Methane Hydrates: Production of Natural Gas and Storage of CO_2 below the Seabed

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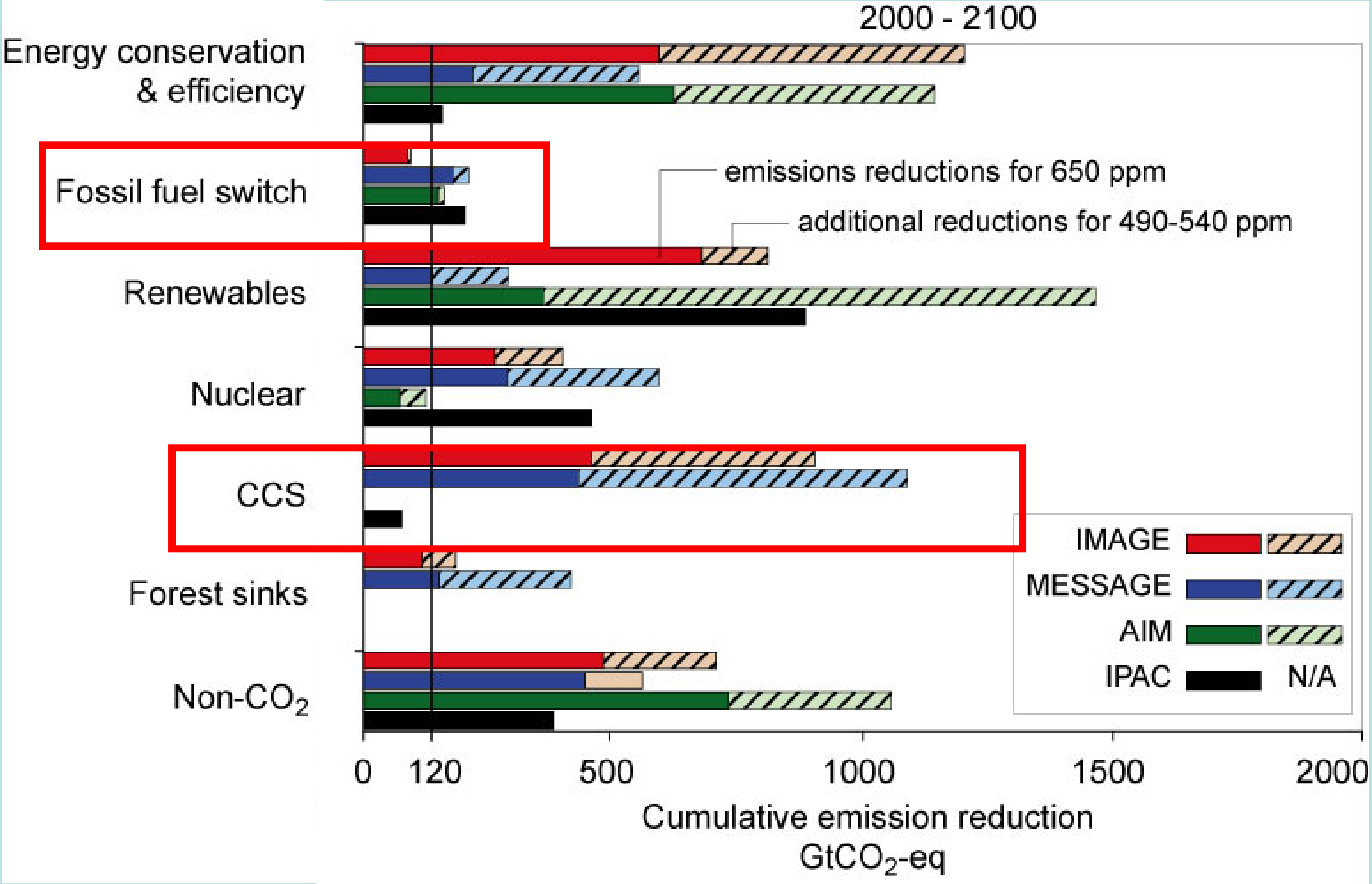
CO_2 →

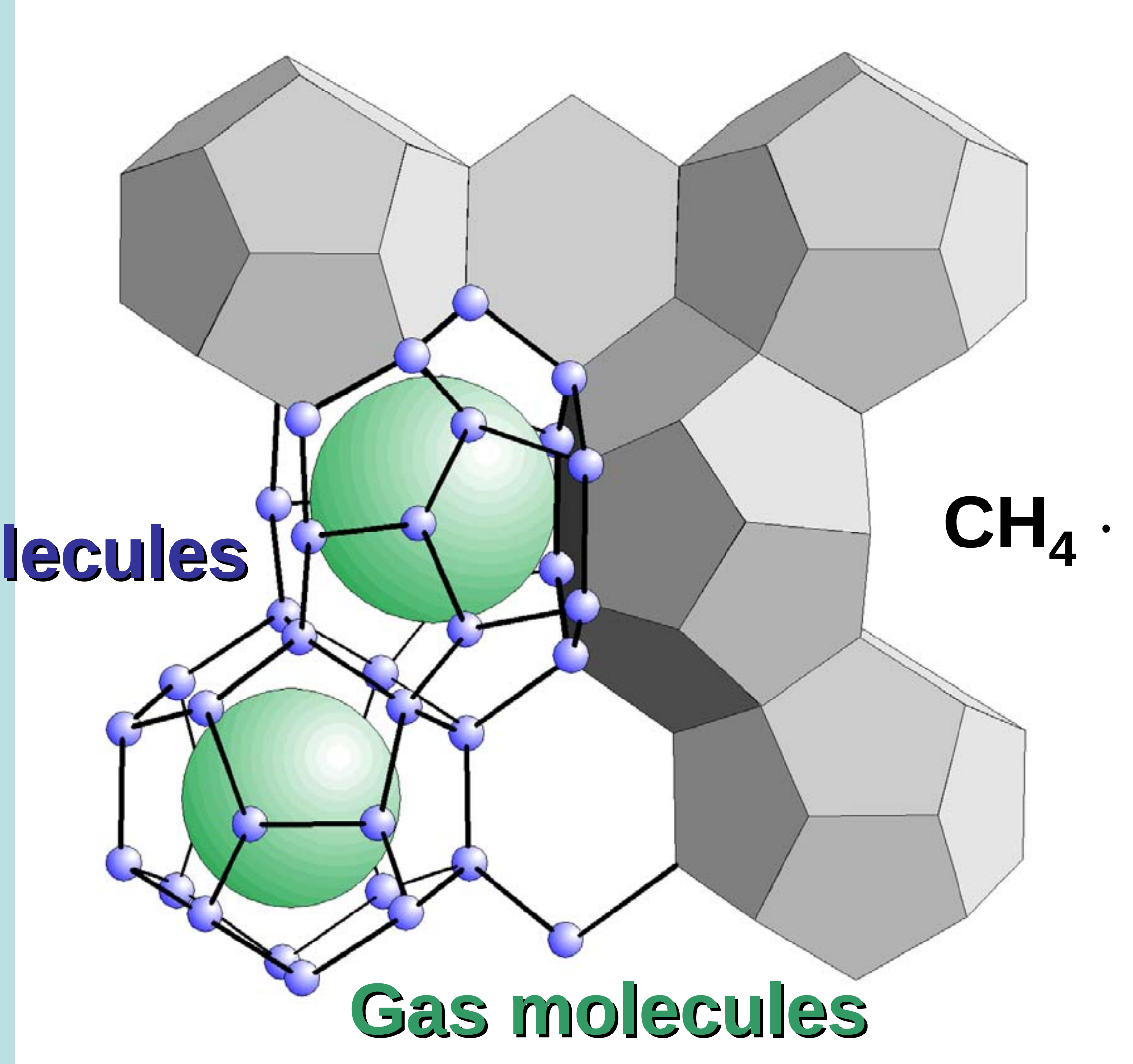
→ CH_4

Hydrate technologies may contribute to the reduction of CO_2 emissions from fossil fuel power plants



Source: IPCC (2007): Climate Change - Mitigation

Hydrate Structure

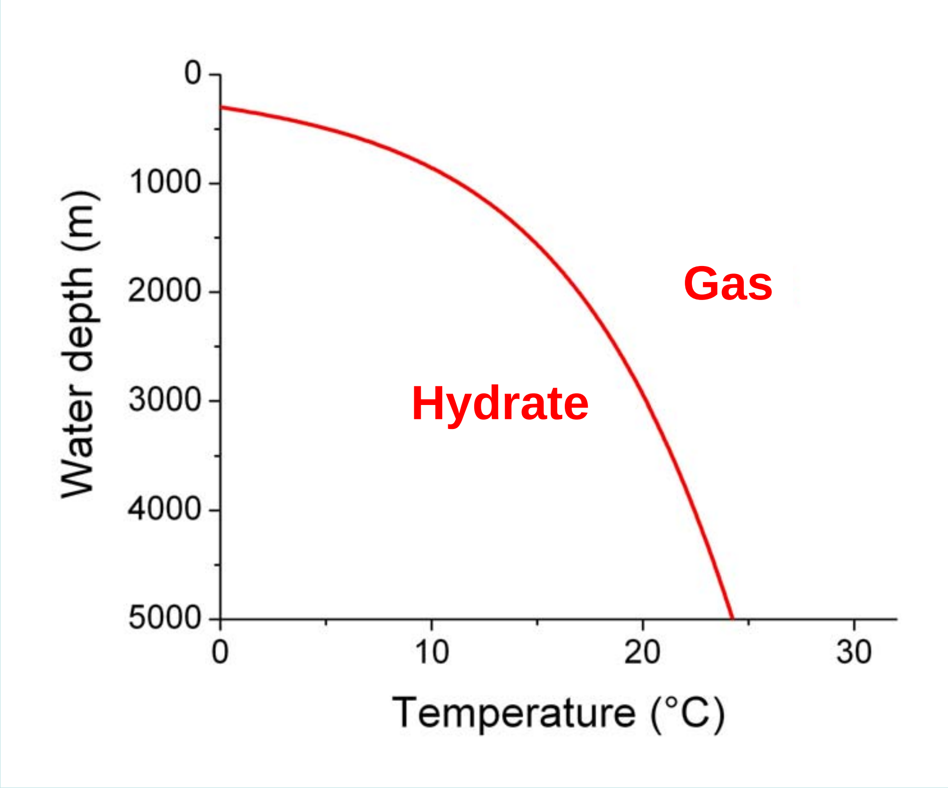


Water molecules

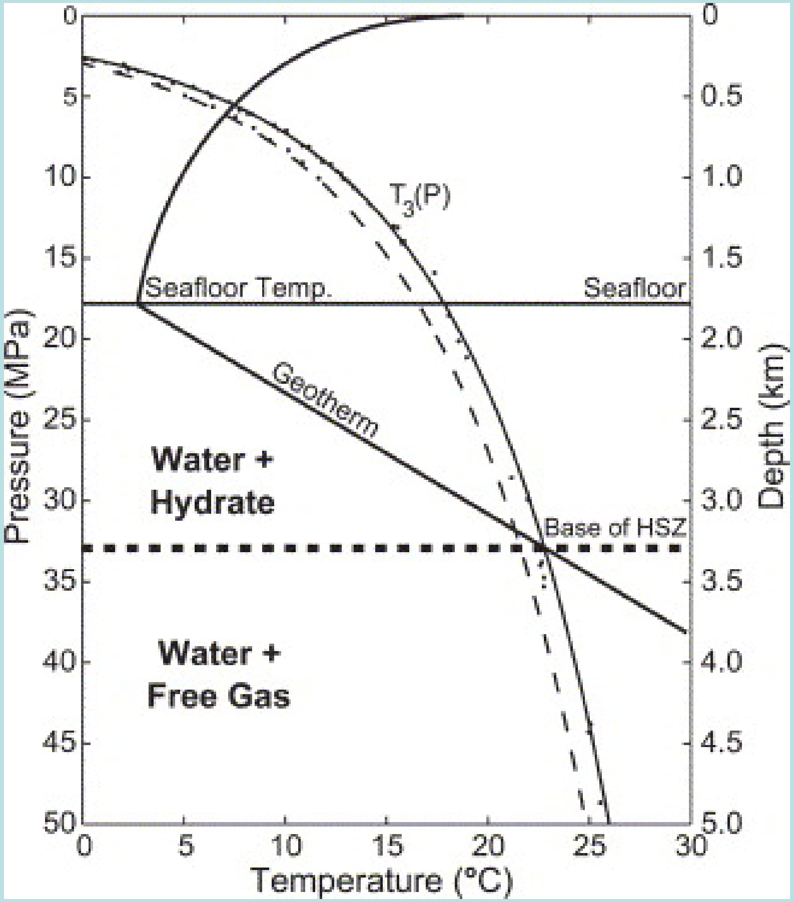
$CH_4 \cdot 5.7\ H_2O$

Gas molecules

Methane Hydrate Stability



Tishchenko, Hensen, Wallmann & Wong (2005)

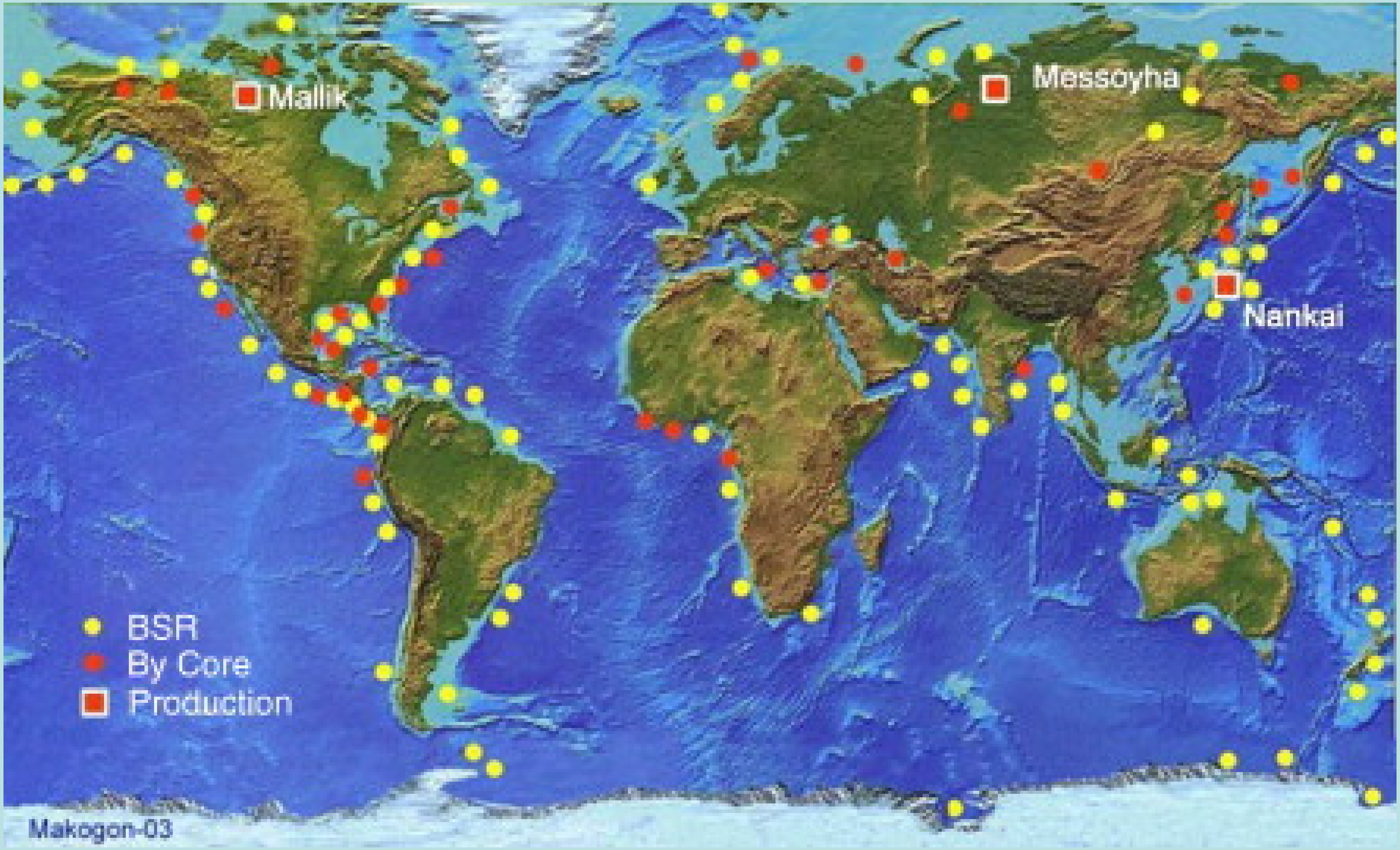


Buffett & Archer (2004)

Methane hydrates are formed by methane:

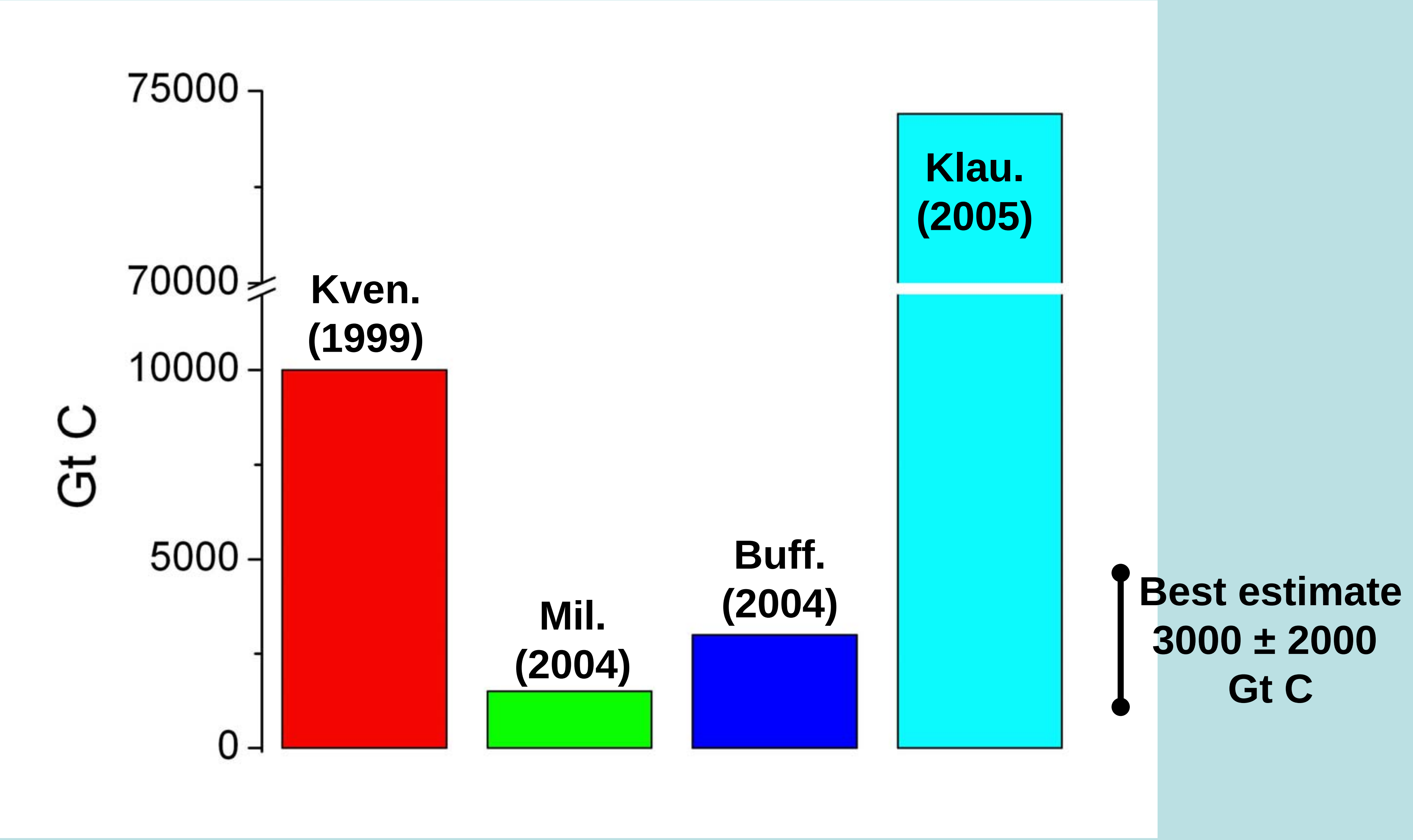
- microbially produced within the hydrate stability zone (HSZ)
- produced at large sediment depth and transported to the surface by *upward fluid flow*
- produced at large sediment depth and transported to the surface by *gas bubble ascent.*

Global Methane Hydrate Distribution

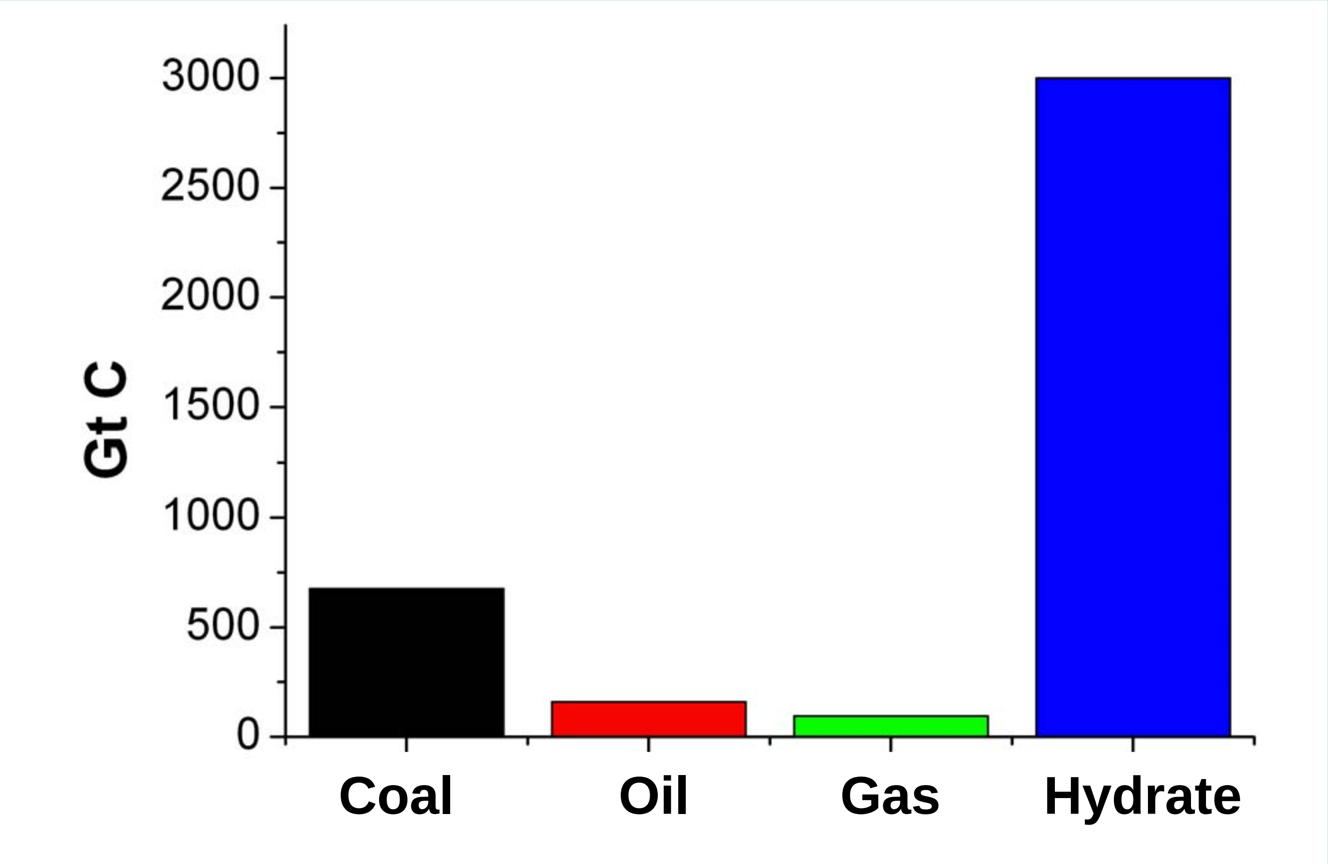


Source: Makogan et al., 2007

Global Methane Hydrate Inventory in the Seabed



Global Methane Hydrate Inventory



Source: Energy Outlook 2007, Buffett & Archer (2004)
Coal, oil, gas: reserves economically exploitable at current market prices
Gas Hydrates: total marine inventory

Hydrate Exploitation

Methane gas may be produced from hydrate deposits via:

- Pressure reduction
- Temperature increase
- Addition of chemicals (incl. **CO_2**)

Hydrate Exploitation

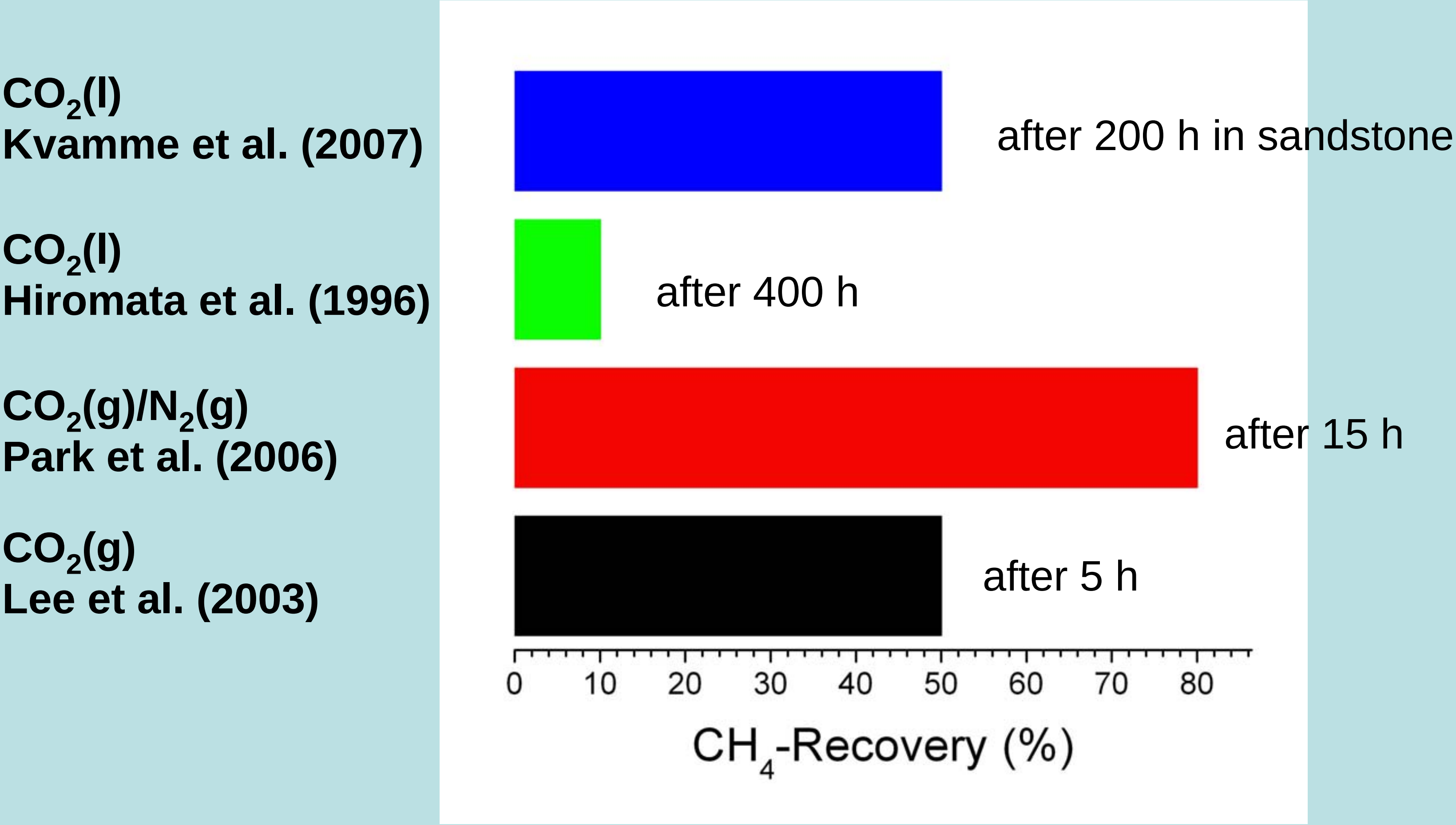
Energy balance for gas production via temperature increase at Blake Ridge (Makogon et al. 2007)
2000 m water depth, two ~3 m thick hydrate layers

~40 % of the potential energy can be used for energy production

~60 % of the potential energy is lost during development, gas production, gas pressurization and transport

Japanese Hydrate Exploitation Program
Hydrate exploitation via pressure reduction has a much better energy balance and may be economically feasible at an oil price of ~54 $/barrel

CH_4(g)-Recovery from Hydrates Exposed to CO_2

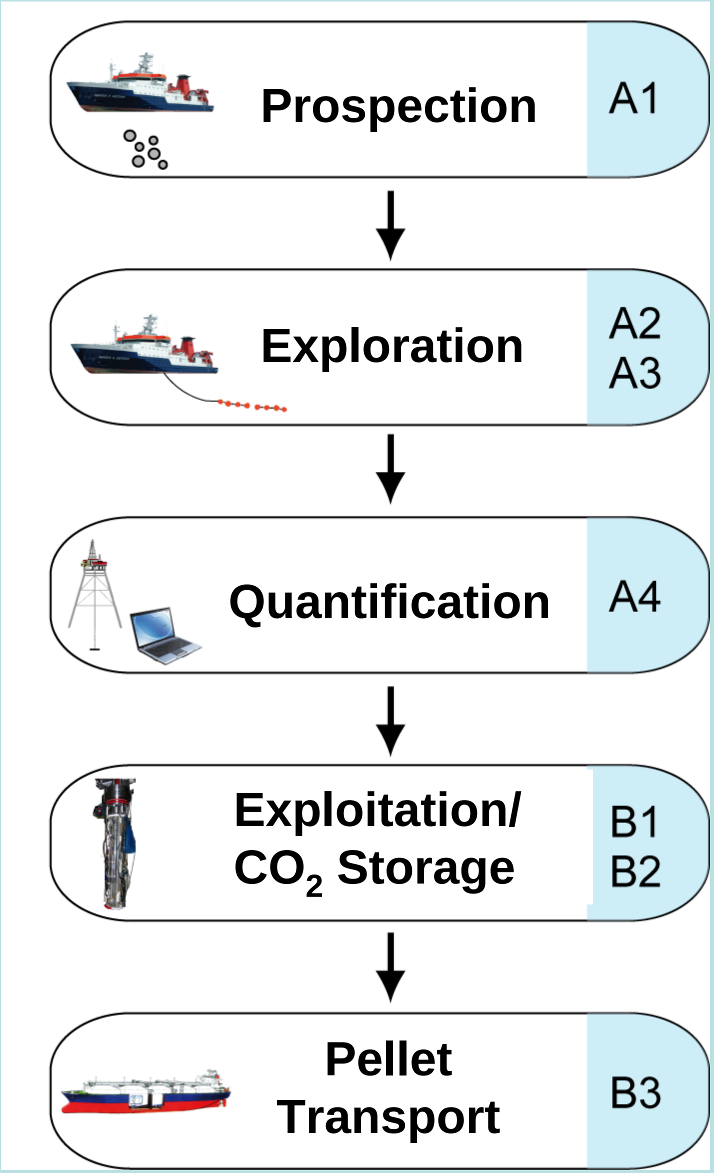


Spontaneous exothermic reaction

The SUGAR Project

- Funded by German Federal Ministries (BMWi, BMBF)
- First funding period: June 2008 – May 2011
- Total funding: ~13 Mio € (incl. support by industries)

The SUGAR Project



A: Exploration

A1: Hydroacoustics

A2: Geophysics

A3: Autoclave-Drilling

A4: Basin Modeling

B: Exploitation and Transport

B1: Reservoir Modeling

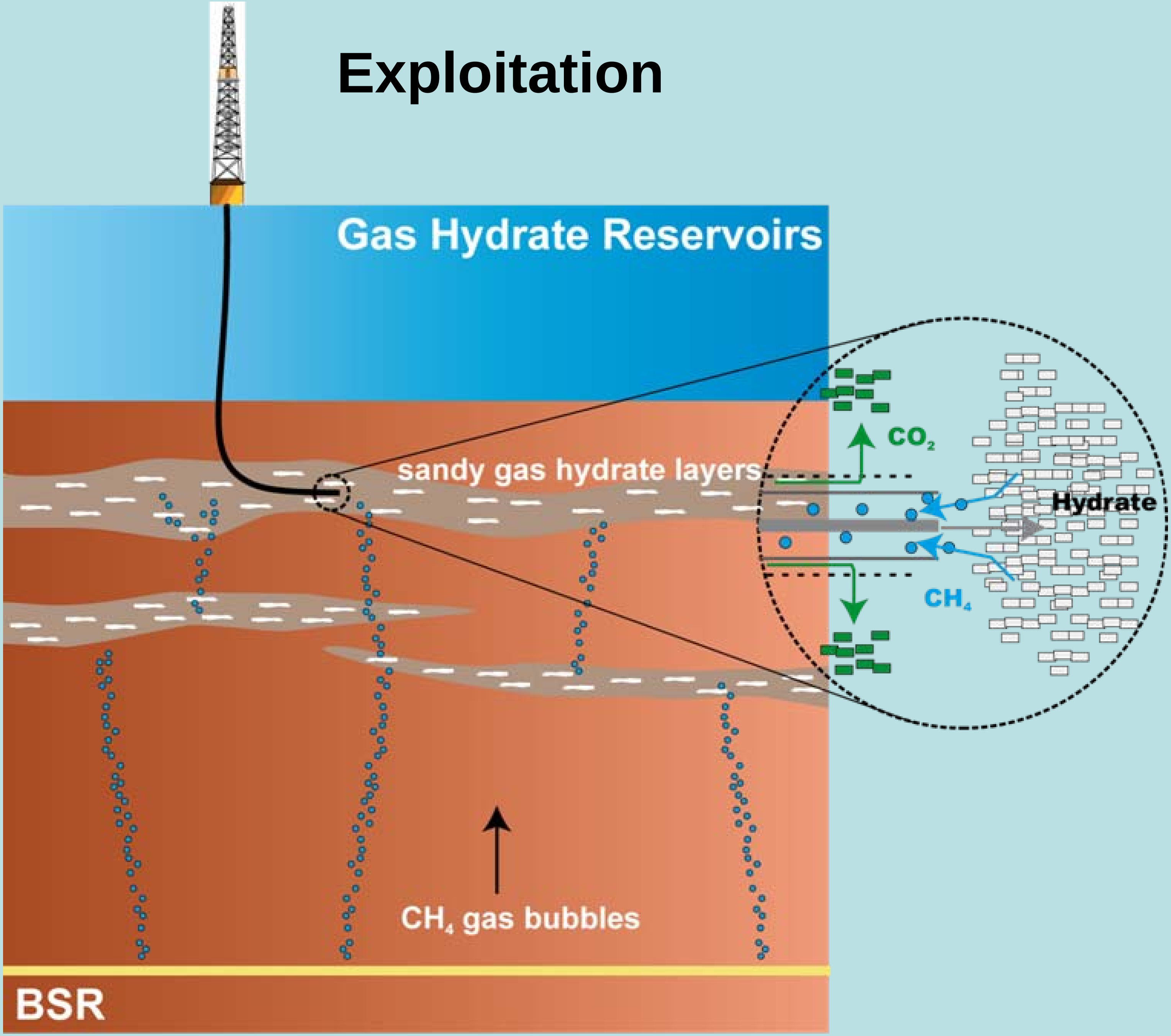
B2: Laboratory Experiments

B3: Gas Transport

SUGAR Partners

Project	Academia	Industries
A1	IFM-GEOMAR	L3 Communications ELAC Nautik GmbH
A2	IFM-GEOMAR, BGR Hannover	K.U.M. Umwelt- und Meerestechnik GmbH, Magson GmbH, SEND Offshore GmbH
A3	University of Bremen, TU Clausthal	PRAKLA Bohrtechnik GmbH
A4	IFM-GEOMAR	Schlumberger-IES
B1	Fraunhofer UMSICHT, GFZ Potsdam, IFM-GEOMAR	Wintershall, Aker-Wirth GmbH
B2	FH Kiel, GFZ Potsdam, Fraunhofer UMSICHT, IFM-GEOMAR, Uni Göttingen	BASF, CONTROS GmbH, R&D Center at FH Kiel, 24sieben Stadtwerke Kiel AG, RWE Dea, Wintershall, E.ON Ruhrgas AG
B3	IOW, FH Kiel	Linde AG, Meyer Yards, Germanischer Lloyd, BASF

Exploitation



Exploitation

Options

- Addition of supercritical CO_2
- Addition of CO_2(l) and heat from
  - deep and warm formation waters (Schlumberger)
  - surface water (UMSICHT, mega pump)
  - in-situ methane burning (GFZ)
- Addition of CO_2(l) and polymers (BASF)
- Addition of CO_2(l) and other gases (IOW)

Exploitation will probably be done combining:

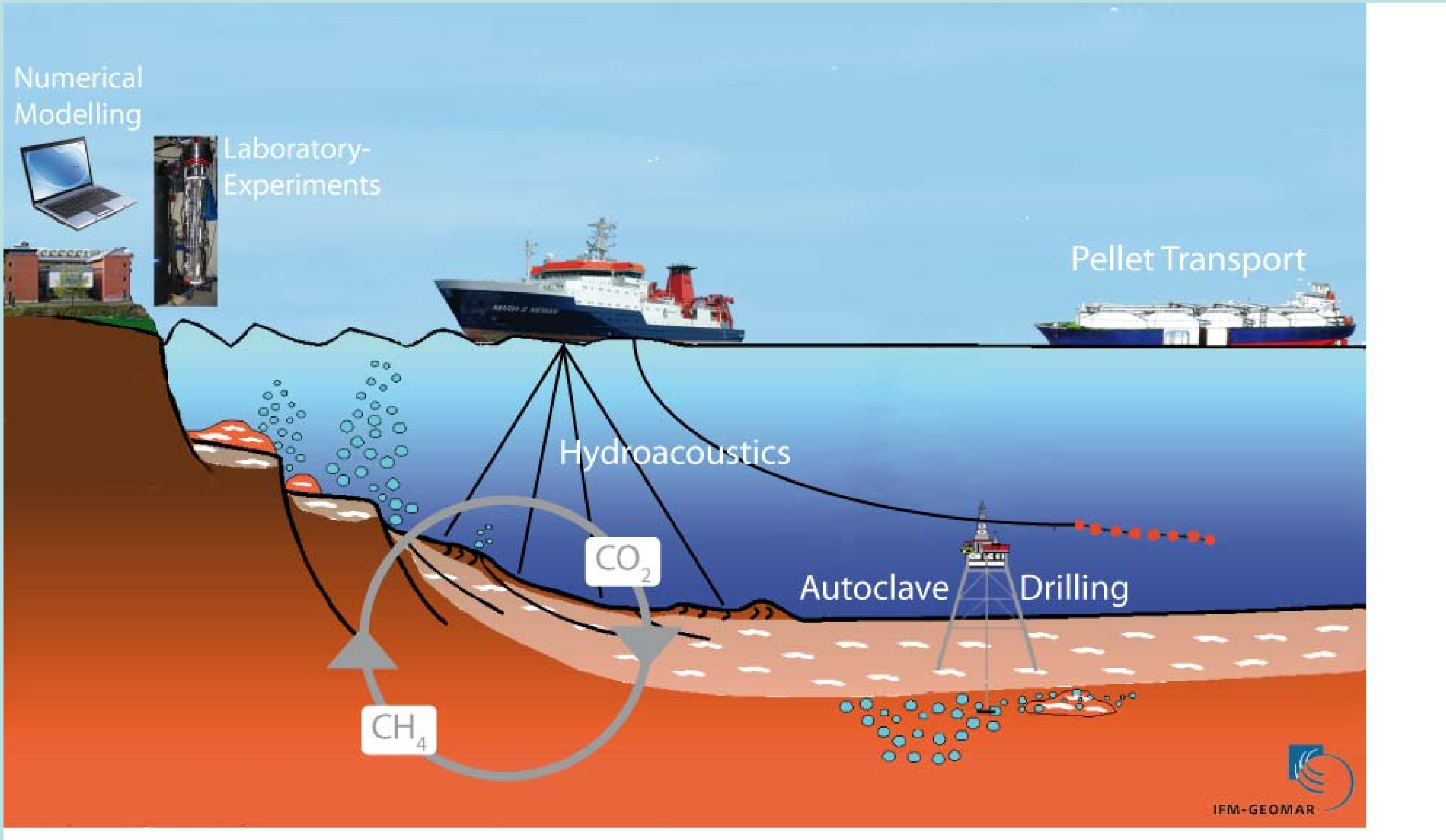
- *Pressure reduction*
- *Heat supply*
- *Addition of CO_2 + X*

Exploitation

Critical issues that need to be addressed:

- Sluggish kinetics of gas swapping
- Slope stability (avoid steep terrain)
- Integrity of the unconsolidated cap sediments (overpressure < 10 bar)
- Permeability of reservoir sediments (use sands)
- Clogging by CO_2 hydrate formation at the injection point (add polymers or heat)
- CO_2 content of the produced methane gas (avoid very high temperatures)

SUGAR Technologies



Timeline Hydrate Research (2010 – 2015)

Field production tests (USA, Japan)

Press. Reduction (BP, DOE)
CO_2 (ConocoPhillips, DOE)
On-shore Alaska

Press. Reduction (MH 21)
Off-shore Japan

Off-shore Japan

2010 2012 2014

SUGAR

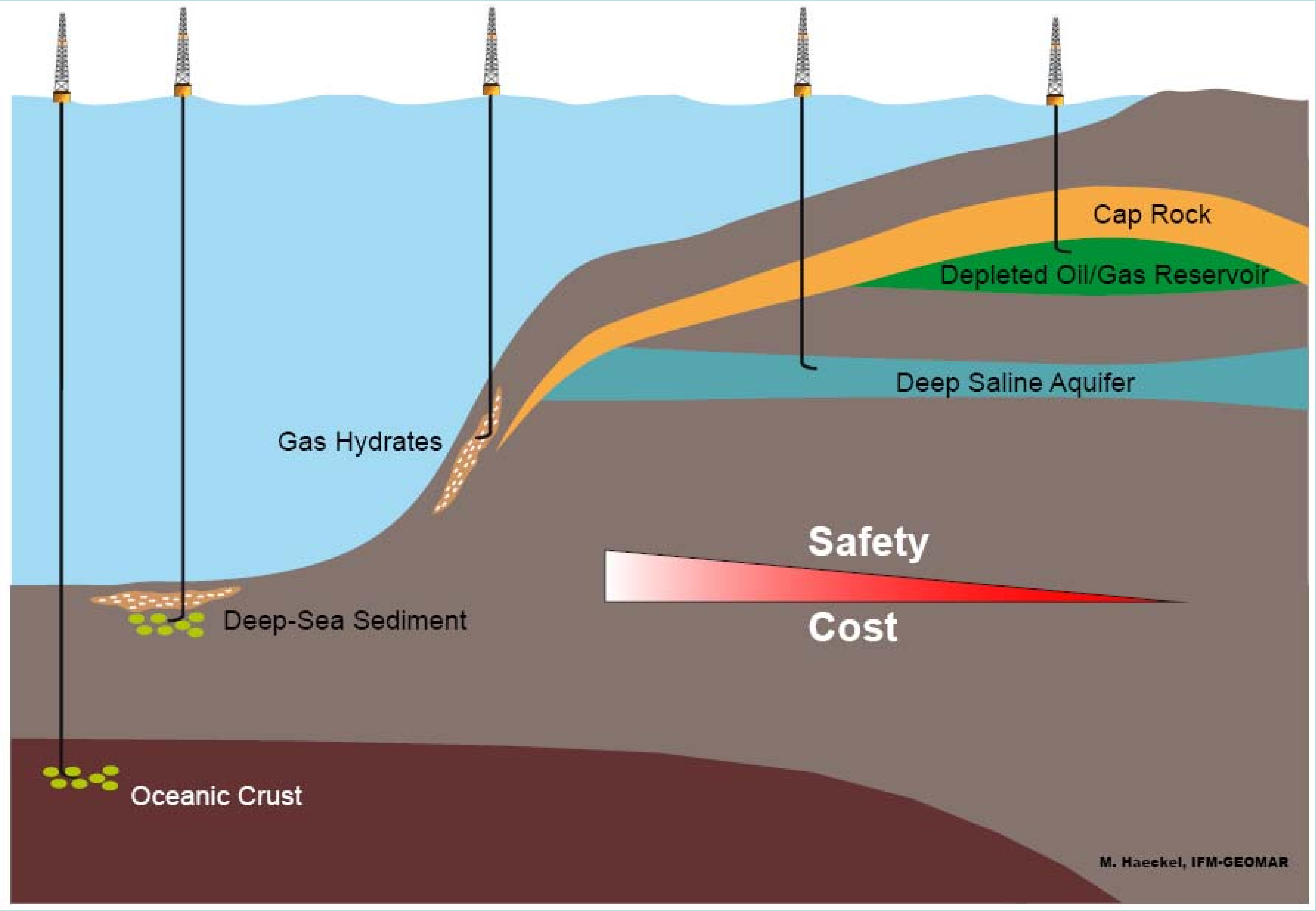
Lab, modeling, and engineering studies to improve gas production (CO_2, T, P, X) and transport technologies

Exploration: India New Zeeland Taiwan Brazil China

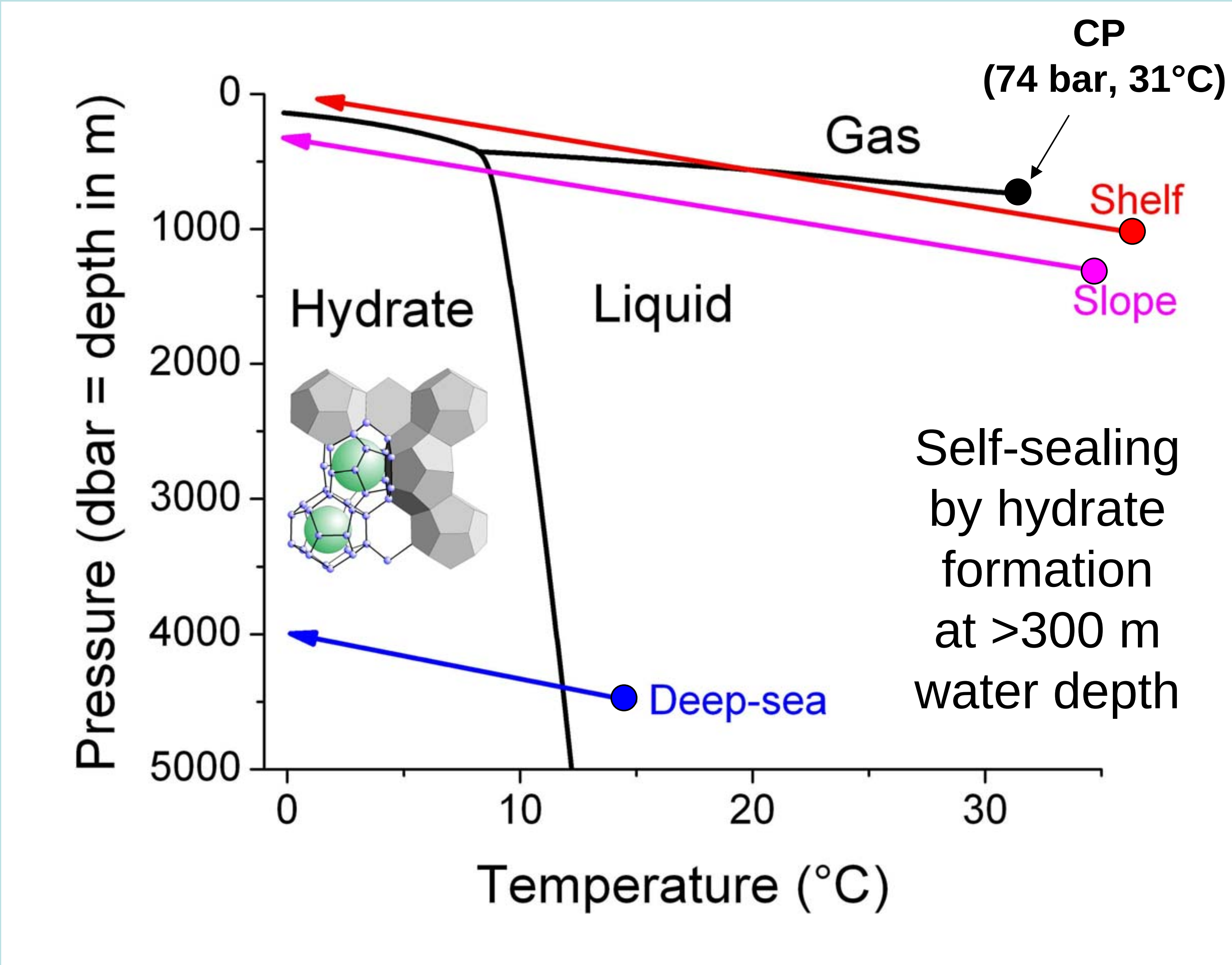
2010 2012 2014

2015: International off-shore production test with CO_2 injection

CO_2-Storage Options Below the Seabed

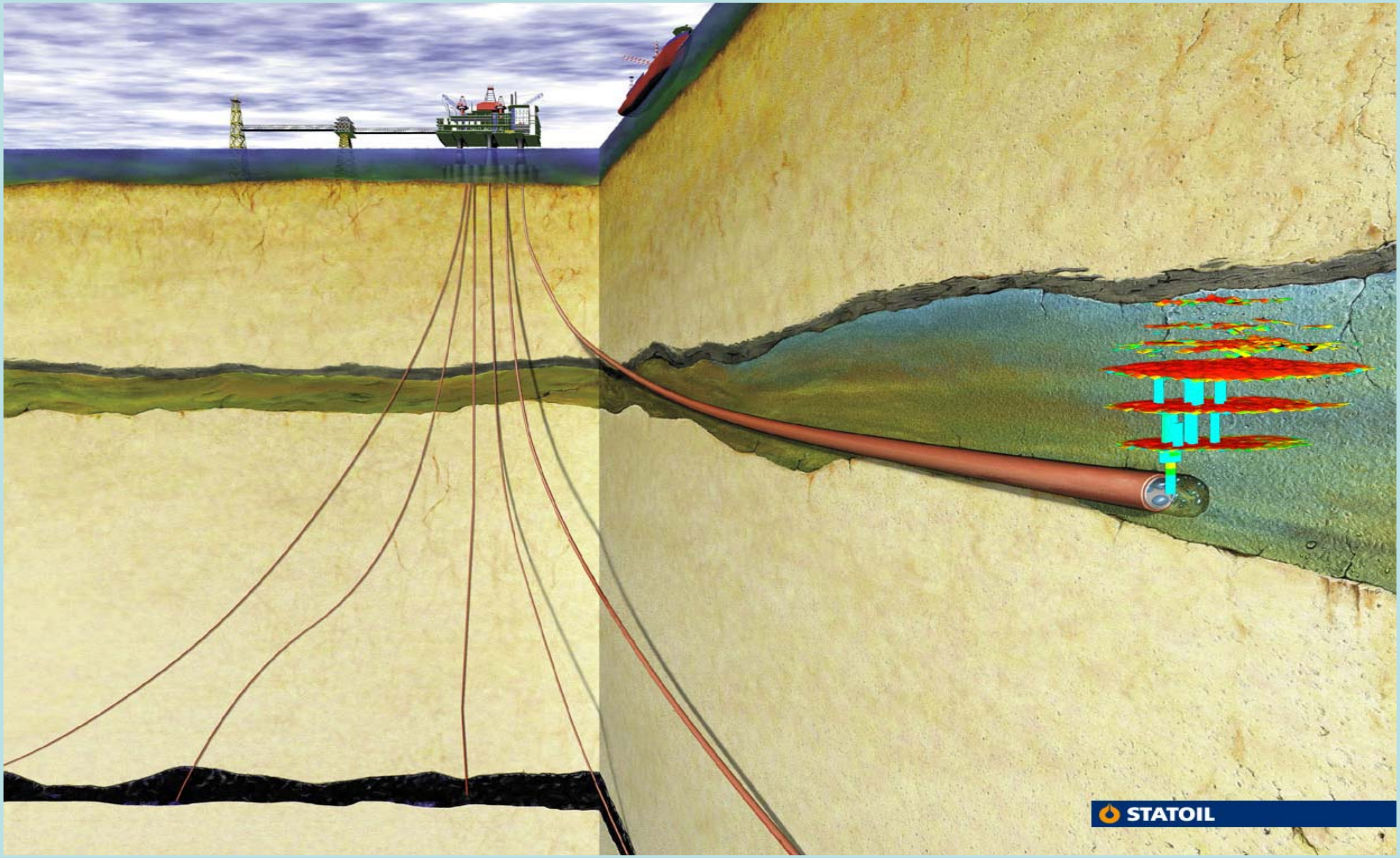


Phase Diagram of CO_2

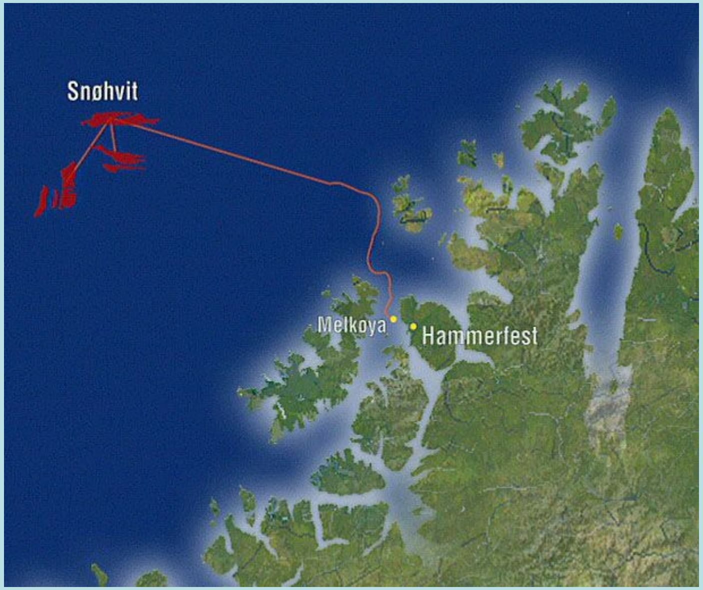


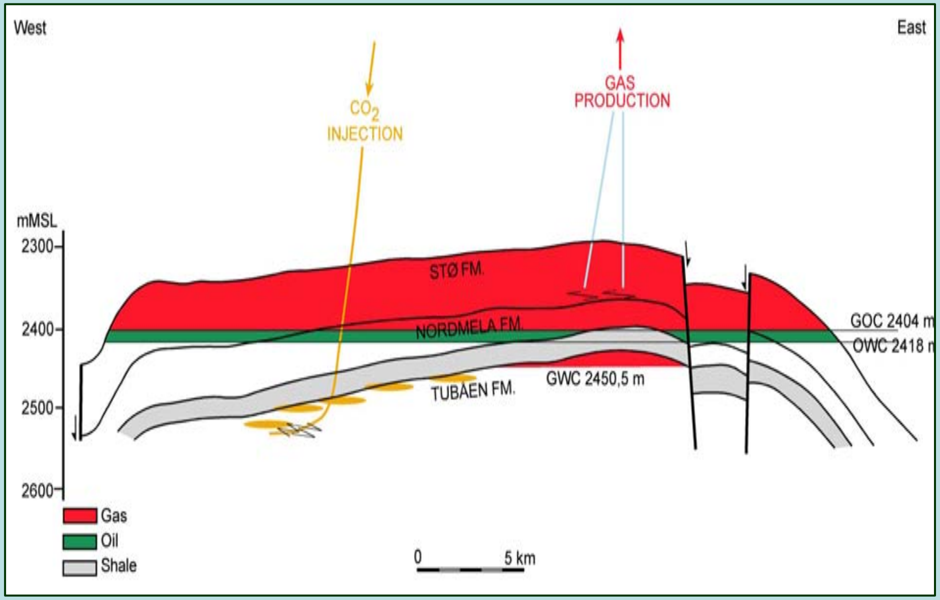
CO_2 Storage in Slope Sediments at Sleipner

CO_2 separated from natural gas, 1 Mt CO_2/a, since 1996,
water depth: 80 m, sediment depths: 900 m



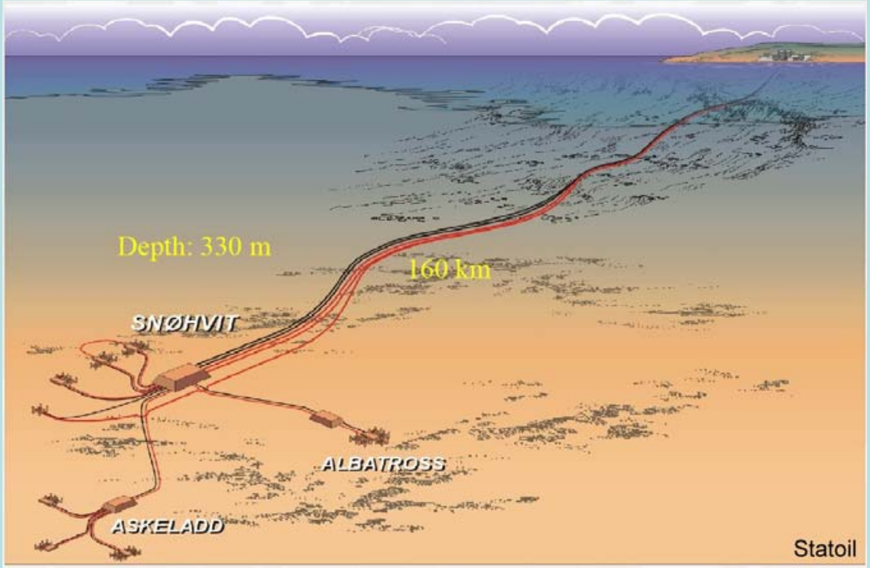
CO_2 Storage in Slope Sediments





Snoehvit, Barents Sea

CO_2 separated from natural gas
0,7 Mt CO_2/a, since 2009
water depth: 330 m
sediment depth: 2600 m



Eco₂ Initiative

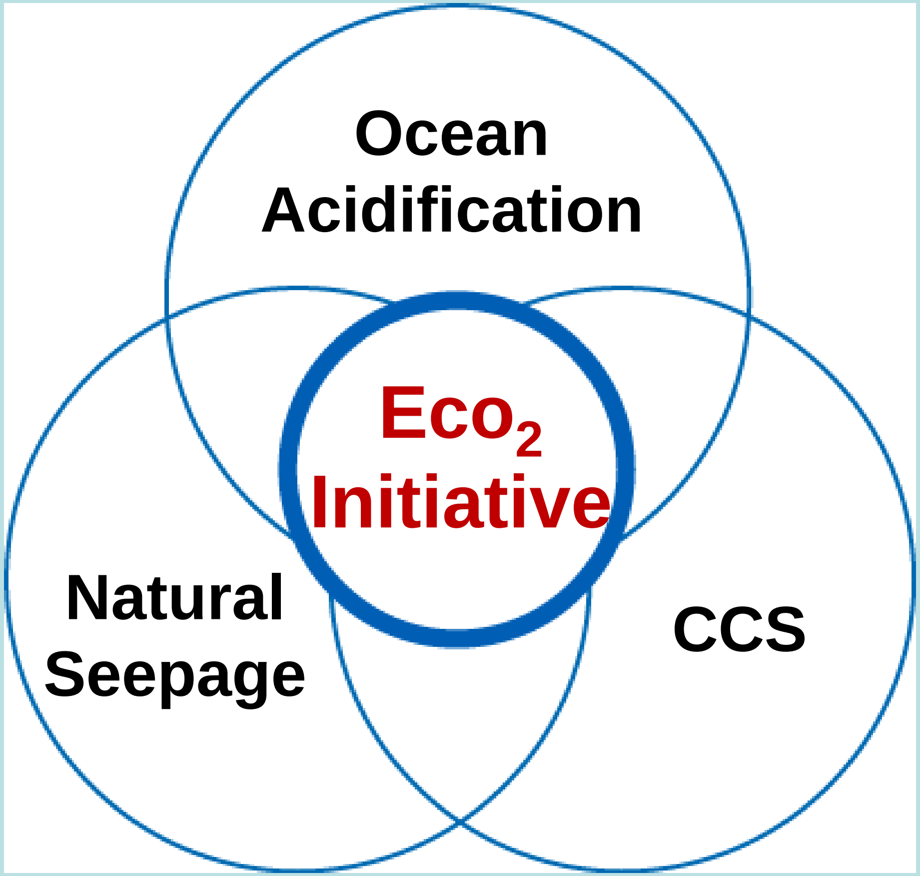
Addressing the call "Sub-seabed carbon storage and the marine environment"

Eco2

Sub-seabed CO_2 Storage: Impact on Marine Ecosystems

27 partners from Norway, GB, Germany, Netherlands, France, Italy, Poland
Coordinated at IFM-GEOMAR (Germany)

Eco_2: A Merger of three different scientific communities



to evaluate the likelihood, ecological impact, economic and legal consequences of leakage from sub-seabed CO_2 storage sites

Study areas

Legend

Storage sites

CO_2 seeps

+ potential storage sites off Australia and natural CO_2 seeps off Japan

Thesen und Zusammenfassung

Methanhydrate enthalten weltweit deutlich mehr Erdgas als konventionelle Lagerstätten. Die Vorkommen sind an fast allen Kontinenträndern anzutreffen. Durch die Erschließung der Methanhydrate kann daher die zukünftige Versorgung mit Erdgas gesichert werden.

Methanhydrate können durch die Einspeisung von CO_2 aus CCS-Kraftwerken in CO_2-Hydrate umgewandelt werden. Dabei wird Erdgas für die Energiegewinnung freigesetzt und gleichzeitig CO_2 sicher im Meeresboden gespeichert.

Durch diese Kombination aus CO_2-Speicherung und Erdgasgewinnung können die CO_2-Emissionen des fossilen Energiesektors massiv reduziert werden.

Die Hydrattechnologien befinden sich noch in einer frühen Phase. Es sind noch wenigstens 10 Jahre intensiver Forschung und Entwicklung nötig, um sie zur industriellen Anwendung zu bringen.

CO_2 wird schon heute im industriellen Maßstab in Europäischen Randmeeren gespeichert. Die Akzeptanz der CCS-Technologie in Deutschland könnte steigen, wenn neben den On-shore auch die Off-shore Speicheroptionen untersucht würden.