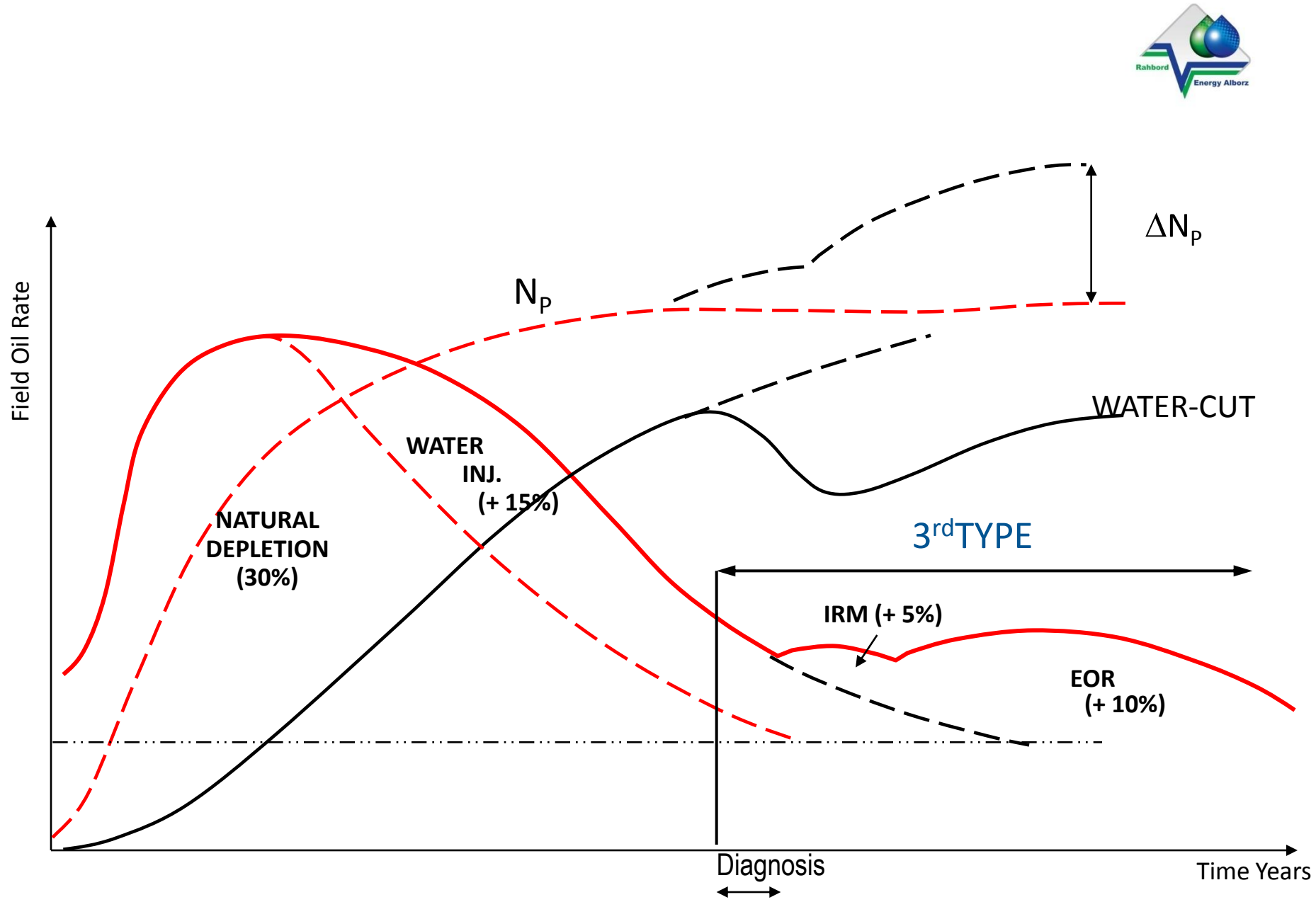
Enhanced Oil Recovery

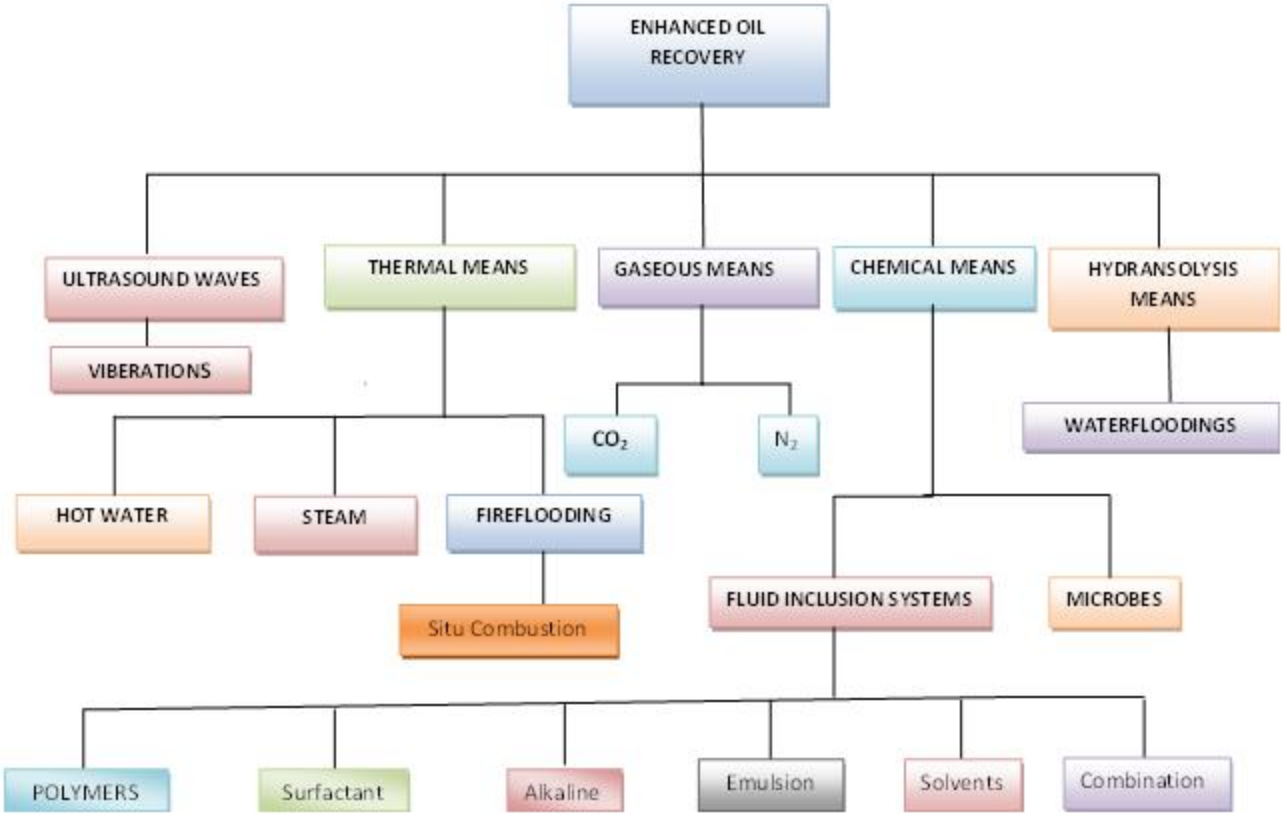
Rahbord Energy Alborz ltd

Oil Recovery

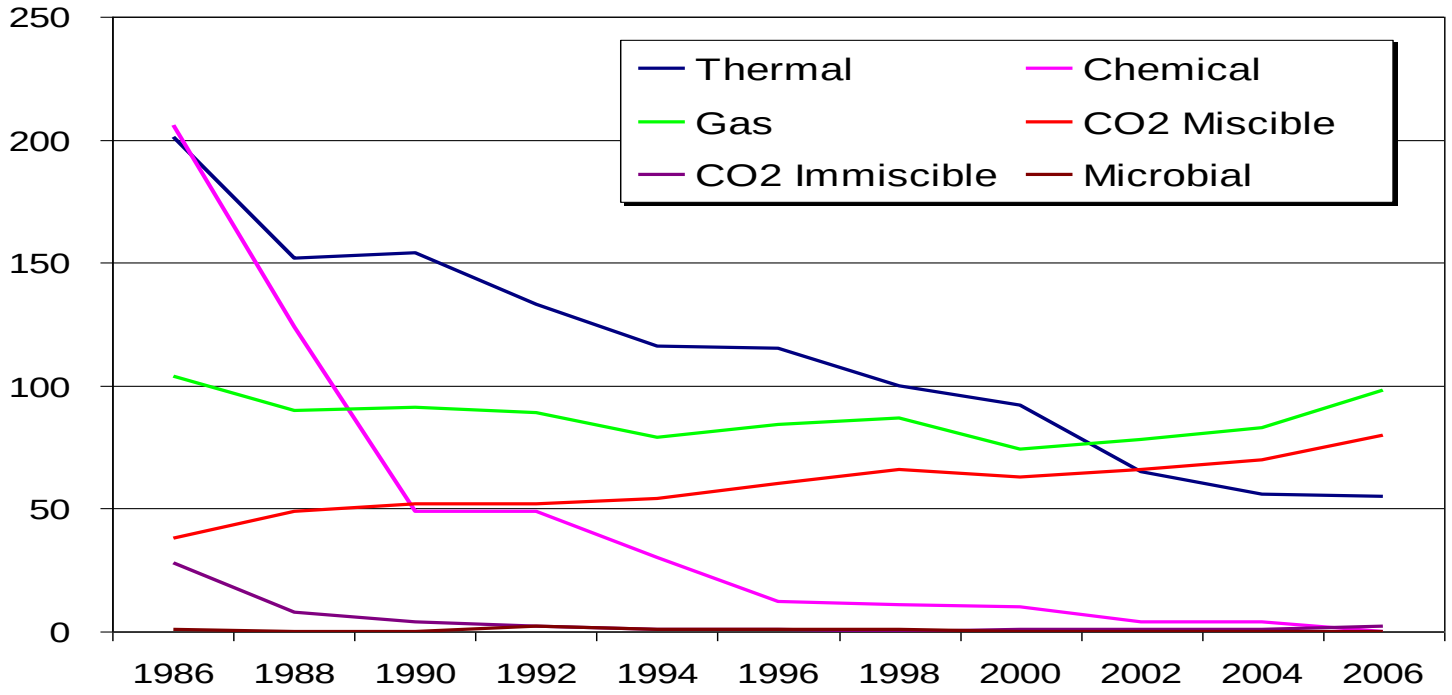
- Primary recovery (Natural Depletion)
- Secondary recovery (IOR)
- Tertiary recovery (EOR)


Field Oil Rate
ΔN_P
N_P
WATER-CUT
WATER
INJ.
(+ 15%)
NATURAL
DEPLETION
(30%)
3rdTYPE
IRM (+ 5%)
EOR
(+ 10%)
Diagnosis
Time Years

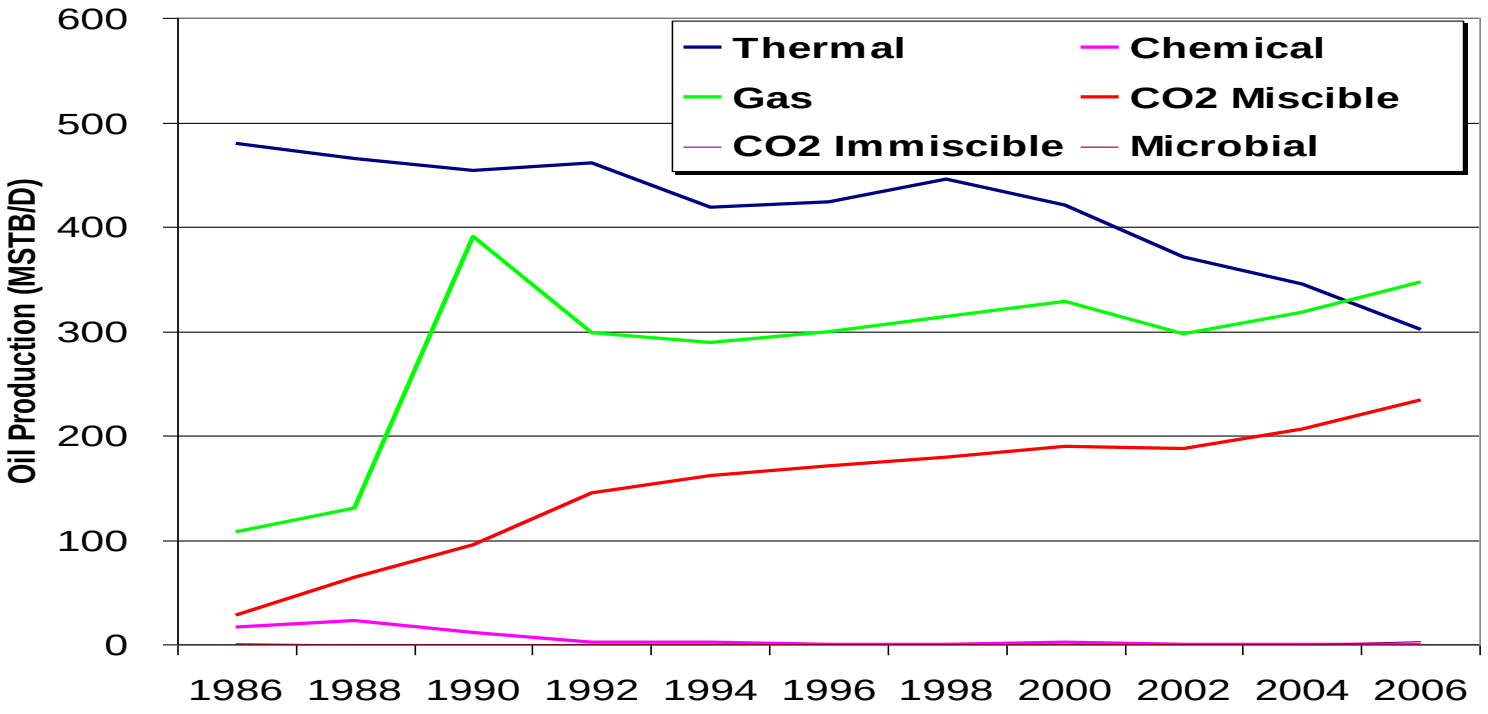
EOR Methods

- 
ENHANCED OIL RECOVERY
ULTRASOUND WAVES
VIBERATIONS
THERMAL MEANS
HOT WATER
STEAM
FIREFLOODING
Situ Combustion
GASEOUS MEANS
CO_2
N_2
CHEMICAL MEANS
FLUID INCLUSION SYSTEMS
POLYMERS
Surfactant
Alkaline
Emulsion
Solvents
Combination
MICROBES
HYDRANSOLYSIS MEANS
WATERFLOODINGS

EOR Projects USA



EOR Methods

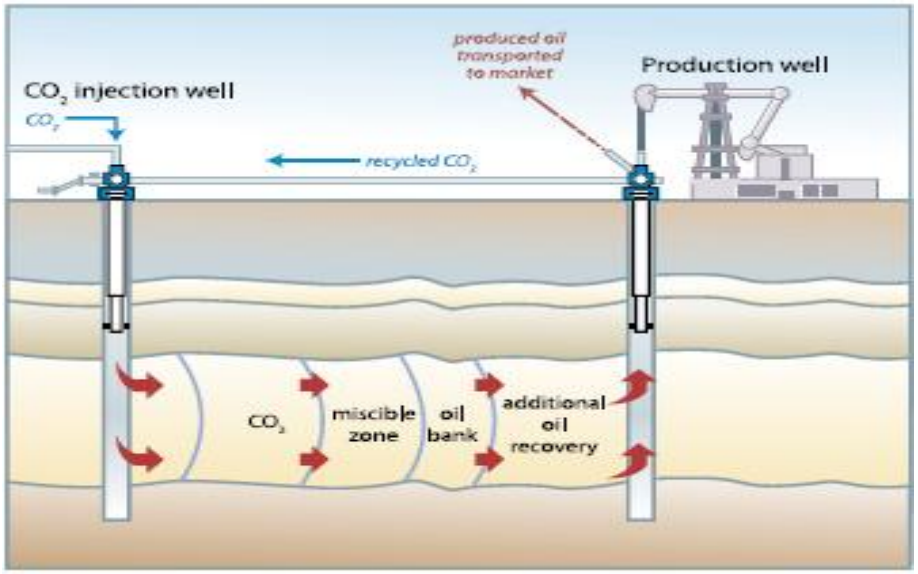

Thermal
Chemical
Gas
CO2 Miscible
CO2 Immiscible
Microbial
Oil Production (MSTB/D)
600
500
400
300
200
100
0
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006

- Screening Criteria

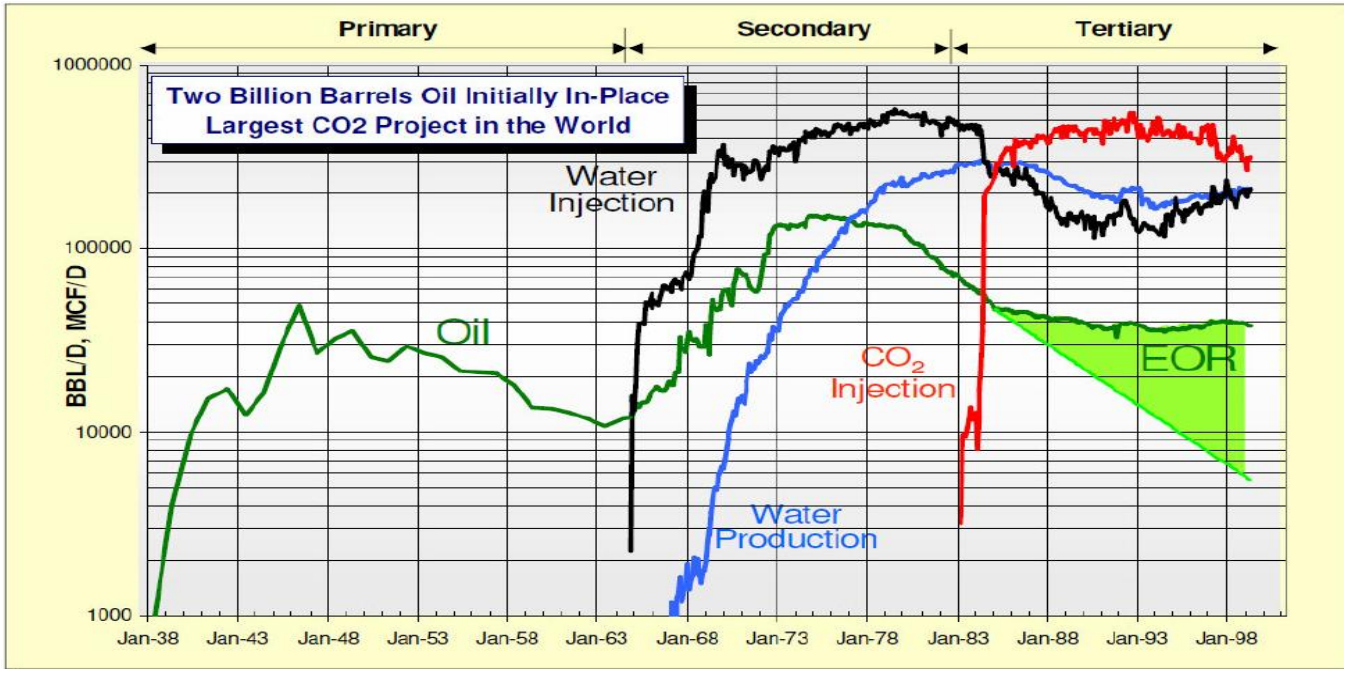
Properties	Nitrogen and flue gas	Hydrocarbon	Carbon Dioxide	Immiscible Gases	Miscellar/polymer, ASP, and alkaline flooding	Polymer flooding	Combustion	Steam
Oil API Gravity	> 35 Average 48	> 23 Average 41	> 22 Average 36	> 12	> 20 Average 35	> 15, < 40	> 10 Average 16	> 8 to 13.5 Average 13.5
Oil Viscosity (cp)	< 0.4 Average 0.2	< 3 Average 0.5	< 10 Average 1.5	< 600	< 35 Average 13	>10, <150	< 5,000 Average 1200	< 200,000 Average 4,700
Composition	High % C1-C7	High % C2-C7	High % C5-C12	Not critical	Light, intermediate. Some organic acids for alkaline floods	Not critical	Some asphaltic components	Not critical
Oil Saturation (%PV)	> 40 Average 75	> 30 Average 80	> 20 Average 55	> 35 Average 70	> 35 Average 53	> 70 Average 80	> 50 Average 72	> 40 Average 66
Formation Type	Sandstone or Carbonate	Sandstone or Carbonate	Sandstone or Carbonate	Not critical	Sandstone preferred	Sandstone preferred	High porosity sandstone	High porosity sandstone
Net Thickness (ft)	Thin unless dipping	Thin unless dipping	Wide range	Not critical if dipping	Not critical	Not critical	> 10 feet	> 20 feet
Average Permeability (md)	Not critical	Not critical	Not critical	Not critical	> 10 md Average 450 md	> 10 md Average 800 md	> 50 md	> 200 md
Depth (ft)	> 6000	> 4000	> 2500	> 1800	< 9000 Average 3250	< 9000	< 11500 Average 3500	< 4500
Temperature (deg F)	Not critical	Not critical	Not critical	Not critical	< 200	< 200	> 100	Not critical

- **CO2 EOR Advantage:**
- **Better weep efficiency**
- **Less Minimum Miscibility Pressure**
- **Swelling Effect**

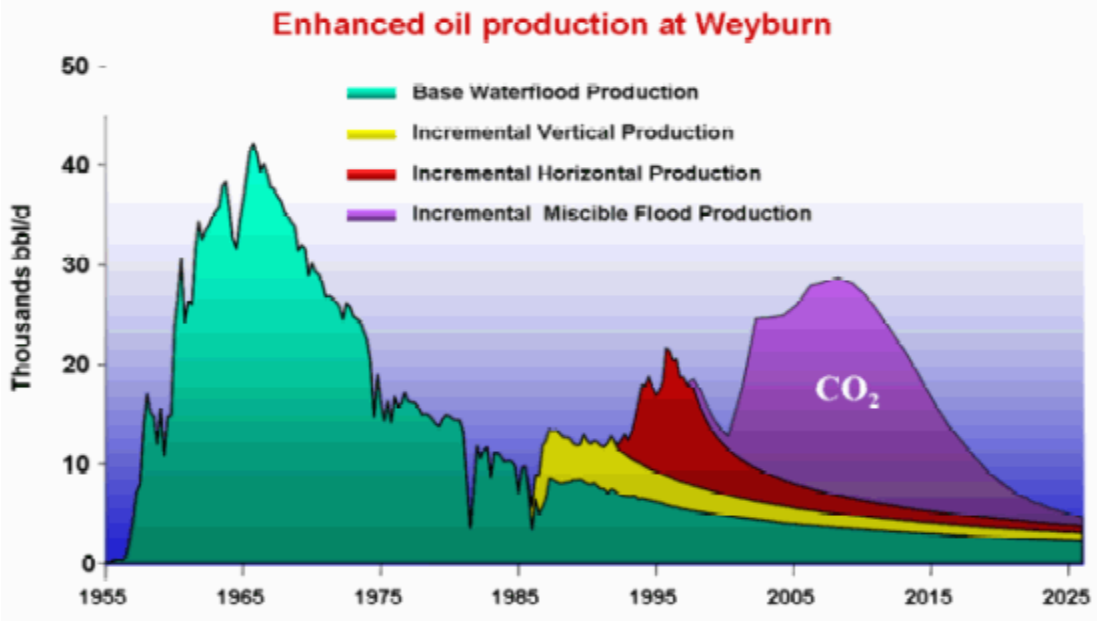
MMP	API=40
1200psi	T=120f
3000psi	T=250f



- **CO2 EOR Successful Projects:**
- **Denver USA , Operator: Shell**



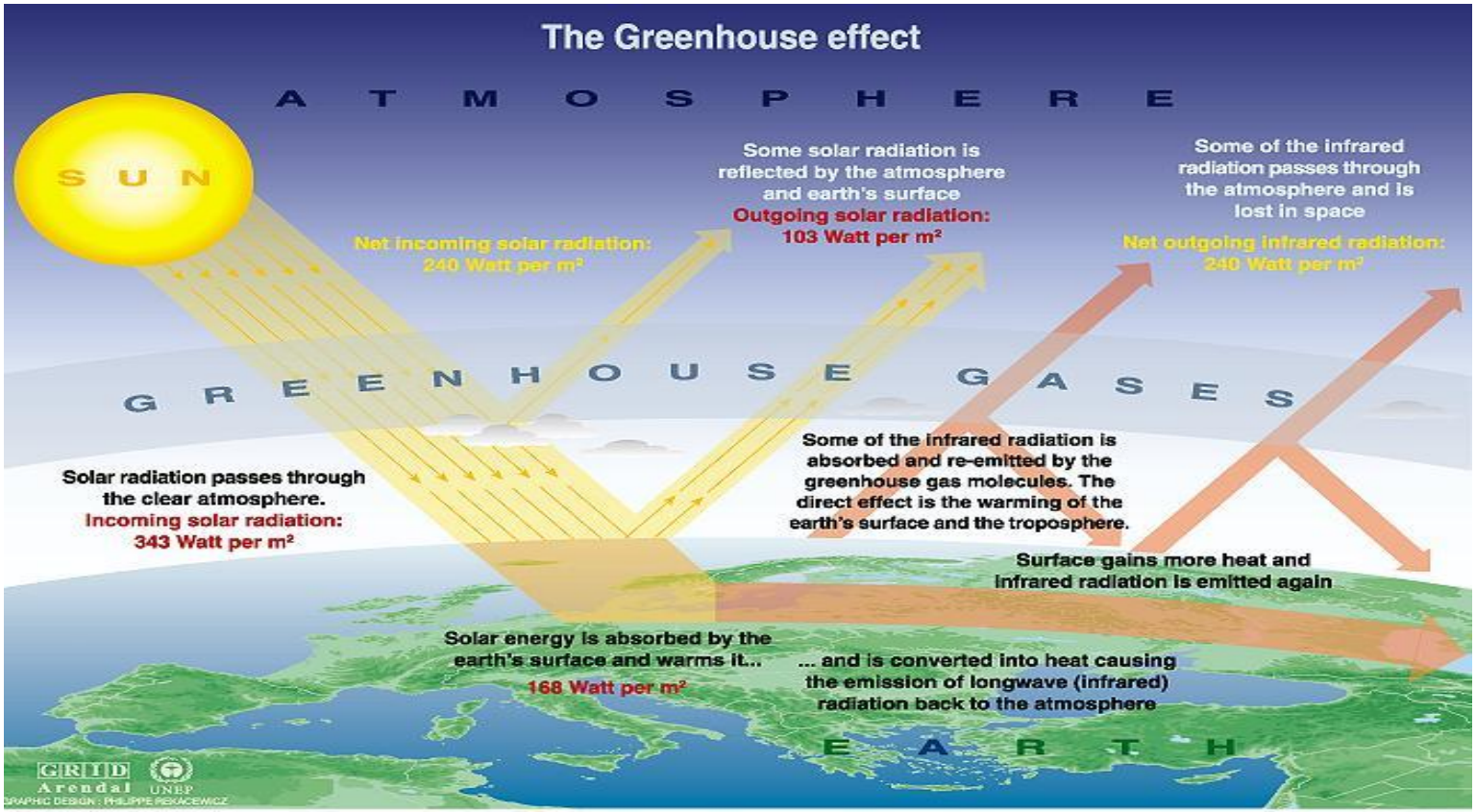
- **CO2 EOR Successful Projects:**
- **Weyburn Canada**



- **CO2 EOR & Environment**

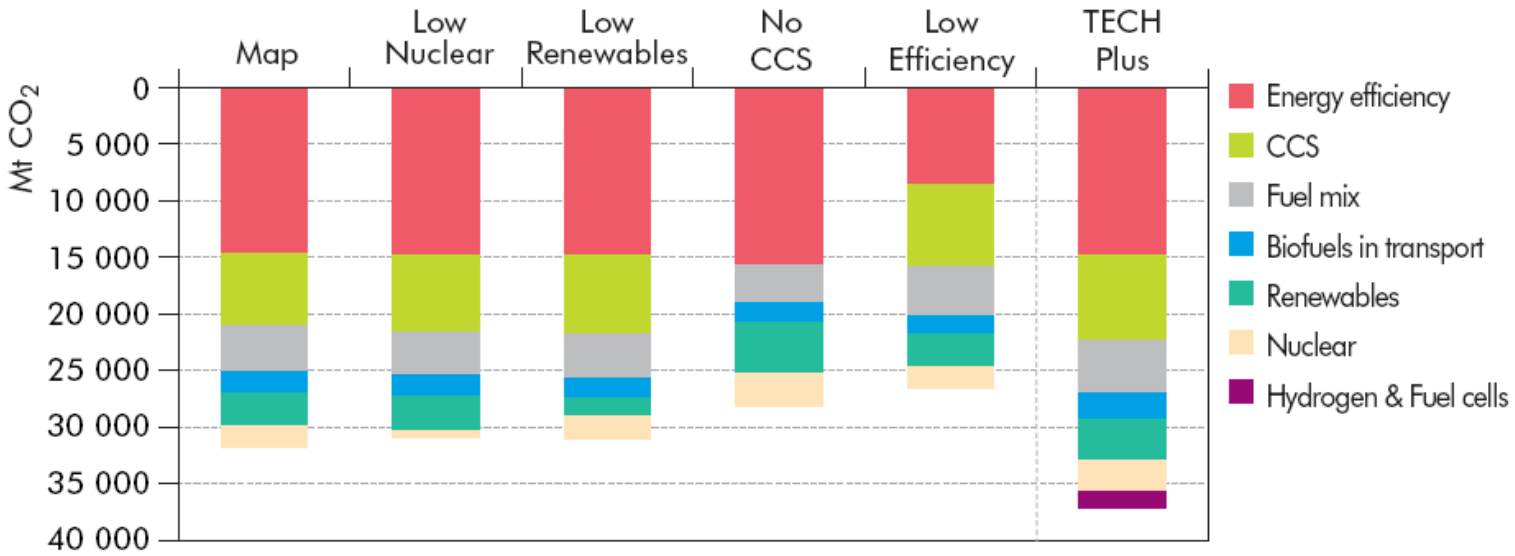
Global Warming

- **Global Warming:**

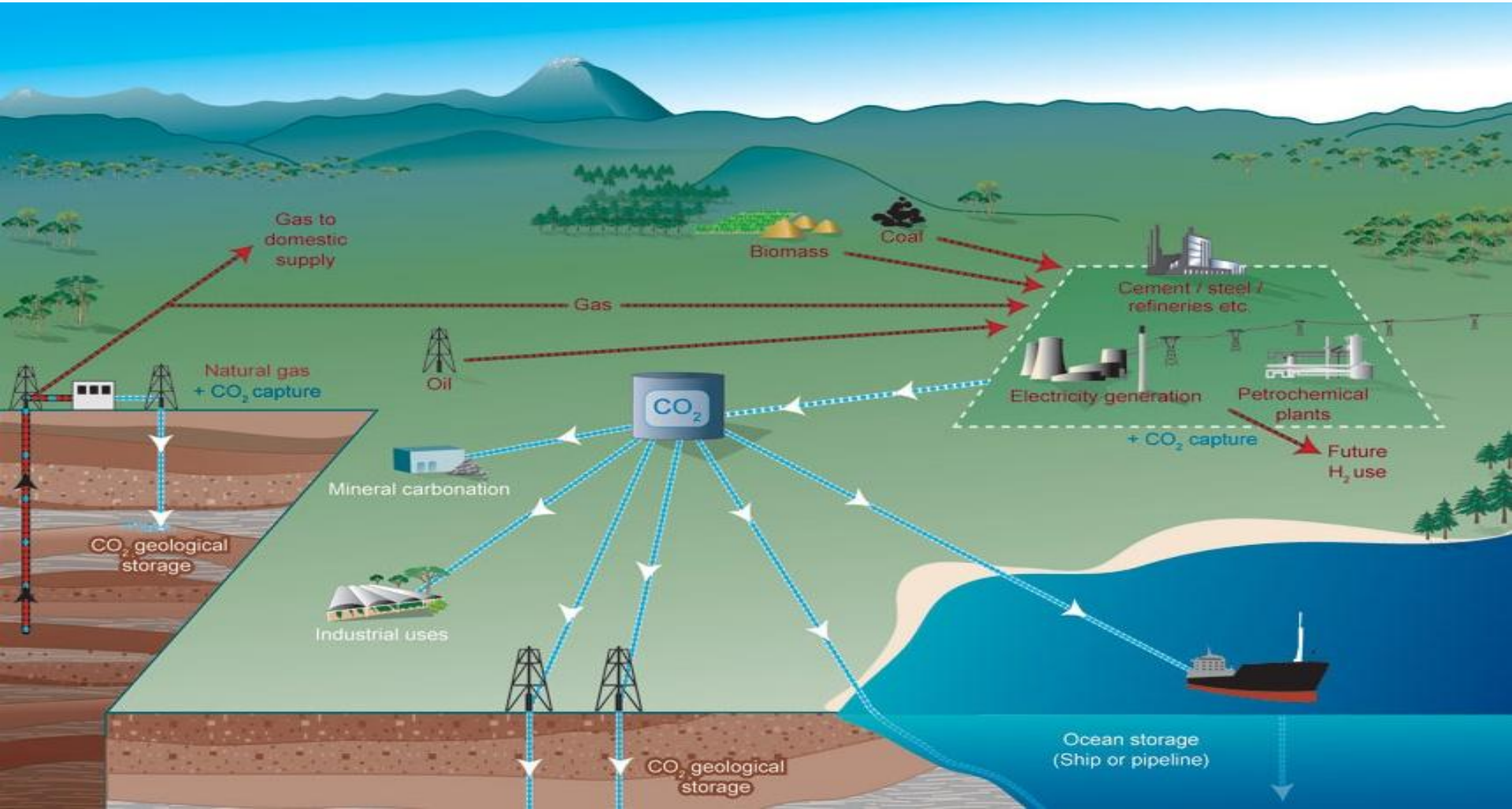


Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

- **The Role of CCS in CO2 Mitigation:**

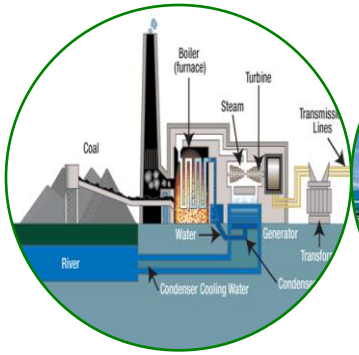


- **What Is CCS:**


Gas to domestic supply
Biomass
Coal
Gas
Cement / steel / refineries etc.
Natural gas + CO_2 capture
Oil
CO_2
Electricity generation
Petrochemical plants
+ CO_2 capture
Future H_2 use
Mineral carbonation
CO_2 geological storage
Industrial uses
CO_2 geological storage
Ocean storage (Ship or pipeline)

Carbon Capture & Safe Sequestration (CCSS) Process

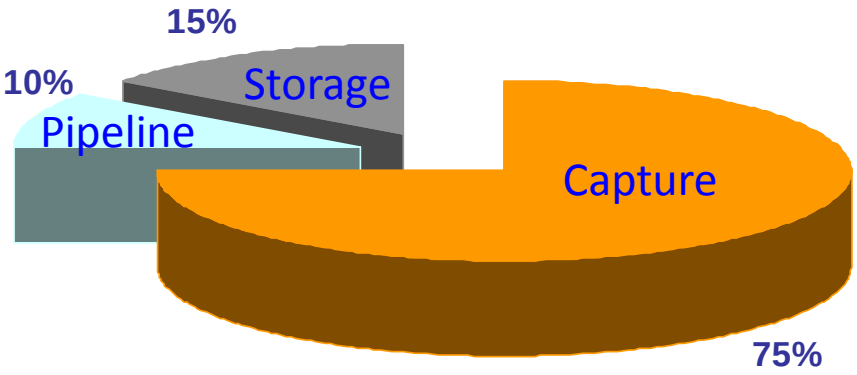
CO_2 Source



Capture/ Compression

Pipeline

Injection/ Storage



Cost breakdown

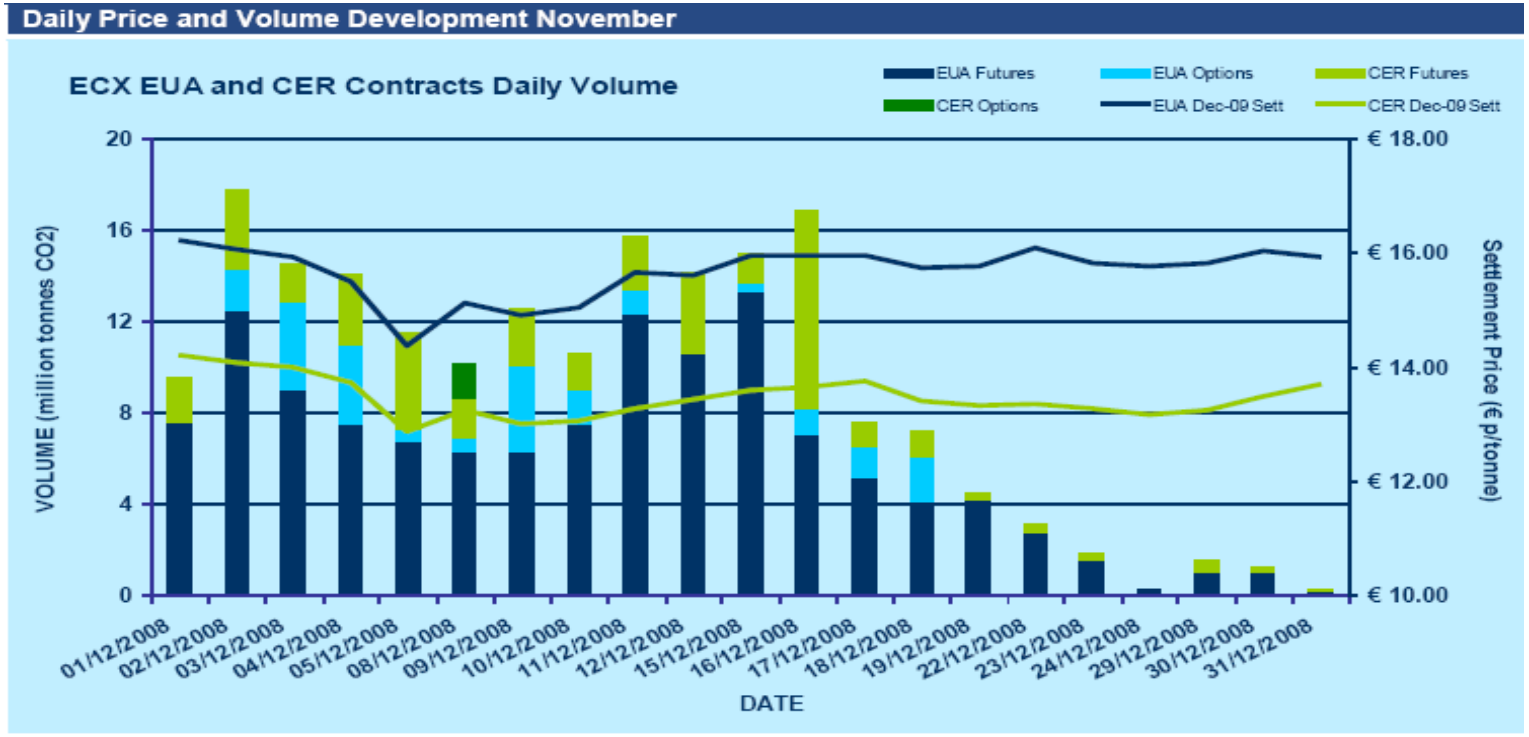
- **CCS & CO2 EOR Projects:**

Project	Country	Scale of Project	Lead organizations	Injection start date	Approximate average daily injection rate	Total storage	Storage type	Geological storage formation	Age of formation	Lithology	Monitoring
Sleipner	Norway	Commercial	Statoil, IEA	1996	3000 t day^{-1}	20 Mt planned	Aquifer	Utsira Formation	Tertiary	Sandstone	4D seismic plus gravity
Weyburn	Canada	Commercial	EnCana, IEA	May 2000	3-5000 t day^{-1}	20 Mt planned	CO_2-EOR	Midale Formation	Mississippian	Carbonate	Comprehensive
Minami-Nagoaka	Japan	Demo	Research Institute of Innovative Technology for the Earth	2002	Max 40 t day^{-1}	10,000 t planned	Aquifer (Sth. Nagoaka Gas Field)	Haizume Formation	Pleistocene	Sandstone	Crosswell seismic + well monitoring
Yubari	Japan	Demo	Japanese Ministry of Economy, Trade and Industry	2004	10 t day^{-1}	200 t Planned	CO_2-ECBM	Yubari Formation (Ishikari Coal Basin)	Tertiary	Coal	Comprehensive
In Salah	Algeria	Commercial	Sonatrach, BP, Statoil	2004	3-4000 t day^{-1}	17 Mt planned	Depleted hydrocarbon reservoirs	Krechba Formation	Carboniferous	Sandstone	Planned comprehensive
Frio	USA	Pilot	Bureau of Economic Geology of the University of Texas	4-13 Oct. 2004	Approx. 177 t day^{-1} for 9 days	1600t	Saline formation	Frio Formation	Tertiary	Brine-bearing sandstone-shale	Comprehensive
K12B	Netherlands	Demo	Gaz de France	2004	100-1000 t day^{-1} (2006+)	Approx 8 Mt	EGR	Rotliegendes	Permian	Sandstone	Comprehensive
Fenn Big Valley	Canada	Pilot	Alberta Research Council	1998	50 t day^{-1}	200 t	CO_2-ECBM	Mannville Group	Cretaceous	Coal	P, T, flow
Recopol	Poland	Pilot	TNO-NITG (Netherlands)	2003	1 t day^{-1}	10 t	CO_2-ECBM	Silesian Basin	Carboniferous	Coal	
Qinshui Basin	China	Pilot	Alberta Research Council	2003	30 t day^{-1}	150 t	CO_2-ECBM	Shanxi Formation	Carboniferous-Permian	Coal	P, T, flow
Salt Creek	USA	Commercial	Anadarko	2004	5-6000 t day^{-1}	27 Mt	CO_2-EOR	Frontier	Cretaceous	Sandstone	Under development
Planned Projects (2005 onwards)											
Snehvit	Norway	Decided Commercial	Statoil	2006	2000 t day^{-1}		Saline formation	Tubaen Formation	Lower Jurassic	Sandstone	Under development
Gorgon	Australia	Planned Commercial	Chevron	Planned 2009	Approx. 10,000 t day^{-1}		Saline formation	Dupuy Formation	Late Jurassic	Massive sandstone with shale seal	Under development
Ketzin	Germany	Demo	GFZ Potsdam	2006	100 t day^{-1}	60 kt	Saline formation	Stuttgart Formation	Triassic	Sandstone	Comprehensive
Otway	Australia	Pilot	CO2CRC	Planned late 2005	160 t day^{-1} for 2 years	0.1 Mt	Saline fm and depleted gas field	Waarre Formation	Cretaceous	Sandstone	Comprehensive
Teapot Dome	USA	Proposed Demo	RMOTC	Proposed 2006	170 t day^{-1} for 3 months	10 kt	Saline fm and CO_2-EOR	Tensleep and Red Peak Fm	Permian	Sandstone	Comprehensive
CSEMP	Canada	Pilot	Suncor Energy	2005	50 t day^{-1}	10 kt	CO_2-ECBM	Ardley Fm	Tertiary	Coal	Comprehensive
Pembina	Canada	Pilot	Penn West	2005	50 t day^{-1}	50 kt	CO_2-EOR	Cardium Fm	Cretaceous	Sandstone	Comprehensive

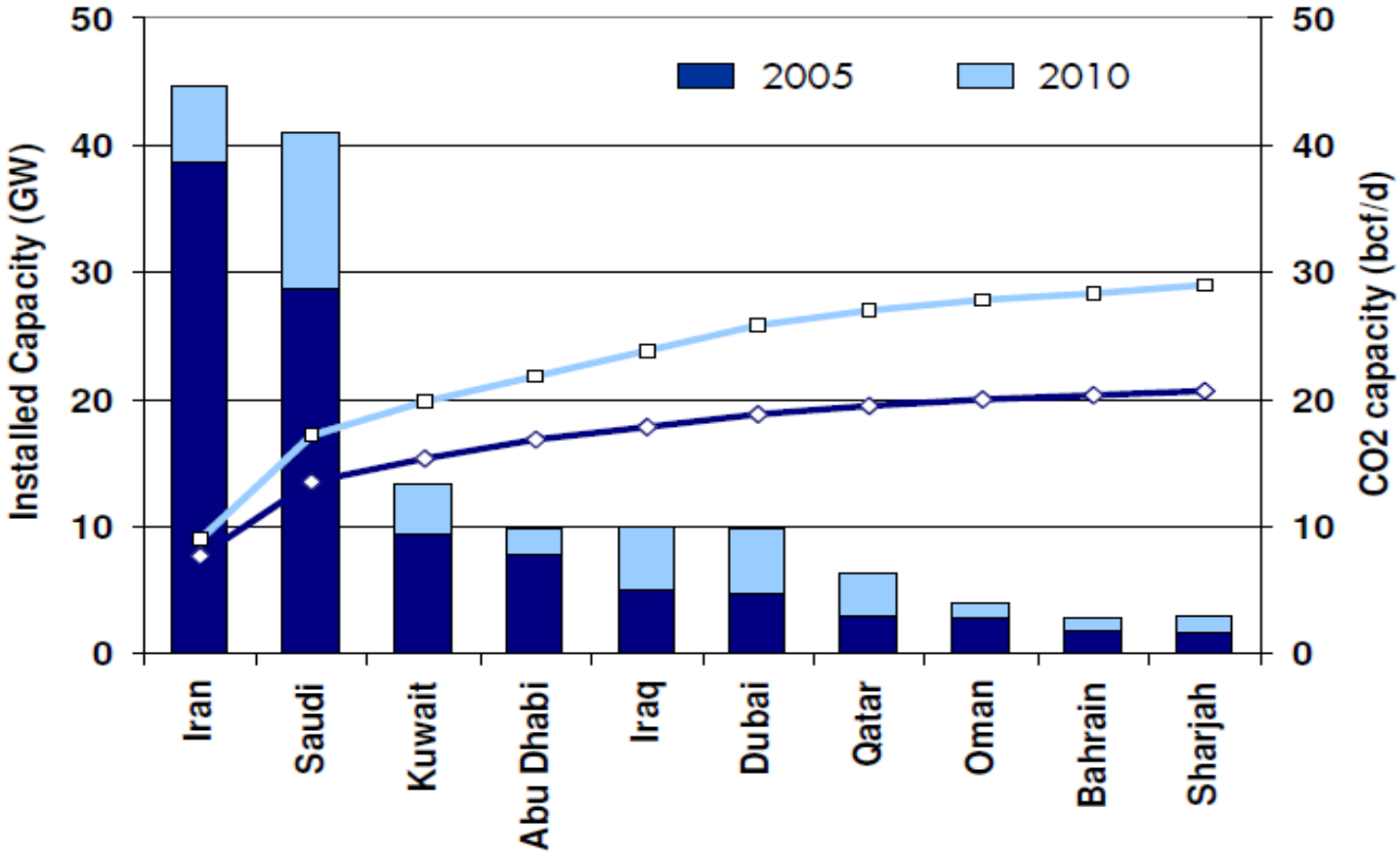
- **CCS & CO2 EOR Projects:**

- **CCS & CO2 EOR Projects:**

- **Addition of CO2 Market:**

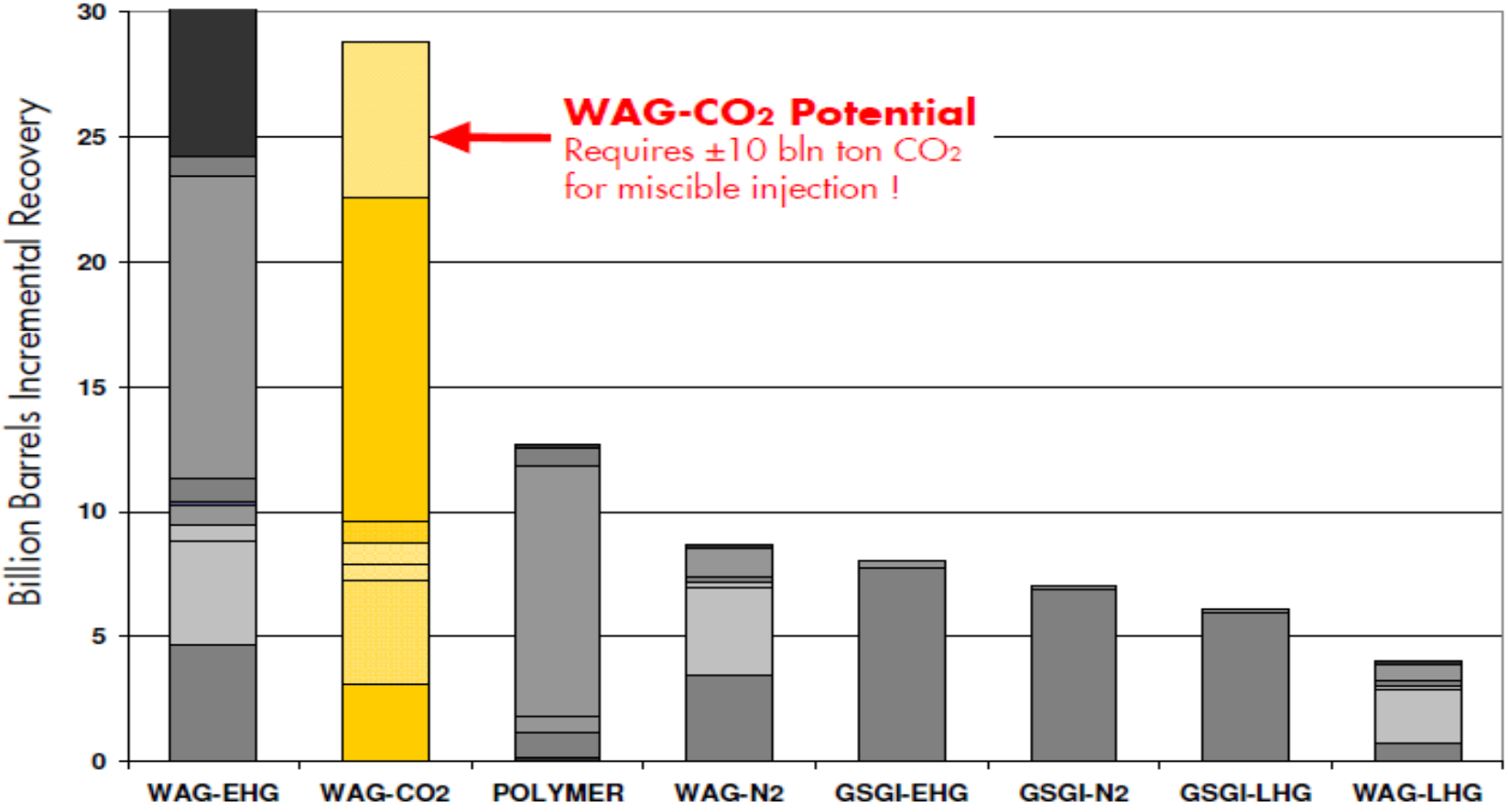


- **CO2 EOR Opportunity in Middle east:**

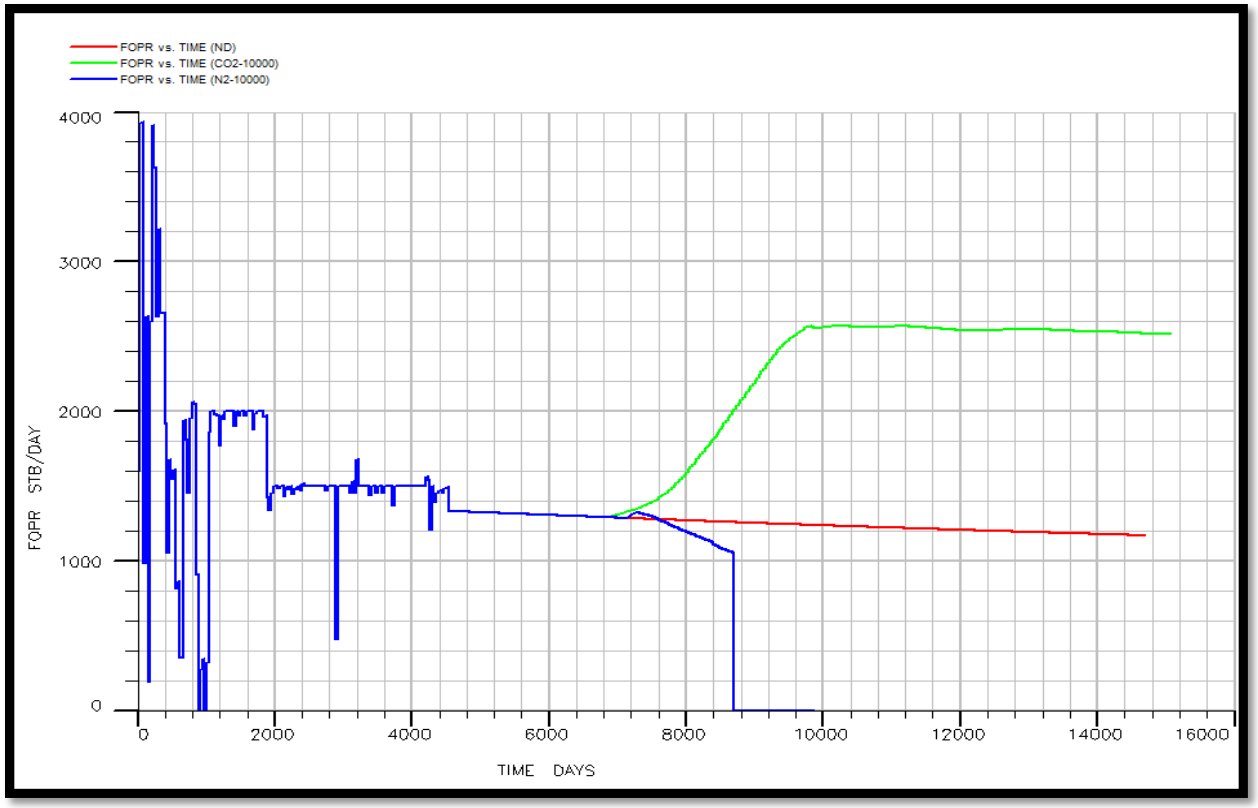


Inventorisation of Middle East EOR Opportunities

- Technical EOR Volume Based on Study of 49 Oil Fields (25% of Regional OIIP)



- **CO2 EOR Advantage:**
- **Case Study Iran**

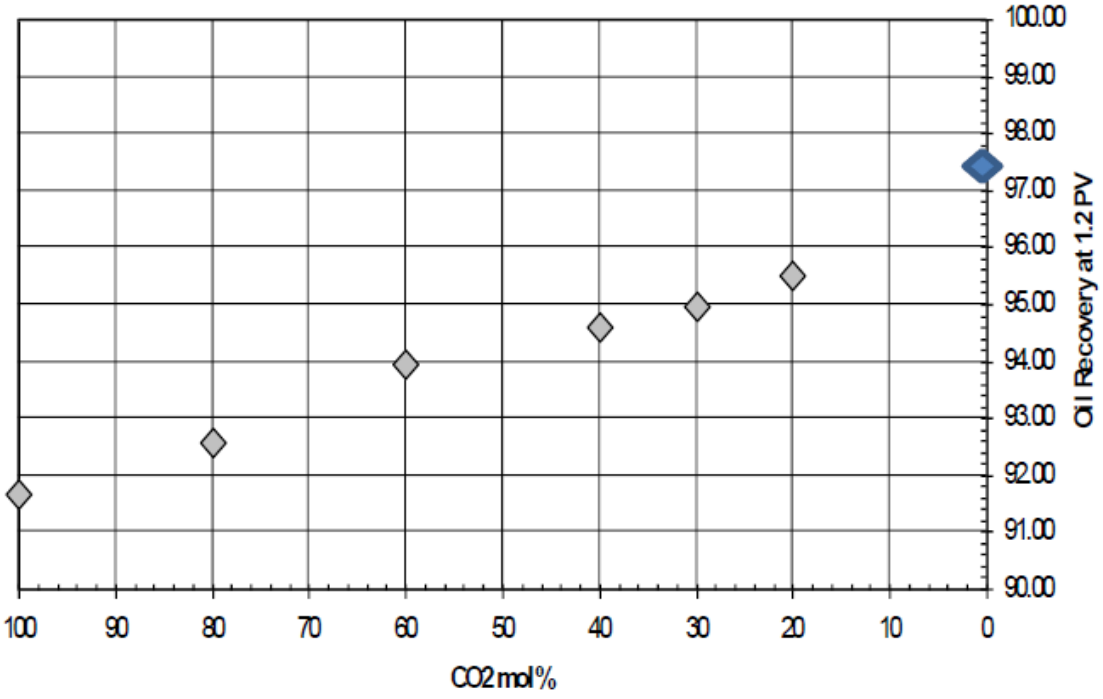


N2 -10000 MSCF/Day Immiscible

Natural Depletion

CO2 -10000 MSCF/Day Miscible

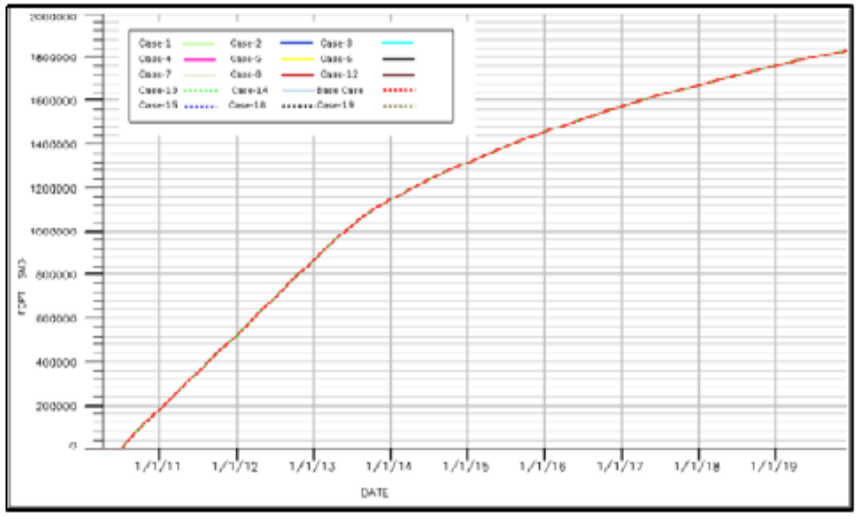
- **Kuwait Experimental data:**

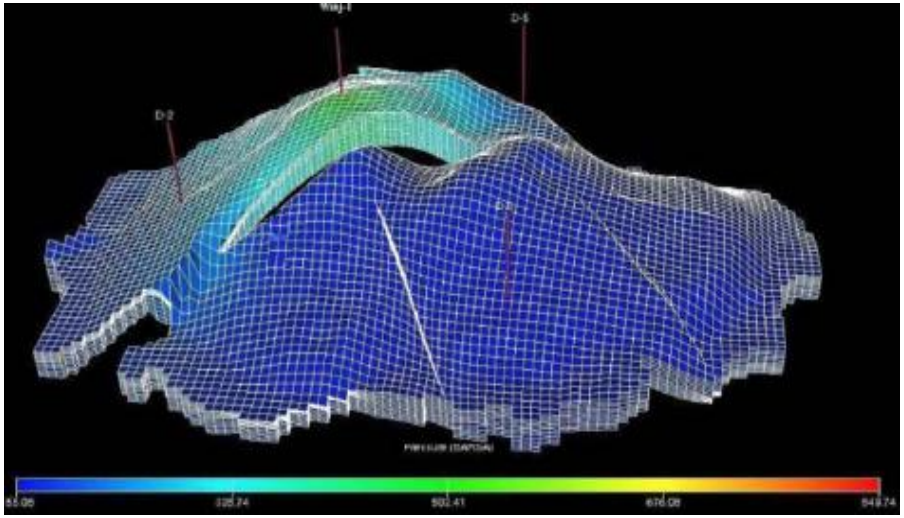


100 % CO2 : 0 % CO2/NGL Mixture

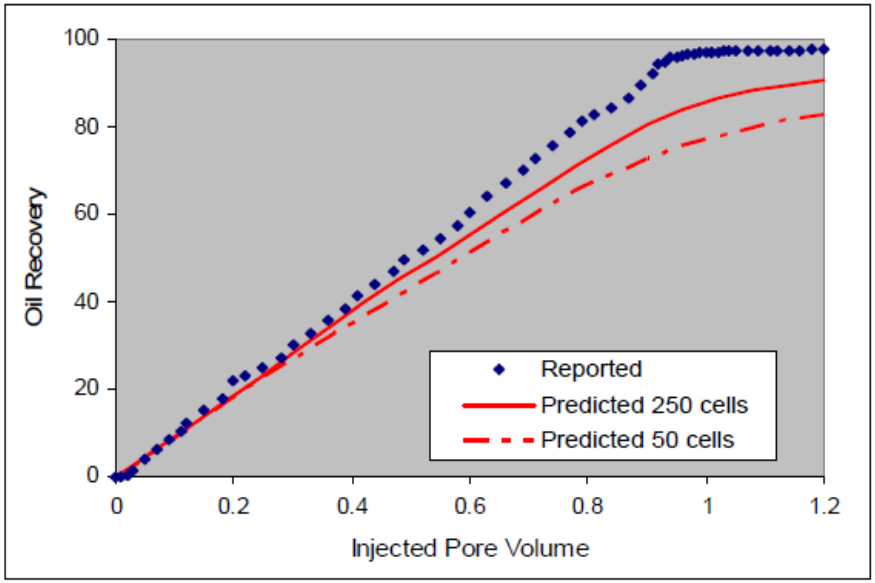
0 % CO2 :100 % CO2/NGL Mixture

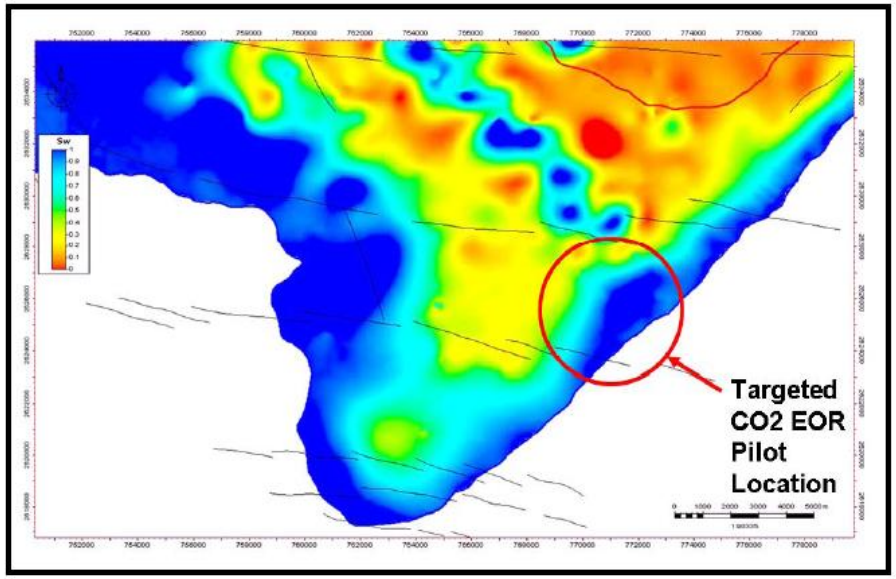
- **Egypt study:**


Case-1
Case-2
Case-3
Case-4
Case-5
Case-6
Case-7
Case-8
Case-12
Case-13
Case-14
Base Case
Case-15
Case-16
Case-17
Case-18
Case-19
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
FGPT SM3
1/1/11
1/1/12
1/1/13
1/1/14
1/1/15
1/1/16
1/1/17
1/1/18
1/1/19
DATE

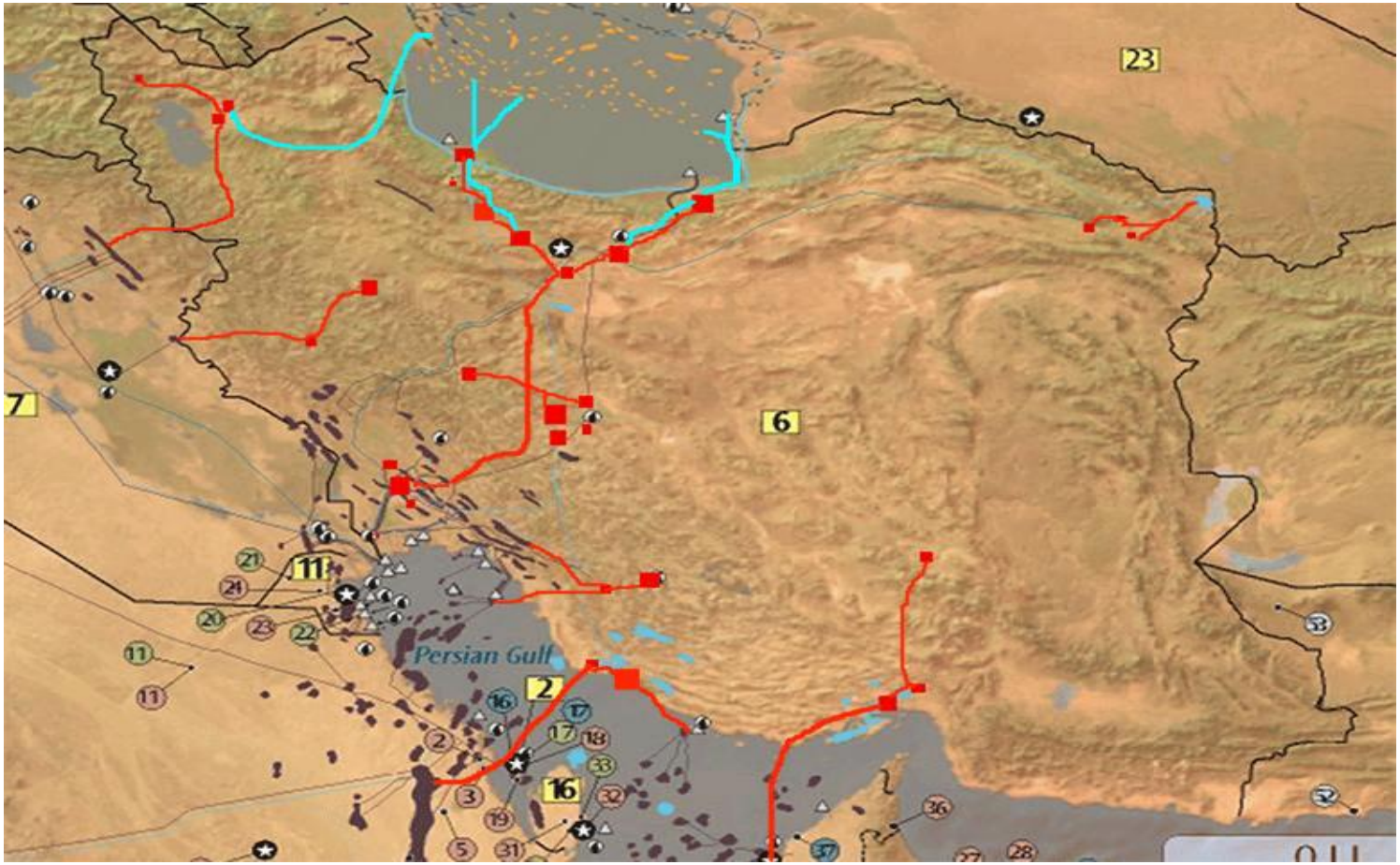

D-2
D-5

- **UEA study:**


100
80
60
40
20
0
Oil Recovery
0
0.2
0.4
0.6
0.8
1
1.2
Injected Pore Volume
Reported
Predicted 250 cells
Predicted 50 cells


Sw
Targeted
CO2 EOR
Pilot
Location

- **Visions :**



- **Strategic Target :**
- **More than 50,000,000 Tones CO2 Available**
- **2 Million Tons CO2 Ready**
- **At least 300,000 bbl per Day More Oil**