IHI
Realize your dreams

IHI's Solution to Achieve Carbon Neutrality
~ Fuel Ammonia & Biomass technology in ASIA ~

IHI

September 6th, 2022

IHI Corporation

Table of Contents

About IHI - Business areas and products -

IHI

Resources, Energy and Environment

（Boiler, Gas Turbine, Gas Engine, LNG Terminal, Process Plant, Nuclear Equipment etc.）

Aero Engine, Space and Defense

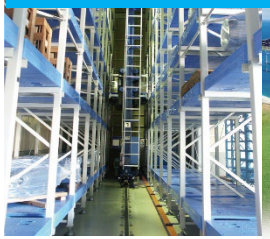
（Jet engine, Rocket）

Social Infrastructure and Offshore Facilities

（Bridge, Transportation System, Security etc.）

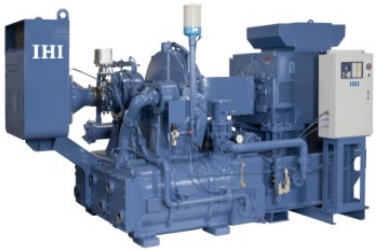
Industrial Systems

（Steel Manufacturing furnace,
Heat /Surface Treatment , Material Handling System etc.）



General-Purpose Machinery

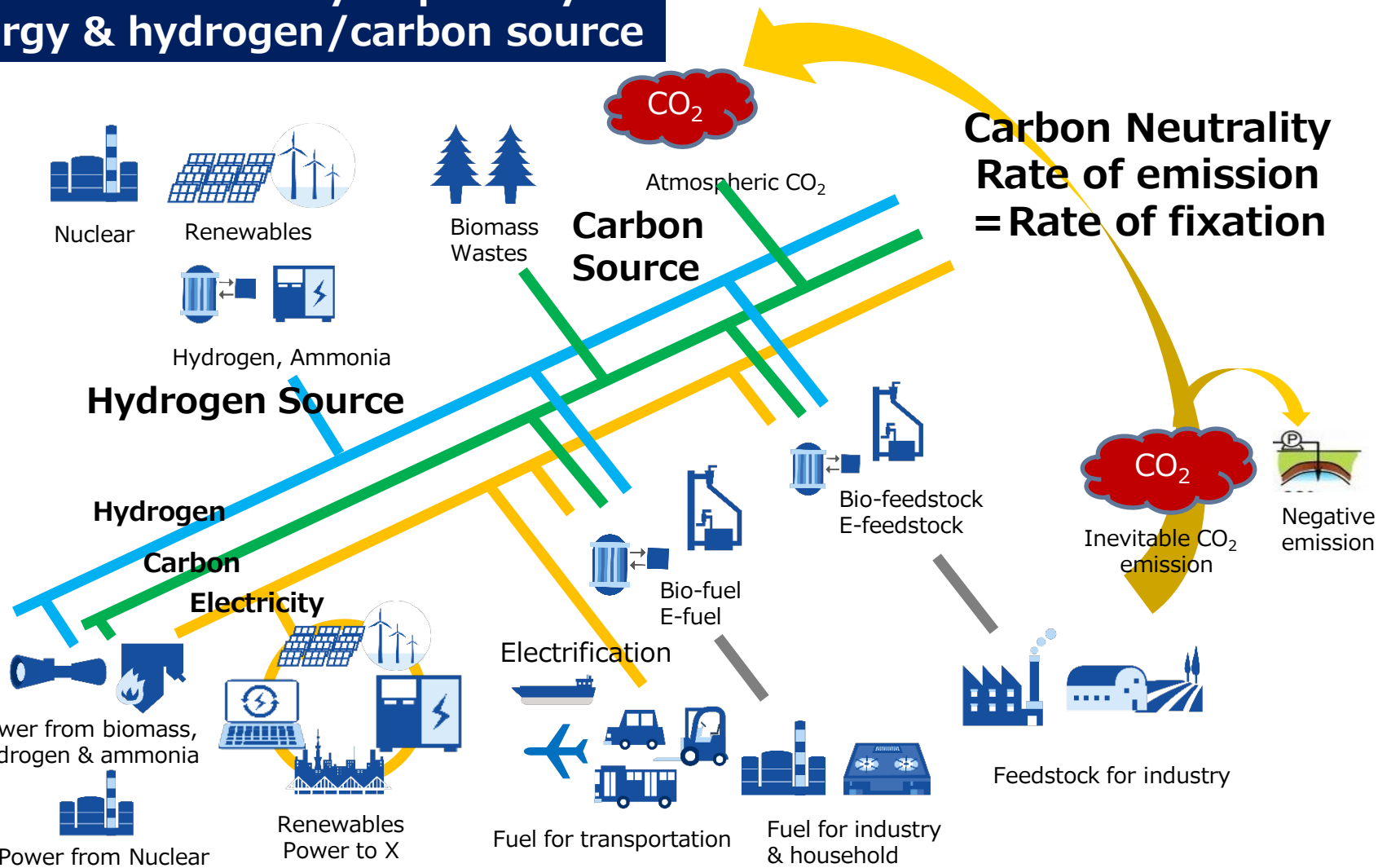
(Compressor, Separator, Turbo Charger etc.)



IHI' s vision - Carbon neutrality in the future -

IHI

Carbon neutrality of primary energy & hydrogen/carbon source



Carbon neutrality of power generation

Carbon neutrality of fuel

Carbon neutrality of feedstock

IHI's Action for Carbon Neutrality in ASIA

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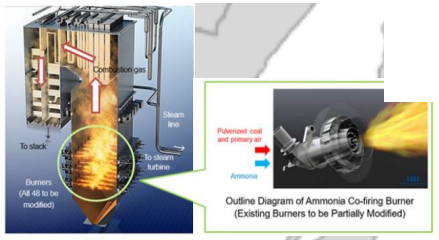
Sustainable Energy Transition

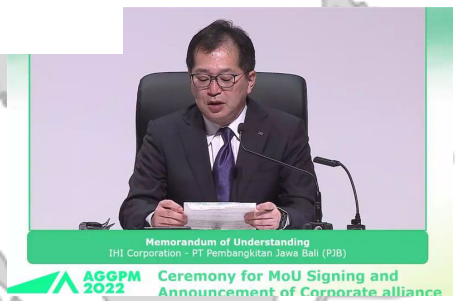
- ✓ So many inquires about technologies for Sustainable energy transition has been delivered to IHI.
- ✓ IHI with METI is focusing on projects in Asian countries.

Feasibility study for 20% ammonia co-firing



Advance technologies for Sustainable energy transition

Feasibility study for
Clean ammonia production and 20% ammonia co-firing

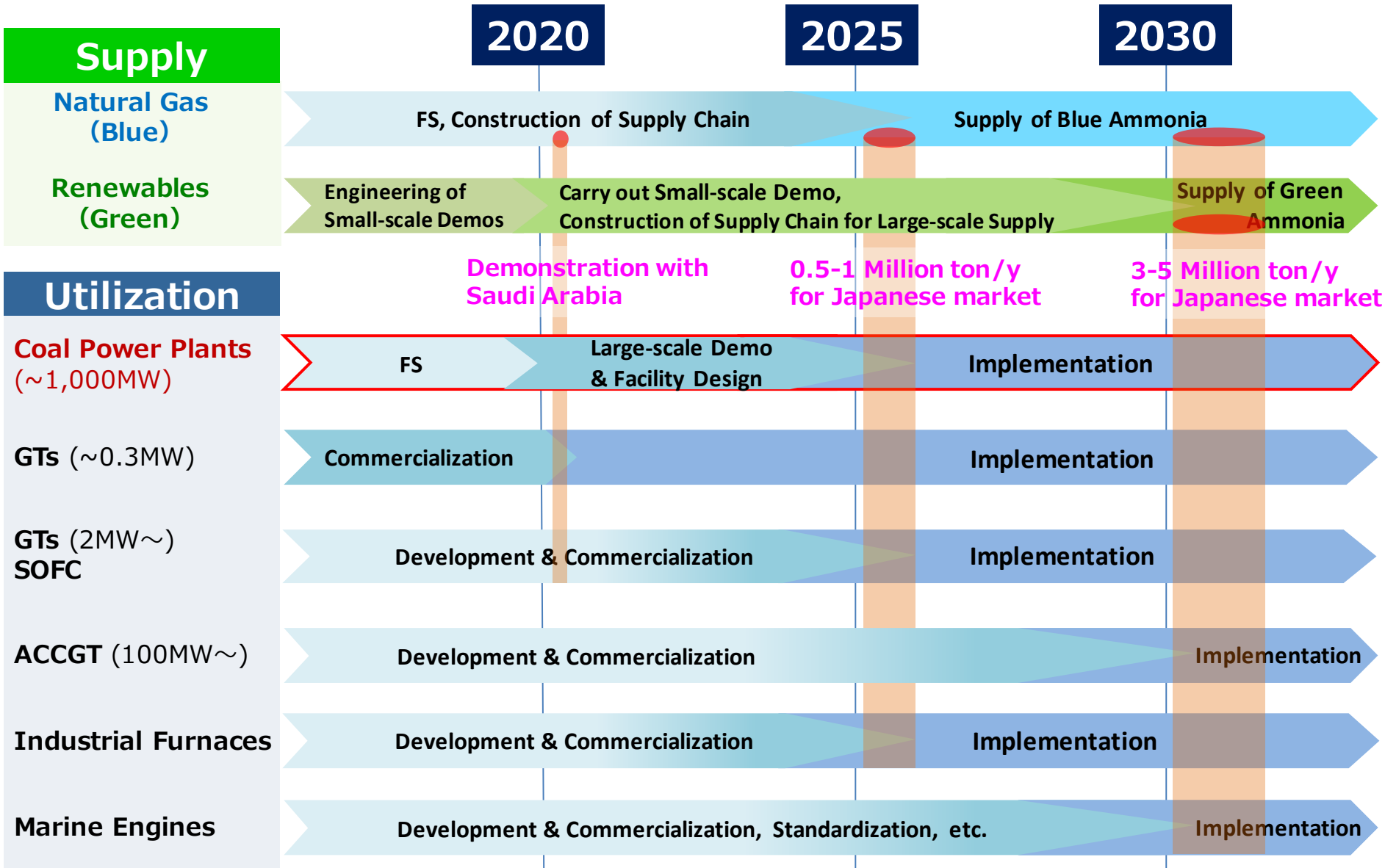


MoU between IHI and PJB
On Energy transitions by Ammonia and Biomass

Fuel Ammonia - Roadmap for fuel ammonia -

IHI

Roadmap for fuel ammonia implementation



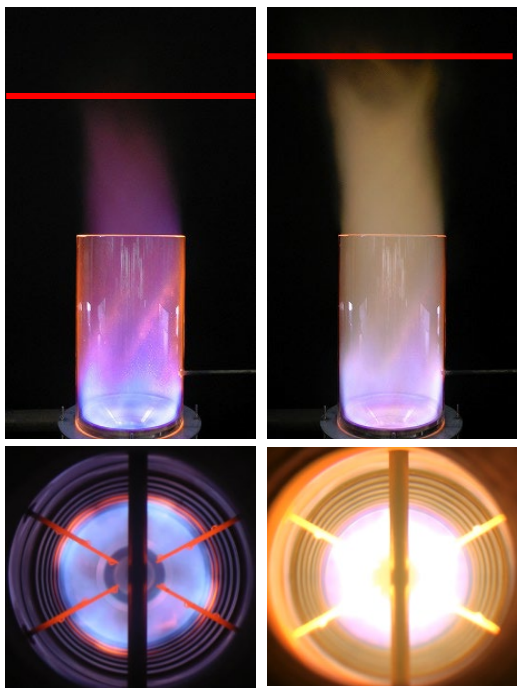
CLEAN FUEL AMMONIA ASSOCIATION

Fuel Ammonia - About ammonia -

IHI

Problems to overcome

(1) Optimized combustor design for stable flame and reduction of fuel-NOx to use ammonia in thermal power plant.
(2) Evaluation of performance of power plant
(3) Safety measures
(4) Feasibility studies



City gas　　Ammonia co-firing

Comparison of swirl flame

Fuel	NH_3	H_2	CH_4	C_3H_8
Boiling temperature at 1 atm (˚C)	-33.4	-253	-161	-42.1
Condensation pressure at 25 ˚C (atm)	9.90	-	-	9.40
Lower heating value, LHV (MJ/kg)	18.6	120	50.0	46.4
Flammability limit (Equivalence ratio)	0.63~1.40	0.10~7.1	0.50~1.7	0.51~2.5
Adiabatic flame temperature (˚C)	1800	2110	1950	2000
Maximum laminar burning velocity (m/s)	0.07	2.91	0.37	0.43
Minimum autoignition temperature (˚C)	650	520	630	450

Source : Prof.Kobayashi, Tohoku Univ.

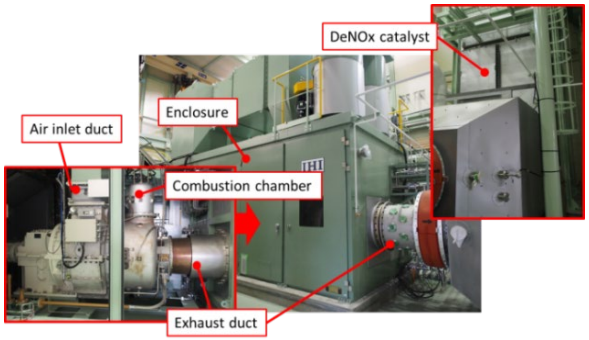
Fuel Ammonia - Ammonia utilization technology -

IHI

Coal fired boiler

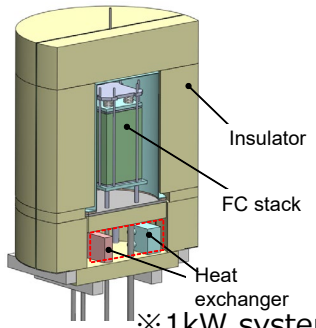
※CFT(10MWth Coal Firing Test furnace)

Gas turbine



※2MW class gas turbine(IM270)

SOFC



※1kW system

FY2014-2018

SIP 戦略的イノベーション創造プログラム Cross-ministerial Strategic Innovation Promotion Program

- Basic research of ammonia combustion mechanism
- Development of co-firing technology : stable combustion & NOx reduction
- Brief feasibility study for commercialization

FY2019-2020

NEDO

- Improvement of technology :
  - ・Improvement of co-firing ratio (over 50%)
  - ・Simplification of the system
- Feasibility study for demonstration

Target :

- **Scaling up to 10kW**
- **Application for decentralized power**

FY2021-

Target :

- **Demonstration by 1,000MW commercial boiler (20% ammonia co-firing)**

Target :

- **Development of 100% ammonia fueled 2MW class GT**
- **Application for zero-emission combined heat and power**

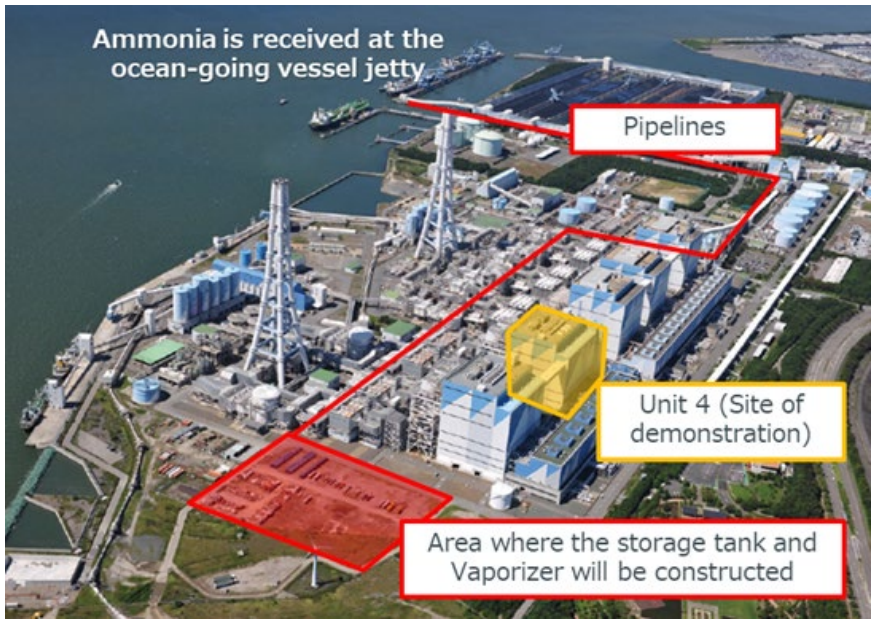
Fuel Ammonia - Ammonia utilization technology -

IHI

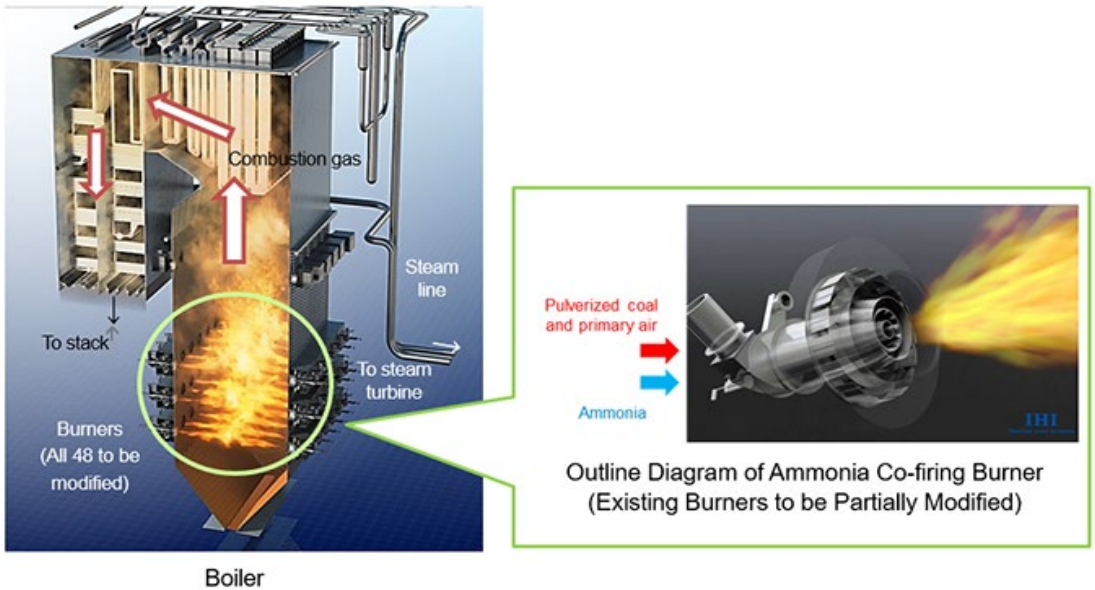
JERA and IHI Move Up the Start of Large-Volume Co-firing of Fuel Ammonia in the Demonstration Project at Hekinan Thermal Power Station

- May 31, 2022 -

JERA Co., Inc. and IHI Corporation have been conducting, under the New Energy and Industrial Technology Development Organization(NEDO) 's "Development of Technologies for Carbon Recycling and Next-Generation Thermal Power Generation / Research, Development and Demonstration of Technologies for Ammonia Co-Firing Thermal Power Generation" program <NEDO JPNP16002>.



Hekinan Thermal Power Station (Hekinan City, Aichi Prefecture), where the demonstration project will be conducted



Outline of Boiler and Modified Burners

https://www.ihi.co.jp/en/all_news/2022/resources_energy_environment/1197931_3488.html

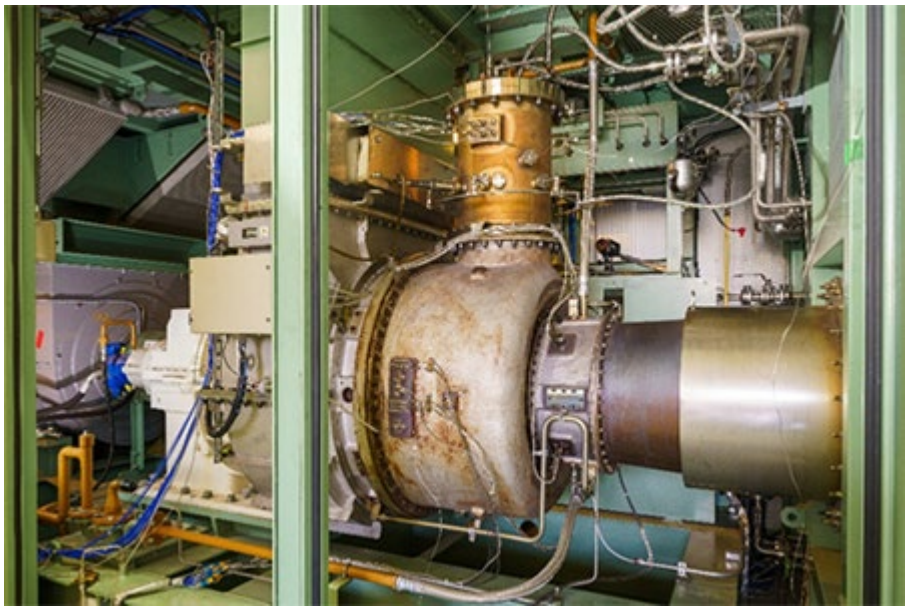
Fuel Ammonia - Ammonia utilization technology -

IHI

CO_2-free power generation achieved with the world's first gas turbine using 100% liquid ammonia
–Reduction of over 99% greenhouse gases during combustion–

- June 16, 2022-

IHI has succeeded in reducing greenhouse gases by over 99% during combustion of liquid ammonia in a 2,000-kilowatt-class gas turbine achieving truly CO_2-free power generation.
Looking forward, we will further reduce NOx levels, improve operability, evaluate long-term durability, and proceed with efforts toward the practical application of a 100% liquid ammonia combustion gas turbine in 2025.
This research and development is supported by the Green Innovation Fund, under the New Energy and Industrial Technology Development Organization (NEDO).
<NEDO JPNP21020>



2,000-kilowatt-class gas turbine at IHI Yokohama Works

https://www.ihi.co.jp/en/all_news/2022/resources_energy_environment/1197938_3488.html

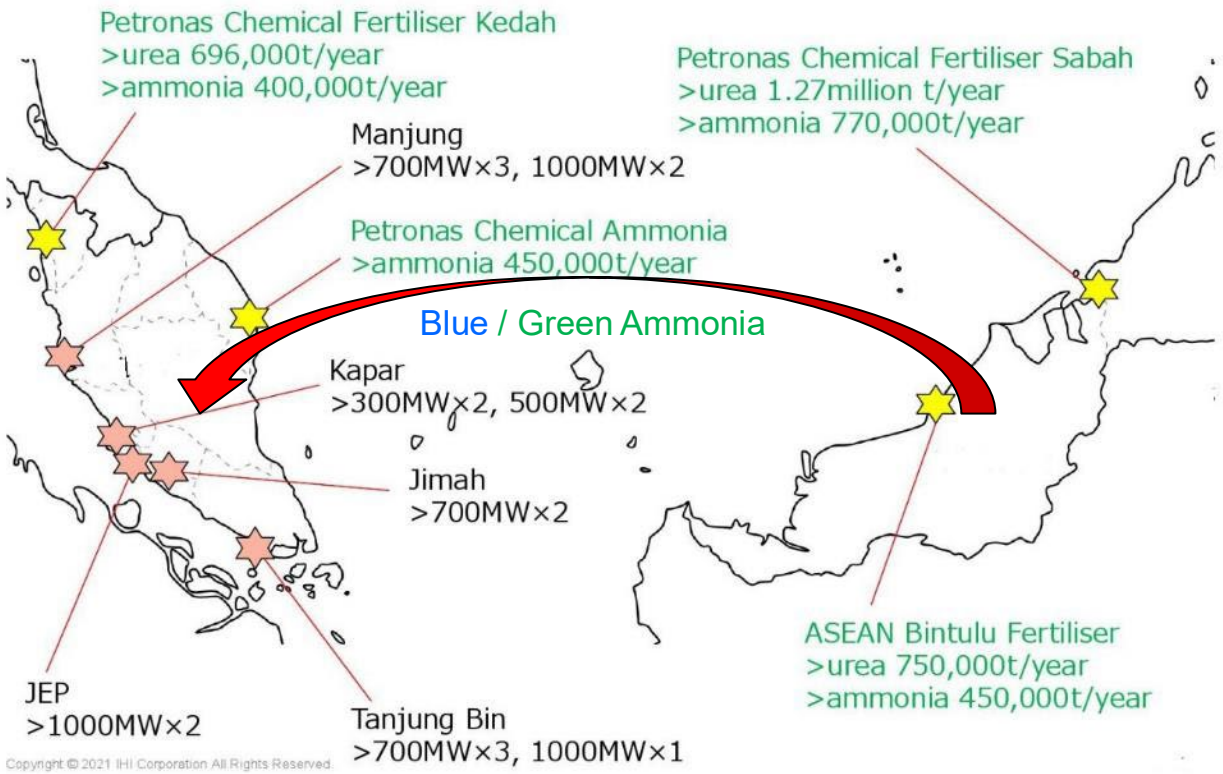
Fuel Ammonia - Introduction in ASIA 1 -

IHI

Feasibility Study on Ammonia Fuel to Decarbonize Power Sector in Peninsular Malaysia

- METI grant to investigation / Exports of High-Quality Energy Infrastructure to Overseas
- Joint FS between IHI(IPSM) / TNB / Petronas
- FS on Ammonia Co-Firing at TNB/Janamanjung #1 (700MW)
- FS on Ammonia Supply Chain in Malaysia

Ammonia production (Sabah, Sarawak)⇒Transportation⇒ Fuel Ammonia Utilization (Peninsula Malaysia)



TNB's Coal Fired PS and Petronas's Ammonia Plant

https://www.ihi.co.jp/en/all_news/2021/resources_energy_environment/1197552_3360.html

Fuel Ammonia - Introduction in ASIA 2 -

IHI

Commencement of Technical and Economic Feasibility Study in order to Achieve Ammonia Co-Firing at a Coal Fired Power Plant in India

IHI Corporation announced that it has signed a Memorandum of Understanding (MoU) along with Adani Power Limited (APL) and Kowa Company Ltd. (Kowa) to explore sustainable power generation. The three will collaborate to performe and evaluate a technical and economic feasibility study concerning a potential modification in order to achieve 20% liquid ammonia co-firing ratio and higher co-firing ratio up to 100% mono-firing at the Adani Power Mundra Coal Fired Power Plant.

https://www.ihi.co.jp/en/all_news/2021/resources_energy_environment/1197687_3360.html

IHI to Verify Ammonia Co-Firing and Mono-Firing Technologies at Indonesian Thermal Power Plants

IHI Corporation (IHI) will conclude a memorandum of understanding today with PT Pembangkitan Jawa-Bali (PJB) to jointly verify the application of ammonia and biomass co-firing technologies and mono-firing technologies, and their economic feasibility. IHI and PJB formalized their agreement during the Asian Green Growth Partnership Ministerial Meeting Public-Private Forum, being held by Japan's Ministry of Economy, Trade and Industry. PJB is a wholly owned subsidiary of PT Perusahaan Listrik Negara (PLN), Indonesia's state-owned electric power company. IHI and PJB will conduct technical studies on boilers at PJB's Gresik Thermal Power Plant and others with a view to ammonia co-firing and mono-firing down the track.

https://www.ihi.co.jp/en/all_news/2022/resources_energy_environment/1197857_3488.html

Fuel Ammonia - Fuel ammonia supply chain -

IHI

IHI and Subsidiary Sign EPC Contract for Demonstration Plant at Australian Carbon-Free Hydrogen Project

- March 29, 2022 -

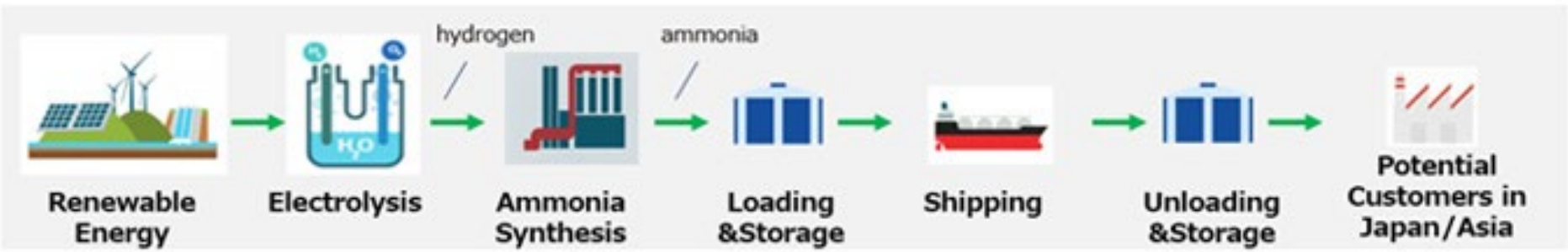
IHI announced today that Australian electricity provider CS Energy Ltd has awarded subsidiary IHI Engineering Australia Pty Ltd an engineering procurement and construction contract for the Kogan Renewable Hydrogen Demonstration Plant (HDP). This project will be adjacent to the Kogan Creek Power Station in Queensland, Australia.

Woodside, IHI and Marubeni to Study Hydrogen Exports as Green Ammonia from Tasmania

- May 20, 2021 -

Woodside Energy Ltd.
IHI Corporation
Marubeni Corporation

Woodside Energy Ltd., IHI Corporation and Marubeni Corporation have signed a Heads of Agreement to investigate the production and export of green ammonia produced from renewable hydro power in the Australian state of Tasmania.



Green Ammonia Supply Chain

https://www.ihi.co.jp/en/all_news/2021/resources_energy_environment/1197717_3360.html
https://www.ihi.co.jp/en/all_news/2021/resources_energy_environment/1197397_3360.html

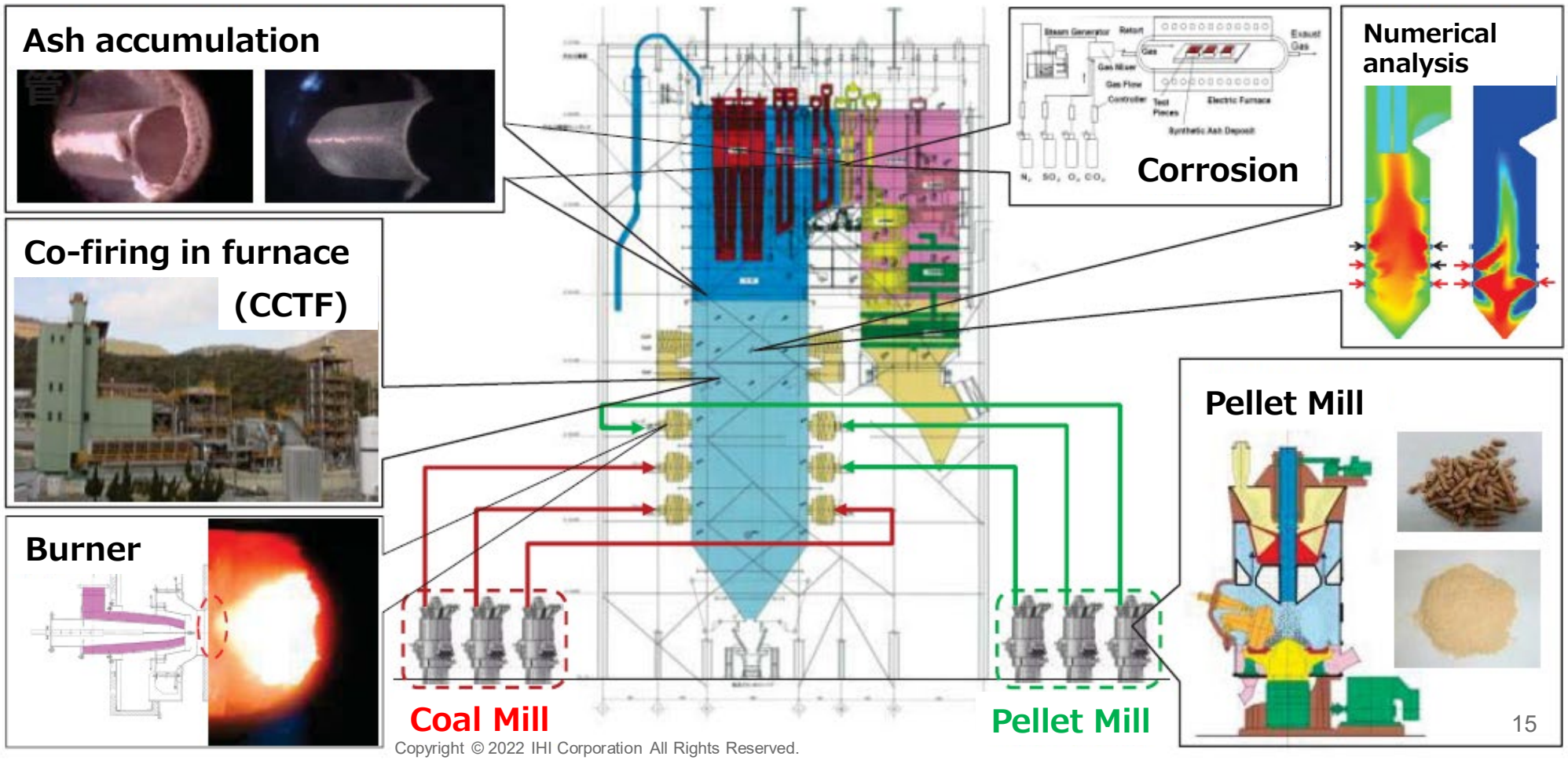
Biomass - Biomass technology -

IHI

Biomass (co-)firing

To reduce CO2 emissions (carbon neutral) from coal-fired power plant,
IHI are working on the development of technology for biomass (co-)firing.

◆ IHI's development of technology related to biomass combustion



Biomass - About biomass -

IHI

Example of Biomass

Various shape

Woody Chip
11.7 MJ/kg, 33%

Easy to handle in pellet form

Woody Pellet
16.7MJ/kg, 12%

Pruned Wood
8.0 MJ/kg, 43%

Bark
7.4 MJ/kg, 52%

WOODY

WASTE

Including Chlorine and foreign matter such as nails etc.

Waste Wood
13MJ/kg, 25%

High moisture
Low Calorific value

Paper Sludge
2.6 MJ/kg, 64%

AGRICULTURAL

Palm Waste
14.6 MJ/kg, 10%

Bagasse
6.9 MJ/kg, 49%

Coffee Grounds
8.8 MJ/kg, 60%

High moisture content

Biomass type
LHV, Moisture (Typical)

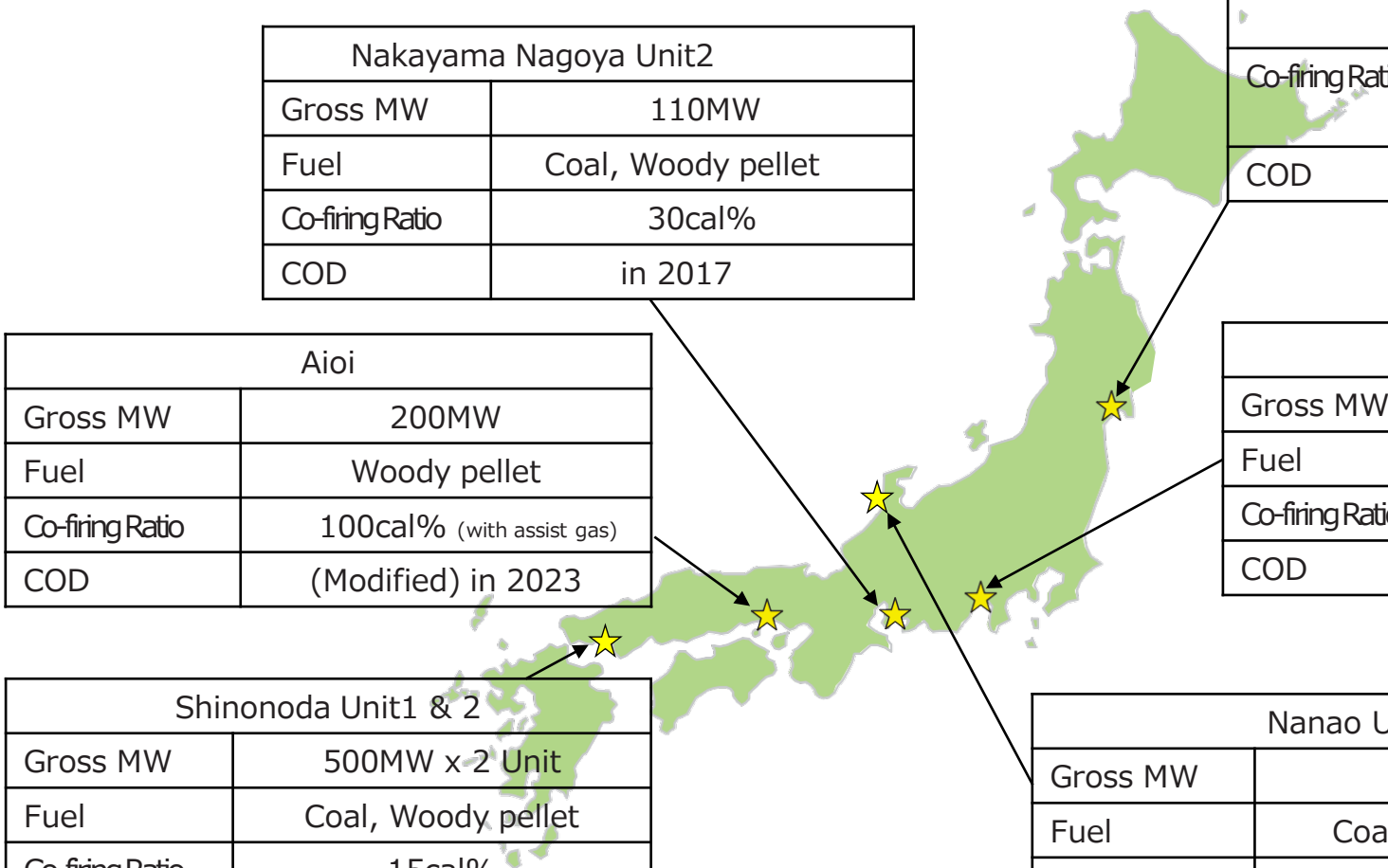
LHV: Lower Heating Value (as received base)

Biomass - IHI biomass (co-)firing power plant -

IHI

IHI biomass (co-)firing power plant

IHI already has a result of more than 30cal% biomass co-firing.
And is working toward 100cal% by modification.



Ishinomaki	
Gross MW	149MW
Fuel	Coal, Woody pellet, Woody chip
Co-firing Ratio	30cal% →Modified (～42cal%)
COD	(Modified) in 2023

Nakayama Nagoya Unit2	
Gross MW	110MW
Fuel	Coal, Woody pellet
Co-firing Ratio	30cal%
COD	in 2017

Aioi	
Gross MW	200MW
Fuel	Woody pellet
Co-firing Ratio	100cal% (with assist gas)
COD	(Modified) in 2023

Suzukawa	
Gross MW	112MW
Fuel	Woody pellet
Co-firing Ratio	100cal% (with assist oil)
COD	(Modified) in 2022

Shinonoda Unit1 & 2	
Gross MW	500MW x 2 Unit
Fuel	Coal, Woody pellet
Co-firing Ratio	15cal%
COD	(Modified) in 2020

Nanao Unit2	
Gross MW	700MW
Fuel	Coal, Woody pellet
Co-firing Ratio	15cal%
COD	(Modified) After FY2024

Biomass - Biomass utilization for thermal power -

IHI

Received an order for the conversion heavy oil and crude oil boilers to woody biomass fuel

-October 30, 2018-

IHI and IUK have received an order from Aioi BioEnergy Co., Ltd. for the woody biomass fuel change work of Unit 2 of KEPCO Aioi Power Plant. This project is for the woody biomass power generation project promoted by Aioi BioEnergy, and commercial operation is scheduled to begin in January 2023.

KEPCO Aioi power station

Received an order for the conversion to woody biomass fuel of boilers for power generation

-December 04, 2019-

IHI has received an order from Suzukawa Energy Center Co., Ltd. for the woody biomass conversion work of the thermal power plant. This project is for the woody biomass conversion project promoted by Suzukawa Energy Center and will be the first woody biomass conversion work in Japan at a PC-fired boiler. Commercial operation is scheduled in summer 2022.

Suzukawa Energy Center Power Station

https://www.ihi.co.jp/ihi/all_news/2018/resources_energy_environment/1190426_1616.html

https://www.ihi.co.jp/ihi/all_news/2019/resources_energy_environment/1190454_1591.html

Biomass - Biomass supply chain -

IHI

IHI technologies and contribution to the creation of carbon neutrality, solving the issues in the world largest vegetable oil industry.

Oil Palm Trunk (OPT)

Dump

Soil Pollution & GHG Emission

- OPT amount:30mill-t/year
- GHG amount:15mill-t･CO2/year

Empty Fruit Bunch (EFB)

Dump

Soil Pollution & GHG Emission

- EFB amount:20mill-t/year
- GHG amount:10mill-t･CO2/year

Palm Oil Mill Effluent (POME)

Discharge

Water Pollution・GHG Emission

- POME amount:60mill-t/year
- GHG amount:35mill-t･CO2/year

IHI Palm Solutions

OPT Pellet

- Carbon reduction
- Improve environmental
- Circular economy

EFB Pellet

- Carbon reduction
- Improve environmental
- Circular economy

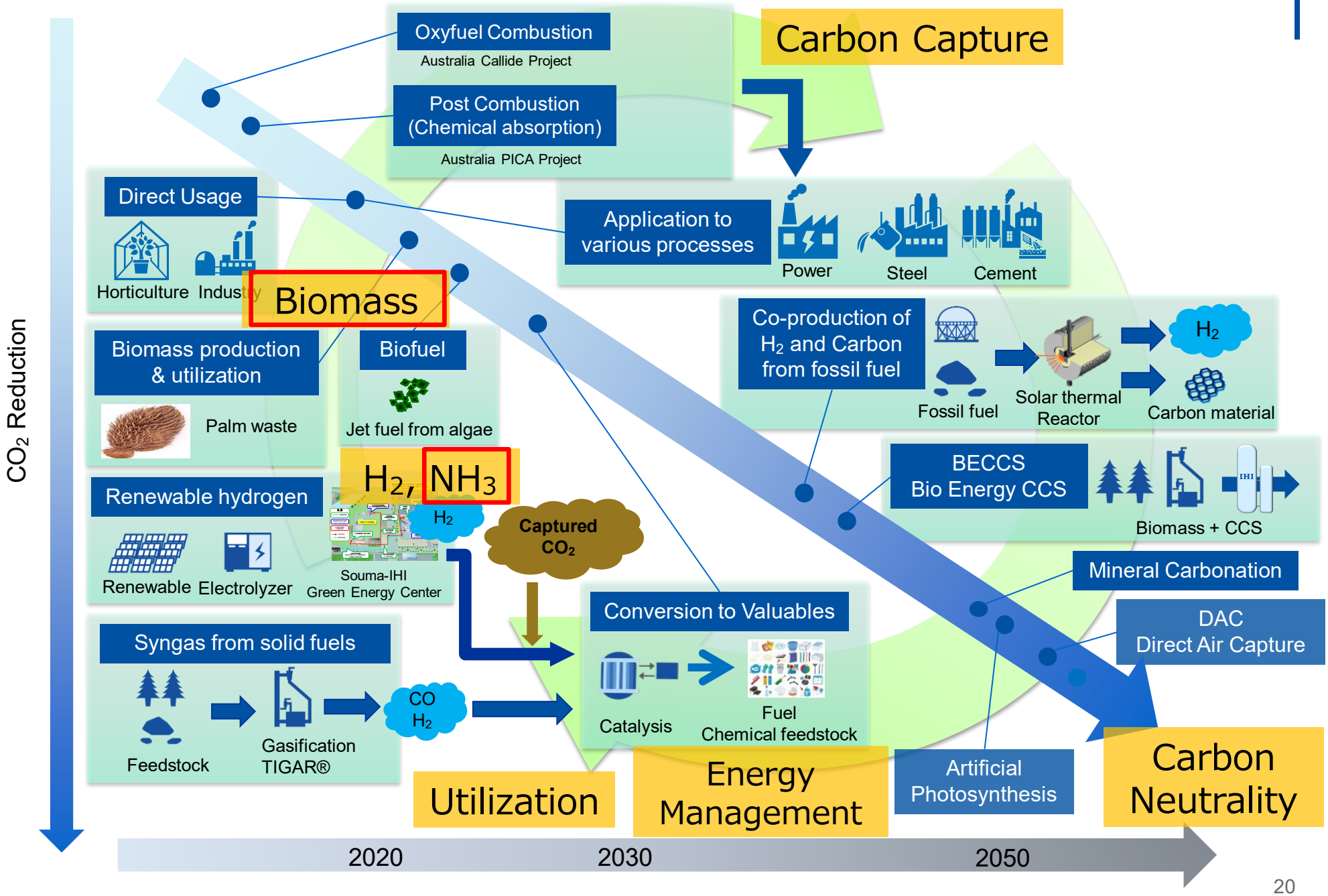
Crude Palm Oil

Clean Water

- Improve environmental
- Generate Renewable Energy
- Improve productivity

Under IHI's Business Development

Summary -IHI's Technology Roadmap for Carbon Neutrality- IHI



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