Enhancing Oil Recovery: what role for CO_2 capture and storage (CCS)

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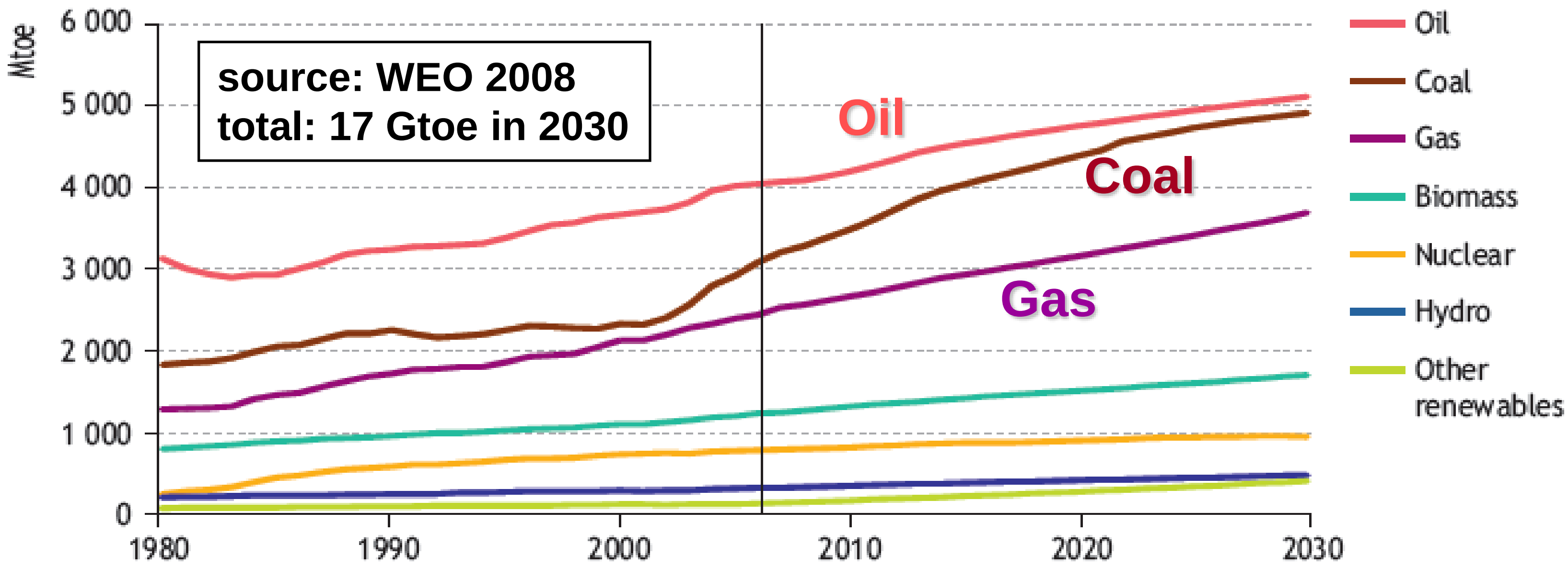
Sustainable Development Technologies

Innovation Energy Environment

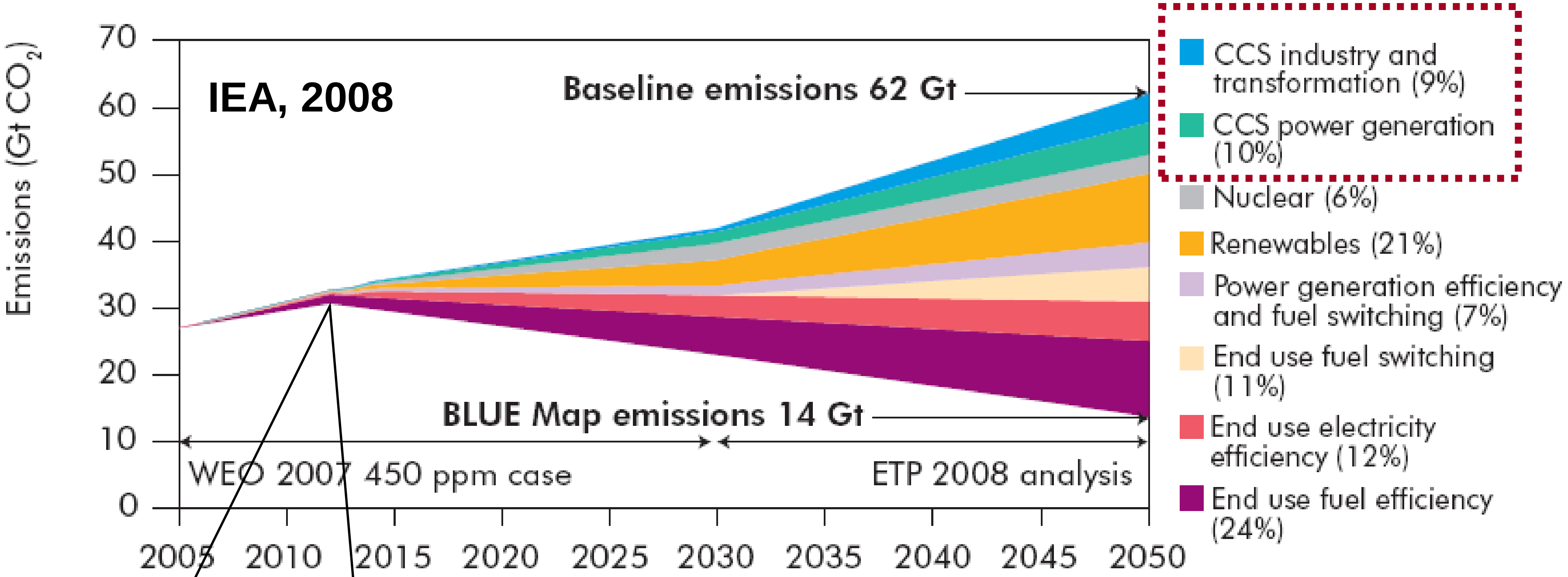
Energy demand



- ***The World Energy Demand should rise by 60% between 2002 and 2030 and requires more than $26 trillions of investments from 2007 to 2030***
- ***Fossil fuels should bring 80% to the total energy mix in 2030***
- ***CO_2 emissions globally should rise by 45% between 2006 et 2030, from 28 to 41 GtCO2 (China + India + Middle East account for 75% of the increase)***

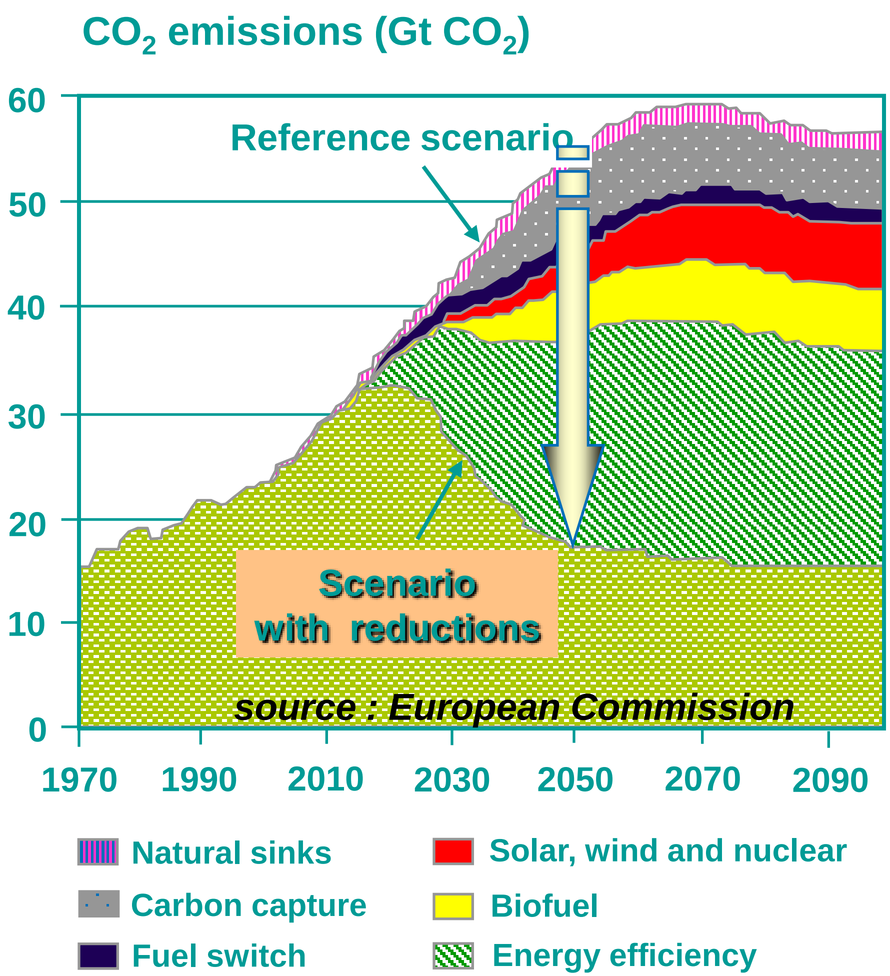
IEA, WEO 2008

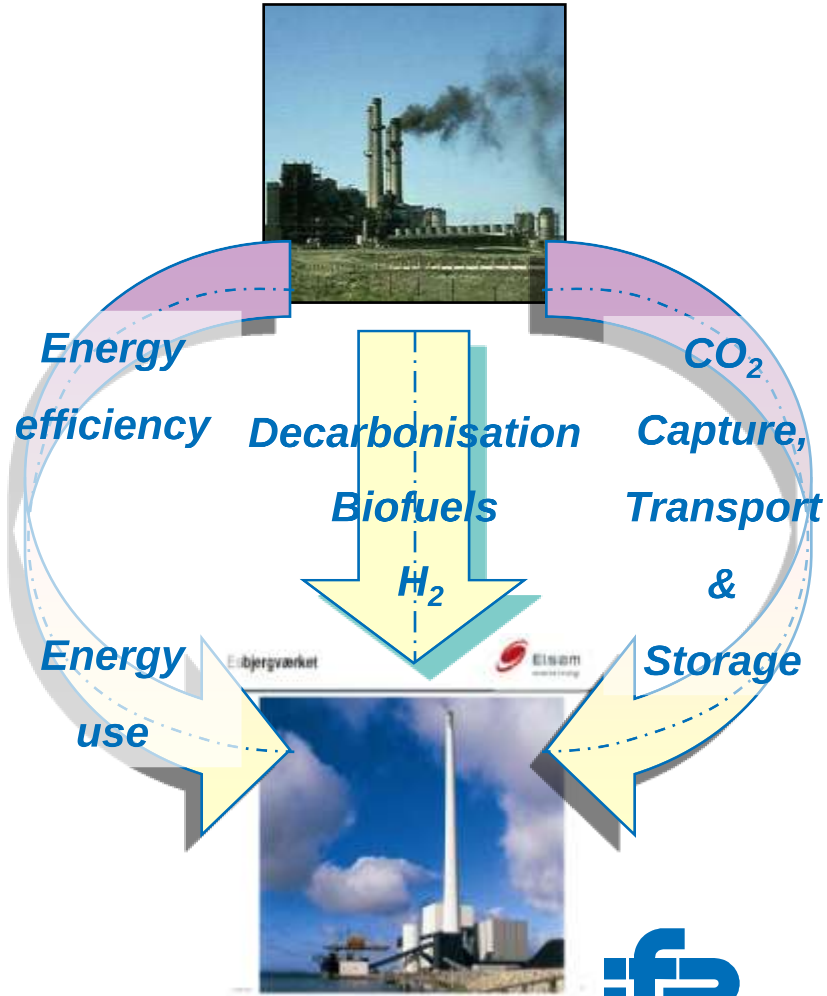
CO2 emissions mitigation is required



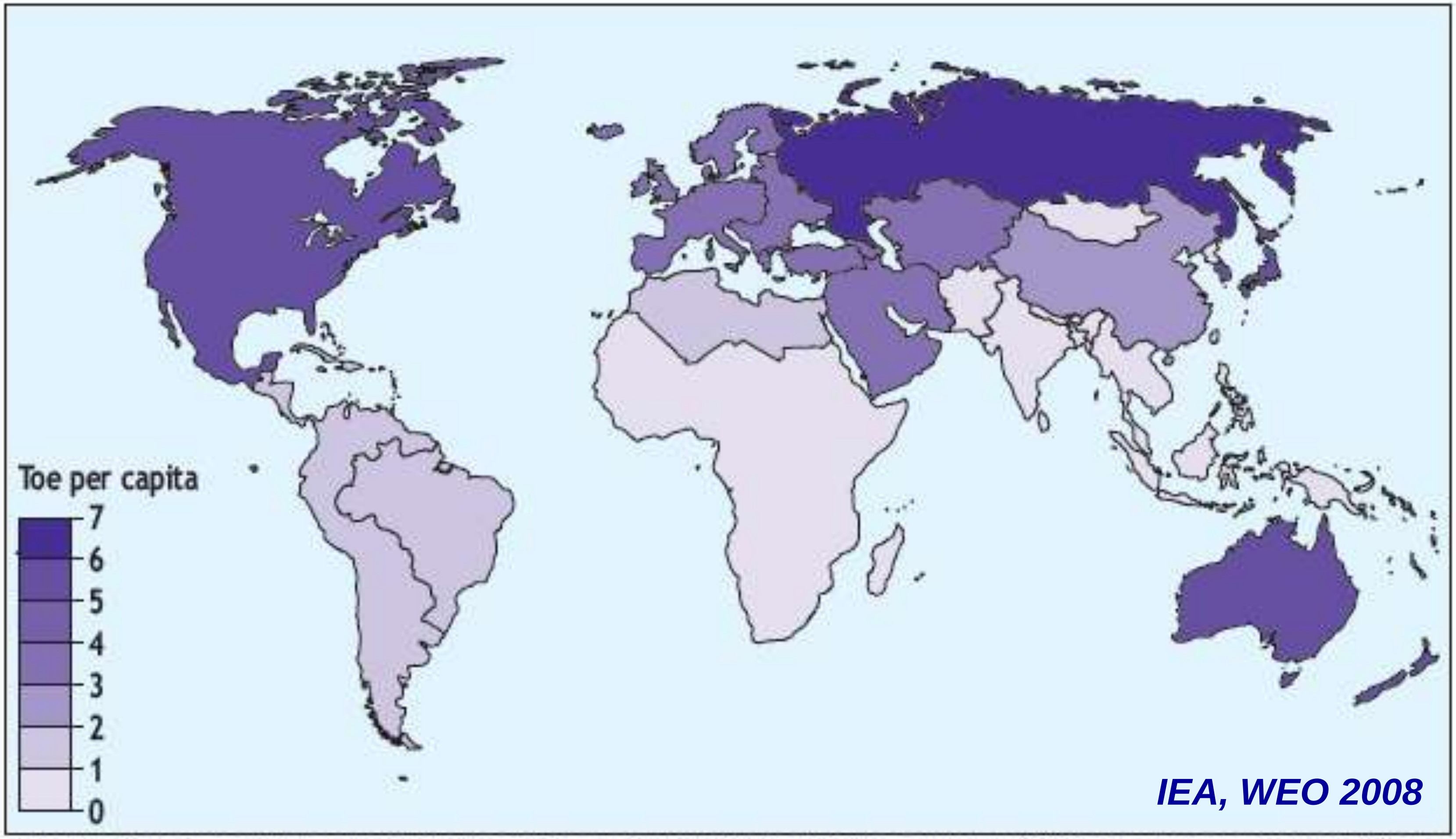
peak of CO2 emissions to limit the temperature increase within 2° C

Reducing CO_2 emissions





Increasing energy efficiency (status in 2030)



The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Outline

- Reducing CO_2 emissions for mitigating global warming
  - CO_2 capture and geological storage
- Storing CO2 in the underground
  - the options
  - a driver for revitalizing mature oil fields
- From CO2 avoidance to CO2 EOR
  - properties, issues
- From CO2 EOR to CO2 storage
  - challenges
- Conclusions

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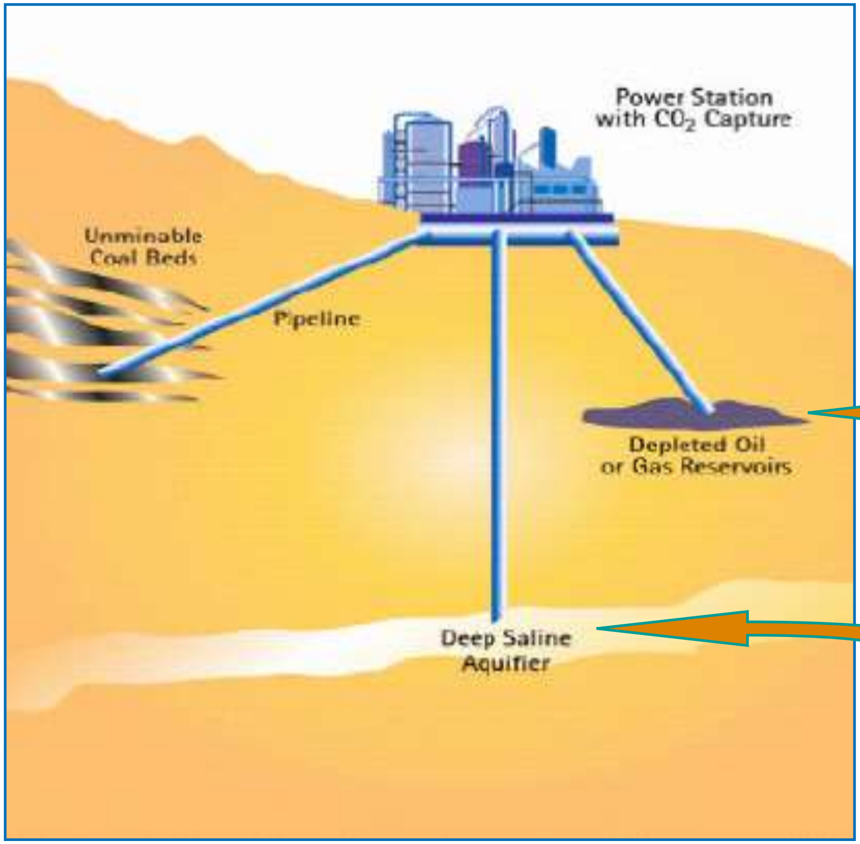
Storing CO_2 in the underground
- the options

*the challenge: 20% of CO_2 abatement - **6.5 $GtCO_2$** - in 2050*

Coal seams

40 Gt CO_2
< 2% of emissions to 2050



CO_2 EOR / EGR

(IEA) 920 Gt CO_2
45% of emissions to 2050

Deep saline aquifers

400 - 10,000 Gt CO_2
20 - 500% of emissions to 2050

source: IEA GHG
Comparative potentials at storage cost of up to US$ 20/tCO_2

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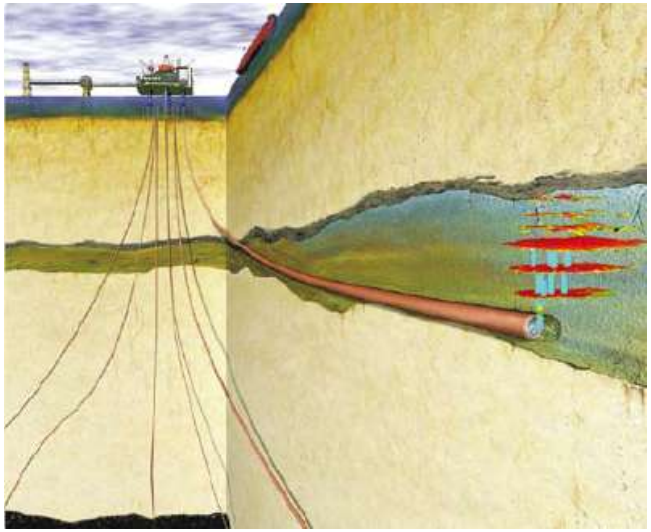
Storage options: advantages / drawbacks

- **Depleted hydrocarbon fields**
  - **Trapping and confined structures**
  - **Well described and secure**
  - **Added value through CO_2 EOR/EGR**
  - **Easier to implement (low hanging fruits): infrastructures**
    - ✓ **easier societal acceptance**
  - Not evenly distributed worldwide
- Unminable coal seams
  - Enhanced production of CBM
  - Limited accessible pore volume and low injectivity
- Saline aquifers
  - Huge storage capacity
  - More evenly distributed
    - ✓ shorter 'source-to-storage' distance
  - Poorly described
  - Check confinement
  - Absence of regulation
  - Economics
  - ***Public acceptance***

Sleipner

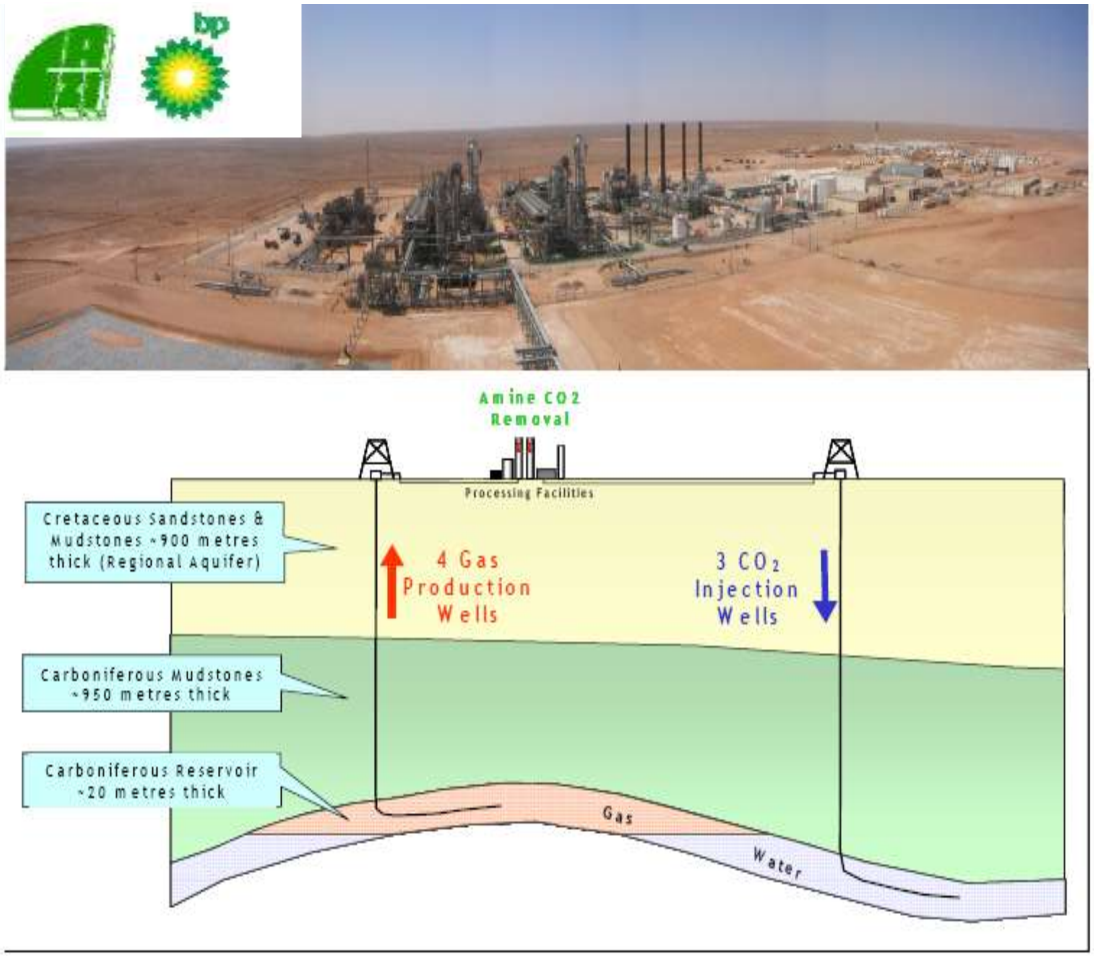
Tax regime : US$ 40/tCO2



- **Capture**
  - amine gas treatment
- **Compression & Reinjection**
  - Utsira formation (saline aquifer): 50-100km wide; 50-250m thick; 1000m below the sea floor
- **Storage**
  - 1MMtCO2 / yr
  - 25 MMtCO2 over 25 years

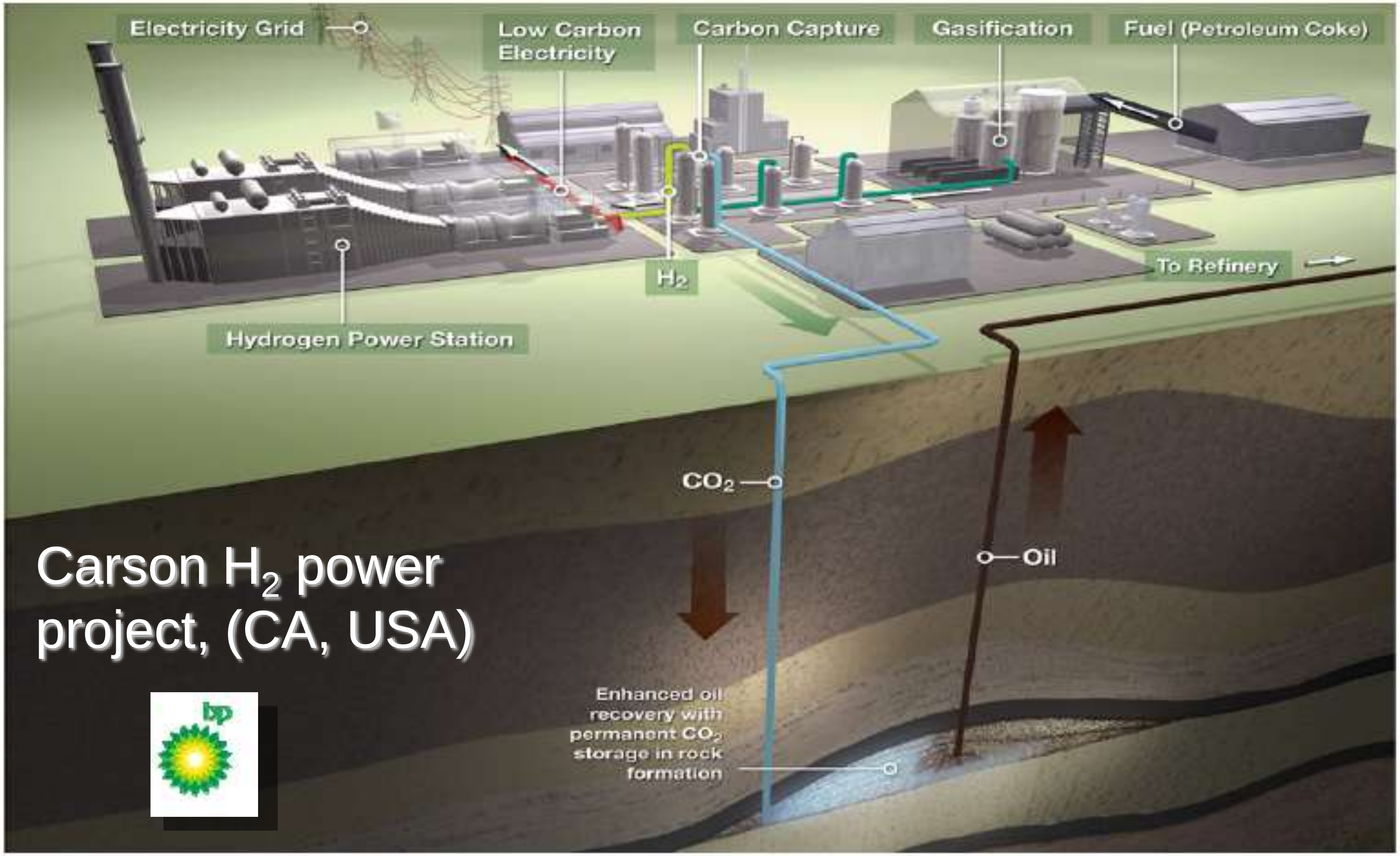
started in 1996

In Salah CO_2 storage operation

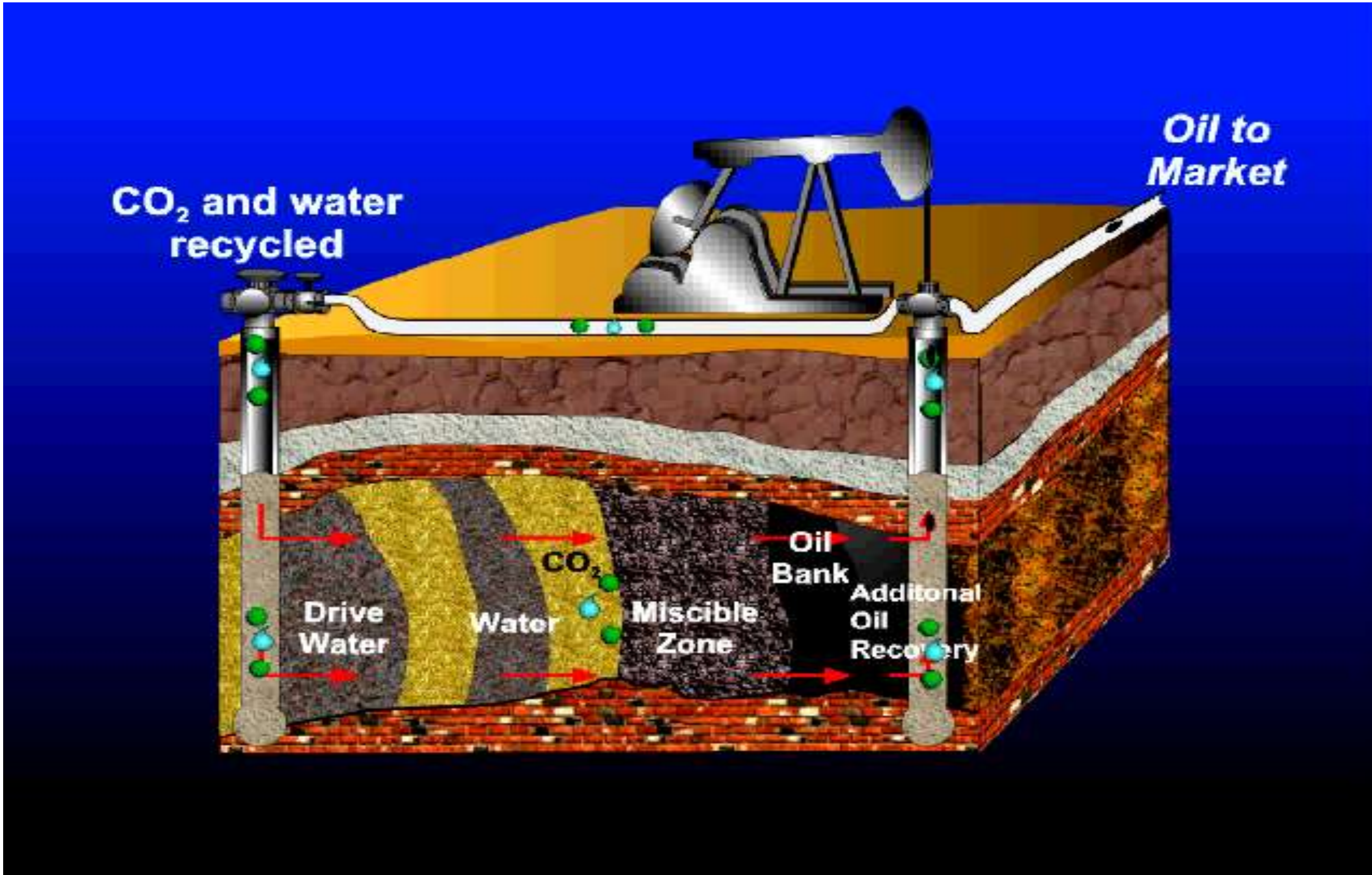


- ✓ Industrial scale demonstration of CO_2 geological storage
- ✓ Started August 2004
- ✓ 1 MM tCO_2 stored p.y.
  - 17 mm tonnes lifetime
- ✓ \$100mm incremental cost (\$6/tCO_2)
  - no commercial benefit
- ✓ Test-bed for CO_2 monitoring technologies

From CO_2 avoidance to CO_2 EOR
- the concept -



CO2 EOR

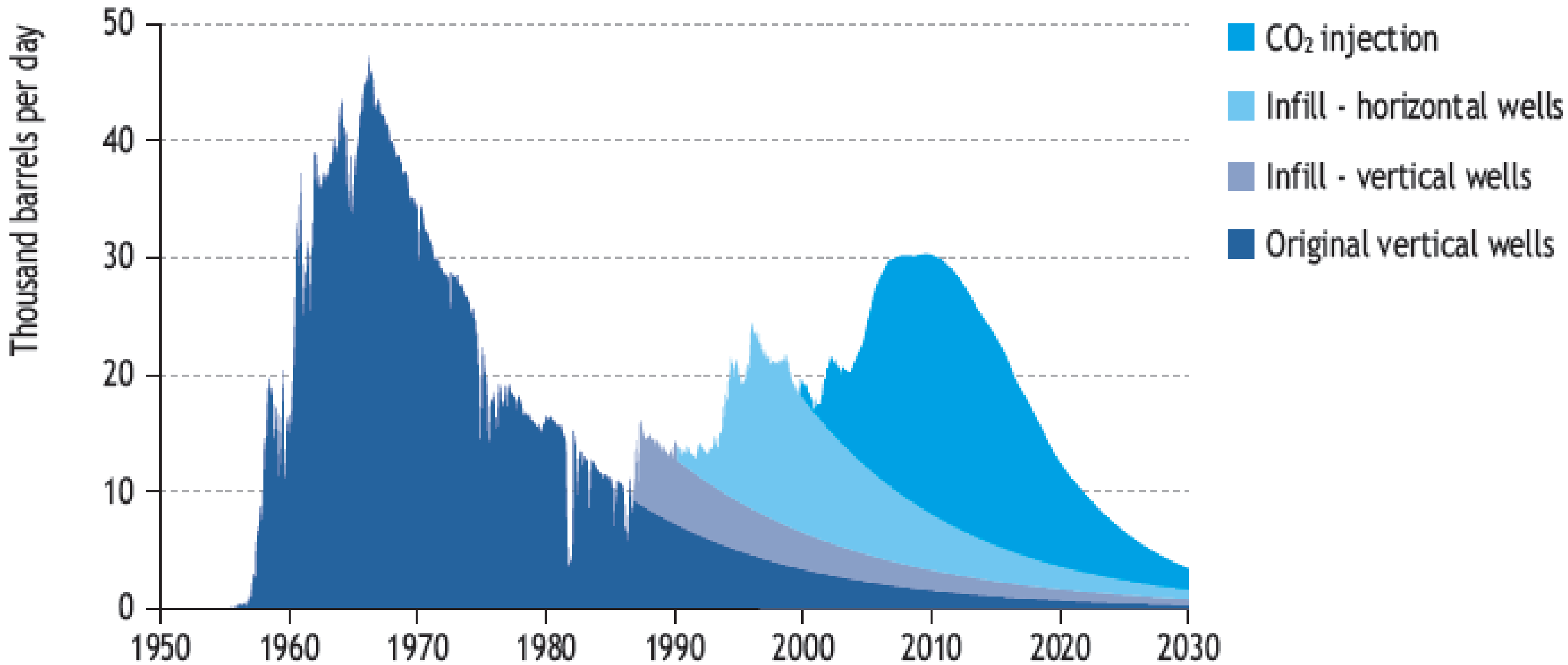


CO_2 and water recycled
Oil to Market
Drive Water
Water
CO_2
Miscible Zone
Oil Bank
Additonal Oil Recovery

Weyburn (Canada)

- **Capture**
  - coal gasification plant located in the US (DGC)
- **Transport**
  - pipeline, over 330 km
- **Storage**
  - 1MMtCO2/yr in a the mature Weyburn field (CO2 EOR)
- *155 MM added barrels*
- *23 MMtCO2 stored while EOR*
- *55 MMtCO2 stored afterwards*

Weyburn: incremental oil through COE EOR



Source: PTRC Weyburn-Midale website (www.ptrc.ca).

CO_2 EOR : a driver for revitalizing mature fields - Properties

- Solvent properties
  - Miscibility from partial to fully developed
  - Very high swelling
  - Viscosity reduction
    - 45 cP Shrader Bluff reservoir oil (14-21 °API) down to 3 cP
    - Production rate increased (doubled for SB reservoir)
- Density of a liquid
  - minor gravity override
- Utility ratio
  - 5 to 10 MCF per STB

Additional recoveries (%OOIP) as a function of the volume of injected CO2 (%HCPV) for a set of onshore fields

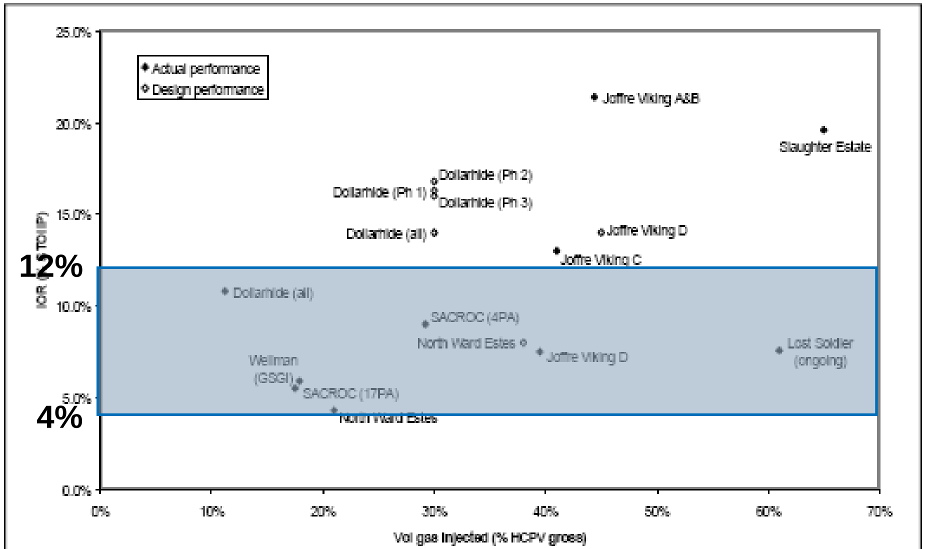


Figure 1: IOR vs. gross gas volume injected for onshore tertiary CO2 projects

4 to 12% OOIP additional recovery in tertiary conditions (Goodyear et al.)

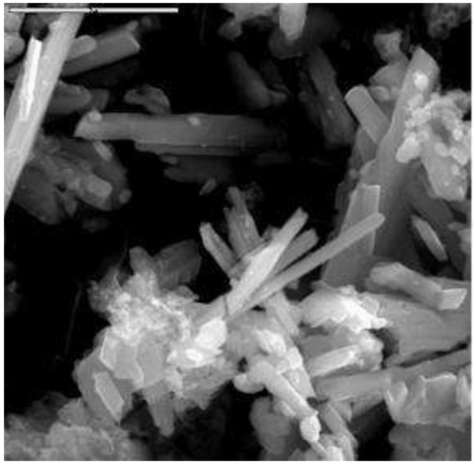
From CO_2 EOR to CO_2 storage

Storing CO_2 in a mature oil field

- CO_2 EOR and CO_2 storage issues are quite different
  - CO_2 EOR : requires to minimize the amount of injected CO_2 and maximize the production of oil
  - CO_2 storage maximizes the volume of CO_2
  - Cap rock integrity, overburden matters for CO_2 storage
  - Time frames are different, long term issues for CO_2 storage
    - cap rock and well integrity
    - physico-chemical effects to be accounted for
- CO_2 injection strategies have to be adapted
  - well architecture
  - injectivity
  - ...

CO_2 EOR
- some challenges

- **Complex phase behavior**
  - coexistence of up to 5 phases
  - hydrate formation
  - asphaltene destabilization
- **Acid behavior**
  - corrosion
  - dissolution-reprecipitation
    - anhydrite formation
    - fracture sealing/opening
    - permeability, injectivity
  - geomechanical effects
- **Low viscosity**
  - low volume sweep efficiency
  - impact of heterogeneities
  - Combined water and CO_2 injection
    - WAG, SWAG



Anhydrite precipitation

Calcite dissolution

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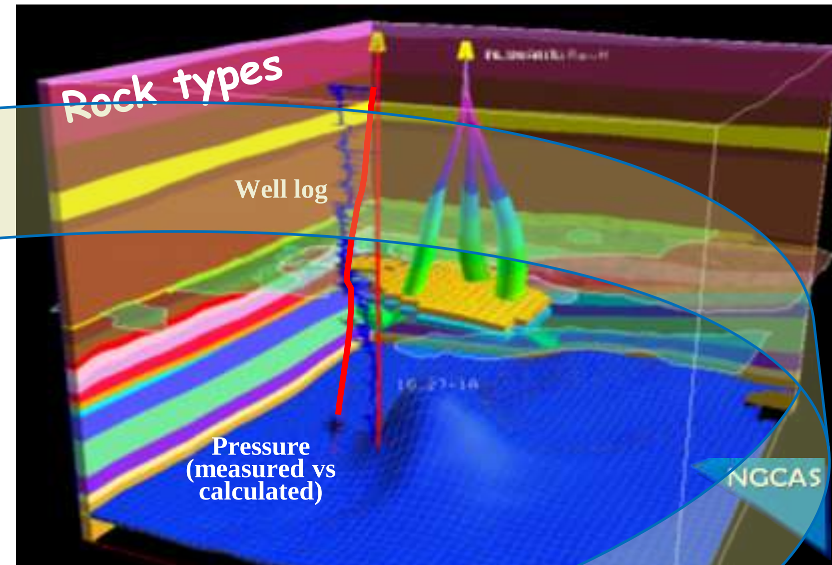
From CO_2 EOR to CO_2 storage
Modeling issues: the different scales

From basin ...

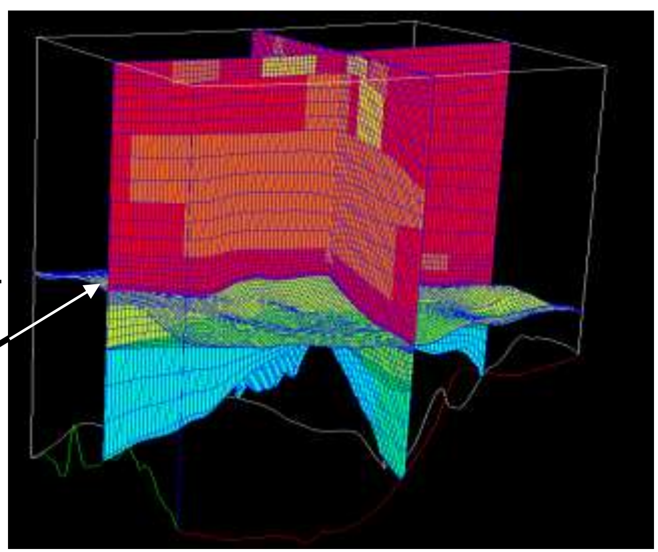


... to reservoir

0 m

2125 m

Reservoir seal



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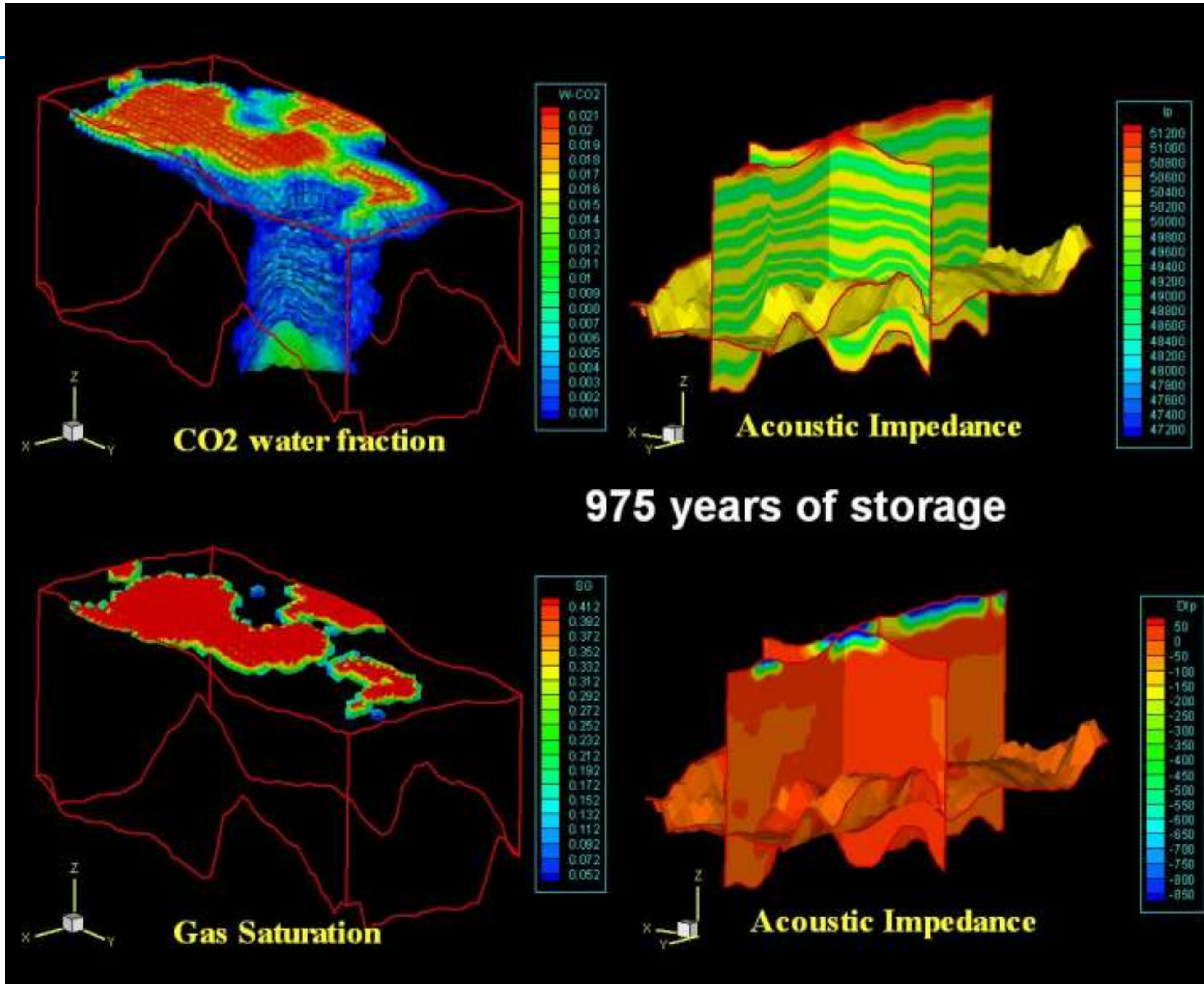
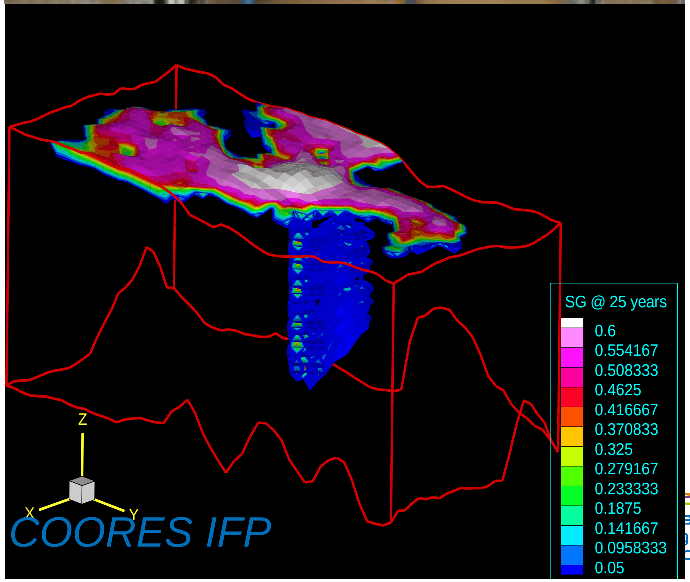
COORES Model (IFP) - Sleipner



Technical challenges for storage

- Technologies for well completions
  - New formulations for cements
  - Tests on long-term behaviour of materials (steels, cements)
  - Specific study of interfaces
- Predictive modelling of storage
  - from well scale to basin scale
  - multiphase fluid flow, transfers, coupling with geochemistry and geomechanics, thermodynamics
- Monitoring & Surveillance
  - Seismic tracking of the injected CO_2
  - Leakage detection
- Risk assessment


Ageing cell for acid gas environment



Some close industrial partners of IFP

Prosernat: subsidiary, 100% IFP

CO2 capture

Geogreen: spin-off, 40% IFP

CO2 Transport & Storage

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Conclusions (1/2)

- **Mitigation strategies have to be urgently deployed**
- **CO_2 capture and geological storage (CCS)** can account for 20% of the CO_2 abatement strategies
- **Near term opportunities**, economic factors, public acceptance call for studying carefully the **storing of CO_2 in mature hydrocarbon reservoirs**
- **CCS represents thus a huge driver for CO_2 EOR** why may raise the recovery factor by 4 to 12% OOIP
- **Optimizing both CO_2 EOR and CO_2 storage** requires to honor different constraints; it demands adapted infrastructures and injection strategies

Conclusions (2/2)

- Optimizing CO_2 EOR, addressing short term economy as well as long term storage integrity requires pursuing **innovation** (characterization, monitoring, modeling)
- **International cooperation** between companies and research centers is needed to inspire, challenge and validate new technologies
- **The IFP group** is focused, develops advanced and highly efficient tools and contributes to build capacity. It is ready to cooperate with industrial partners **to bring solutions to global climate change** and convert CO2 constraints into opportunities for rejuvenating mature hydrocarbon fields

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