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EOR as a Driver for CCS Projects in Mexico

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CCS in Mexico: Policy Strategy Options for CCS. March 7-8, 2012

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Outline

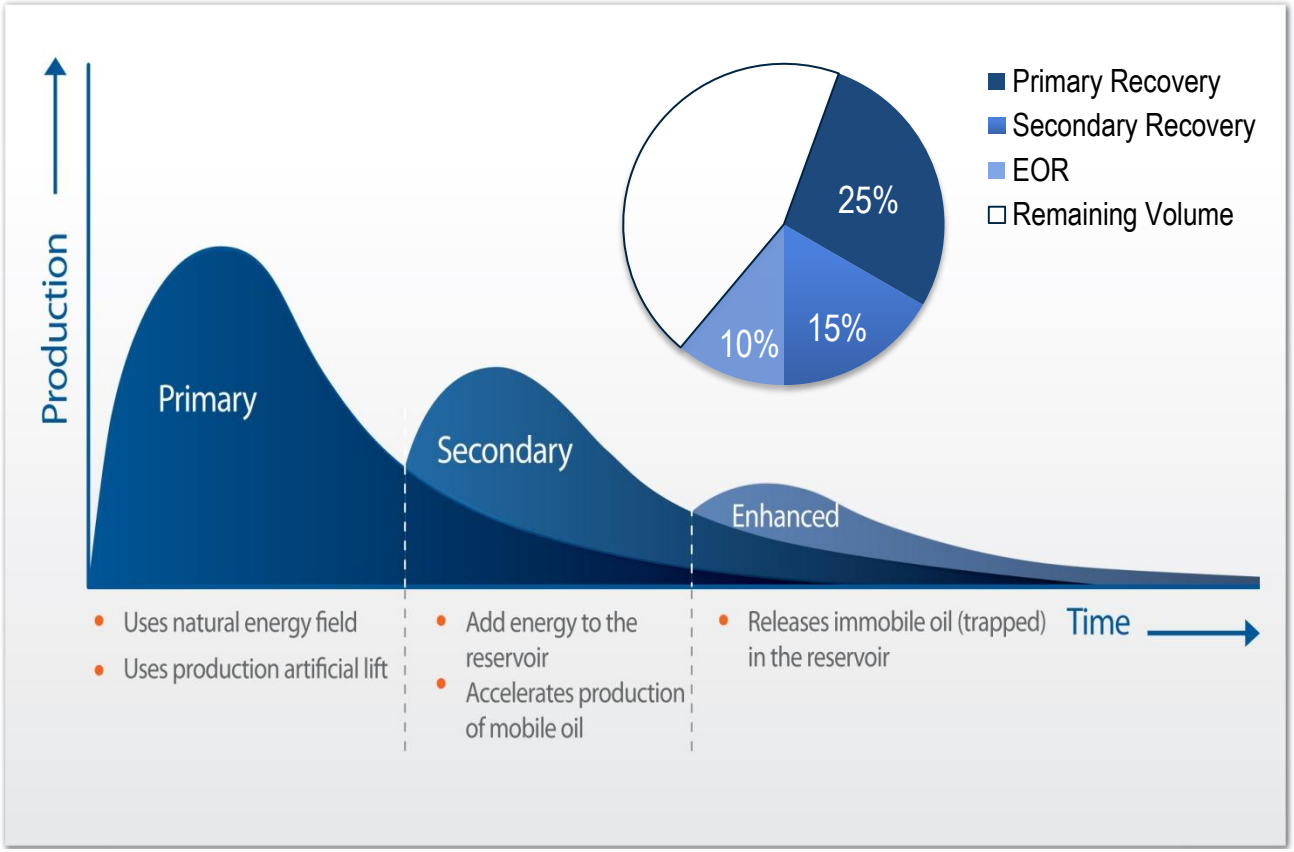
- Introduction
- Status of EOR in PEMEX
- Incremental Oil by CO2 EOR: Expectations from first round
- Final Thoughts

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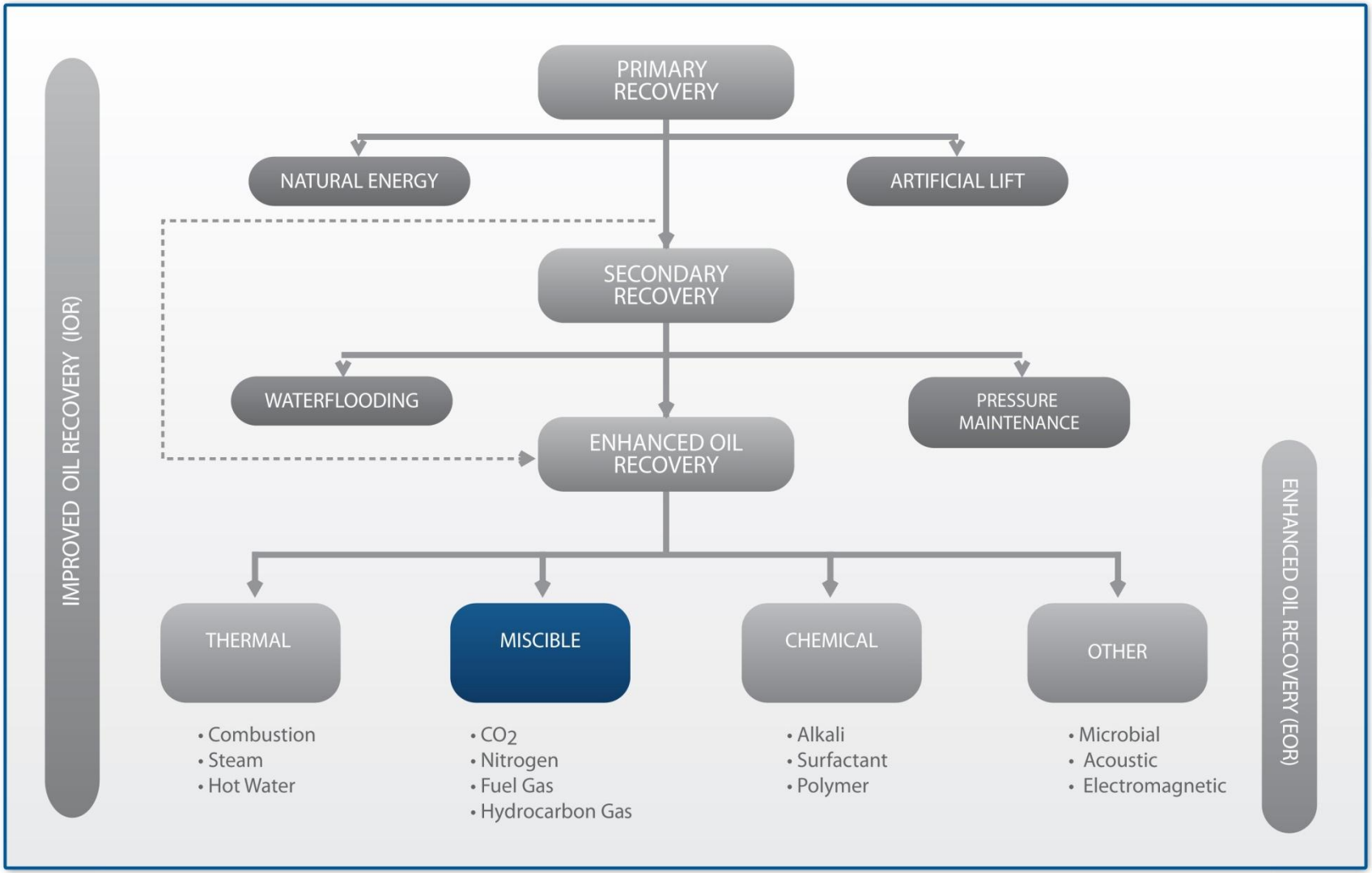
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Production stages of an oil field



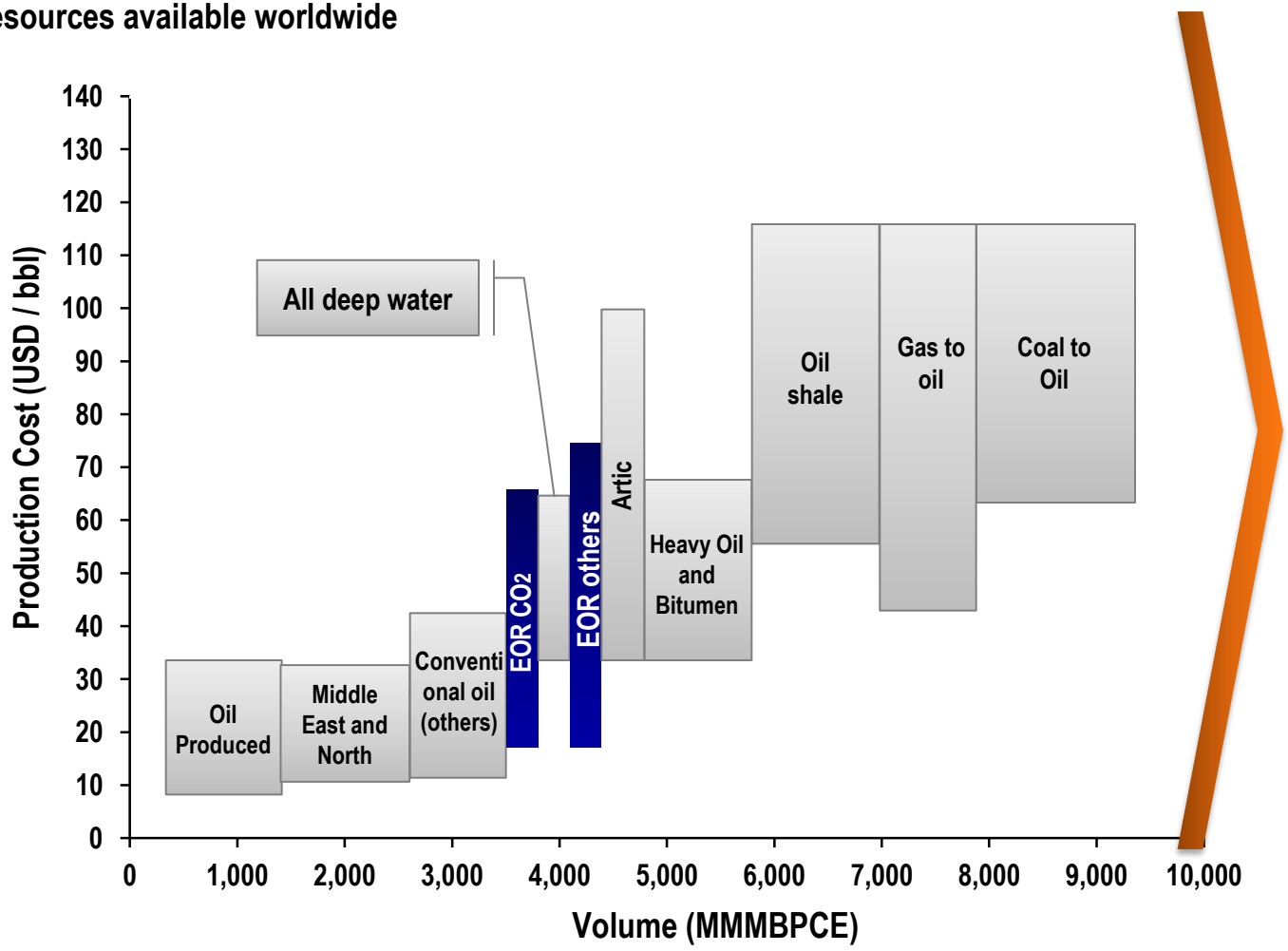
The production of an oil field usually involves three main stages: Primary, Secondary and Enhanced Oil Recovery (EOR).

Enhanced Oil Recovery Methods



EOR Oil Production Costs

Resources available worldwide



- EOR Oil production costs are higher than primary or secondary production
- Oil produced by PEMEX mostly comes from primary production and some from secondary recovery methods

Source: IEA World Energy Outlook 2008, Oil & Gas Journal

Basics of CO_2 EOR

CO2 has two main characteristics when used as EOR fluid:

- It is miscible, or partially miscible, with the oil
- Less expensive than other miscible gases

Screening criteria for CO2 candidates

PARAMETER	UNIT	AMOUNT
Depth	ft	<9,800 and > 2,000
Temperature	°F	<250, but not critical
Pressure	psia	>1,200 to 1,500
Permeability	mD	> 1 to 5
Oil gravity	°API	>27 to 30
Viscosity	cp	<10 to 12
Residual oil saturation		>0.25 to 0.30

Source: NETL, march 2010.

CO_2 EOR: Benefits and Challenges

Major benefits:

- ✓ Solubility of CO_2 in the oil produces oil viscosity reduction and swelling.
- ✓ Interfacial tension reduction between oil and CO_2.
- ✓ Lower miscibility pressure requirement for CO_2, compared to other gases.
- ✓ CO2 has water-like injectivity
- ✓ Standard injection facilities.

Technical Challenges:

- × Large volumes of water and CO_2 produced.
- × In heavy oil the Minimum Miscibility Pressure (MMP) is difficult to reach.
- × Higher levels of corrosion.
- × Gravity Segregation in the reservoir.
- × Viscous fingering in the reservoir.
- × Application in the Mexican naturally fractured reservoirs.

Source: GEOGREEN, 2010.

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Recovery Factors : Fields from Canada and USA

Field	Oil Gravity (°API)	Oil Viscosity (cP)	Amount Injected (%HCPV)	RF, Incremental Recovery Factor (% OOIP)	Total Factor (Mcf/STB)	Net Factor (Mcf/STB)	Start
Dollarhide	40	0.4	30	**14**		**2.4**	1985
East Vacuum	38	1.0	30	**8**	**11.1**	**6.3**	1985
Ford Gerldine	40	1.4	30	**17**	**9**	**5**	1981
Means	29	6.0	55	**7.1**	**15.2**	**11**	1983
North Cross	44	0.4	40	**22**	**18**	**7.8**	1972
Northeast Purdy	35	1.5	30	**7.5**	**6.5**	**4.6**	1982
Rangely	32	1.6	30	**7.5**	**9.2**	**5**	1986
SACROC (17 pattern)	41	0.4	30	**7.5**	**9.7**	**6.5**	1972
SACROC (4 pattern)	41	0.4	30	**9.8**	**9.5**	**3.2**	1981
South Welch	34	2.3	25	**7.6**	**--**	**--**	--
Twofreds	36	1.4	40	**15.6**	**15.6**	**8**	1974
Wertz	35	1.3	60	**13**	**13**	**10**	1986

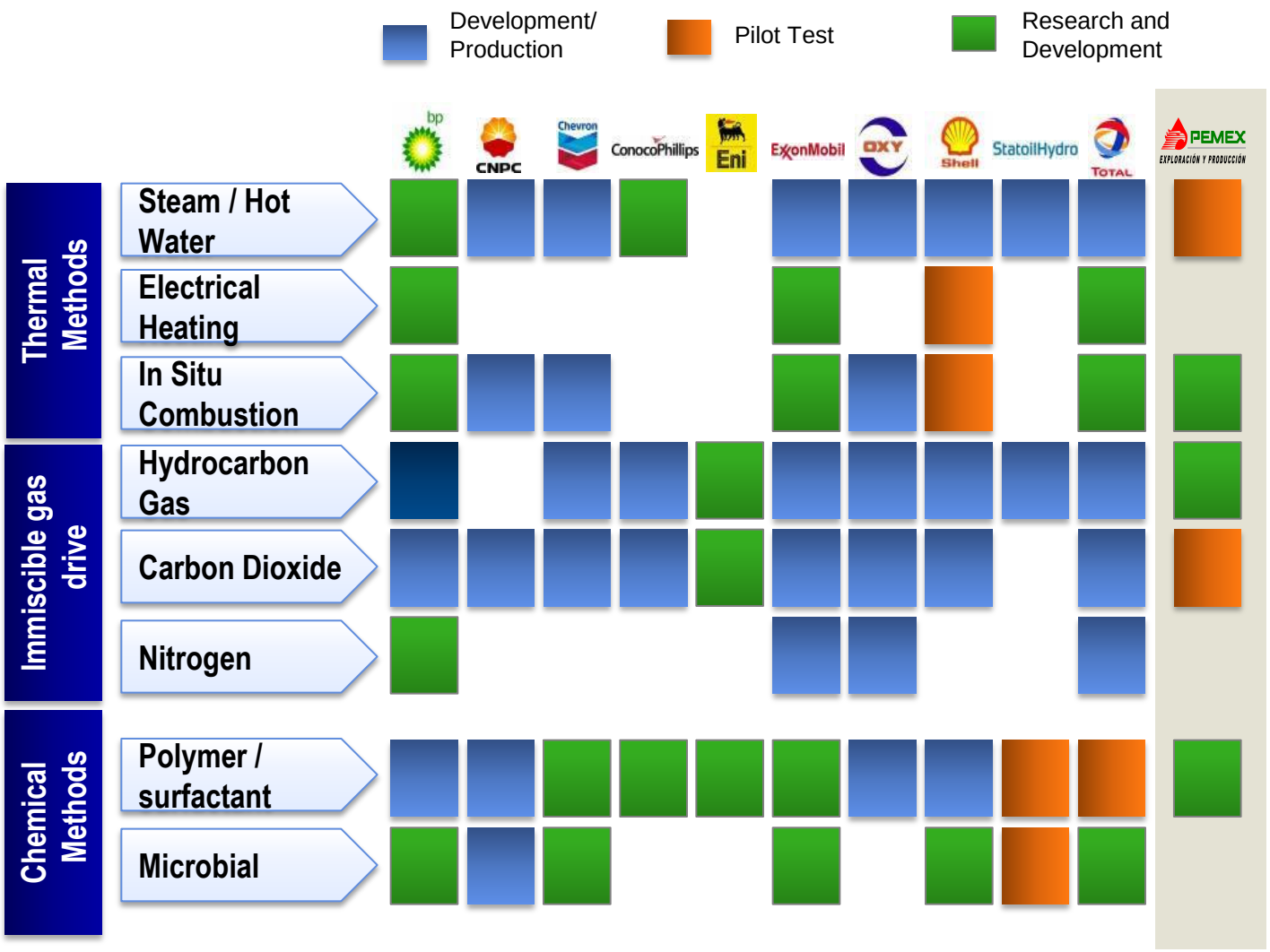
Source: Brock, W.R. and Bryan, L.A., «Summary Results of CO2 EOR Tests, 1972-1987» Tulsa, OK, April 22-25.

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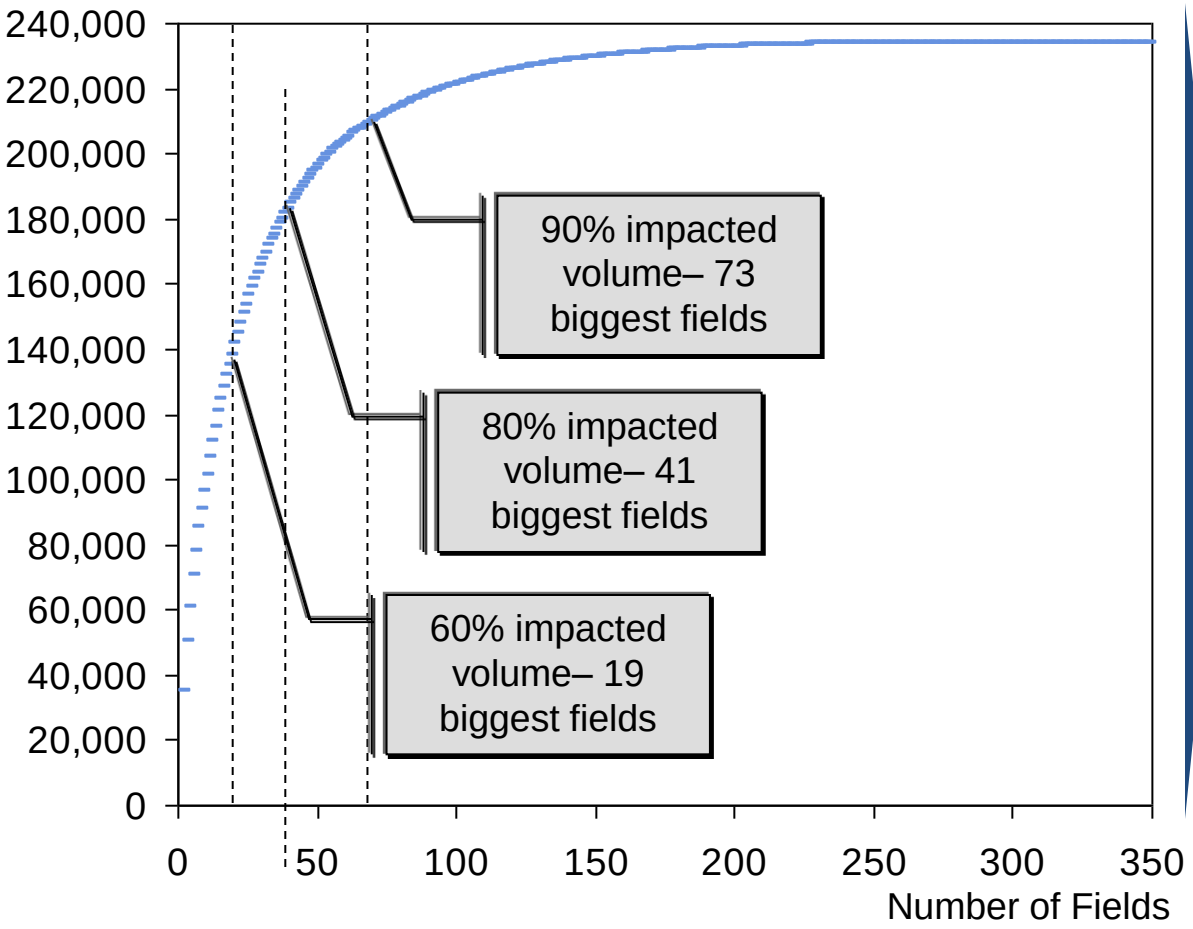
EOR Experience in PEMEX - E&P



- PEMEX EOR experience is mostly limited to lab and simulation studies: yet conducted CO2 pilots in Chicontepec fields and steam injection in Samaria Terciario field
- More than 350 EOR projects implemented worldwide: 2.2% share of the world oil production
- Very limited worldwide experience on EOR in Naturally Fractured Reservoirs. 92% of PEMEX oil production comes from NFR

* Nitrogen injection processes applied as secondary recovery, not enhanced.
Source: OGJ 2008, Websites of the companies mentioned

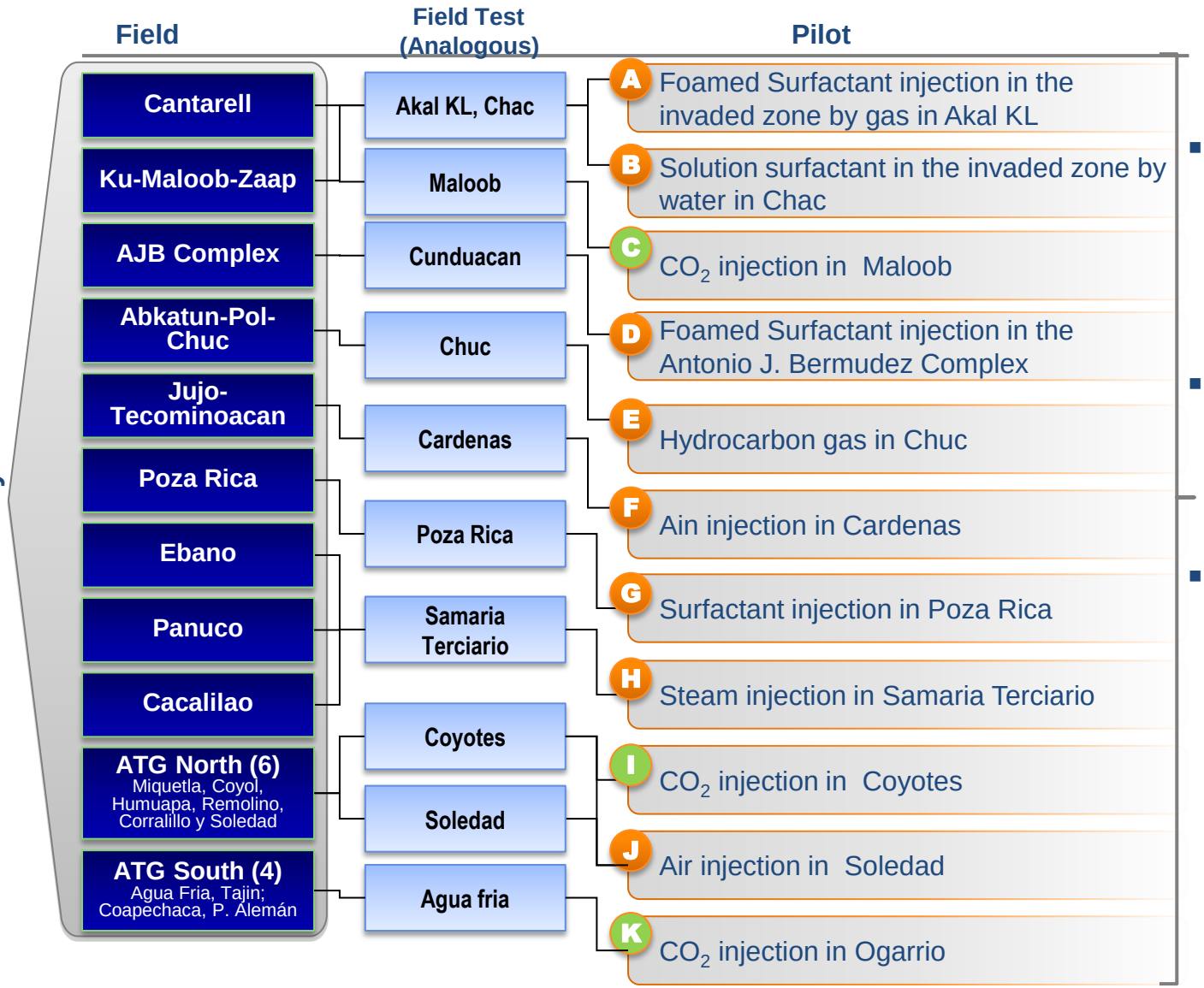
The EOR strategy of PEMEX is focused on the 19 biggest fields



- EOR implementation on the 19 biggest fields of Mexico will have a potential impact on 60% of the total OOIP of all fields
- These 19 fields involve onshore and offshore fields as well as non fractured clastic and fractured carbonate reservoirs

Source: Producción y Reservas por campo – Pemex 2008

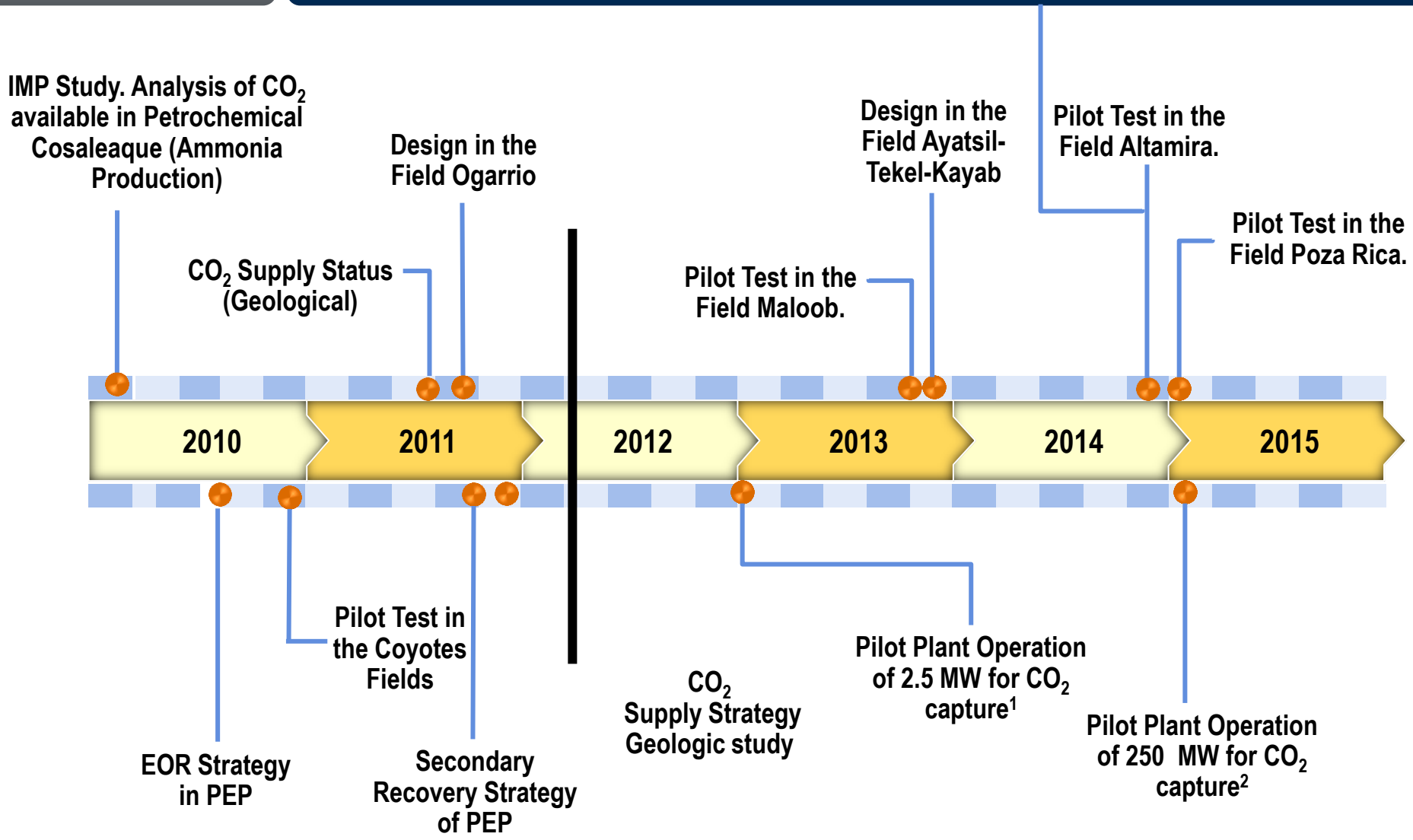
EOR Strategy in PEMEX E&P



- Will start with 11 pilot tests covering most of the EOR technologies
- Results from pilots will extend to other analogous reservoirs
- The air injection in NFR pilot is strategic since 50% of Mexico´s oil reserves come from NFR reservoirs.

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CO_2 EOR: Road Map



Location of CO_2 Pilot Tests



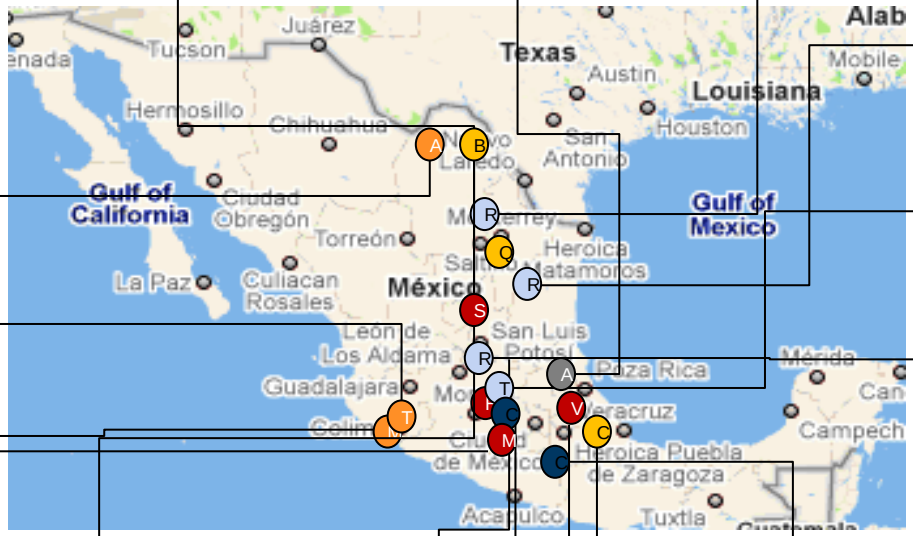


CO_2

Anthropogenic Sources of CO_2

Natural Sources of CO_2

Location of main sources of CO_2



CFE, San Luis Potosí
MMPCSD: 114

Cangrejera Complex
MMPCSD:790

Cadereyta, NL, Refinery
MMPCSD: 107

Madero, Tamps., Refinery
MMPCSD: 120

Miguel Hidalgo Refinery
MMPCSD: 159

Guanajuato Refinery
MMPCSD: 251

CEMEX Puebla
MMPCSD: 101

CEMEX Hidalgo
MMPCSD:

AHMSA
MMPCSD: 762

Las Truchas
MMPCSD: 132

Mittal Steel
MMPCSD: 263

Burgos
MMPCSD: ~100

Quebrache
MMPCSD: 260

Carmito
MMPCSD: 50

CFE, Valle de Mexico
MMPCSD: 126

CFE Tula, Hidalgo
MMPCSD: 623

CFE Tuxpan, Veracruz
MMPCSD: 390

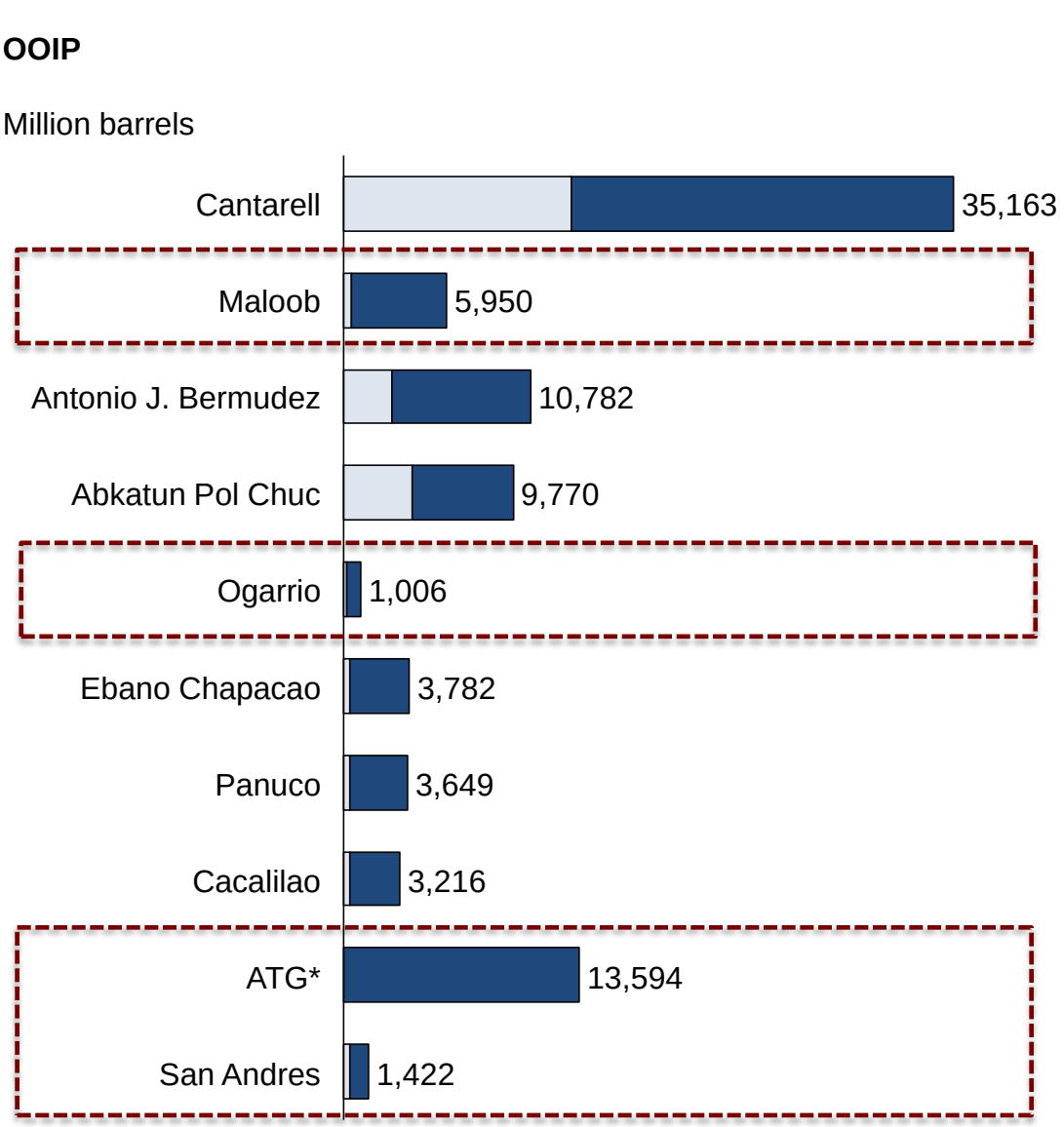
- Refineries
- CEMEX
- Reservoir
- Steel
- CFE

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11 out of the 19 priority fields are candidates for CO2 EOR



- CO2 EOR could be first implemented in fields that add up to **22** MMMB of OOIP (first round)
- Would represent 9% of the OOIP in all fields and 16% of the OOIP in the fields considered in the EOR strategic program

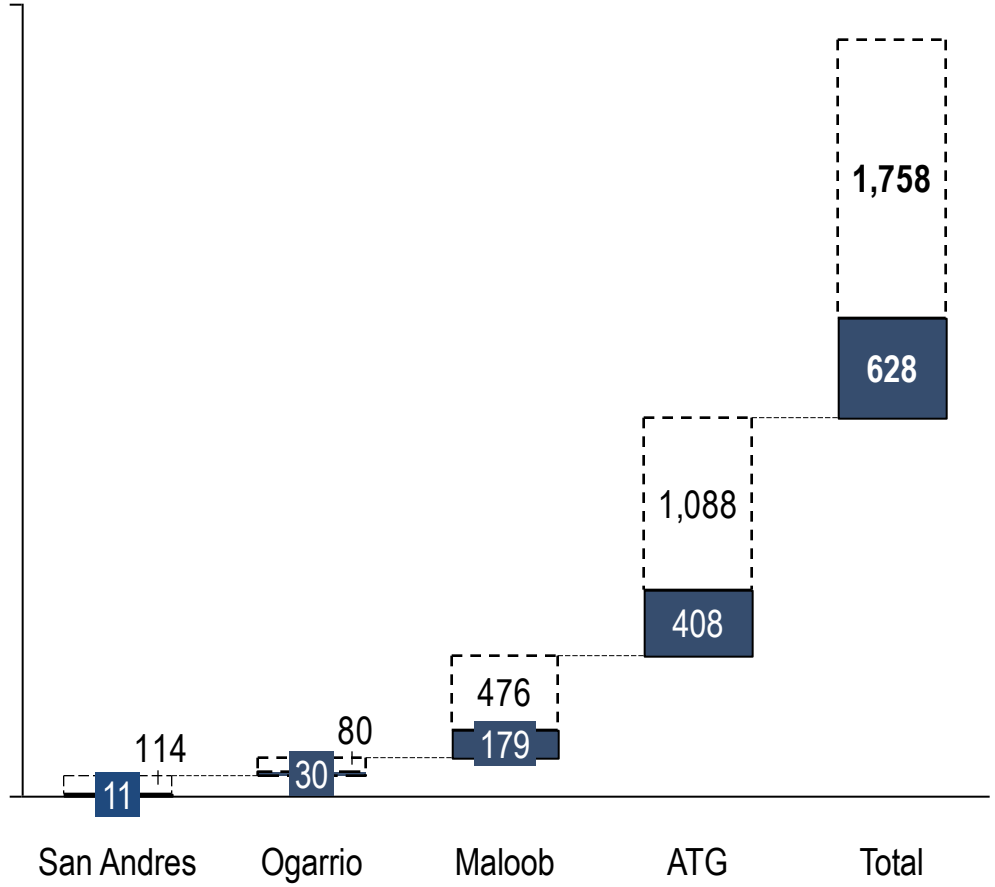
* Fields: Coyotes, Soledad and Humapa

Soruce: Production and Reserves by field- Pemex 2008

Potential Incremental Oil from first round CO2 Floods

INCREMENTAL OIL POTENTIAL BY ENHANCED RECOVERY

Million barrels



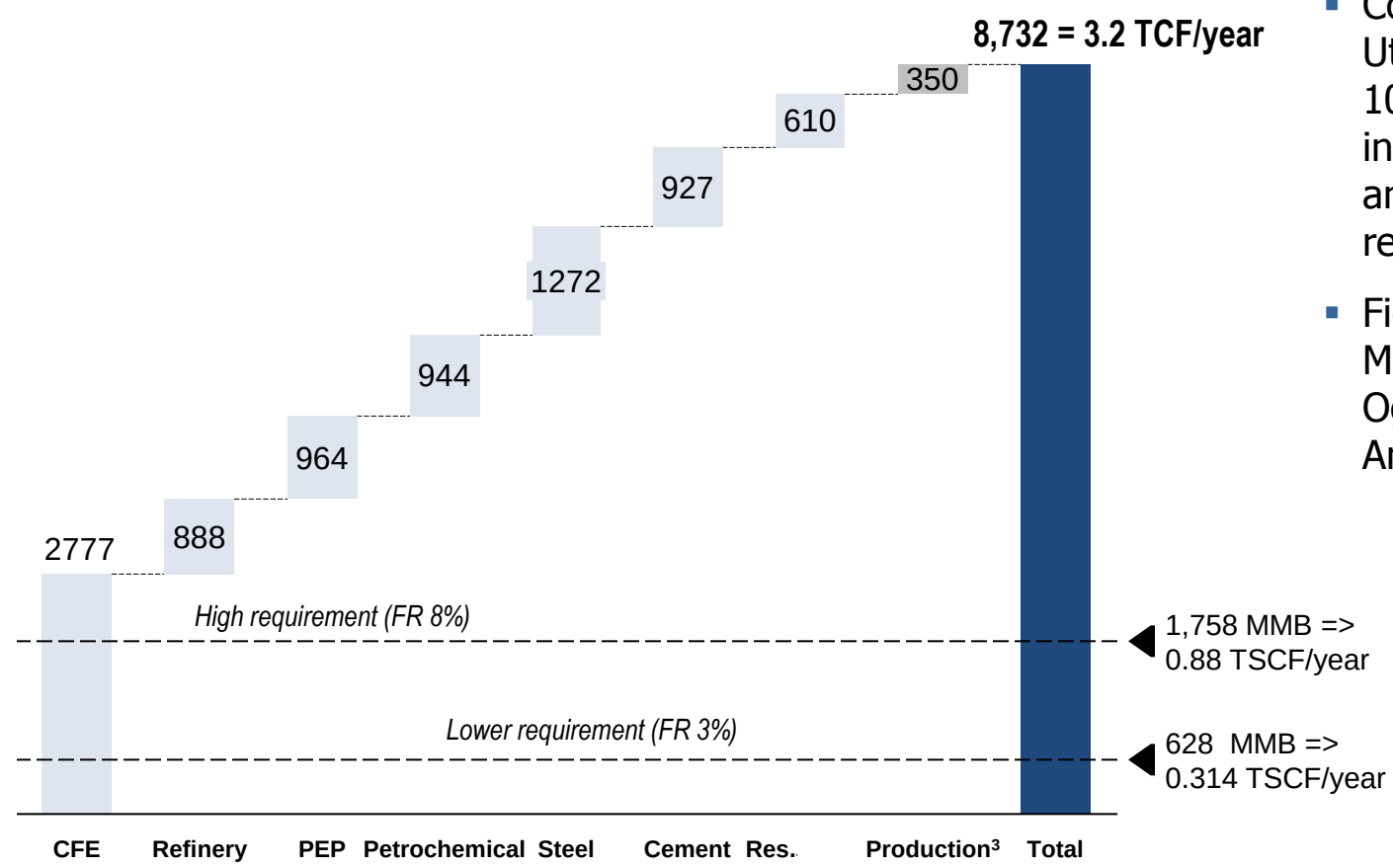
- Assuming an incremental oil recovery ranging from 3 to 8 %, oil attributable to CO2 flooding will range from 600 to 1700 MMB for fields considered in the first round fields.

* Coyotes, Soledad and Humapa

Volume of CO_2 Required

CO_2 Volume by source[2]

MMPCD



- Considering a Utilization Factor of 10,000 SCF/Bl of incremental oil, a trivial analysis gives the CO2 requirements
- Fields considered: Maloob, ATG Fields, Ogarrio and San Andres.

* Fields: Coyotes, Soledad and Humapa
(1) 20 years of Time horizont analyzed
(2) SEMARNAT. CO2 source emision 2007 (3) Utility factor of 10,000 CF/B of oil

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Final Thoughts

- CO_2 EOR is playing, and will play, an important role in the exploitation of oil reservoirs, and therefore, it could contribute in the near future with the development of CCS Projets.
- After successful CO_2 pilot testing, CO_2 EOR could be an effective driver for strategic-large scale CCS projects.
- CO_2 recycling has to be considered when deploying CO_2 EOR field-scale projects
- Reduction in CO_2 capture costs will impact possitively the EOR projects of PEMEX.



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