

أرامكو السعودية  
Saudi Aramco



# Carbon Management: a Saudi Aramco Perspective

EU-OPEC Round Table on CCS  
September, 2006, Riyadh

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# Outline

- General Perspective on Climate Change mitigation
- Saudi Aramco efforts pertaining to Carbon Management
- SA Carbon Management Technology Roadmap
- General considerations on CO<sub>2</sub>-EOR and CCS
- Summary

# General Perspective on Climate Change Mitigation

- Affordable & reliable energy supply is essential to sustaining modern life
- Emission reduction solutions should take into consideration global energy needs
- Fossil fuels are expected to remain the main source of global energy supply for decades
- CCS is emerging as a high potential option:

CCS can mitigate up to 55% of CO<sub>2</sub> emissions until 2100 (IPCC Report on CCS, Oct 2005)

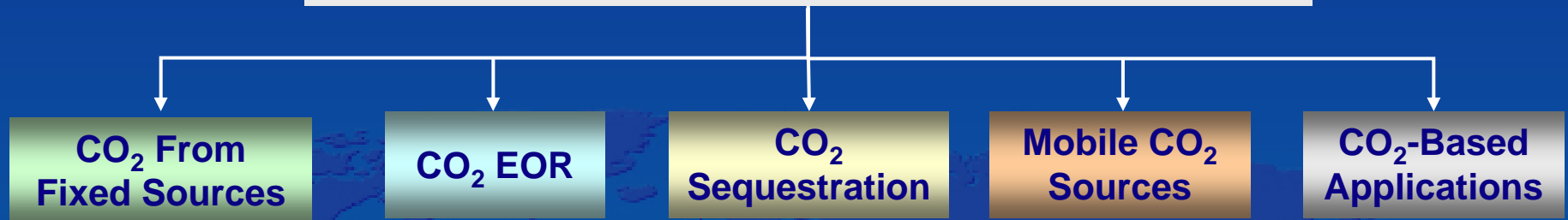


# SA CM Activities

- Formed a multidisciplinary team to address this issue:
  - Research & Development Center
  - Environmental Protection
  - Reservoir Management
  - E&PE Technology
  - Reservoir Characterization
  - Process & Control Systems
- Developed Carbon Management Technology Roadmap
- Working toward:
  - Raising regional and industry awareness (1st Regional Symposium on Carbon Management, 2006)
  - Enhancing engagement of and collaboration among National Oil Companies (NOC-Environmental Working Committee)
  - Enhancing collaboration with technology developers



# CARBON MANAGEMENT TECHNOLOGY ROAD MAP



## Aims toward

- Enhancing petroleum presence in global CM technological development
- Leveraging petroleum industry resources and know-how
- Enhancing the value created from the carbon cycle

CO<sub>2</sub> From  
Fixed Sources

CO<sub>2</sub> EOR

Geological  
Sequestration

Mobile CO<sub>2</sub>  
Sources

Industrial  
Application

- 
- Promote development of technological solutions for petroleum-based applications in stationary sources
  - Identify value added means to reduce CO<sub>2</sub> emissions from Saudi Aramco facilities
  - Promote utilization of CDM



CO<sub>2</sub> From  
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Industrial  
Application

- General Outlook
- SA Perspective
- SA Efforts pertaining to CO<sub>2</sub>-EOR
- CO<sub>2</sub>-EOR Challenges



# CO<sub>2</sub>-EOR, General Outlook

- Known for ~ 2 decades:  
Mostly small scale projects relying on natural CO<sub>2</sub> reservoirs (USA)
- CO<sub>2</sub> has favorable properties
- Gaining popularity (~80 projects)
- High value added emission reduction scheme:
  - Reduces CO<sub>2</sub> release to the atmosphere
  - Enhances oil recovery
  - Optimized CO<sub>2</sub>-EOR can significantly expand global recoverable oil reserves (Game Changer Study, DOE)
- The majors are moving in:
  - BP – North Sea Millar field
  - BP – CO<sub>2</sub> to Californian oil fields
  - Statoil/Shell consortium – power plants in Norway to Draugen and Heidrun oil fields



- High solubility in oil
- MMP < N<sub>2</sub> & HC gases
- Wide API range

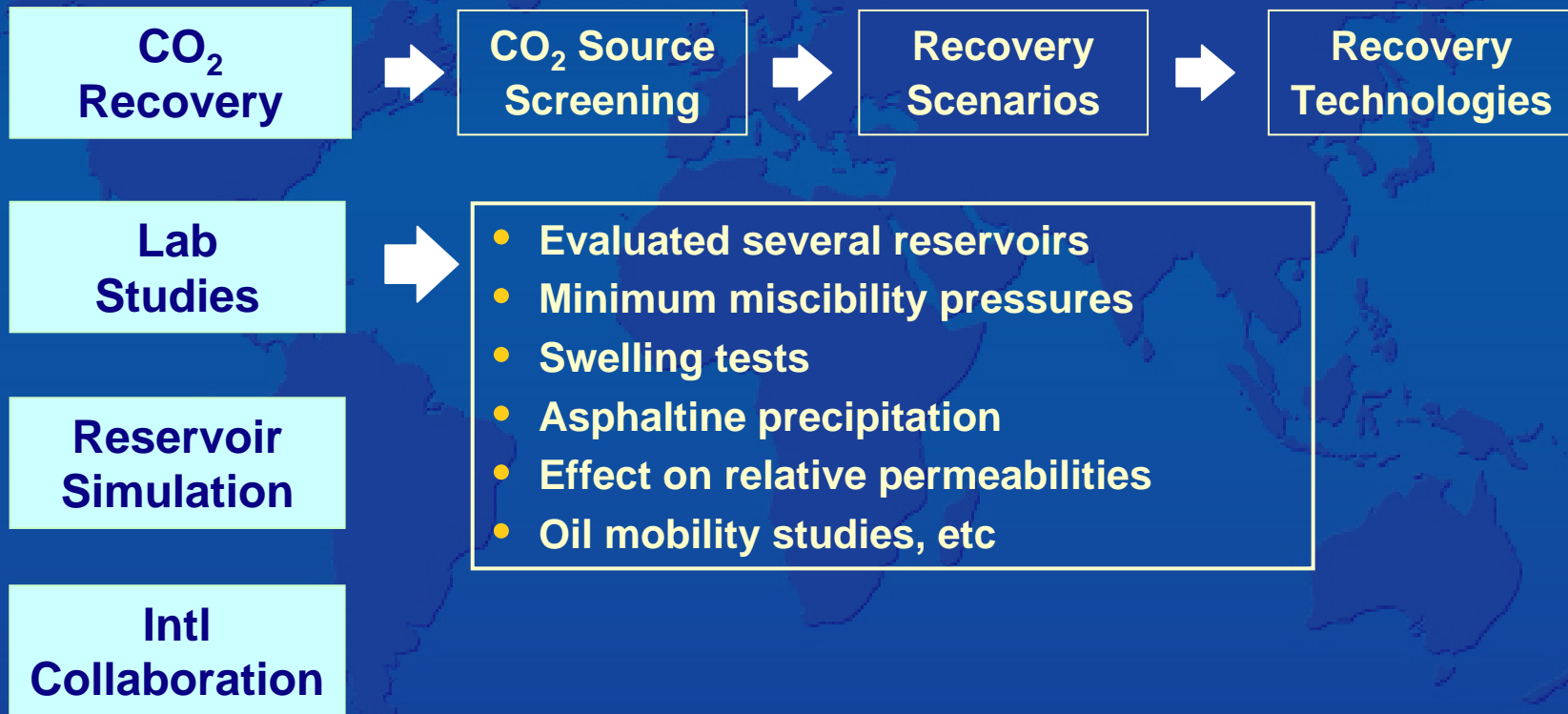


# CO<sub>2</sub>-EOR, Saudi Aramco Perspective

- Saudi Aramco is running highly optimized and cost effective water flooding operations
- Saudi Aramco is raising MSC to 12.5 MBD without the need for EOR
- CO<sub>2</sub>-EOR can be approached primarily as a value added emission reduction scheme
- Potentially phased approach:
  - Phase I: Pilot scale project to develop knowledge base (1-2 MtCO<sub>2</sub>)
  - Phase II: Commercial scale project (long term)



# Saudi Aramco Efforts on CO<sub>2</sub>-EOR



# Saudi Aramco Efforts on CO<sub>2</sub>-EOR

**CO<sub>2</sub>  
Recovery**

**Lab  
Studies**

**Reservoir  
Simulation**

**Intl  
Collaboration**



- **Compositional modeling**
- **CO<sub>2</sub> Recovery vs immiscible gas**
- **WAG ratios**
- **CO<sub>2</sub> use factors**
- **Well placement**
- **Incremental recovery beyond water flooding**



# CO<sub>2</sub>-EOR Challenges

## Economical Challenges



- High capital cost for CO<sub>2</sub> capture and delivery
- High oil recovery cost
- Susceptible to oil price fluctuations
- Securing CO<sub>2</sub> supply require strategic alignment with utilities
- CDM is not yet applied to CO<sub>2</sub>-EOR

## Technical Challenges

## Regional Challenges

# CO<sub>2</sub>-EOR Challenges

**Economical  
Challenges**

**Technical  
Challenges**

**Regional  
Challenges**



- **Need to enhance CO<sub>2</sub> capture technologies**
- **Need to enhance knowledge about CO<sub>2</sub> impacts:**
  - interactions with reservoir rocks and cements
  - CO<sub>2</sub> induced corrosion
- **Need to optimize CO<sub>2</sub>-EOR field performance for large scale projects :**
  - Optimizing operational parameters for various geological setup “enhancing CO<sub>2</sub> injection to target the ‘right’ areas”
  - Enhancing “real time” performance/monitoring
  - Optimizing CO<sub>2</sub> properties (Viscous fingering, Gravity segregation)

# CO<sub>2</sub>-EOR Challenges

**Economical  
Challenges**

**Technical  
Challenges**

**Regional  
Challenges**



- Lack of EOR technical expertise in GCC
- No operating CO<sub>2</sub>-EOR pilot projects in GCC
- Need to collect data and build knowledge specific to GCC reservoirs:
  - Generally high reservoir temperatures
  - Thick oil bearing zones (prone to CO<sub>2</sub> gravity override problems)
- Need align long term strategies with utilities (CO<sub>2</sub> for commercial scale projects)

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Industrial  
Application

- High potential Climate Change mitigation option
- An opportunity for oil producers to leverage their assets, knowledge and experience
- Adds new value generating stage to reservoir life cycle when augmented with CO<sub>2</sub>-EOR
- Significant efforts worldwide to bridge the knowledge gaps pertaining to CO<sub>2</sub> impacts, monitoring, verification, risks, etc

Conventional  
Recovery

CO<sub>2</sub>-EOR

Geo  
Sequestration

CO<sub>2</sub> From  
Fixed Sources




CO<sub>2</sub> EOR

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Mobile CO<sub>2</sub>  
Sources

Industrial  
Application



- Transportation accounts for ~24% of global CO<sub>2</sub> emissions (IEA report, 2005) 
- Transportation is a vital sector for petroleum (~96%)
- Environmental performance of motor vehicles improved significantly 
- R&D efforts focus on petroleum alternatives (biofuels & Hydrogen Fuel Cells)
- Significant potential for CO<sub>2</sub> reduction in petroleum based power trains: (Advanced ICEs, weight reduction, Hybrid vehicles)
- Think outside the box (stationary solutions for a mobile problem) 
- Need to enhance collaboration among R&D centers, automakers and petroleum fuels manufacturers

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Mobile CO<sub>2</sub>  
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Industrial  
Application

- View CO<sub>2</sub> as a feedstock rather than waste stream
- There are value added CO<sub>2</sub> based applications:
  - Methanol, Urea, Propylene Carbonate Soft Drinks, etc
- Promote development of innovative CO<sub>2</sub> based applications to enhance the value created from the carbon cycle

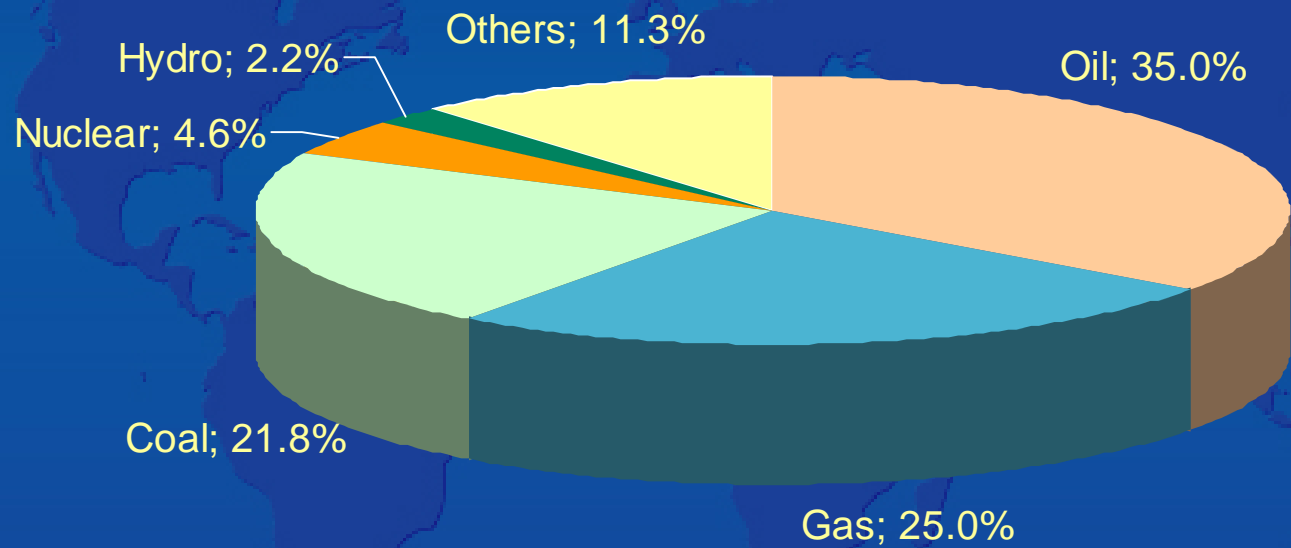


# Summary

- Fossil fuels expected to remain dominant for decades
- Carbon Management technologies have great potential to reduce emissions in a value added manner
- CO<sub>2</sub>-EOR provides a win-win scenario
- The main challenges for CO<sub>2</sub>-EOR are CO<sub>2</sub> capture cost and flood optimization
- Applying CDM to CO<sub>2</sub>-EOR and CCS is an essential milestone
- Need to increase R&D efforts to produce innovative CO<sub>2</sub> based applications/products and reduce emissions from petroleum based power trains

*Thank You*

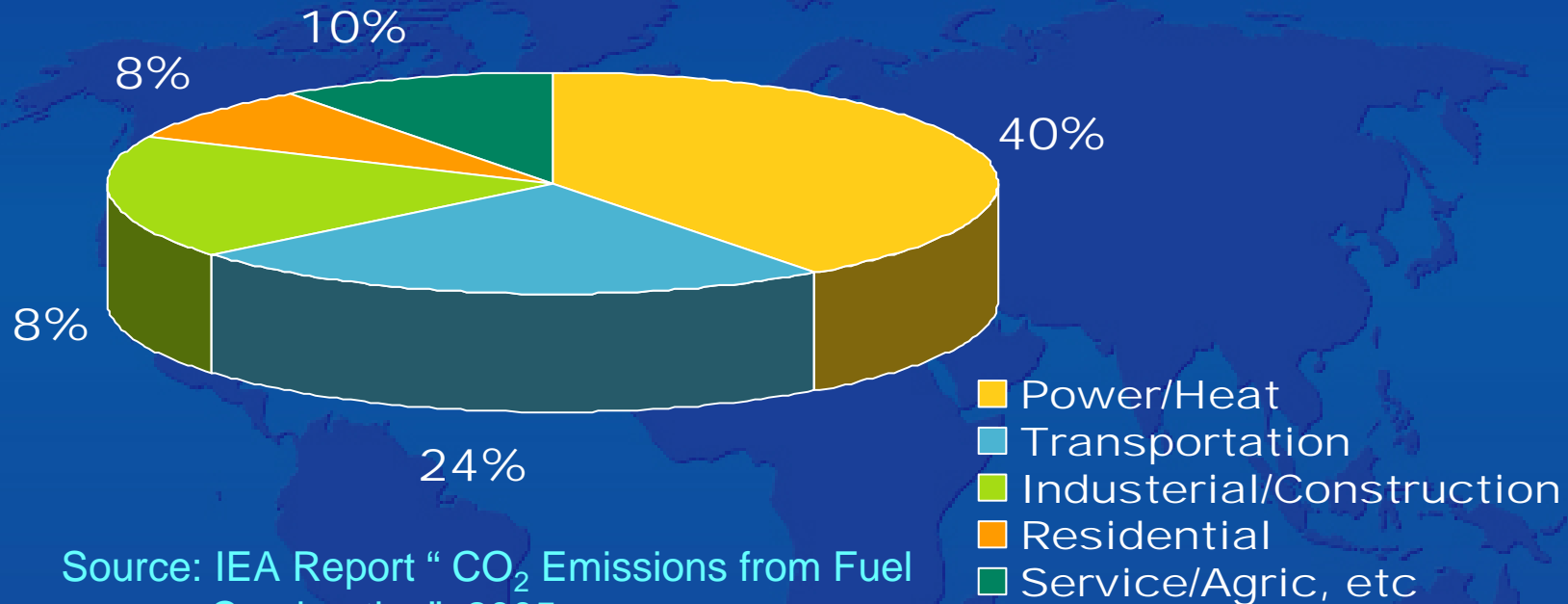
# 2030 Energy Supply Outlook



IEA World Energy Statistics, 2005



# Global CO<sub>2</sub> Emissions by Sector (2003)

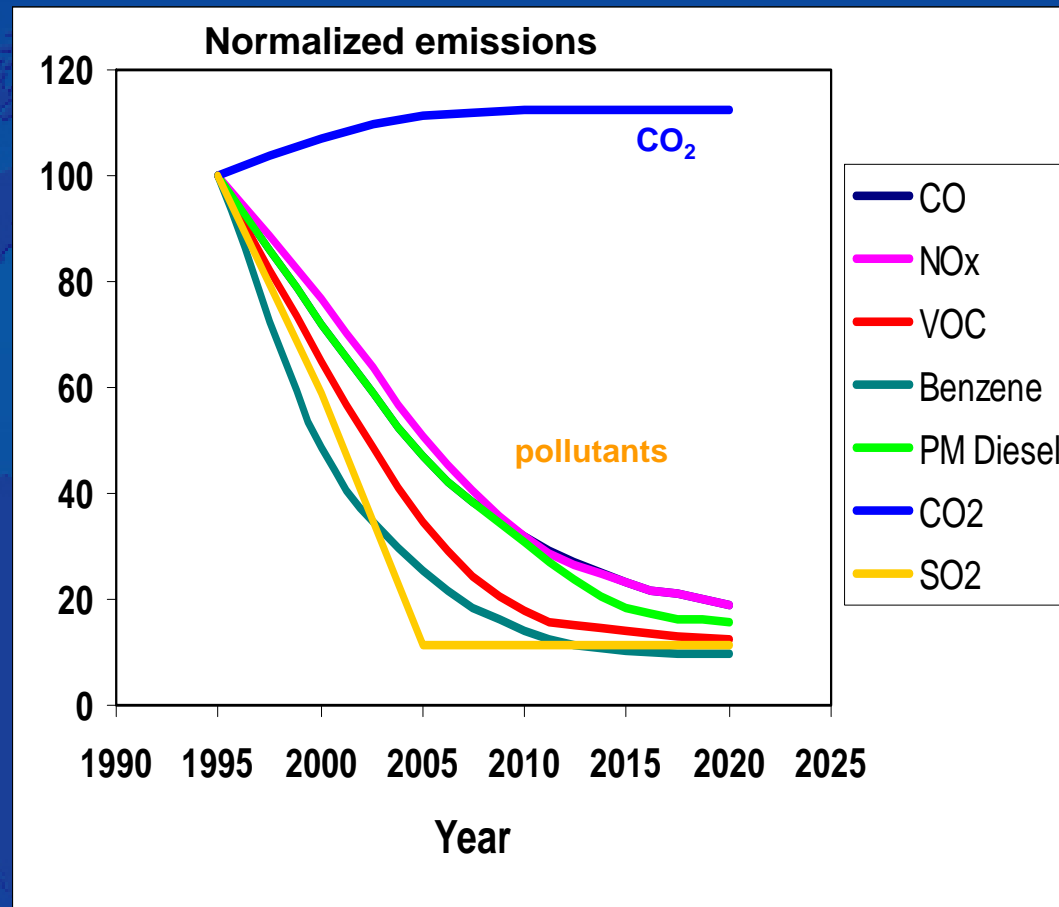


In 2030, number of vehicles expected to reach 1.3 billion (~50% increase compared to 2000)

Sustainable Mobility Report: CO<sub>2</sub> emissions from vehicles will be a **"critical"** driver for transition to **"carbon neutral"** substitutes



# Passenger Cars Emissions



Predicted pollutants emissions of passenger cars in Europe (Auto Oil 2000)



# CO<sub>2</sub> Capture Towers

- Envisioned by Center for Carbon Management, Columbia University
- Not restricted by automobiles design/cost constraints
- Each tower can capture 90,000 t CO<sub>2</sub>/year, equivalent to ~15,000 cars



# EOR Production Rates in the US

(Data from Oil & Gas Journal, 2006)

