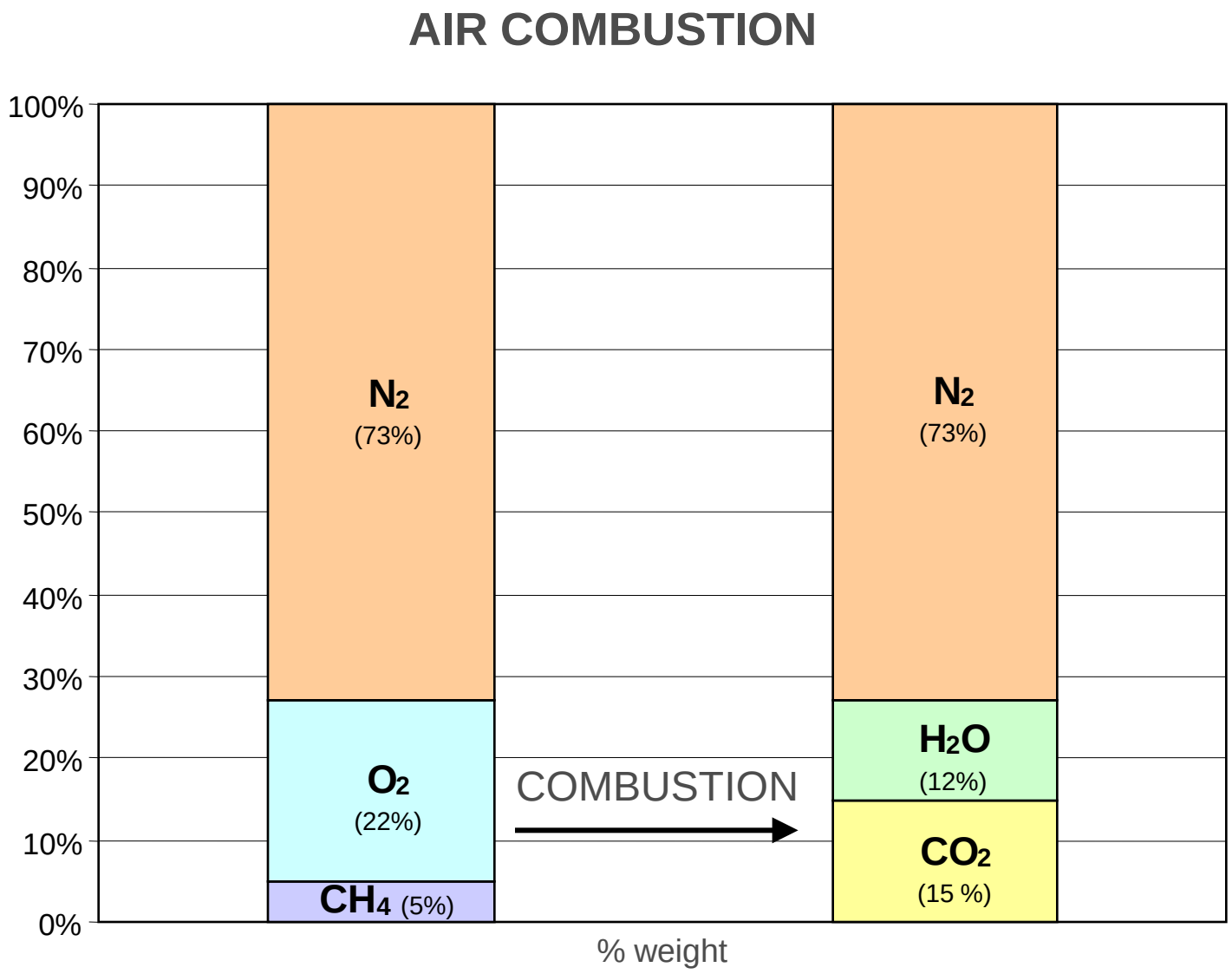
Official integrated project inauguration on Jan. 11th, 2010

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**

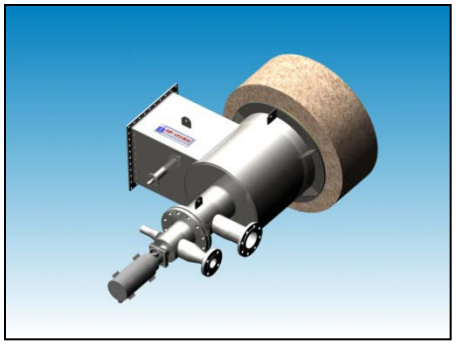
Principle of oxycombustion



Oxyburner and oxyboiler upscaling program set up

Size

1 MW prototype
AL-CRCD rig

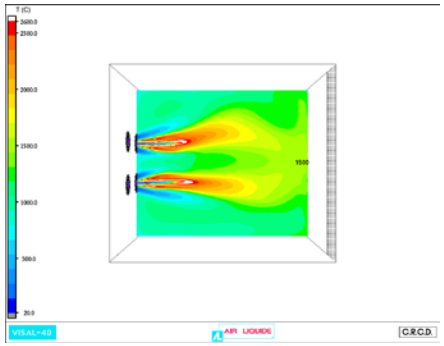


4 x 8 MW demo
Total-Lacq pilot plant

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

2006 2008 > 2010

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



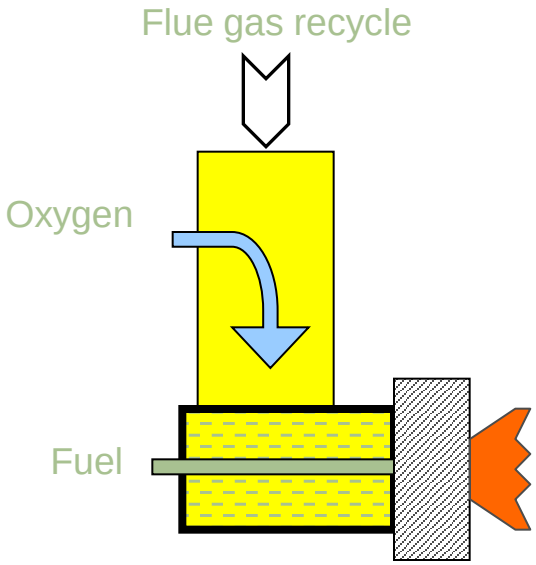
1 MWth Oxycombustion test rig

- **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

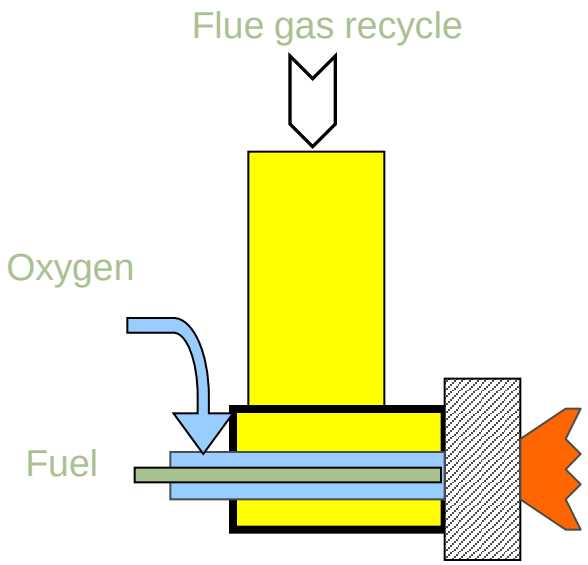
Air Liquide Oxy-burner Principle

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.**

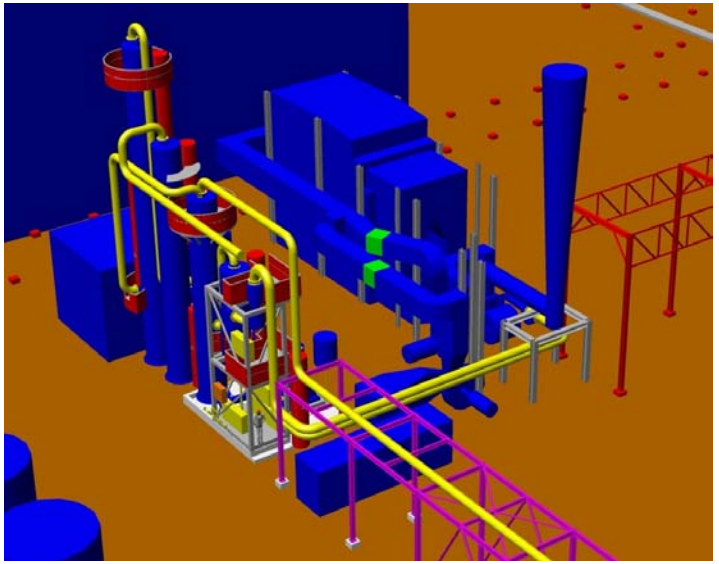


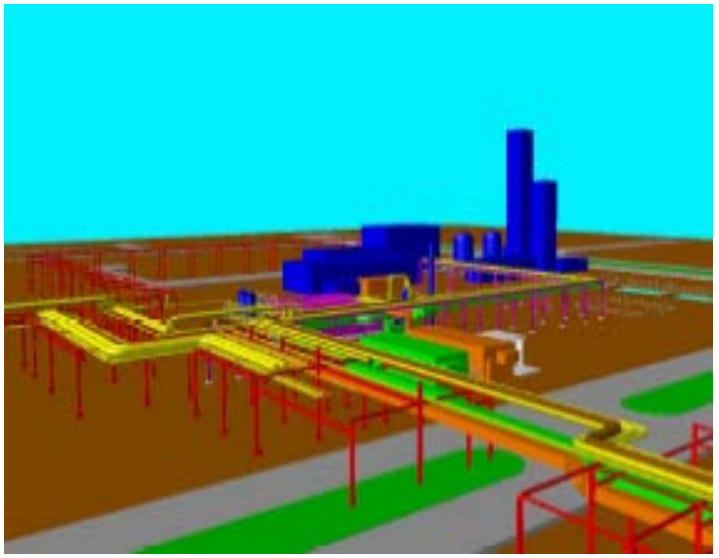
Synthetic air approach



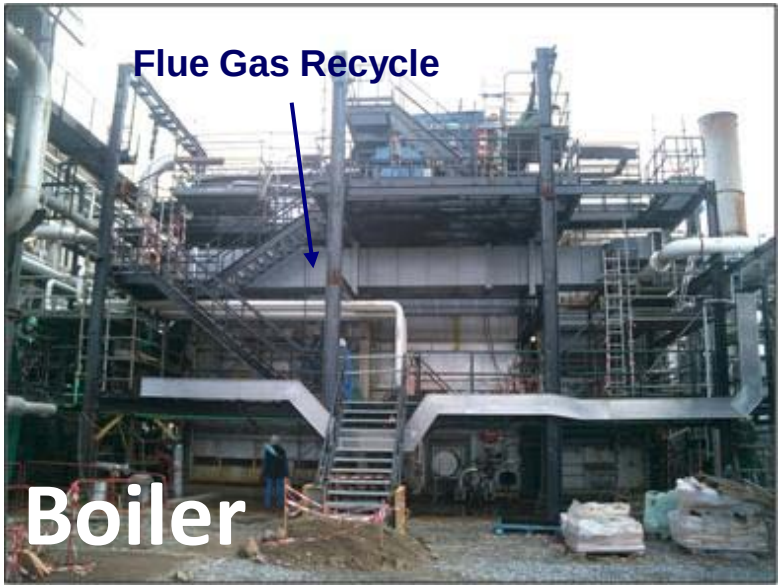
Air Liquide oxy-burner

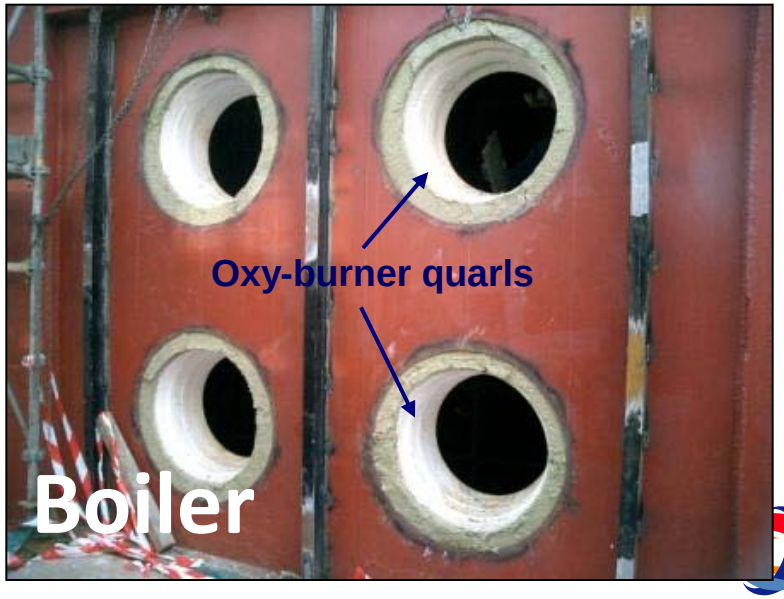
Capture facilities within Lacq existing utilities plant





Construction Phase at Lacq



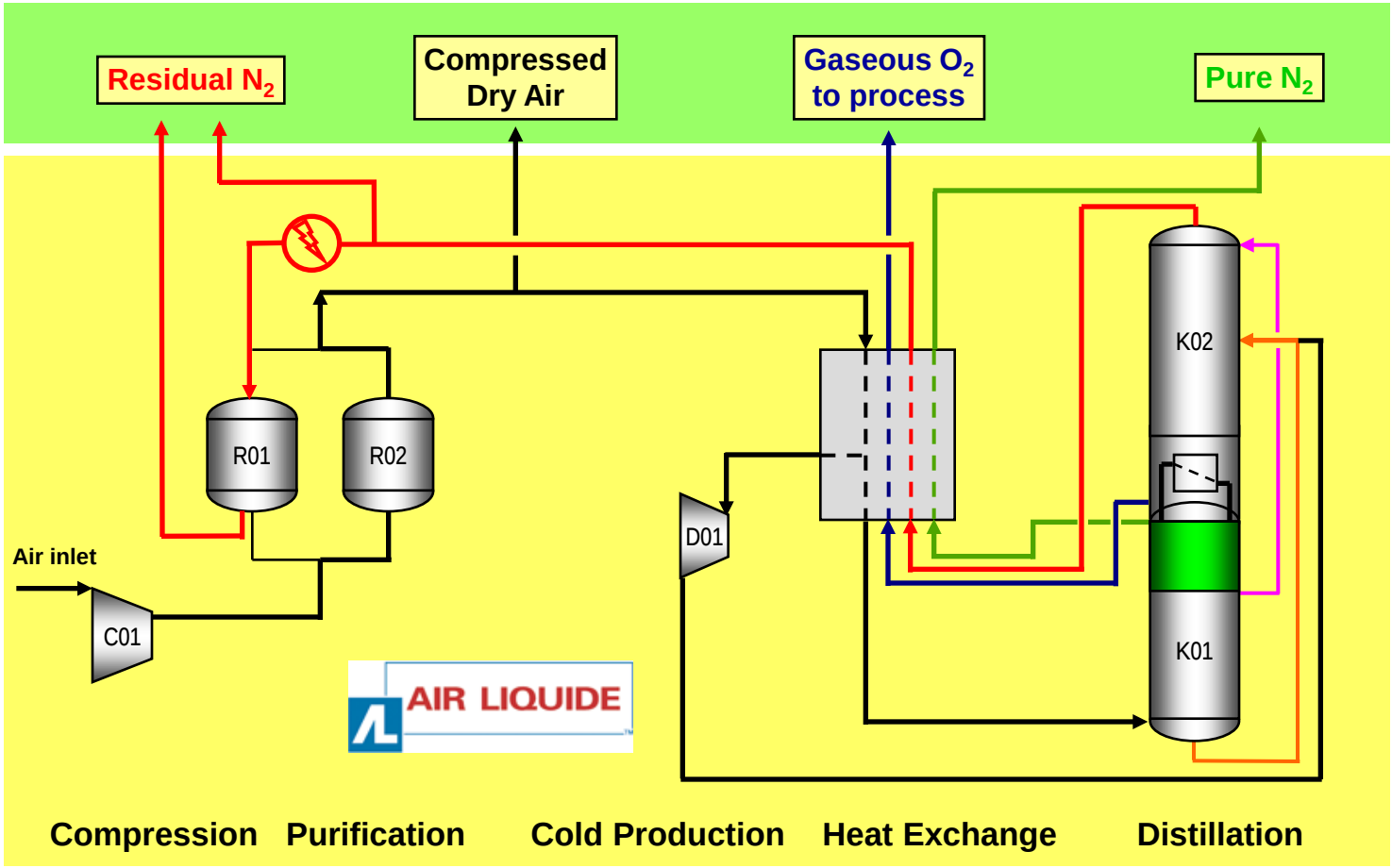


Air Separation unit by cryogenic distillation

- 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 O_2
- LP: 1,8 bar abs
- Variable purity (95-99,5% O_2)
- No oxygen storage

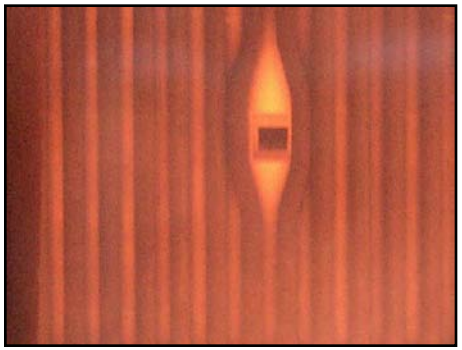


Industrial steam boiler in oxycombustion mode

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

Wet scrubbing of high CO2 content flue gas

- **Flue gas (~ 48% H_2O, 48% CO_2) @ 200°C and atm pressure**
- **Venturi scrubbing**
- **Wet scrubbing**
  - Water condensed
  - flue gas outlet @ 50°C

CO2 compression, dehydration and export

Transportation and injection into a gas depleted reservoir

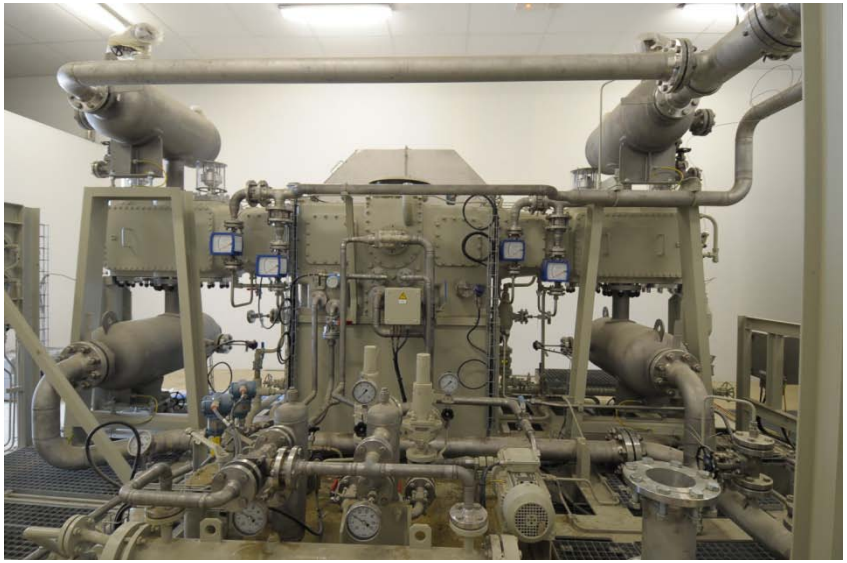
Typical CO_2 composition

CO_2:	92.0 %
O_2:	4.0%
Ar:	3.7%
N_2:	0.3%

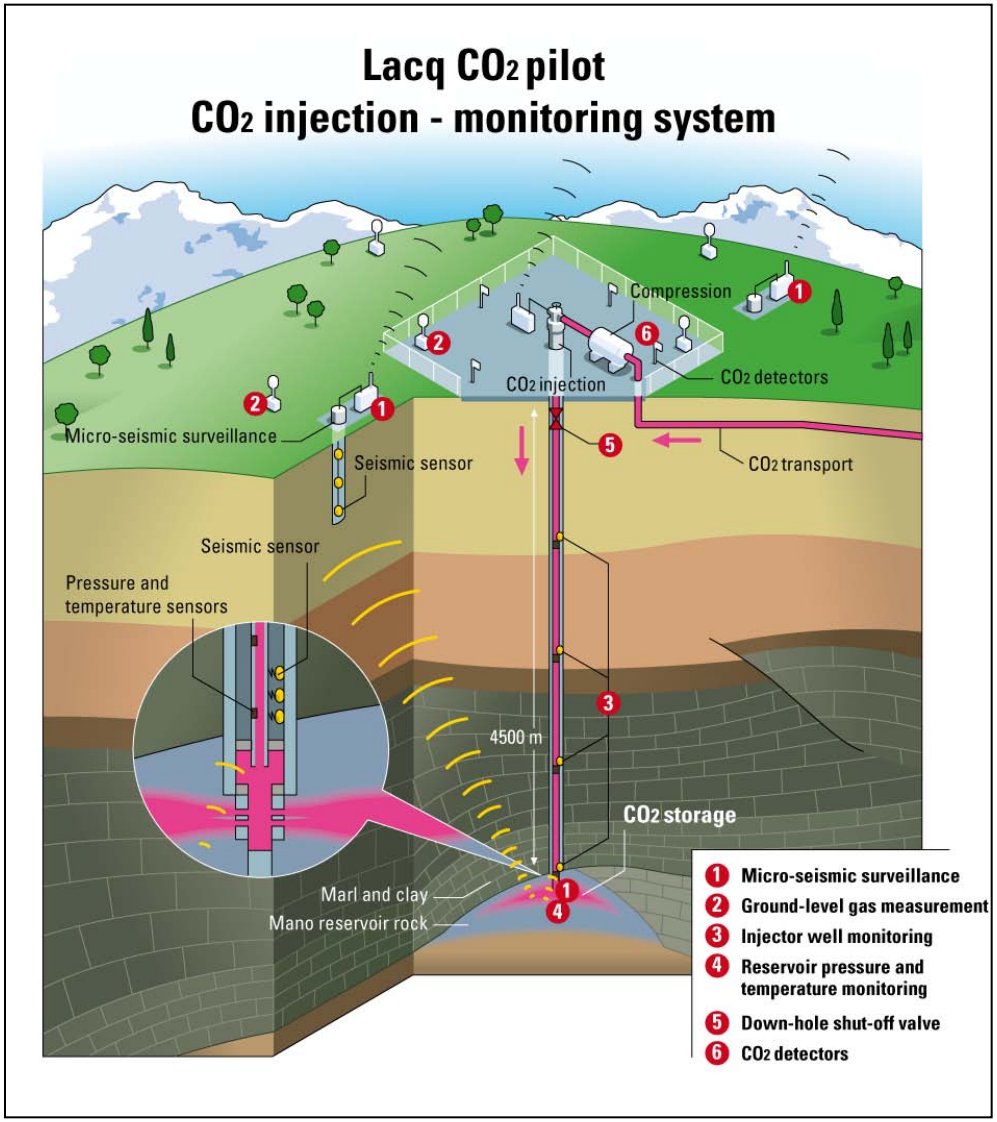
water content # 30ppm

TOTAL

Facilities at Rousse well pad



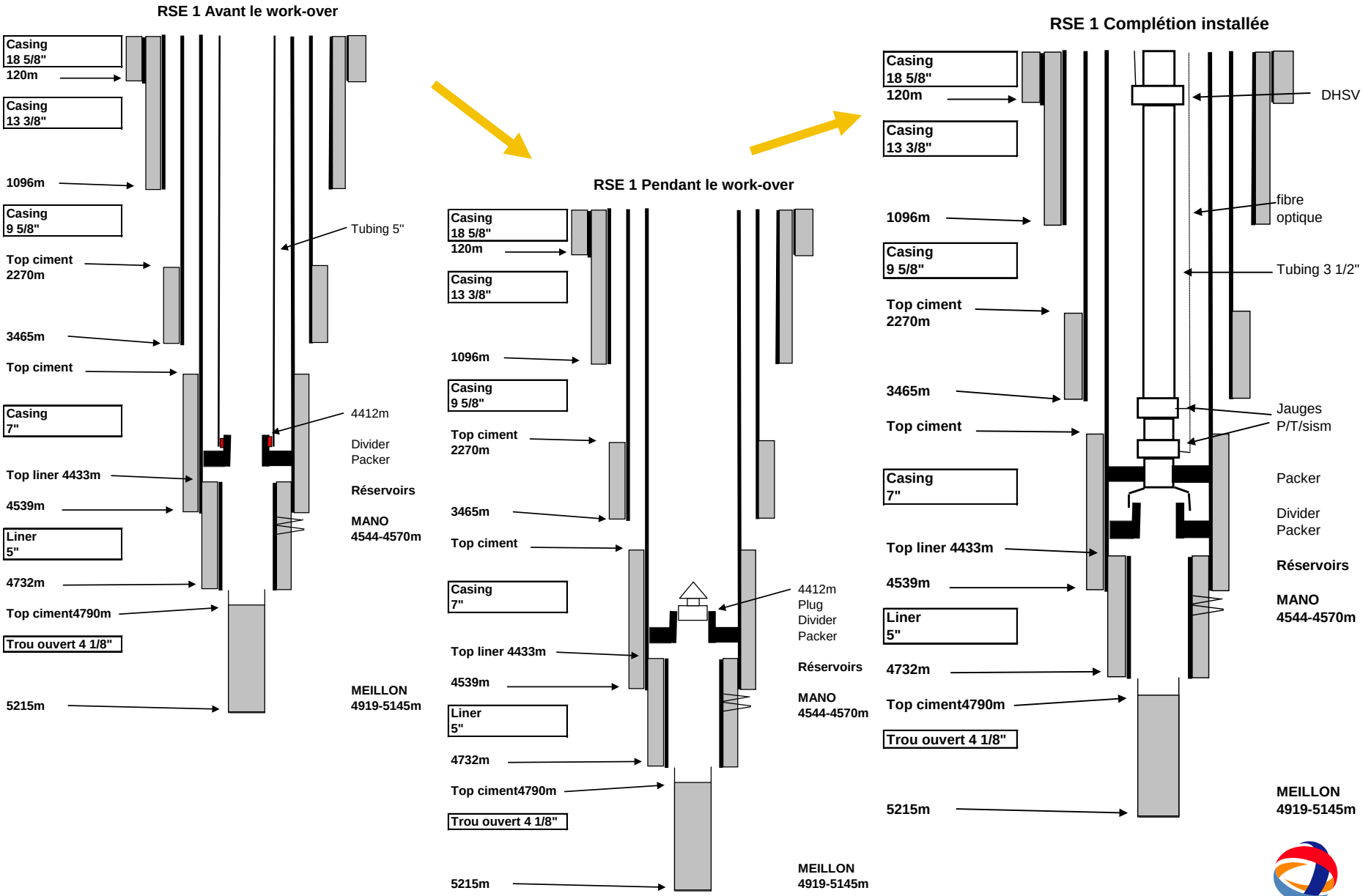
CO_2 Monitoring plan



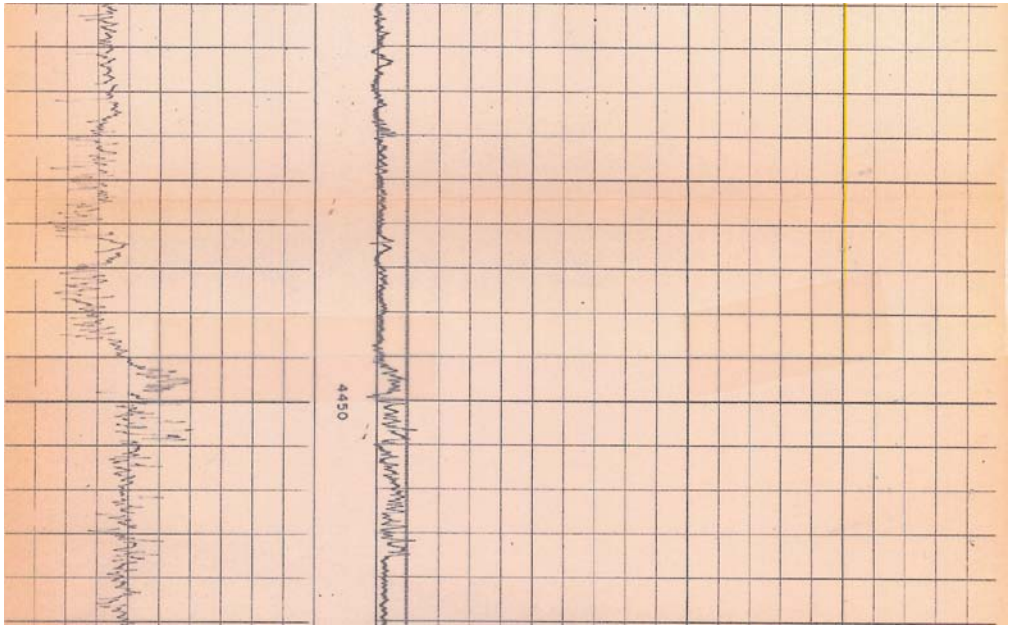
- **Injection phase**
- **Flowrate & composition of injected gas**
- **P and T borehole and reservoir pressure (optical fibre)**
- **Microseismic monitoring of reservoir and caprock**
  - baseline before injection
- **Gas migration at the surface :**
  - soil gas survey (baseline before injection)
  - 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

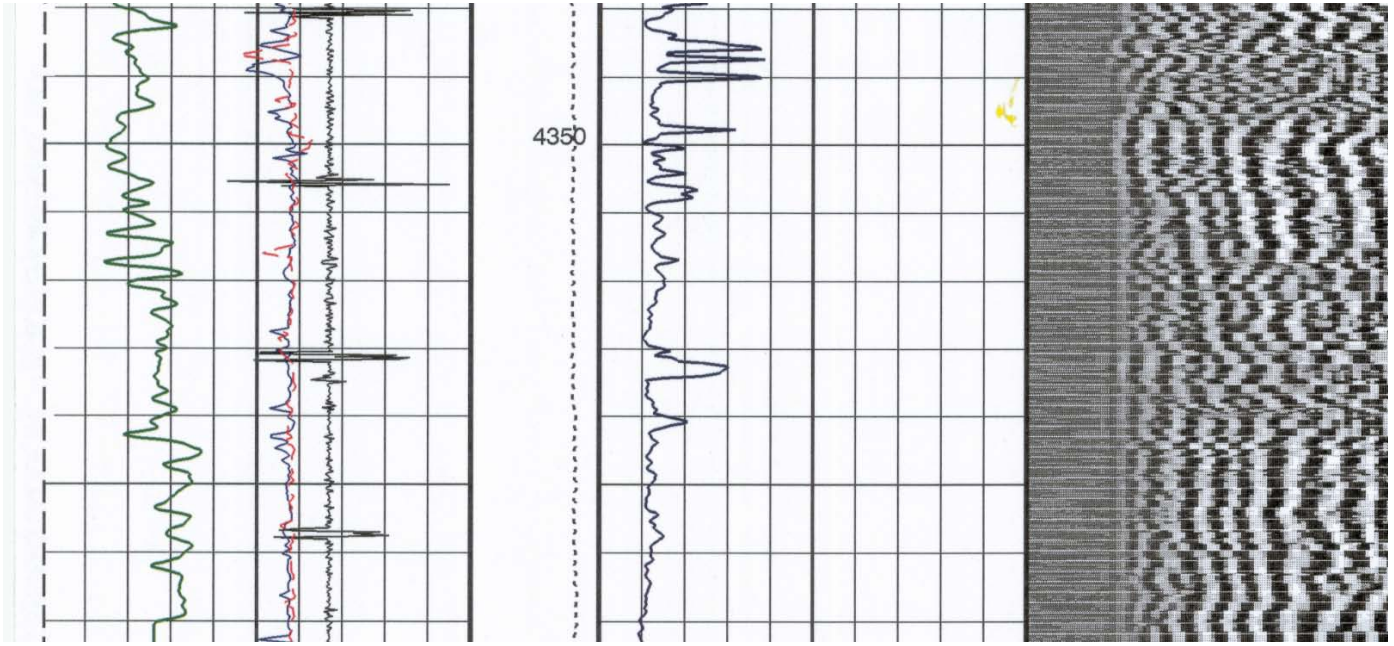
OPERATIONAL SEQUENCE

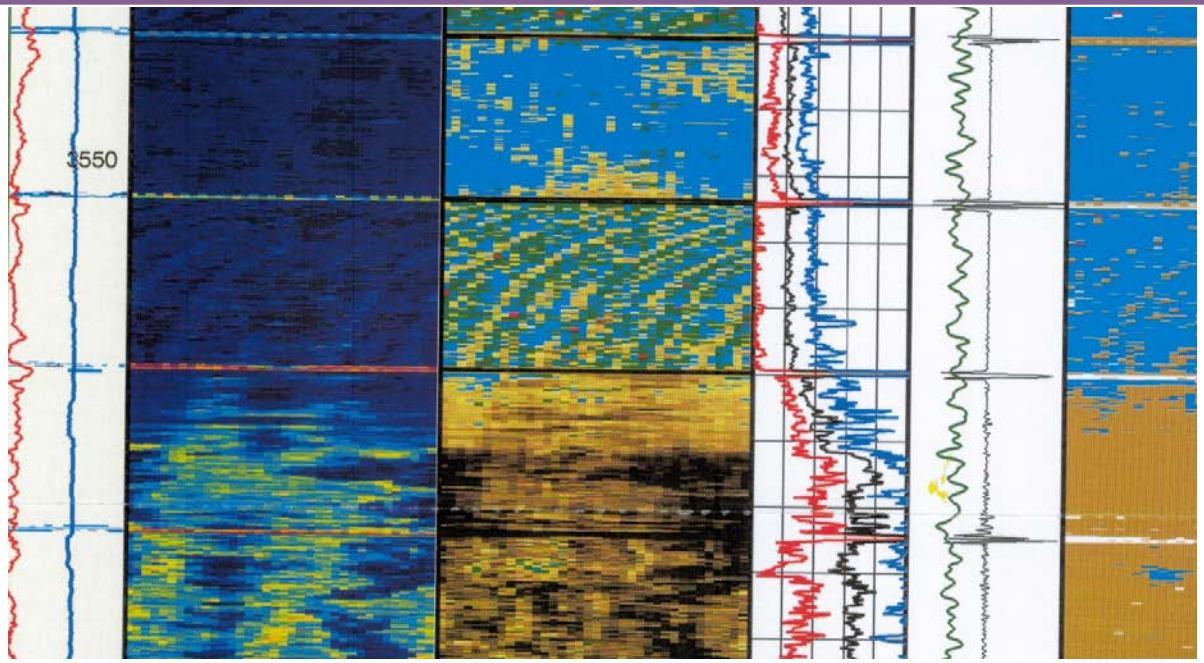


CBL 7” 1967
Bottom cement log

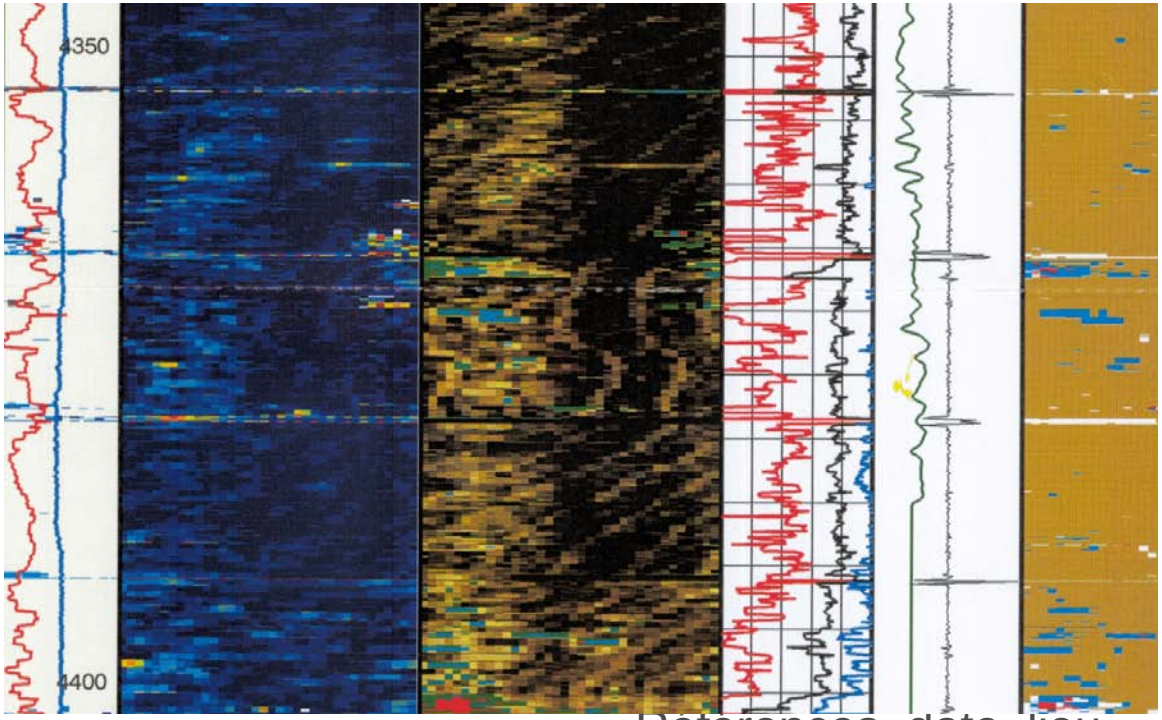


2009

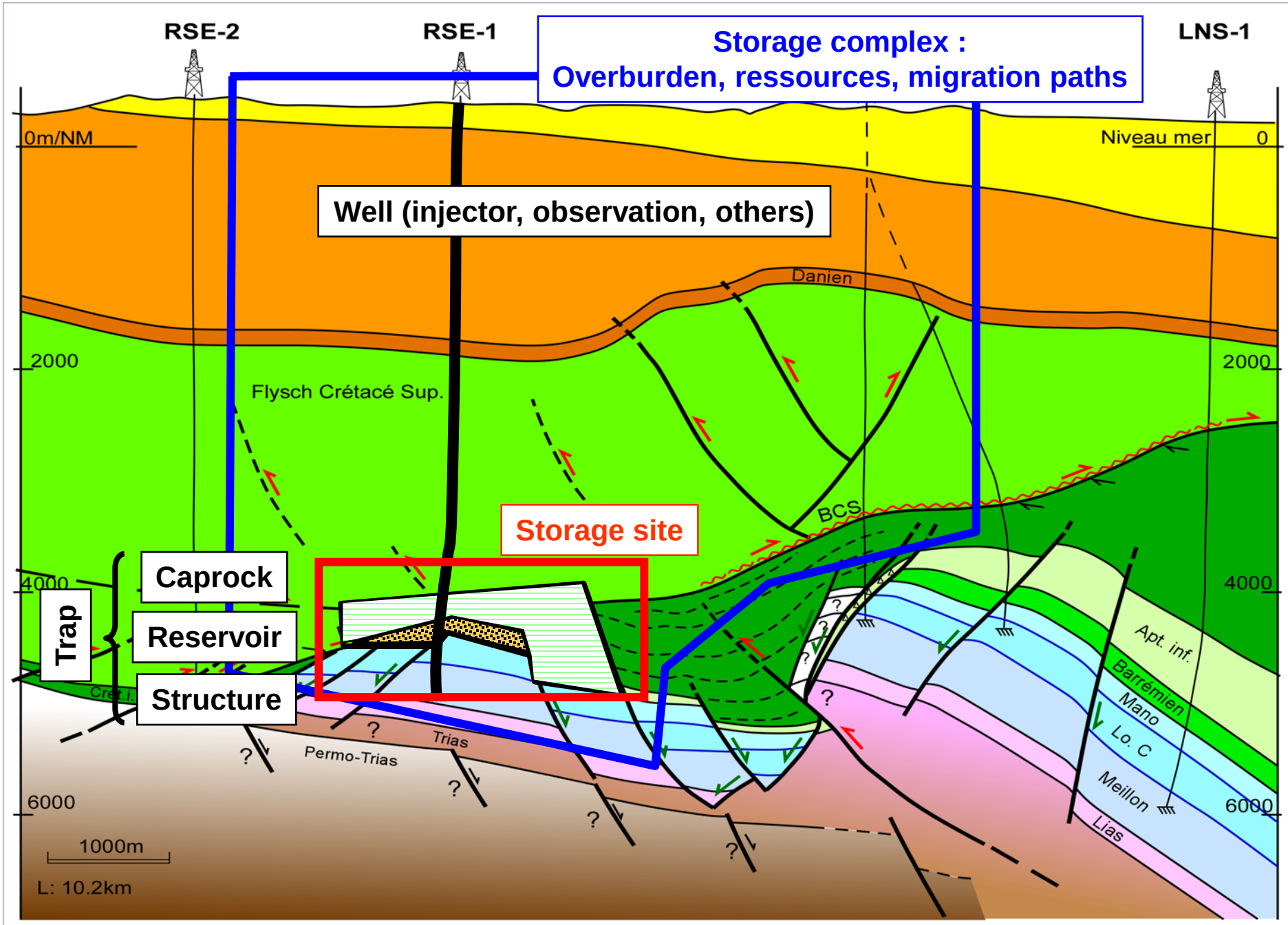




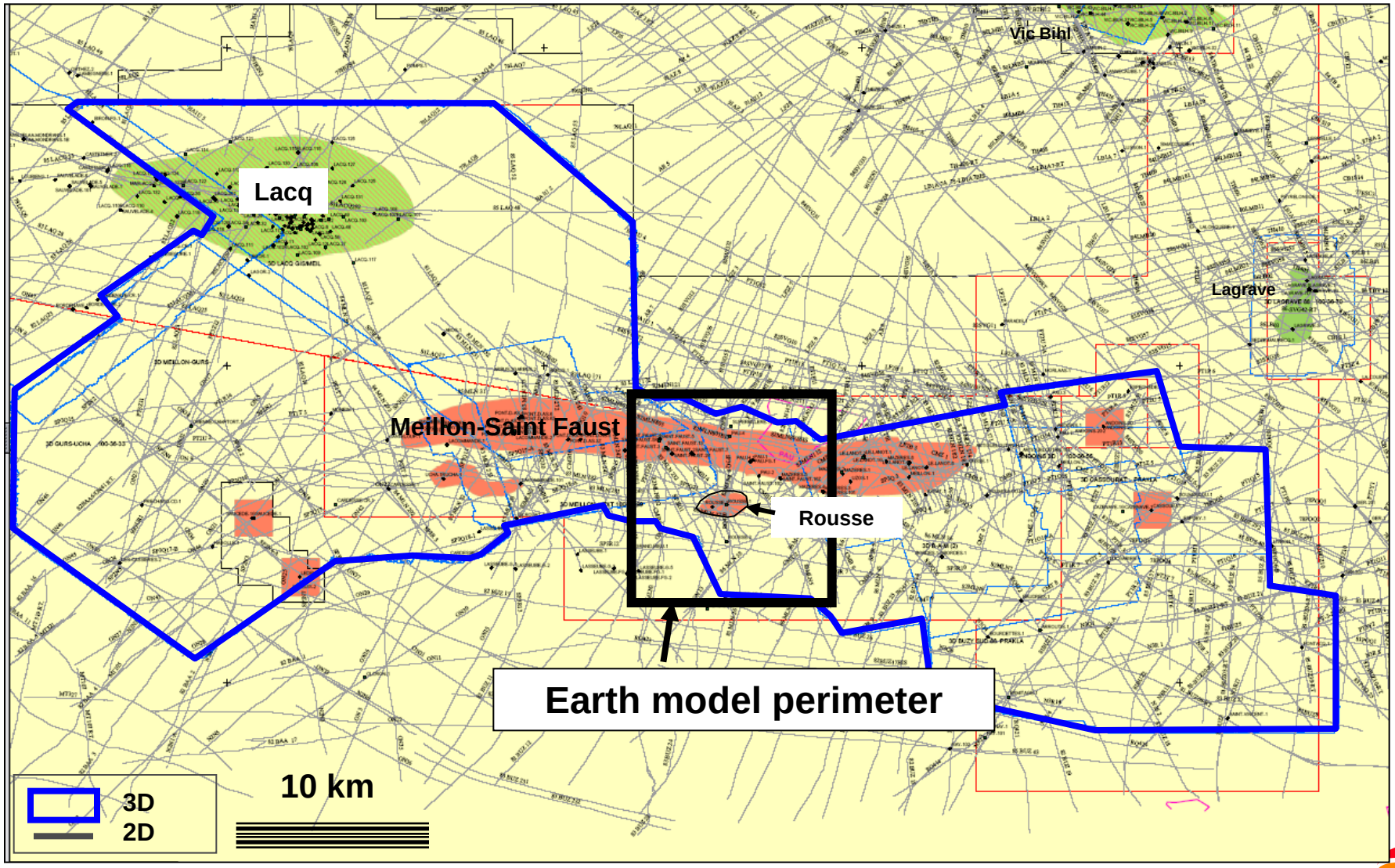
USIT 2009
top cement



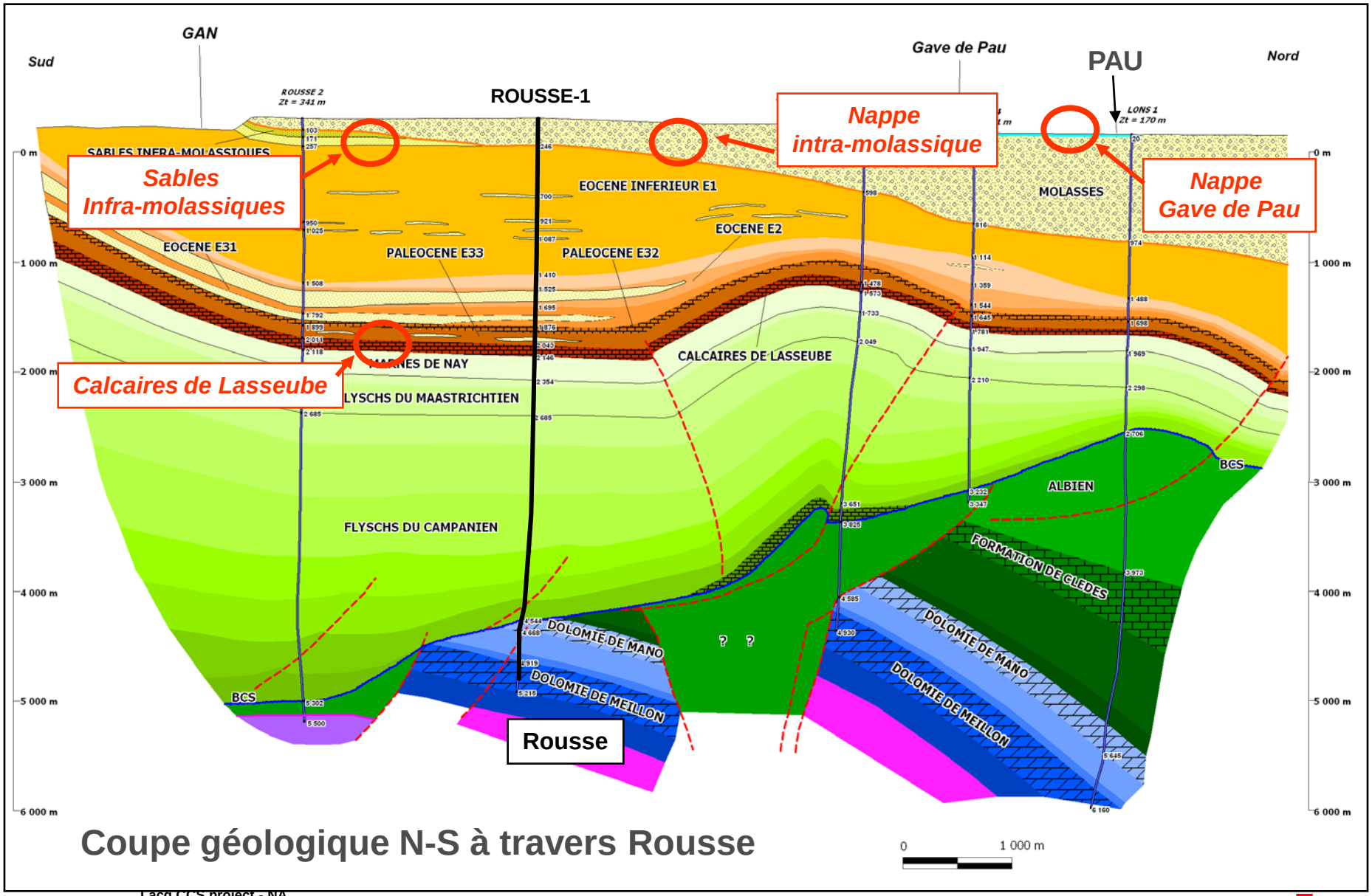
Bottom cement


RSE-2
RSE-1
LNS-1
Storage complex :
Overburden, ressources, migration paths
0m/NM
Niveau mer
0
Well (injector, observation, others)
Danien
2000
Flysch Crétacé Sup.
BCS
Storage site
Caprock
Trap
Reservoir
Structure
4000
Cret.i.
Trias
Permo-Trias
Apt. inf.
Barrémien
Mano
Lo. C
Meillon
Lias
6000
1000m
L: 10.2km

Seismic data and wells available

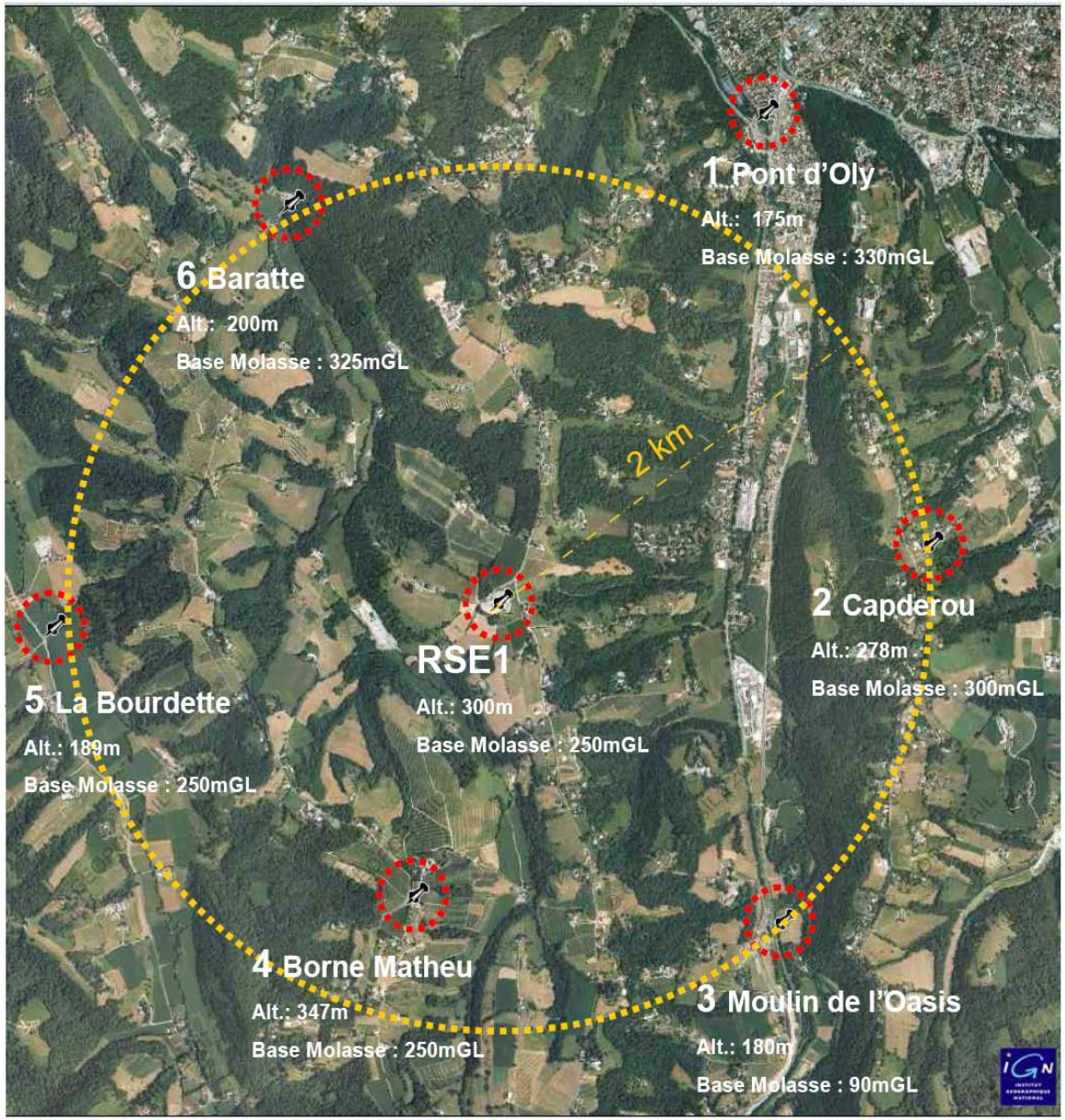


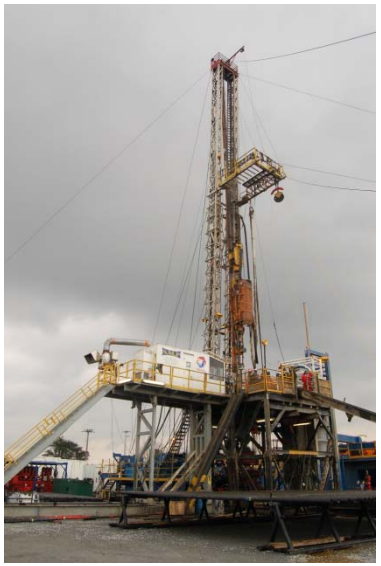
Aquifers within the storage complex



Coupe géologique N-S à travers Rousse

Microseismic monitoring and RSE1 well work over





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**

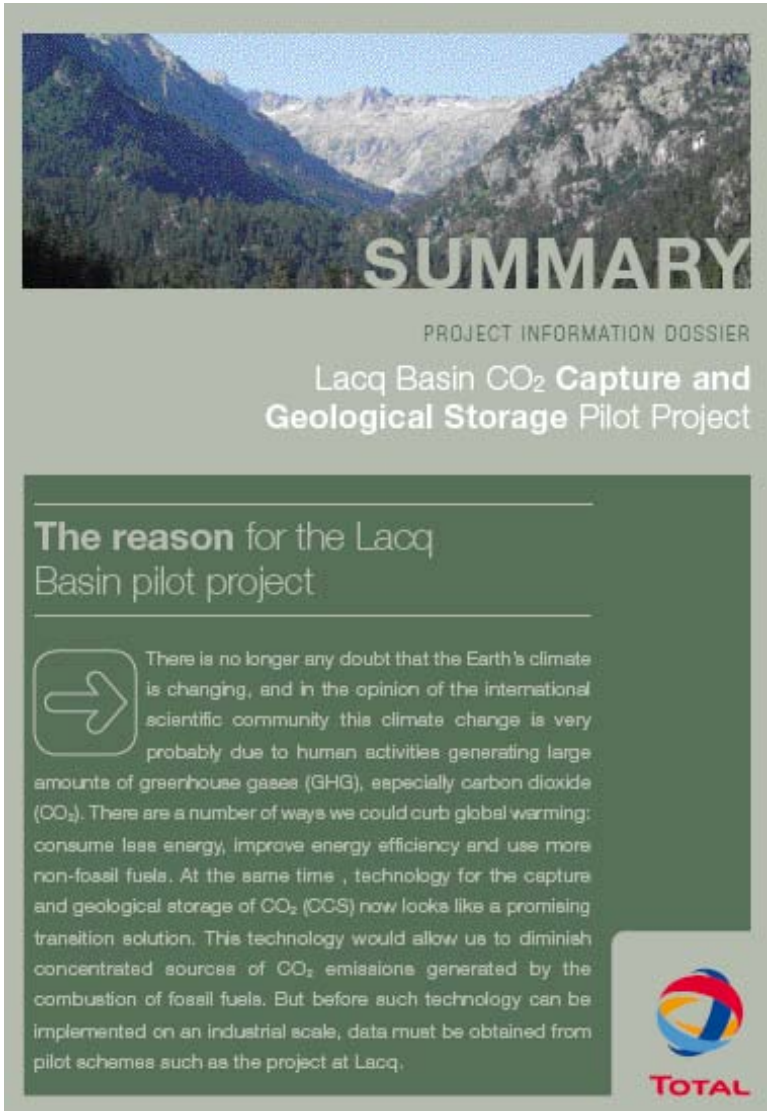
Project information also available on
www.total.com/corporate-social-responsibility

LACQ CO_2 CAPTURE AND
GEOLOGICAL STORAGE PILOT PROJECT

TOTAL'S COMMITMENT TO STAKEHOLDER CONSULTATION

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 public information**
  http://www.pyrenees-atlantiques.pref.gouv.fr/

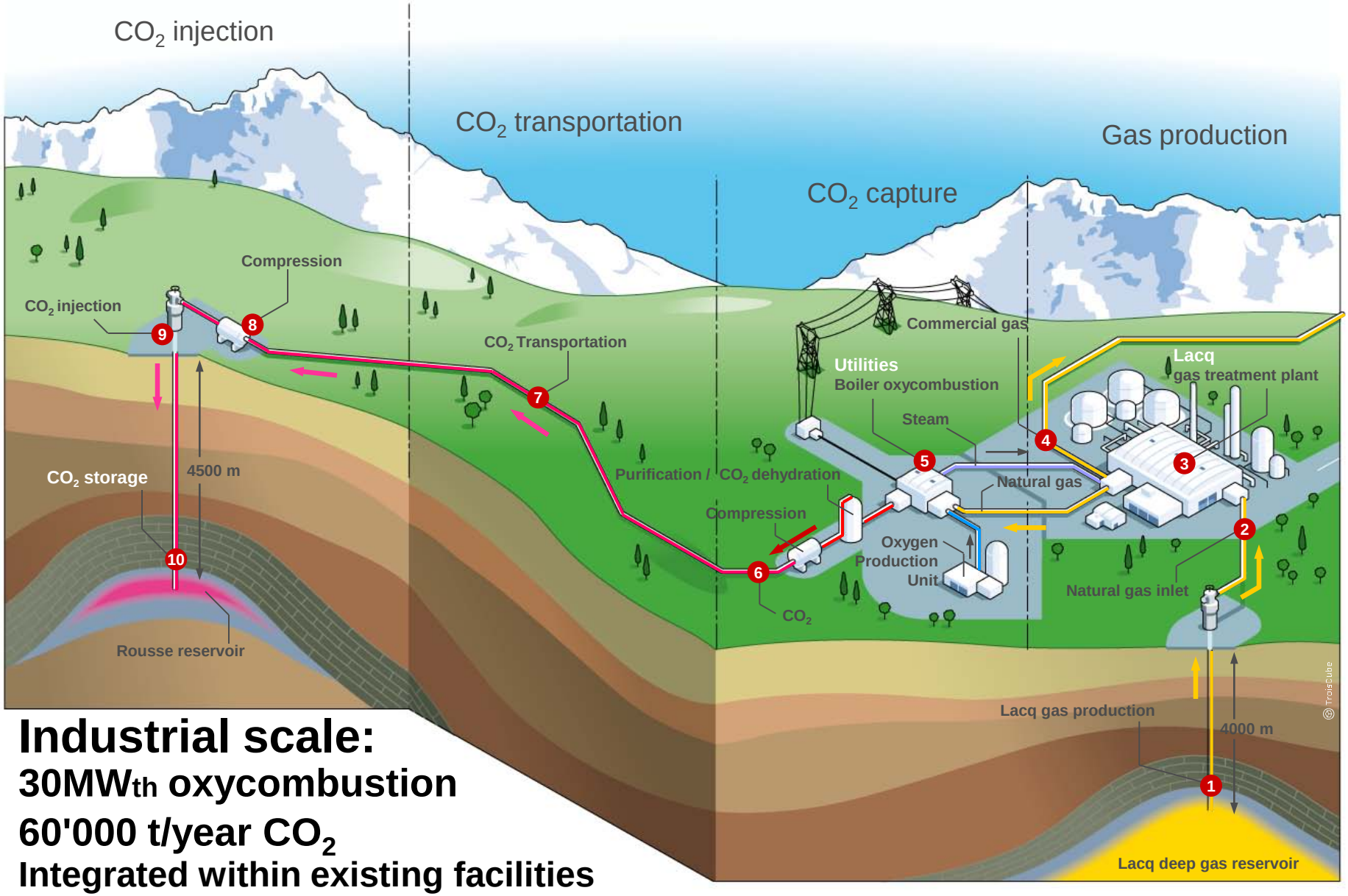
Leassons learned from early operations

- **Oxycombustion**
  - No major issue from revamping (but initial boiler status assesment critical)
  - Several weeks of control system tuning
    - Presure 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

An integrated carbon capture, transportation and geological storage in a depleted gas field project



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