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EOR – The Time is Now

Its Contribution to World Oil Supply

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Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl

Enhanced Oil Recovery (EOR) – The Time is Now

Churchill once said:

"the best time to plant a tree is twenty years ago. The second best time is now."

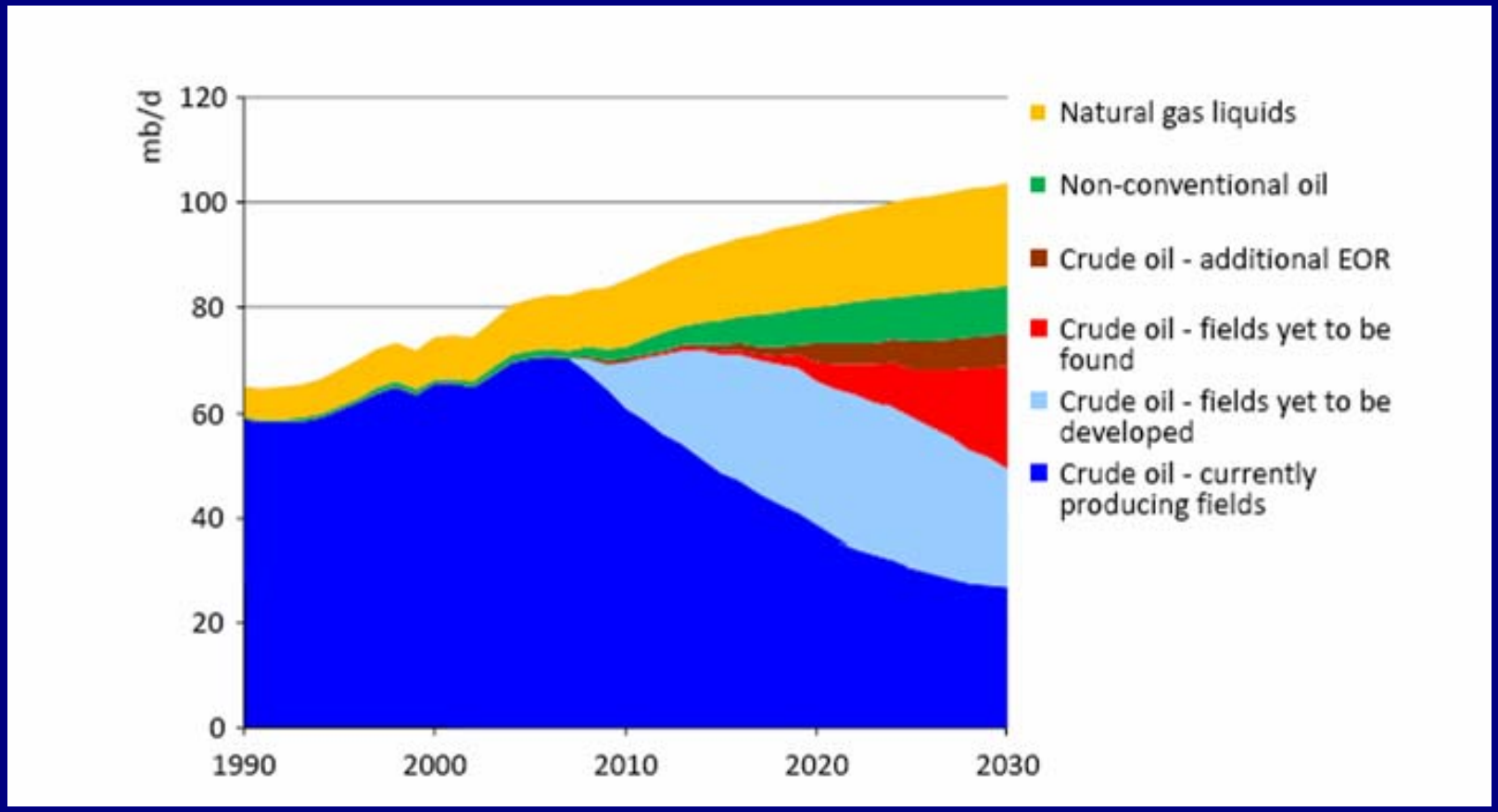
In E & P, the best time to plan and begin implementation of EOR is during original development planning.

The second best time is Now!

Outline

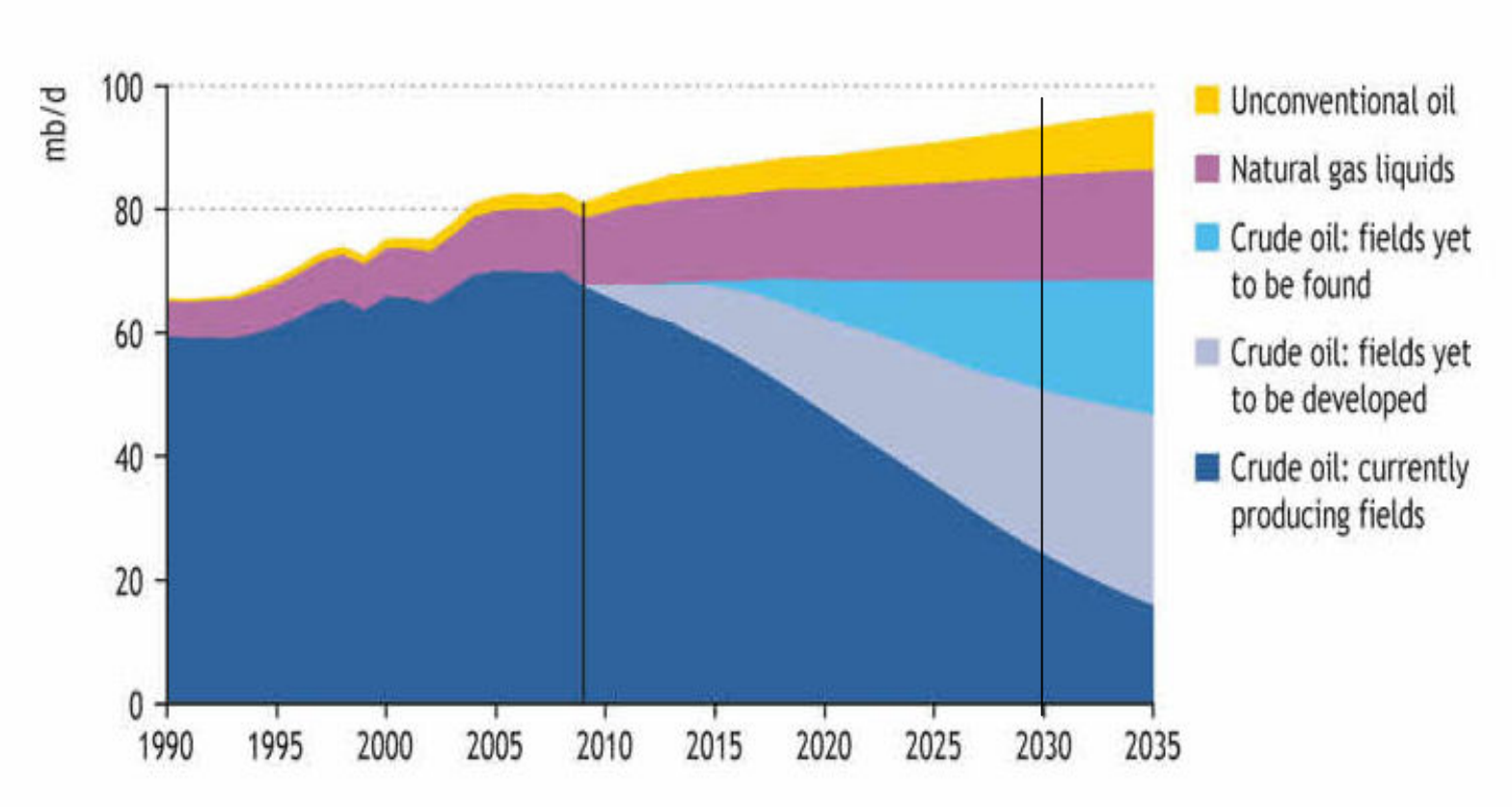
- Status and potential of EOR
- Why EOR?
- What's new – Technical
- Why now?
- Planning for EOR
- EOR Opportunities and Challenges
  - Both offshore and onshore
  - Economic
  - Political
- Summary

World Oil Production Forecast (IEA) 2008



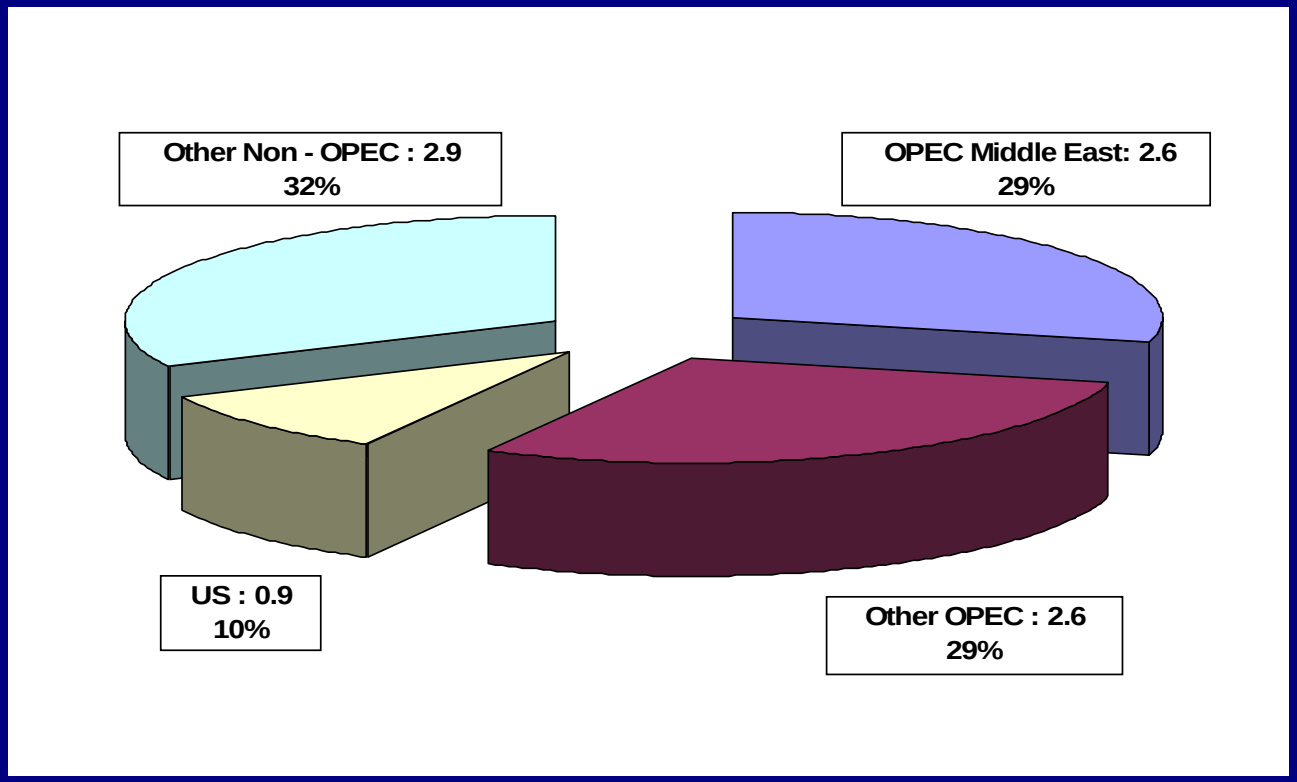
- **74 million b/d of capacity additions needed by 2030**
- **5 million b/d is forecast to be supplied by additional EOR in 2030**
- **20 million b/d is from "fields yet to be found"**

World Oil Production Forecast (IEA) 2010



- **70 million b/d of capacity additions needed by 2030**
- **Additional EOR not included as a separate category**
- **20 million b/d is from "fields yet to be found"**

World Conventional Oil In-Place, ~ 9 Trillion Barrels

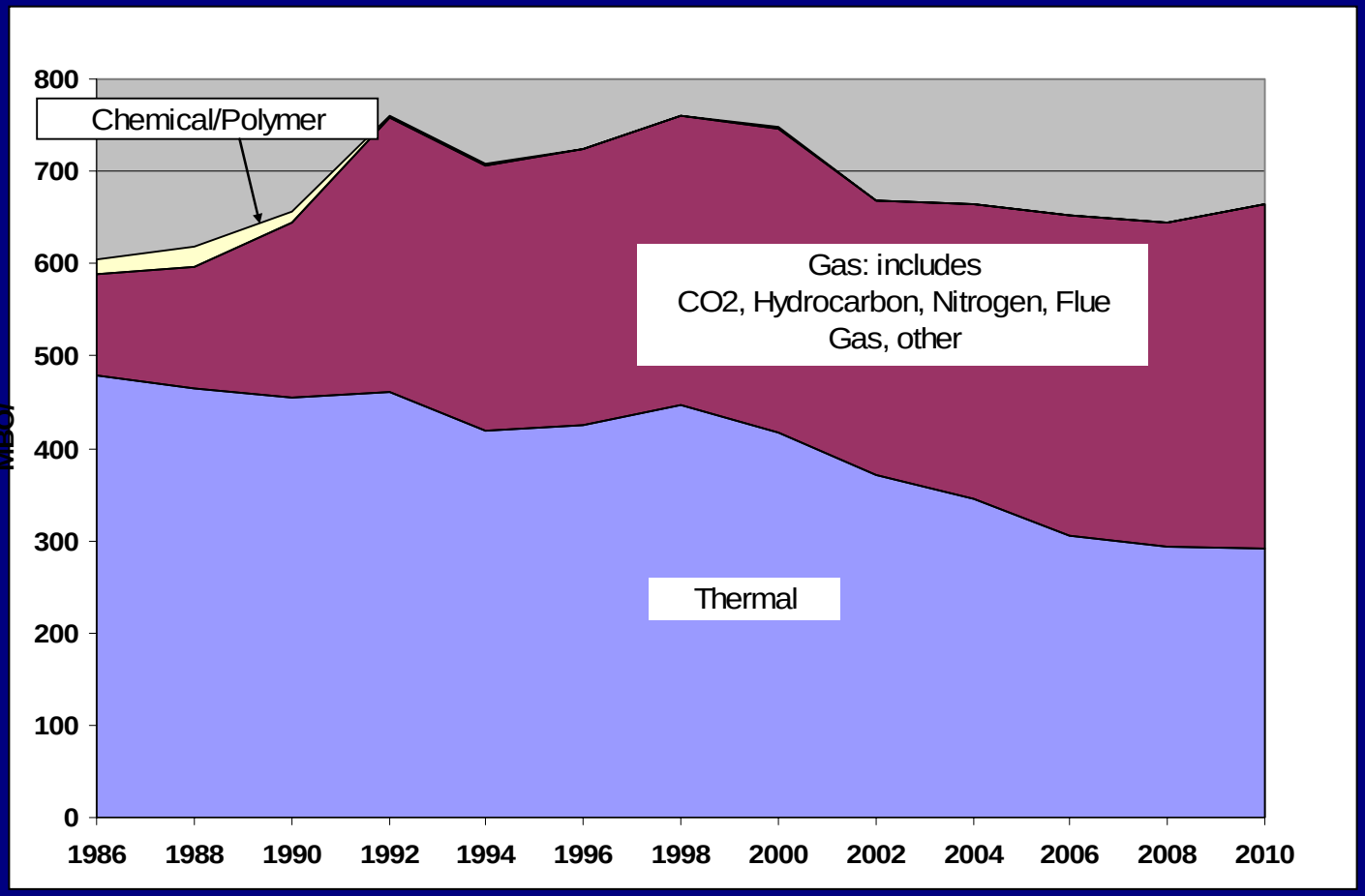


Of the 9 trillion barrels in place, ~ 1.1 trillion barrels has been consumed.

33% recovery efficiency ⇨

EOR target of 2.2 trillion barrels in discovered fields!

US EOR Production since 1986: ~ 6.4 billion barrels!

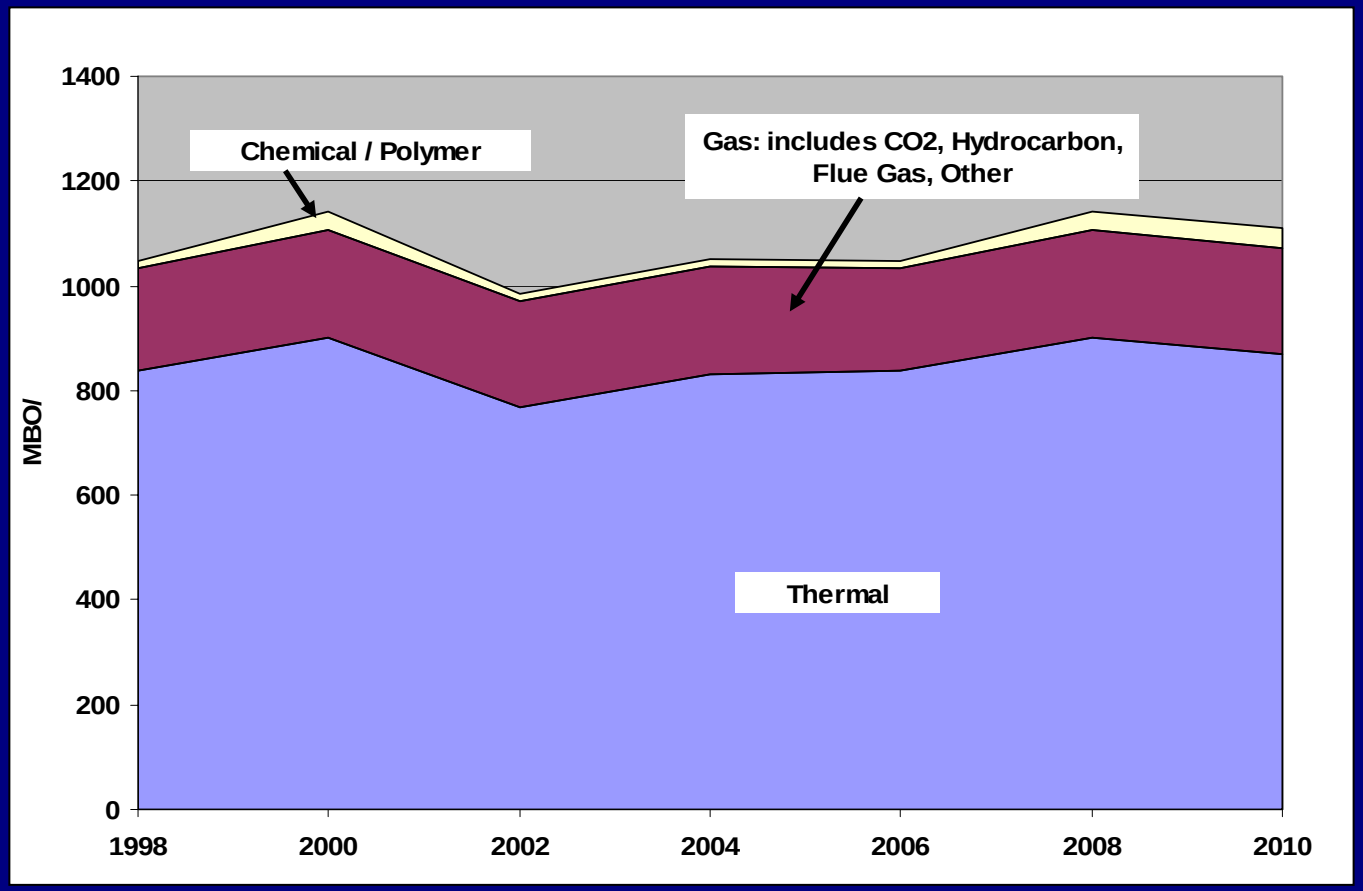


U.S. EOR production is ~12% of the U.S. total

Two major contributors:
Thermal recovery using steam injection
Carbon dioxide miscible recovery

From OGJ biennial surveys

EOR Production outside the US since 1998: ~ 5.5 billion barrels!



Thermal recovery in Venezuela, Indonesia, China, Canada.

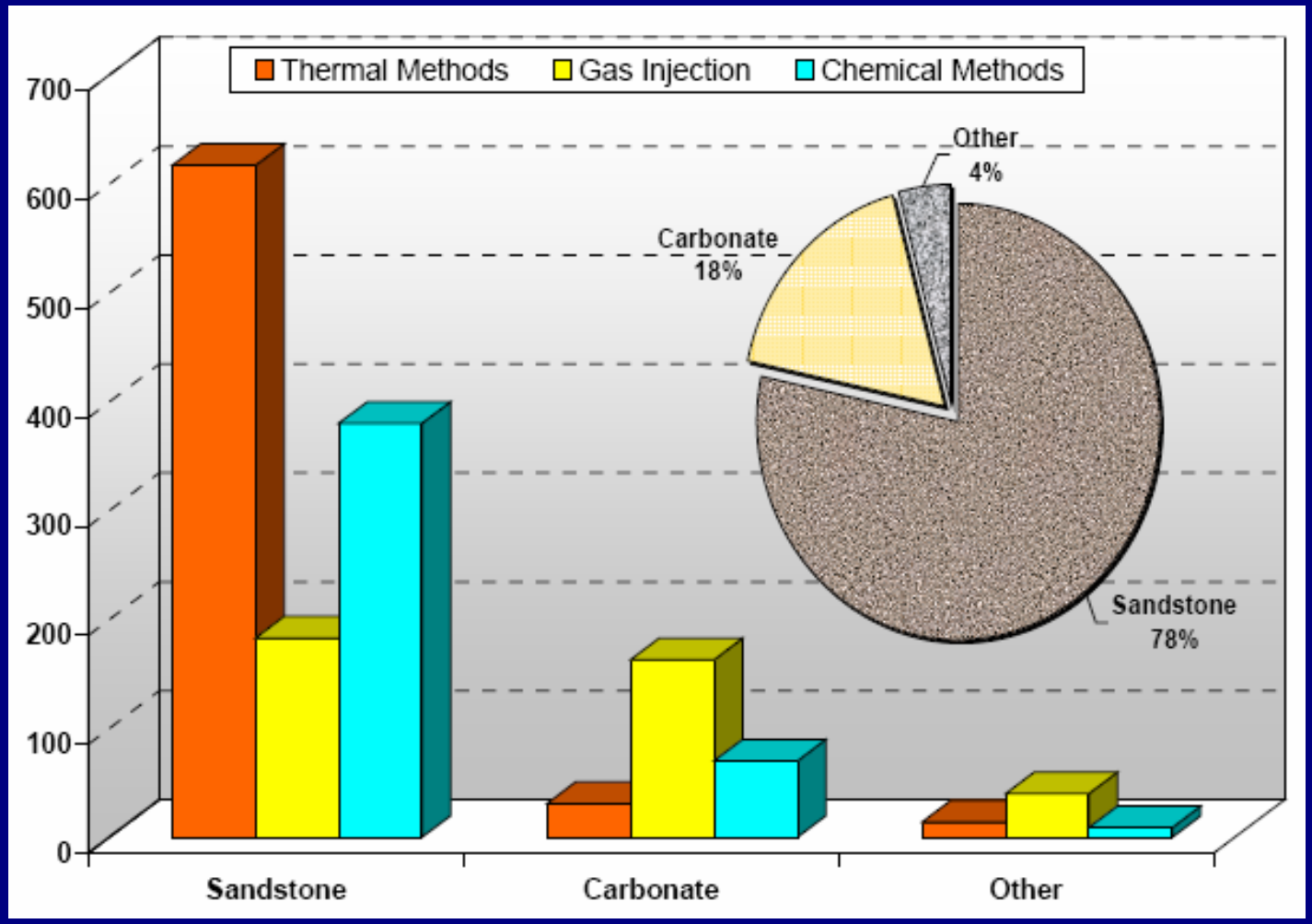
Gas injection in Canada, Venezuela, and Libya

Chemical/polymer applications in China.

From OGJ biennial surveys

EOR Methods Based on Lithology

This plot is based on 1507 worldwide projects



Source: SPE 130113, Manrique E., et al; April 2010

Why EOR?

- Access to new exploration acreage is difficult and expensive
- There is significant oil in place in discovered reservoirs that will otherwise not be recovered
- EOR can make an important contribution to world oil supply in the long term
- EOR economics can be attractive

EOR Today

- Mature technologies:
  - Thermal
  - CO_2 miscible
- Technologies with unrealized potential:
  - Chemical
  - Polymer
  - Combustion
- Barriers:
  - Long lead times
  - Economics
  - Politics

Not your Grandfather's EOR (1)

What is new in Mobility Control:

Polymers:

- PetroChina has made significant advances in the design and manufacture of polymers
  - Narrow range of molecular weights
  - Tailored to application
  - Can be applied economically in lower permeability formations
- **In-depth diversion technology**
  - Thermally activated plugging agents
- Foams
  - Advances in the laboratory

Not your Grandfather's EOR (2)

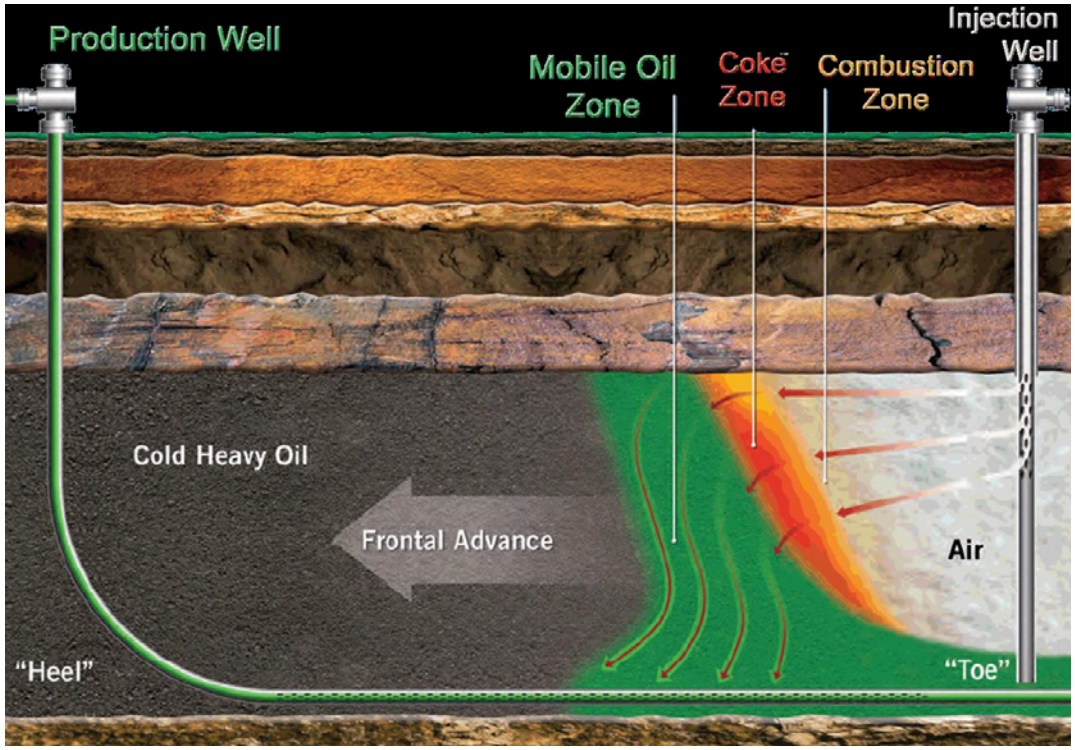
What is new in Chemical Flooding:

- Advances in surfactants:
  - Thermally stable surfactants (e.g., sulphonates) remove temperature restrictions
  - Surfactants designed to be active at 0.1% concentrations
  - Sacrificial agents (e.g., sodium carbonate) reduce adsorption to very low levels
- Alkaline flooding:
  - Alkaline-polymer (AP) and alkaline-surfactant-polymer (ASP) are new, lower-cost EOR methods

Not your Grandfather's EOR (3)

What is new in Thermal Recovery:

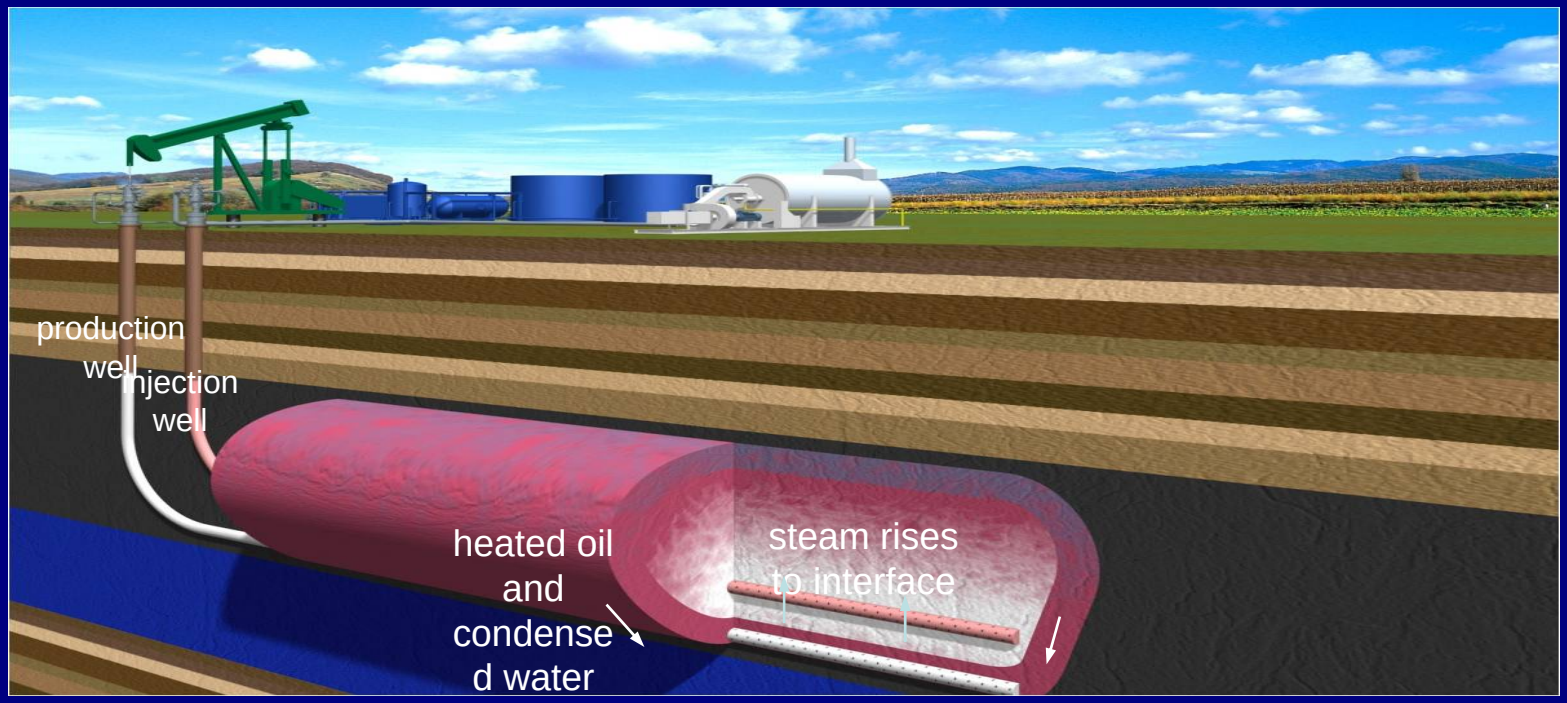
- **Controlled Combustion –THAI (Toe to Heel Air Injection)**
  - Removes depth, pressure restrictions of steam
  - Applicable to light oils



Not your Grandfather's EOR (4)

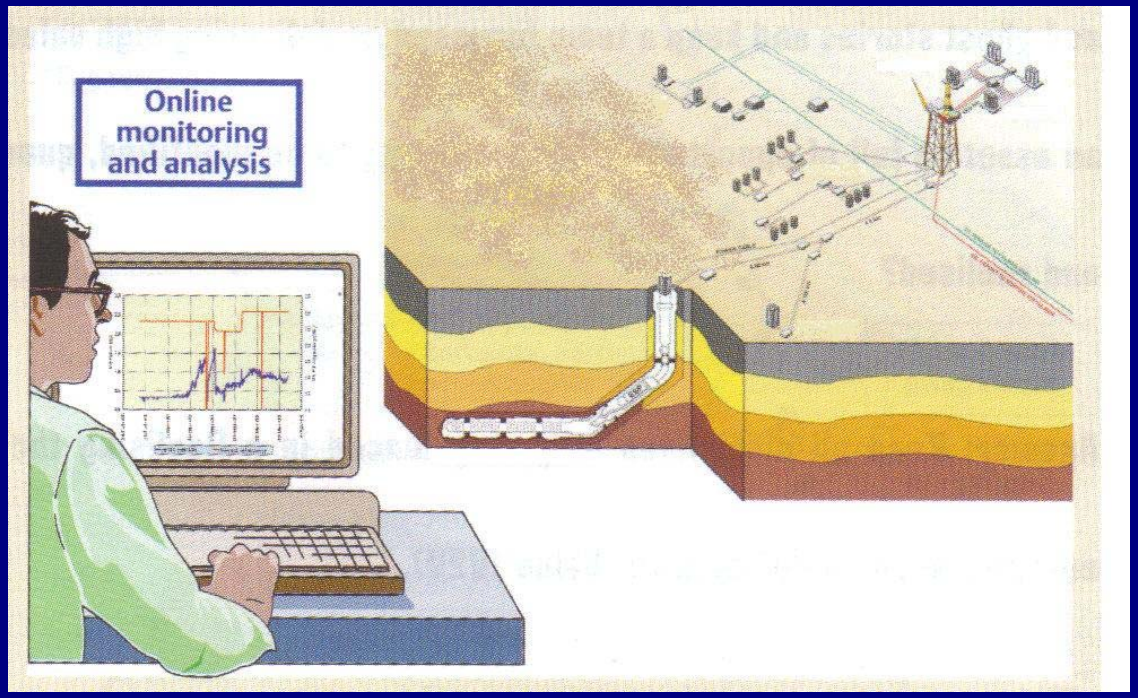
What is new in Thermal Recovery:

- **Steam-Assisted Gravity Drainage (SAGD)**
  - Uses horizontal wells to contact formation, reduce well costs
  - Modification of steam drive



What's New in Tools and Techniques (1)

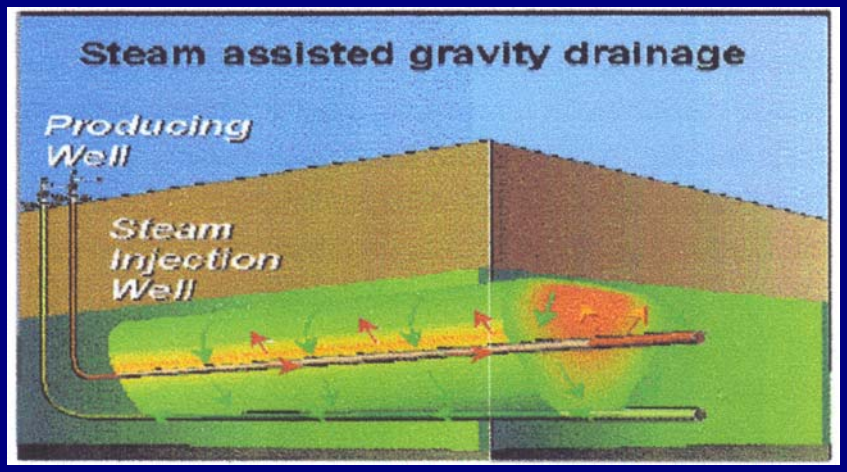
More efficient project design and management is possible using:



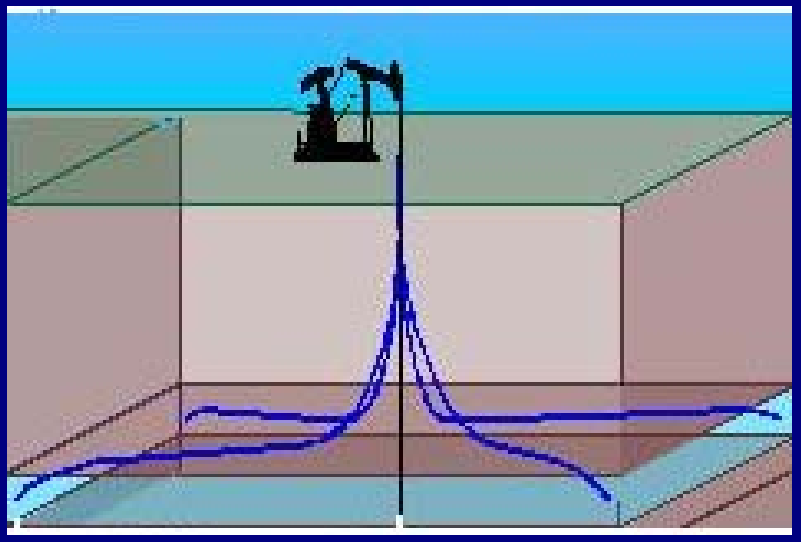
Real-time information gathering, analysis …

What's New in Tools and Techniques (2)

Horizontal wells …

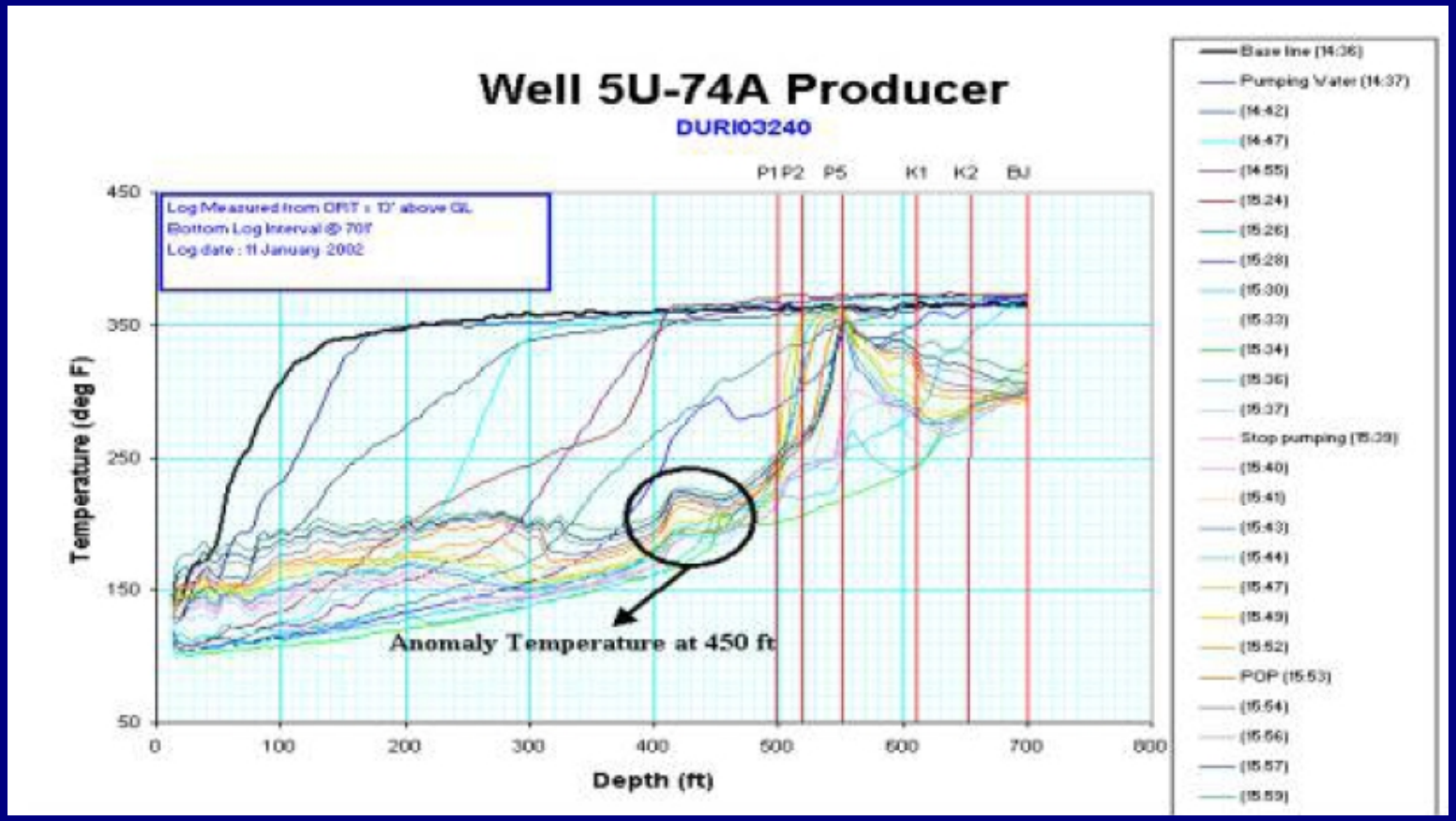


Smart wells, multilateral wells …



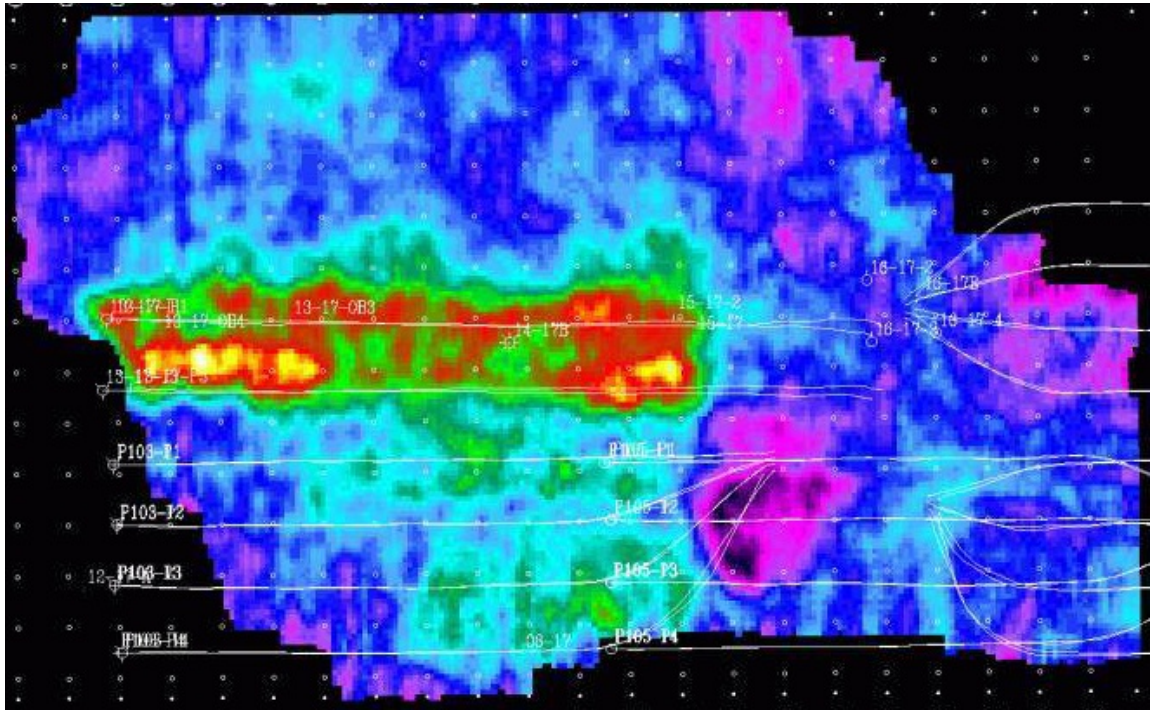
What's New in Tools and Techniques (3)

Permanent downhole monitoring using fiber optics – pressure, temperature, multiphase flow rate …



What’s New in Tools and Techniques (4)

4-D seismic …



Etc, etc …

Promising Technologies

- Microbial EOR
- Nanotechnologies
  - Smart tracers
  - Delivery of materials
  - Detailed reservoir description
- Down-hole steam generation

Why Now?

- Design and implementation of an EOR project takes time
- After implementation (especially as a tertiary project) production response does not occur immediately

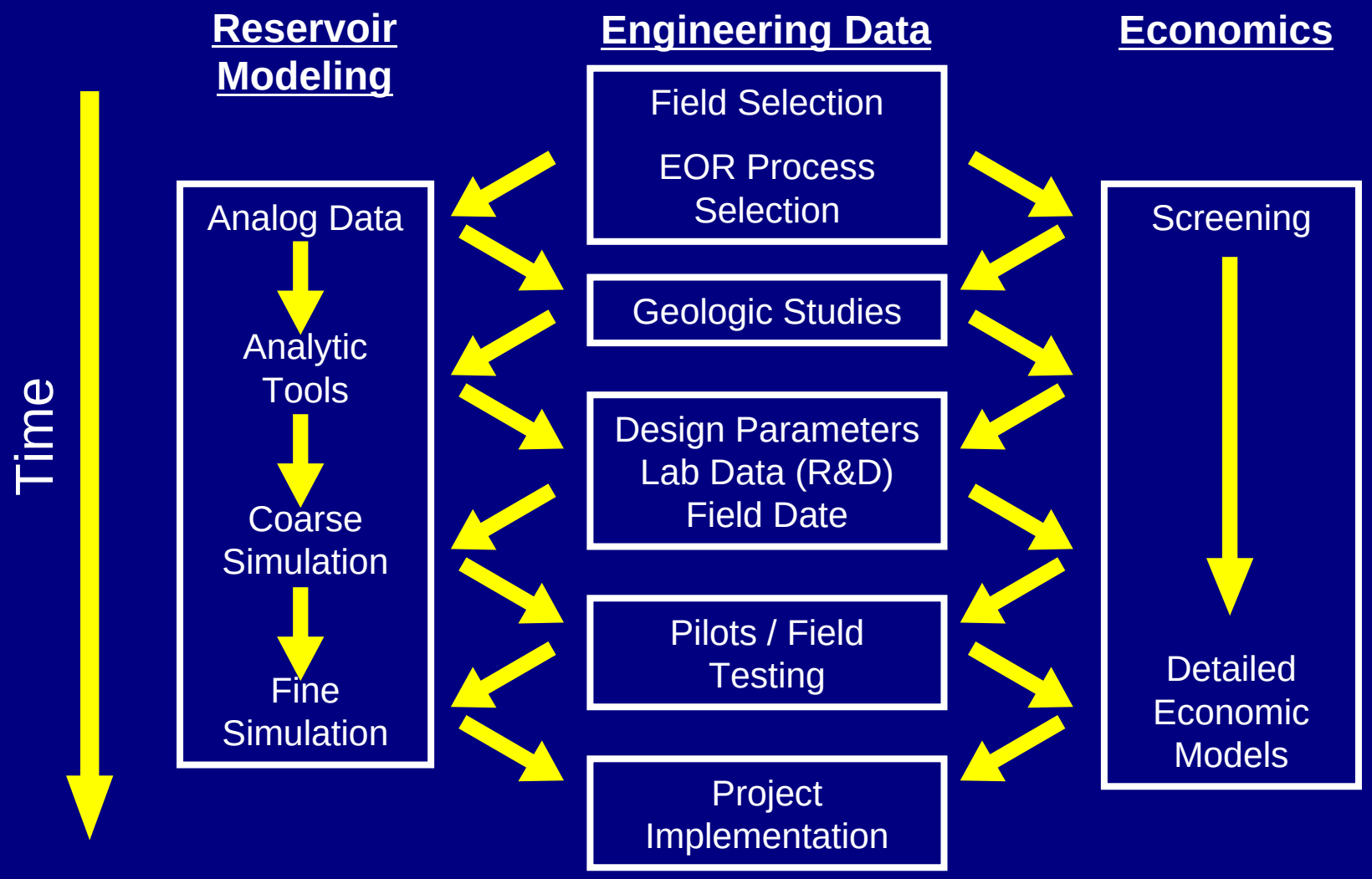
Steps to a Successful EOR Project (1)

- Field selection
  - Successful secondary?
    - A water-based EOR process will go where the waterflood water went
  - In-place target
    - Is there sufficient remaining oil in place to justify an EOR project?

Steps to a Successful EOR Project (2)

- Process selection: what is the objective?
  - Improved sweep efficiency
    - Overcome reservoir heterogeneities or poor mobility ratio
  - Improved displacement efficiency
    - Is the objective to recover a residual oil saturation in a swept zone?

Steps to a Successful EOR Project (3)



Pilot Testing

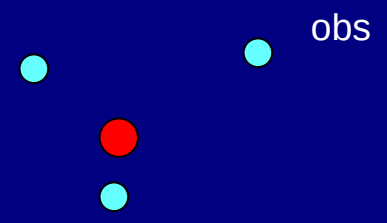
- Use to reduce critical uncertainties
- Most expensive, most time-consuming
- Design with specified objectives
  - Oil-in-the-tank not sufficient
  - Profitable pilot usually unrealistic
- Need dedicated personnel

Types of Pilot Test

Single Well

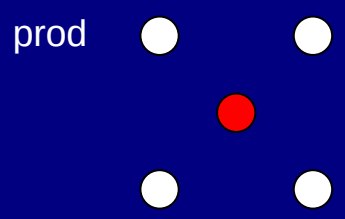
ROS Determination
Injectivity

Mini-Test



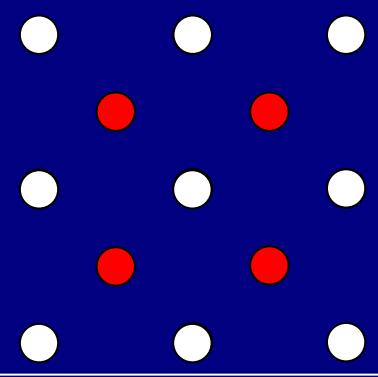
+ Build oil bank
+ Vertical, Areal conformance

Single Five-Spot



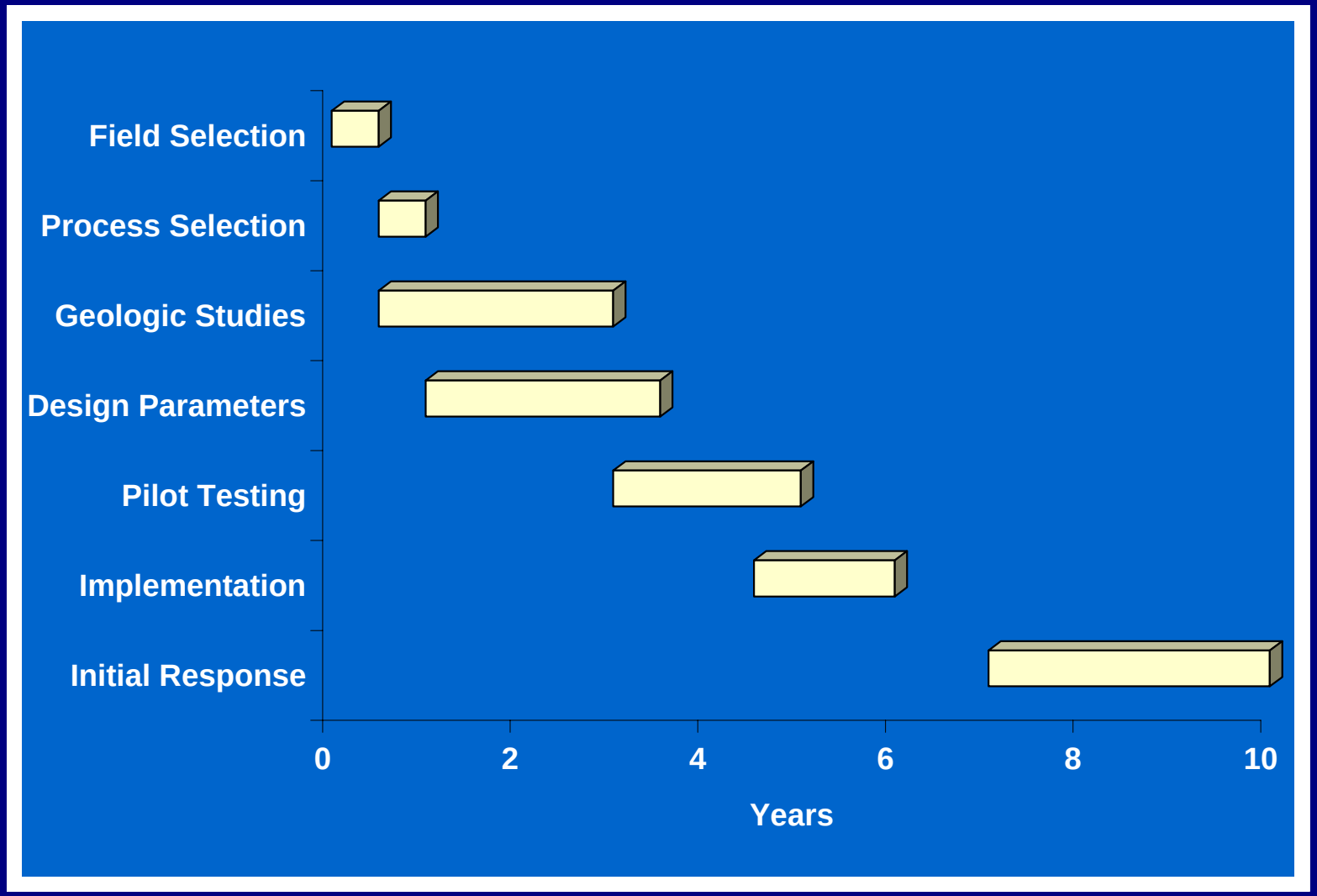
+ Displacement efficiency
+ Sweep efficiency
+ Operations experience

Confined Five-Spot



+ Redundancy
+ Improved capture efficiency

EOR Project Time Line



EOR Potential

Opportunity:

- **Target resource for EOR applications is 6 trillion barrels, of the 9 trillion initially in place**
- **Widespread application could far exceed the current forecasts**
- **Chemical / polymer flooding has large unrealized potential**
- **Both hydrocarbon and CO2 miscible flooding have large potential internationally**
- **A significant resource exists in the offshore, as well as onshore**
- **CO2 sequestration may provide an additional impetus and opportunity**

EOR Challenges

However, there are significant challenges:

- **Application Onshore:**
  - **old wells,**
  - **commingled wells,**
  - **reservoir understanding**
- **Application Offshore:**
  - **large well spacing,**
  - **logistics,**
  - **reservoir understanding**

Economics Challenges

- **Thermal:**
  - **Greenhouse gas emissions**
  - **Combustion - perceived high risk**
- **Chemical – Polymer**
  - **Long lead times, long payout**
  - **Perceived high risk**
- **CO_2 Miscible**
  - **Access to CO_2**

However: Long term demand and price increases present opportunities!

Political Opportunities

- NOC, IOC, Governmental Relationships can harm EOR opportunities:
  - Mutual interests are hampered by short-term considerations, different objectives
- Solution: treat EOR differently!
  - Jointly share technical, economic risk
  - Revise concession terms to include life-of-project for EOR

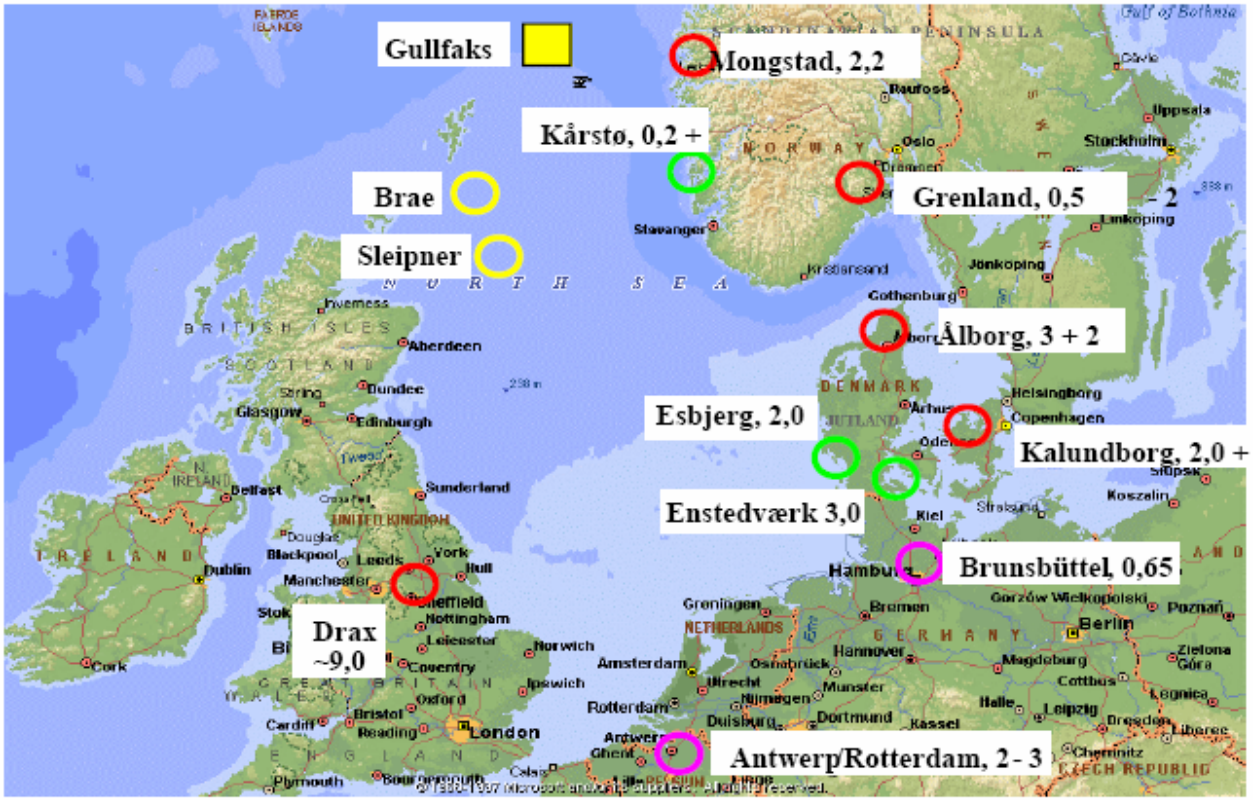
CO_2 Sequestration

Finally, carbon capture initiatives may present an economic opportunity for increased recovery

- Joint industry-government efforts to gather CO_2 for sequestration
  - Examples: North Sea, U.S. GOM, Middle East
    - Large volume in developed fields in the subsurface
    - Opportunity for collection of CO_2 (power plants, petrochemical facilities), delivery to offshore fields
- These opportunities may not be practical for an individual oil company, but are feasible with a joint industry-government approach

North Sea Example (1)

Some Regional CO_2 Sources



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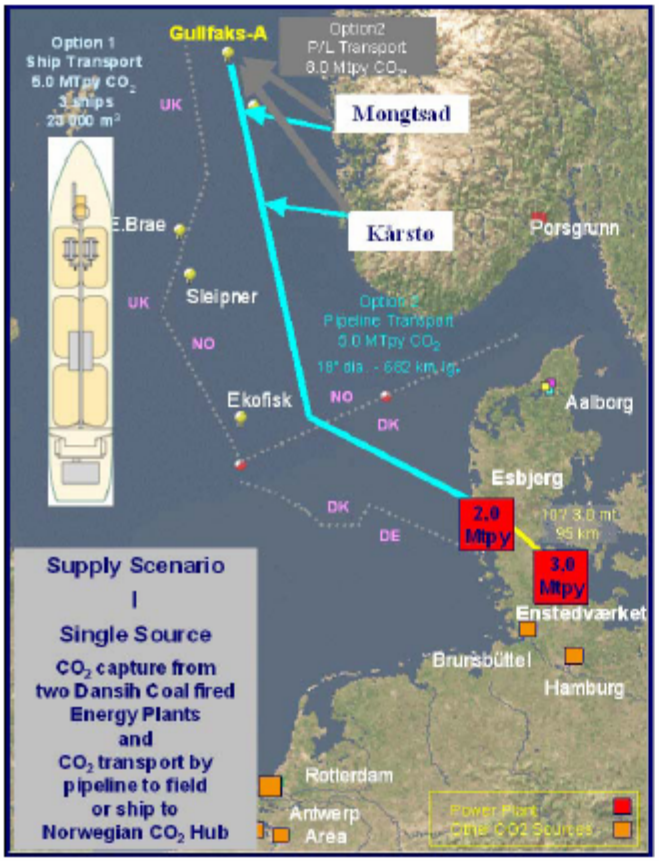
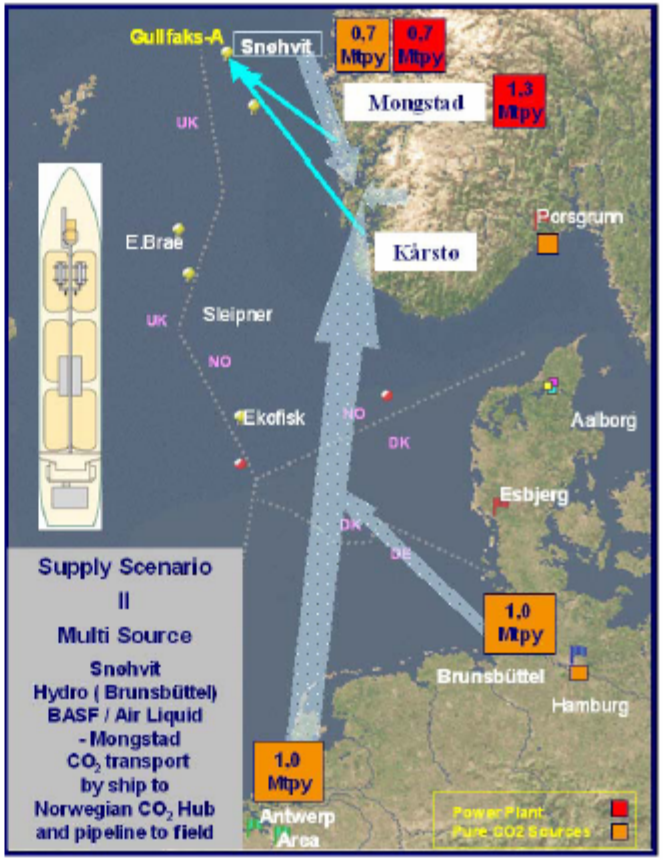
North Sea Example (2)

Two Supply Alternatives, 5 Mt/year





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Summary

- EOR Technologies exist that reduce project technical risk
- EOR can make a much more significant contribution to world oil supply than is currently forecast
- EOR is a long-term business
- Cooperation between IOCs and NOCs can result in mutual benefits
- CO2 sequestration presents an additional E&P opportunity

The second best time to plan and begin implementation of EOR is ***Now****!*