Engineering for CO_2 geological storage

EOR - CO_2
Feasibility issues
Economics and business cases

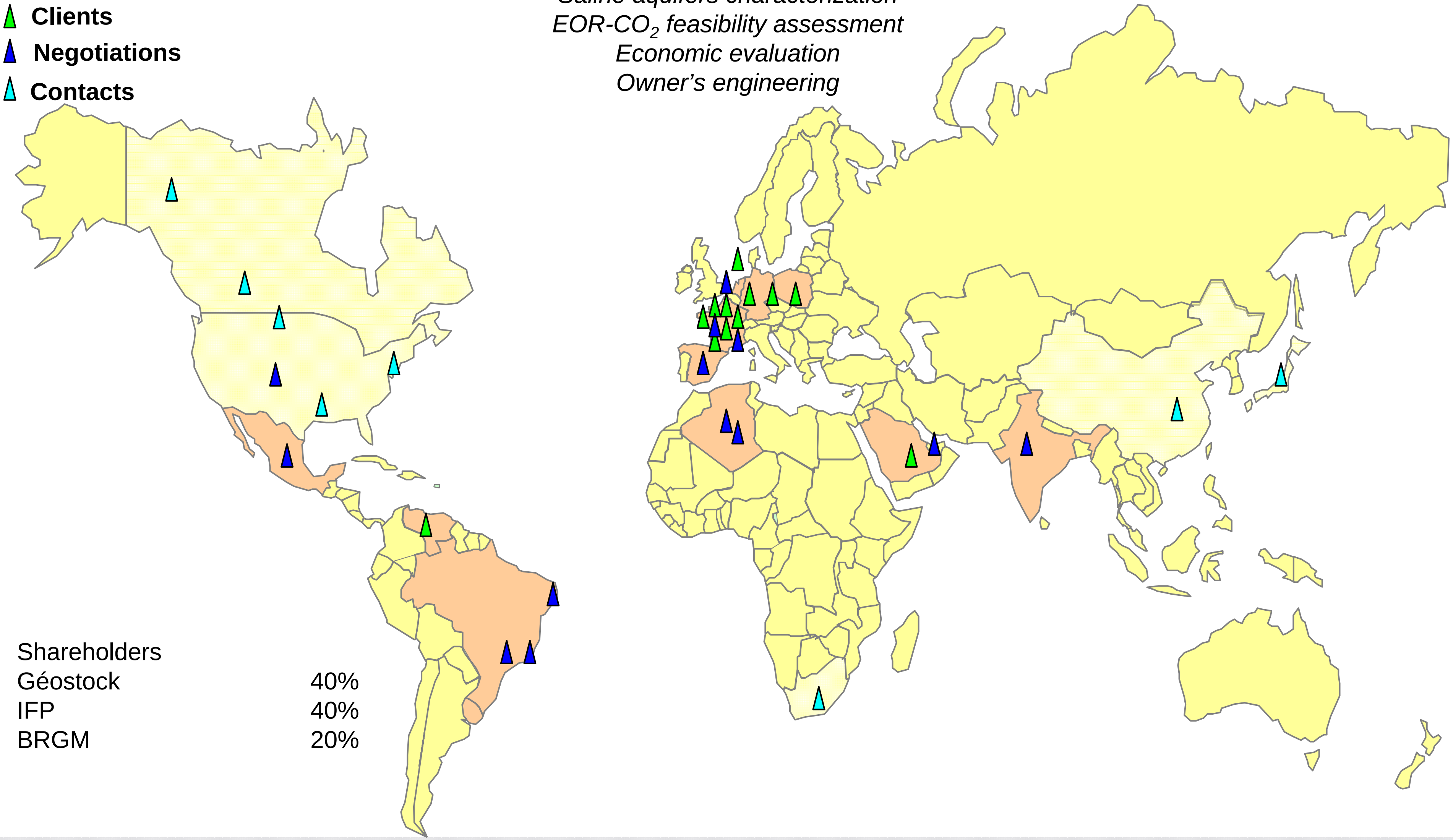
Gilles Munier
Chief Executive Officer

IEF/GCCSI Symposium on CCS

31 May – 01 June 2010, Hotel El Aurassi, Algiers, Algeria

Global Activity

Feasibility, conceptual, pre-FEED for transport and storage
Saline aquifers characterization
EOR-CO_2 feasibility assessment
Economic evaluation
Owner's engineering



Shareholders	
Géostock	40%
IFP	40%
BRGM	20%

geogreen

EOR projects worldwide

Process	CO_2		STEAM	POL	IC	SAP	N_2		HW	GAS HC		BAC
	M	I					M	I		M	I	
Planning	12	4	7	6	1	2						
USA	101	5	45		12	2	1	3	3	1	12	
CANADA	7		14	1	3			1		1	22	
Others	1	10	82	21	1			1			3	1
Total	**121**	**19**	**148**	**28**	**17**	**4**	**1**	**5**	**3**	**2**	**37**	**1**

EOR report, OGJ, 2008

140 projects for CO_2

CO_2	**140**
N_2	**6**
Others	240
Total	**386**

POL: Polymer injection

SAP: Surfactant-Alkaline-Polymer injection (eg Daqing)

HW: Hot Water

IC: In-Situ Combustion

BAC: Microbial

- In USA, about 250,000 bopd through CO_2-EOR
- ~ 85 billion barrels technically recoverable, from which 50 billion economically recoverable ($70 per barrel - $50 per ton CO_2) of recoverable oil (1 billion proven) primarily in the Permian Basin, East Texas and the Gulf Coast
- Weyburn: 5000 tonnes/day CO_2 coming from a coal-gasification plant in Dakota - 320 km pipeline. Recovery of 130 million additional barrels of oil from a partially depleted reservoir using a CO_2 miscible flood

CO_2-EOR processes

- Miscible WAG
  - 5-15% OOIP incremental recovery
- Gravity stable gas injection (immiscible)
  - Up to 20% OIIP incremental recovery
- Factors are also extremely favourable, ranging from about 3 mcf/stb for WAG applications to 6 mcf/stb for straight CO_2 floods (3 to 4 bbl / tonne of CO_2).

Layer n - Pore Volume occupation

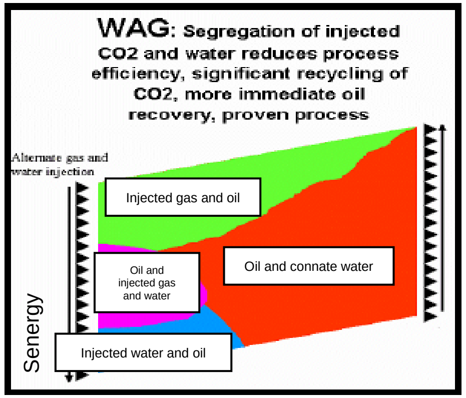
	trapped water	mobile water	mobile oil	trapped oil
CO2	swells	replaces (WAG ?)	displaces	swells

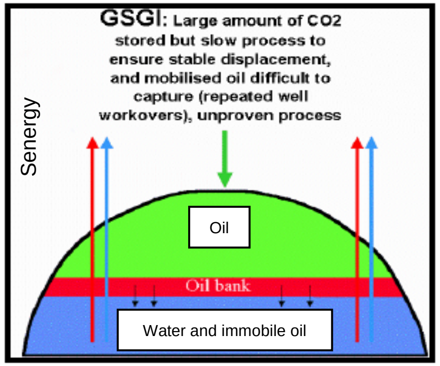
Major beneficial effects:

- Oil viscosity reduction
- Lower miscibility pressure requirements for CO_2
- Oil swelling

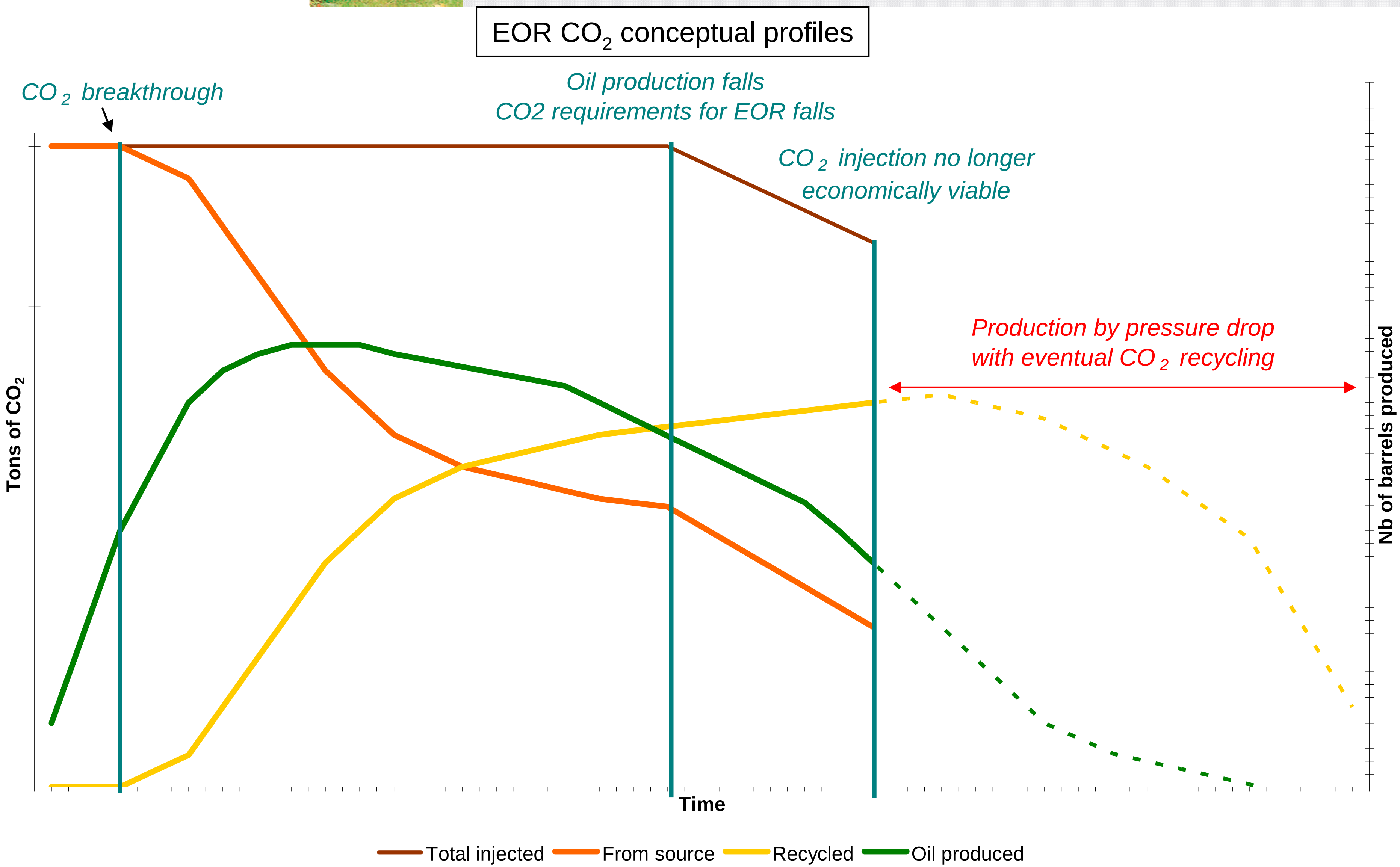
Technical challenges:

- Viscous fingering
- Gravity segregation
- Conformance (placing CO_2 in the “right” zones”)
- Corrosion
- Complex geology (fractured reservoirs)
- What to do with not injected CO_2?





Operational considerations



Economic and operational considerations

- Driving parameters
  - Cost of CO_2 versus oil price visibility
  - Contract structure
  - Threshold effect of Opex
  - Decreasing volumes with time (genuine versus recycled CO_2) compared to capture lifetime
  - Optimization of transport design
  - Old wells WO needs
  - WOC increase jeopardizes EOR
  - Buffer storage required

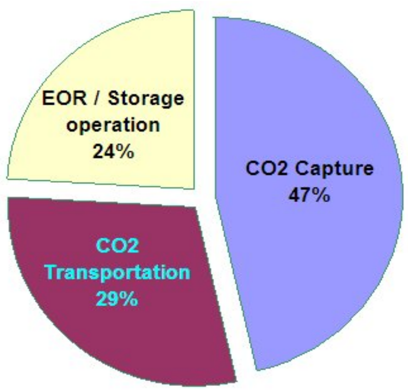
From DOE - 2009

Assumed Oil Price ($/B)	**$70**
Less:	
• Gravity/Basis Differentials, Royalties and Production Taxes	($15)
Net Wellhead Revenues ($/B)	**$55**
Less:	
• Capital Costs	($5 to $10)
• CO2 Costs (@ $2/Mcf for purchase; $0.70/Mcf for recycle)	($15)
• Well/Lease O&M	($10 to $15)
Economic Margin, Pre-Tax ($/B)	**$15 to $25**

Costs breakdown for a CO_2-EOR/storage operation in the North-Sea (after SINTEF)

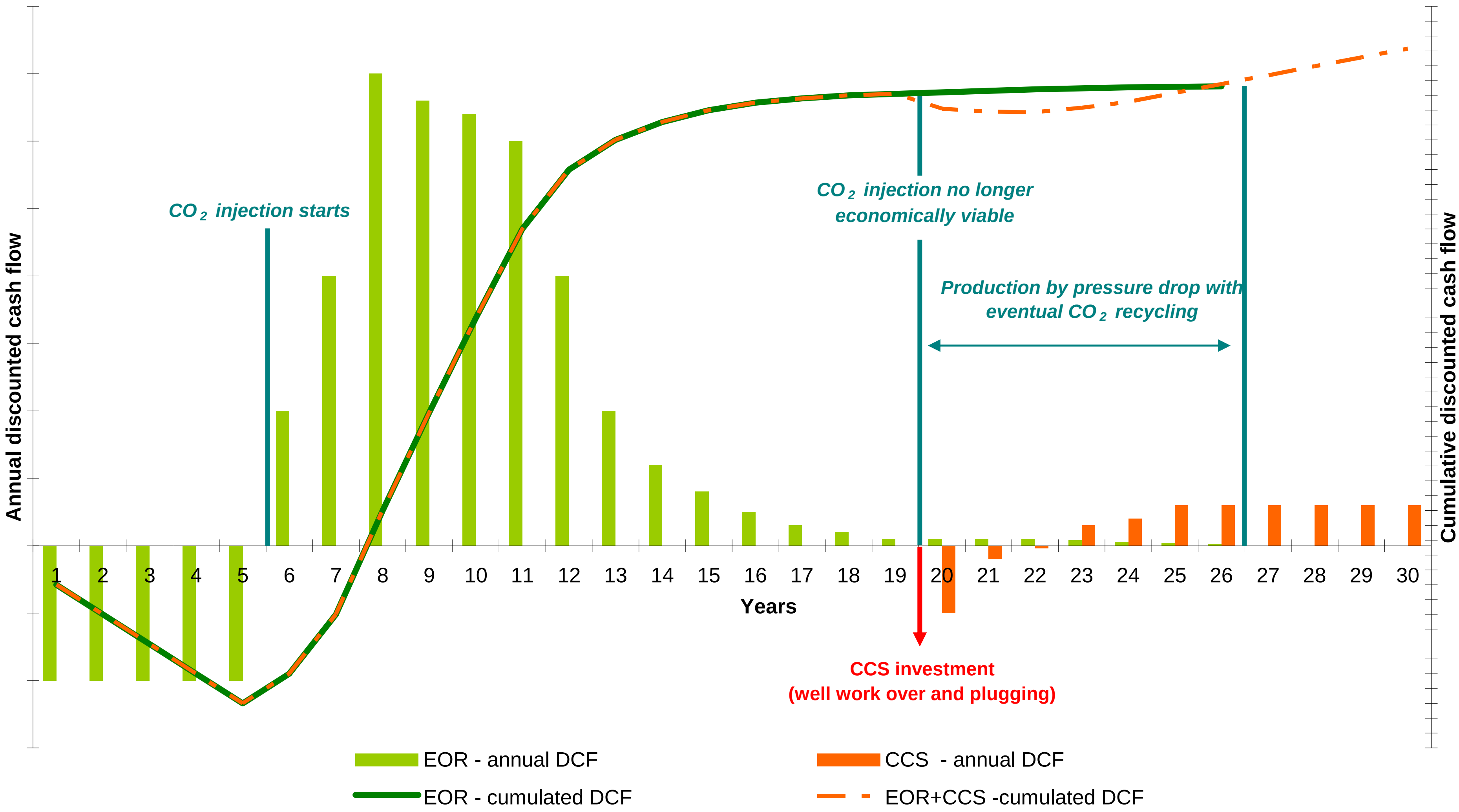
→ CO_2 captured from an onshore coal fired power plant and transported by pipeline to the North Sea

→ Cost of oil production: $43.2/STB



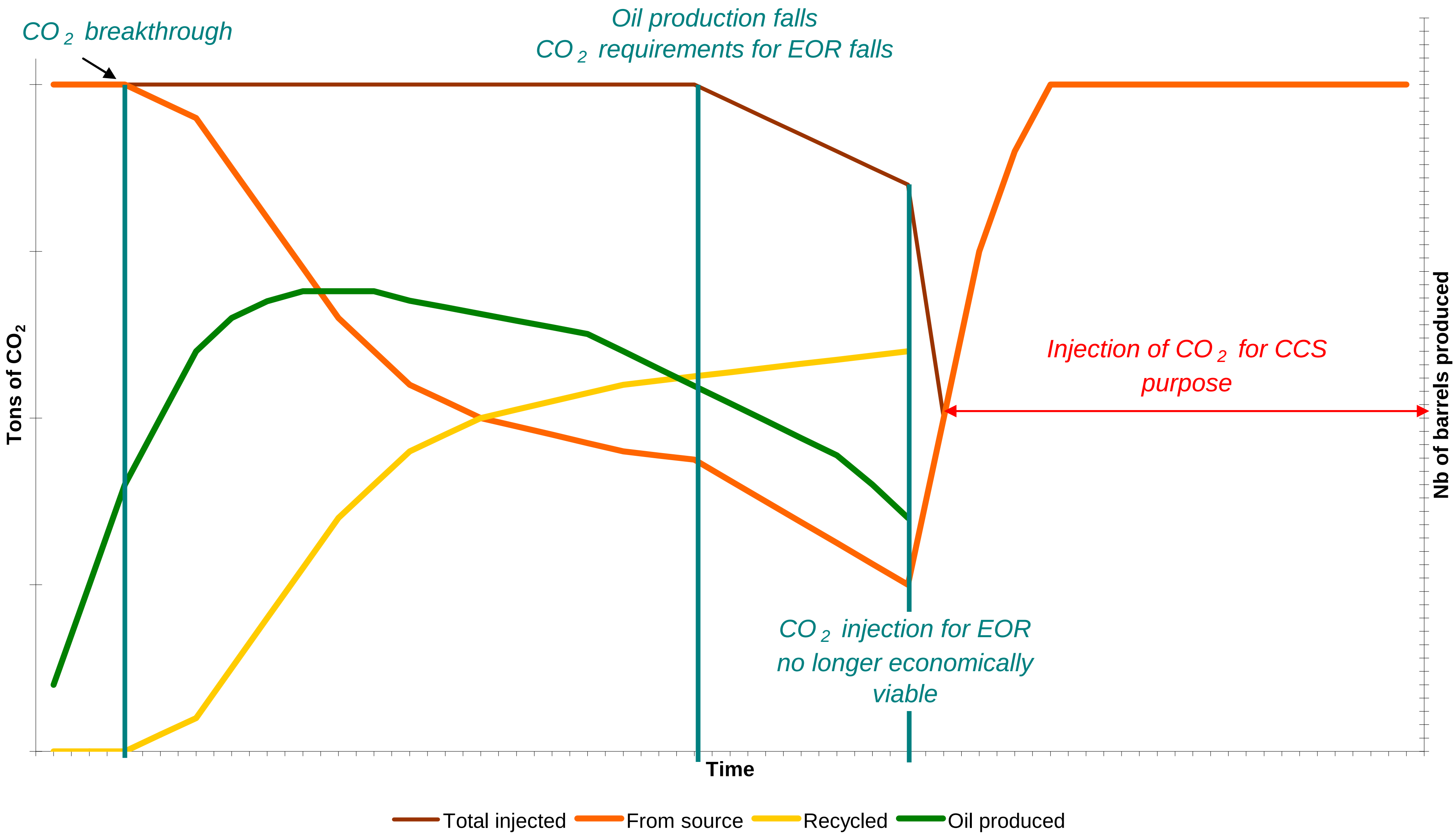
Economic considerations

EOR project VS EOR+CCS project Net Cash Flow



Economic considerations

EOR CO_2 needs profile+ CCS



Storage in hydrocarbon fields: pros and cons

Gas fields

Pros of injection in depleted gas field	Cons of injection in depleted gas field
Known physical trap and seal to hydrocarbon gas (at least originally)	Significant pressure drop may have compromised trap
Well characterised (knowledge of reservoir architecture and dynamic performance)	Abandoned wells may compromise trap
Known capacity (volume previously occupied by produced gas)	CO_2 expansion required at base of well (CO_2 delivered in dense phase but initially stored in gas phase)
Known injectivity (inferred from productivity)	Aquifer influx may limit capacity/injection rate
Existing infrastructure	Facilities and well upgrades required

Oil fields

Pros of injection in depleted oil field	Cons of injection in depleted oil field
Incremental oil recovery	Large volumes of water and CO_2 produced
Known seal/enclosure/trap to oil (gas?)	Significant additional CO_2 generated to power recycling
Existing injection facilities	Facilities and well upgrades required
Well characterised (knowledge of reservoir architecture and dynamic performance)	Limited window of opportunity prior to cessation of production
Modest pressure change during lifetime	Abandoned wells may compromise trap