CO_2 Geological Storage: Principles and Application to Field Projects

Scott W. Imbus / Susann B. Nordrum
Chevron Energy Technology Co.
Sugar Land, Texas / Richmond, California USA

Arthur Lee
Chevron Corporation
San Ramon, California USA

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Presentation Outline

- Introduction
  - Climate Change Science
  - Magnitude of Mitigation
  - CO_2 Capture, Transportation and Geologic Storage*
- CO_2 Geologic Storage
  - Venues & Capacity
  - Technology
- Geologic Storage Projects
  - Commercial
  - Planned (Gorgon)
- Outlook for CO_2 Capture and Storage
- For Further Information…

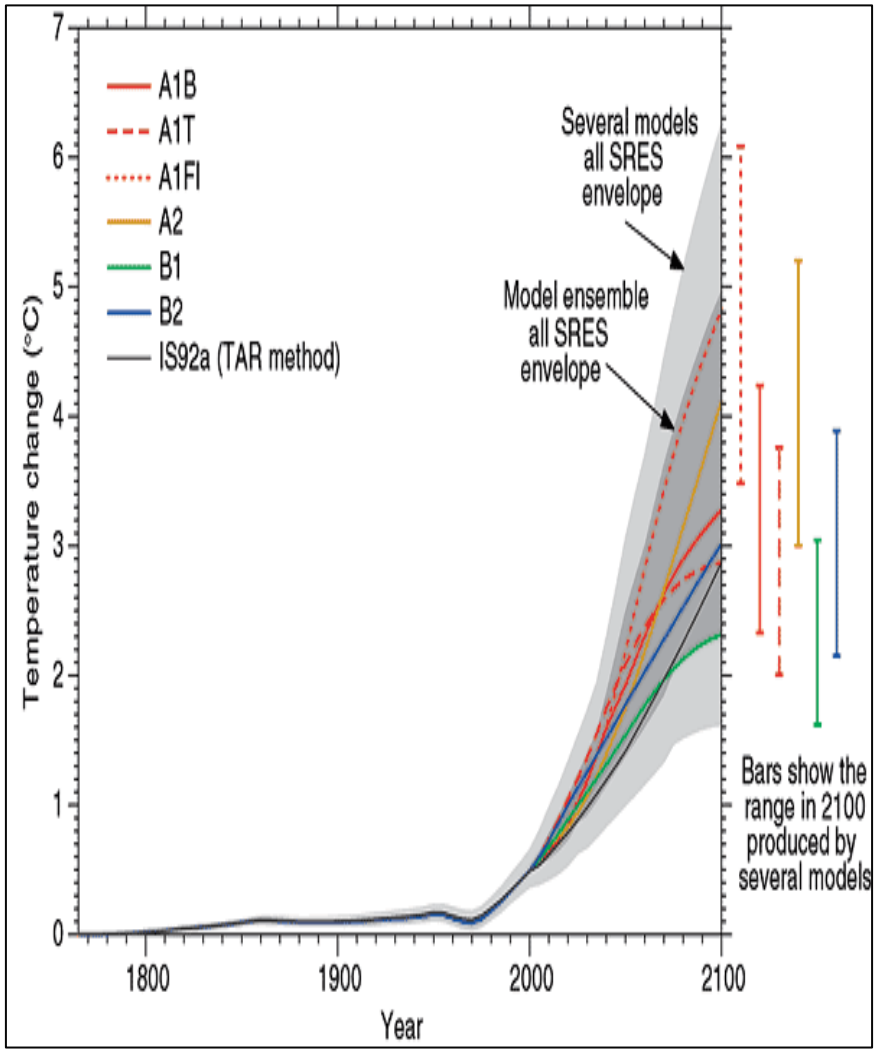
*Nomenclature: CO_2 Sequestration = CO_2 Capture, Transportation and Storage

Introduction – Climate Change Science

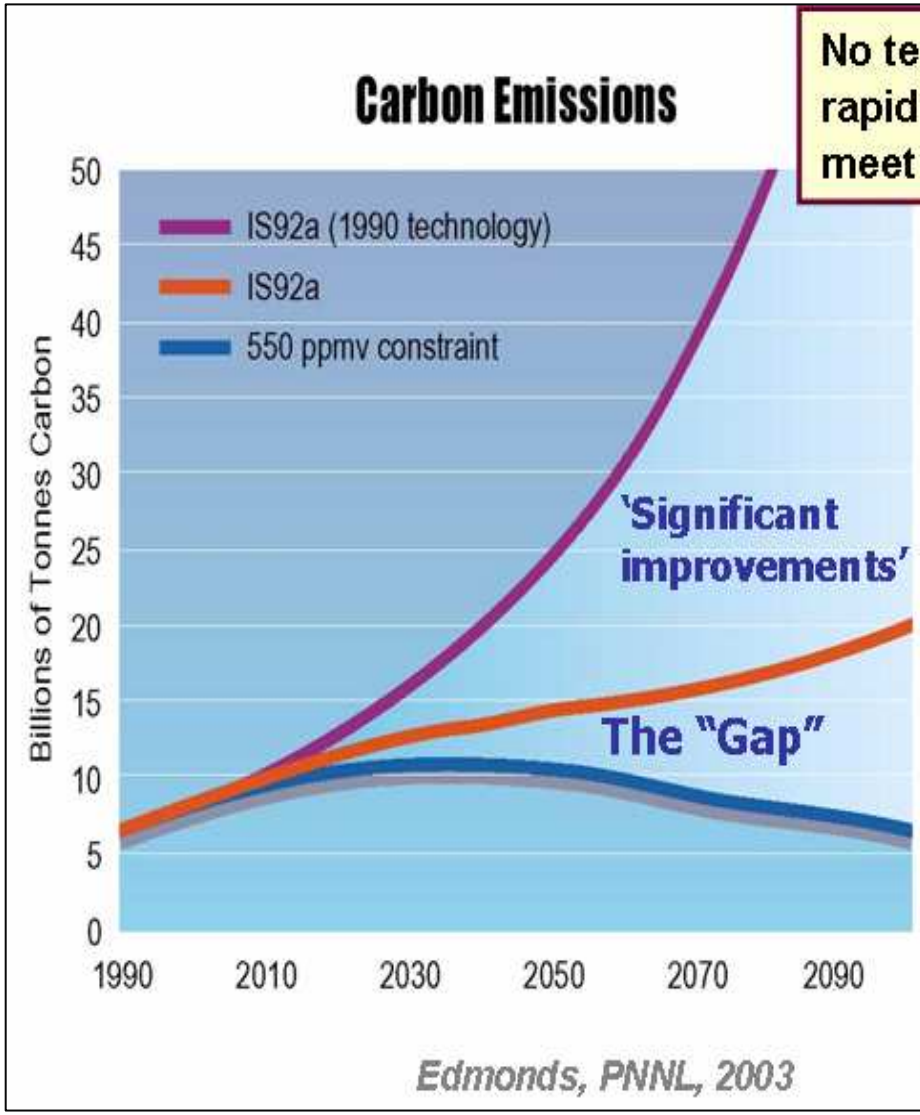
Inter-governmental Panel on Climate Change (IPCC) - Third Assessment Report [TAR] (2001) Scenario Projections for 2100:

- 500-900 ppm atm. CO_2*
- +1.6-6.2°C Temp. Incr.
- 0.2-0.7m Sea level Rise
- Extreme weather patterns / events; extinctions & habitat changes; etc.

* Pre-Industrial ~280ppm; Present ~380ppm (+1.5/yr.)



Introduction – Magnitude of Mitigation



No technology improvement – rapid growth in GHG levels to meet development needs

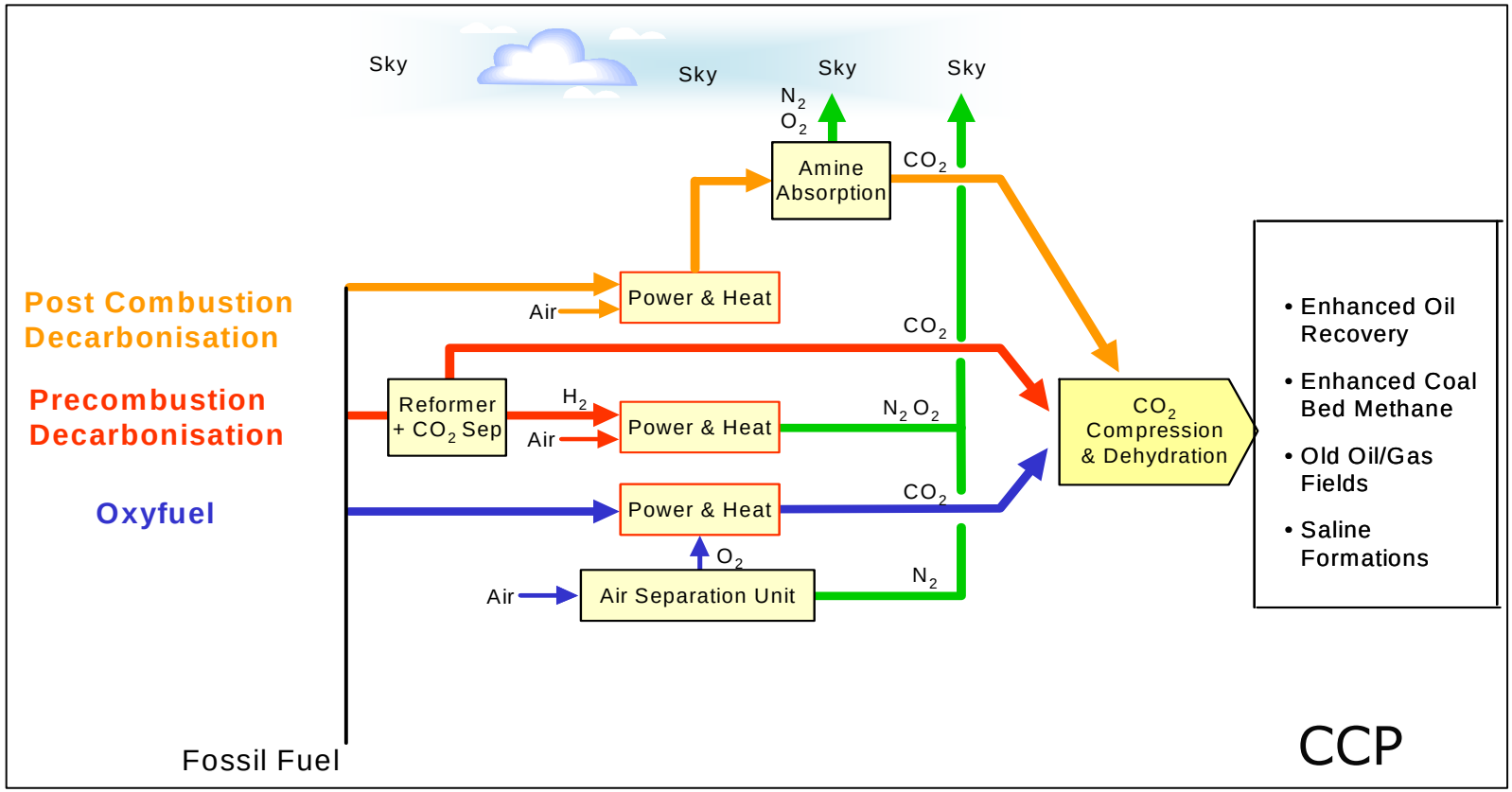
With significant technology improvement, development still drives GHG levels up.

- Fossil fuels improvements
  - Energy intensity
  - Nuclear
  - Renewables

New technologies will be needed if stabilization is desired.

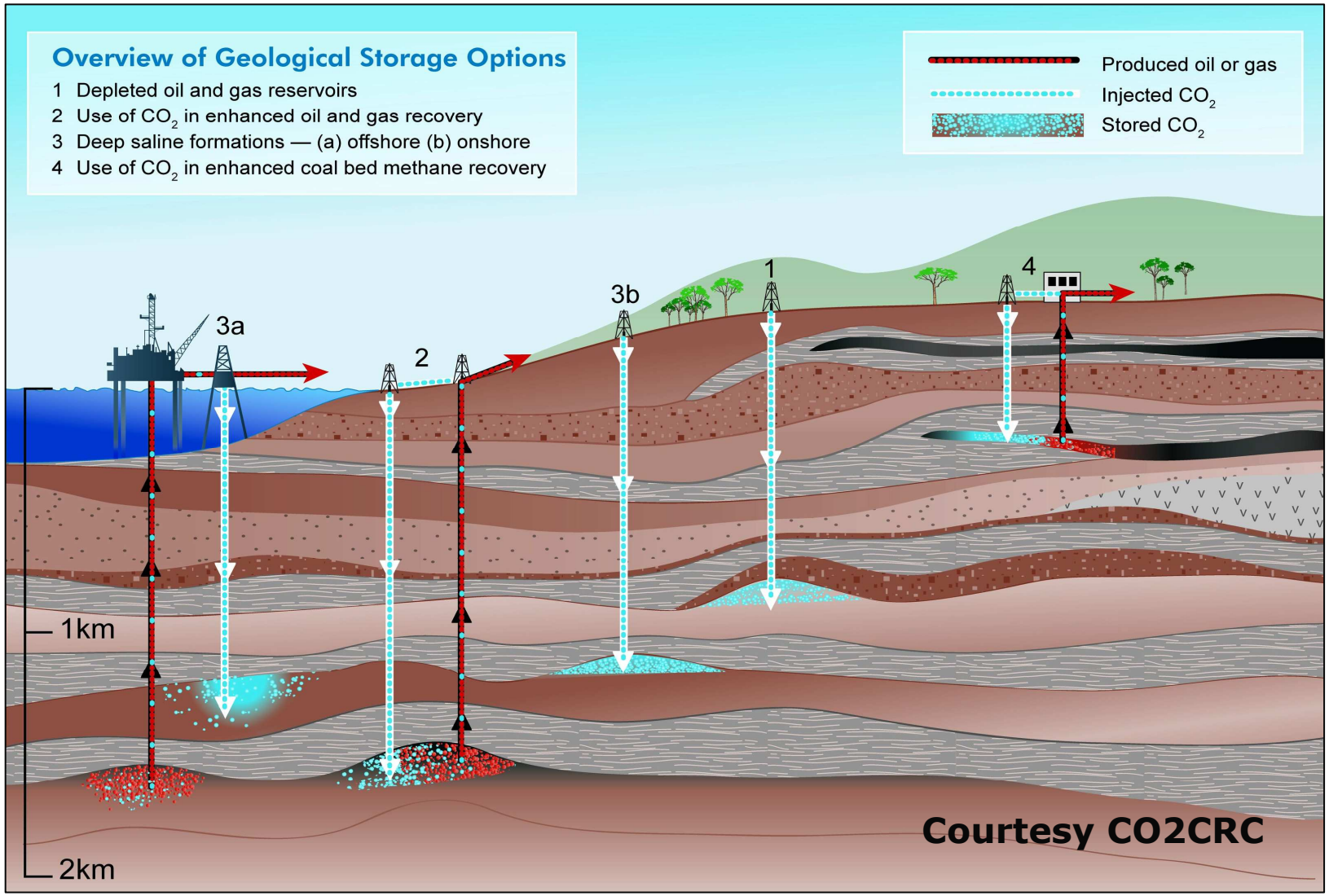
- H2 and Adv. Transportation
- Biotechnologies (Soils, Bioenergy)
- Carbon capture & disposal

Introduction – CO_2 Capture and Storage (CCS)



- "Low hanging fruit" includes gas processing, chemical & H_2 plants
- Post-combustion, pre-combustion and oxy-firing (in order of present technical development) projected at US$40-60/tonne CO_2
- Costs vary considerably based on transport distance and compression needs

Geologic CO_2 Storage – Venue Types



CO_2 Storage – Capacity & Feasibility

Major Storage Venues	Capacity ($GtCO_2$)*	Major Issues
Natural & Enhanced Sinks		
▪ Oceans	Huge	Politically Infeasible
▪ Forests	?	Permanence, Accounting
▪ Soil Mgmt.	?	Permanence, Accounting
▪ Mineral Reactions	?	Kinetics, Materials
Geological Storage**		
▪ Depleted O&G Fields	450	Well Leakage; Phase Interactions
▪ Coal Beds	60-150	Complexity, Injectivity
▪ Saline Formations	300-10000	Characterization, Closure?

Perspective

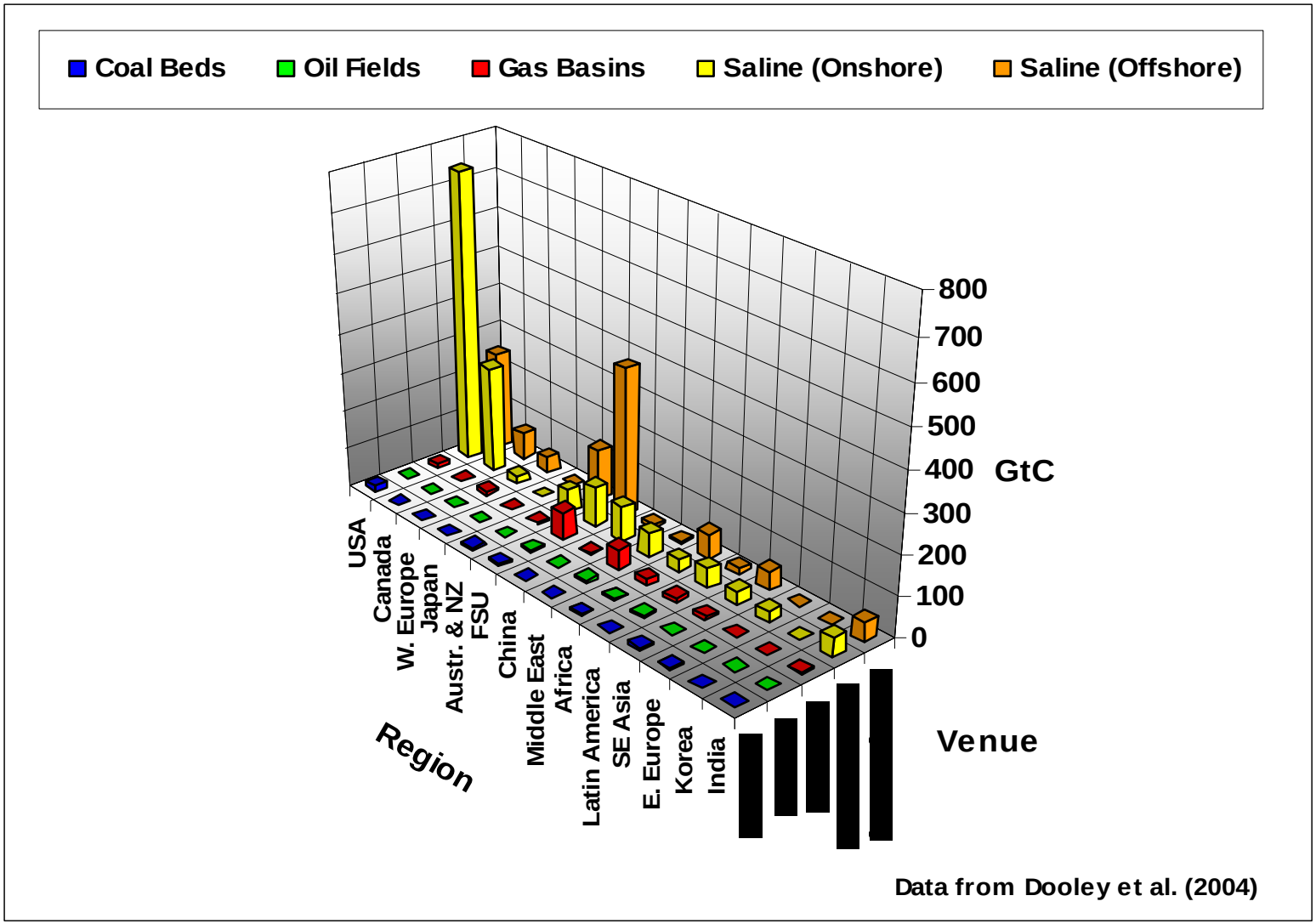
- UN IPCC SRCCS – at least 2,000 $GtCO_2$ potential "likely" (66-99% CI) for geologic storage

- 25 $GtCO_2$PA presently emitted globally

- 0.02 $GtCO_2$PA injected into 50 W. TX fields for EOR (n.b., recycle)

Data from Stevens et al. 1999, 2001; IEA GHG R&D Program

Geologic CO_2 Storage – Distribution of Venues



Geologic CO_2 Storage – Status of Technology (CO_2 Capture Project [CCP])

System Integrity

- Geologic
- Engineered (Wells)

Optimization

- HC fluid interactions
- Injection Strategies
- Reservoir Simulation

Monitoring

- Imaging
- Leakage to Surface

Risk Assessment

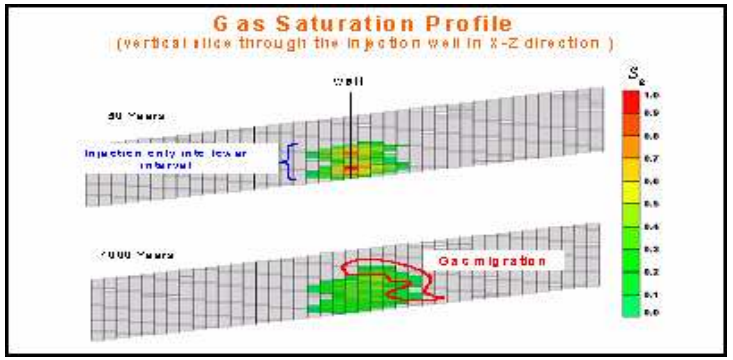
- Methodologies
- Communication

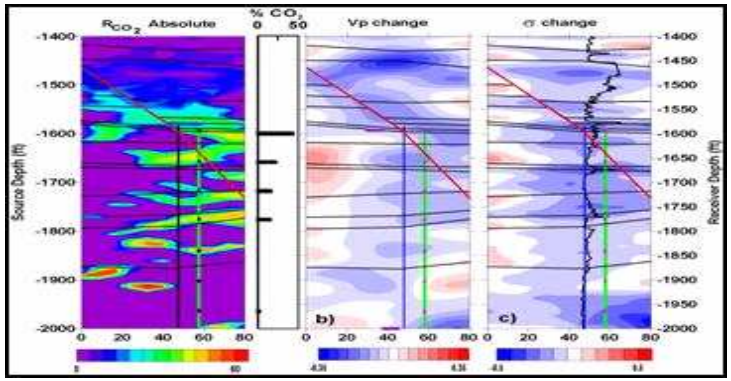
Readiness:

Advanced/**Adequate**/**Needs Attention**

Crystal Geyser Utah (Utah St U)

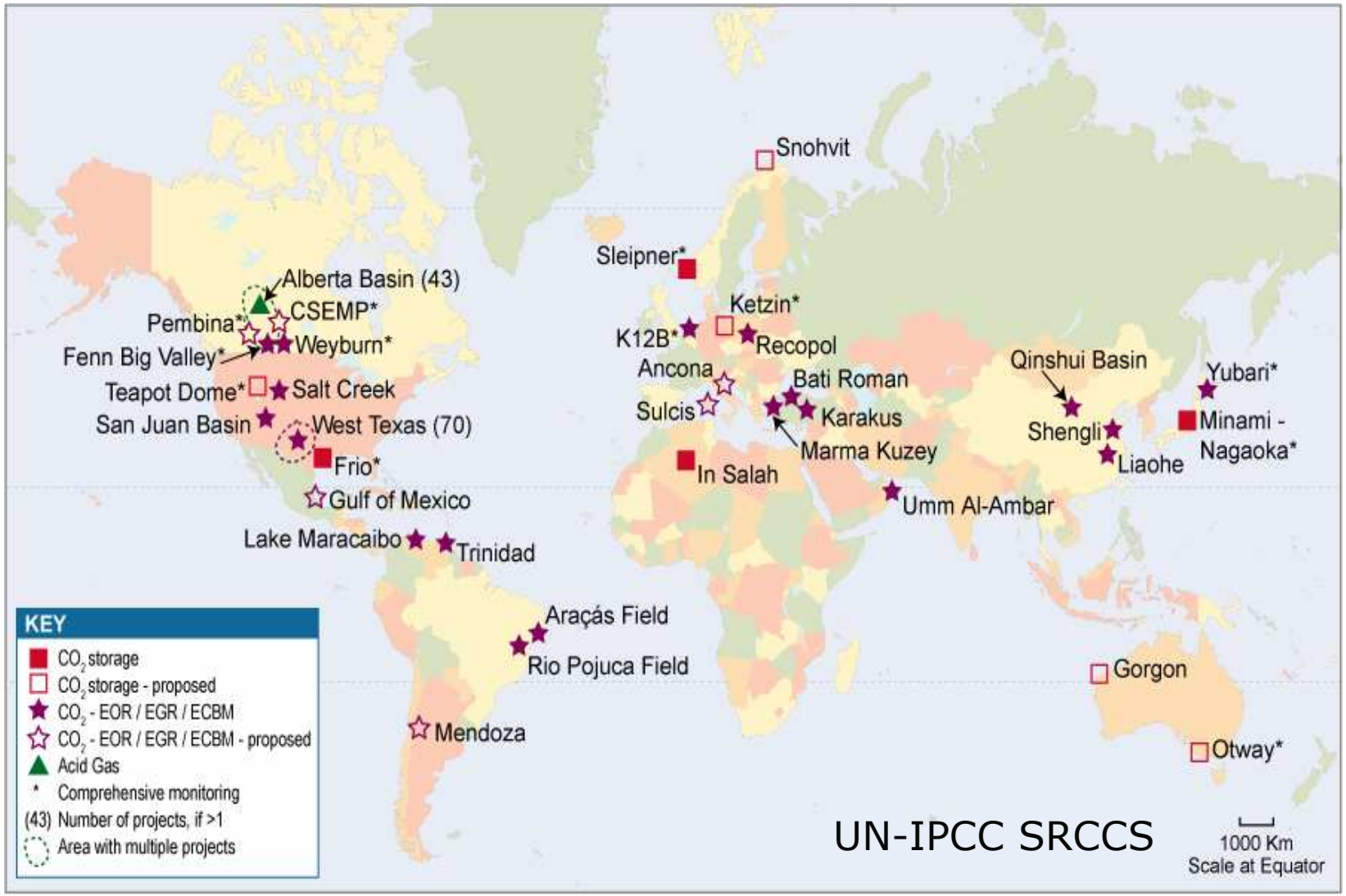
Injection Simulation (U Texas)





Sub-Surface Imaging (LBNL)

Geologic CO_2 Storage – Commercial Projects (Operating and Planned by Type)



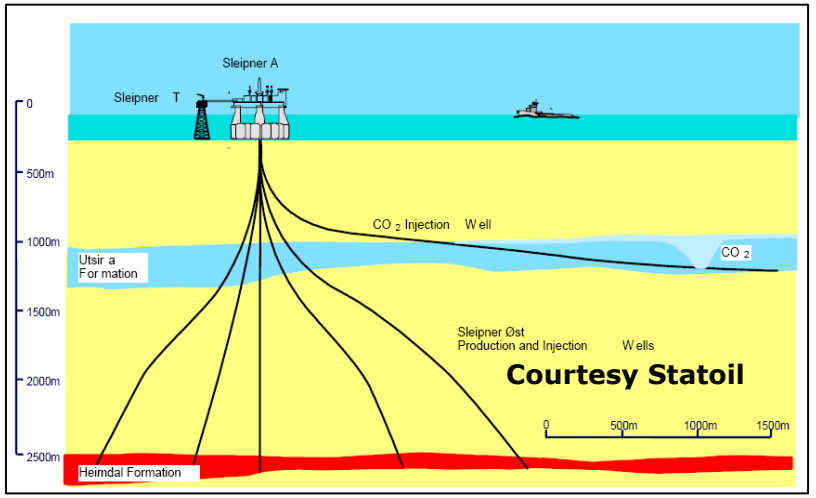
Commercial Projects – Sleipner (Nor. North Sea)

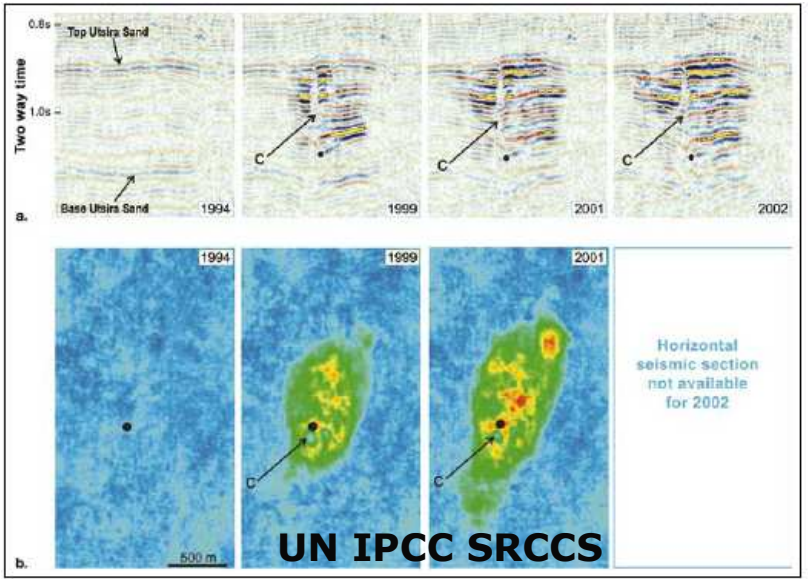
First "Commercial" Purpose – Built CO_2 Storage Project

Operated by Statoil with injection of ~ 1MtCO_2PA since 1996

- Avoid Norwegian (first) carbon tax
- Offshore processing of 9% CO_2 Sleipner Gas (sales) via amine separation
- Utsira saline formation very high permeability, unconsolidated

Repeat 3D seismic shows "no" leakage





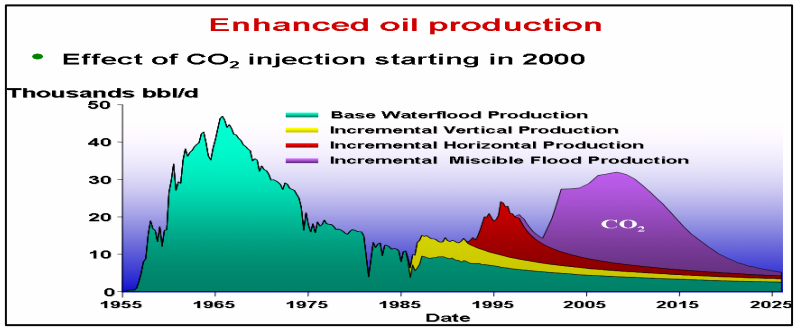
Commercial Projects – Weyburn (SK, Canada)

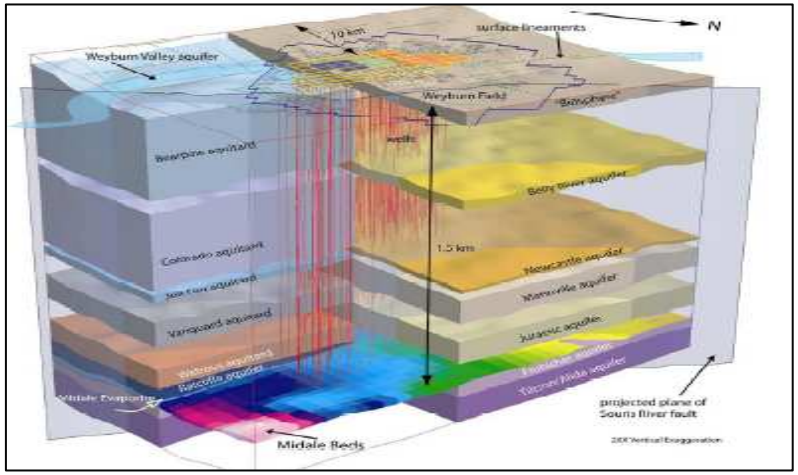
CO_2 EOR-"Storage" Project

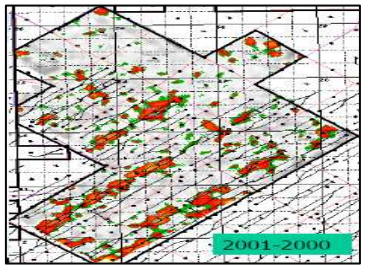
- Operated by EnCana since 2001 to revitalize 50 yr. old field
- > 1.5 $MtCO_2PA$ injected into carbonate reservoir
- Anthropogenic source (lignite gasification in N.D.)

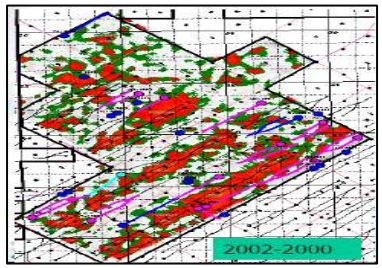
Extensive R&D Program (JIP)

- Geologic Modeling
- Repeat Seismic
- Reservoir Simulation
- Geochemistry
- Risk Assessment









IEA Weyburn

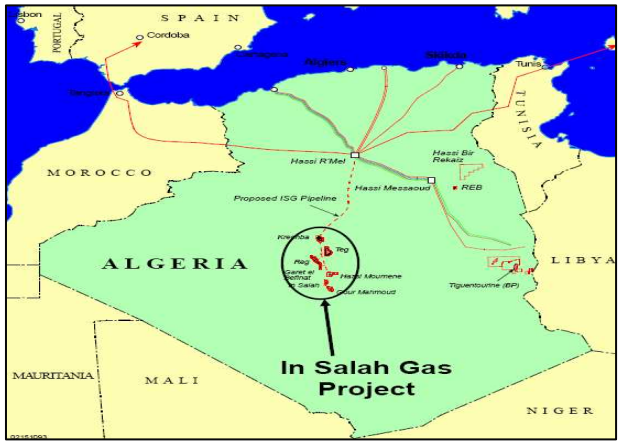
Commercial Projects – In Salah (C. Algeria)

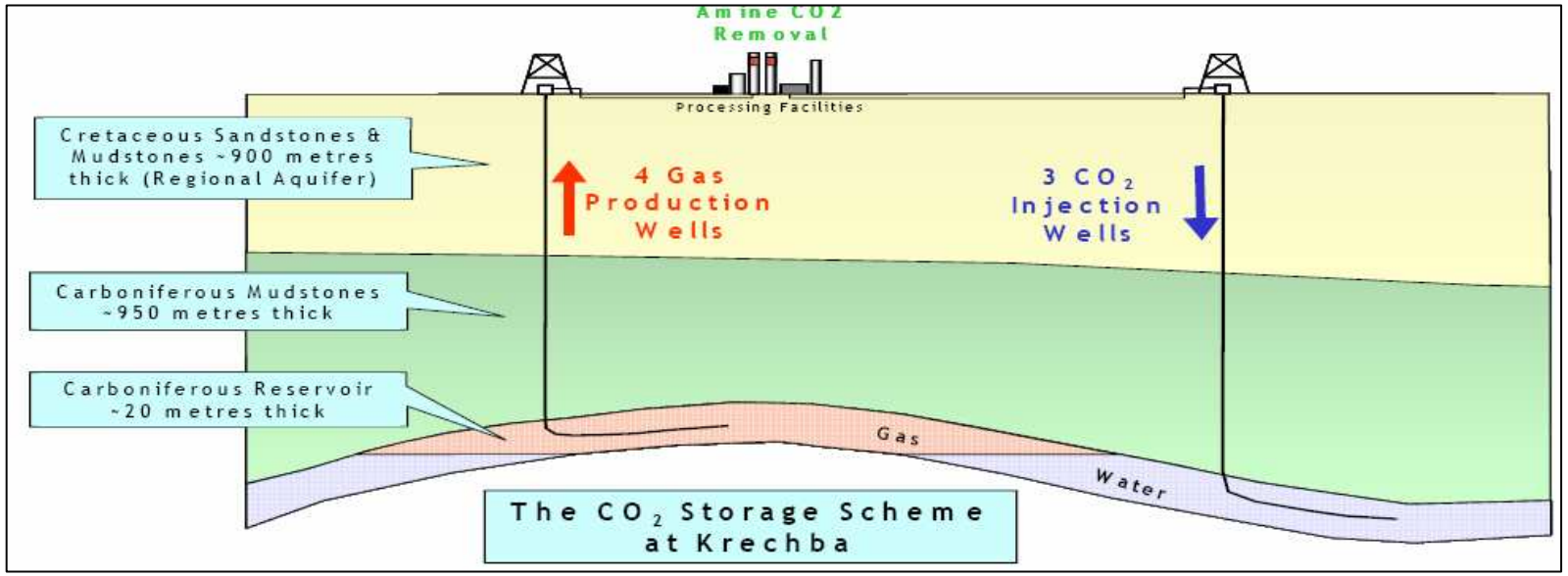
Operated by BP (w/ Statoil & Sonatrach) since 2004

Process Gas for Export (9% CO_2)

1 $MtCO_2PA$ into water leg of gas reservoir (Cumm. ~17$MtCO_2$)

EU-Funded "Assurance" JIP





Courtesy BP, Sonatrach & Statoil

Commercial Projects (Planned) – Gorgon (NW Australia)

Process Gas (14% CO_2) for LNG

Operated by Chevron

- 25% ExxonMobil / 25% Shell
- Co-development of Jansz

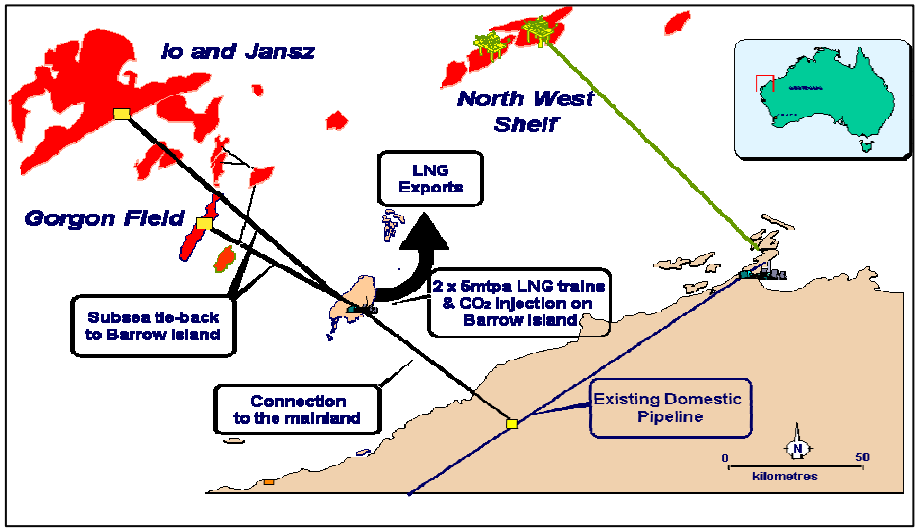
First gas with CO_2 separation & injection in 2010 if "technically and economically feasible"

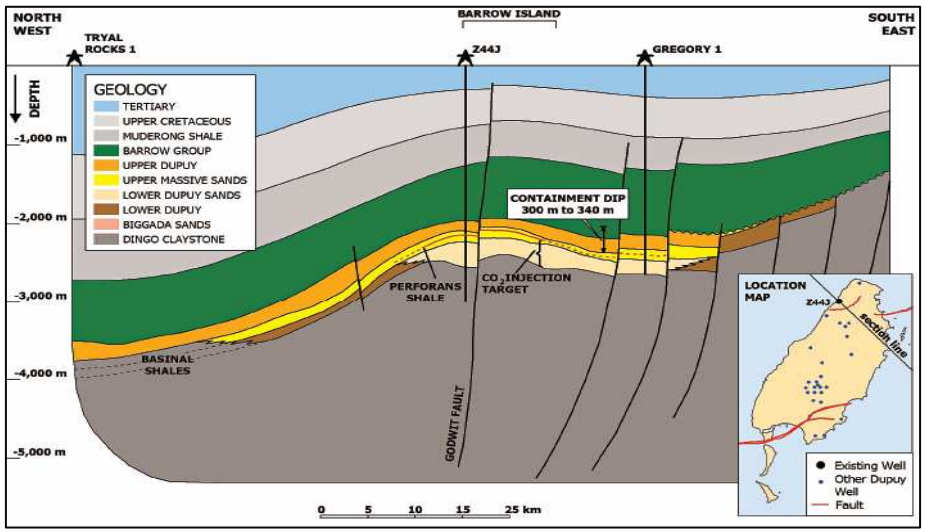
Dupuy Saline Formation Target

- "Optimal" site in region
- Onshore Barrow Island (Class A Nature Reserve)
- Overburden includes thick saline formation and regional seals

GHG Reductions

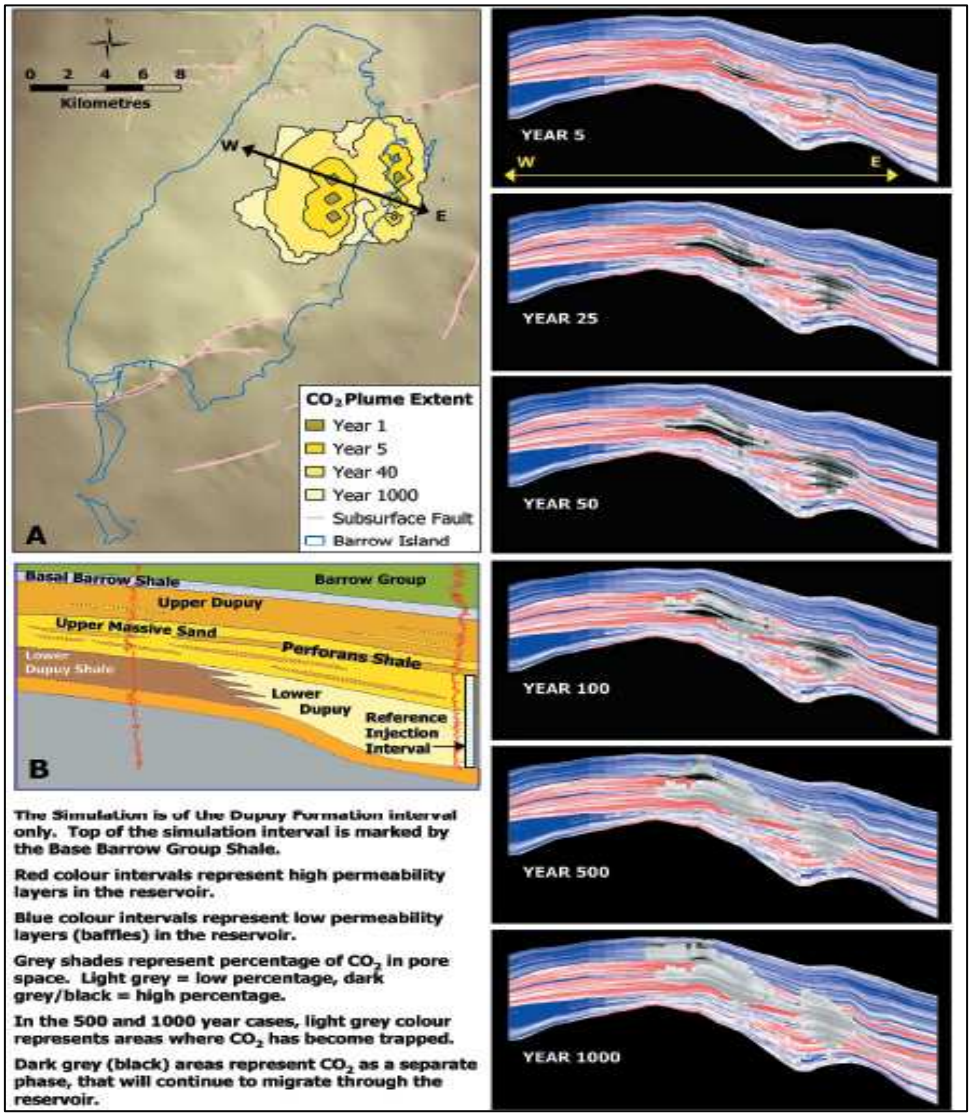
- Process efficiencies
- ~2.7 $MtCO_2PA$ (cumm. ~130)





Commercial Projects (Planned) – Gorgon (NW Australia) – cont.

- Development Plan – 7 injectors from 2 centers
- Permeability Distribution Prevents Rapid Vertical Migration
- Pressure Field Peaks at ~30 yr.
- Major Mechanisms Likely to Immobilize Most CO_2 Within 1000 yr.
- Aerial Extent of Plume Increases Slowly After 40 yr. (Operational Phase)
- Comprehensive Environmental Impact Statement (EIS) / Environmental Review & Management Plan (ERMP) posted at www.gorgon.com.au



Security of CO_2 Storage

O&G Industry has Decades Long Experience in Processing, Transporting & Injecting Gases

Multiple Trapping Mechanisms

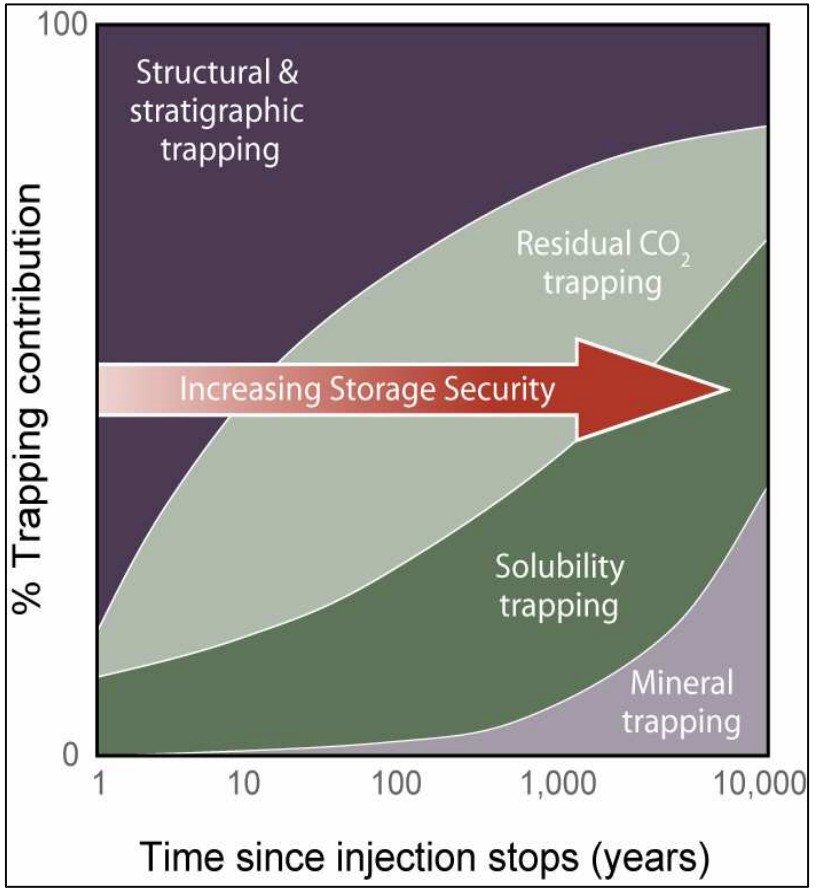
Injection Strategies

UN-IPCC SRCCS Consensus:

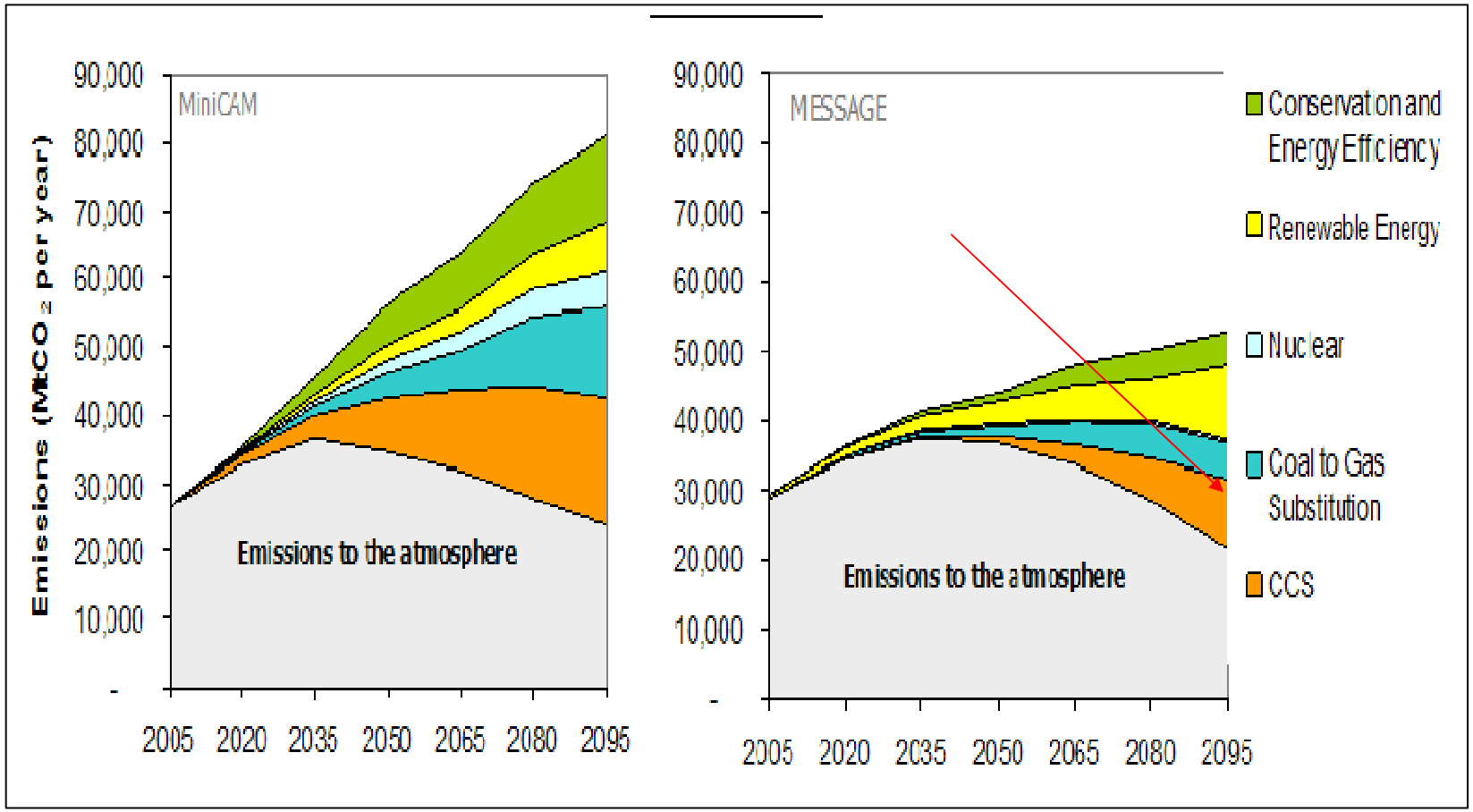
- "Very likely" (90-99% CI) to exceed 99% over 100 yr.
- "Likely" (66-90% CI to exceed 99% over 1000 yr.

Intervention Options Available

Challenges: Well Integrity, Certification and Communication



CCS Role in GHG Mitigation

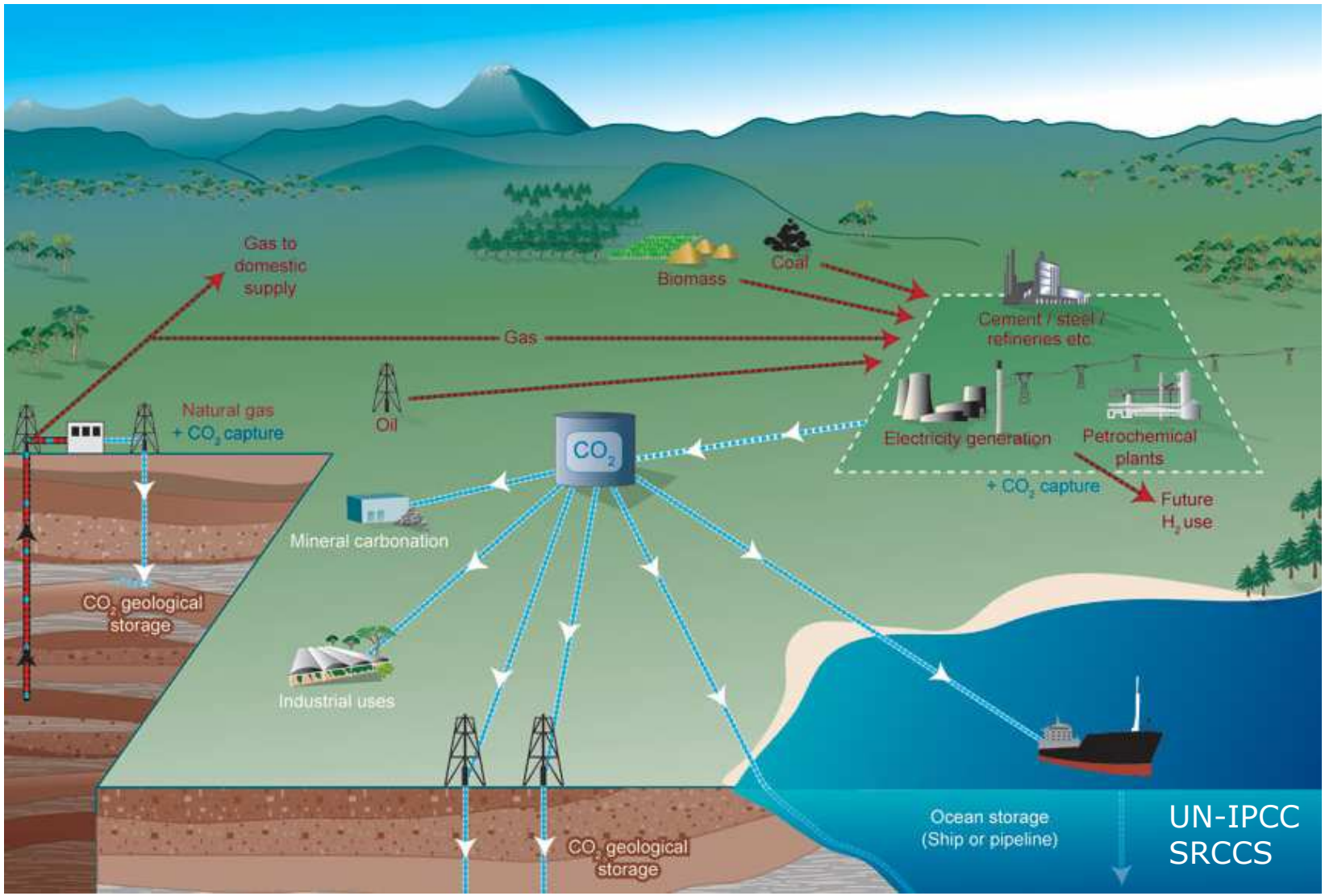


UN-IPCC SRCCS

Existing & Planned "Commercial" CCS Projects

Project	Operator	Date	Location	Source	Sink	MTPA	Sum
Sleipner	Statoil	1996	Nor. North Sea	Gas Proc. (Sales)	Sal. Fm.	1.0	1.0
Weyburn	EnCana	2001	Canada (SK)	Power (Coal)	EOR	2.0	3.0
In Salah	BP	2004	C. Algeria	Gas Proc. (Sales)	Sal. Fm.	1.0	4.0
Snohvit	Statoil	2007	Nor. Barents Sea	Gas Proc. (LNG)	Sal. Fm.	0.8	4.8
Gorgon	Chevron	2010	Australia	Gas Proc. (LNG)	Sal. Fm.	3.0	7.8
White Tiger-1	MHI	2010	Vietnam	Power (Gas)	EOR	3.0	10.8
Miller	BP	2011	UK North Sea	Refining (H2)	EOR	1.3	12.1
Tangguh	BP	2011	Indonesia	Gas Proc.	Sal. Fm.	2.0	14.1
Edison	BP	2011	USA (CA)	Power (Petcoke)	EOR	4.0	18.1
Tjeldbergodden	Statoil	2011	Nor. North Sea	Power (Gas)	EOR	2.5	20.6
"Germany"	RWE	2014	Germany	Power (Coal)	TBA	2.5	23.1
White Tiger-2	MHI	2014	Vietnam	Power (Gas)	EOR	4.0	27.1
LVSCA-1	Anglo	2015	Australia	Power (Coal)	Sal. Fm./EOR	15.0	42.1
"UK"	RWE	2016	UK	Power (Coal)	TBA	5.0	47.1
LVSCA-2	Anglo	2022	Australia	Power (Coal)	Sal. Fm./EOR	0.0	47.1
LVSCA-3	Anglo	2030	Australia	Power (Coal)	Sal. Fm./EOR	5.0	52.1

Future, De-Carbonized Energy Concept



Thank You

For Further Information…

Inter-Government Organizations

- United Nations Intergovernmental Panel on Climate Change (UN-IPCC): www.ipcc.ch
  - Third Assessment Report (TAR) (2001) – Climate Change
  - Special Report on Carbon Dioxide Capture & Storage (SRCCS) (2005)
- Carbon Sequestration Leadership Forum (CSLF): www.cslforum.org

Industry Organizations

- International Energy Agency – Greenhouse Gas Program (IEA-GHG): www.ieagreen.org.uk
- International Petroleum Industry Environmental Environmental Conservation Association (IPIECA) www.ipieca.org