Enhanced Oil Recovery Combined with Carbon Storage: means, status and barriers to deployment

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ECONOMIC POTENTIAL FOR CO_2 EOR IN ALBERTA

- Potential for CO_2 EOR use in Alberta: 10-20 Mt/yr of CO_2
- Incremental production: 1.4 billion barrels of incremental oil production.
- Potential extension of production in the conventional Alberta oilfield by 20 to 30 years.

Source: ICO_2N 2009:
Carbon Dioxide Capture and Storage – A Canadian clean energy opportunity)

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ANALOGUES FOR COMMERCIAL CO_2 EOR

- CO_2 EOR technologies in commercial scale applications for over 30 years in the United States.
- Transport is very well understood. Large amounts of CO_2 routinely transported via pipeline.
- 33 million ton of CO_2 are injected every year in US for 74 EOR projects for a combined production of 234,000 barrels per day.
- Cenovus Weyburn and Apache Midale projects in SE Saskatchewan: 30,000 and 6,500 barrels per day.

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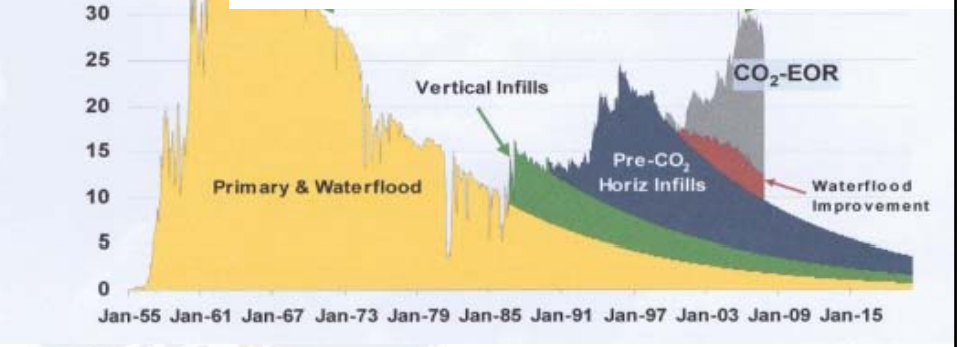
CENOVUS WEYBURN, SASKATCHEWAN

- Only commercial CO2 EOR in Canada
- CO_2 injection : 2.8 Million tons per year.
- Additional recovery by CO_2 EOR: 20.7 x 10^6 m^3 (130 x 10^6 bbls) oil
- Life extension of Weyburn Oilfield: 25 years.
- CO2 Source: 5,000 tonnes/day (3 x 10^6 m^3) from Great Plains Synfuels Plant in Beulah, ND, transported via 320 km pipeline.



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RESIDUAL OIL ZONES (ROZ)

EMERGING OPPORTUNITY FOR CO_2 EOR

- ROZ: Partially saturated; produce non- commercial volumes of oil under primary or secondary production. Generally not completed or even drilled.
- EOR possible where S_{ow} >20%, similar to waterflood swept intervals.
- Extensive and thick ROZ exist below the OWC in many pools of Alberta, under certain geologic and hydrodynamic conditions.
- Reservoir modelling in US: CO2 EOR in TZ/ROZ would technically double current recoverable resources, with a significant increase of sequestered CO2 through EOR.

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MAJOR BARRIERS FOR CO_2 EOR INDUSTRY IN WESTERN CANADA

- **Lack of readily available pure CO_2 source**
  - Man made: only sources available in Western Canada.
  - Natural sources of CO_2 known in WCSB (i.e. SE Saskatchewan).
- **Lack of transportation infrastructure**
  - No pipeline infrastructure for CO2, unlike US
  - ACTL project: Base for CO2 EOR development in Alberta.
- **Fragmented ownership**
  - CO2 EOR done on a pool-wide basis, but many pools with 50+ stakeholders.
  - Many parties involved: province, native bands, landowners, freehold rights owners, other operators in the pool.
- **Other obstacles**
  - limited technical expertise,
  - long-term commitment (strategic versus opportunistic outlook required),
  - certain corporate structures less suited to take on CO2-EOR risks, and
  - volatility of oil prices.

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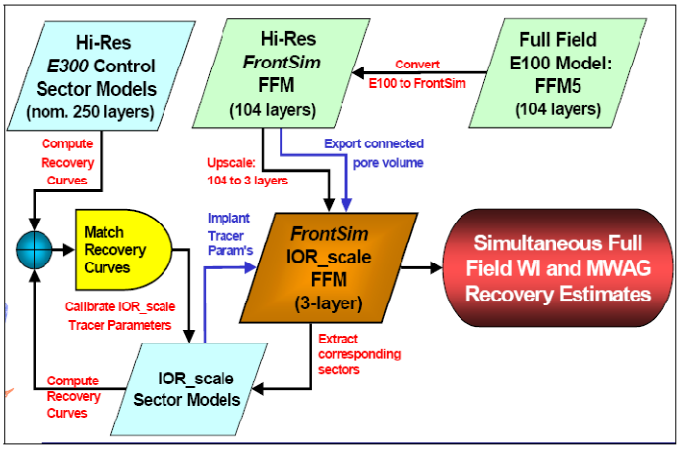
Field Trial Example

Unknowns

Parameter	Value		
	Twofreds	Lost Soldier	Wertz
OOIP, MMSTB	15.4	240	172
Pore volume, MMRB	33.7	299	222
Injection rate, RB/day	4,322	101,800	136,000
Initial formation vol. factor, RB/STB	1.18	1.12	1.16
Initial water saturation, %	46.2	10	10
E_R, %	17.2	11.2	10.1
Terminal oil cut, %	1	2.3	1.3
Δt_{D2}	0.025	0.02	0.03
Δt_{D3}	0.28	0.24	0.24
Δt_{D4}	1.25	1.7	1.95
Δt_2, mo.	6	1.9	1.6.
Δt_3, yrs	6.0	2.0	1.0
Δt_4, yrs	27.9	12.7	8.9
t_{iWF}	1/1/1969	1/1/1988	1/1/1985
q_{iWF}, STB/day	450	2900	6200
b_{WF}	0.10	0.50	0.01
D_{iWF}, %/year	70	40	30
b_{tEOR}	0.30	0.20	0.10

Pre-existing model



Experimental Costs

Drilling new wells or reworking existing wells	
Experimental design costs	Labour
Investigator	Materials
Labour	Equipment
Materials	Various miscellaneous costs
Equipment	Normal well operation and maintenance
Providing surface equipment for new wells	Labour
Experimental design costs	Materials
Investigator	Equipment
Labour	Lifting costs of the produced fluids
Materials	Experimental design costs
Equipment	Investigator
Installing the CO2 recycle plant	Labour
Experimental design costs	Materials
Investigator	Equipment
Labour	Costs of capturing, separating and reinjecting the produced CO2
Materials	Experimental design costs
Equipment	Investigator
constructing a CO2 spur-line from the main CO2 trunkline to the oil field	Labour
Experimental design costs	Materials
Investigator	Equipment

References

- [1]http://www.energy.ca.gov/process/pubs/electrotech_opps_tr113836.pdf - beautiful overview + diagrams
- [2]http://www.ogbus.ru/eng/authors/RamazanovDN/RamazanovDN_1e.pdf - Russian economic simulation
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