ASTRI Annual Symposium

A Stable Solar Future

An Industrial Perspective on Business Potential of Solar Hydrogen

May 2th, 2016

Ayako MATSUMOTO

Technology and Innovation Studies Division

Mitsui Global Strategic Studies Institute(MGSSI)

Disclaimer

IMPORTANT NOTICE

All information Mitsui Global Strategic Studies Institute (the “Company”) contained in this document is issued on a forward-looking basis only for the purpose of providing certain information for preliminary study, and does not constitute any commitment to offer in any nature whatsoever.

By accepting this document, the recipient undertakes to keep permanently confidential the information contained herein. The recipient further undertakes not to copy, reproduce or distribute this document to any other person.

No representation, express or implied, is or will be made, neither is nor will any responsibility or liability be accepted by the Company or any of its officers or employees in relation to the accuracy or completeness of this document. Any liability is therefore expressly disclaimed.

An Industrial Perspective on Business Potential of Solar Hydrogen

Contents

About Mitsui & Co., Ltd

MITSUI & CO., LTD.

- Since 1947 (the former company since 1876)
- Employees: 6,097, Consolidated: 47,118 (As of Mar. 31, 2015)
- 145 offices in 66 countries (As of April, 2016)
- Multilateral business ranging from product sales, worldwide logistics and financing, through to the development of major international infrastructure and other projects.

Mitsui & Co.(Australia) Ltd.

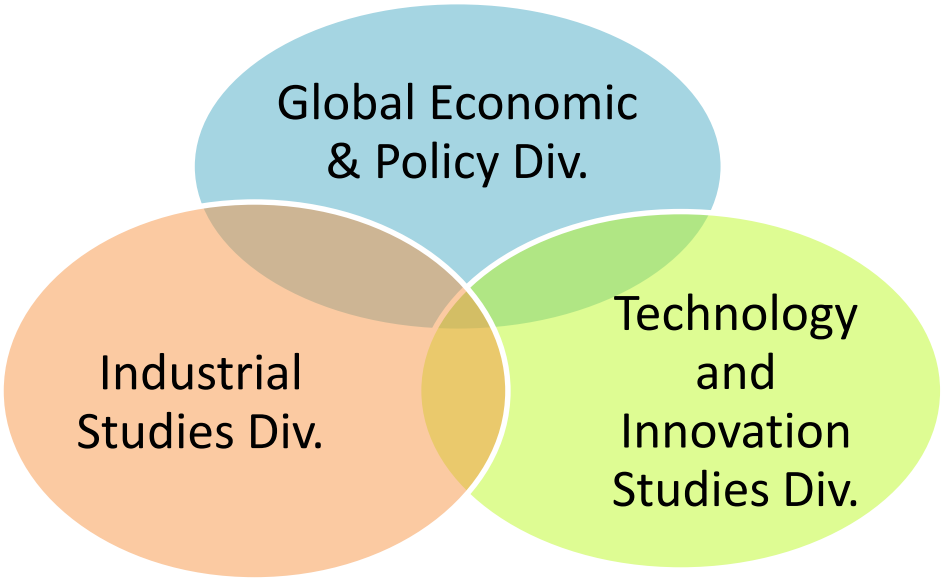
- 4 Offices: Melbourne, Sydney, Brisbane, Perth
- The forth largest exporter of Australia with 8 billion AUS in total exports
- Natural resources and agricultural commodities.

15 business units of Mitsui

- Iron & Steel Products Business Unit
- Mineral & Metal Resources Business Unit
- Infrastructure Projects Business Unit
- Integrated Transportation Systems Business Unit
- Basic Materials Business Unit
- Performance Materials Business Unit
- Nutrition & Agriculture Business Unit
- Energy Business Unit Ⅰ
- Energy Business Unit Ⅱ
- Food Business Unit
- Food & Retail Management Business Unit
- Healthcare & Service Business Unit
- Consumer Business Unit
- IT & Communication Business Unit
- Corporate Development Business Unit

Mitsui Global Strategic Studies Institute (MGSSI)

- MGSSI was established in 1999 as the in-house think tank of Mitsui&Co.Ltd.
- 100 employees based in Tokyo and 7 offices in the world(Washington, NY, Dusseldorf, Brussels, Beijing, Singapore)
- Implements “Business-oriented” research and analysis which provide Mitsui with Long-term business vision.
- Extensive field covering economy, politics, society, industry, enterprise, technology and innovation.



Energy and environment, natural resources — Solar Fuels

ICT, robotics, traffics, smart grid

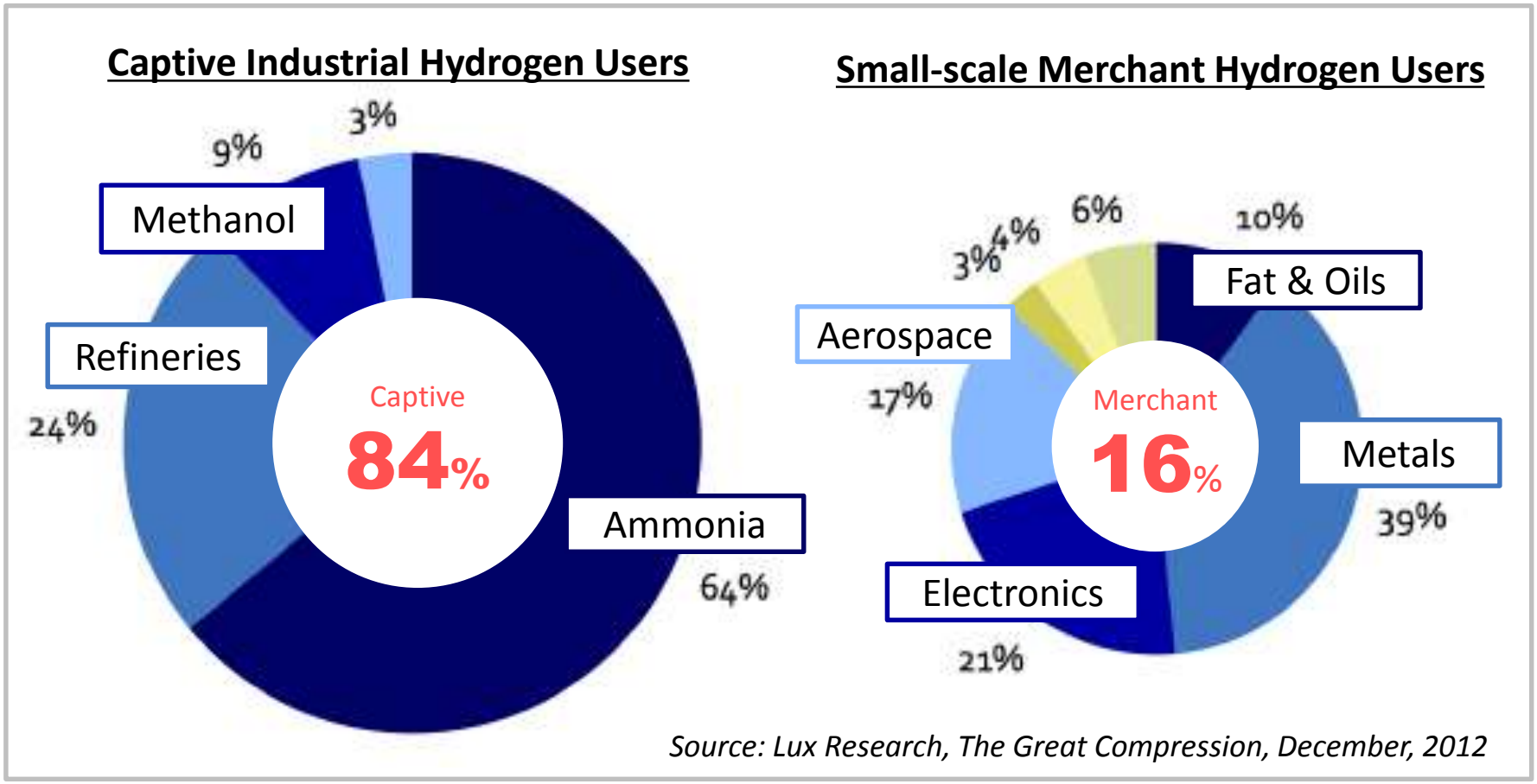
Materials, medical & healthcare, food & agriculture

1

Potential Hydrogen Market in Japan

Global Hydrogen Production and consumption

- Global hydrogen production and consumption in industries today is over 52.5 billion kg.
- More than 95% of hydrogen is produced from fossil fuels. 48% from natural gas, 30% from refineries, 18% from coal gasification, 4% from electrolysis.



Source: Lux Research, The Great Compression, December, 2012

Advantages of Hydrogen as Energy

No Carbon Emission

- Hydrogen combustion produces only water, which makes hydrogen called clean energy.

$$2H_2 + O_2 \rightarrow 2H_2O$$

High Efficiency

- Fuel Cell generates electricity and heat from H_2 and O_2 through electrochemical reaction at higher efficiency than ICE or turbine do.
- No polluted substances left but water.

Energy Storage

- Volatile electricity (from wind, PV etc) can be converted to H_2 through electrolysis and stored stable for long time.

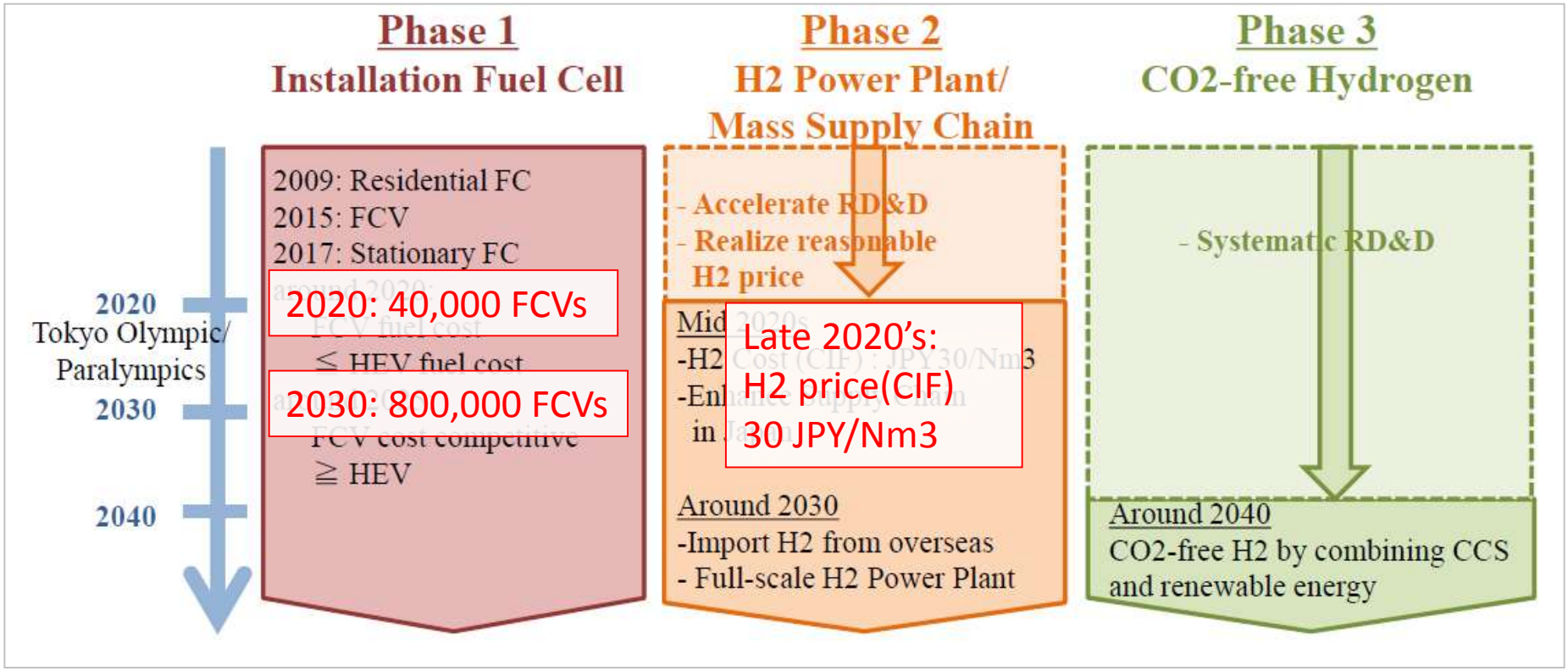
The Strategic Energy Plan of Japan(2014) states….

As for future secondary energy, hydrogen is expected to play the central role as well as electricity and heat. Hydrogen, though it is necessary to secure safety in handling it, it has many superior characteristics such as excellent utility and energy efficiency, and emits no greenhouse gas and is expected to be useful in times of emergency.

Source: 4th Strategic Energy Plan, Japan's cabinet, 11th April 2014

“Hydrogen and Fuel Cell Strategic Roadmap” in Japan

- “Hydrogen and Fuel Cell Strategic Roadmap” was set in 2014 and just revised in March 2016.
- Japan takes 3 step approach toward the hydrogen society, (1) the dramatic expansion of hydrogen utilization, (2) the full-fledged introduction of hydrogen power generation and establishment of a large-scale hydrogen supply system, and (3) the establishment of a totally carbon dioxide-free hydrogen supply system.



Source: METI, 24th IPHE SC Meeting(2015.12)

Potential Hydrogen Market in Japan

- Currently domestic hydrogen demand in Japan is 1.6 million TPA, 80% for hydro-desulfurization, 18% for ammonia production.
- The existing industries have spare capacity or byproduct to supply additional 778,000 ton hydrogen, which corresponds to fuel for 830,000 FCVs, means that even the FCV target in 2030 (800,000 FCVs) is achieved, still the whole demand of hydrogen fuel could be supplied domestically.
- Besides, a 1GW power plant consumes 200,000~400,000 ton hydrogen per year, which corresponds to 2~4 million FCVs, means hydrogen combustion at power plant seems the economic drive force to import hydrogen from overseas.

Annual Hydrogen consumption (Per unit)

FCV
94 kg/yr

(H_2-type)
residential FC
201 kg/yr

FC Bus
4,600 kg/yr

1GW H_2 power plant
(100% H_2 fuel)
200,000~400,000 ton/yr

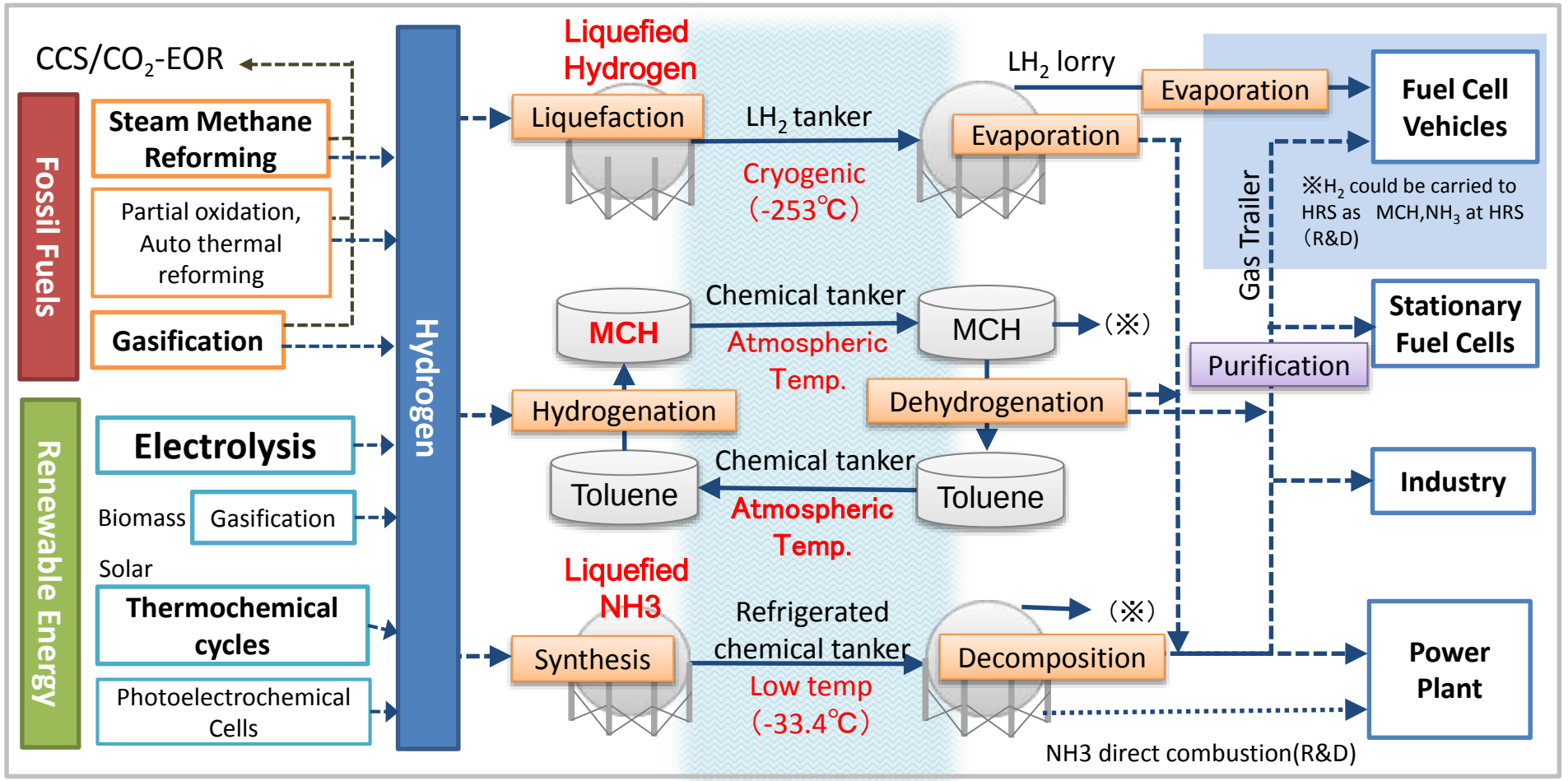
= 2~4 million FCVs

Data Source: Hydrogen Office, METI, Japan

2 Technology Development for Hydrogen Import

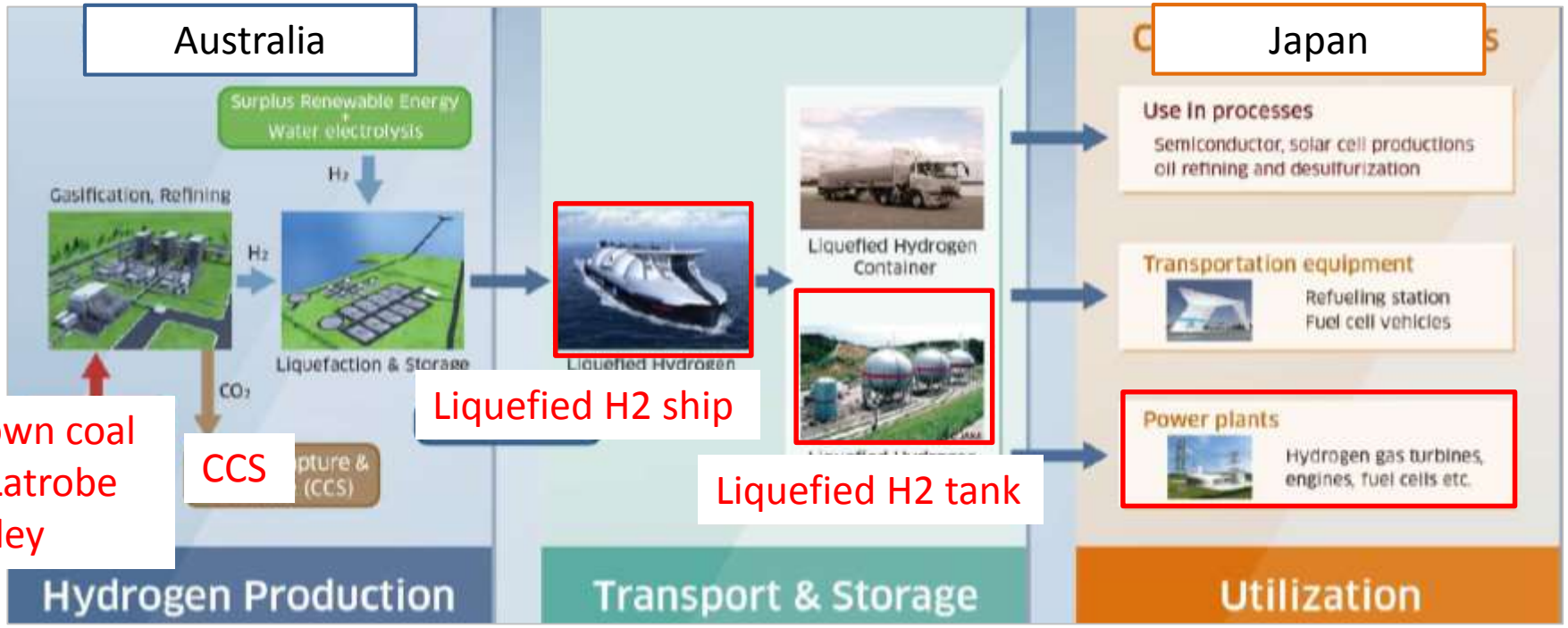
Hydrogen Supply Chain from Overseas

- Recognizing the technologies of marine transport and hydrogen combustion are the key in large-scale hydrogen supply chain,
  NEDO supports the four projects, whose total investment is around 40Bil JPY (470mil AUD).



Brown Coal Gasification and Liquefied Hydrogen

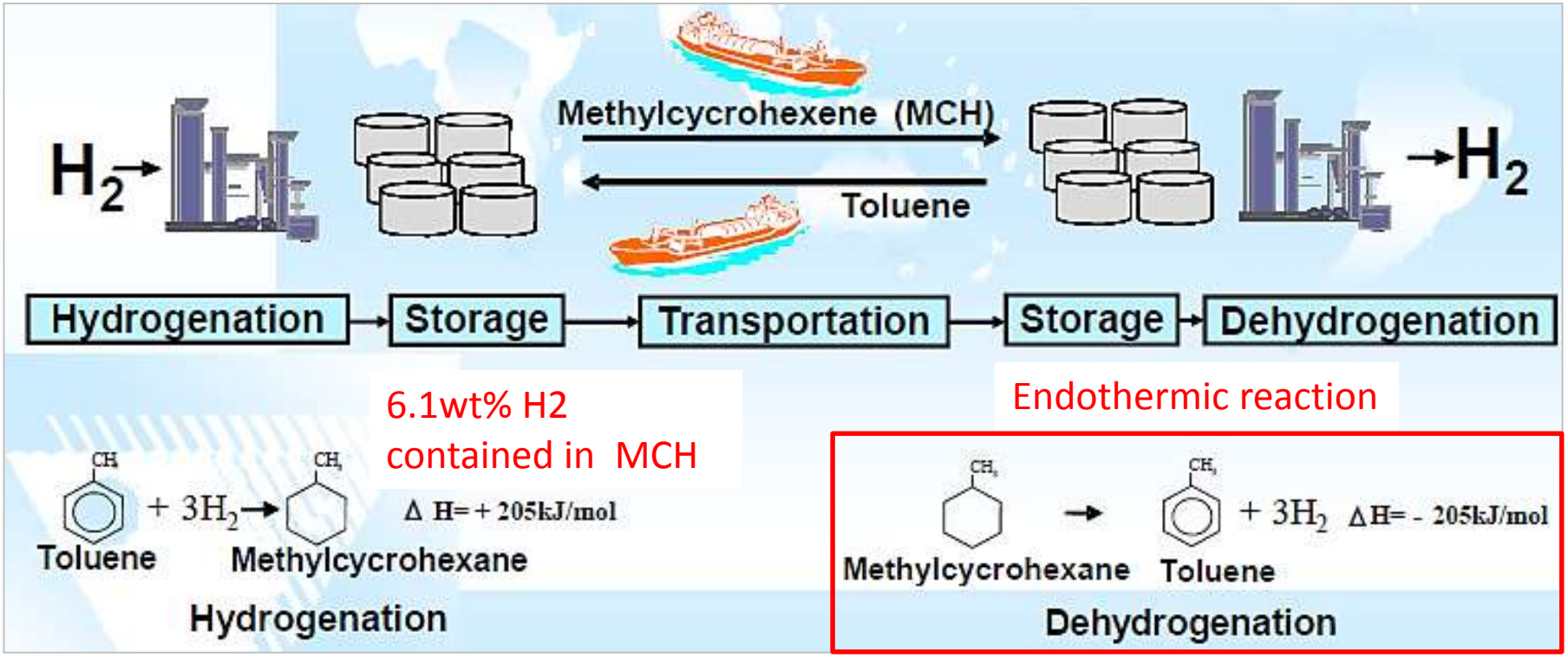
- Partnership: Kawasaki, Iwatani, J-POWER, Shell, NEDO
- Duration: FY2015-2020
- Purpose: Demonstrate brown coal gasification, marine transportation and loading of liquefied hydrogen, whose volume is 1/800 of its gaseous state.
- Advantages of Australia: plenty of brown coal in Latrobe Valley and CCS potential.
- Liquefied hydrogen shipping infrastructure (ship and tank) to be proven before commercialization, which is planed in 2025.



Source: Kawasaki Heavy Industries

Organic Hydride (MCH) as Hydrogen Carrier

- Partners: CHIYODA CORPORATION, Mitsubishi Corporation, MITSUI&CO., 日本郵船
- Duration: FY2015-2020
- Purpose: Demonstrate scaled-up toluene/MCH cycle
- Toluene/MCH are both safe and stable at atmospheric temperature and pressure. Transported and stored in conventional containers.
- Dehydrogeneration process is energy consuming and to be improved.



Source: Chiyoda Corporation, 21st Joint GCC-Japan Environment Symposium 2013

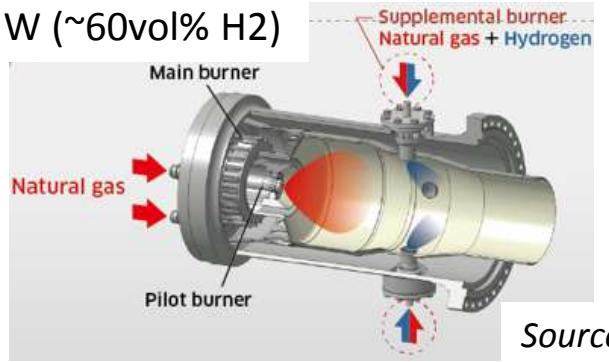
Hydrogen Combustion Technologies

Hydrogen Combustion

- *Low volumetric calorie fuel (1/3 of CH_4) → More volume of fuel gas inlet is required*
- *High speed of combustion (x7) → Backfire damages combustor*
- *High temperature of flame (+10%) → NOx increases*

- The technology of NOx reduction with high efficiency is being developed through modification of burner and combustion control system etc.
- Synergy effect of IGCC technology development is expected.

30MW (~60vol% H2)



Source: KHI

Kawasaki / OBAYASHI / NEDO

- FY2015-FY2017
- Demonstrate 1MW gas turbine co-firing 0-100% hydrogen with natural gas for CHP in smart community

MHPS GROUP / NEDO

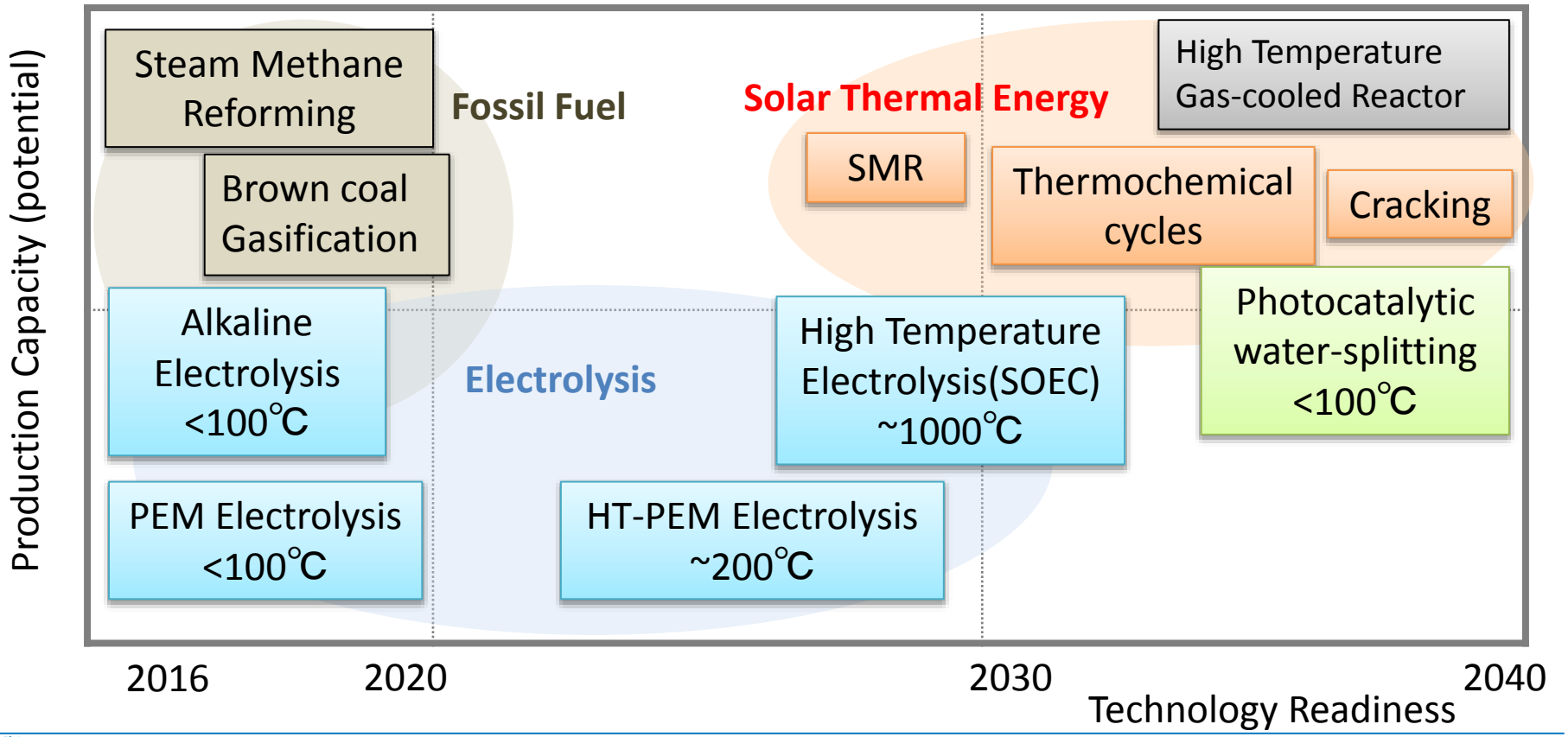
- Duration:FY2015-FY2018
- Demonstrate 200~300MW gas turbine co-firing 5~20vol% of hydrogen with natural gas at 1500~1600℃
- C/C output is 500MW

3

Solar Hydrogen's Competitors

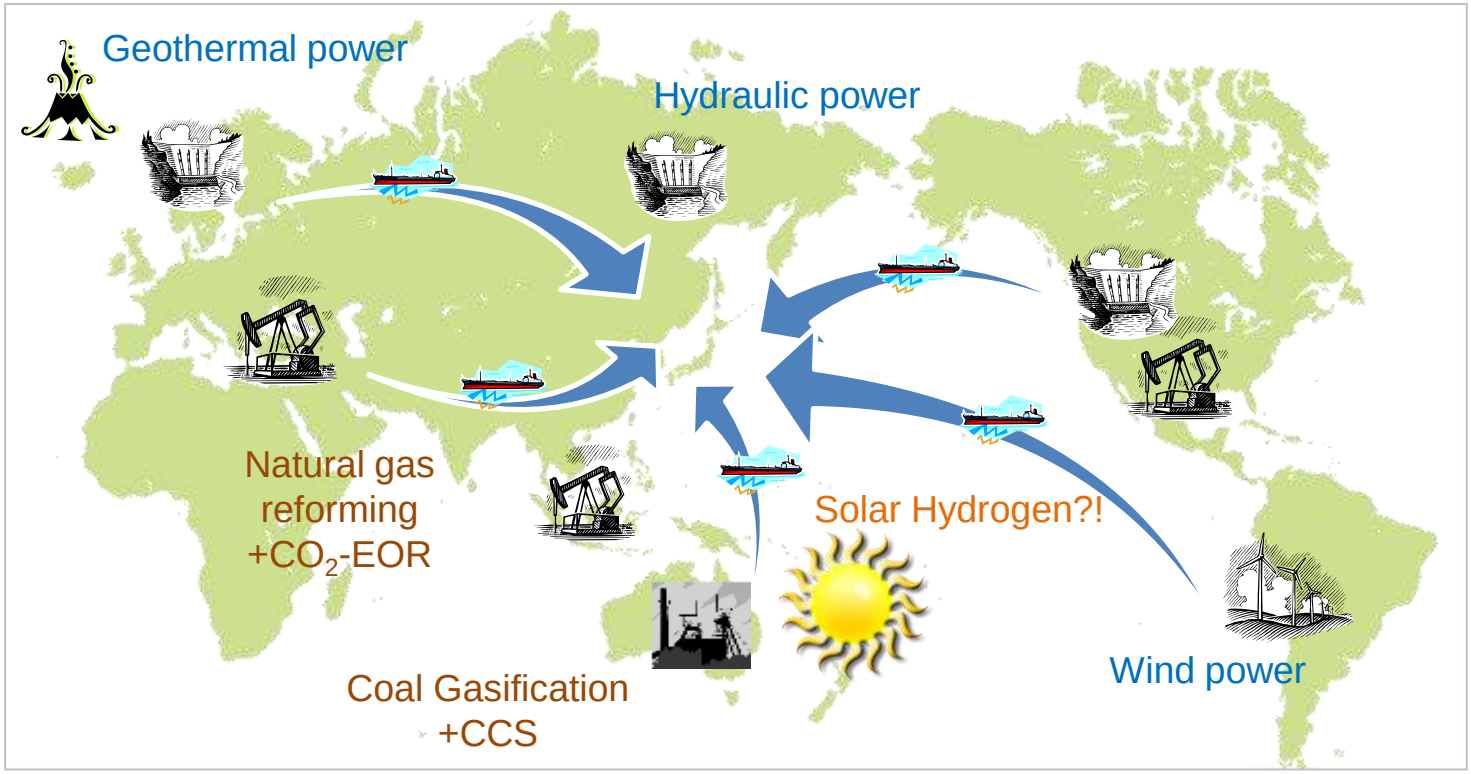
CO2-Free Hydrogen Pathways

- Fossil fuel reforming needs CO2-EOR or CCS technology to mitigate CO2 emission.
- Electrolysis requires more production capacity to compete with conventional process like steam methane reforming. Electricity price has large impact on hydrogen production cost.
- Solar hydrogen has potential of large production capacity and low OPEX. CAPEX reduction is strongly desired.



Where to Procure Hydrogen From?

- Japan set the target to procure "CO2-free" hydrogen in 2040 and look for clean and cost competitive hydrogen globally.
- The availability of CCS and CO2-EOR technology is essential to integrate with conventional hydrogen production.
- The low-cost and stable power generation is the advantage in electrolysis, looks the only solution for CO2-free hydrogen production at commercial scale at present.



Target Cost of Hydrogen in Japan

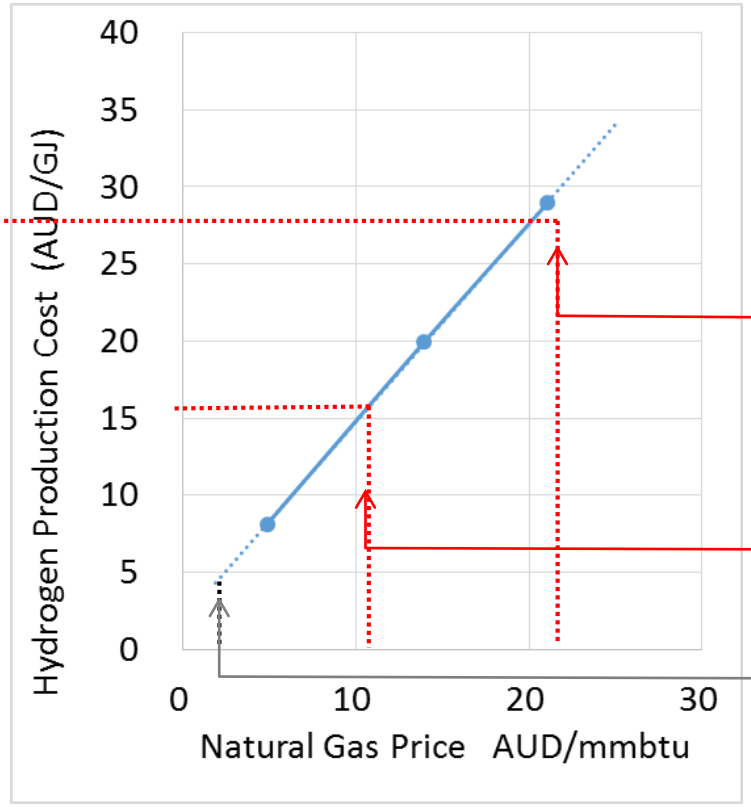
- Japan targets to procure hydrogen at CIF price of 30 JPY/Nm3 (27.7 AUD/GJ, HHV) in 2020's, and produce electricity at the cost of 17 JPY/kWh (0.2 cents/kWh).
- However, natural gas prices are halved down compared to the value in 2012-2013.
- Unless carbon incentive is applied, the competitive hydrogen CIF price is around 15 AUD/GJ.

Hydrogen Production cost (Central SMR)

Exchange rate
1USD=0.77AUD
1USD=110JPY
1AUD=85JPY

30 JPY/Nm3
=27.7AUD/GJ

?



Japan LNG Import Price(2012-2013)
: 22 AUD/mmbtu

Japan LNG Import Price(Mar 2016)
: 11 AUD/mmbtu

Natural gas price at HH, USA (Apr 2016)
: 2.2 AUD/mmbtu

Summary

- The government of Japan set up “hydrogen and fuel cell roadmap” toward low-emission society, where hydrogen is expected as energy and fueled to gas power plant as well as used in conventional industries.

- Japan intends to import CO2-free hydrogen in the future. However, the conventional petrochemical processes which emit CO2, to be integrated with CCS or CO2-EOR. Electrolysis, the most matured technology to produce CO2-free hydrogen, still requires more capacity of each device. Solar fuel, having the potential of no emission, large production and low operation cost, can be the solution in the future.

- Hydrogen CIF price target is 30 JPY/Nm3(27.7 AUD/GJ), which was competitive to domestic hydrogen production cost in industries before the oil & gas market fell down. Though import hydrogen should compete to hydrogen from low-cost fossil fuels ideally, carbon incentive is still required to make it feasible economically.

Thank You for your attention

Mitsui Global Strategic Studies Institute