Can Methane Hydrate Be Converted to Carbon-Neutral Energy?

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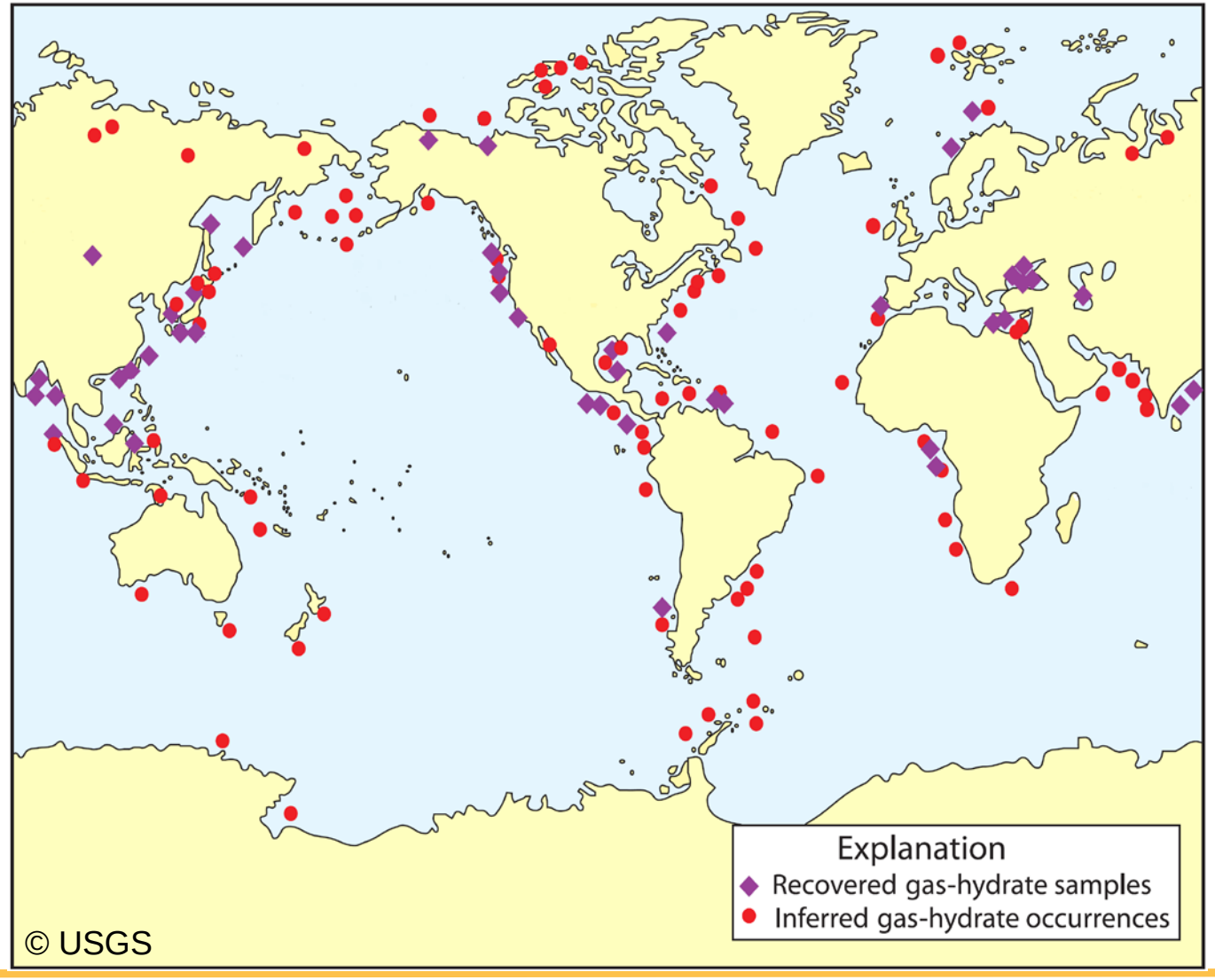
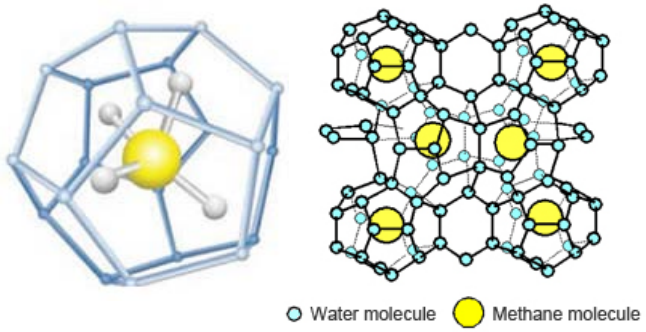
Methane (gas) hydrate – an enormous reservoir of energy



~730 gigatonnes of CH_4 ≈ 38,000 quadrillion BTU (quads)

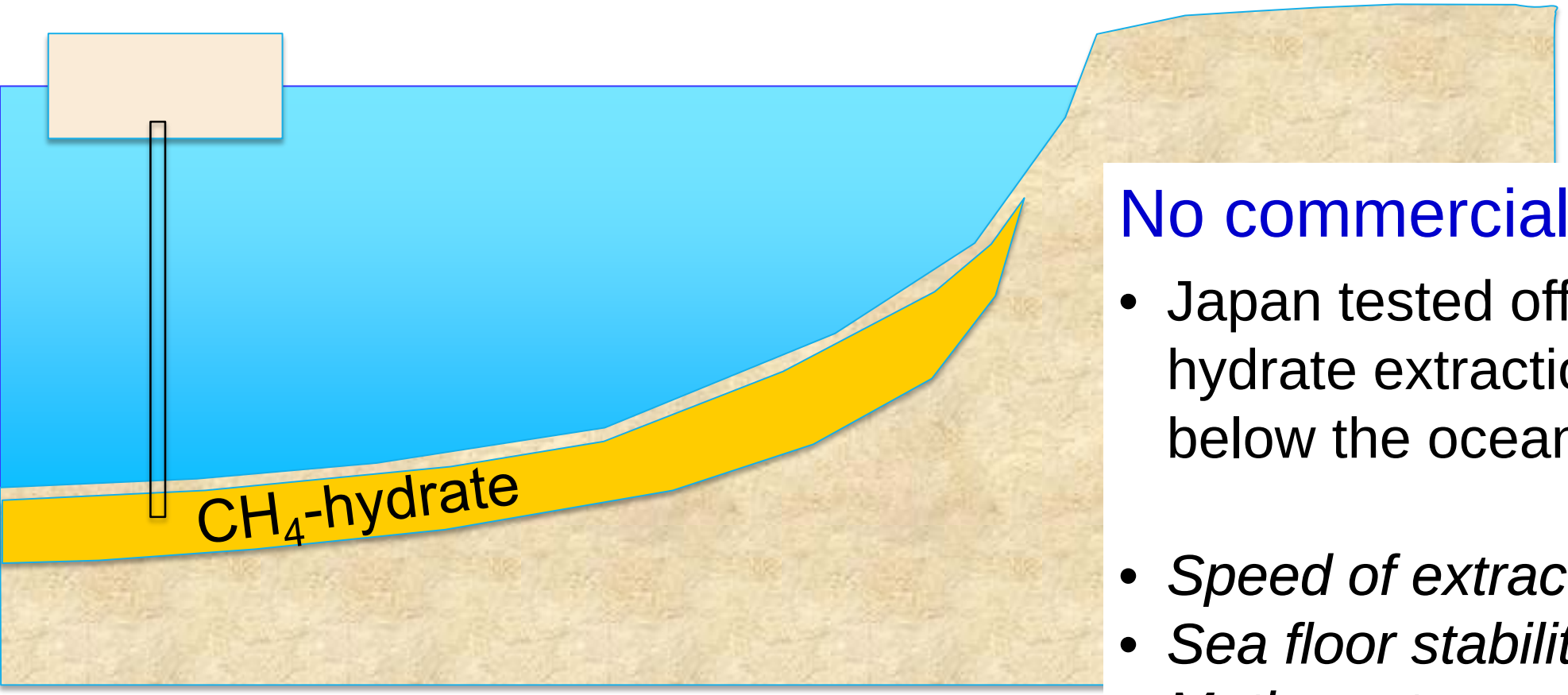
- More than twice the global natural gas reserve
- Widespread in continental margins & slope sediments



arpa·e CHANGING WHAT'S POSSIBLE

Images from USGS, Geology.com, Ingworldnews.com, AIP.org

Methane hydrate extraction



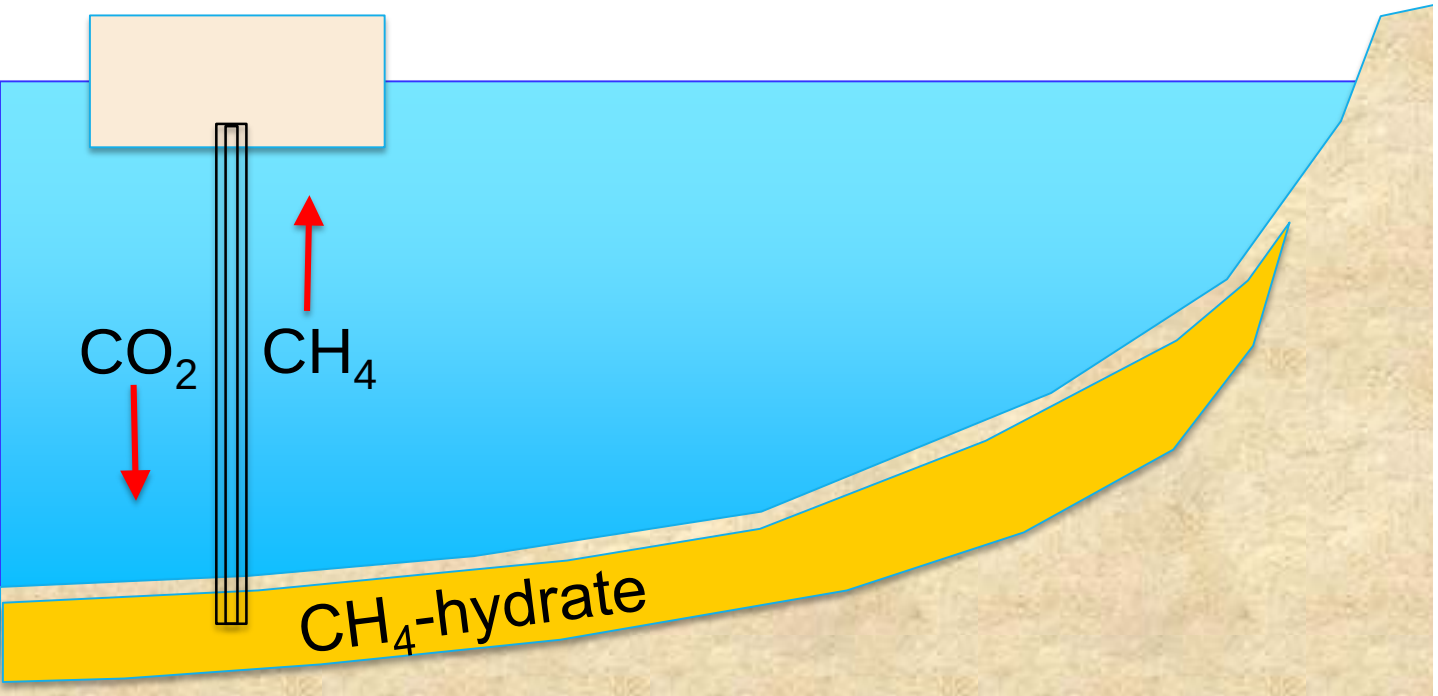
No commercial extraction yet

- Japan tested offshore methane hydrate extraction from >1.3 km below the ocean surface

- *Speed of extraction*
- *Sea floor stability concern*
- *Methane transport cost*

Methane hydrate extraction: CO_2 substitution

$CO_2 + CH_4\text{-hydrate} \rightleftharpoons CO_2\text{-hydrate} + CH_4$



CH_4-hydrate → CO_2-hydrate

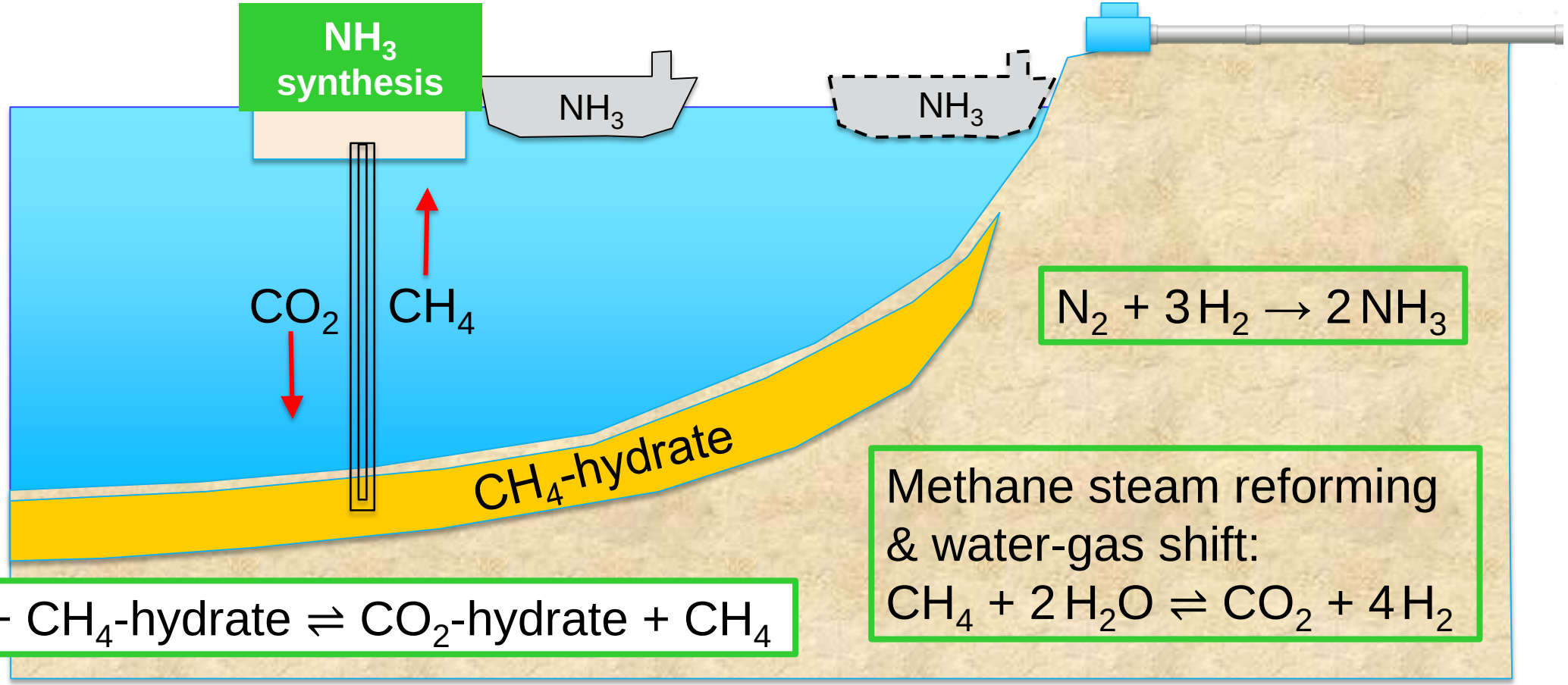
Good idea with challenges

- CO_2 substitution of methane hydrate demonstrated in several laboratory studies
- DOE-ConocoPhillips-Japan Oil demonstration at Prudhoe Bay
- **CO_2 sequestration benefits**

- *CH_4 transport cost*
- *CO_2 transport cost*
- *Speed & extent of reaction*

The idea: Carbon neutral production of NH_3

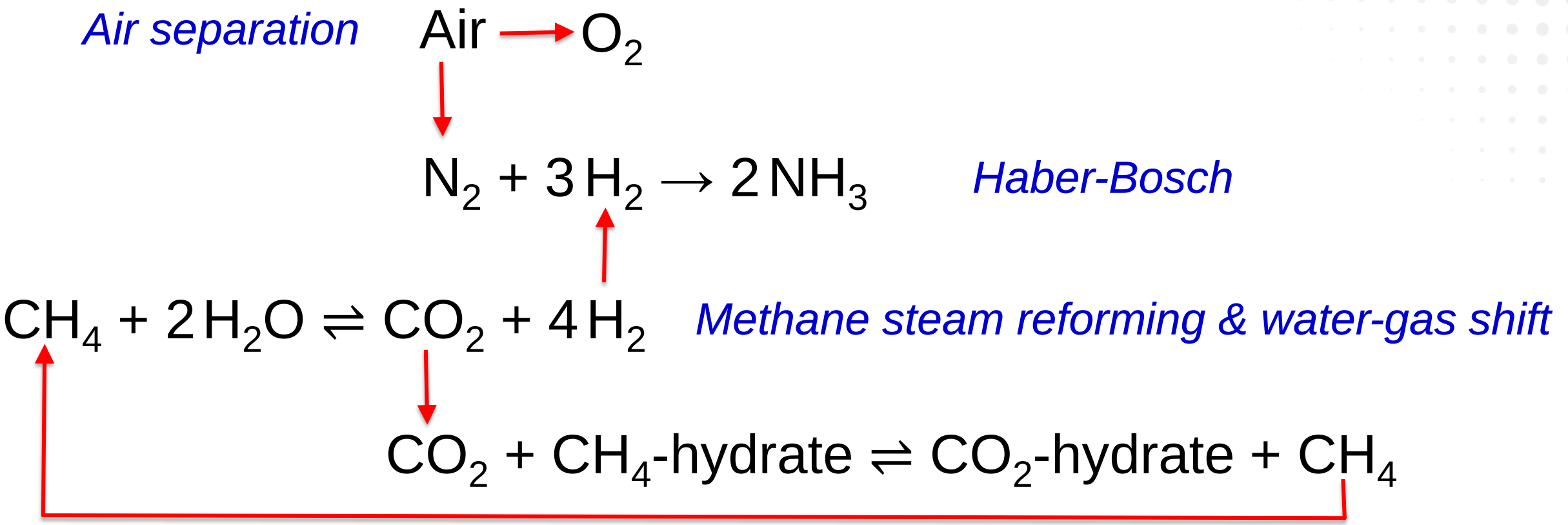
$$3\,CH_4\text{-hydrate} + 6\,H_2O + 4\,N_2 \rightleftharpoons 3\,CO_2\text{-hydrate} + 8\,NH_3$$



- *Preliminary patent application filed by DOE*
- *Government employee disclosure submitted – awaiting determination of invention rights/ownership*

Carbon-neutral NH_3 production from methane hydrate

Air separation



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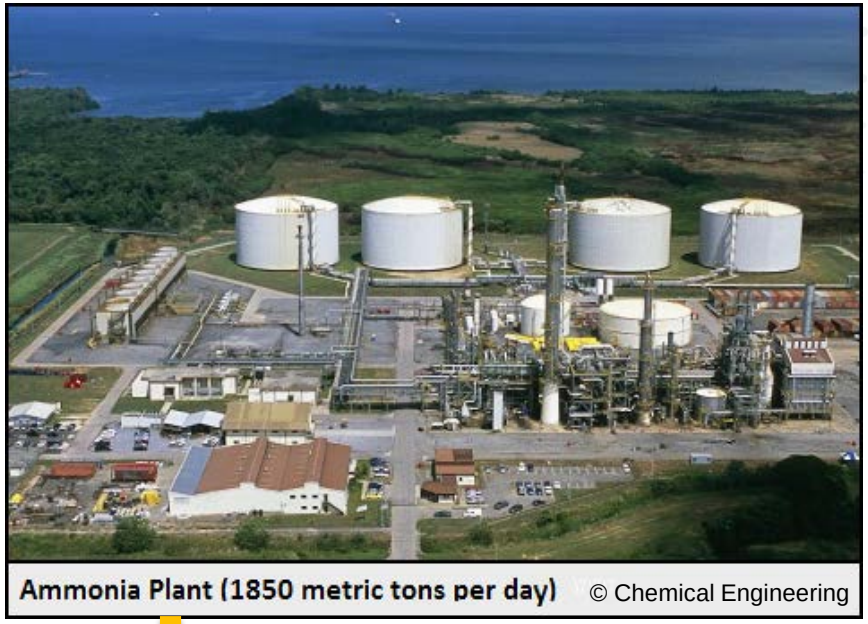
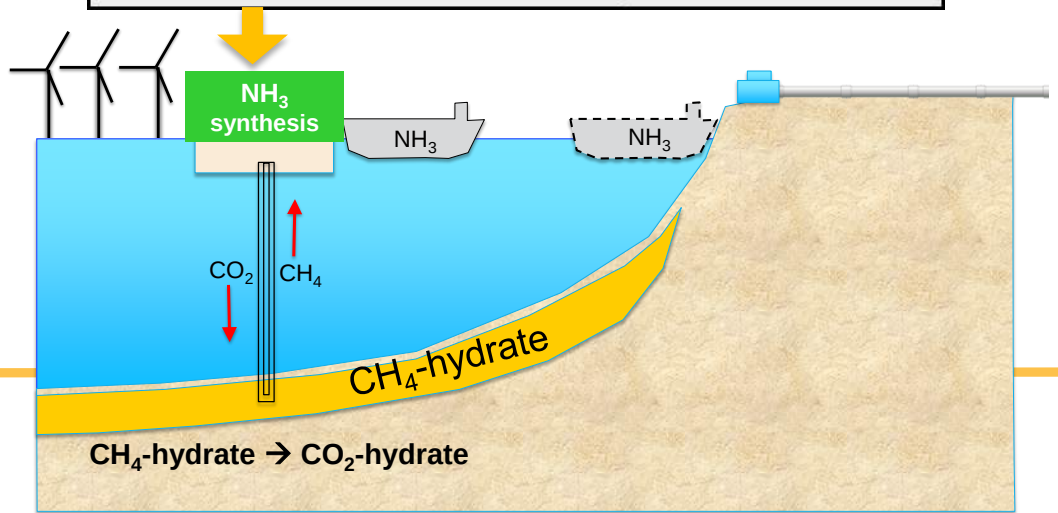
What needs to be done?

1. Efficient modular NH_3 synthesis – shrink a NH_3 production plant to fit an ocean platform

- Lots of research in recent years on more efficient NH_3 synthesis.
- ARPA-E REFUEL program is supporting modular NH_3 synthesis.
- NH_3 production: heat from CH_4 combustion; electricity from CH_4 gas turbines or wind turbines.





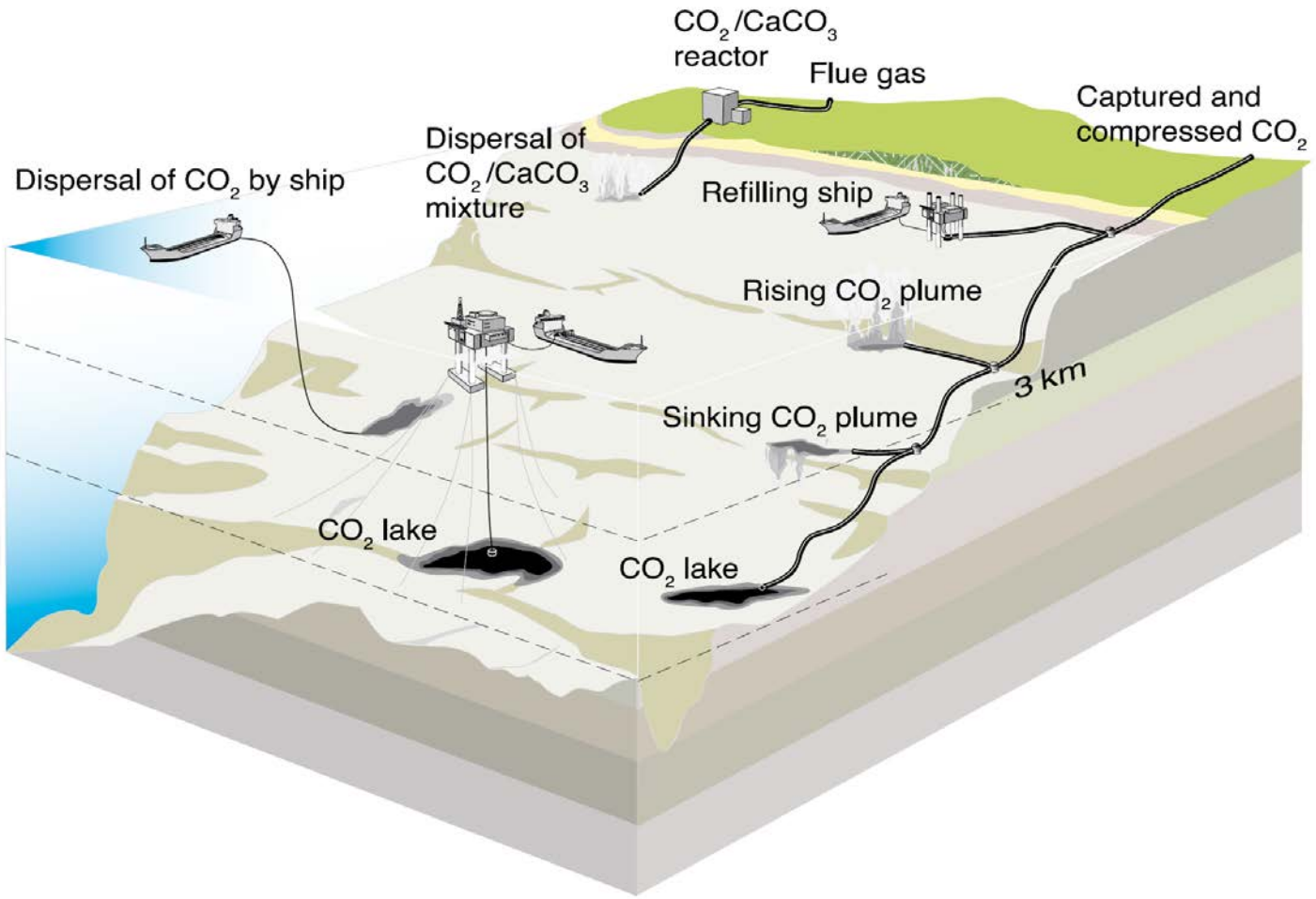
What needs to be done?

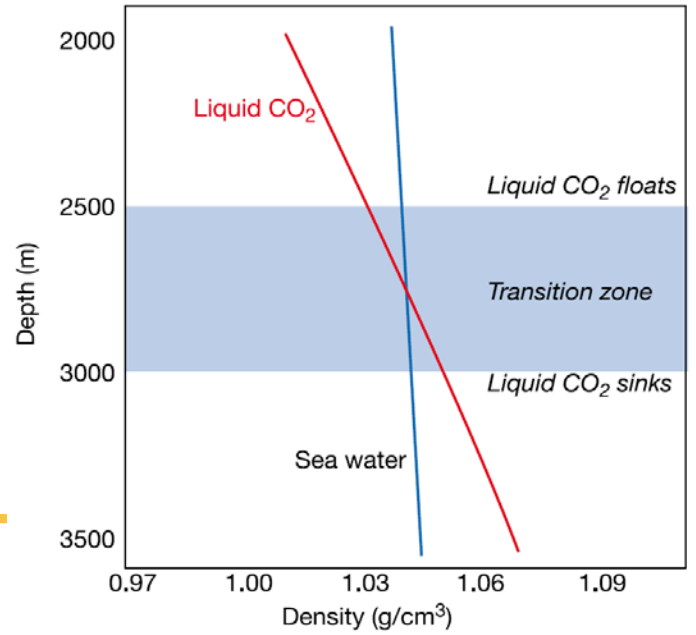
2. Cost-effective conversion of CO_2-hydrate into permanent CO_2 storage

- Deep-ocean liquid CO_2 lake
- Reaction with basalt rock (carbonate neutralization)

CO_2-hydrate ⇌ CO_2 + n H_2O

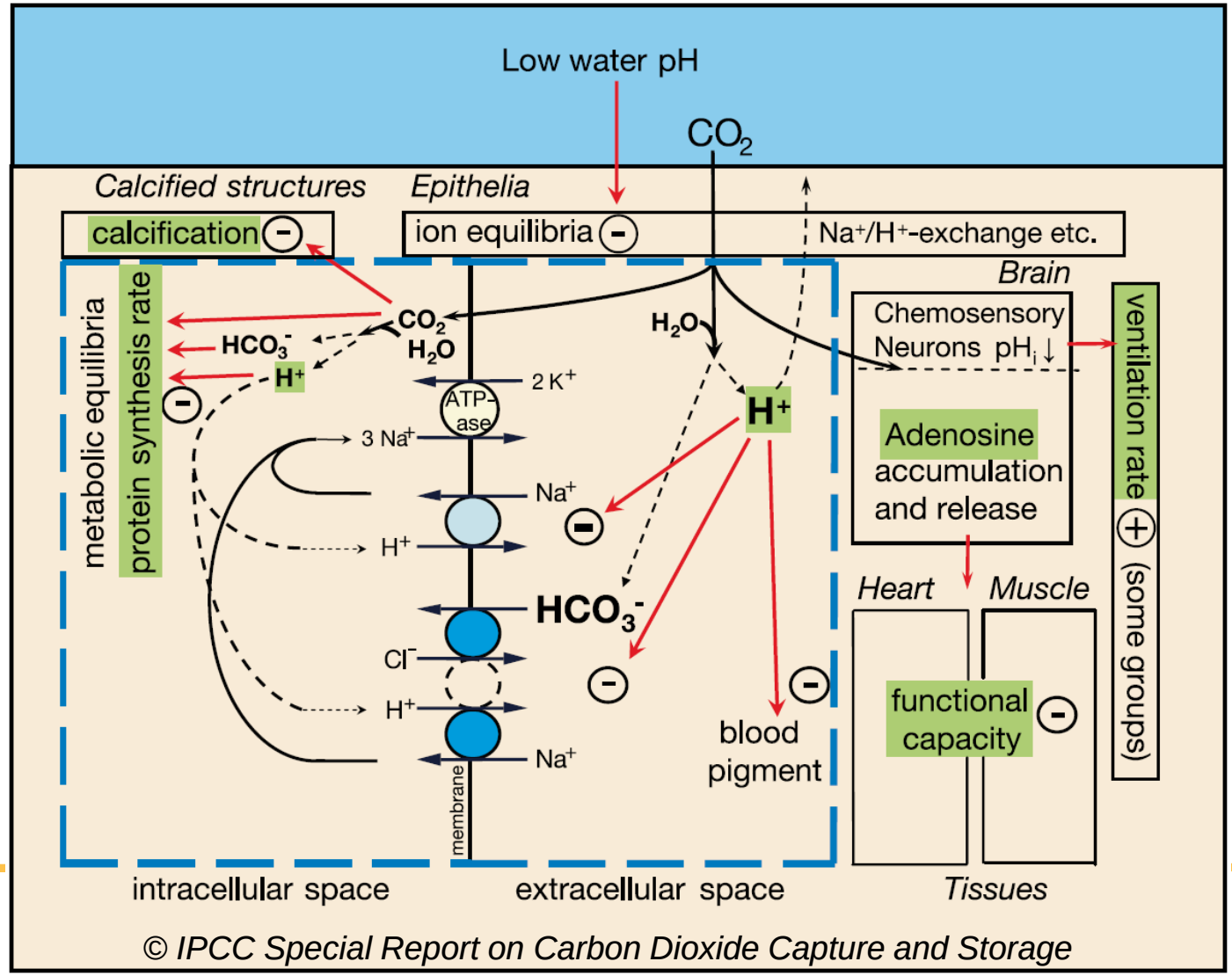
(CH_4-hydrate ⇌ CH_4 + n H_2O)





What needs to be done?

3. Careful study of the effect of ocean floor CO_2 on ocean chemistry



Summary: Carbon neutral production of NH_3

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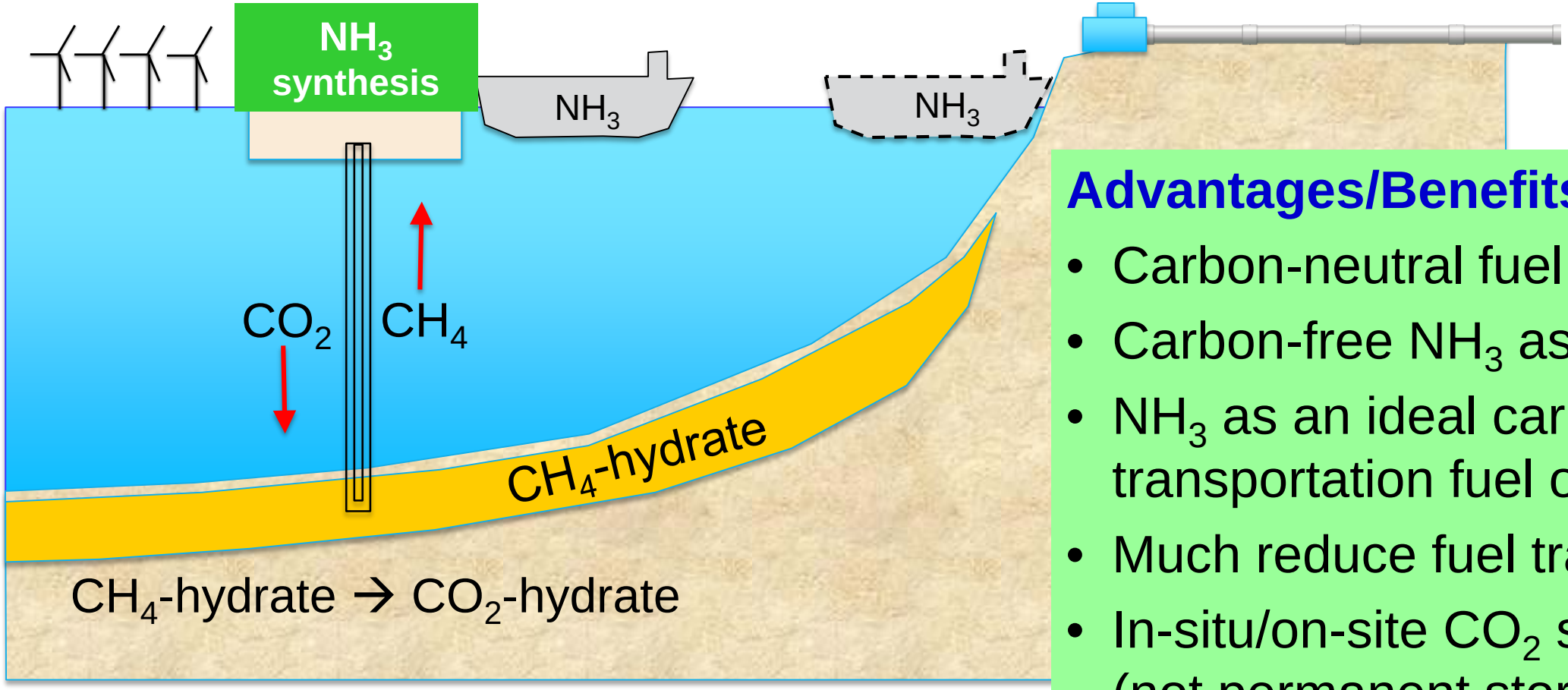

Advantages/Benefits:

- Carbon-neutral fuel production
- Carbon-free NH_3 as a clean fuel
- NH_3 as an ideal carbon-free transportation fuel of the future
- Much reduce fuel transport cost
- In-situ/on-site CO_2 sequestration (not permanent storage yet)