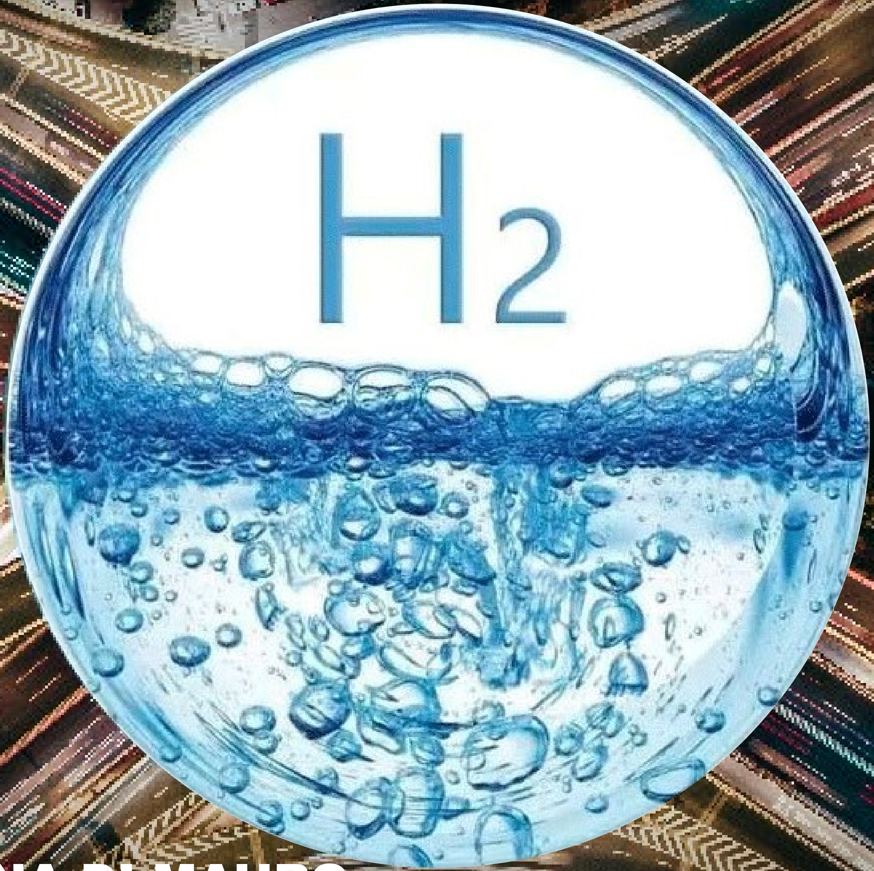
HYDROGEN ECONOMY
BANKABLE HYDROGEN TRANSPORT PROJECTS



MIKE MCBRIDE AND VALENTINA DI MAURO

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Honeywell
UOP

Mike McBride
BD & IPS
Honeywell UOP
Michael.McBride2@Honeywell.com

Valentina Di Mauro
Director BD LOHC
Honeywell UOP
Valentina.DiMauro@Honeywell.com

Honeywell
UOP

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BANKABLE INVESTMENT - TODAY

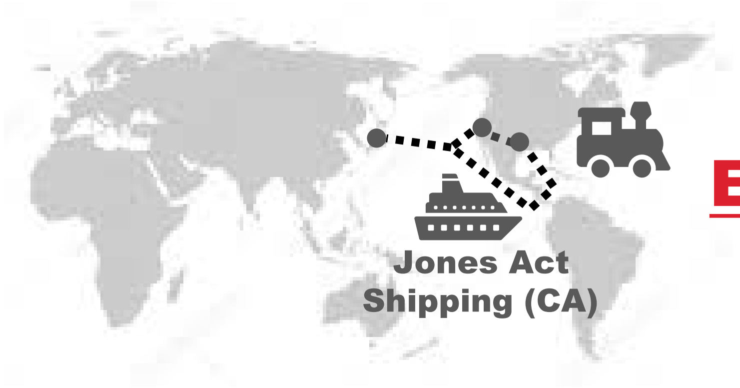
BLUE H_2 USGC TO JAPAN OR CALIFORNIA

USGC

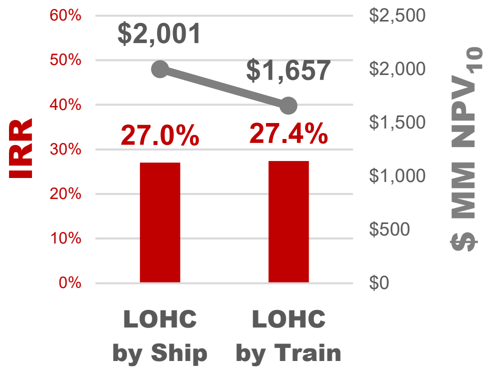
Blue Hydrogen

Japan

California



LOHC is Bankable



Enables Decarbonization

Comparable CO_2 footprint to electric vehicles

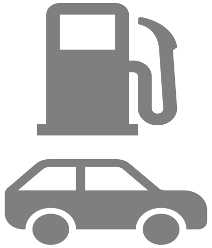
Bankable LOHC investment opportunity

1. Economics shown for 120 MMSCFD blue H_2 investment in USGC and LOHC transport to CA at $9.kg offtake; and includes Jones Act shipping penalties of $3.5/bbl (each way for LOHC), which is needed when not US based shipping owned / built / operated when moving materials from one place in the US to another
2. LCA assessment shows on a per mile driven basis, blue hydrogen made in USGC and transported via LOHC to Japan or California results in comparable CO_2/mile for electric vehicles operating on today's electric grids at today's charge/mileage efficiency in both locations

EXISTING H_2 INFRASTRUCTURE

READY FOR HYDROGEN

Japan



H_2 FCVs
Fuel Cell Vehicles

California

Has:

- 161 operational H_2 fueling stations

Plans:

- 1,000 H_2 fueling stations by 2030
- Grow FCVs from 8k to 800k by 2030

Has:

- 56 operational H_2 fueling stations

Plans:

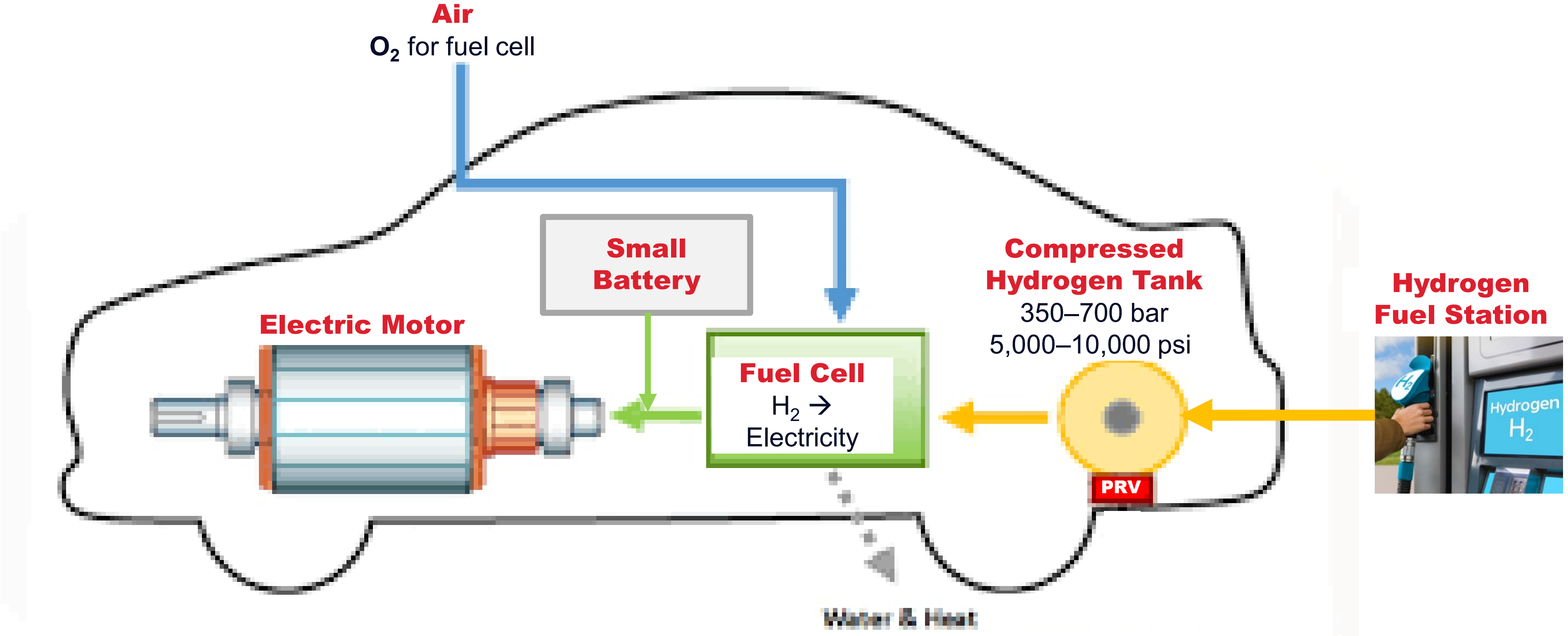
- 200+ H_2 fueling stations by 2030
- Grow FCVs from 12k to 3.6 MM by 2030

Hydrogen infrastructure well underway – needs H_2

1. Japan to spur clean hydrogen with $20 B in subsidies" Nikkei Asia Jan 30, 2024
2. California hydrogen filling stations exist in high density zones with greater than 50% of their vehicles (bay area and greater LA and a few between); assuming each station can support 18k vehicles per year (12 fill stations at 60% utilization with 6 min fill time and transition; and 12.5kmiles per year at 72 miles/kg hydrogen with 5 kg tank load)

HYDROGEN FUEL CELL VEHICLES (FCVs)
HOW DO THEY WORK?

FCVs have 2X energy efficiency vs ICEs



Reverse electrolysis: $H_2 + O_2 \rightarrow H_2O$ + Electricity

1. PRV = Pressure Relief Valve
2. Small battery: recover deceleration power to assist in acceleration power – nickel metal battery
3. The H_2 fuel cell system can use 60% of the fuel's energy—corresponding to more than a 50% reduction in fuel consumption compared to a conventional vehicle with a gasoline internal combustion engine.

TOYOTA MIRAI

CURRENT H_2 FCV WITH NO SUBSIDIES

2024 Mirai

Starting MSRP $50,190

HONDA 2025 SUV FCV

H_2 FUEL CELL VEHICLES

WHAT H_2 PRICE COMPETES WITH GASOLINE?

- Toyota Mirai gets 72 miles/kg of H_2 (360-mile range)
- Typical car gets 30 miles/gallon of gasoline

$5.07/gallon gasoline

LA County April 2024

$12/kg H_2 CA Breakeven

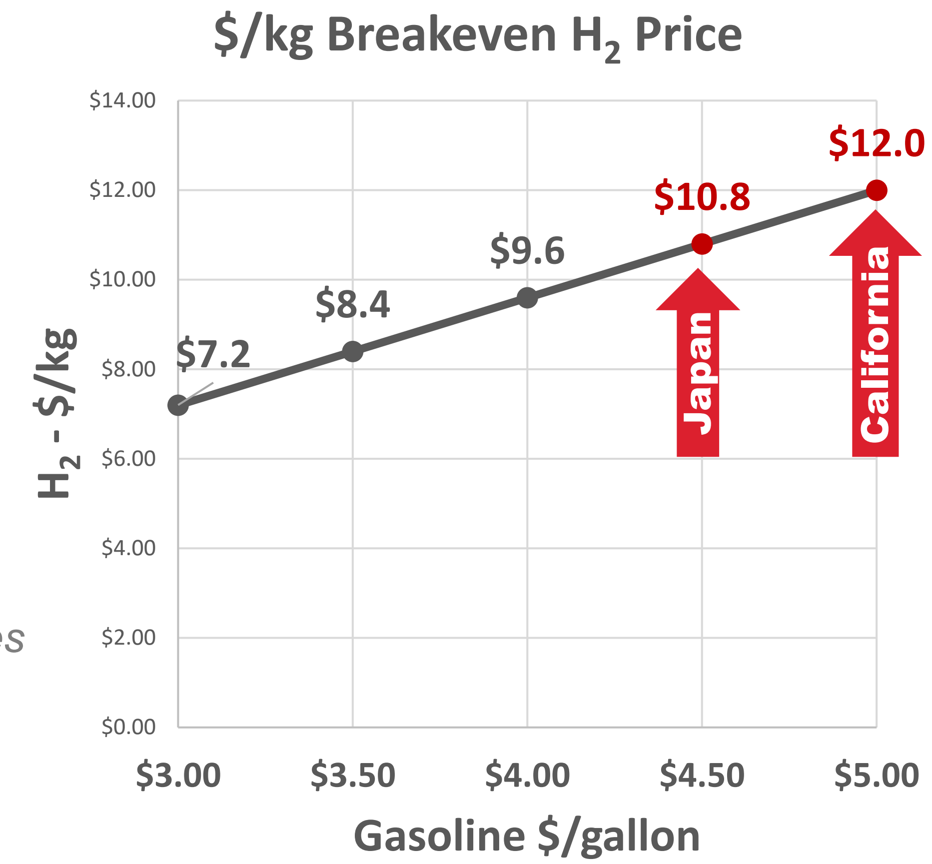
($5.07/gallon x 1 gallon/30 miles x 72 miles/kg H_2)

175 Yen/liter gasoline

Japan Jan 2024

$11/kg H_2 JP Breakeven

($4.48/gallon x 1 gallon/30 miles x 72 miles/kg H_2)

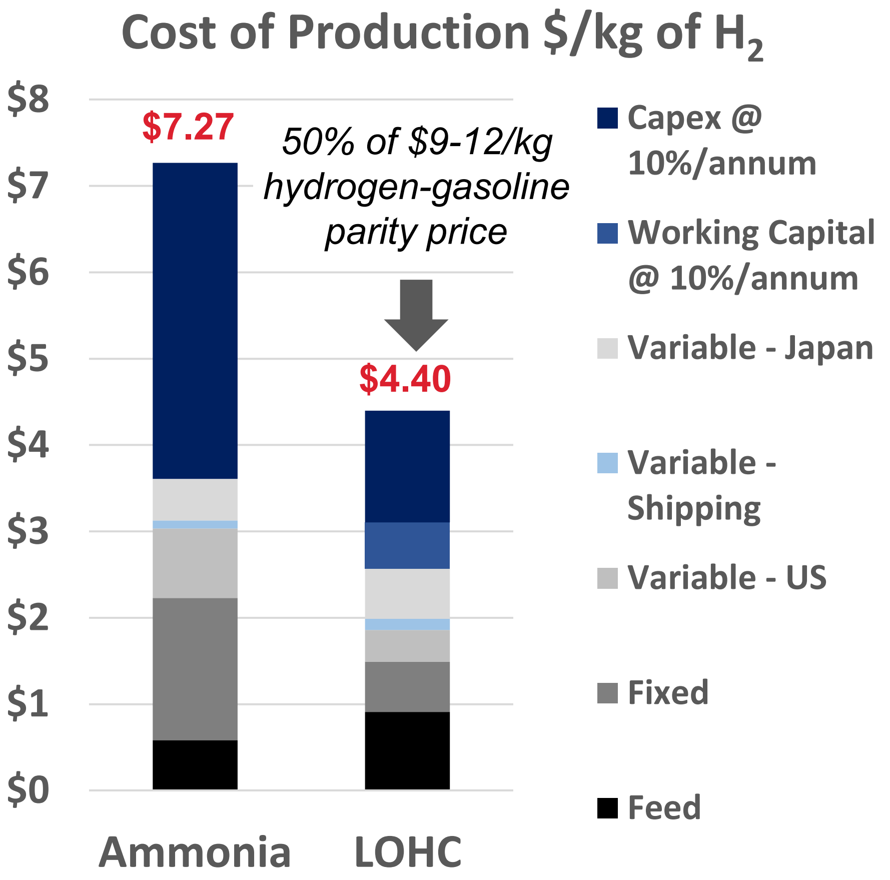


Consumers should be willing to pay $9 - 12 / kg hydrogen – sets the bar

CASE STUDY - BLUE H_2 USGC TO JAPAN

$5 – 7 / KG H_2 OFFTAKE CREATES VIABLE LOHC WITH 10 - 20% IRR

- Does not include any capital subsidies from Japan
- Does not include any IRA incentives beyond $80/t CO_2 capture incentives
- Includes estimated capex and opex based on
  - Hydrogen plant with conventional CO_2 capture & compression to pipeline specifications
  - $20/tonne CO_2 tolling for short pipeline & storage
  - Converting H_2 into carrier molecule
  - Purchase and operation of ships + one spare
  - Working capital inventory for toluene
  - Converting carrier molecule back into H_2
  - Tankage and other OSBL needs
  - Toluene make-up @ 4% of feed rate – for losses

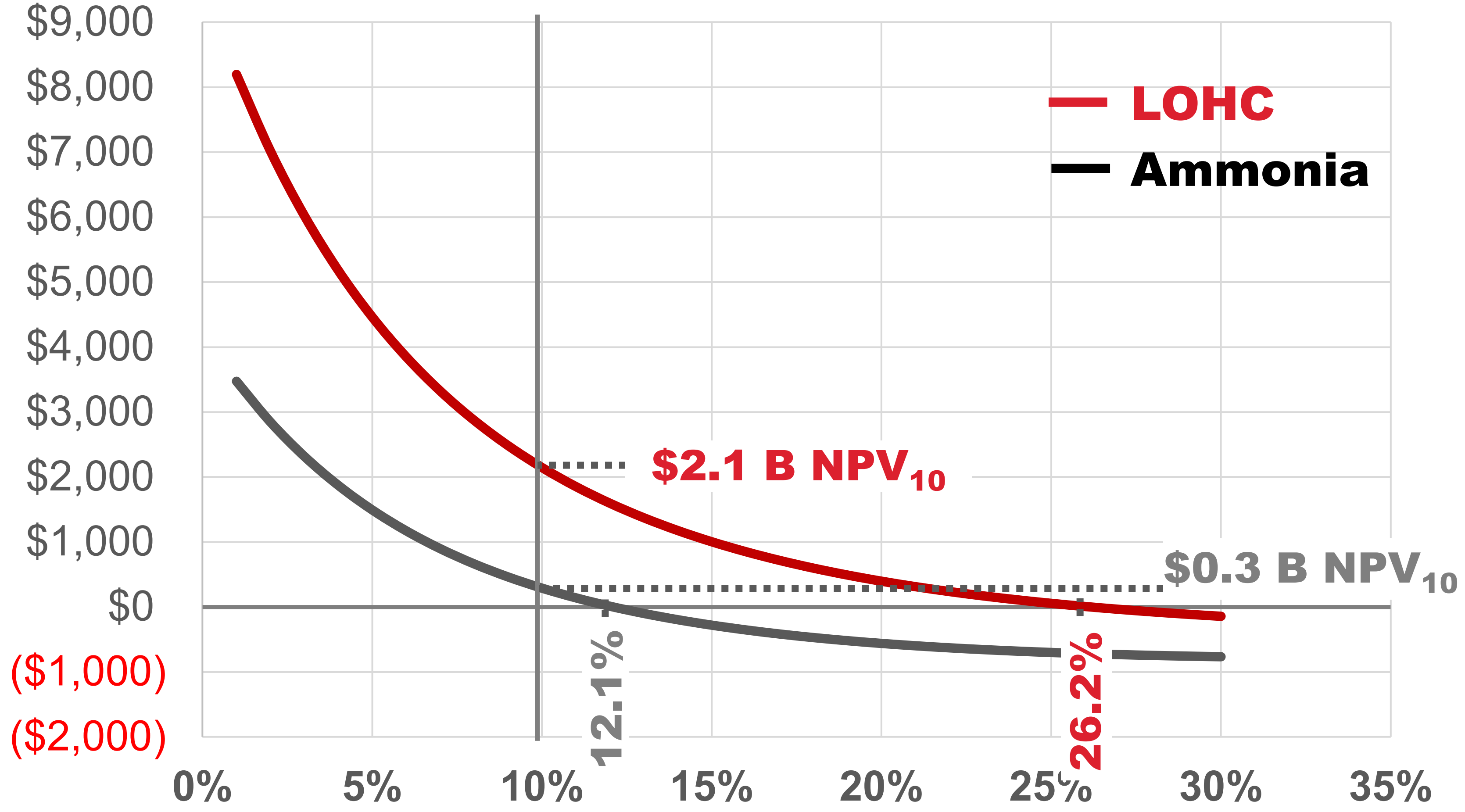


LOHC delivers lowest cost blue hydrogen from US to Japan – BANKABLE!

1. Feed cost of production calculations only includes portion of natural gas used to make H_2, and toluene make-up – remainder of natural gas purchased is considered variable cost of production
2. IRA – USA Inflation Reduction Act

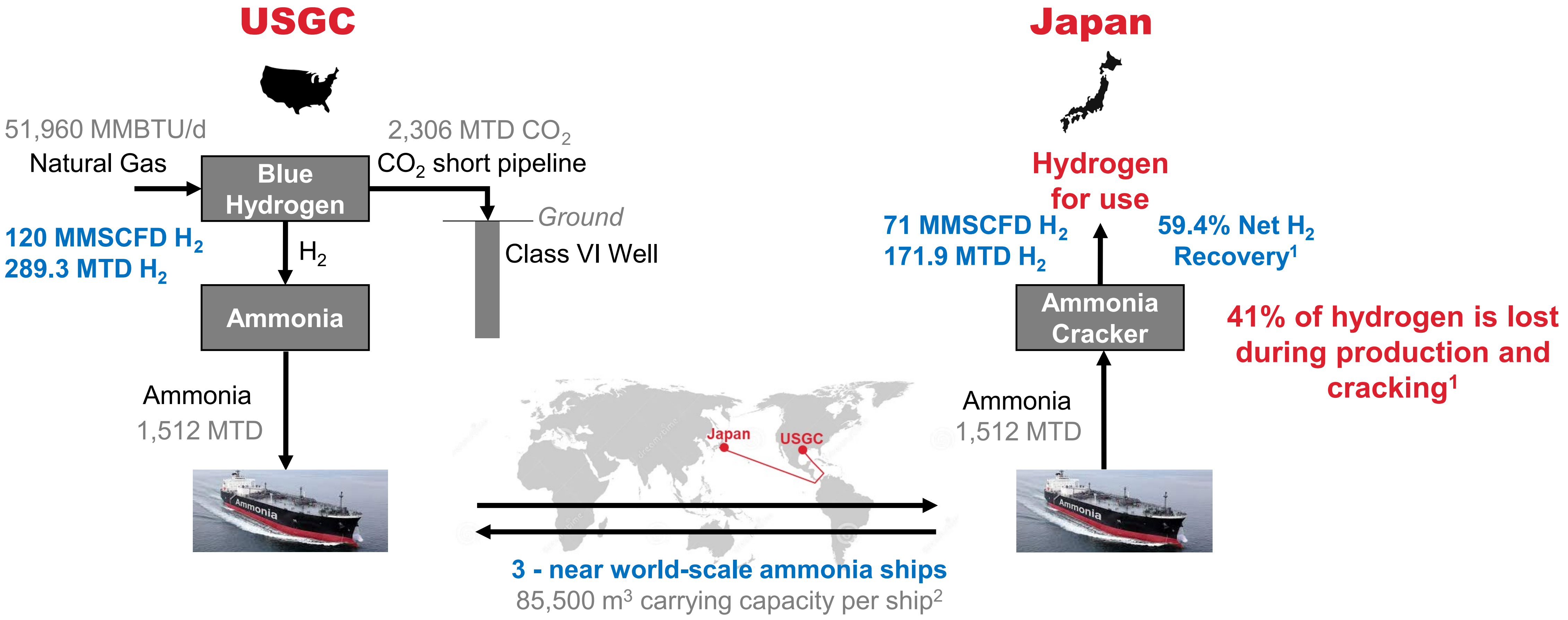
RESULTS - BLUE H_2 USGC TO JAPAN

NPV $MM VS. DISCOUNT RATE @ $9 / KG H_2 OFF-TAKE



LOHC delivers $1.8 billion improvement in NPV_{10}

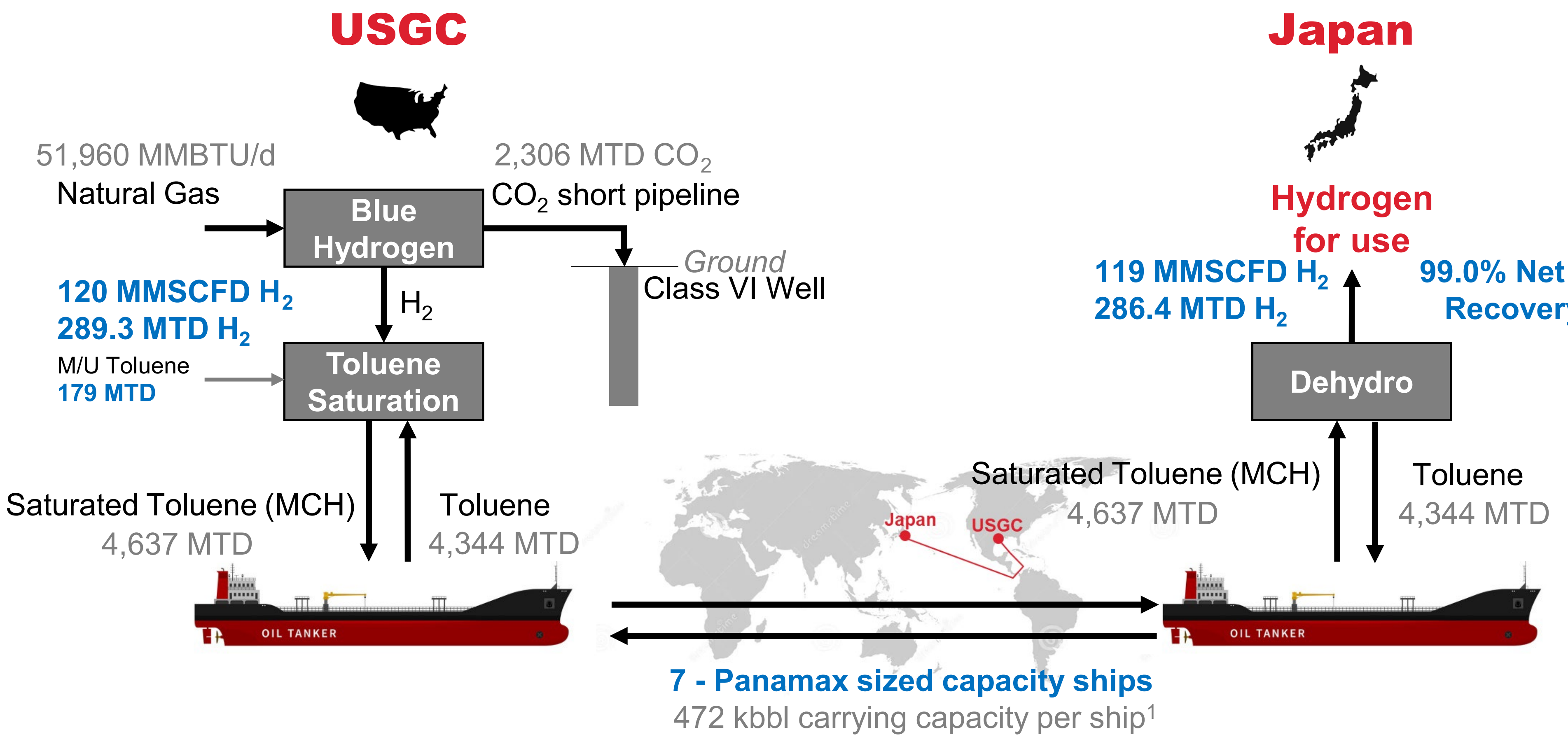
TECHNOLOGY & LOGISTICS OPTIONS
1. AMMONIA AS A HYDROGEN CARRIER



$2.2 billion CapEx, $217 MM/yr OpEx → $373 MM/y NCM, 12% IRR, $0.3 B NPV$_{10}$

1. 93,000 m3 carrying capacity is largest ammonia ship in construction to date; shipping estimates based on 12 knot average speed with 9598 nautical miles one way distance between USGC and Japan…volume set by ammonia load at 0.62 sg, roundtrip calculated at 66.7 days per ship…2 ships on water at given time…extra ship needed for maintenance/OSA…average fuel use estimated at 0.135 tonne of fuel per nautical mile/ship (adjusted for ship size and weight)
2. H_2 losses from ammonia production (~7%) and cracking (~36%) from IHS Markit Hydrogen Deliver Option PRP Report – Dec 2021
3. Economics shown @ $9/kg hydrogen offtake

TECHNOLOGY & LOGISTICS OPTIONS
2. LIQUID ORGANIC HYDROGEN CARRIER



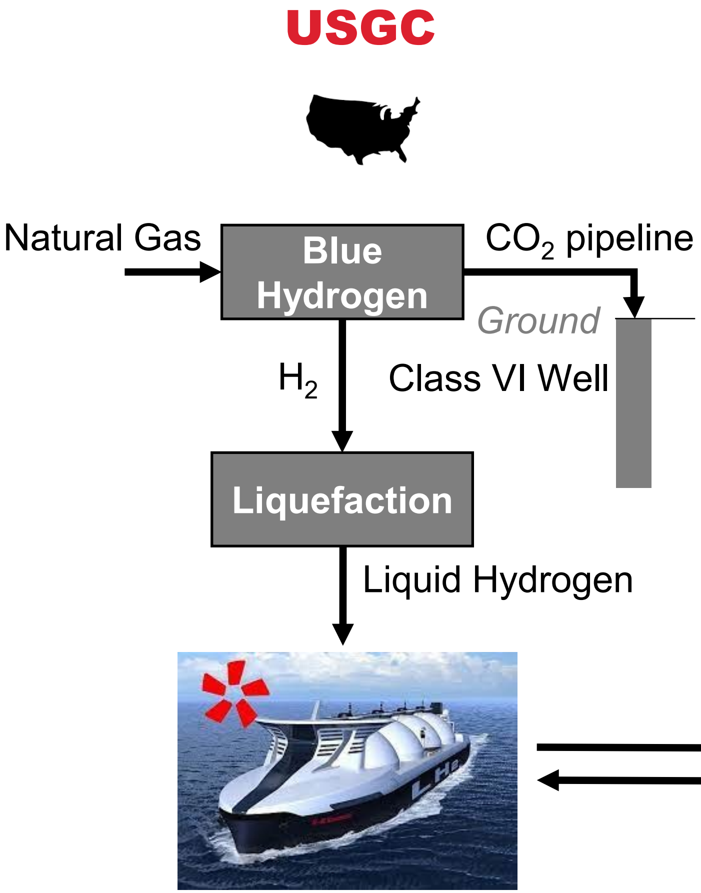
40% better H_2 recovery & 20% lower Capital than Ammonia[2]

LOHC is the more BANKABLE transport option

\$1.8 billion Capital, \$261 MM/y OpEx → \$690 MM/y NCM, 26% IRR, \$2.1 B NPV_{10}

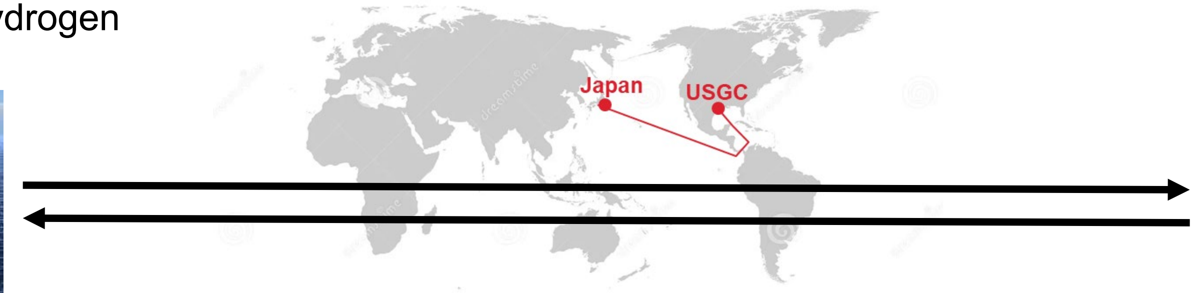
1. Shipping estimates based on 12 knot average speed with 9598 nautical miles one way distance between USGC and Japan…volume set by MCH load, roundtrip calculated at 66.7 days per ship…2 ships on water at given time…extra ship needed for maintenance/OSA…average fuel use estimated at 0.323 tonne of fuel per nautical mile/ship (adjusted for ship size and weight)
2. Net, initial capital includes CapEx and working capital inventory for Toluene (3 ship equivalents with 2 on the water at a given time)
3. Economics shown @ \$9/kg hydrogen offtake

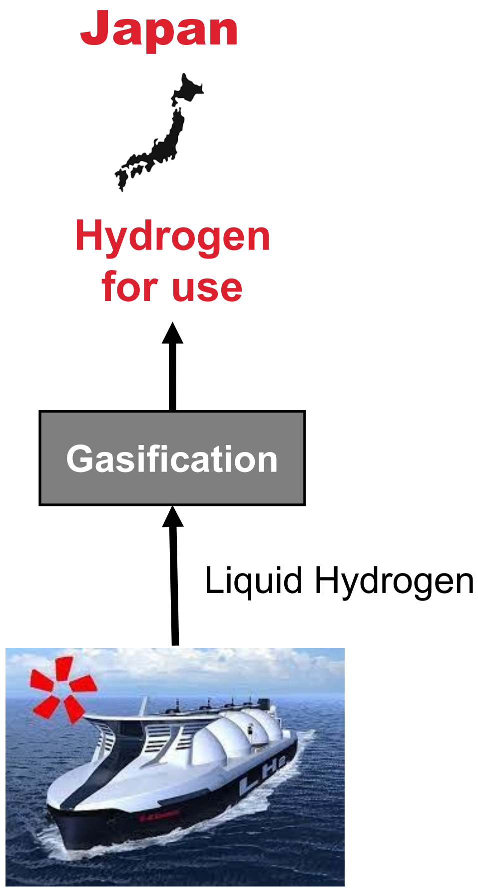
TECHNOLOGY & LOGISTICS OPTIONS
3. HYDROGEN LIQUEFACTION



Not deemed a viable long-term transport option

- Supported by numerous other studies[1]
- High losses (~14% from ME to Japan from one study @ -192°C liquid H_2)
- High costs for shipping/liquefaction
- Excessive process safety risk
- Decision coming down to ammonia vs LOHC if transporting hydrogen





Considered 3rd choice in other studies – not assessed here

1. Other studies include : The Future of Hydrogen, IEA, June 2019; IEA: Ammonia and LOHC will be Cheaper Options for Shipping Hydrogen than Liquefied H_2 - Even with Reconversion Costs, Hydrogen Insight, January 2023; Hydrogen Delivery Options IHS Markit, Dec 2021

CASE STUDY SUMMARY

BLUE H_2 USGC TO JAPAN

LOHC is revolutionizing the hydrogen economy

- Access to regions with low-cost blue hydrogen production capability
- Access to developing CO_2 sequestration hubs
- No need to wait for green hydrogen

	Ammonia	LOHC	LOHC Advantage
NCM, \$MM/y	\$373	\$690	1.8 X
Capital, \$MM	\$2,200	\$1,800	0.8 X
COP, \$/kg H_2	7.27	\$4.40	0.6 X
IRR @ \$9/kg H_2	12.1%	**26.2%**	**BANKABLE**
NPV_{10} @ \$9/kg H_2	\$288	**\$2,145**	

LOHC - bankable investments today

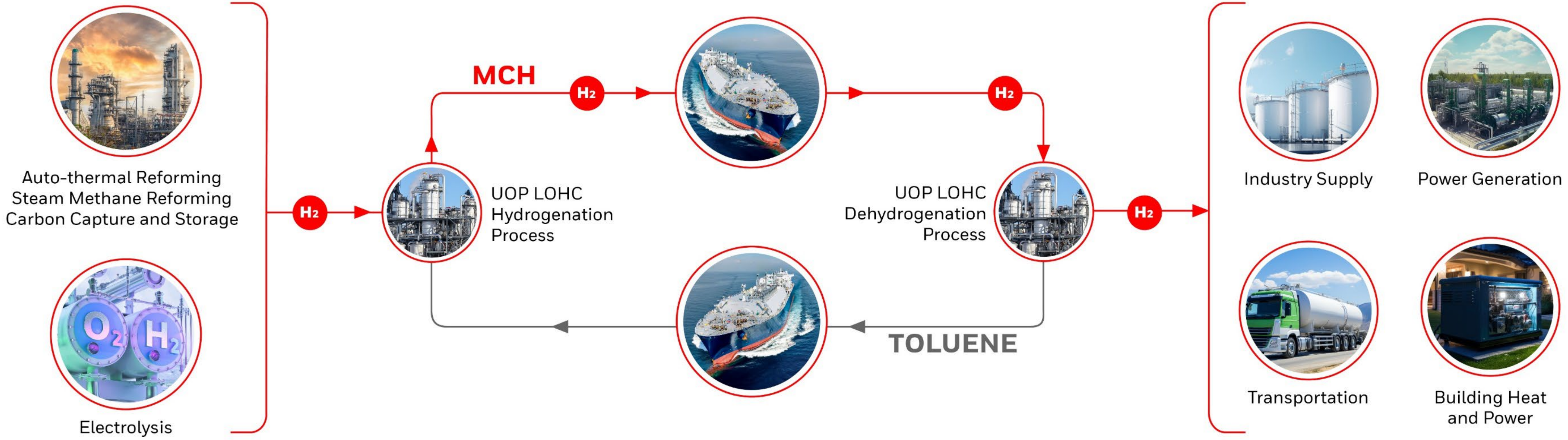
1. Economics shown for 120 MMSCFD blue H_2 SMR plant investment basis

H_2 SOLUTIONS
LOHC COMMERCIAL EXPERIENCE

Honeywell

THE WORLD'S FIRST COMMERCIAL SCALE LIQUID ORGANIC HYDROGEN CARRIER PROJECT

HONEYWELL TECHNOLOGIES ARE HELPING TO BUILD A HYDROGEN POWERED FUTURE



Commercially Proven and Ready at Scale
100 Years of technology expertise and know how

Leverage Existing Infrastructure for Implementation
Seamless project execution to implement grassroots and revamp design options

Industry Leading H_2 Purity and Transport Volume
Independently evaluated by EPC contractors and multiple customers

Single Source Optimization for Import and Export
Minimize project risk with a holistic approach to technology and ownership of the catalyst supply chain

THE WORLD'S FIRST COMMERCIAL SCALE LIQUID ORGANIC HYDROGEN CARRIER PROJECT

HONEYWELL TECHNOLOGIES ARE HELPING TO BUILD A HYDROGEN POWERED FUTURE

"ENEOS, a leading energy company in Japan, will develop the world's first commercial scale LOHC project using Honeywell's solution at multiple sites…"

Commercially Proven and Ready at Scale
100 Years of technology expertise and know how

Leverage Existing Infrastructure for Implementation
Seamless project execution to implement grassroots and revamp design options

Industry Leading H_2 Purity and Transport Volume
Independently evaluated by EPC contractors and multiple customers

Single Source Optimization for Import and Export
Minimize project risk with a holistic approach to technology and ownership of the catalyst supply chain

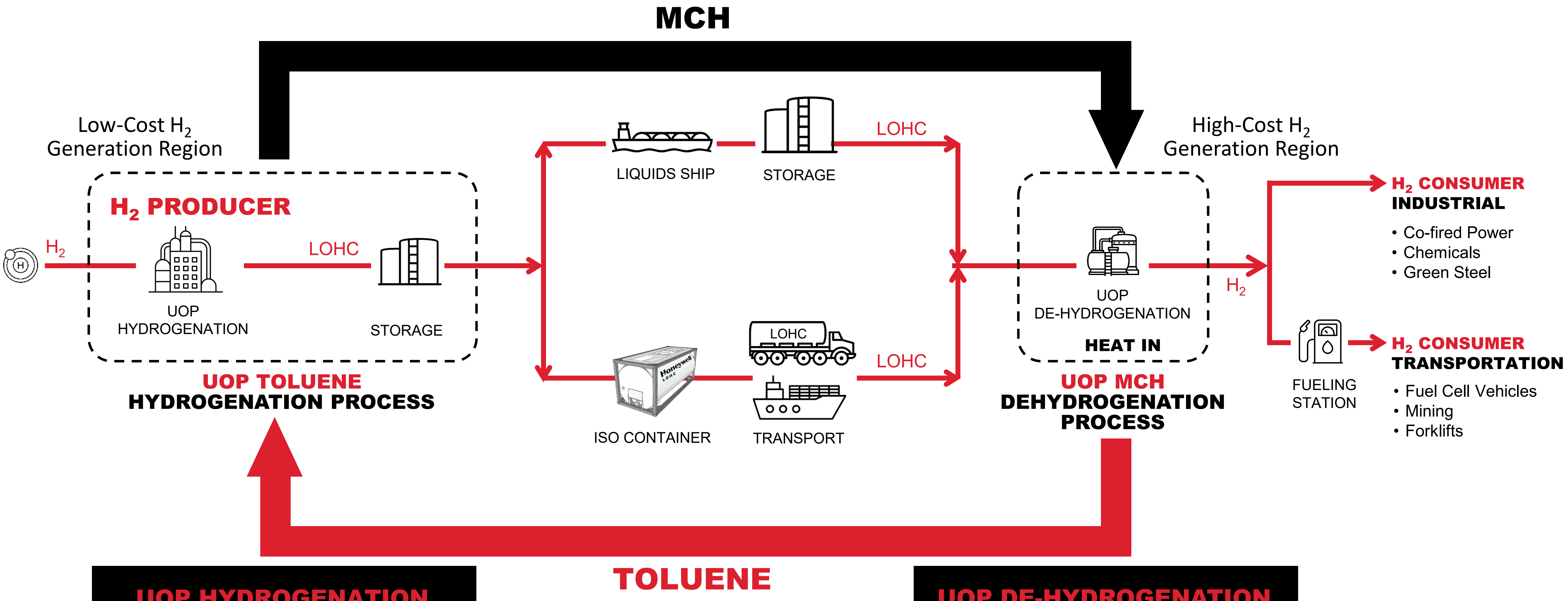
HONEYWELL LOHC

LOWEST RISK OPTION RELATIVE TO COMPARABLE ALTERNATIVES

	Honeywell LOHC (MCH)	LOHC (BT/DBT)	NH_3	Liquid H_2
Technology Readiness at commercial scale	🟢	🔴	🟡	🟢
Carrier availability	🟢	🔴	🟢	–
Liquid at ambient Temperature and Pressure	🟢	🟢	🔴	🔴
Infrastructure	🟢	🟢	🟡	🟡
H_2 Purity	🟢	🟢	🟡	🟢
Retrofit options	🟢	🔴	🔴	🟡
Flammability	🟡	🟢	🟡	🔴
Health Hazard	🟡	🟡	🔴	🔴
Reconversion costs	🟡	🟡	🔴	🟢
Energy Density	🟡	🟡	🟢	🟡

Sources:
- The Future of Hydrogen, IEA, June 2019
- Determining the Production and Transport Cost for H_2 on a Global scale, Collis et al, 2022
- EU Commission assessment of hydrogen delivery options, EU Joint Research Centre, 2021
- Hydrogen Carrier Economics, KBR Advisory Consulting, 2021
- Hydrogen transportation- The key to unlocking the clean hydrogen economy, Roland Berger, 2021
- Assessing opportunities and weaknesses of green hydrogen transport via LOHC through a detailed techno-economic analysis, GASP and ENI, 2023
- An economic and greenhouse gas footprint assessment of international maritime transportation of hydrogen using LOHCs, CERENA and Copernicus institute of Sustainable Development, 2023

HONEYWELL LOHC SOLUTION
COMMERCIALLY PROVEN TECHNOLOGY AND CATALYST



UOP HYDROGENATION

45+ commercial reference units on similar technology for Benzene/Aromatics processing

UOP DE-HYDROGENATION

1000+ commercial reference units on similar technology for Heavy Naphtha processing

ADVANTAGES OF HONEYWELL LOHC

- Commercially proven and ready to execute at large scale
- Single source optimization for import and export
- Maximum H_2 transported
- Minimum carrier makeup
- No catalyst makeup

Thank You

Valentina Di Mauro
Director BD LOHC
Honeywell UOP
Valentina.DiMauro@Honeywell.com

Mike McBride
BD & IPS
Honeywell UOP
Michael.McBride2@Honeywell.com

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