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Carbon Capture, Utilization & Storage; Challenges, Prospects and R&D Activities

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The Challenges

Today's energy pattern and trends in overall demand and supply are not sustainable.

This can only change if the inherent benefits of efficiency and alternative technologies are harvested through integrated the following strategies:-

- Meeting high demand for electricity.
- Reducing or preventing high emission rates.
- Meeting high demand on new resources.

The Solutions

To devote substantial amount of resources and possible special programs to establish energy portfolio of both economical end-use efficiencies and alternative technologies, and their combination with each other to achieve sustainable targets.

The Prospects

Potentials

Can be a significant, competitive option to simultaneously slow the growth of CO_2 emissions while promoting economic development and energy security for decades to come.

Assuming that :

- CCS would reach its full potential in the next 30 to 50 years;
- CCS could curb energy-related global CO_2 emissions concentrations by up to one third by 2050 (compared with a BAU case).

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CCS system components - Current highest maturity status

CCS component	CCS technology	Research phase	Demo phase	Techno-economic feasible	Mature market
Capture approach	Post-combustion			●	
	Pre-combustion			●	
	Oxyfuel combustion		●		
	Industrial separation				●
Transporting option	Pipeline				●
	Shipping			●	
Geological storage applications	Enhanced Oil Recovery (EOR)				●
	Gas or oil fields			●	
	Saline formations			●	
	Enhanced Coal Bed Methane recovery (ECBM)		●		
Ocean storage applications	Direct injection	●			
	Direct injection (lake type)	●			
Mineral carbonation	Natural silicate minerals	●			
	Waste materials		●		
Industrial uses of CO_2					●

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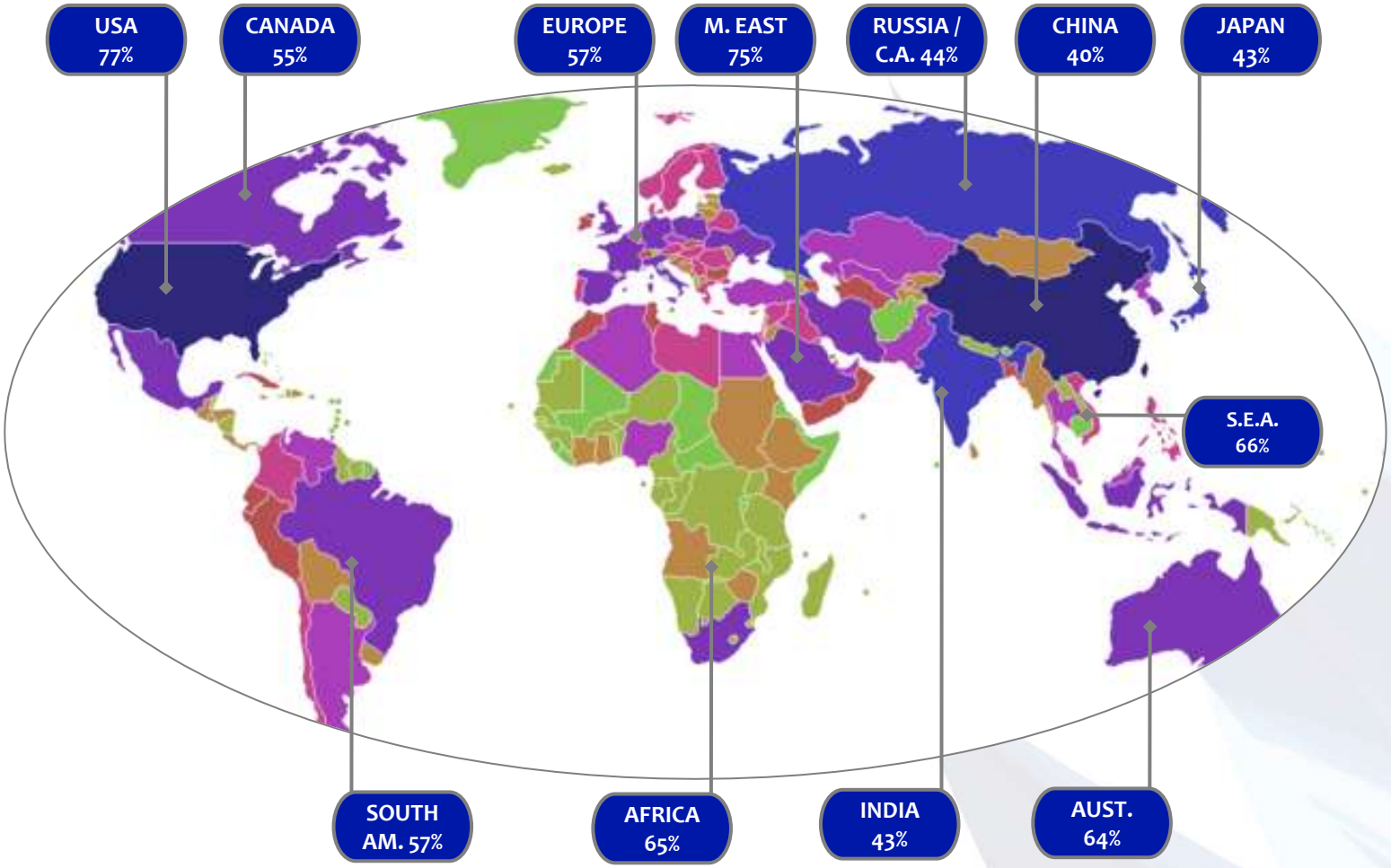
Worldwide Regional - High prospective opportunities for CO_2 storage



Data Source: Bradshaw & Dance (2004) and IPCC - CCS

Actions

Successful deployment of CCS depends on

- Predictable and affirmative climate control and non-discriminatory energy policies to attract investors;
- Integration of the CCS option(s) into energy policies, scenarios and emission trading, as part of a portfolio of mitigation measures;
- Enabling CCS laws and regulations on licensing, decommissioning, safety, liabilities;
- Conduct International agreements on international cooperation, cross-border transportation and acceleration of RD&D, in particular on the durability of storage;
- Building of several cost-effective large-scale demonstration plants;
- Allow involvement of all stakeholders to decisions making on emission trading and carbon storage.

The Prospects

Gaps in Knowledge

- Technologies for capture and storage
  - Mainly in the integration of capture, transport and storage in full-scale projects, R&D and widespread deployment experience.
- Geological storage capacity monitoring and effectiveness.
- Successful research studies on EOR using CO_2 and Activates.
- Legal and regulatory requirements.
- Impact and contribution of CCS to mitigating climate change.

CCS cost outlook

Estimates

- Approximately 90% of total CCS costs goes to the capture of CO_2, that requires additional energy: Example 10-40% new coal or gas-fired power plant. Older plants with retrofitting cost considerably higher;
- IPCC estimate the cost and economical potential of CCS depends entirely on the type of process technology used;
- Overall estimated that capturing, transporting and storing the CO2 from new or power plant (coal) would increase the cost of electricity generated by that plant between 37%-92%;
- This translate into a CO2 mitigation cost of US$ 30-90/tonne, which very high at lease for the time being.

These cost estimates maybe considered uncertain mainly due to little commercial experience scaling the cost of the whole integrated CCS system along with deployment estimates.

However, CCS maybe economically feasible in certain applications whereby the CO_2 in captured from a low cost- point source such as gas-processing or ammonia plants and used in a more productive end such as enhancing oil recovery (EOR) of nearby oil fields.

Carbon Capture & Storage

The Prospects

Cautions **As technically significant as it may be**

CCS is not a universal remedy;

Deployment would slow the growth of, and ultimately curb, CO_2 emissions;

Assuming that:

- Emissions would remain above present levels unless special measures were applied worldwide (compared with base-line scenario).

CCS is not the only option;

Implementation could be affected by other carbon constraints and related competition from alternative mitigation options (market penetration still need to be determined).

CCS projects are site-specific;

- Driven by local conditions and opportunities, hence unlikely to be replicable all-around.
- Durability of storing billions of tons of CO_2 for centuries. Failure to prevent or control leakage (and re-assure the general public on this issue) would severely reduce the prospects of implementation.
- In transportation, the (likely) mismatch between the location of the emitter and the sink may be a limiting factor for small volumes and very long distances.

The Prospects

Looking forwards

- Developments of a comprehensive energy strategy; interaction with policy makers and stakeholders, thru a road-map for technology implementation, GHG regulatory guidelines, awareness campaigns and application incentive schemes.

- Research Development and Demonstration; sets a road-map for technology evaluation and implementation thru financing large-scale demonstration projects.

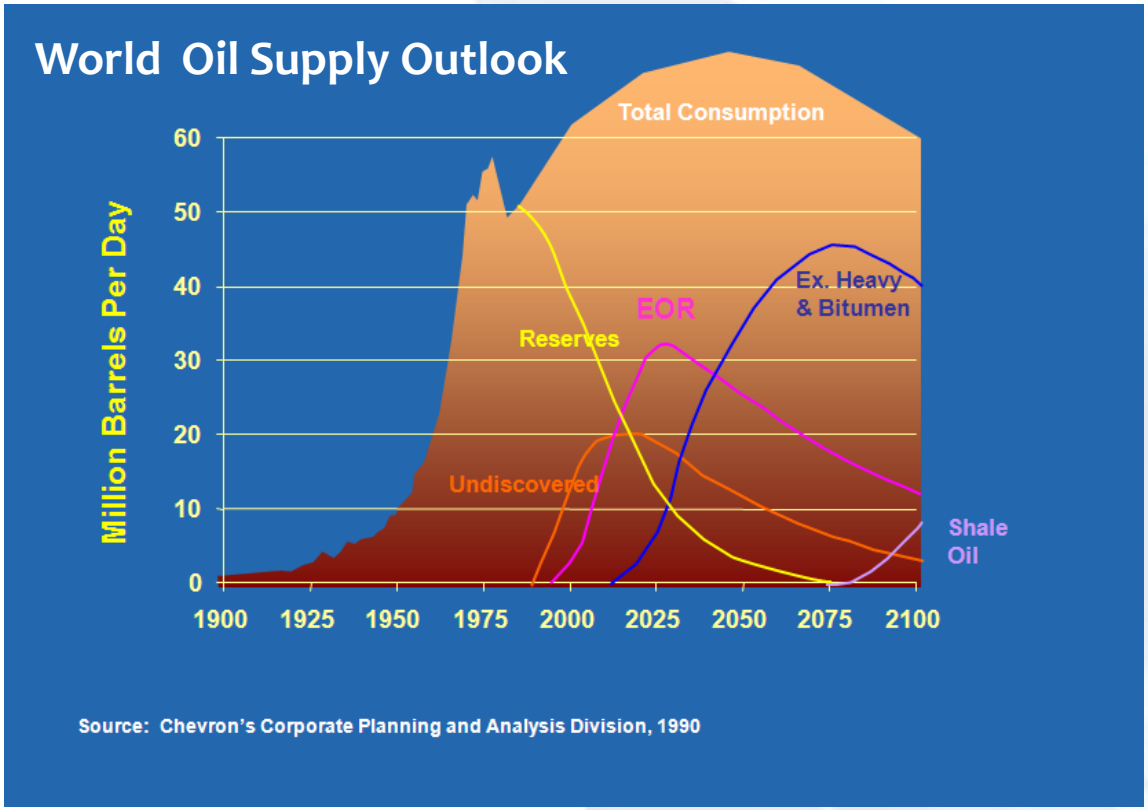
- Establishment a Center of Excellence; know-how transfer and training thru state-of–art laboratory testing facilities to support government / private sectors in implementation projects.

Possible Sources of Oil in the future

- EOR from existing matured reservoirs.
- Heavy oil value: Heavy oil will be strategic in the next 15 years.
- Gas and Gas Condensate

New Development

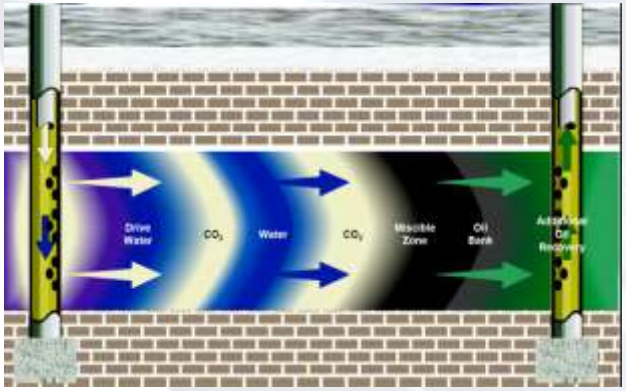
- Environmental Concern
- CO^2 Storage / Sequestration (CCS)



Carbon Capture& Storage; Utilization

Road Map

- To Initiate And Establish EOR Research Activity Program In Kuwait
- To Train And Develop Local Expertise On This Line Of Activities
- Comprehensive Data Collection, Compilation And Database
- Comprehensive Reservoir/Technique Screening
- Carefully Designed Experimental Program
- Simulation And Optimization Studies
- Conceptual Pilot Plant Design
- To Evaluate The Performance
- Economics Of Applicable EOR Methods of Selected Reservoirs
- Monitoring
- Up-scaling, Field Development

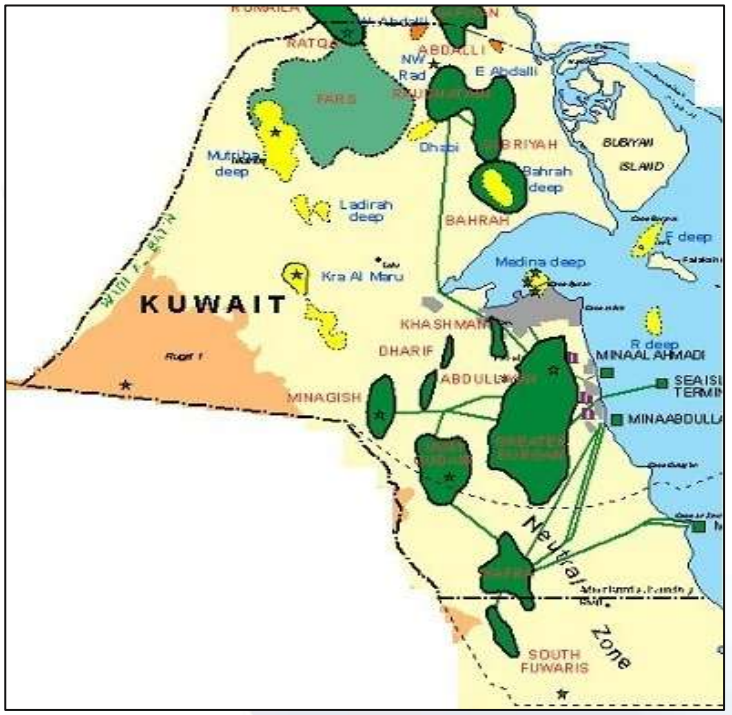


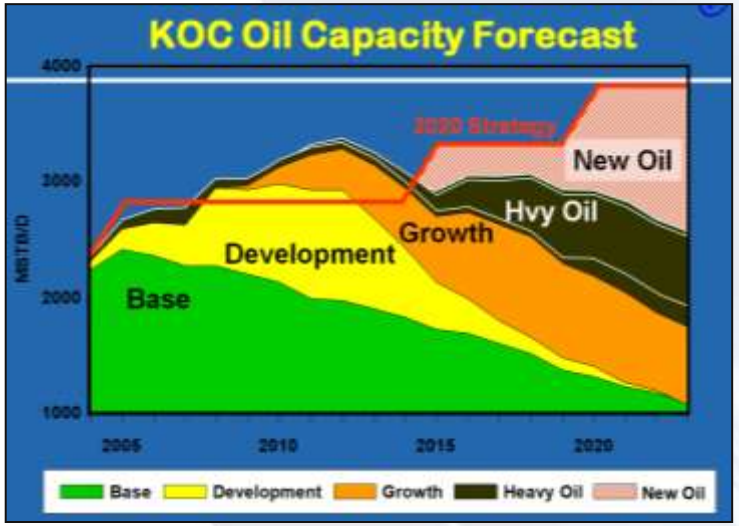
Total Amount of CO_2 Emitted from Main Stationary Sources in Kuwait

CO^2 main Stationary Source Sector	Total CO^2 emissions (ton/yr)	Percentage of CO^2 from Main Stationary Source Sectors in Kuwait
Power Stations	37,840,468	76
Refineries	11,248,570	22
Cement Factories	1,050,000	2
Total	50,139,038	100

Application of EOR Technologies in Kuwait

1. Estimated Recoverable Oil in Kuwait 96.5 billion bbl, 45% Recoverable, 50 billion bbl Target for EOR
2. Many Kuwaiti oil reservoirs are in an advanced state of depletion from primary production mechanisms
3. Producing the second half of the world's ultimate recovery will be more difficult than producing the first half
4. Sharp increase in oil prices

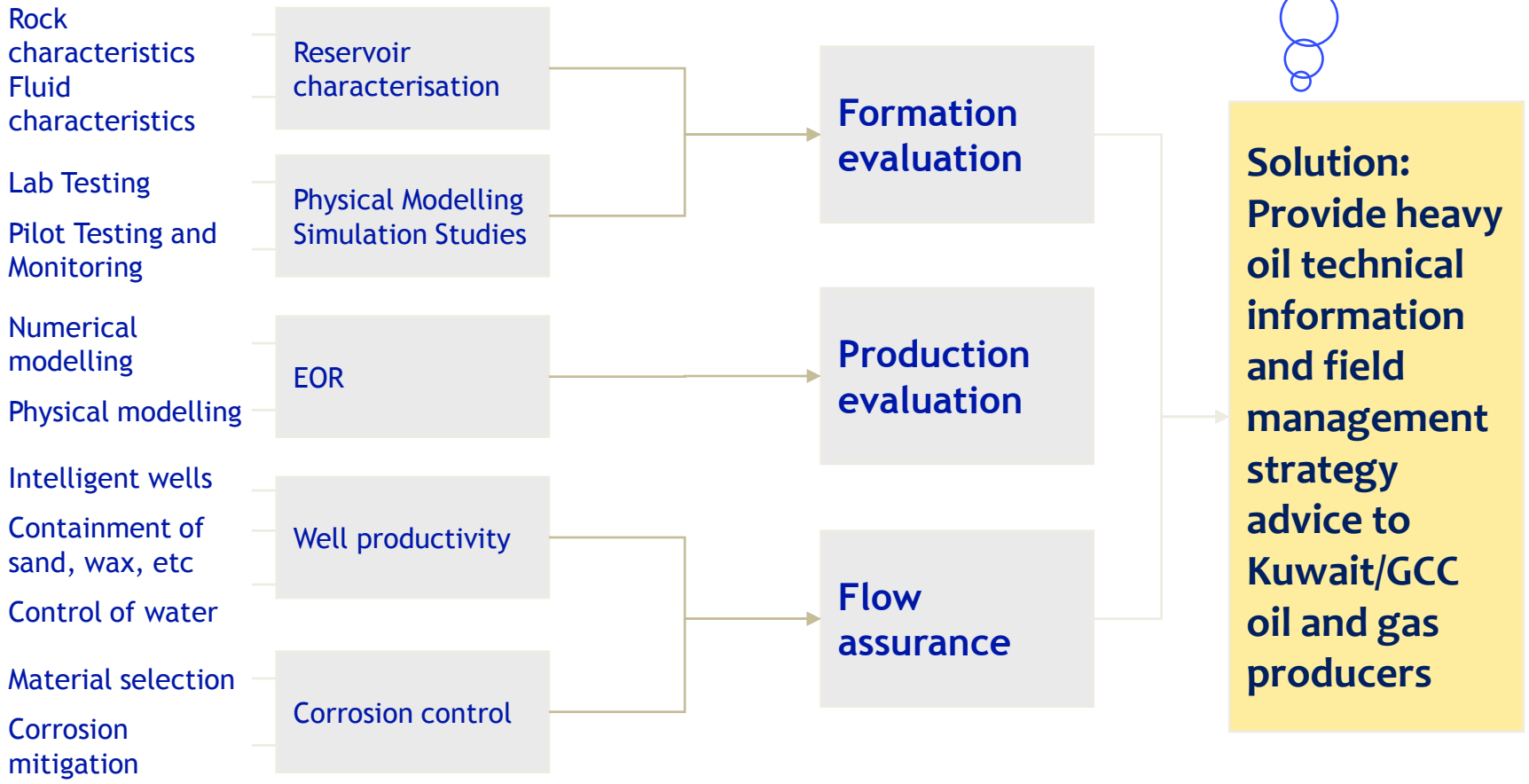




Petroleum Production Applied Research focus areas for Heavy oil

Challenge: become a Regional leader in heavy oil reservoir characterisation and production

Applied research Programme



R&D - EOR Reservoir Screening Projects

		Reservoir													
		North Kuwait										West Kuwait			
	Processes	SA-LB	SA-UB	SA-MA	RQ-LF	RQ-ZU	AD-ZU	RA-UB	RA-LB	RA-MA	RA-ZU	MN-WS	MN-BS	MN-MO	EUG-MO
	Waterflood	FAIL	PASS	PASS	PASS	COND	PASS	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	COND
Chemical Processes	Polymer Flooding	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
	Alkaline/Polymer Flooding	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
	Surfactant/ Polymer Flooding	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
	Alkaline/ Surfactant/ Polymer Flooding	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
Gas Processes	Carbon Dioxide Miscible	PASS	PASS	PASS	FAIL	PASS	PASS	PASS	COND	PASS	PASS	COND	COND	PASS	COND
	Hydrocarbon Miscible	PASS	PASS	PASS	FAIL	PASS	PASS	PASS	COND	PASS	PASS	COND	COND	PASS	COND
	Nitrogen Miscible	FAIL	FAIL	FAIL	FAIL	COND	COND	FAIL	FAIL	FAIL	PASS	FAIL	FAIL	PASS	FAIL
	Immiscible Gas	FAIL	PASS	PASS	FAIL	COND	PASS	PASS	FAIL	PASS	PASS	PASS	FAIL	PASS	COND
Thermal Processes	Cyclic Steam Stimulation	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
	Steam Flooding	FAIL	FAIL	FAIL	PASS	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
	Steam Assisted Gravity Drainage	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
	In Situ Combustion	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	PASS	PASS	FAIL	FAIL

Conclusions of Screening Studies : Successful processes Recommended :

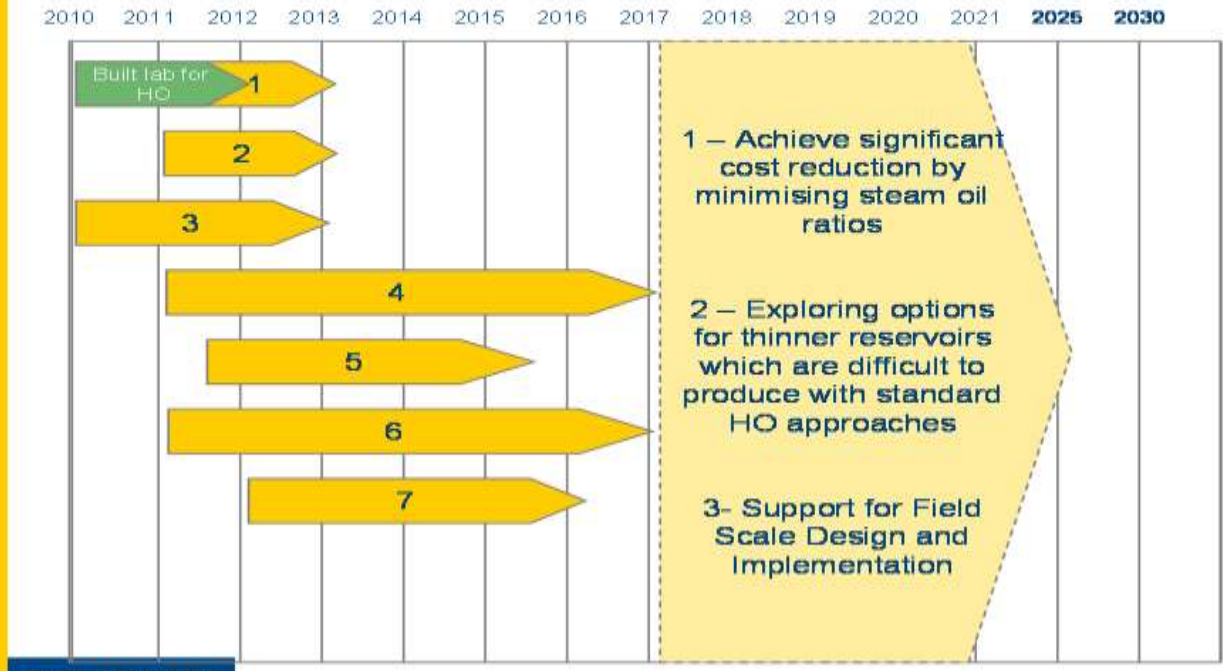
1. Horizontal Wells
2. Water flood
3. Miscible HC and CO_2 , More Than 80%
4. Steam Injection for Heavy Oil

List of Research & Development Project Activities

MATERIAL UNDER DEVELOPMENT FOLLOWING 18th JUNE PRESENTATION

KISR TRANSFORMATION PROJECT

Proposed HO Program Projects and Schedule



1. Development of laboratory techniques for friable rocks
2. Development of laboratory techniques for carbonate rocks
3. Heavy oil PVT and phase behavior studies (labs tests and simulations) at different temperature
4. Reservoirs simulation studies to investigate field development scenario of heavy oil reservoirs
5. Coupled geo-mechanical reservoir simulator (development of a simulator)
6. Experimental lab scale evaluation of production techniques:
7. Development of a real time data interpretation models for steam injection operations and monitoring A) what data to collect B) interpretation C) optimize flow control

Arthur D Little

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The message

Churchill once Said:

" The best time to plant a tree is 20 years ago, the second best time is NOW "

Carbon Capture and Storage

"Is essential bridge to sustainability and secure energy future"