



HEC Hydrogen Sessions

Hydrogen Hubs and the Emerging Global Trading Market for Hydrogen

June 4, 2021

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Agenda

Hydrogen Energy Center

Velerity

Global Hydrogen Market Forecast

Low Cost Solar

Hydrogen Hubs

Case Studies

Question & Answer

Hydrogen Energy Center

HEC is a nonprofit professional society focused on accelerating the hydrogen as an enabling solution for renewable energy

HEC provides public forums, conducts research and implements projects focused on accelerating the clean energy future

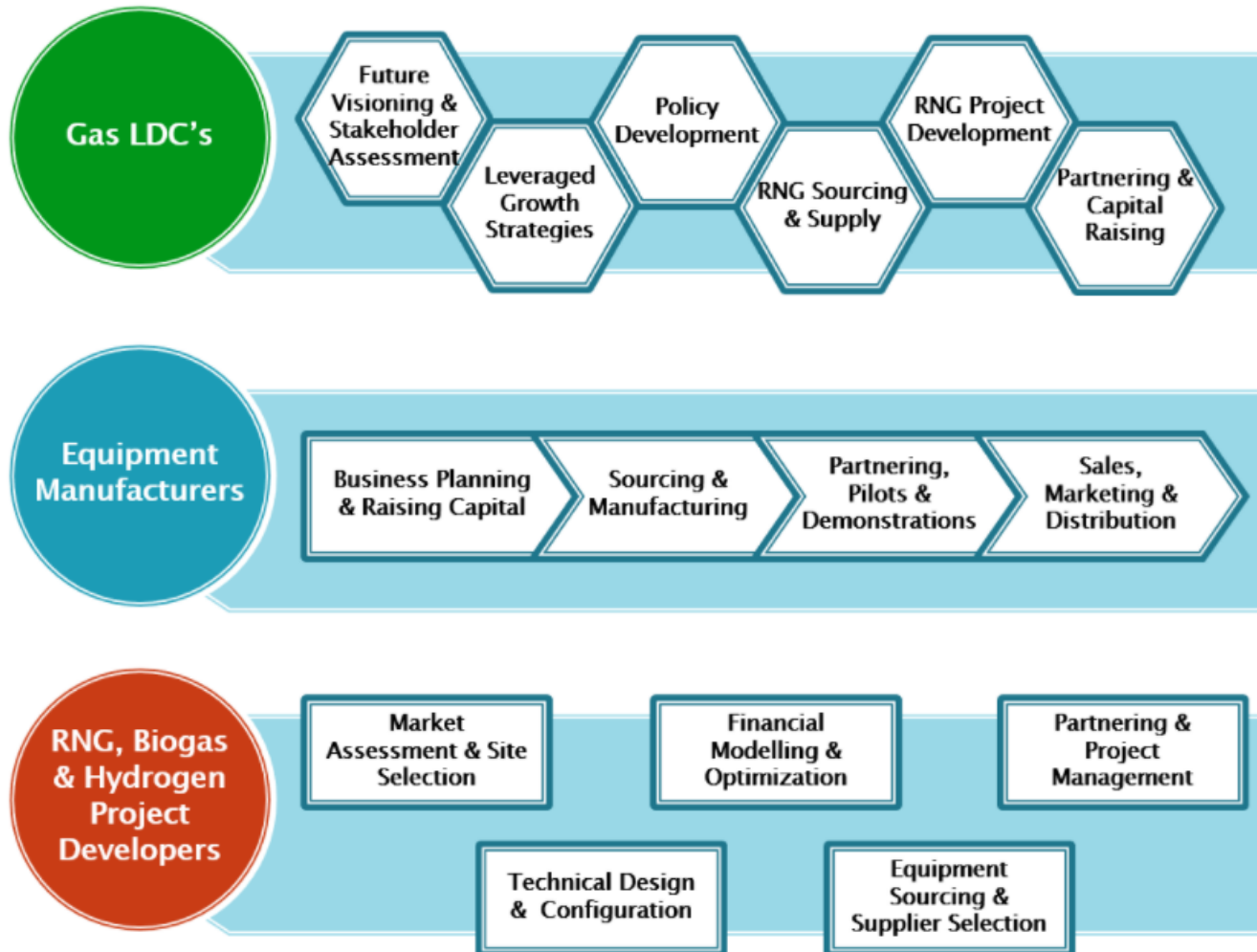
Consider supporting this important effort by becoming a member:

- Influence the course of renewable hydrogen energy technology and policy.
- Be a part of projects that really build hydrogen solutions.
- Have full access to white papers, technical reports, and meeting minutes from our projects and from other organizations.
- Immerse yourself in the hydrogen "goings-on" by connecting with developments & networking with people who are collectively driving the hydrogen "bus".

Upcoming Hydrogen Sessions

- ▶ June 4, 2021 Hydrogen Hubs & the Global Hydrogen Trade
- ▶ June 11, 2021 Sources of Hydrogen: Electrolysis and Water Splitting
- ▶ June 18, 2021 Hydrogen Production with Carbon Separation
- ▶ June 25, 2021 Wind to Hydrogen

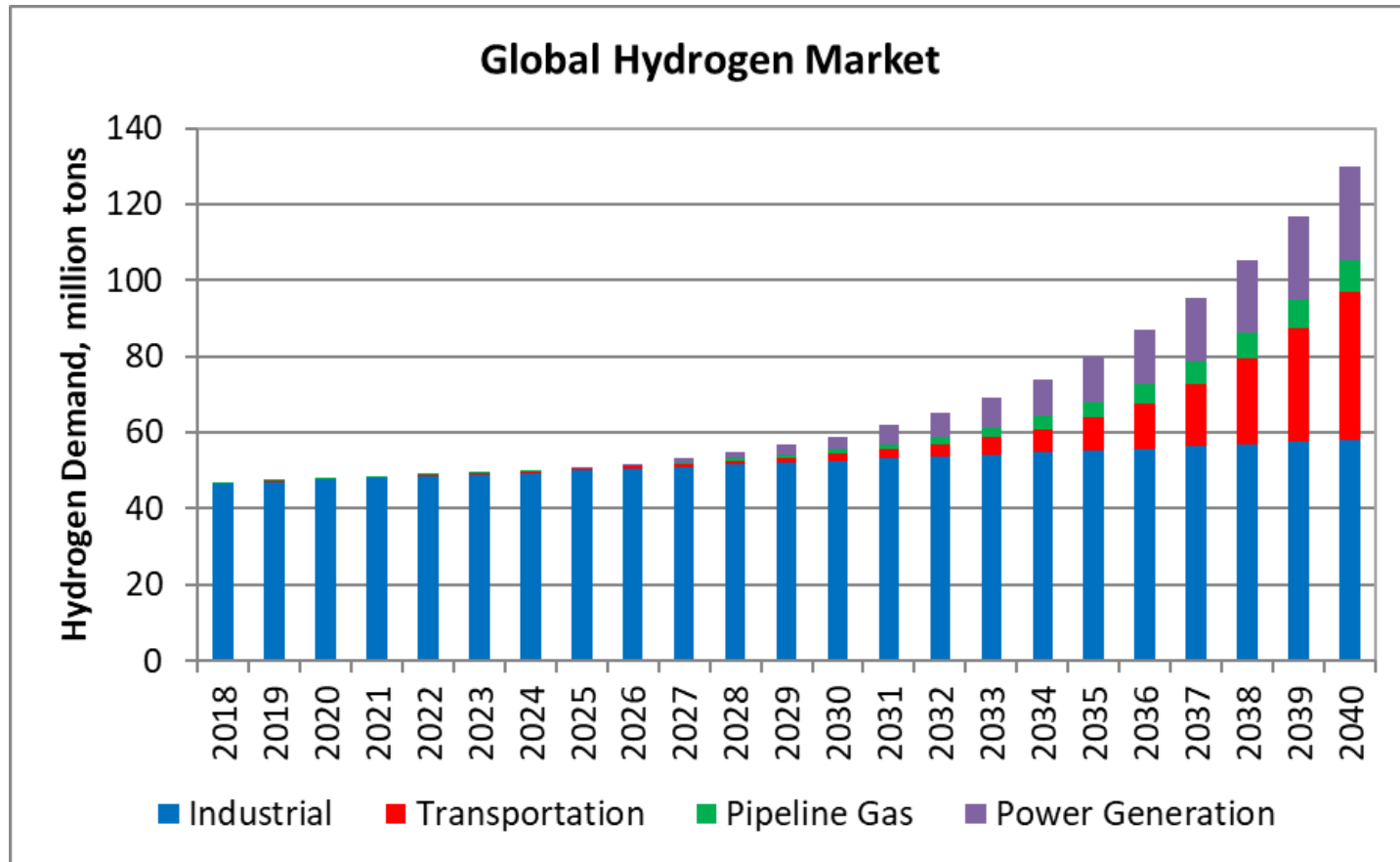
Velerity Services



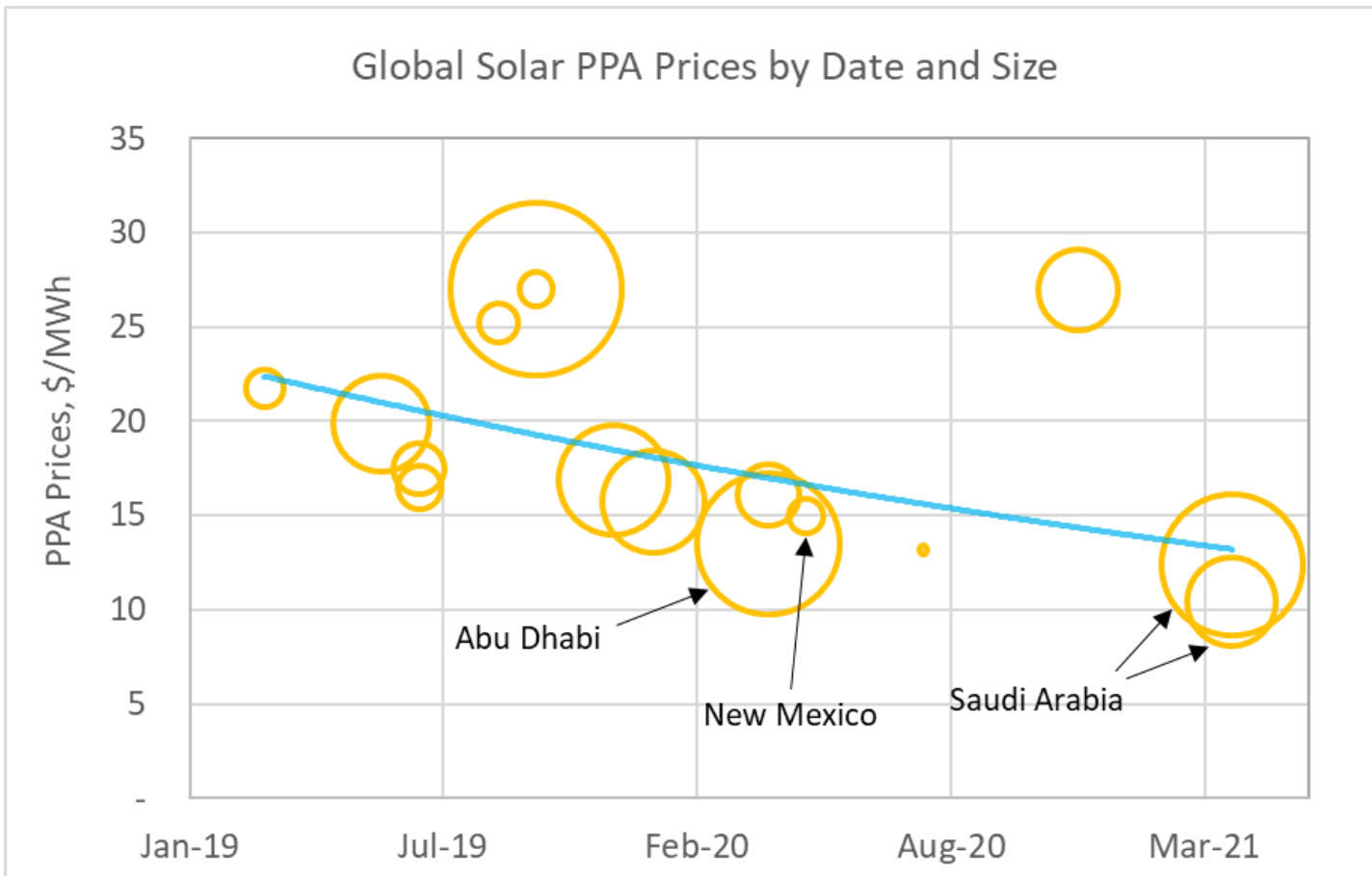
Velerity – Illustrative Clients



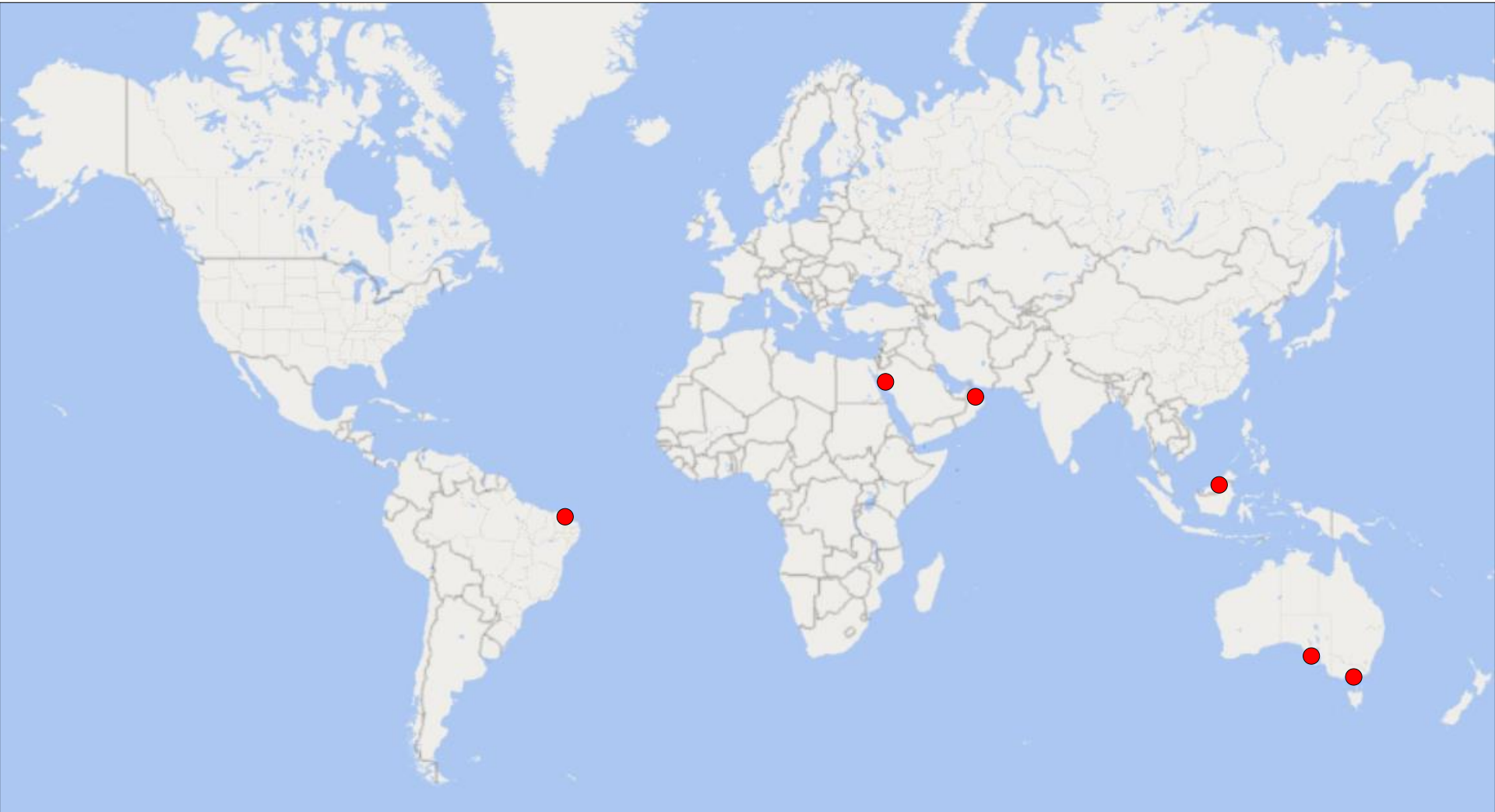
The global hydrogen market is expected to nearly double by 2035, driven by power generation and transportation markets



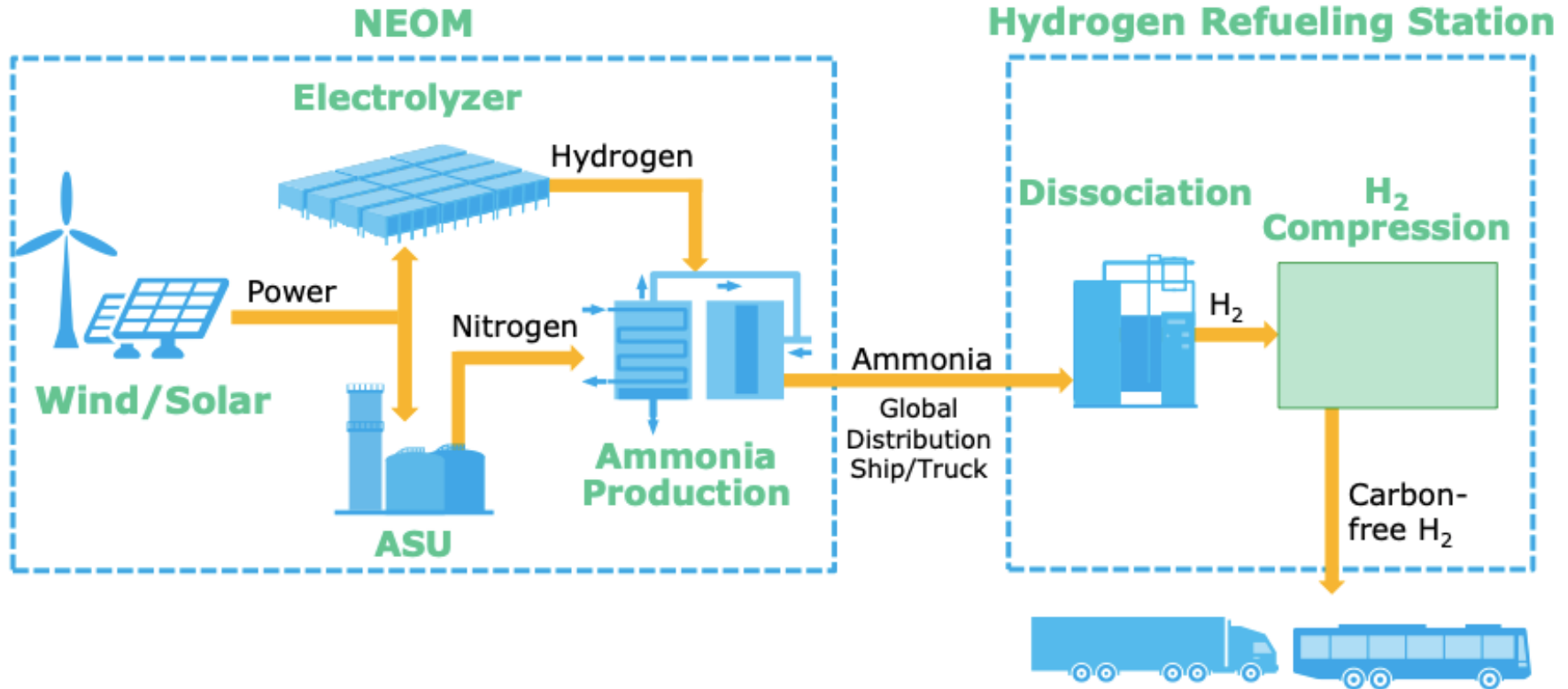
Globally, PPA prices for solar are nearing 1 cent per kWh, implying marginal cost of hydrogen production at 50 cents per kilogram



Multiple hydrogen hubs are being developed around the world, representing billions of dollars of investment



Neom is a \$7 billion project to produce renewable hydrogen, convert the hydrogen to ammonia, and ship the ammonia around the world



The Noem project will produce and distribute green ammonia globally for refueling trucks and buses with hydrogen



نيوم, NEOM



thyssenkrupp



- ▶ Wind & solar 4 GW
- ▶ Investment in Noem \$5 bil.
- ▶ Hydrogen production 650 tons/day
- ▶ Ammonia production 1.2 mil. tons/yr
- ▶ Distribution infrastructure \$2 bil.
- ▶ Noem Facility Partners
 - Noem 33%
 - Air Products 33%
 - Acwa Power 33%
- ▶ Electrolyzers Thyssenkrupp
- ▶ Ammonia Tech. Haldor Topsoe
- ▶ Ammonia Distribution Air Products

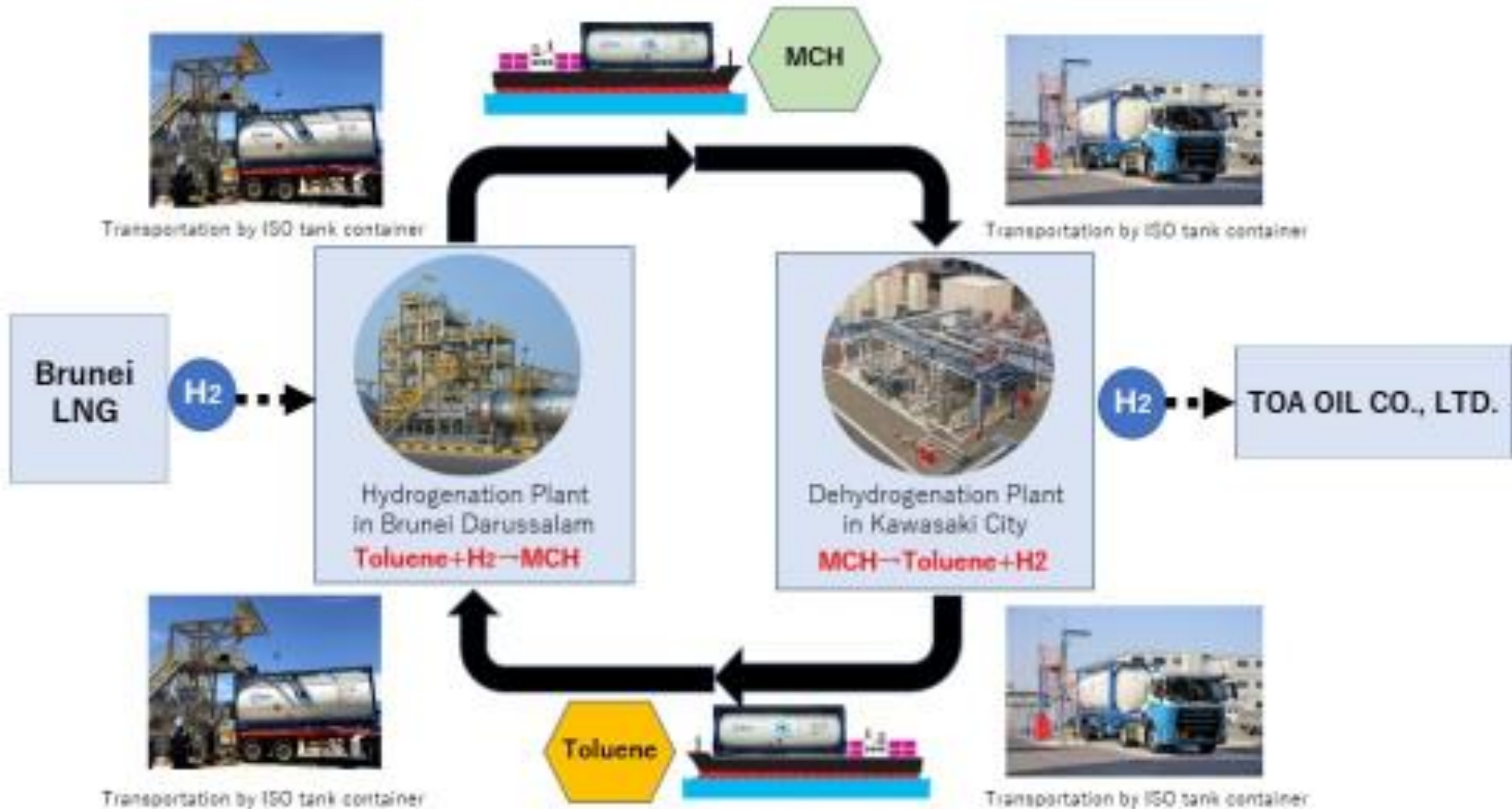
Japan is aggressively developing a global hydrogen supply chain to decarbonize and diversify their energy system

- ▶ Under its basic hydrogen strategy, Japan aims to procure 300,000 mt/year of hydrogen, amounting to 1 GW of power generation capacity, and reduce the cost of hydrogen to Yen 30/normal cubic meters by around 2030.
- ▶ Japan's current hydrogen procurement cost estimates stand at around Yen 170/normal cu m based on current technologies, according to the latest estimate released by METI Dec. 21, which is aiming to bring that down in stages to Yen 20/normal cu m by 2050.

Japan's first operating international hydrogen supply chain is sourcing LOHC hydrogen from Brunei and shipping it to Kawasaki, Japan

- ▶ The Advanced Hydrogen Energy Chain Association for Technology Development (AHEAD) has started the world's first international demonstration operation to transport hydrogen using methylcyclohexane.
- ▶ In the supply country, hydrogen, chemically fixed to toluene, is converted by a hydrogenation reaction into methylcyclohexane (MCH), a liquid at ambient temperature and pressure, for storage and transport.
- ▶ Hydrogen is extracted from MCH by a dehydrogenation reaction and supplied as hydrogen gas.
- ▶ Methylcyclohexane (MCH) produced in Brunei Darussalam has already been transported to Japan by ship, separated into hydrogen and toluene at a dehydrogenation plant located on the Kawasaki city waterfront, and the hydrogen has been supplied to a gas turbine at the Mizue power station owned by Toa Oil Co. Ltd.
- ▶ Chiyoda, Mitsubishi Corp, Mitsui & Co and Nippon Yusen, have been working on the hydrogen demonstration project since 2015, using the organic chemical hydride method
- ▶ Plan is for transporting 210 tonnes of hydrogen per year from Brunei to Japan

The MCH - Toluene cycle



Hydrogenation plant in Brunei



Tanks used for transporting MCH and Toluene



Dehydrogenation facility in Kawasaki City, Japan



Latrobe Valley, Australia to Kobe, Japan

- ▶ This project involved:
 - Brown coal gasification and hydrogen refining in the Latrobe Valley in southeastern Australia
 - Hydrogen liquefaction and storage of liquefied hydrogen at the port of Hastings
 - Marine transportation of liquefied hydrogen from Australia to Japan
 - Unloading of liquefied hydrogen at Kobe, Japan
- ▶ Transportation is accomplished using liquid hydrogen, using the 8,000 gross tonnes Suiso Frontier, the world's first liquefied hydrogen carrier with a cargo loading capacity of 1,250 cubic meters

Latrobe Valley, Australia to Kobe, Japan

- ▶ The first liquified hydrogen tanker, Suiso (hydrogen) Frontier
- ▶ The tanker is 116 meters long and can transport 75 tons of liquified hydrogen kept at temperatures of minus 253 degrees.
- ▶ The hydrogen will be liquified after lignite mined in Australia is steamed.
- ▶ Carbon will be separated and sequestered underground
- ▶ Total expected volume of liquified hydrogen imports in 2050, including vehicle fuel, is estimated at 20 million tons, about 5,000 times the volume imported in 2020.
- ▶ Kawasaki Heavy plans to build 80 tankers to transport 9 million tons of liquified hydrogen.



H2U and RWE have established a hydrogen supply chain agreement, shipping 40,000 tons/yr of ammonia from Australia to Germany



Eyre Peninsula Gateway Project

- ▶ 75 MW of Electrolyzers
- ▶ Produce 40,000 tons per year of ammonia
- ▶ Second phase – 1.5 GW of electrolyzers

H2-Hub Gladstone Project in Queensland

- ▶ Hydrogen Utility’s proposed \$1.61 billion industrial complex for the large-scale production of green hydrogen and ammonia. The H2-Hub™ Gladstone facility will be built in stages to integrate up to 3 GW in electrolysis plant, and up to 5,000 tonnes per day ammonia production capacity.

RWE Supply & Trading

- ▶ Receive ammonia at the Brunsbuettel LNG terminal
- ▶ Provide ammonia to ships for motive power
- ▶ Store hydrogen at the Brunsbuettel terminal and feed hydrogen gas into the regional natural gas pipeline system
- ▶ Building one of the largest solar farms in Australia in Limondale
- ▶ RWE considers solar productions costs of 2 cents/kWh feasible

Brazil: \$5.4 billion hydrogen hub investment commitment by Enegix Energy

Enegix Energy

- ▶ Project: Base One
- ▶ \$5.4 billion investment
- ▶ 615 million kg/yr of hydrogen

Enewind

- ▶ 3.4 GW wind and solar
- ▶ Potential to scale to 100 GW

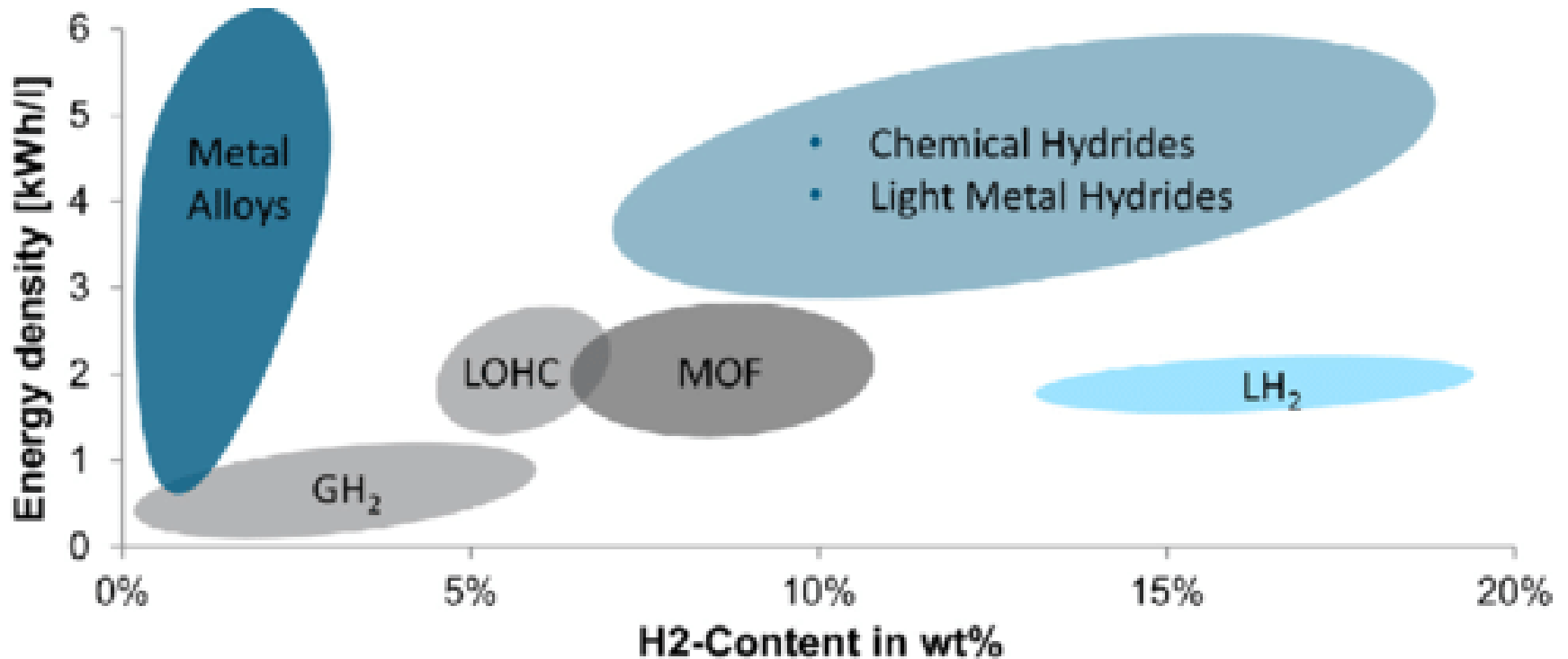
State of Ceará

- ▶ Pecém Industrial & Port Complex

Rotterdam

- ▶ Receiving Point

Energy density and energy content by weight for several hydrogen storage technologies



Question and Answer