TECHNOLOGY

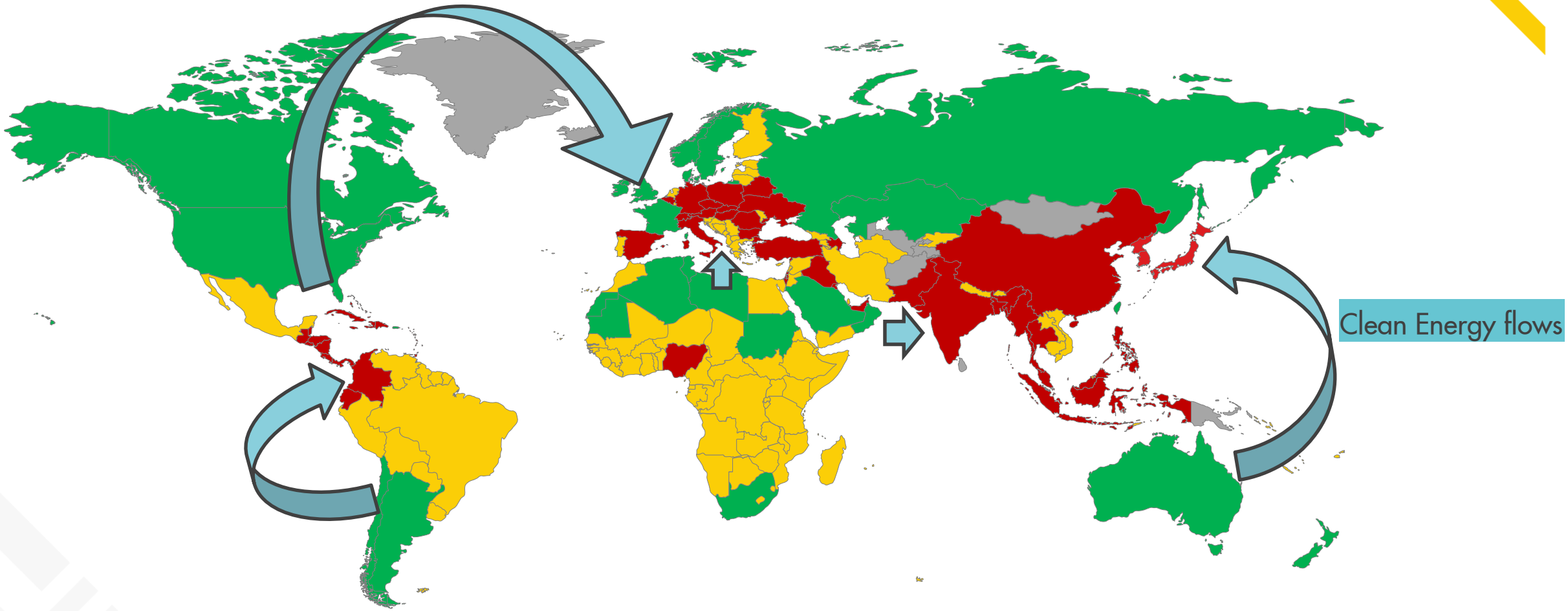
US

IMPACT

Liquid Hydrogen – A carbon free complementary to LNG

NIKUNJ GUPTA
Team & Portfolio Lead – Hydrogen Value Chains

Hydrogen is needed to move energy without carbon



Potentially renewable energy short

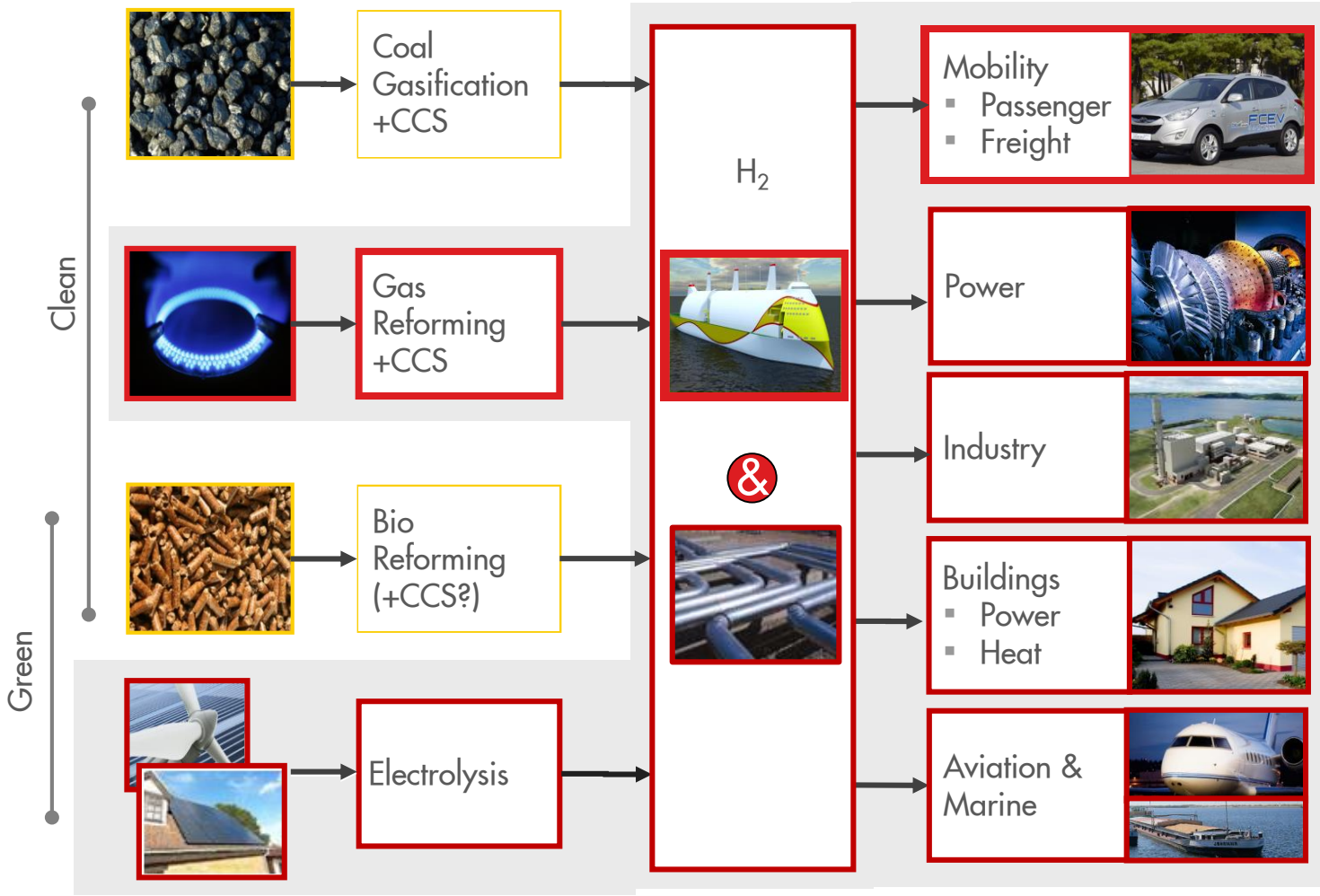
As well to decarbonize "difficult" segments

Heavy Duty Transport

Industry

Marine

Global Hydrogen Supply Chains



Benefits

- Higher efficiency
- Higher range than BeV

- Easily blended in gas turbine
- No need for CCS at plant

- Only real clean solution

- Distributed power, limiting grid investments

- Clean
- Higher efficiency

LH_2 basic advantage for clean energy transport & storage

GH_2 @700 Bar

1.67 X

LH_2

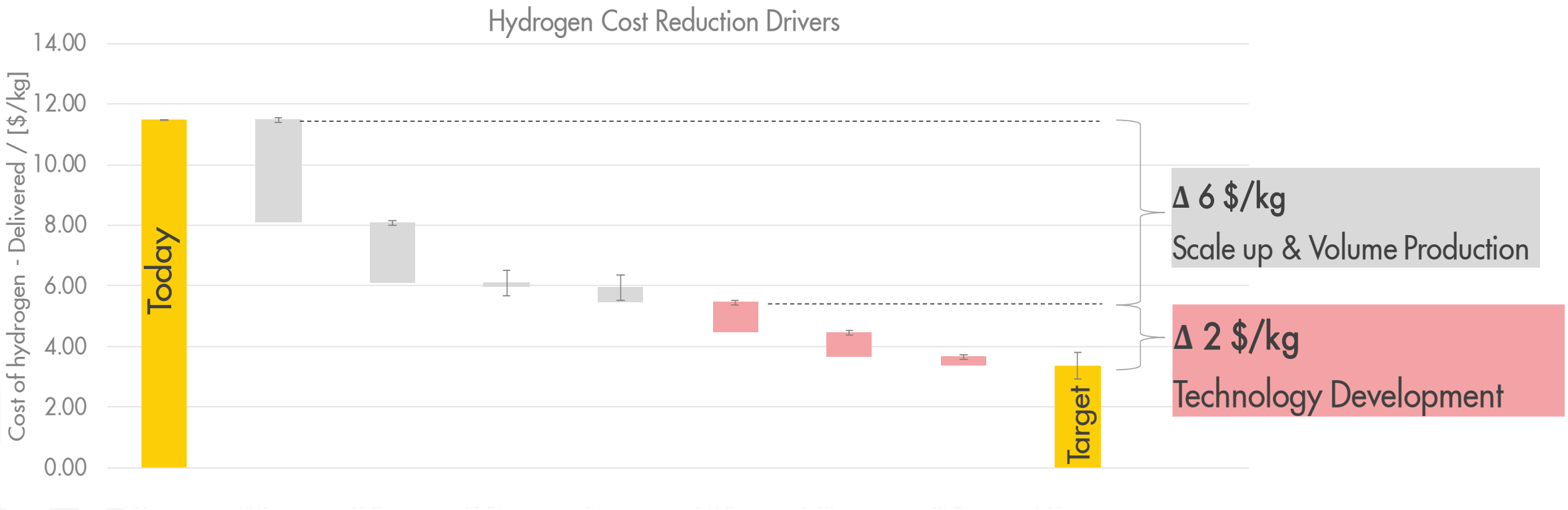
LNG (CH_4)

- Carbon

LH_2

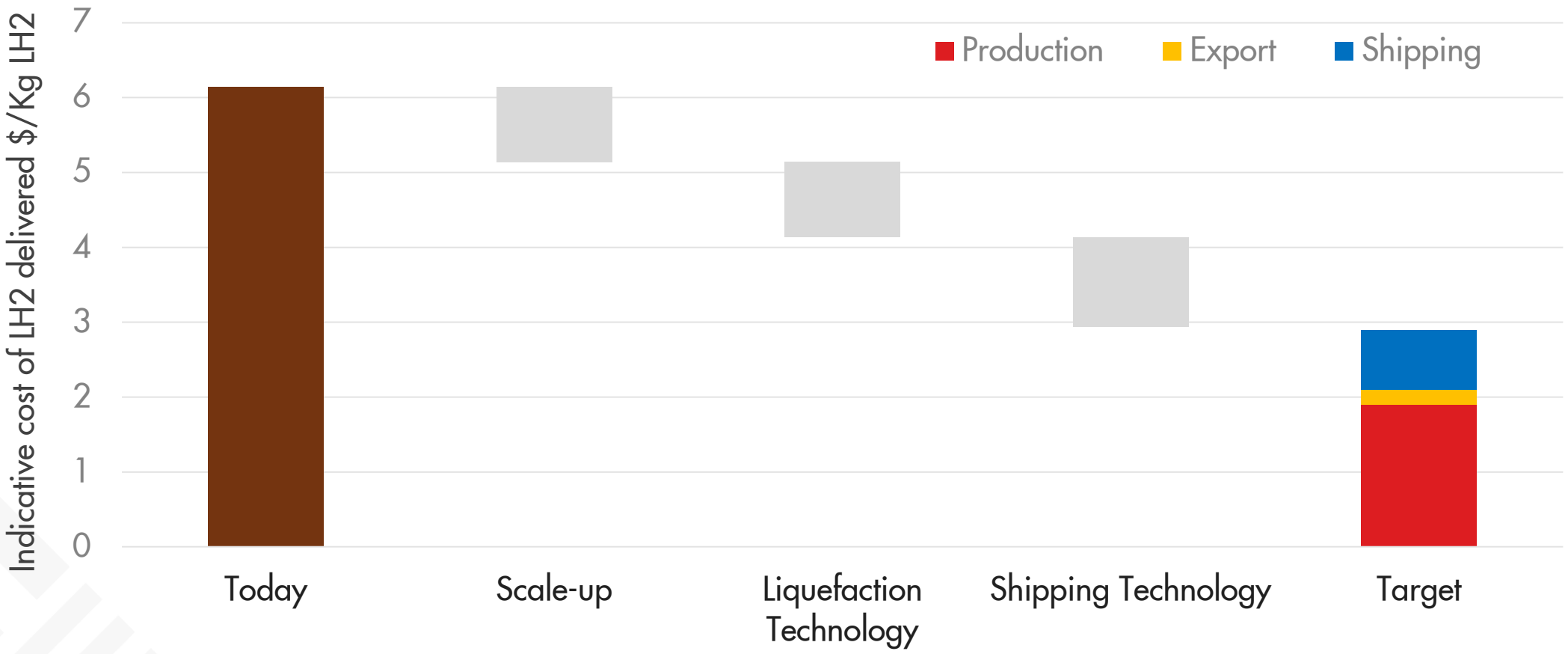
Japan's benchmark for first commercial scale import

Roadmap to $3/kg based on Renewable LH2 imported from Australia

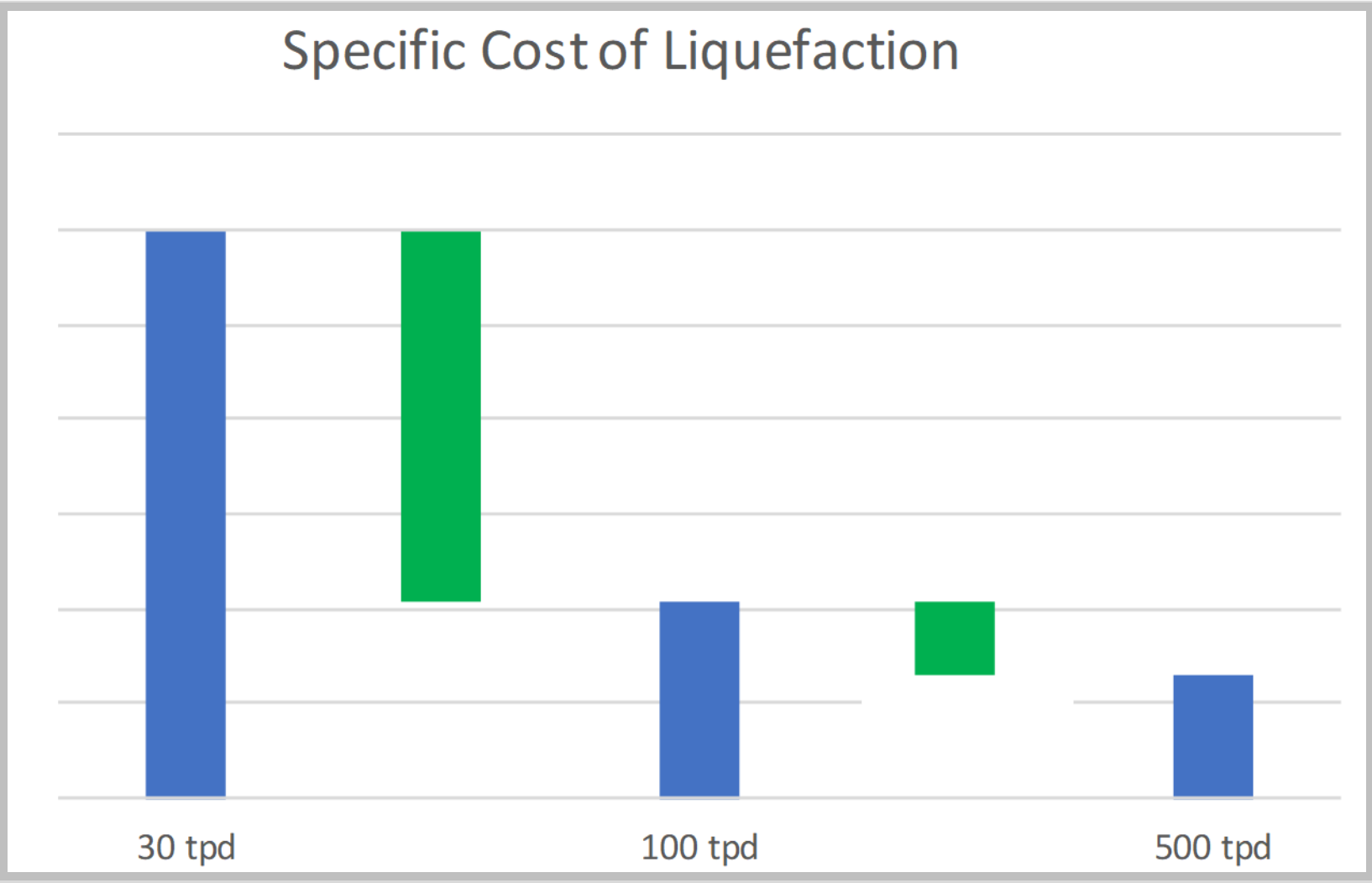


Japan's benchmark for first commercial scale import

Roadmap to $3/kg based on NG+CCS LH2 from USGC



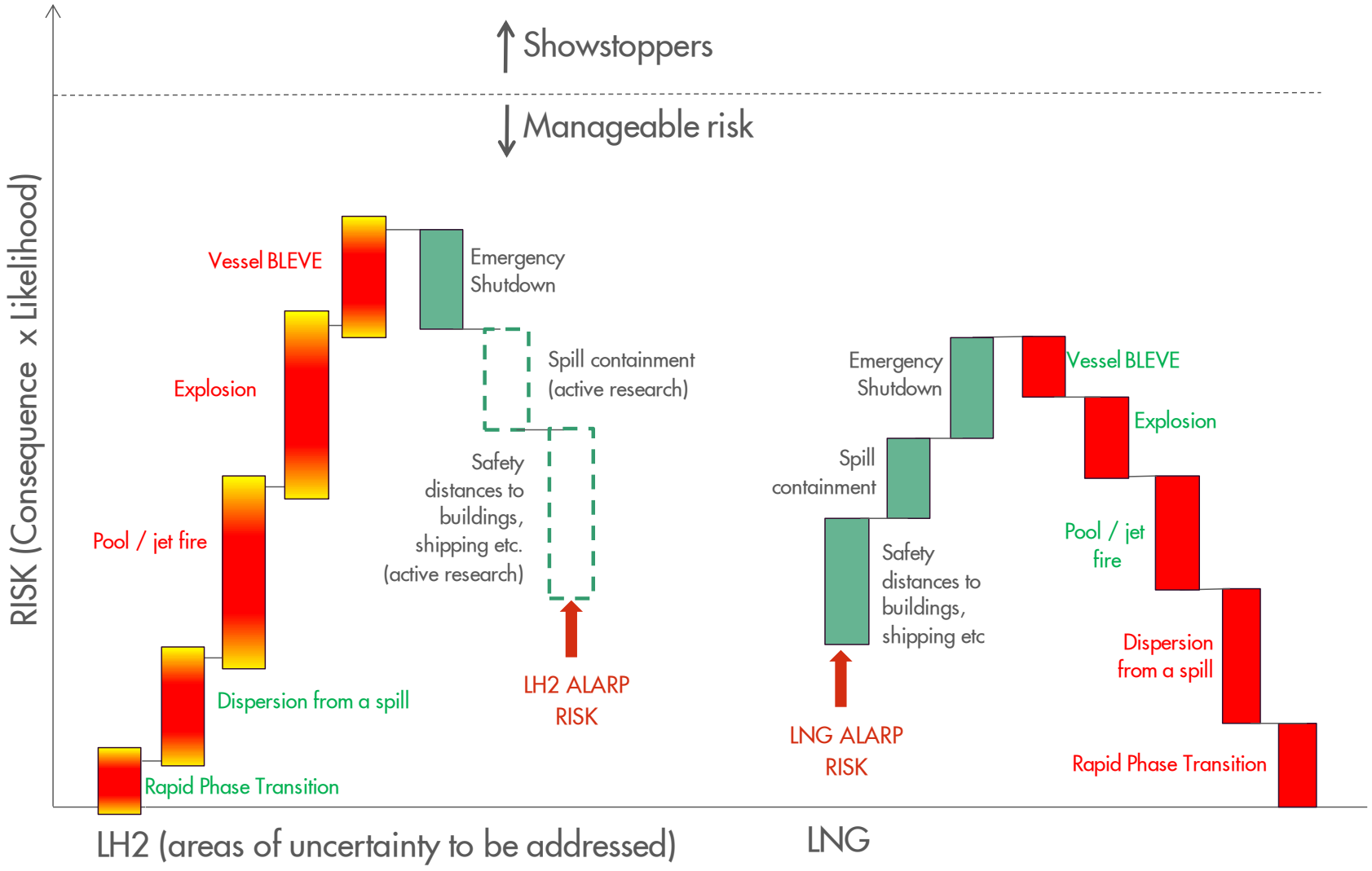
What does Scale-up Bring?



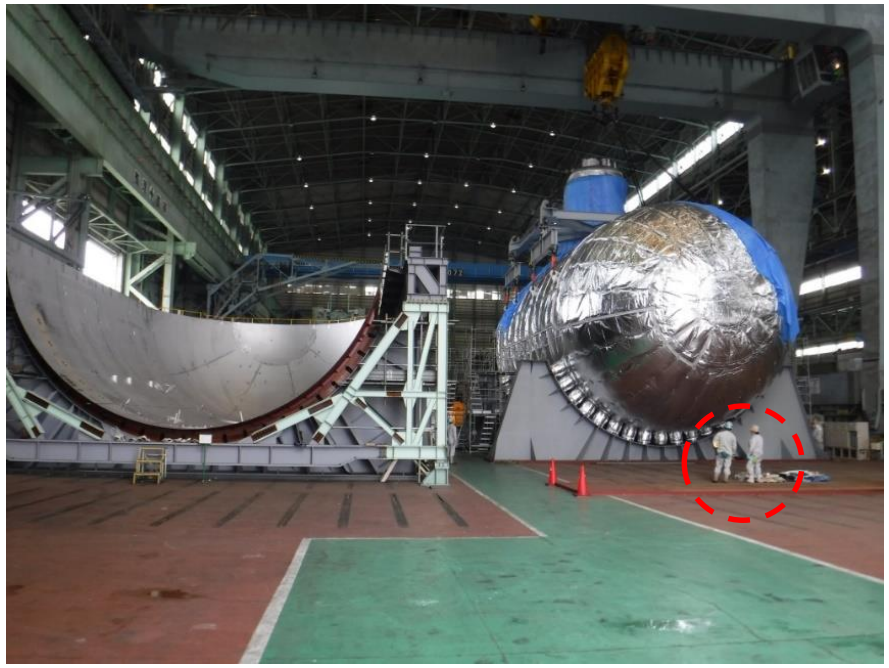
LH_2 Scale up : Technology challenges

	LNG	LH_2 (Current)
Safety	No major incidents	Entirely different molecule, lack of experience
Extreme Cryogenics [New Materials & Equipment]	120K	20K
Boiloff Rate (BOR) [Insulation Technology]	<1%/day	6-8X more
Cost of Shipping [>20,000m3 LH2 tank]	<$0.2/Kg LH2 Eq	> $2/Kg LH2
Affordable Large Scale Liquefaction [5 -> 500 ton/d]	<$0.4/Kg LH2 eq.	> $2/Kg Lh2

LH_2 assessed to be higher safety risk than LNG, but manageable



LH_2 Containment Tech Development



HySTRA Ship Tank: 1250 m3

40-50X

Large LNG cargo tank: 50000 m3

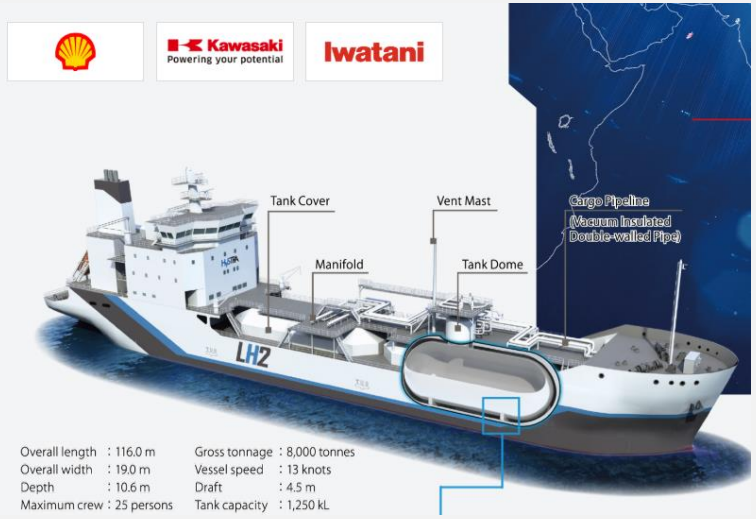
Key Challenges: Cost ← Boil off ← **Insulation v/s structural strength**

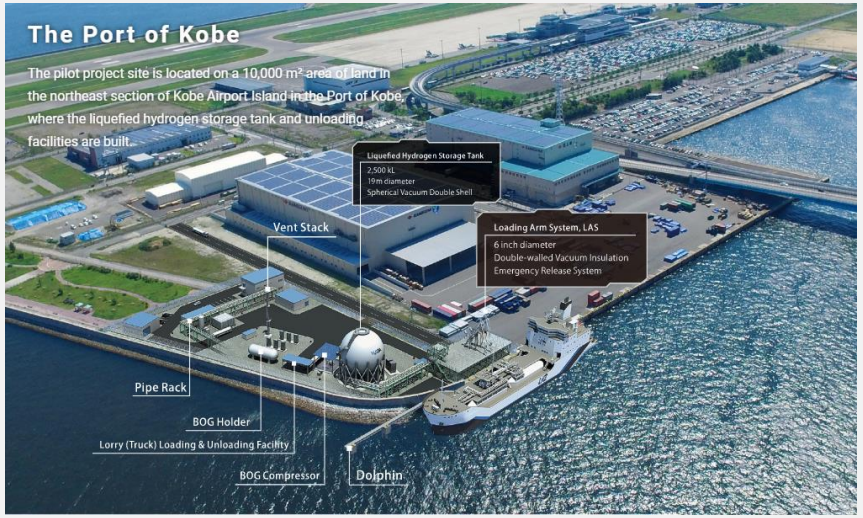
HySTRA JV: pioneering LH_2 Shipping

Kawasaki
Powering your potential

Iwatani

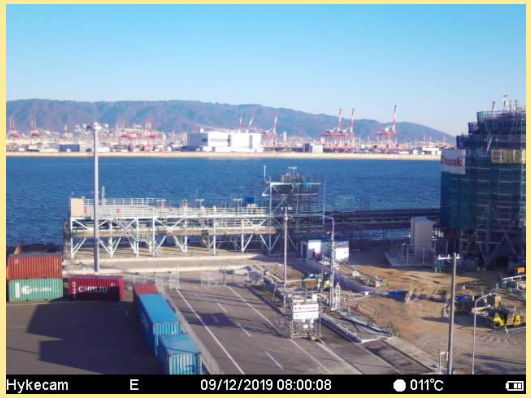
HySTRA ASSETS…. IN CONSTRUCTION





Artist Renditions

Actuals



Liquefaction Scale-up Tech Development

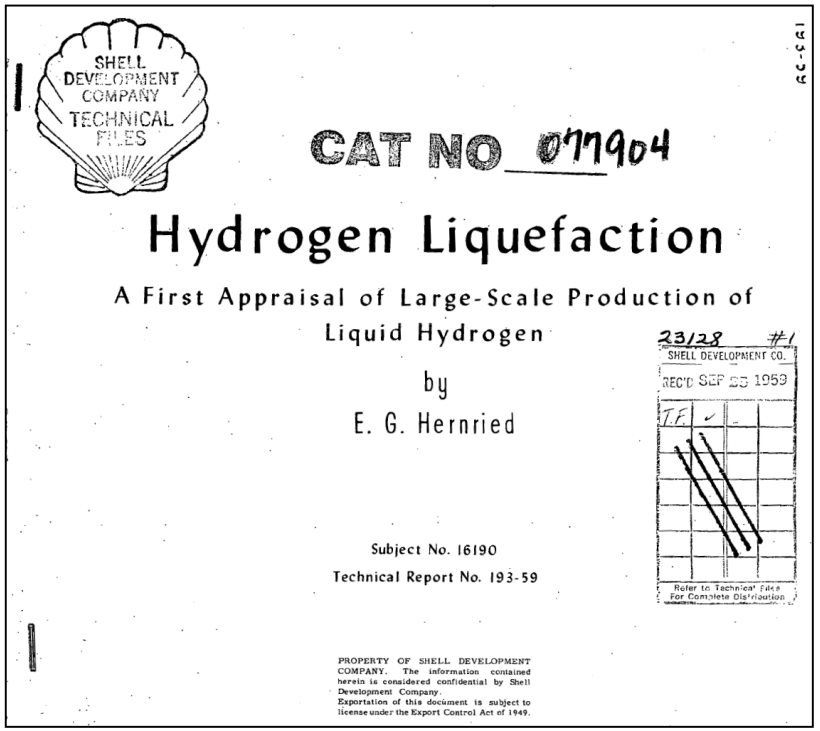
Current: 5 tons/day

40 - 100X

Needed: 200-500 tons/day

Key Challenges: Cost ← Scale-up ← **Insulation, Turbo machinery, HEXs**

Shell and LH2 technology



SHELL DEVELOPMENT COMPANY TECHNICAL FILES

CAT NO 077904

Hydrogen Liquefaction

A First Appraisal of Large-Scale Production of Liquid Hydrogen

by

E. G. Hernried

23128 #1

SHELL DEVELOPMENT CO.

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Subject No. 16190

Technical Report No. 193-59

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- Earliest work dates back to 1959
- 2000 – Shell Hydrogen business

Recent activities focused on large scale

2011 – 2013	IdealHy consortium. Enabling Economically viable LH2 technology: 100 tpd LH2 liquefaction capacity with higher energy efficiency (on paper)
2013 - 2021 –	Hystra consortium: Development of the first liquid hydrogen bulk liquid carrier.
2016 – 2019	Hyper consortium. Large scale low cost liquefaction (500 tpd) out of Norway. (4 trains of 125 tpd)

LH2 safety related consortia

Preslhy	Pre normative research
SH2IFT	RPT/BLEVE of LH2 containers