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TOYO's Solution for Energy Transition in Ethylene Plant

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TOYO ENGINEERING CORPORATION

Corporate Profile

Established	:	May 1, 1961
President & CEO	:	Haruo Nagamatsu
Listed	:	Prime Market of Tokyo Stock Exchange
Offices	:	Head Office (Chiba) & Tokyo Head Office
Capital Stock	:	US$ 0.16 Billion

Agenda

0 Toyo's Solution for Energy Transition in Ethylene Plant

1 Cold Energy Recovery

2 Green Methanol

3 Ammonia Firing Cracking Furnace

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TOYO's Solution for Energy Transition in Ethylene Plant

CO_2 Reduction Level → High

Short Term

Key point
- ✓ Proven technology
- ✓ Retrofitting of existing plant
- ✓ Seamless integration of existing plant

Solution
- **Cold Energy Recovery**
- **Gas Turbine Integration**
- **Gas Cracker Integration**
- **Etc.**

Middle/Long Term

Key point
- ✓ Integration of TOYO's Core technology + New CN technology
- ✓ Co-Creation with Partners

Solution
- **Green Methanol**
- **Fuel Ammonia**
- **Sustainable Aviation Fuel (SAF)**

2020 — 2025 — 2030

Short Term Solution : Proven technology + Retrofitting of existing plant
Middle/Long Term Solution : TOYO's Core technology + New CN Technology

Your Success, Our Pride.

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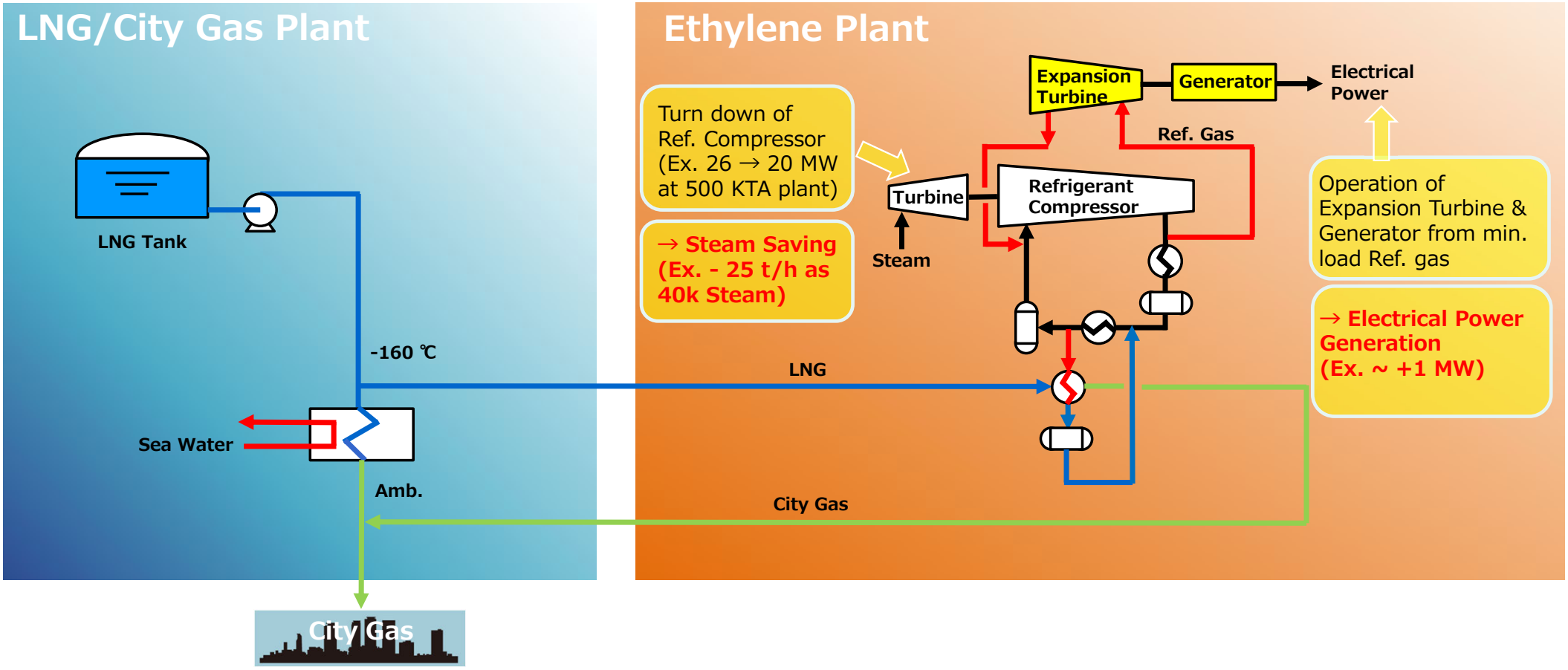
Cold Energy Recovery in Ethylene Plant integrated with LNG/City Gas Plant



Key Point for design :

- Steam saving and Electrical power generation in Ethylene Plant.
- In case of LNG trip, smooth change over from LNG recovery to Ref. Compressor.

Cold Energy Recovery in Ethylene Plant integrated with LNG/City Gas Plant

- Client : Mitsui Chemical Inc.
- Location : Osaka, Japan
- Project scope : FS, FEED and EPC
- Project completion : 2010
- Award : Client awarded of IPEEC* for 1st list of international Top 10 Best Practices in 2016.


https://jp.mitsuichemicals.com/jp/release/2016/2016_0822.htm

*IPEEC : International Partnership for Energy Efficiency Cooperation

- Seamless Retrofitting with Existing plant.
- Reliable continues operation since 2010.

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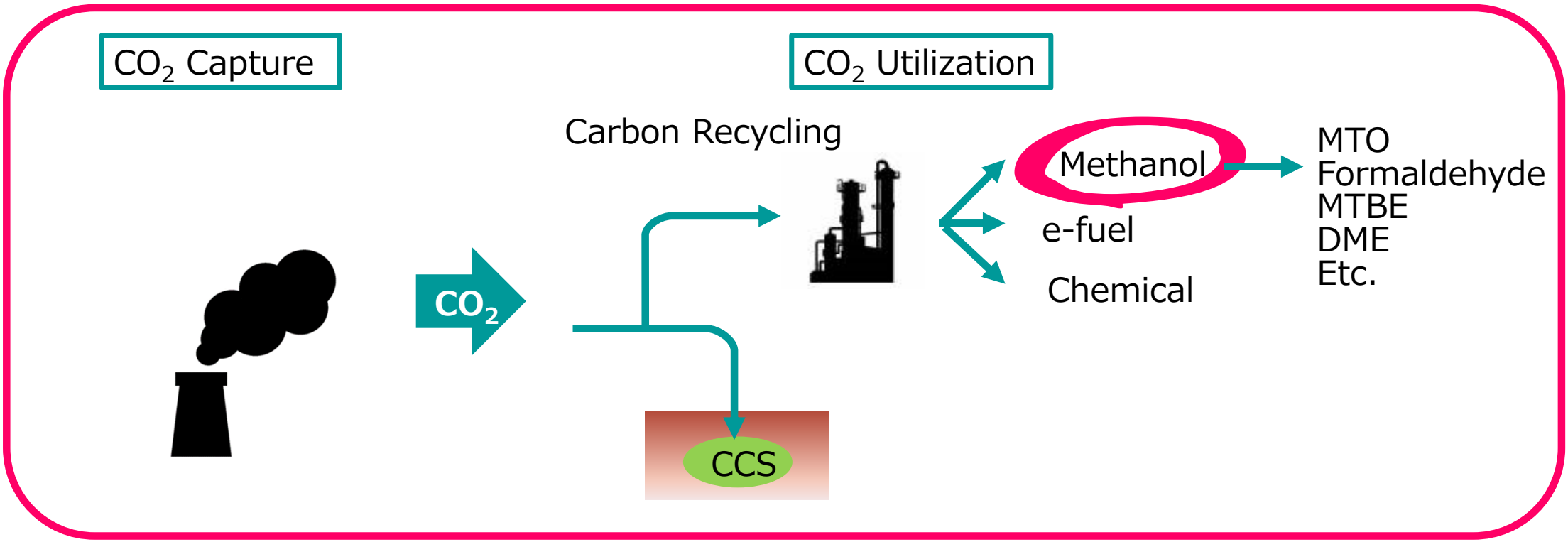
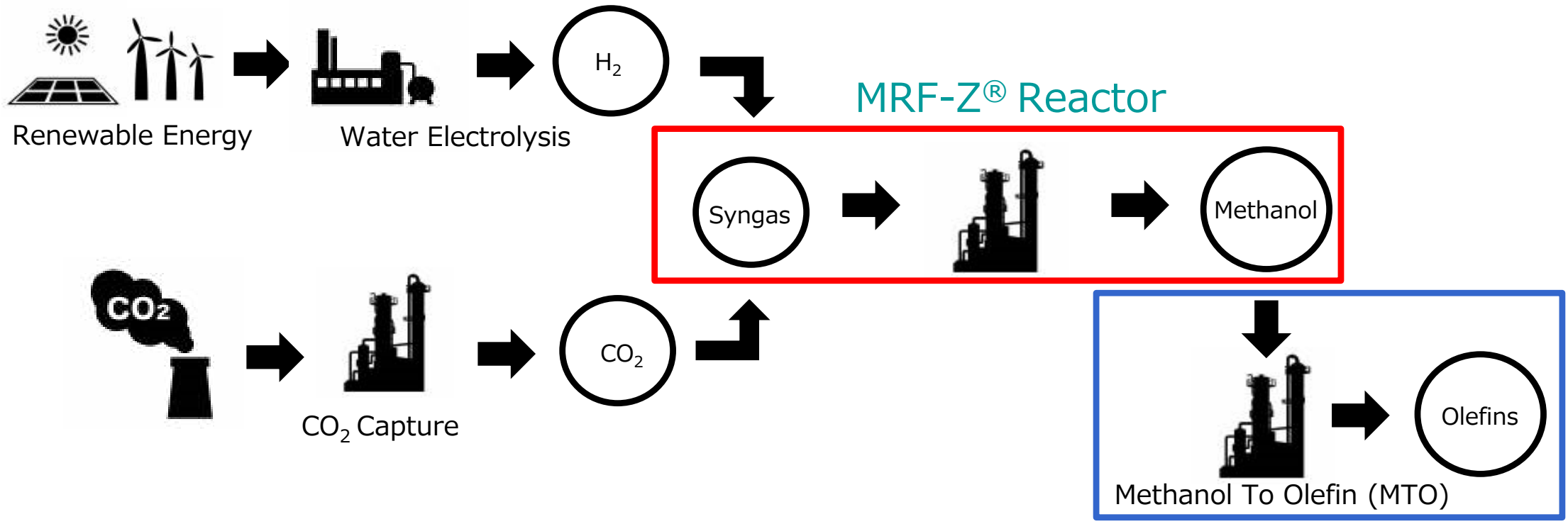
Offering overall CO_2 value Chain



- CCUS is focused to realize carbon neutrality in 2050.
- "Carbon Recycling" is key role to utilized CO_2 as resource.

g-Methanol® & MRF-Z® Reactor



- **g-Methanol®** :Process for producing Methanol by CO2 and H2 using renewable energy.
- **MRF-Z®** Reactor :TOYO's proprietary methanol synthesis reactor.

➡ Olefin can be produced by integrating with MTO Process

Methanol Synthesis Reaction

Carbon Oxides Hydrogenation:

$CO + 2\,H_2 \rightleftharpoons CH_3OH$ ($\Delta H_r = -90.6$ MJ/kmol)

$CO_2 + 3\,H_2 \rightleftharpoons CH_3OH + H_2O$ ($\Delta H_r = -49.4$ MJ/kmol)

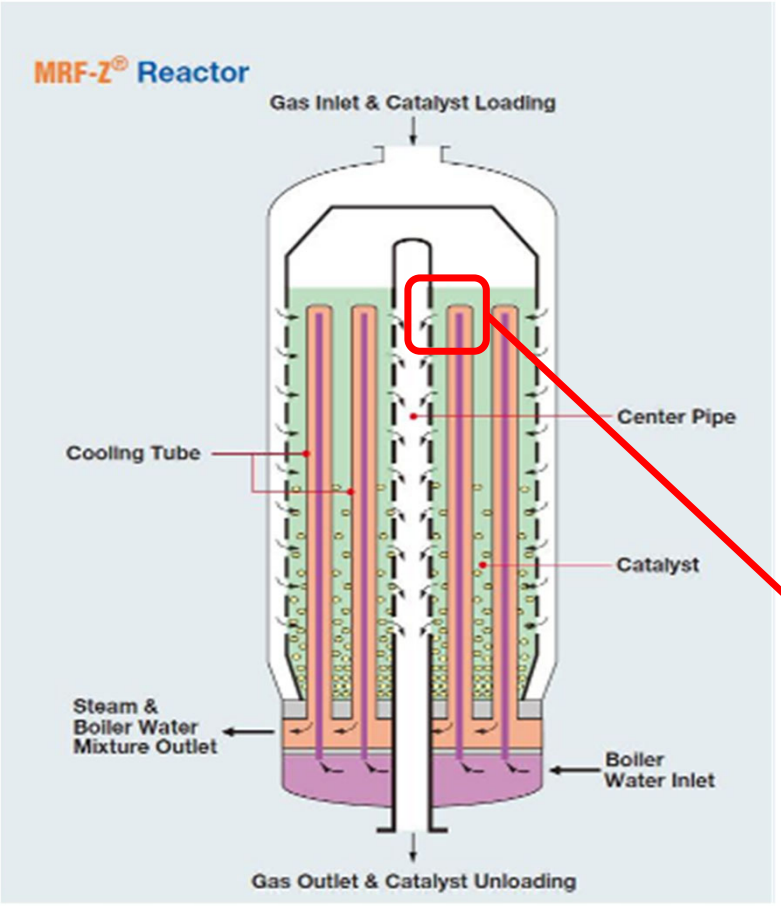
Reverse Shift:

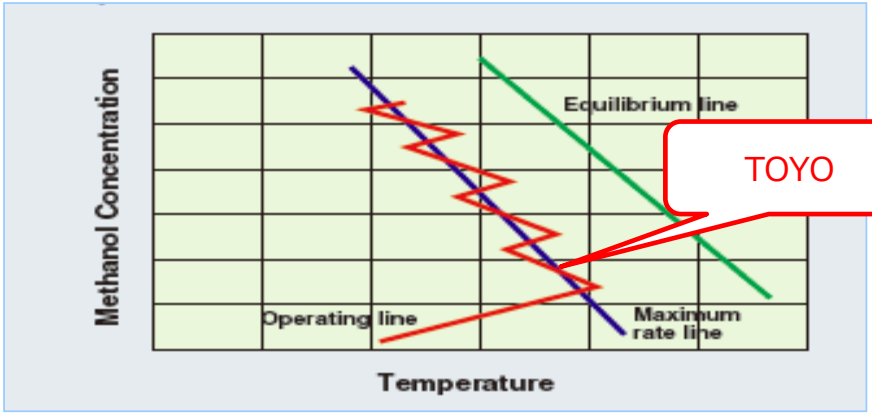
$CO_2 + H_2 \rightleftharpoons CO + H_2O$ ($\Delta H_r = 41.2$ MJ/kmol)

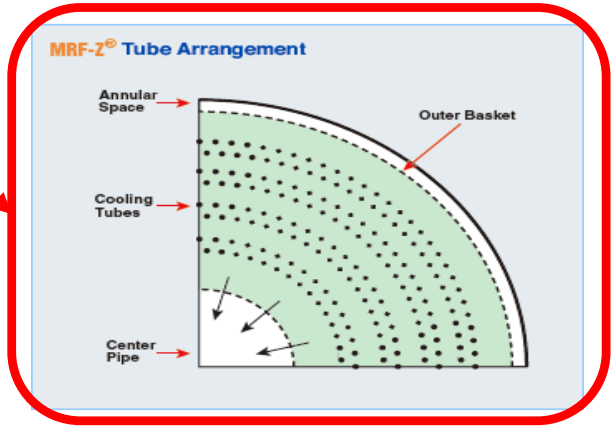
The three reactions proceed at the same time and the overall reaction is exothermic.
The reaction heat is recovered by generating M.P. steam.

What is MRF-Z® Reactor?

- Multi-stage cooling
- Radial Flow
- Type-Z temp profile







Key technology : Effective Heat Removal can realize competitive cost by min catalyst volume

Capacity of MRF-Z®

Pilot Plant, Japan (1985)

50 t/d

Trinidad & Tobago Methanol Co. (1990)

300 t/d

(For Acetylene Off Gas)

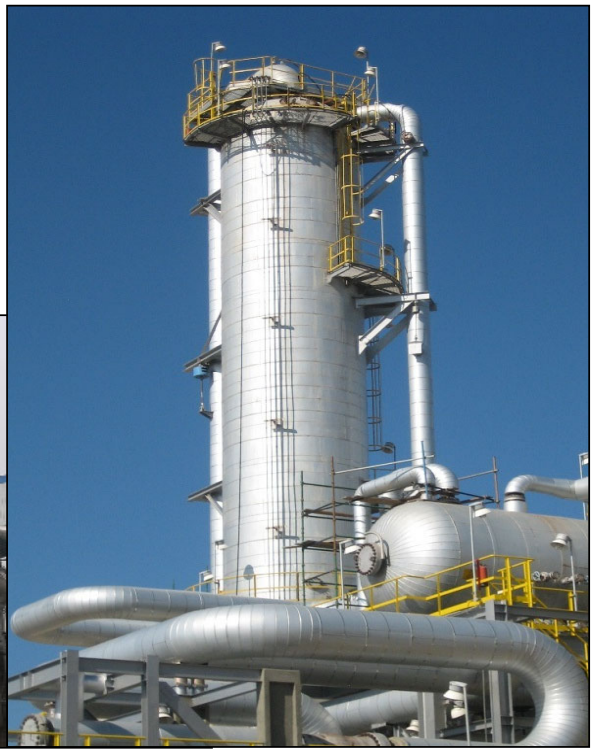
Sichuan Vinylon Works, China (1998)

420 t/d

(If NG, 600-700 t/d)

Lu Tian Hua, China (2006)

1,350 t/d



Oman Methanol Co. (2007)

3,000 t/d

Ready for 5,000 t/d Design by 1 train

Available 5,000 t/d Design for 1 Train.
➡ Integrated with MTO, Appx. 550 KTA Olefins can be produced.

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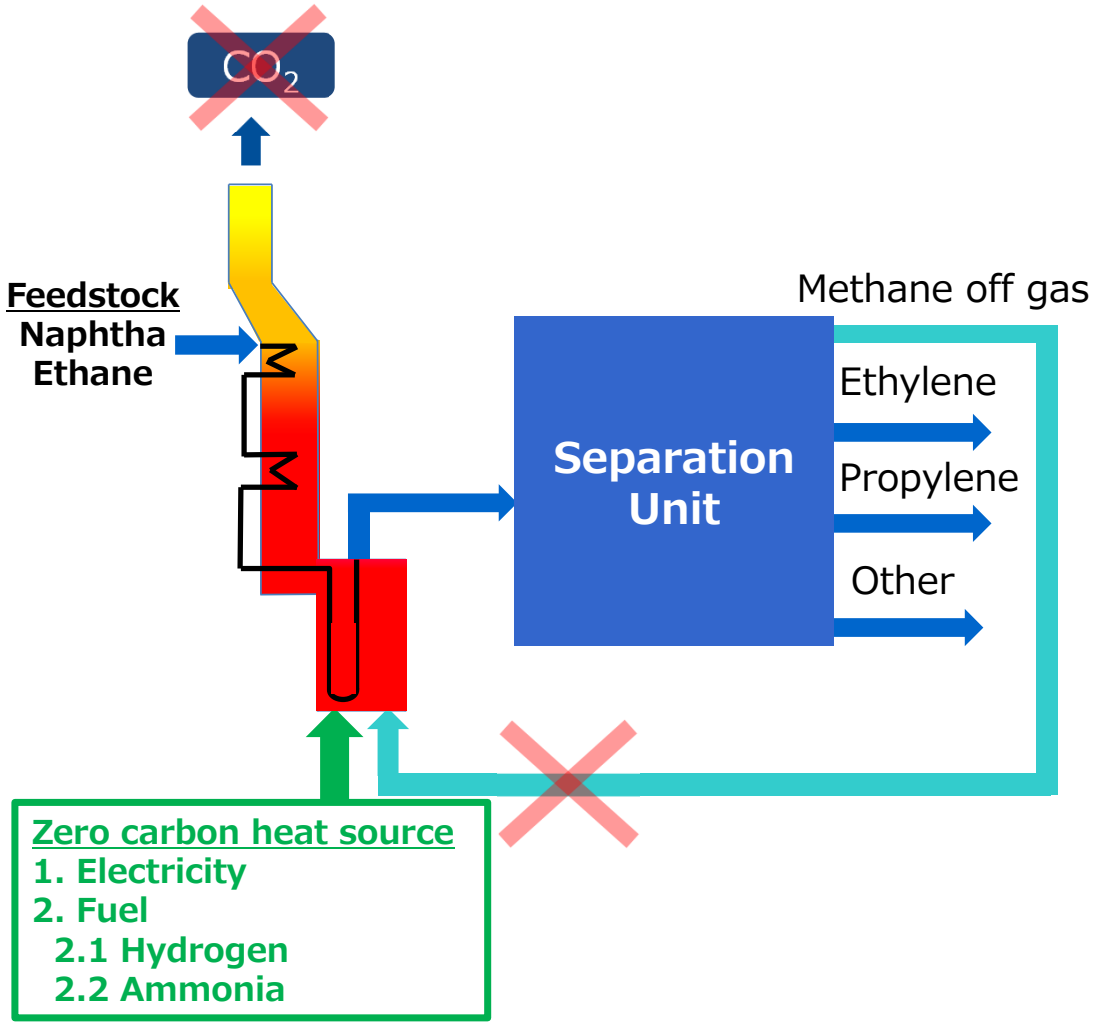
Energy Transition for Cracking furnace

- The major source of CO2 emissions in ethylene plant is cracking furnace due to combustion of methane off gas.
- Significant reduction of the emission is possible by energy transition to zero carbon heat source.
- Zero carbon heat sources are;
  1. Electricity (Electrical furnace)
  2. Fuel
     - 2.1 Hydrogen
     - 2.2 Ammonia



Electrical furnace development

#	Country	Technology Holders	Partner/Plant Owner	Technology
1	Germany	Linde Engineering	BASF SABIC	Electrically heated steam cracker furnaces
2	USA- Netherland	TNO+ISPT	Shell Dow	TNO FL
3	EU	Technip Energies Siemens Energy	Borealis, BP, Repsol, Total Energies SE, Versalis	Rotating Olefins cracking furnace (ROC)
		Technip Energies	LyondellBasell Chevron Phillips Chemical	E-Furnace by T.EN™
4	Finland- Netherlands	Coolbrook	Shell	Roto Dynamic Reactor (RDR)
5	USA	Lummis Technology	-	SRT-e

- **Development is proceeded all over the world by major Licensors.**
- **Status is still under development & demonstration by Pilot plant only.**

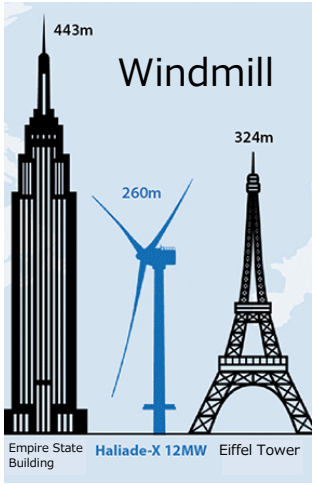
Challenging for Electrical furnace

600KTA Naphtha cracking furnace
(8 furnaces)

Required electricity = **560 MW**

If it is supplied by renewable energy power

- Typical Windmill (80 m class) **2 MW×280 items**
- Largest Windmill (200m class) **10 MW × 56 items**
- Solar Photovoltaics (Largest class) **235 MW× 3 places**
- Nuclear Power Generation **1,100 MW**



◆ **Significant amount of green electricity is required for typical capacity of Naphtha cracking furnaces.**

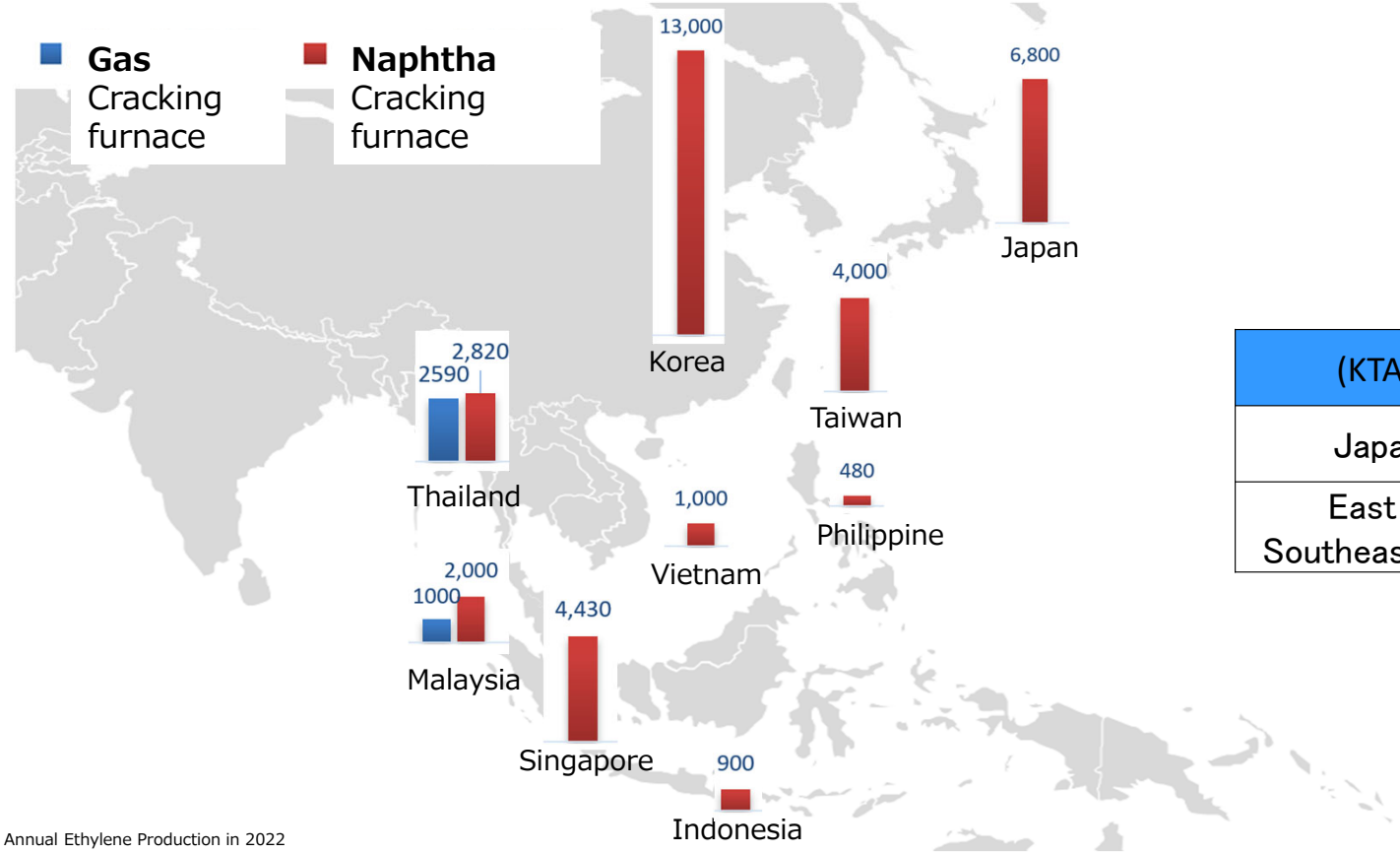
Hydrogen & Ammonia fuel

Good Challenge bad

Fuel	Production	Transportation /Storage	Consumption	Aptitude
Hydrogen	**Gas cracking furnace** ~85% H2 off gas as by-product. - Only Balanced H2 by water electrolysis etc.	Difficulty due to Extremely light gas	◆ ~85%H2 off gas is already used. ◆ Under development 100% combustion burners.	**Gas cracking furnace** **(Ex. USA, import Shale gas and Hydrogen through pipeline)**
	Naphtha cracking furnace Methane rich off gas only. - Amount of H2 is required.	Possible short transportation by piping line		
Ammonia	◆ Proven & commercial technology. ◆ Need to expand production base and supply chain.	◆ Easy ship and storage ◆ widespread infrastructure	◆ ~50% NH3 fuel to industrial furnace only ◆ Under development 100% combustion burners	**Naphtha cracking furnace** **(Ex. Japan & Asia, import Naphtha & Ammonia by ship)**

- **Different aptitude by mainly furnace type and transportation.**
- **Hydrogen fuel : Gas cracking furnace is suitable since ~85% of H2 is included in Ethylene plant off gas and only balanced H2 to be imported through pipeline.**
- **Ammonia fuel : Naphtha cracking furnace is suitable since easy ship and storage like feedstock Naphtha.**

Annual Ethylene Production in East & Southeast Asia



Annual Ethylene Production in 2022

(KTA)	Gas	Naphtha
Japan		6,800
East & Southeast Asia	3,590	28,630

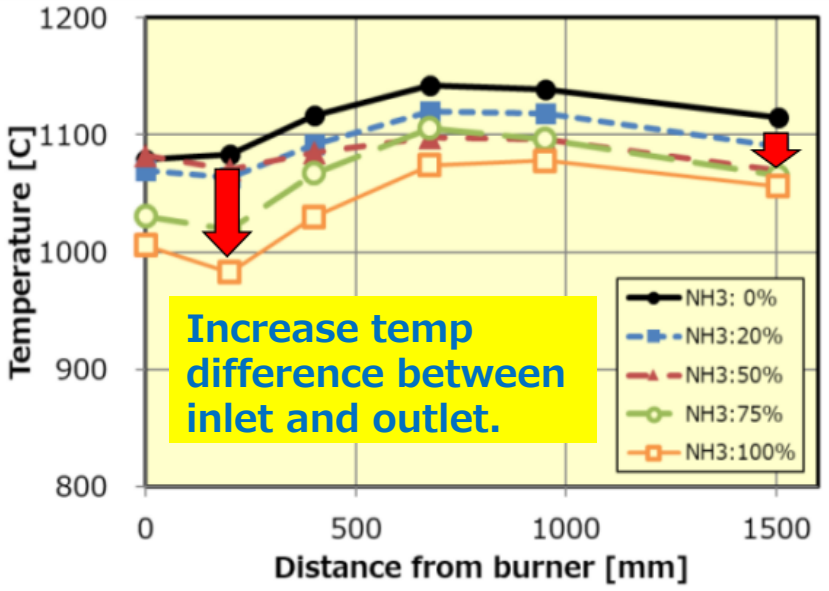
East & Southeast Asia has many naphtha cracking furnaces potentially capable of Ammonia fuel.

Challenging for Ammonia fuel to cracking furnace

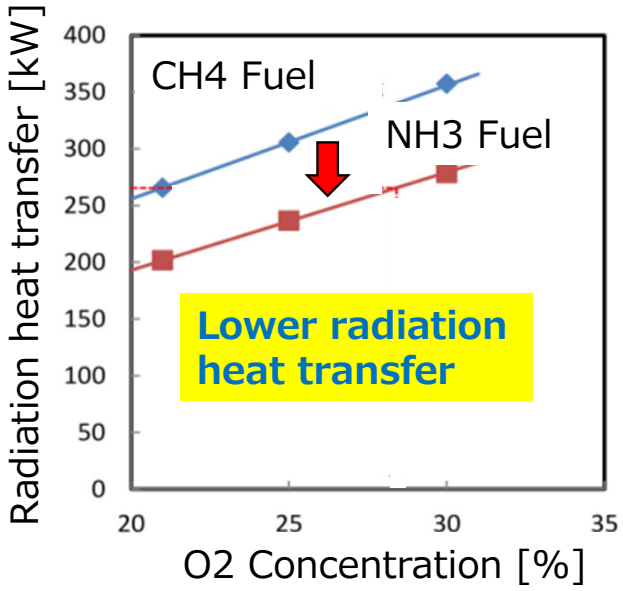
Reference: R&D for Ammonia firing in industrial furnace compared with Methane firing

(https://www.jst.go.jp/sip/dl/k04/end/team6-3.pdf)

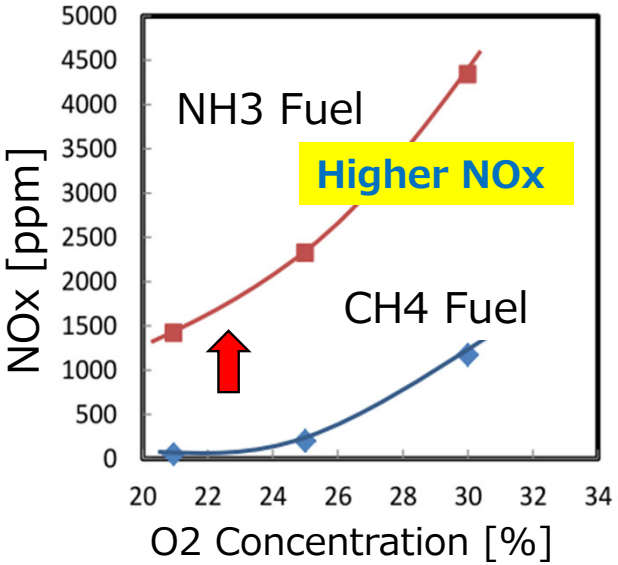
① Temperature profile furnace of several ratio of CH4/NH3 fuel



② Radiation heat transfer of CH4 fuel and NH3 fuel



③ NOx Concentration of CH4 fuel and NH3 fuel



① Increase un-uniform temperature profile
② Lower radiation heat transfer
③ Higher NOx

TOYO is developing Ammonia Firing Cracking Furnace as Green Innovation Project in Japan.

Green Innovation Project in Japan

Practical application of Naphtha cracking furnace adapted to Ammonia Burners

1. R&D Organization

National Research and Development Agency in Japan (NEDO*)

*New Energy and Industrial Technology Development Organization

Mitsui Chemicals, Inc.

- Leader Company
- Construction Application
- Furnace Operation

Maruzen Petrochemical Co., Ltd.

- Construction Application
- Furnace Operation

Toyo Engineering Corp.

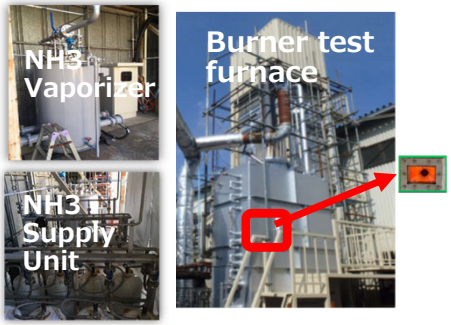
EPC for Furnace

Sojitz Machinery Corp.

Development & Fabrication of Burner

2. Target of R&D

① Development of Ammonia burners for Naphtha cracking furnace
② Development of Test size furnace
③ Demonstration of Commercial furnaces by 2030



◆ Co-Creation by Japanese Companies commissioned by NEDO.
◆ Target is application of Naphtha furnace adapted to Ammonia Burner by 2030.

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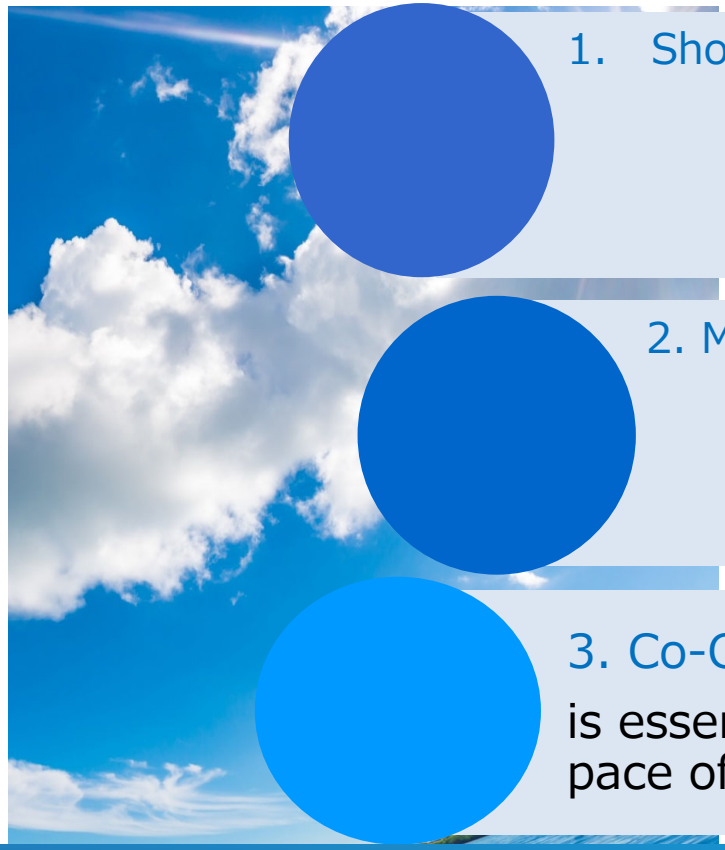
Summary : Towards the Energy Transition



1. Short team : Proven Technology + Retrofitting of Existing Plant
   - ① Cold Energy Recovery
   - ② Gas Turbine Integration
   - ③ Gas cracking furnace integration etc.

2. Middle/Long Term : TOYO's Core technology + New CN Technology
   - ① Green Methanol
   - ② Ammonia Firing Cracking Furnace
   - ③ Sustainable Aviation Fuel

3. Co-Creation with Partners

is essential element of international development to accelerate the pace of innovation for the energy transition.

TOYO contributes to Energy transition for carbon neutral in Ethylene plant!


TOYO
ENGINEERING
Thank you