Risks, legal issues and public perception

Wolf Heidug

Shell International E&P

WMO

UNEP

Capture and transport

Risks proportional to the magnitude of potential hazard and probability that these hazards will occur

Capture: regular health, safety, environment risks in industrial operations – no fundamental challenges

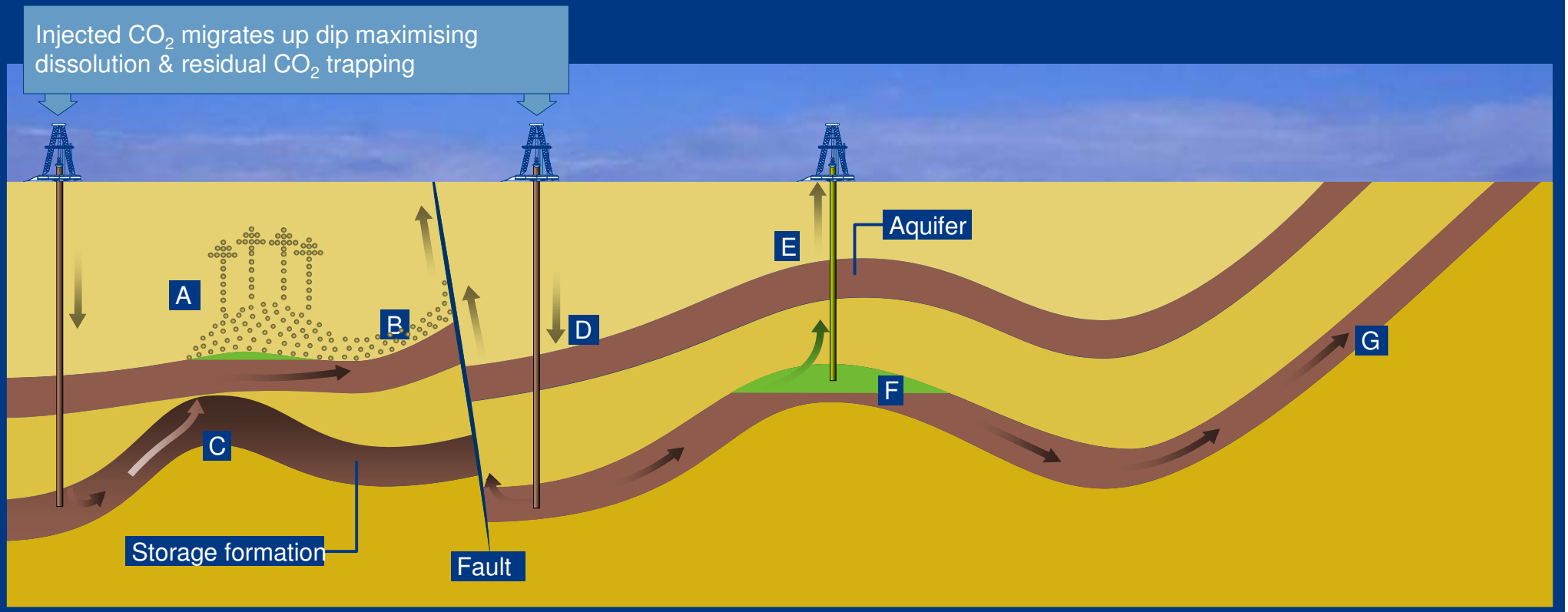
Transport: comparable to or lower than risks of hydrocarbon pipelines

Geological storage

Hazards result from leakage of CO_2 from storage site to the surface and arise from three distinct causes

- Elevated gas-phase concentrations in the near-surface environment
- Effects of dissolved CO_2 on groundwater chemistry
- Effects that arise from the displacement of fluids by the injected CO_2

Leakage paths

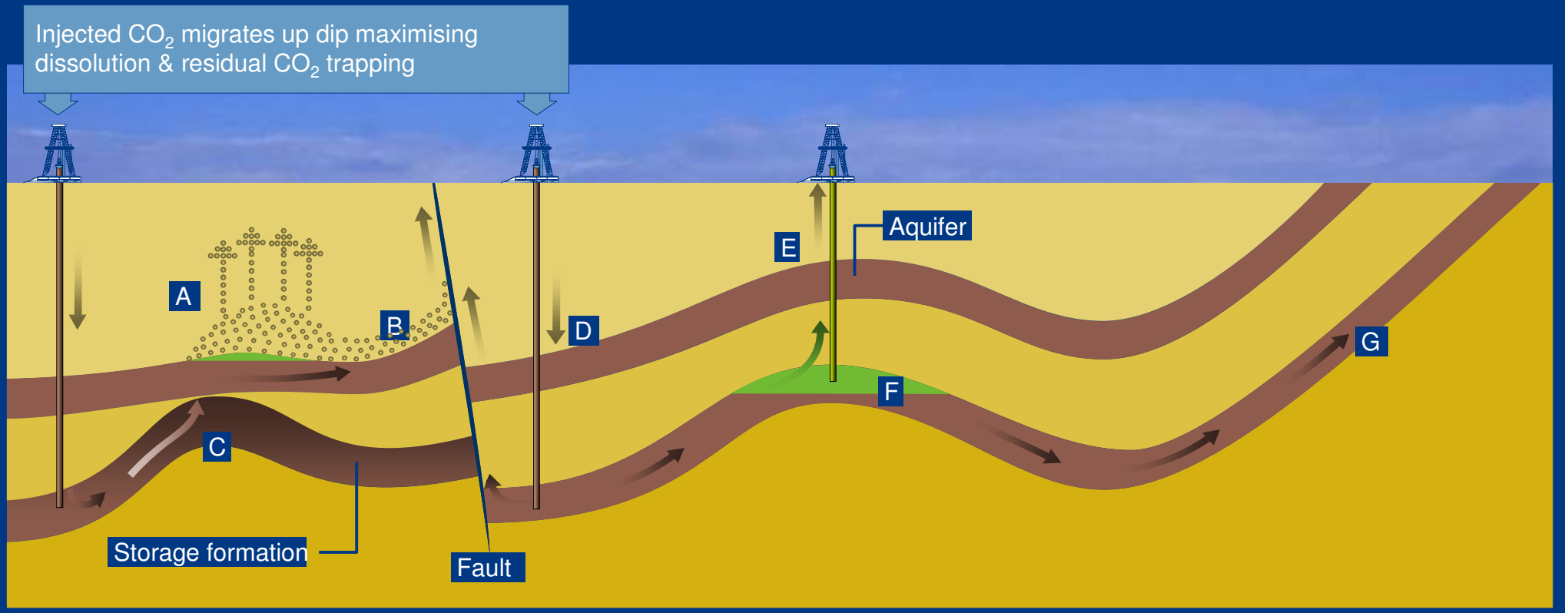


P05018_002 Sl.4

Geological storage

Risk management

- Careful site selection, including performance and risk assessment
- Monitoring to provide assurance that storage project is performings expected
- Effective regulatory oversight
- Implementation of remediation measures



Potential escape mechanisms

A. CO_2 gas pressure exceeds capillary pressure & passes through siltstone	B. Free CO_2 leaks from A into upper aquifer up fault	C. CO_2 escapes through 'gap' in cap rock into higher aquifer	D. Injected CO_2 migrates up dip , increases reservoir pressure & permeability of fault	E. CO_2 escapes via poorly plugged old abandoned well	F. Natural flow dissolves CO_2 at CO_2 /water interface & transports it out of closure	G. Dissolved CO_2 escapes to atmosphere or ocean

Remedial measures

A. Extract & purify ground water	B. Extract & purify ground water	C. Remove CO_2 & re-inject elsware	D. Lower injection rates or pressures	E. Re-plug well with cement	F. Intercept & re-inject CO_2	G. Intercept re-inject CO_2

P05018_002 Sl.6

WMO

UNEP

Geological storage

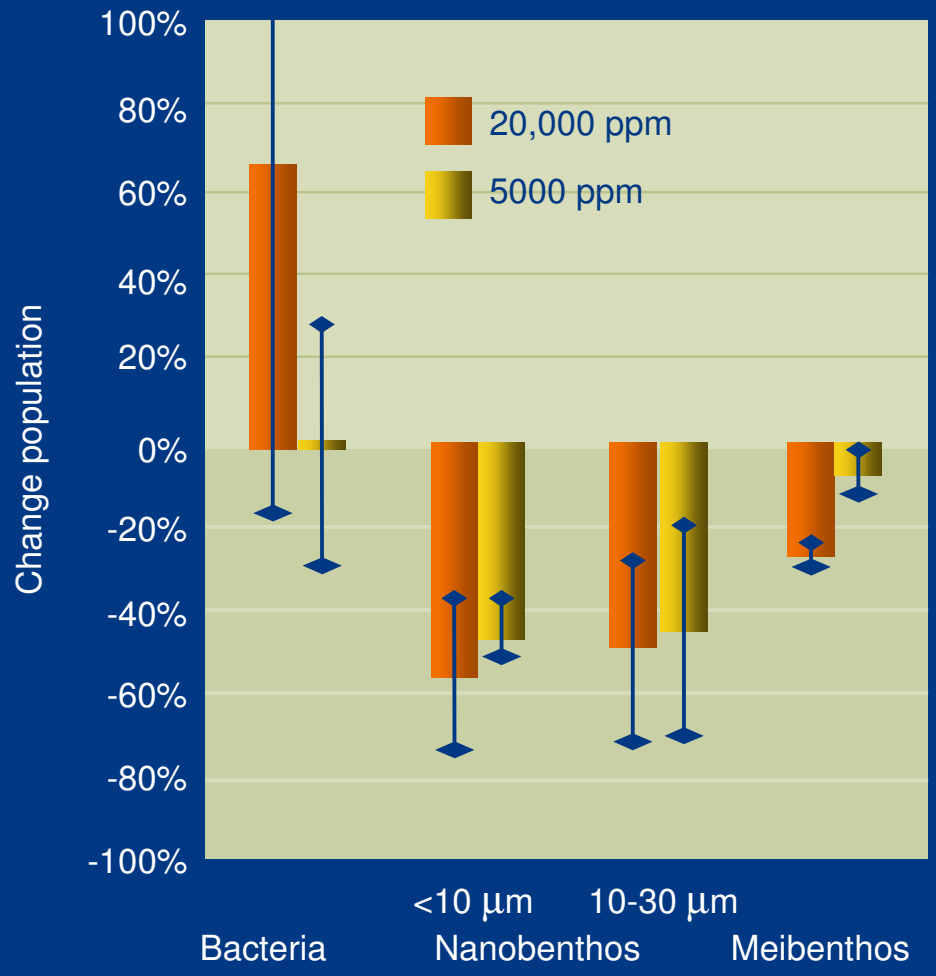
With appropriate risk management in place
local risk of geological storage is comparable
to risks of current activities

- natural gas storage, EOR, disposal of acid gas

Ocean storage

Hazards

- pH change
- Mortality of ocean organisms
- Ecosystem consequences
- Chronic effects unknown



Change of bacteria, nanobenthos and meiobenthos abundace after exposure to 20,000 and 5,000 ppm for 77-375 hrs during experiments carried out at 2000 m depth in NW Pacific

P05018_002 Sl.8

WMO

UNEP

Mineral carbonation

- Environmental impact similar to that of large scale surface mining operations
- Mining and disposal of resulting products
- Some of it may be re-used

Will physical leakage of stored CO_2 compromise CCS as a climate mitigation option?

Fraction retained in appropriately selected and managed geological reservoirs is

- very likely to exceed 99% over 100 years, and
- is likely to exceed 99% over 1,000 years.

"Likely" is a probability between 66 and 90%, "very likely" of 90 to 99%

Release of CO_2 from ocean storage would be gradual over hundreds of years

Year	Injection Depth		
	800 m	1500 m	3000 m
2100	0.78 ± 0.06	0.91 ± 0.05	0.99 ± 0.01
2200	0.50 ± 0.06	0.74 ± 0.07	0.94 ± 0.06

Fraction of CO_2 retained as simulated for 100 years of continuous injection starting in 2000

What are the legal and regulatory issues for implementing CO_2 storage?

Onshore: national regulation

- Few legal or regulatory frameworks for long-term CO_2 storage

Offshore: international treaties

- OSPAR, London Convention
- Ocean storage and sub-seabed geological storage
- Unclear whether or under what conditions CO_2 injection is compatible with international law

Public perception

- Only a handful of studies in Japan, Netherlands, US, UK
- A few percent of the general public is familiar with CCS
- CCS is generally regarded as less desirable than:
  - *energy efficiency improvements*
  - *use of non-fossil energy sources*