CO_2 Capture and Storage: A Promising Technology

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CO_2 Capture and Sequestration in Future International R&D Programmes
Vienna
November 17, 2004

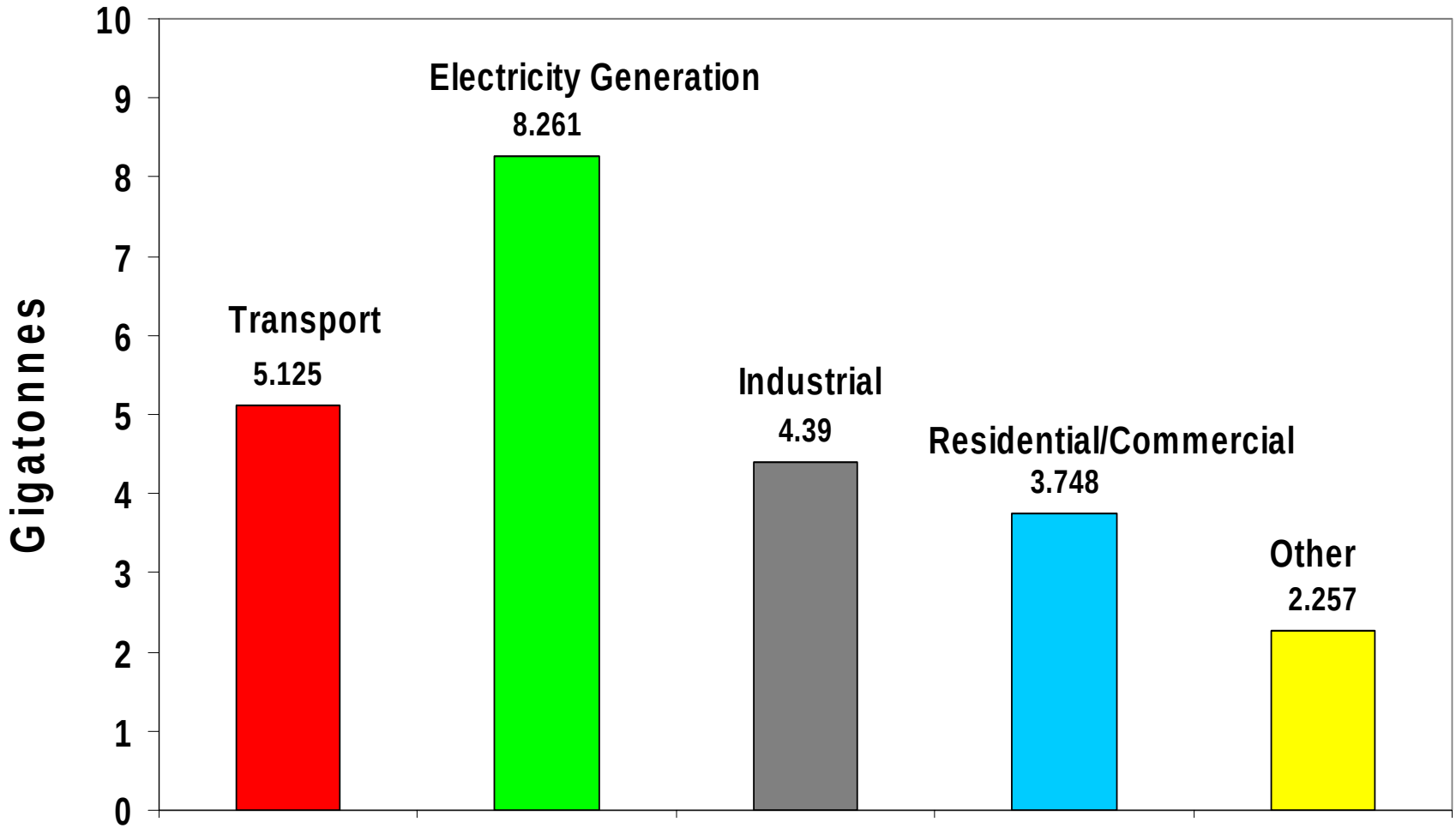
Introduction

- **Fossil energy is expected to remain the predominant source of energy to meet growing world demand**
  - **Fossil fuels have been a driving force behind economic development**
  - **Over 1.6 billion people in the world today have no access to electricity, and over 2 billion don't have modern fuels for cooking and heating**
  - **Provision of modern energy, including fossil energy, is necessary to achieve Millennium Goal of poverty reduction**
- **Impact of GHG emissions on climate change has not yet gained wide undisputable scientific acceptance. However, the precautionary principle is often invoked.**
- **Technologies must continue to be developed to reduce GHG emissions from energy use.**
- **Sustainable development: Balance between economic growth, social progress, and environmental protection.**

Benefits of Carbon Dioxide Capture and Storage

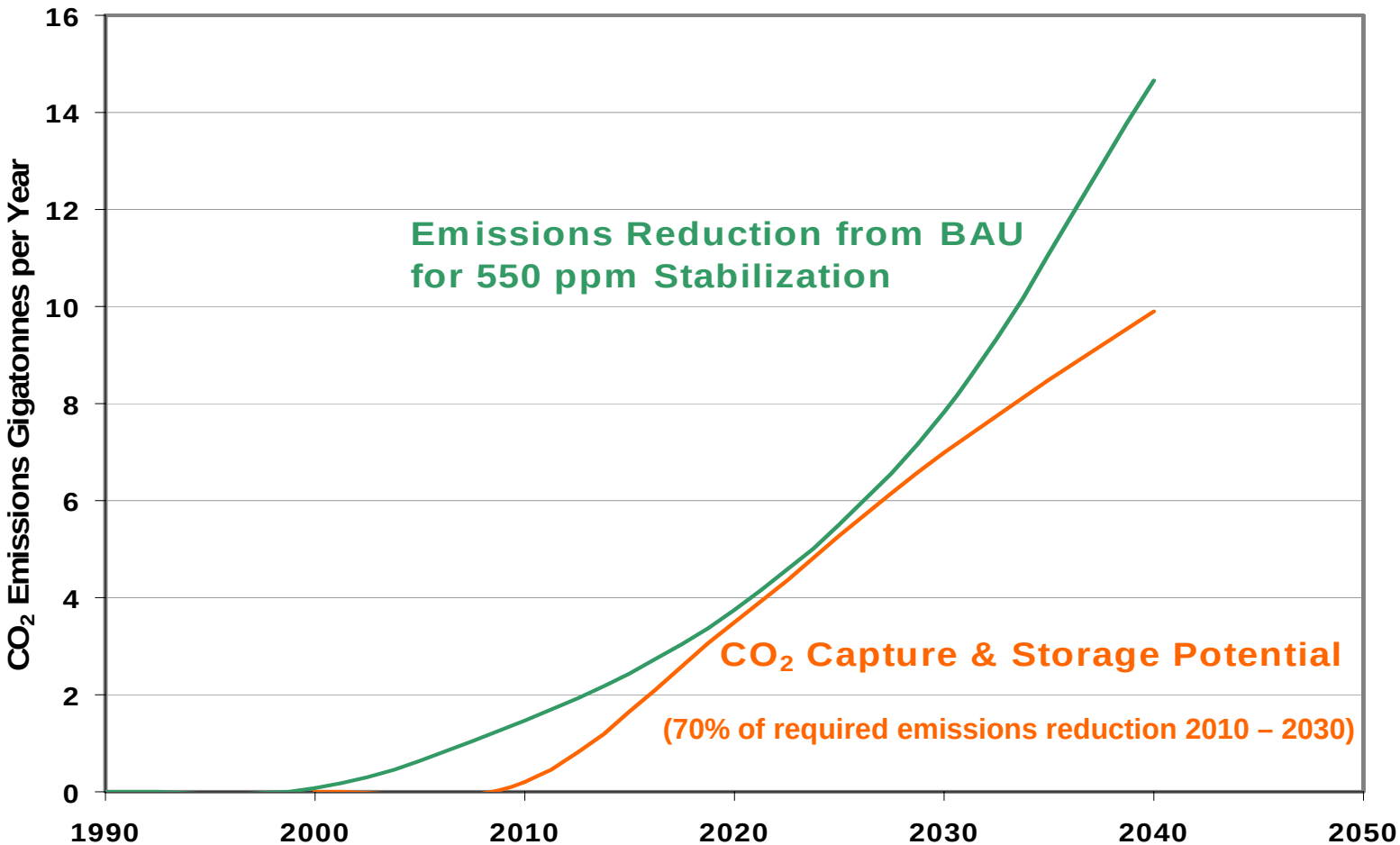
- At present and for the foreseeable future, there are few economically viable substitutes for fossil fuels.
- CO_2 Capture and Storage (CCS) has the potential to make huge reductions in emissions of CO_2 from stationary sources such as fossil fuel-fired power plants and industrial plants.
- Stationary sources contribute over 50% of global CO_2 emissions.
- CCS could provide 70% of the GHG emissions reductions necessary for stabilization of atmospheric CO_2 concentration in the medium to long term.

Global CO_2 Emissions by Sector in 2000



Source: World Energy, Technology, and Climate Policy Outlook, European Commission, 2003

CO_2 Capture and Storage
Potential Contribution to Atmospheric Stabilization



Sources: Dolf Gielen, IEA/EET Working Paper, "The Future Role of CO2 Capture and Storage: Results of the IEA-ETP Model, 2003;
EU World Energy, Technology, and Climate Policy Outlook, 2003;
IPCC Greenhouse gas emissions scenarios.

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- CCS could provide 70% of the GHG emissions reductions necessary for stabilization of atmospheric CO_2 concentration in the medium to long term.
- CO_2 storage in oil reservoirs can substantially increase oil production and recovery through an enhanced oil recovery (EOR) process.

OPEC/WPC Workshop On CO_2 Capture, Storage and EOR; and Gas Flaring Reduction

- OPEC and the World Petroleum Congress see carbon dioxide and storage as a promising technology
- Workshop convened experts to discuss technology, current applications, future potential, and areas for cooperation
- 19 presentations were made plus round table discussions at the end of each day, including:
  - CCS technology state-of-the-art and R&D programmes
  - Case studies on CO_2 storage in saline aquifers and CO_2 EOR
  - Policy, legal, and financing aspects of CCS and gas flaring reduction
  - Gas flaring reduction initiatives
- OPEC Member Countries activities highlighted

CO_2 Capture & Storage Challenges

- The cost of CO_2 capture needs to be further reduced
  - Technologies have been available for years to remove CO_2 from sales gas streams, but these are costly
  - If installed at a power plant, efficiency is reduced
- Issues related to geologic storage require more research
  - Technical issues related to monitoring, verification of storage and leak remediation
  - Legal aspects related to liability and long term ownership of storage sites
- Absence of commercial incentives
- Public awareness must be increased
- These are being addressed by various R&D programmes

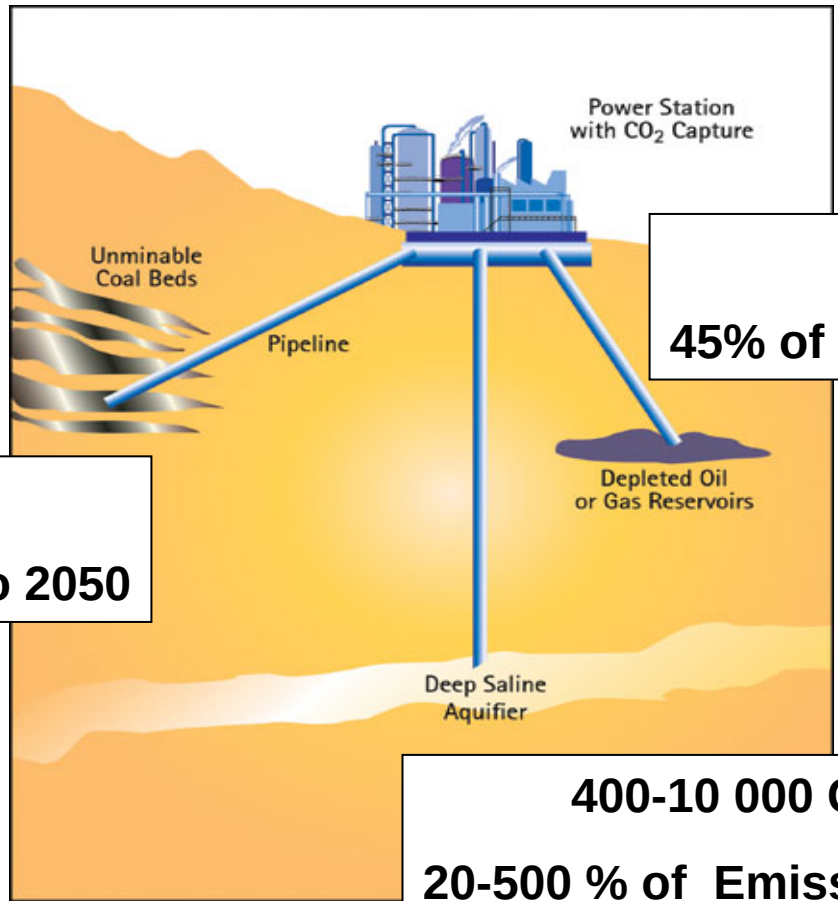
CO_2 Capture and Storage State of the Technology (1)

- **Capture is the largest component of the cost of CCS**
  - **Power plant post-combustion capture costs $40 to $100 per tonne of avoided emissions**
  - **More concentrated CO_2 is less costly to capture but the technology is immature**
    - **Processes such as pre-combustion de-carbonization and oxygen burning promise to reduce costs**
- **R&D is expected to bring down the costs of all methods of capture. Three major programmes:**
  - **CO_2 Capture Project**
  - **IEA Greenhouse Gas Reduction Programme**
  - **US DOE carbon sequestration R&D**

CO_2 Capture and Storage State of the Technology (2)

- **Transportation and injection of CO_2 is relatively low cost**
  - **CO_2 has been transported by pipeline for many years in North America**
  - **CO_2 can be shipped in low pressure LPG vessels**
  - **Infrastructure requirements for large scale CO_2 capture and transport to geologic storage sites could be substantial**
- **For storage in geologic formations, monitoring, verification and long term storage are being addressed through technology development and demonstration projects**
- **However, the potential is huge**

Global Geological Storage Potential



920 Gt CO_2

45% of Emissions to 2050

40 Gt CO_2

<2% of Emissions to 2050

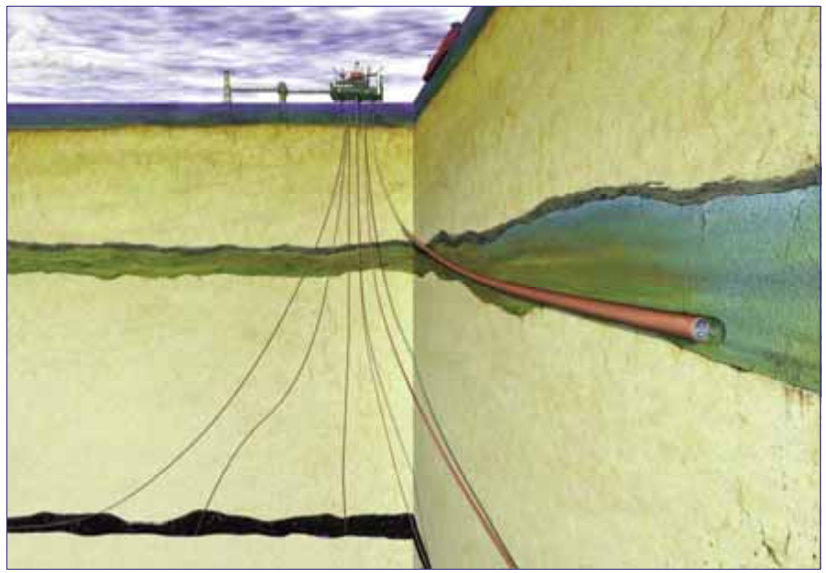
400-10 000 Gt CO_2

20-500 % of Emissions to 2050

Comparative potentials at storage costs of up to $20/t CO_2

Source: John Topper, IEA Greenhouse Gas Reduction Programme, presentation to the OPEC/WPC workshop 8th June 2004

Sleipner West Gas Field (1)

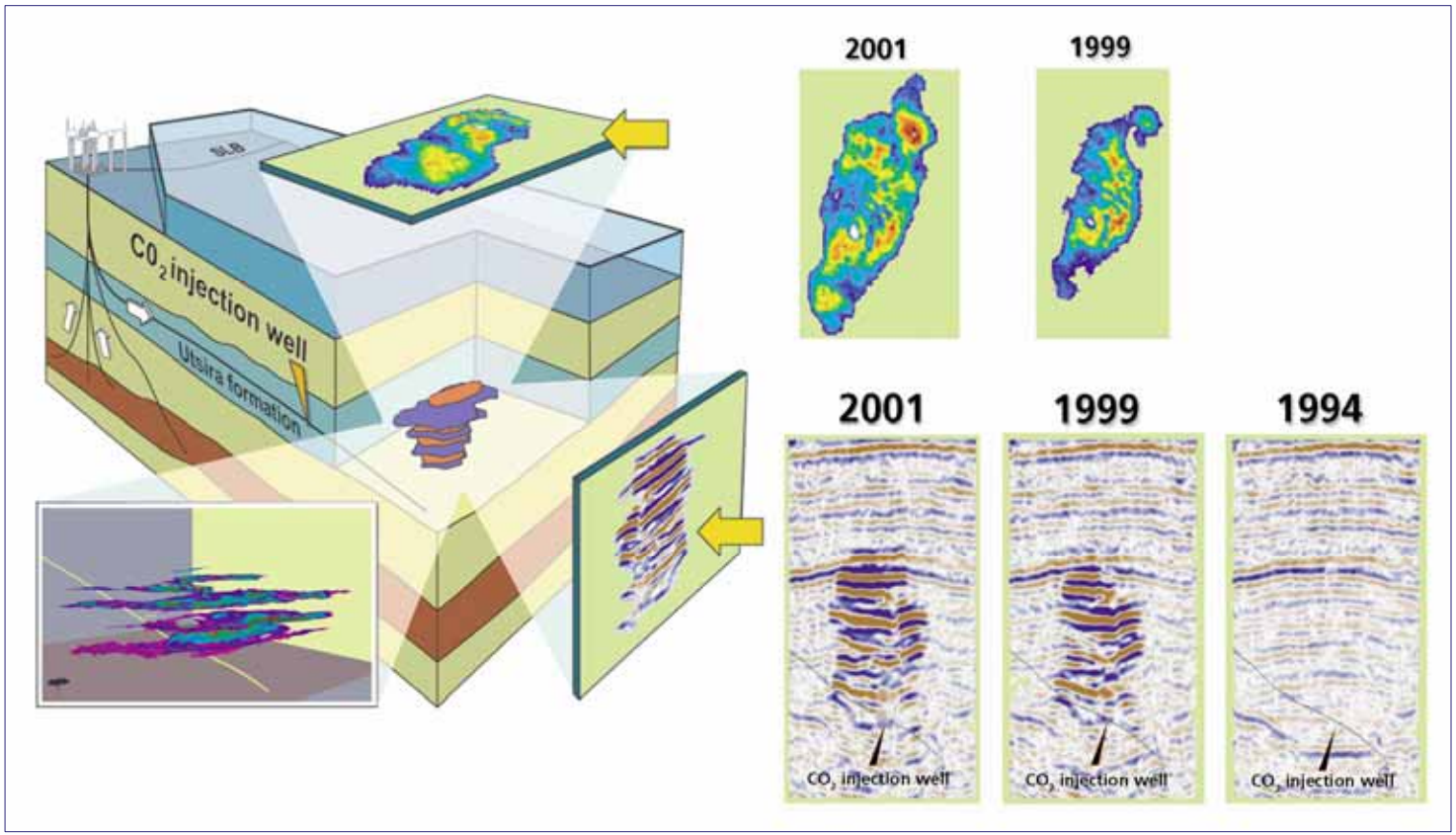


- Natural gas contains 4 to 9.5% CO_2
- Sales gas must contain less than 2.5%
- Large-scale offshore CO_2 capture

- Cost of injection facilities and well - $80 million
- One million tonnes per year injected into the Utsira Formation

Source: Mr. O. Kaarstad, Statoil, presentation to the OPEC/WPC workshop June 8, 2004

SLEIPNER WEST GAS FIELD (2)



Major R&D Results:

- **EU-supported monitoring project (SACS)**
- **3D Seismic indicates CO_2 is being contained in the reservoir**
- **Modeling studies used to predict future performance**

Source: Mr. O. Kaarstad, Statoil, presentation to the OPEC/WPC workshop June 8, 2004

In Salah Gas Project, Algeria

- Joint venture between Sonatrach (SH) and British Petroleum (BP).
  - Objective: Exploration, Appraisal, Development and Joint Marketing of gas produced from 7 fields of the region after its treatment.
- The gas is treated by an Ethanol - Amine solution
- The CO_2 is rejected by two amine regeneration trains
- The CO_2 is compressed through 4 compression stages up to a max of 200 bars
- The CO_2 is injected into the Krechba aquifer
  - 60 mmsdfd <=> 1.15 million tons/year
  - 20 million tons of CO2 re-injected during the life of the project

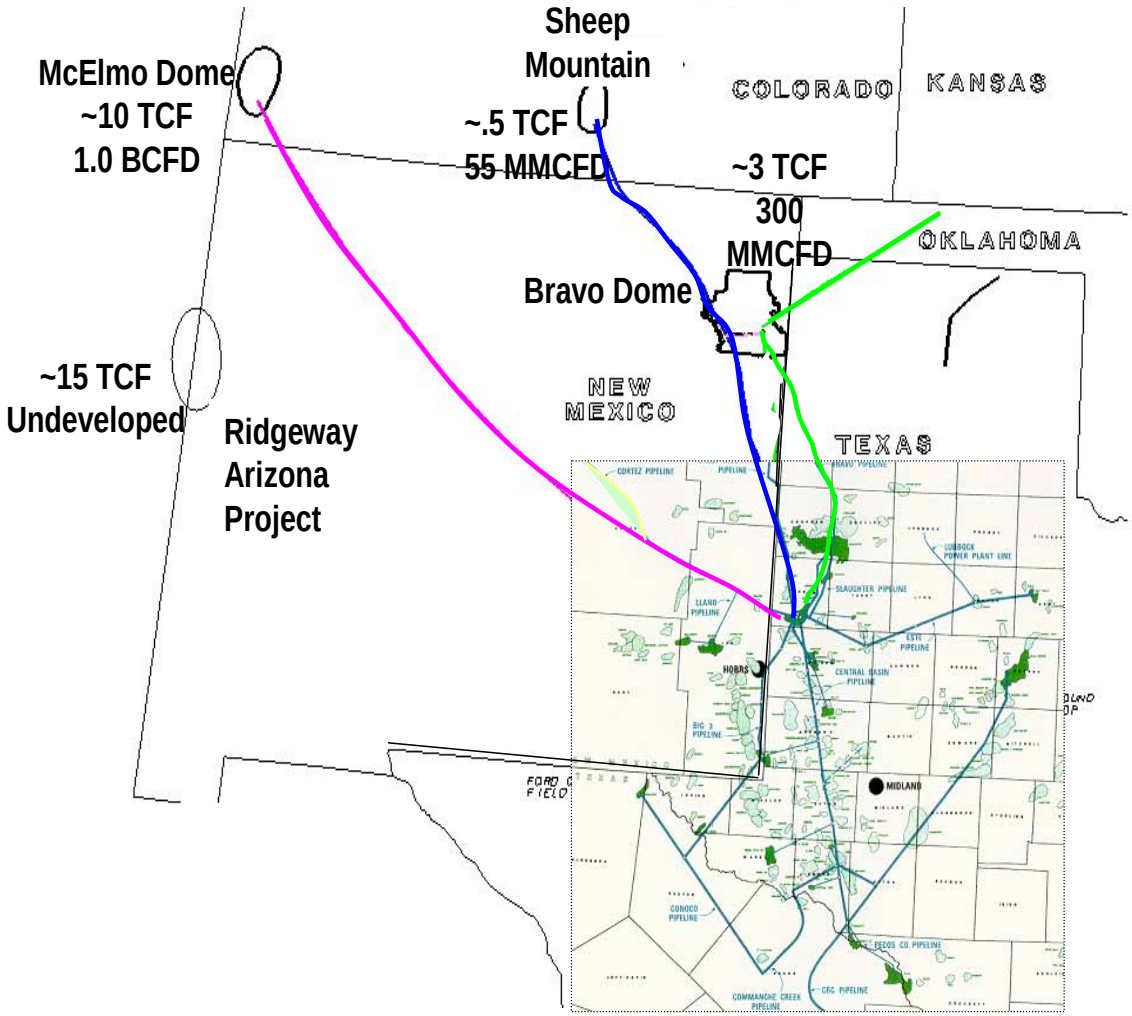
Source: Ms. N. Boudjemaa, P.E., Sonatrach, presentation to the OPEC/WPC workshop June 8, 2004.

CO_2 Enhanced Oil Recovery

West Texas Permian Basin CO_2 EOR Projects

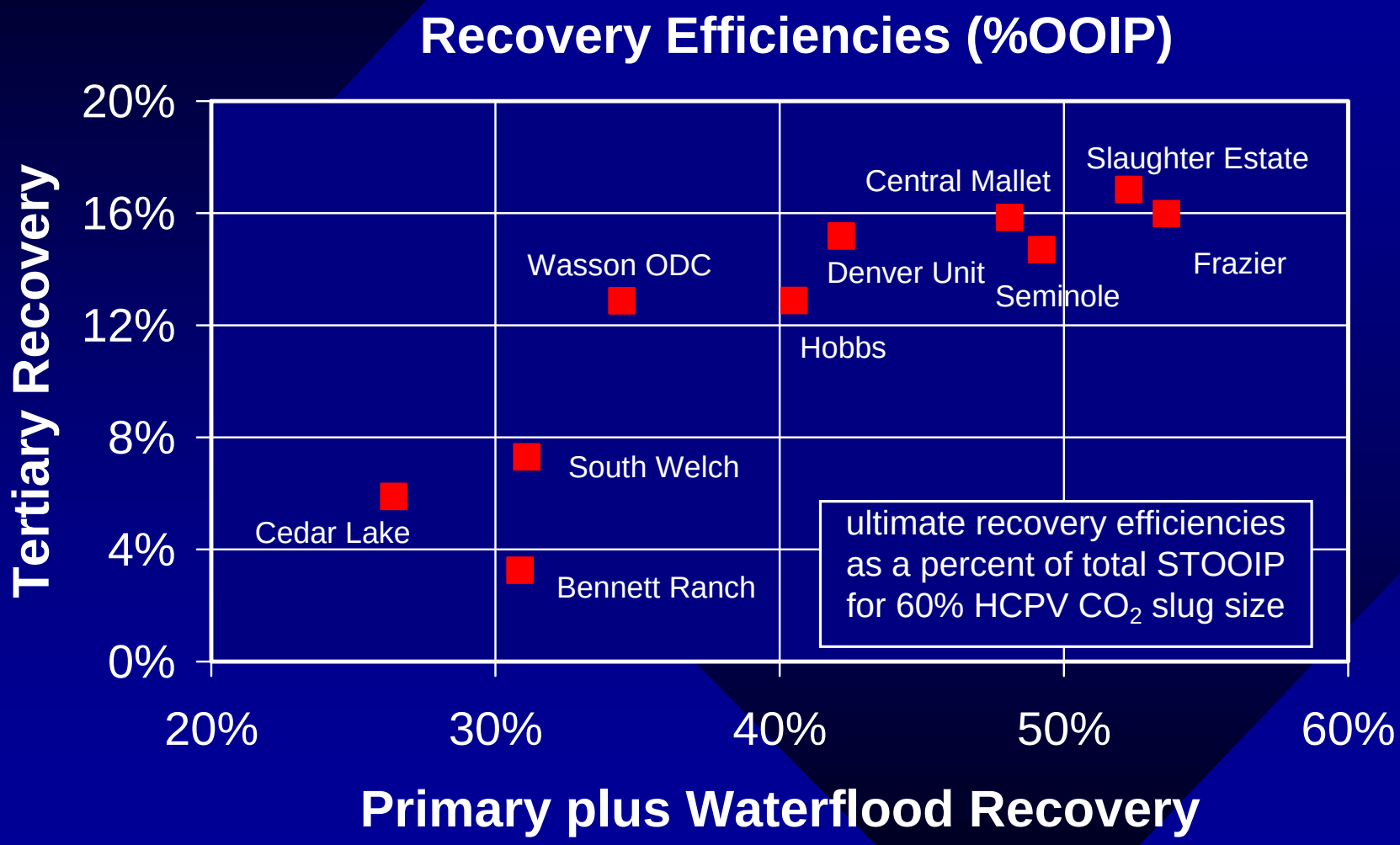
- **CO_2 EOR projects have been in place for 30 years, using natural sources**
- **About 1500 million ft^3 per day injected (42.4 million m^3/day)**
- **More than 50 active floods which contribute 20% of regional production.**

CO_2 Supply System



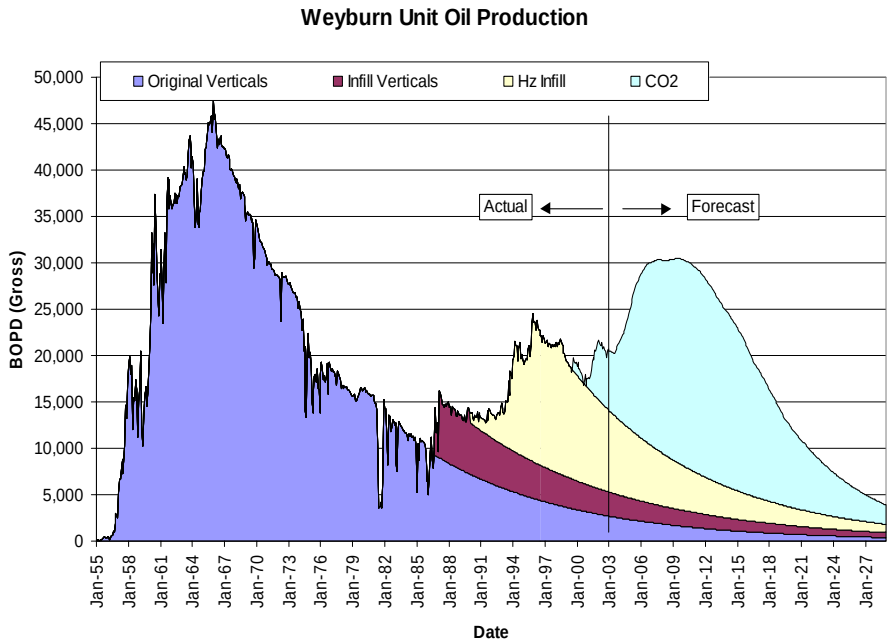
Source: Mr. Leamon Hood, Oxy, presentation at the OPEC/WPC workshop on CCS, June 8, 2004

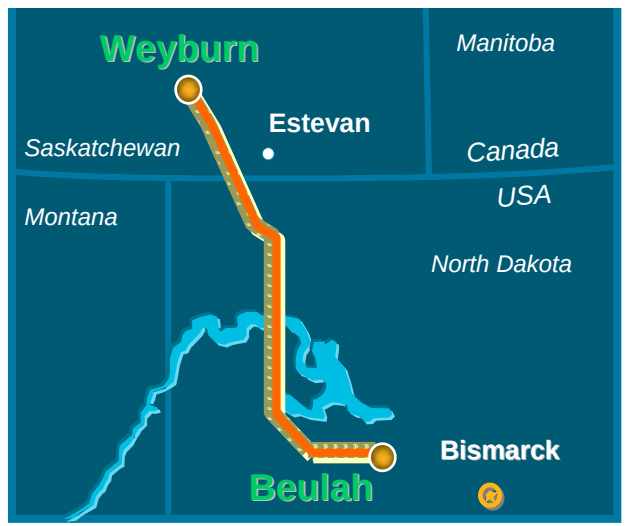
San Andres CO_2 Floods



Weyburn CO_2 EOR Demonstration Project
Saskatchewan, Canada

- The CO_2 is a purchased by-product from the Dakota Gasification Company's synthetic fuel plant in Beulah, North Dakota, USA
- CO_2 is transported through a 320-km pipeline to Weyburn.
- CO_2 injection into Phase 1A started
- September 15, 2000
  - 98 BCF (2776 M m^3) CO_2 injected as of February 2004
  - Current CO_2 purchase is 105 mmscfd
  - 25 mmscfd of associated gas and CO_2 being recycled
- Incremental oil production 9000 bbl/day out of 22,000 bbl/day





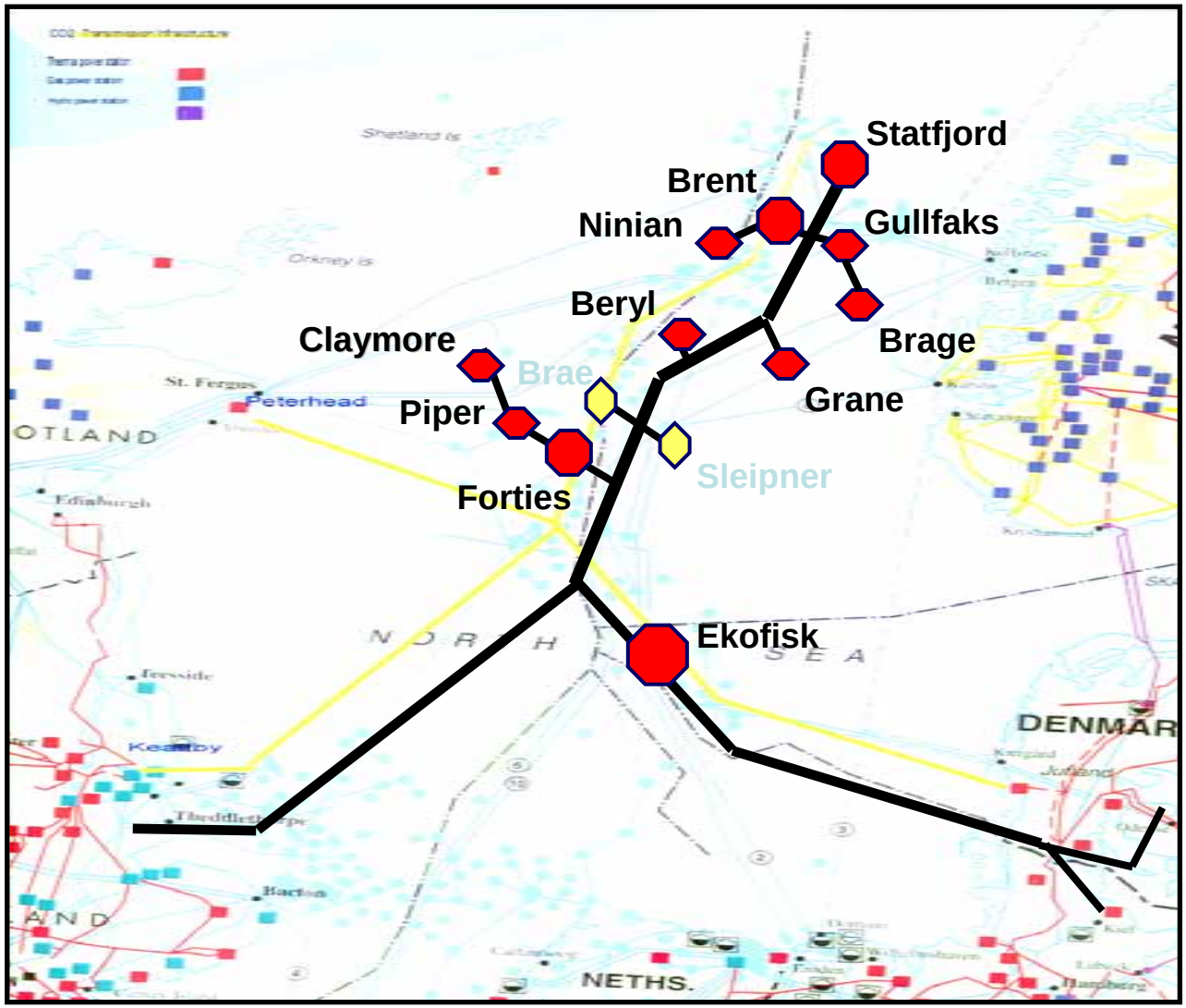
Source: Dr. M. Wilson, Petroleum Technology Research Center, Saskatchewan, Canada, presentation to the OPEC/WPC workshop June 8, 2004

CO_2 EOR Potential

- 126 gigatonnes of CO_2 storage in EOR Projects (IEA estimate)
  - Includes major basins in N. America, Europe, Middle East, Western Siberia
  - More potential if Africa, Latin America, and Asia are included
- Win-win scenario of increasing oil supplies while storing large quantities of CO_2
- EOR can provide financial incentive for early implementation of CO_2 capture technologies, thus helping to bring down the costs
- Revenue from EOR can help support infrastructure investments necessary to transport CO_2 to other geologic storage sites

Possible North Sea CO_2 Infrastructure

- **30 – 40 million t/year CO_2 stored from power stations and factories around N. Sea basin**
- **100 million bbl/year incremental oil**
- **Field life extended for 10 – 30 years**



Source: Hugh Sharman, consultant, presentation to the OPEC/WPC workshop June 8, 2004.

Carbon Capture and Storage Financing and Policy Issues

- **Supportive policies should be enacted and a legal framework developed**
- **Financial incentives for CCS are necessary**
- **The Clean Development Mechanism could facilitate early implementation of CCS in developing countries, if**
  - **It could accommodate large scale projects**
  - **It would recognize additionality and GHG reduction benefits of CCS**

Gas Flaring Reduction

- Global gas venting and flaring is around 100 bcm/ year
- The fraction of gas that is flared has been greatly reduced over the last 20 years
- Individual governments and companies have had successes in reducing flared gas, and significant investments in reduction projects are continuing.
- The World Bank Gas Flaring Reduction Initiative supports national governments' efforts to reduce flaring
  - Helps commercialize small gas volumes
  - Facilitates cooperation on gas infrastructure and markets
  - Promotes use of gas for poverty alleviation

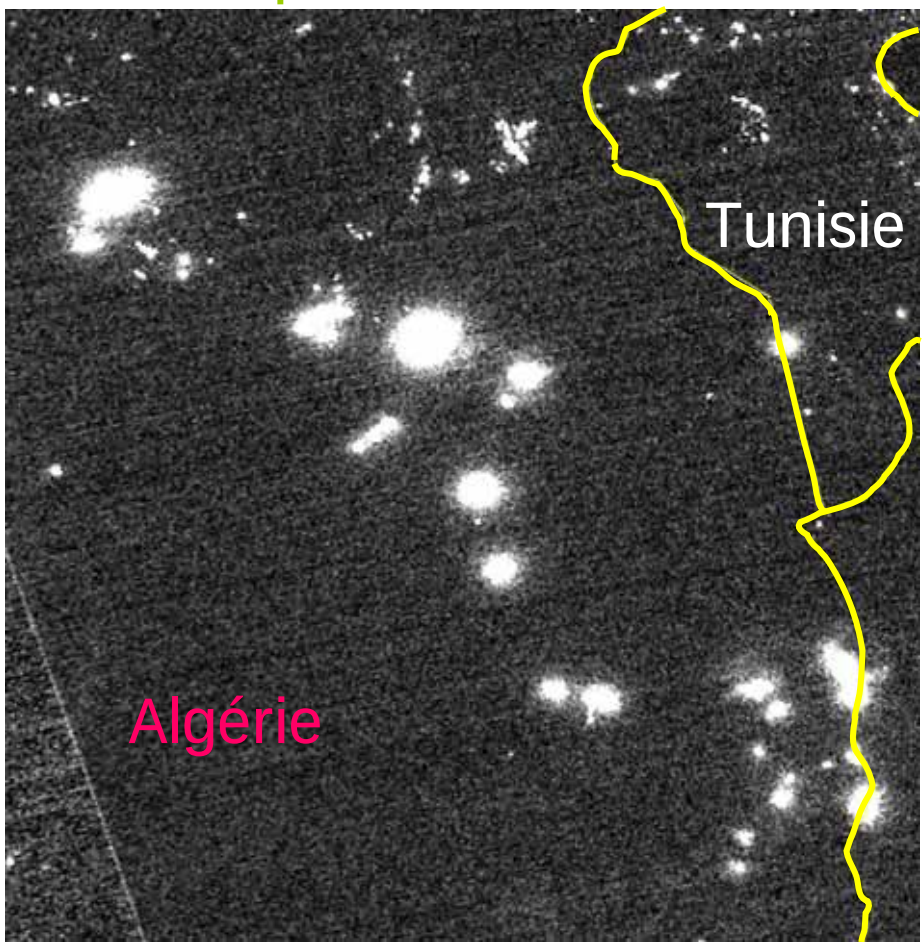
Gas Flaring Reduction
Algeria Example

- Invested over $660 million to reduce gas flaring
- While volumes of produced associated gases have practically quadrupled the 33 last years, the rate of flaring of associated gas decreased from 80% in 1970 to 11% in 2003.
- Less than 1% of the of dry (non-associated) gas is flared.
- In terms of total associated and dry natural gas, the flaring rate is less than 3%.
- Medium-term objective is to recover 93% of produced associated gas by 2007 and 100% by 2010.
- $200 million has been allocated to additional gas flaring reduction projects.

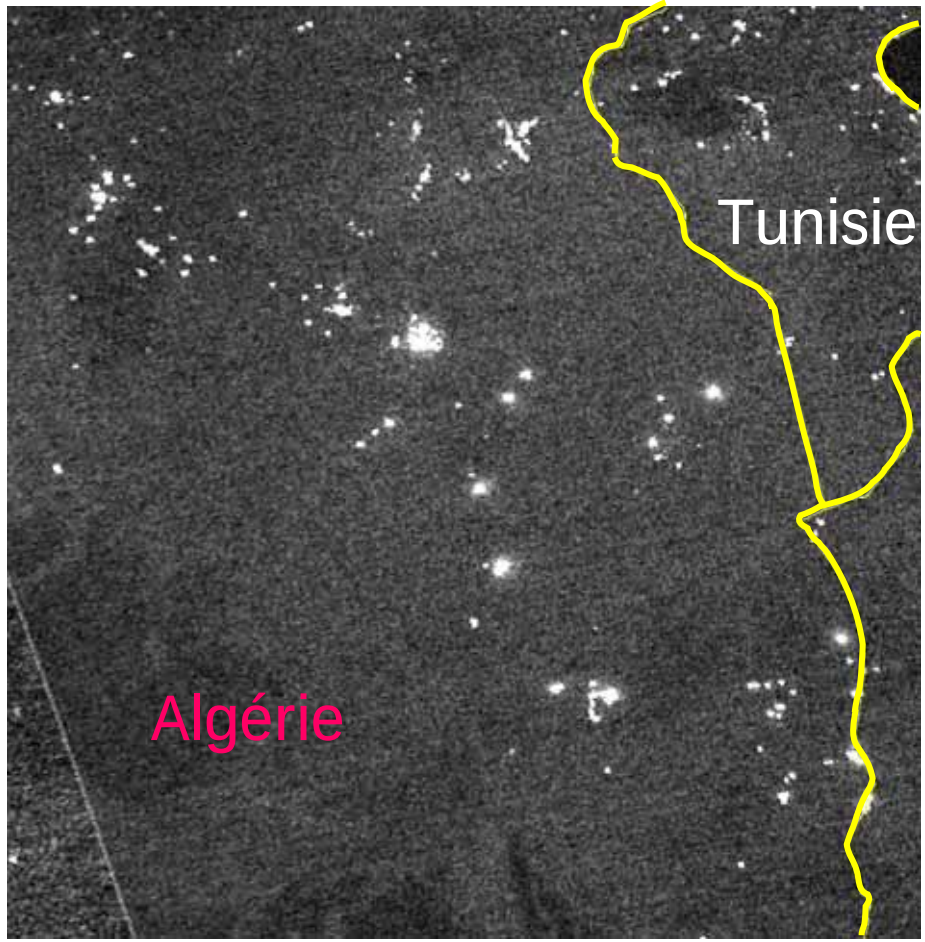
Source: Dr. Rabah Nadir Allouani, Sonatrach, presentation to the OPEC/WPC Workshop 9th June, 2004.

Satellite Observation Showing Net Reduction of Flaring

September 24th, 1992



March 20th, 2002



Source : DMSP-OLS Observations of Gas Flares, Dr. Rabah Nadir Allouani, Sonatrach, presentation to the OPEC/WPC Workshop 9th June, 2004.

Gas Flaring Reduction
Abu Dhabi Example

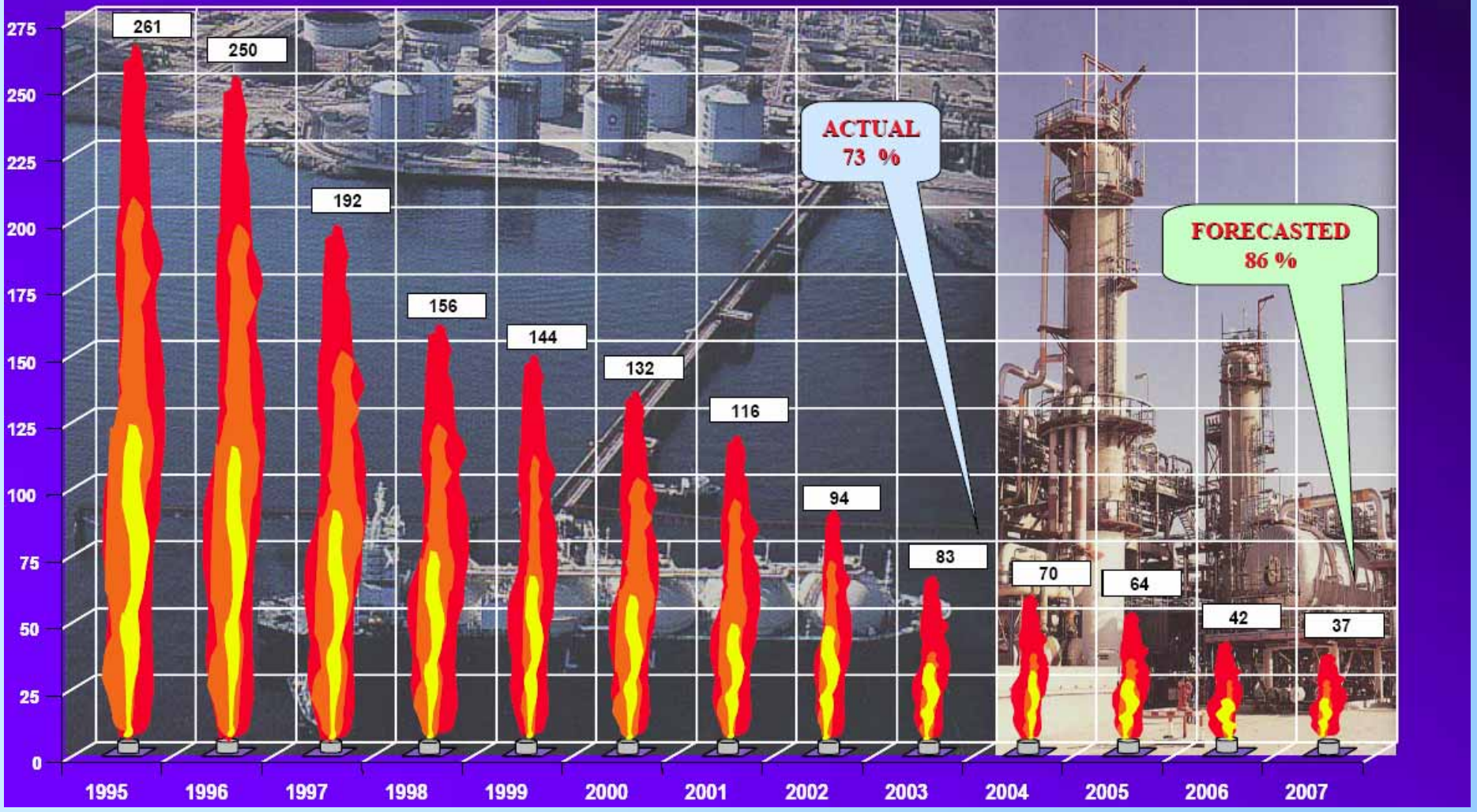
- **Abu Dhabi rapidly reduced gas flaring after 1977 from 4000 mmfcd to < 500 mmcfd in the early 1980s, to < 300 mmcfd in the mid-1990s**
- **Since 1995 many new projects have been implemented to reduce flaring from 270 mmcfd to 70 mmfcd today. This is only about 1% of the more than 6000 mmcfd gas production today**
  - **Reduced the number of flares**
  - **Re-injection of gas into oil reservoirs**
  - **Plants modified to recover gas**
  - **Zero flaring technology installed in some locations**
- **Flaring will be reduced to 30 mmcfd by 2007**
- **Goal is zero flaring**

Source: Mr. Ihab Othman Tarmoon, ADNOC, presentation to the OPEC/WPC workshop 9th June 2004.

ADNOC GAS FLARING TREND

أدنوك
ADNOC

1995 - 2007



Source: Mr. Ihab Othamn Tarmoon, ADNOC, presentation to the OPEC/WPC workshop June 9, 2004

Gas Flaring Reduction
Nigeria Example

- **Over 40% of associated gas is flared**
  - **Down from 70% in 1996**
  - **The flared volume is enough to meet the electricity needs of sub-Saharan Africa**
- **Main challenge is limited domestic demand**
  - **Slow economic growth; underdeveloped local market**
  - **Lack of pipeline infrastructure**
- **Even so, domestic gas utilization has increased from 50 mmcfd in 2000 to 1000 mmcfd today.**
- **Gas gathering systems and use of associated gas to supply part of LNG feed are planned**
- **Policy is to eliminate gas flaring by 2008**

Source: Mr. Abiodun Ibikunle, NNPC, presentation to the OPEC/WPC workshop 9th June, 2004.

Okpai Independent Power Project Overview

Category of the Project	Gas Flaring Reduction
Partners (Equity)	NNPC (60%) - NAOC (20%) -CONOCO PHILLIPS (20%)
Investments	~ $400 million USD
Start-up	January 2005
Project life	20 years + 5 years (possible extension)
GHG reductions	1.8 million tonnes CO_2 per annum

Will be submitted as a CDM Project

Source: Mr. Vito Caruso, Eni, presentation to the OPEC/WPC workshop 9th June, 2004.

Conclusions

- CCS has enormous potential to reduce CO_2 emissions.
- CCS is one of the lowest cost near to medium term options in terms of cost per tonne of avoided emissions, and costs will be further reduced through R&D.
- CCS would allow people to continue to benefit from the use of fossil fuels.
- CO_2 enhanced oil recovery can increase oil reserves and extend plateau production in mature oil fields while storing CO_2.
- Reduction or elimination of gas flaring can contribute to GHG reductions while bringing modern energy supplies to under-developed regions of the world.
- CCS, CO_2 EOR, and gas flaring reduction projects should be:
  - Eligible for financial support, including CDM
  - Supported by appropriate legal and policy frameworks