

Oxy-combustion and the CCS pilot at Lacq

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British – French Flame Days 2009



COMITE FRANCAIS DE LA FONDATION DE
RECHERCHES INTERNATIONALES SUR LES
FLAMMES

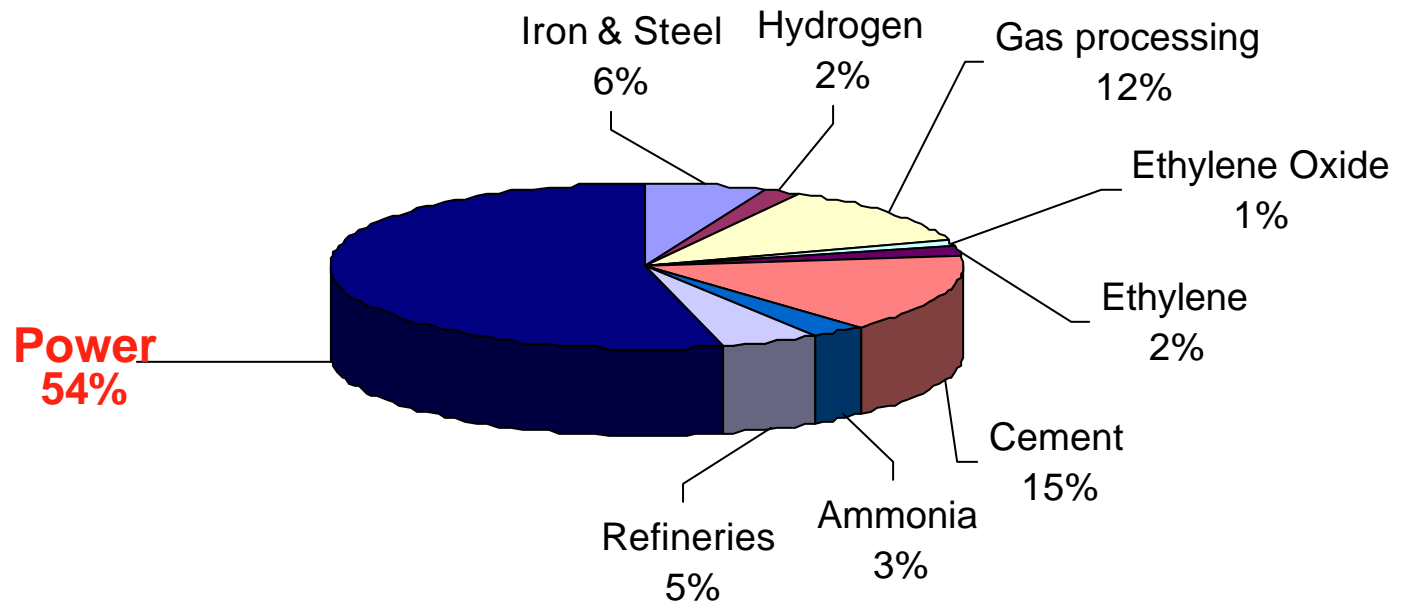


Lille, 9th and 10th March 2009



TOTAL

CO₂ emissions sources and control



- CO₂ emissions are dominated by the Power sector
- Oxyfuel combustion could be an excellent and economical alternative

Why is Total involved in Carbon Capture and Storage ?

Another option to reduce our industrial CO₂ emissions :

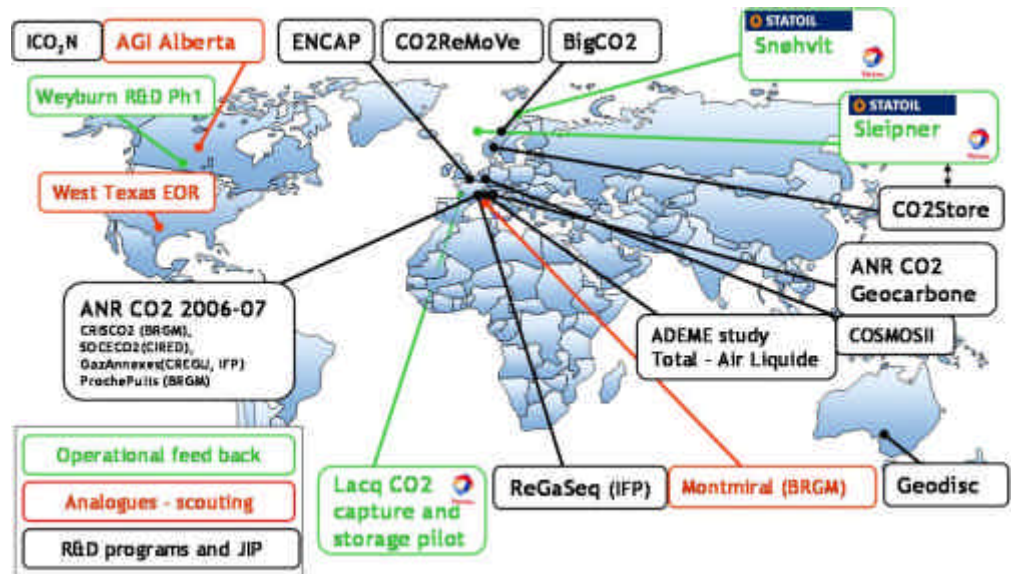
- Gas flaring reduction (world bank GGFR) on existing facilities
- Improve power efficiency
- **CCS as a breakthrough technology**

Dedicated CCS program since 2001 :

- Capture technology development

- CO₂ injection and storage

- Storage integrity
- Well integrity
- Long term fate of CO₂
- Monitoring



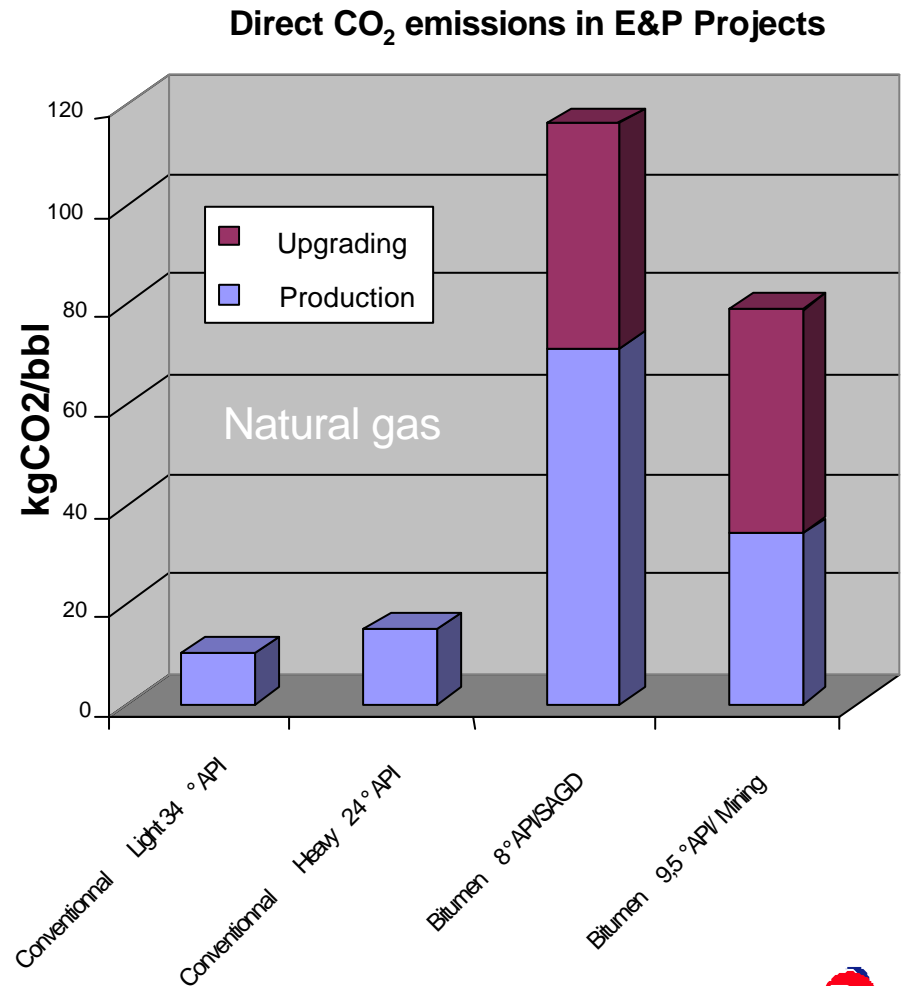
CO₂ emissions in Oil Sands Production

Thermal operations
in Oil Sands

- SAGD (Steam Assisted Gravity Drainage) and Mining
- Upgrading

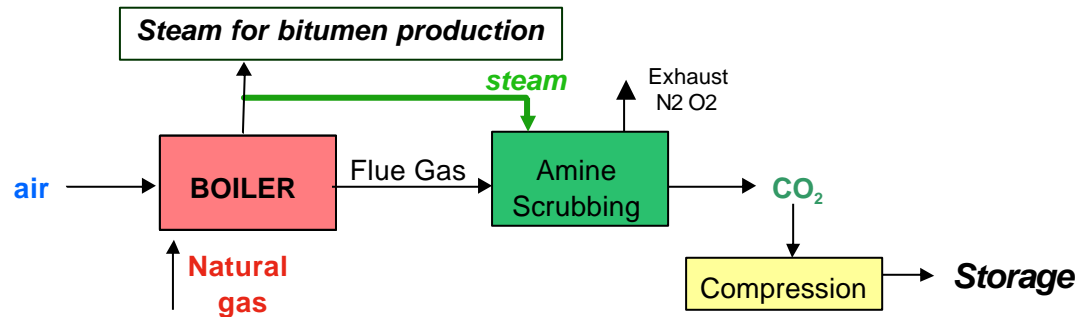
→High demand of Steam, Heat and Power for production and upgrading

→High CO₂ emissions by combustion of fuel in boilers and gas turbines

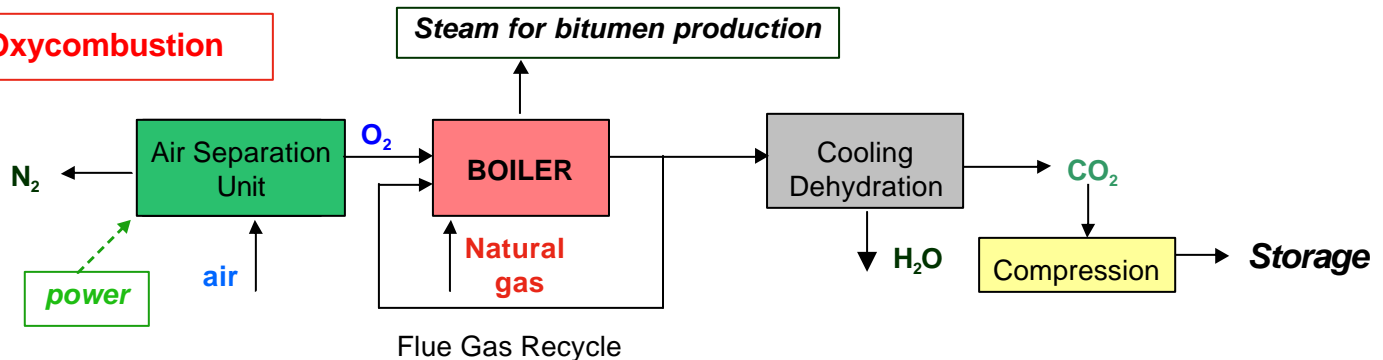


Integration of CO₂ capture in steam generation unit

Post combustion



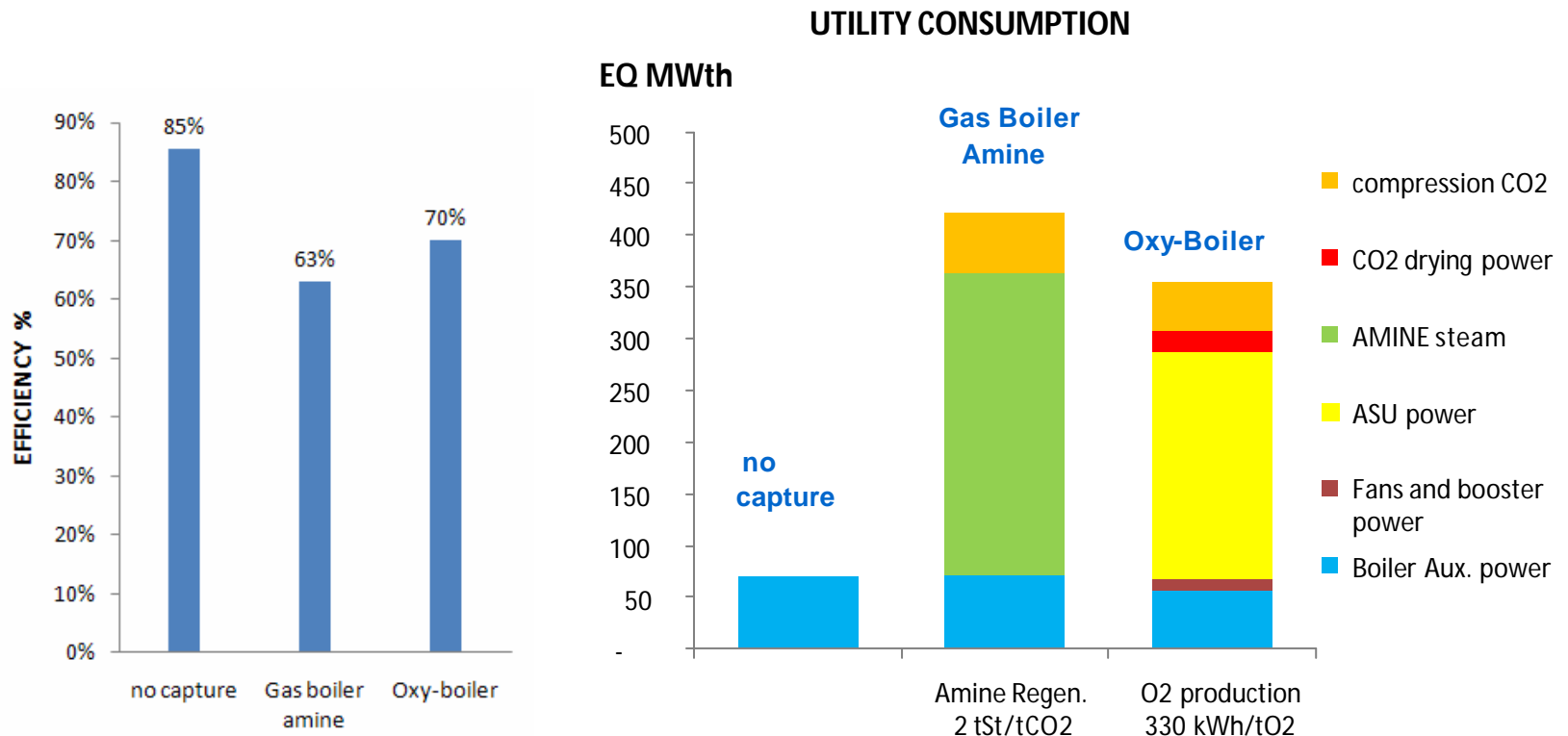
Oxycombustion



CO ₂ Capture	Capture efficiency (%)	Captured CO ₂ purity (%)	Additional energy for capture
Post-combustion (amines)	90	99.9	Steam (amine regeneration) ~2t LP steam/tCO ₂
Oxy-combustion	~100	85 to 95 (purity O ₂ : 95 to 99.5%)	Power (oxygen production) 330kWh/tO ₂

Oxycombustion vs Postcombustion

STEAM PRODUCTION, Imported Power
Efficiency and consumptions



$$EFF = \frac{P[\text{Produced Steam} - \text{Consumed Steam}](\text{MWth})}{Q_{\text{fuel}} \times \text{LHV}(\text{MWth}) + \text{Imported electrical power}(\text{eqMW th})} \times 100$$

P thermal power
 Q mass flow rate
LHV Low Heating Value

Lacq CO₂ Pilot

Lille, 9th and 10th March 2009



TOTAL

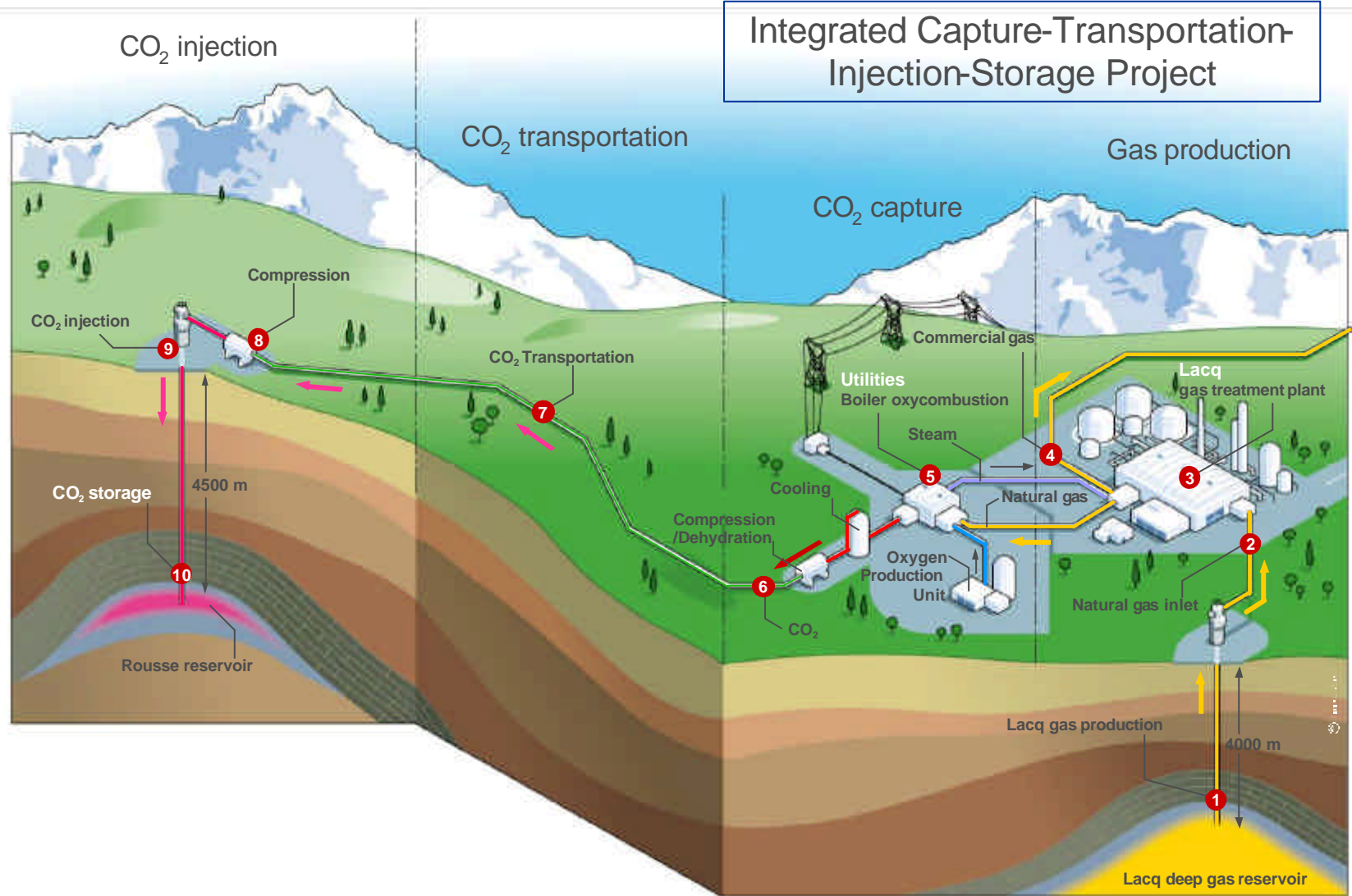
Pilot location - Total Exploration & Production France



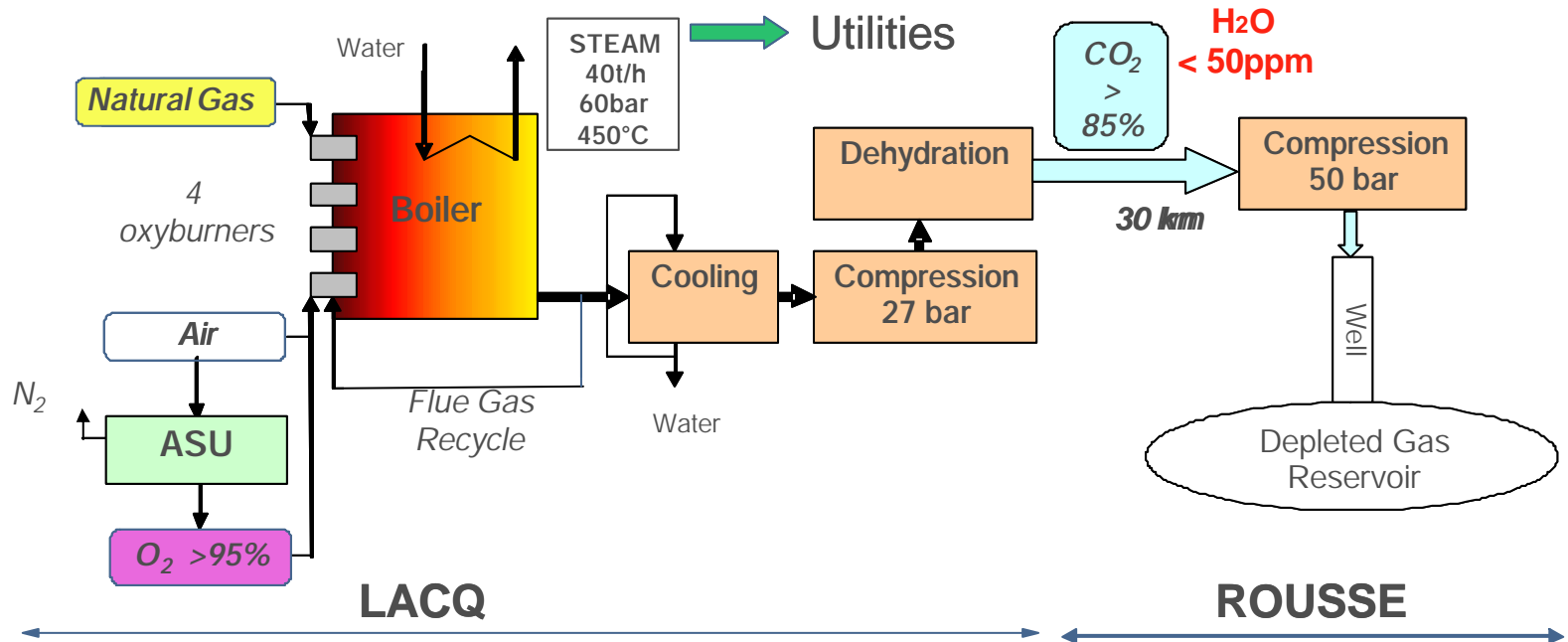
- Gas field
- Oil field
- NG Storage



Carbon capture & geological storage in Lacq region

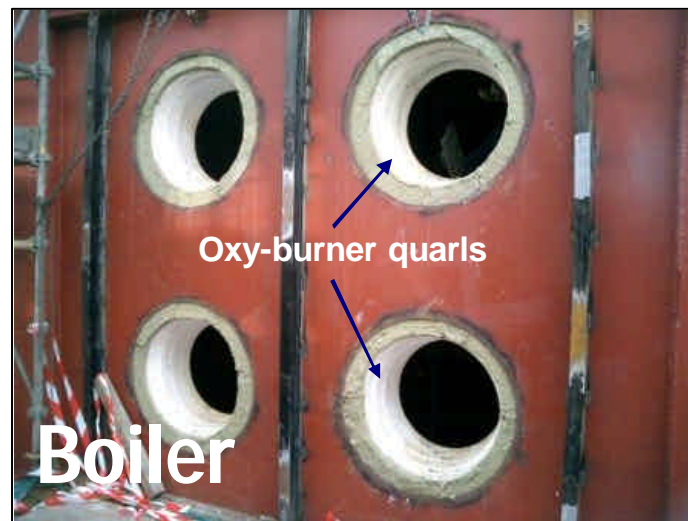
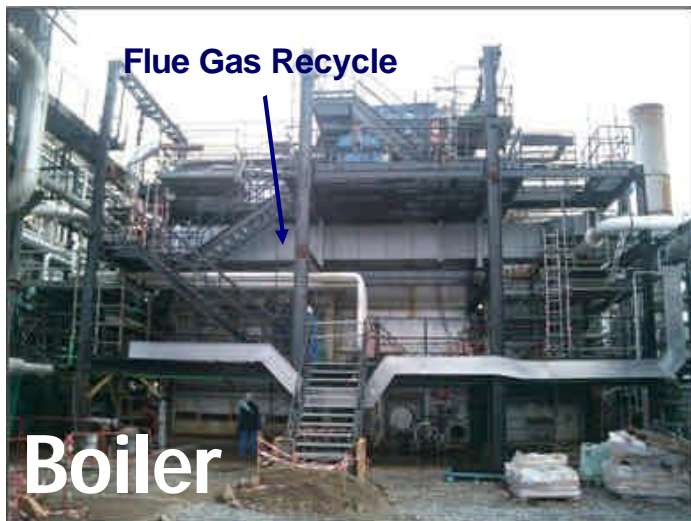


CCS Lacq pilot plant – Major challenges



- Industrial scale 30MWth oxycombustion unit with gas
- Revamping of a conventional boiler
- CO₂ transport and injection for 2 years
- 120 kt CO₂ storage in a depleted reservoir
- First CO₂ injection for storage in France
- Public acceptance with consultation and dialogue
- French and international legal framework not frozen

Construction



Oxy-burner development



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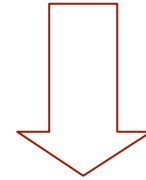


Oxy-burner Concept for Oil & Gas Applications

► Air Liquide's oxyburner concept



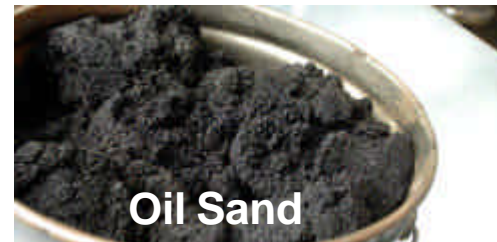
Applications



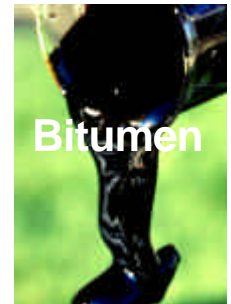
EOR
SAGD

Power generation

- Fuel flexibility for gas & liquid fuels
 - High viscosity/High density liquid fuels
 - High sulphur and metals content
- Variable flue gas recycle rate
- Air mode for transient operation
- Important turndown ratio
- Oxy-flame stability with difficult fuels
- Optimum operating procedures (air-oxy mode)
- Use of typical materials
- Heat flux control



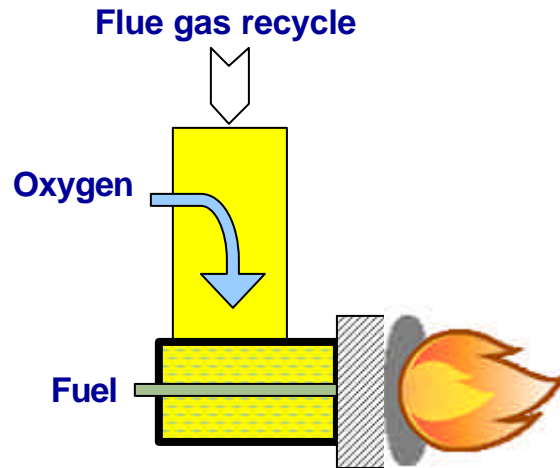
Oil Sand



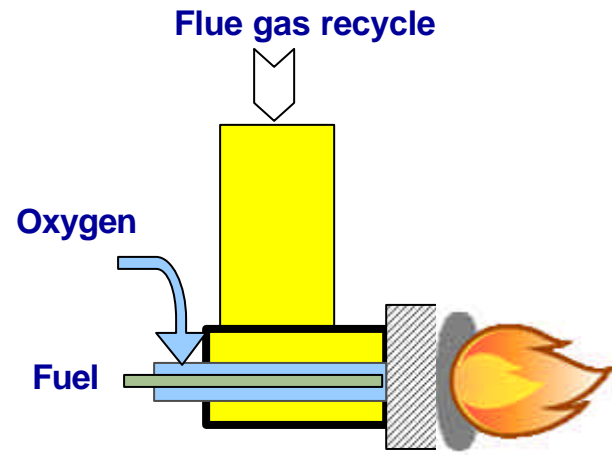
Bitumen

Air Liquide Oxy-burner Principle

- ▶ No external oxygen mixing
- ▶ Advantageous on: flame stability, turndown ratio, difficult fuels.
- ▶ Improved operating safety: dedicated pure oxygen circuit all along distribution system.
- ▶ Additional flexibility to adjust FGR rate.



Synthetic air type



Air Liquide oxy-burner

Oxy-burner Development path

Size

8 MW



8 MW oxy-burner design for Lacq boiler

1 MW prototype AL-R&D center rig



4 x 8 MW burners being set up in Lacq boiler

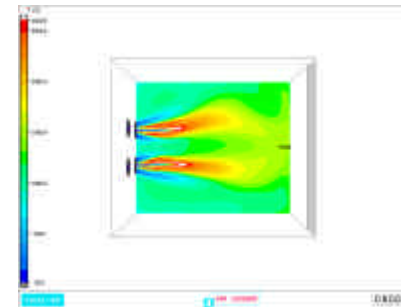
1 MW

2006

2006-2007

2008

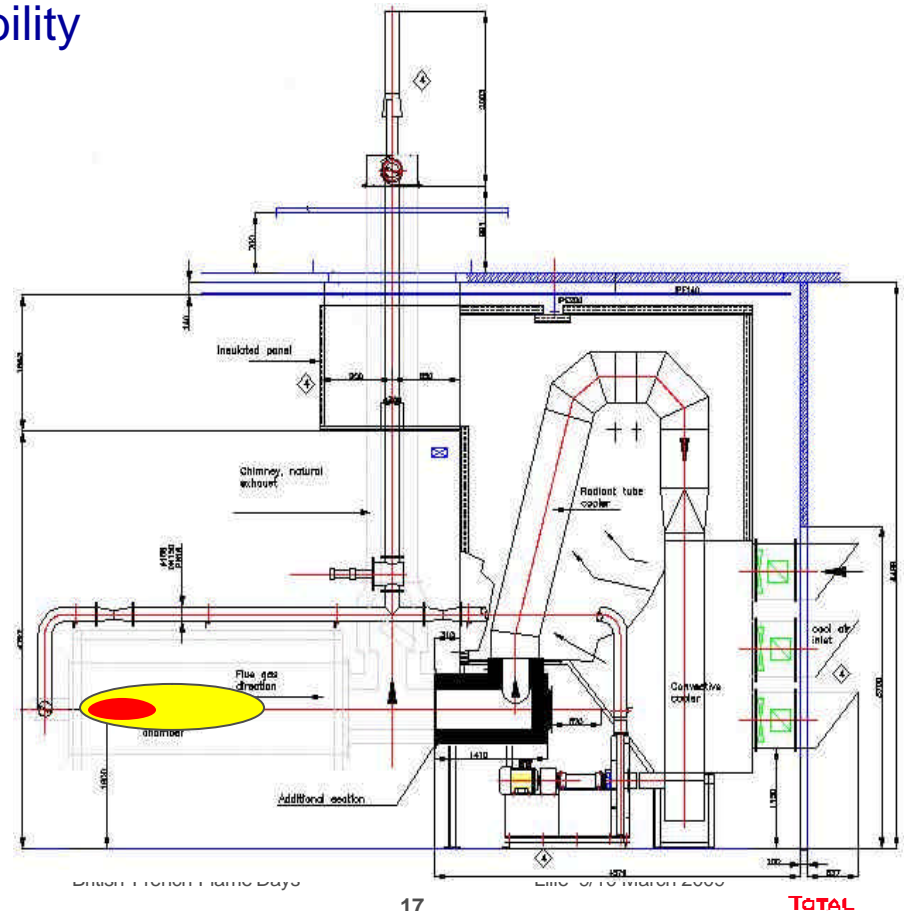
- ▶ **Upscaling know-how**
- ▶ **CFD modeling using proprietary code**
 - Specific to oxy-combustion
 - Fine tuned with oxy-combustion experimental data



1 MWth Oxy-combustion Test Rig

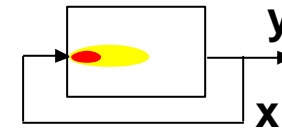
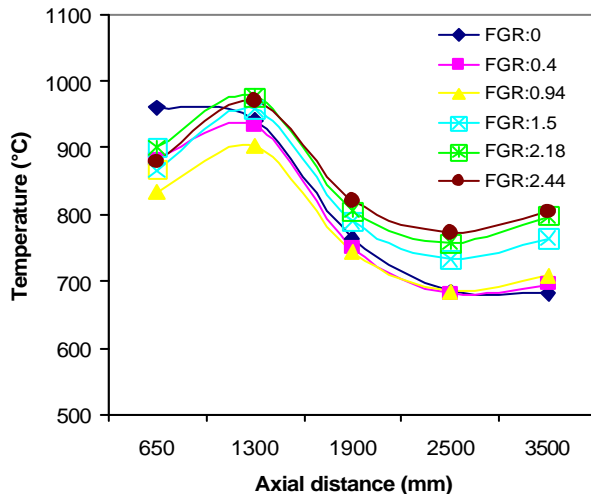
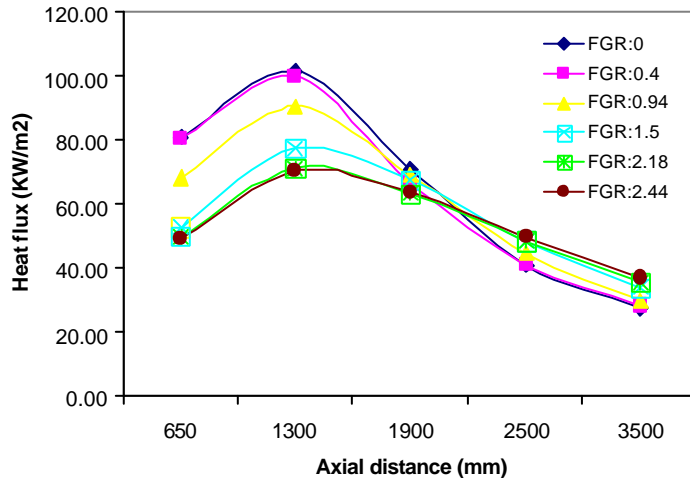
► Versatile and functional test rig

- Variable FGR rate and temperature
- Liquid / gas fuel feed capability
- Cold wall configuration
- Combustion monitoring
- Emission control



Experimental Results at 1 MWth Test Rig

Heat Transfer

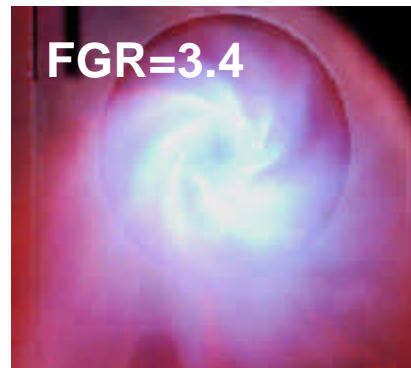
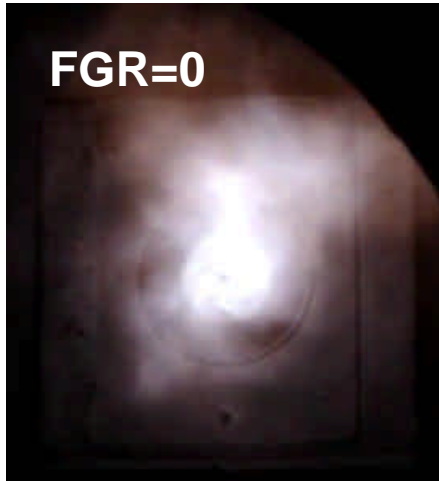


$$\text{FGR rate} = x / y$$

- ▶ Controlled heat flux with FGR
- ▶ Adjustable flame length
- ▶ Air mode for transient operation
- ▶ Large turndown ratio
- ▶ Rehearsal of burner operating mode

Experimental Results at 1 MWth Test Rig

Combustion and Emissions Considerations



- ▶ Flame stability performance was unchanged
- ▶ O₂ in the near burner region can increase flame stability
- ▶ Use of FGR has not impacted on flame stability
- ▶ High CO₂ concentration achieved: 94% vol. dry
 - Importance of pressure control to avoid air in-leakages.
 - Slightly positive pressure in chamber.

Oxy-burner Implementation into Lacq Boiler



- ✓ Retrofitting of an air fired boiler
- ✓ Adapted to existing boiler geometry
 - 4 horizontal burners
 - Chamber: L 5 m; W 4,5m; H 6-7m
- ✓ Careful sealing to minimise air-in leaks
- ✓ Allows slight operating overpressure
- ✓ Provides low pressure drop in Oxygen lines, allowing low-pressure ASU
- ✓ Compatibility of burner auxiliaries was validated
- ✓ Safe operation according to safety analysis
- ✓ Tests and measurement plans
- ✓ Keep Oxy combustion performance

Conclusions

- ✓ Total CO₂ Lacq pilot will demonstrate integrated scheme (from capture to storage) feasibility at industrial scale
- ✓ Oxy-combustion is a proven technology that facilitates CO₂ capture.
- ✓ Air Liquide oxy-burner concept -with separate injection of oxygen and flue gas recycle -enables safe oxygen handling for oxy-combustion in boilers.
- ✓ Oxy-burner performances demonstrated in a 1MW boiler
 - Fuel flexibility
 - Turndown
 - FGR rate flexibility
 - Air to oxy mode for transient operation
- ✓ Scale-up of the oxy-burner to 8 MW
- ✓ Start-up of the retrofitted oxy-boiler is scheduled in 2009.
- ✓ Upscaling of oxyboilers for high steam/power generation

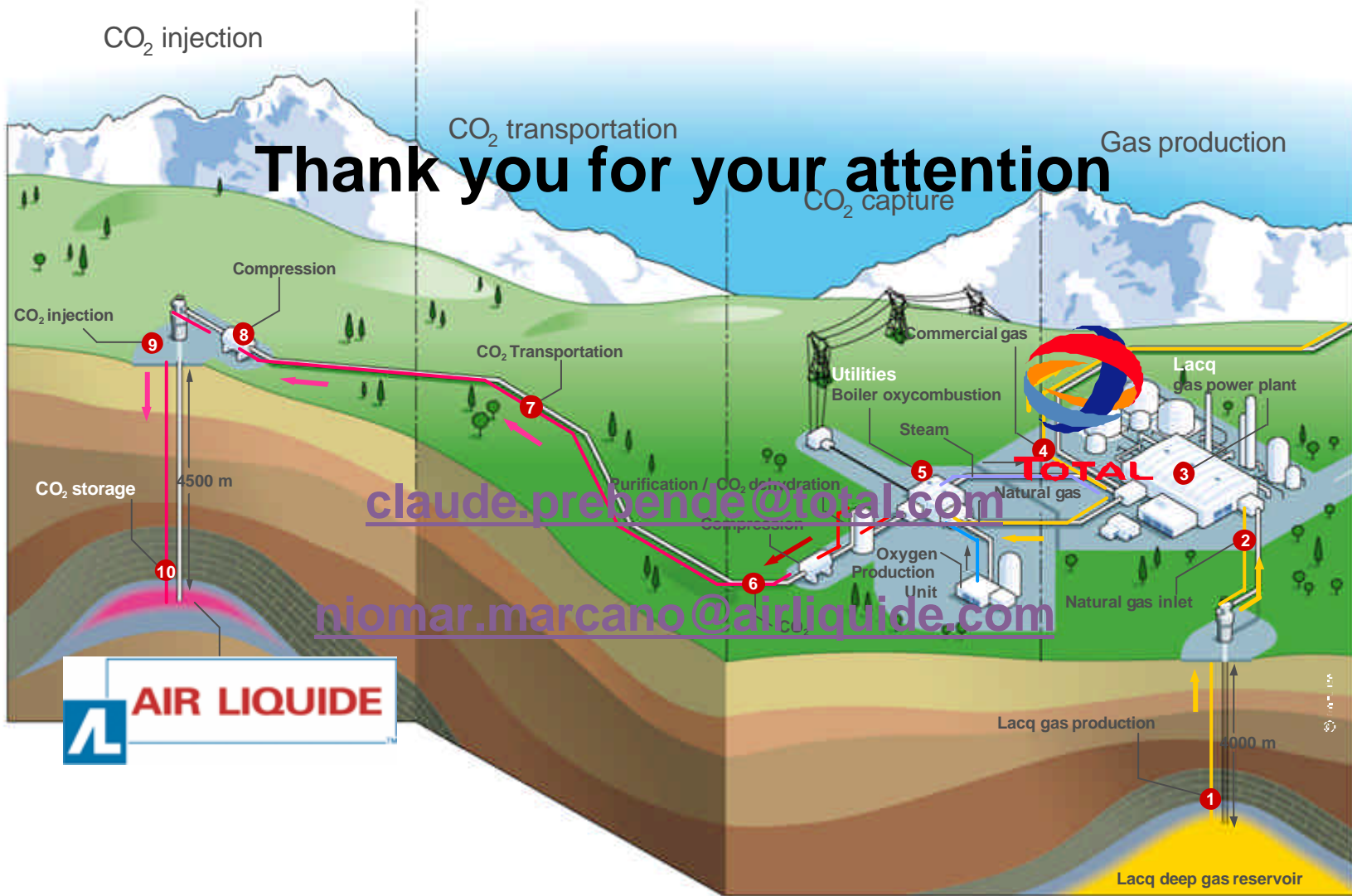
CO₂ injection

CO₂ transportation

Gas production

Thank you for your attention

CO₂ capture



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