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NATURAL GAS HYDRATE
Problem Solver and Resource for Production and Transport

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Presentation

- Early 80's and Early 90's
- Non-Pipeline Technologies
- NTNU-Aker Solutions, R&D
- Early New Century, Mitsui Enters
- NGH Technology Now Ready

Early 80's

"… the first time I heard about hydrates was at a brown bag seminar at Stanford in the early 80's, when Muz Standing told us about problems in pipes on the North Slope of Alaska …"

Early 90's

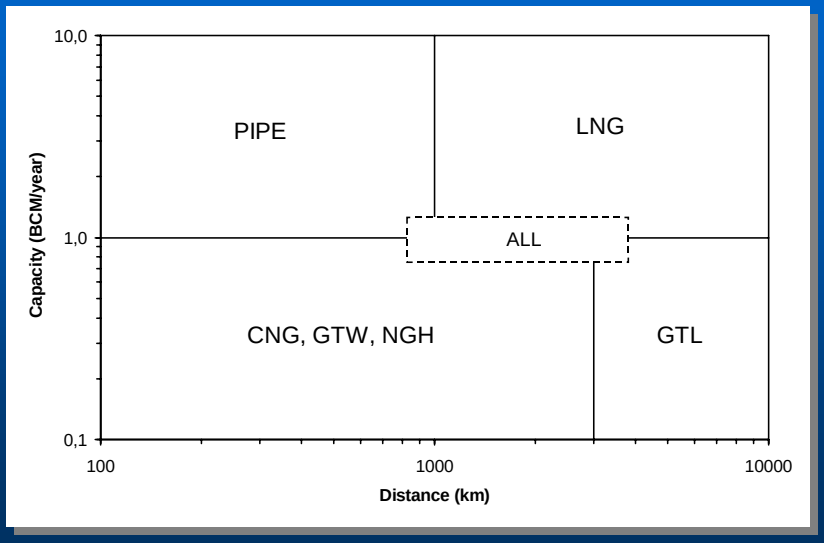
"… when I came to NTH in 1989, the local newspaper was full of news about stranded gas offshore Mid-Norway … after a hike in the woods with my two sons, I started my hydrate work by calculations where an ice layer contained hydrate as a particle, …

Non-Pipeline Technologies

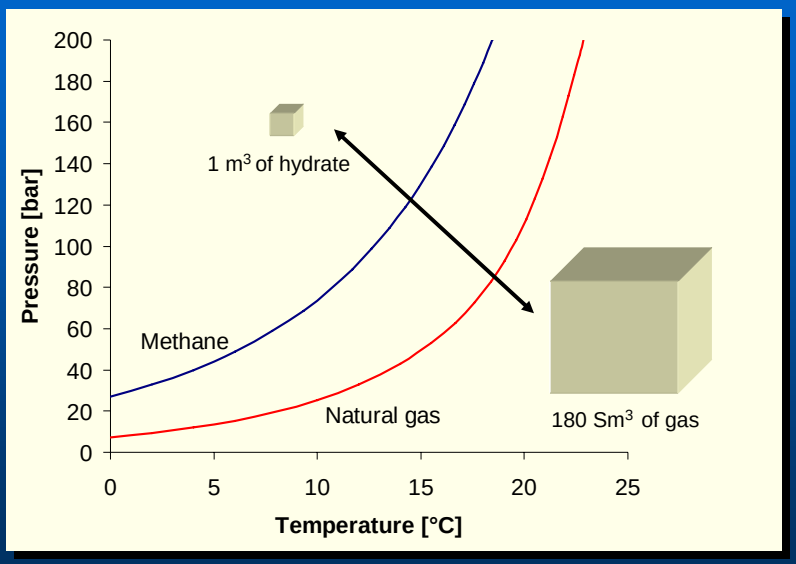
- **CNG** Compressed Natural Gas
- **GTL** Gas-to-Liquid (incl. MOH)
- **GTW** Gas-to-Wire (DC and AC)
- **LNG** Liquefied Natural Gas
- **NGH** Natural Gas Hydrate

CAPACITY-DISTANCE DIAGRAM

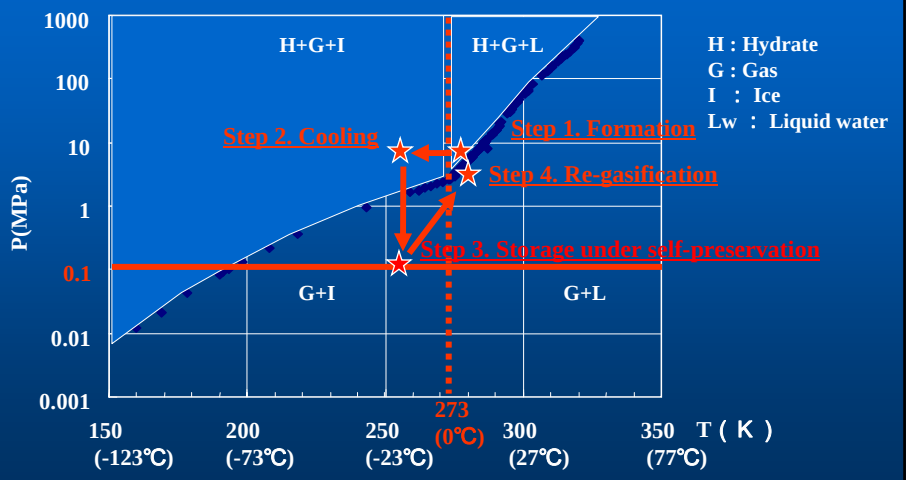
Gudmundsson and Mork (2001)



NGH = Natural Gas + Water



Process Conditions of NGH System on Equilibrium Curve of Methane Gas Hydrate



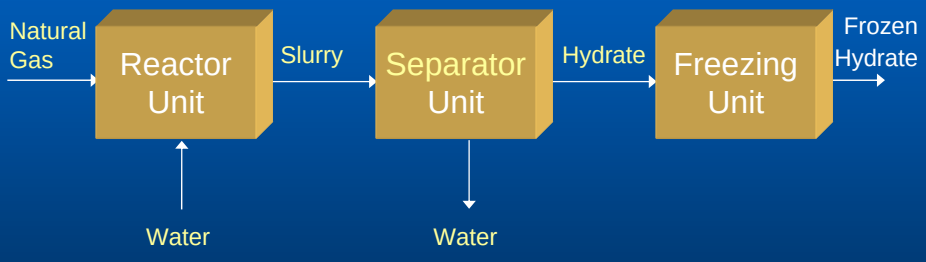
Iwasaki et al. 2005 (ICGH)

NGH Technology Milestones

- NTH (NTNU) demonstrates meta-stability of NGH when below freezing point of water
- Meta-stable NGH suitable for storage and transport of associated gas and non-associated gas
- Aker Kværner estimates cost of NGH ¼ lower than cost of large-scale LNG (seawater temperature 5 C)
- Several oil companies support R&D in Norway on NGH technology for stranded gas
- Aker Kværner and NTNU co-operate to develop NGH technology; carry out studies for oil companies
- Several Japanese corporations investigate NGH production technology and shipping
- Mitsui identifies importance of standardized NGH pellets and built a demonstration plant

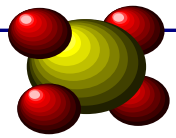
Production of Hydrates

Industrial Process



Capital cost of NGH and LNG chains for 400 MMscf/d production and transport over 3500 nautical miles. Million US dollars mid-1995.

Chain	LNG	NGH	Difference
Production	1220 (51%)	792 (44%)	428 (35%)
Carriers	750 (32%)	704 (39%)	46 (6%)
Regasification	400 (17%)	317 (17%)	83 (21%)
Total	2370 (100%)	1813 (100%)	557 (24%)



PIPE, GTL, LNG, NGH
Capex vs. Distance

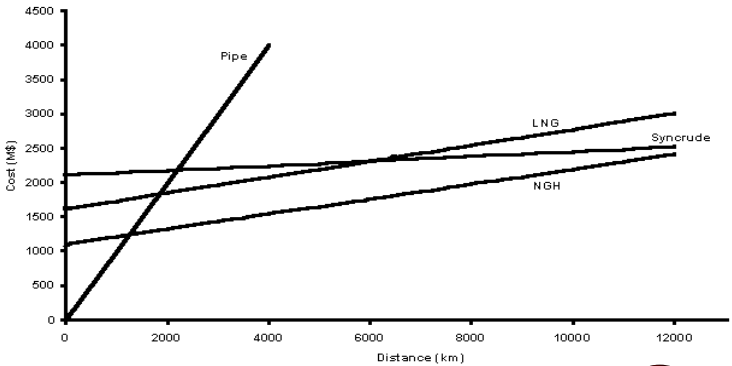
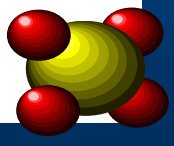
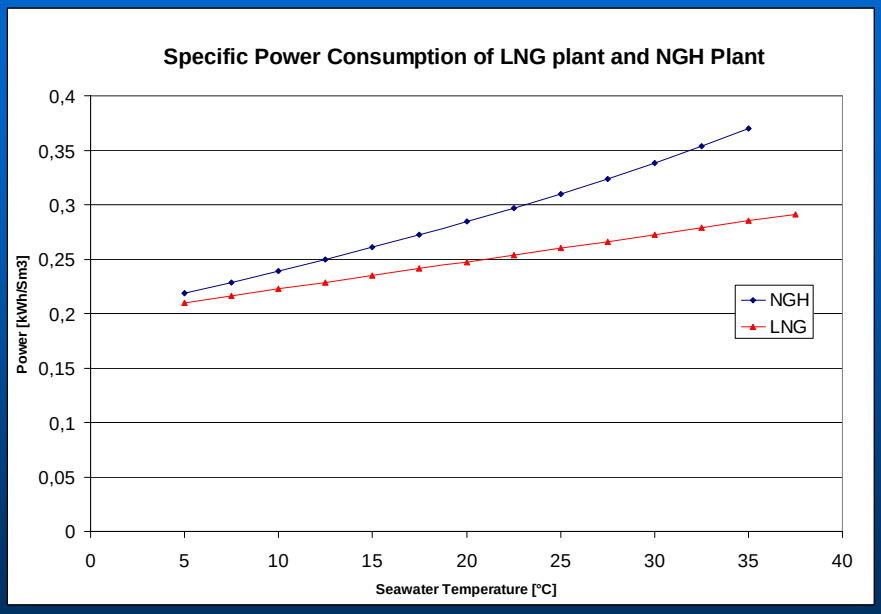


Figure 1 Approximate capital cost with transport distance, dry-hydrate case.





Capital cost of NGH and LNG chains for 400 MMscfs production and transport over 3243 nautical miles (6000 km). Cooling water temperature 35 C (5 C in 1996 study).
Million US dollars mid-2002 (Aker Kværner Technology AS)

Chain	LNG	NGH	Difference
Production	1144 (55%)	992 (54%)	152 (13%)
Carriers	660 (32%)	628 (34%)	32 (5%)
Regasification	285 (13%)	218 (12%)	67 (24%)
Total	2089 (100%)	1838 (100%)	251 (12%)

NTNU's Hydrate Laboratory, Trondheim, Norway

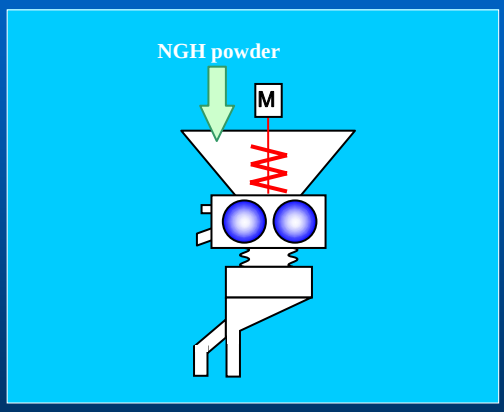
Early New Century

"… Japanese companies embraced the NGH concept and hydrate meta-stability (self preservation); made considerable R&D progress, including hydrate pellets, and are now in forefront to commercialize NGH technology in a few years…

Mitsui's Hydrate Pilot Plant, Chiba, Japan

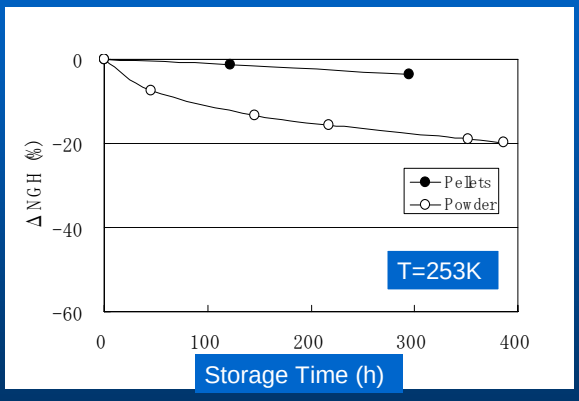
STANDARDIZED PELLETS
Mitsui Engineering & Shipbuilding

Mitsui Twin Roll Pelletizer



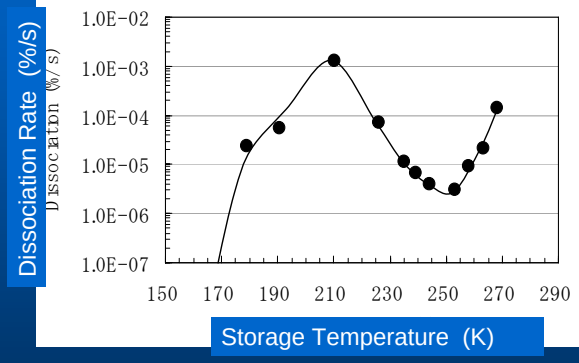
Iwasaki et al. 2005 (ICGH)

Storage stability of NGH pellet



Iwasaki et al. 2005 (ICGH)

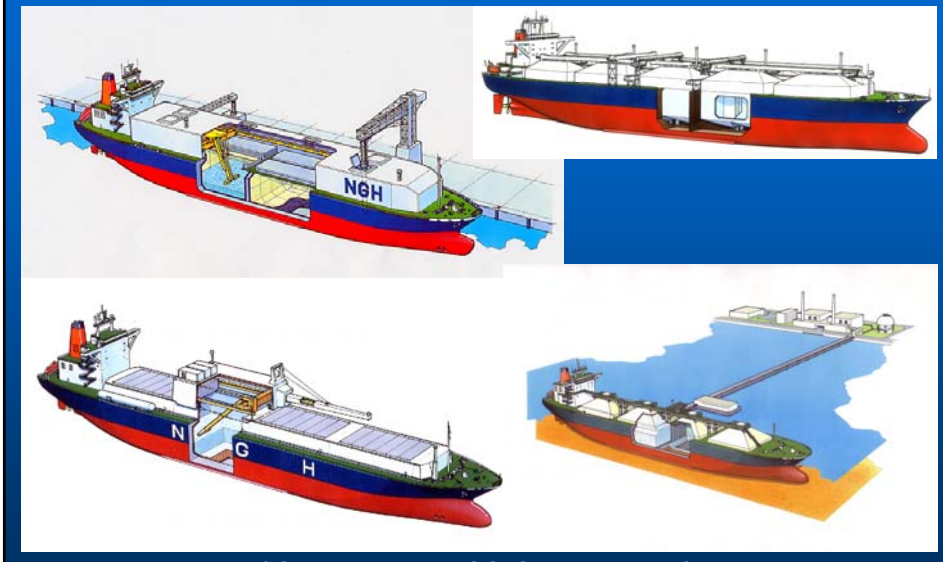
Verification Test on NGH Pellet
(Dissociation Characteristics of Methane Hydrate Pellet)



Dissociation of NGH Pellet is suppressed at around 250K.

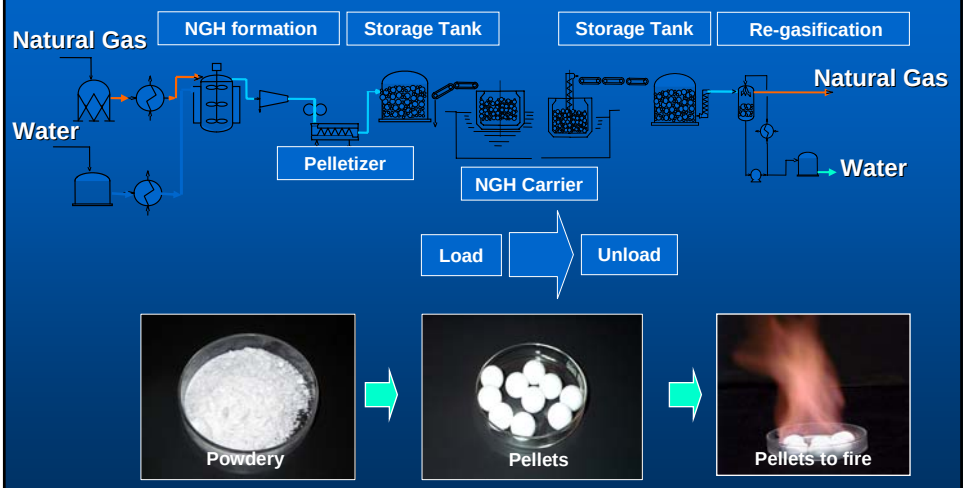
Iwasaki et al. 2005 (ICGH)

Images of NGH carriers

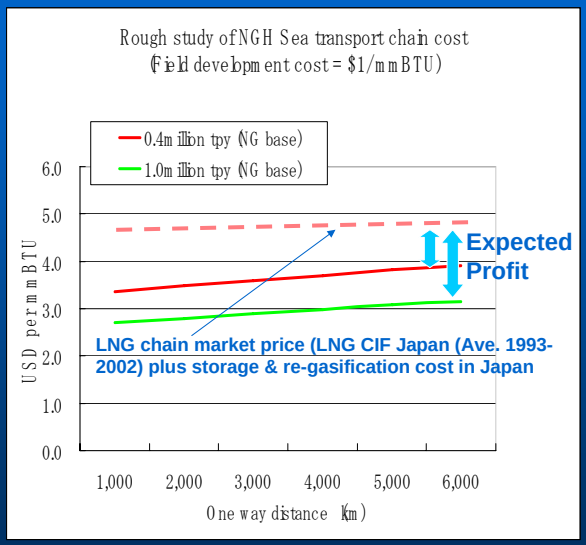


Source; 2001-03 JRTT/Phase-1, Conceptual design on NGH carrier

Natural gas sea transport chain with NGH pellets



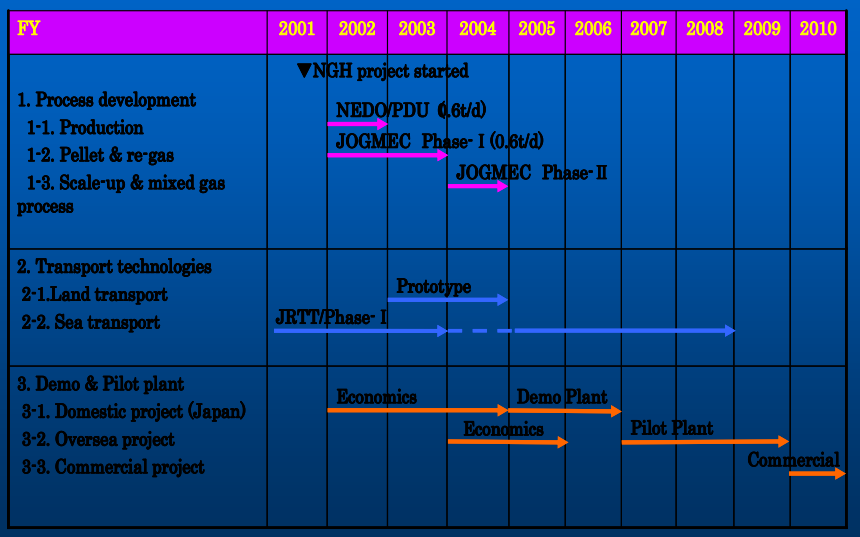
NGH sea transport chain cost has competitiveness compared with LNG



NGH system becomes more profitable than LNG system in medium/small size and short distance transport project.

Notes;
Average Japan CIF from 1993 until 2002 is amounted for $3.8 per mmBTU (BP2003) .

Mitsui Time Line



Iwasaki et al. 2005 (ICGH)

Concluding Remarks

- NGH technology feasible for storage and transport of natural gas
- NGH technology developed in Norway with public and industry funding, also in Japan
- NGH technology now demonstrated for continuous production, transport and re-gasification
- NGH technology soon to be commercial, but without the participation of Norway