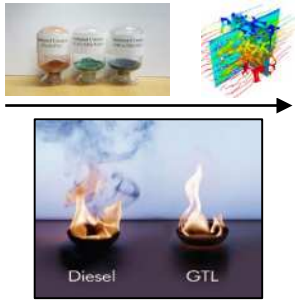
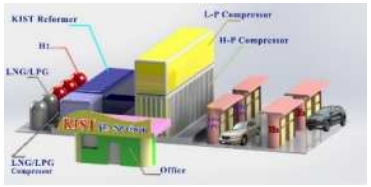
KIST Future Clean Fuels - Hydrogen

Hybrid Energy Station

Stranded Gas
Associated Gas
Flaring Gas
CO_2 Rich NG
Flue Gas





16-19, June, 2021

Project Manager : Dr. Dong Ju, Moon
Clean Energy Research Center, KIST

To : EU Partner (Investor from Spain, France & Germany)

THE KIST, Making New History

KIST
Korea Institute of Science and Technology

KIST Introduction

KIST focuses on **Frontier and Global-Agenda Research** by concentrating on large-scale, long-term, and interdisciplinary R&D projects, thereby strengthening its role as a public research institute and differentiating itself from academia and industry.

Research staff (as of '19.8.22)

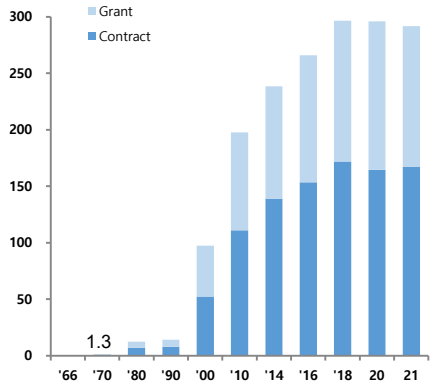
		Principal	Senior	Associate	Total
Regular Position	Executives	2	-	-	**2**
	Researchers	314	234	46	**594**
	Specialists	17	23	64	**104**
	Administrators	39	36	52	**120**
	Assistants	-	-	126	**126**
	Sum	**372**	**293**	**288**	**953**

Temporary Positions	Doctor	Master	Bachelor	Total
	327	**165**	**153**	**645**

Students	Doctor	Master	Bachelor	Total
	331	**361**	**331**	**1023**

Total	2,621

Budget



REUTERS

Ranked 6th among the World's Most Innovative Research Institutions (2016&2017, Thomson Reuters)

2016 Rankings

1	Alternative Energies and Atomic Energy Commission	FRANCE
2	Fraunhofer Society	GERMANY
3	Japan Science & Technology Agency	JAPAN
4	U.S. Department of Health & Human Services	USA
5	National Center for Scientific Research	FRANCE
6	**Korea Institute of Science & Technology**	**SOUTH KOREA**
7	National Institute of Advanced Industrial Science&Technology	JAPAN

Through K-R&D,
KIST is Pursuing a Brighter Future for All Humankind.

2017 Rankings

1	Heath & Human Services Laboratories	USA
2	Alternative Energies and Atomic Energy Commission	FRANCE
3	Fraunhofer Society	GERMANY
4	Japan Science & Technology Agency	JAPAN
5	National Center for Scientific Research	JAPAN
6	**Korea Institute of Science & Technology**	**SOUTH KOREA**
7	Medical Research Council	UK

KIST's Contribution

National Growth Strategy

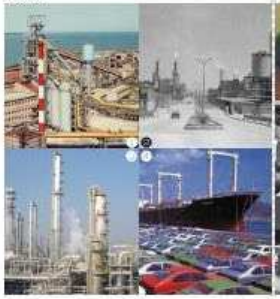
1960s	1970s	1980s	1990s	2000s	2010s
Rapid Industrialization	Building Heavy & Chemical Industries	Building Advanced Economy	Globalization	Building Knowledge Economy	Green & Creative Economy
Economic Development Plan: 1st 1962-1966; 2nd 1967-1971; 3rd 1972-1976; 4th 1977-1981; 5th 1982-1986; 6th 1987-1991; 7th 1992-1996					
1963 Fiber Industry **1964** Cement Industry **1966** KIST established **1967** MOST established	**1970** - Saemaul Undong launched - Seoul-Busan Expressway built **1971** KAIS established **1972-1976** ETRI, KRISS, KIMM established **1973** - Presidential Proclamation of the HCI Policy - POSCO's construction of Pohang Works Phase 1 completed - Daedeok Special Research and Development Zone established	**1980** Economy Stabilization Policy **1986** POSTECH established **1988** Summer Olympics in Seoul	**1991** Korea joins UN **1993** Real-name financial system introduced **1996** Korea joins OECD **1997** Financial crisis **1998** Venture capital introduced	**2001** Incheon International Airport established **2002** FIFA World Cup **2004** KTX introduced **2007** Korea-U.S. FTA established **2008** Global banking crisis	**2010** G20 Seoul Summit **2011** Samsung ranked 1st in smart phone market **2014** Global oil crisis

KIST Strategy

1960s	1970s	1980s	1990s	2000s	2010s
Planning for Heavy & Chemical Industry	Key Industrial Technology	Assimilation of Advanced Technology	Catch-up with Advanced Technology	Frontier & Source Technology	Creative Technology

KIST's Major Achievements

1960s

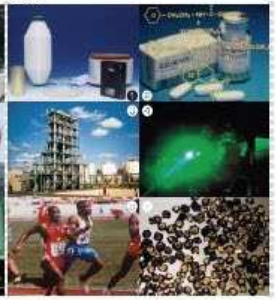


- POSCO Technology Planning ('69)
- Major Chemical Industries
- Korean Heavy Industry
- Automobile Industry

1970s

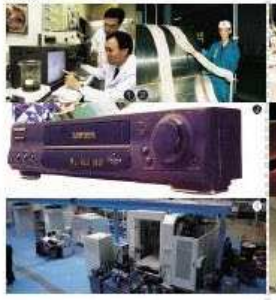
- Color TV ('72)
- Electronic Telephone Exchanger ('74)
- Mini-Computer (Sejong 1) ('75)
- Dongbok Steel Wire ('76)
- Electric Vehicle ('78)
- PET Film ('78)

1980s



- Artificial Fiber ('82)
- Distomatosis ('83)
- CFC Replacement Materials ('83)
- Optical Fiber ('84)
- Doping Control ('88)
- Artificial Diamond ('88)

1990s



- Waste Water Treatment ('92)
- Lyocell ('93)
- Diamond Head Drum ('94)
- Linear Motor ('99)

2000s

- Hydrogen Fuel Cell ('00)
- Brain Science ('01)
- Capsule Endoscope ('03)
- Robhaz ('04)
- Humanoid Robot '05)

2010s

- English-Teaching Robot Mero ('10)
- Polymer Membrane for Fuel Cell ('11)
- FCCL for VLSI ('12)
- Spin Memory Device ('12)
- Robotic Endoscope '12)
- Functional Connectomics for Brain Circuitry '12)


Making the Future Today
GRaND KIST
Globally Recognized and Nationally Dedicating KIST

Dr. Moon's Group Performance

Dr. Moon's R&D Performance

: Korea Patents: 94
Foreign Patents : 46
Papers:156 and Conference: 616

Technology Transfer and Commercialization

: 15 Technologies

No	Project Name	Year
1	Multi-purpose in-situ Catalyst Characterization System	-
2	F2 Electrolytic cell design and operation technology	2019
3	Hydrogen Production System	2014
4	Process Design for Manufacturing Process of C_4F_6	2010
5	Development of Amine Monomer & Derivatives	2010
6	K32 Plant Design & Construction (40 MT / D)	2008
7	Process Design, Construction & Operation Support for manufacturing TFE	2008
8	F116 / F218 Process Design / Plant Construction (300 MT / Y)	2006
9	Commercialization of cellulosic materials by non-polluting process	2006
10	K991 manufacturing and construction (200 MT / Y)	2004
11	Development of manufacturing processes of NF_3	2004
12	Ethylene Carbonate Production Technology	2004
13	Advanced purification process of HFC-23 and Module Development	2003
14	Recovery & purification plant Design of HCl and HFC-23	2002
15	The basic design for HCFC-141b/142b Plant	1999
16	R-22 plant construction on the technical assistance (7500 MT / Y)	1994

Major R&D Awards

Future 100 Technologies and Scientist for leading Korea Industries in 2020s
(NAEK, 2013.12)

2014 National Top 100 R&D Performances (2014. 7)
Min. of Sci. ICT & Future Planning

NANO KOREA 2015 AWARD(2015. 7)
13th Int. Nanotech Sym. Nano-Conv. Expo
Min. of Sci., ICT & Fut. Planning Award

2016 National Top 100 R&D Performances
(2016. 7)., Ministry of Science, ICT & Future Planning

KIST Clean Fuel Production

Structured Catalyst Design

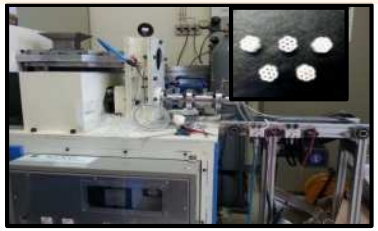



KIST Structured Catalysts

Hydrothermal Syn. Reactor

Rotary Evaporator

Atmospheric Furance



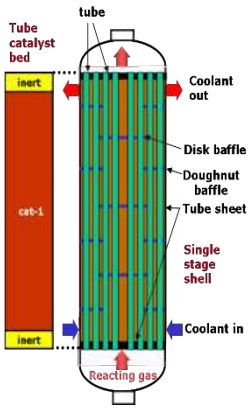
KIST Extruder System

KIST Pelletizer System

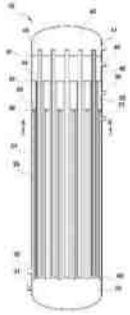
KIST Marumerizer System

Reactor Basic Design

KIST Shell & Multi-Concentric Tube Reactor [KP/USP]



Shell and Multi Double Concentric Tube Reactor



Shell and Multi Triple Concentric Tube Reactor

GTL-FPSO Process Design

KIST Reformer & H_2 Station

LPG-H_2 Station

SK Energy-KIST Collaboration Project

KIST LNG & LPG Reformer

KIST LPG & LNG Fuel Reformer

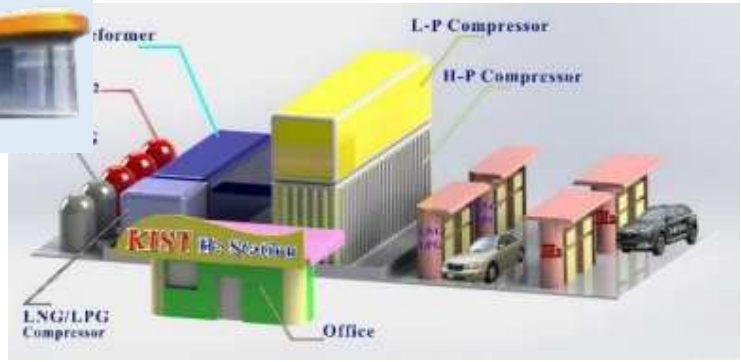
KIST LNG Fuel Reformer(4 kwh)

KIST Glycerol Reformer

Glycerol Reformer (1 Nm^3/h)

→ Design of Glycerol H_2 Station (100 Nm^3/h)

KIST LNG-H_2 Hybrid Energy System



TFE Manufacturing Process

- **Development of CFC Alternatives and Application Technology**

  - HFC-134s, HFC-125/123, 141b/142b, FCFC-22, RC318 and Fuorinated alcohol etc..

- **Design of Fluorinated Monomer**

  - Design of TFE Process by the thermal decomposition of R22 in the dilution of steam.
  - Basic Design of Production of RC318 and HFP by dimerization of TFE (5,000 MT/y).
  - Preliminary Basic Design for the Production of TFE, HFP and VDF monomers.

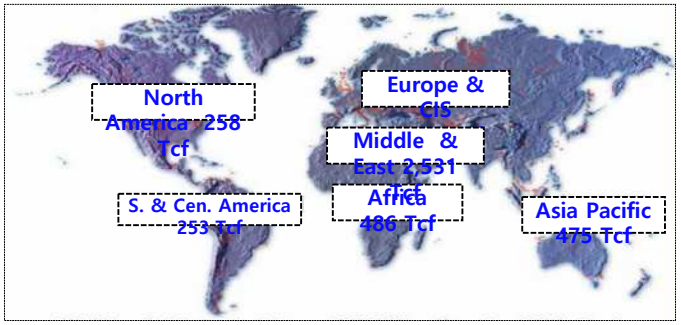
KIST Pilot Plants CFC Alternatives & HCFC Plants

CFC Alternatives & HCFC Plants
in Ulsan Chemical Co. (Korea)

CO_2 Neutralization & Clean Fuels

Global CO_2 Emission Status

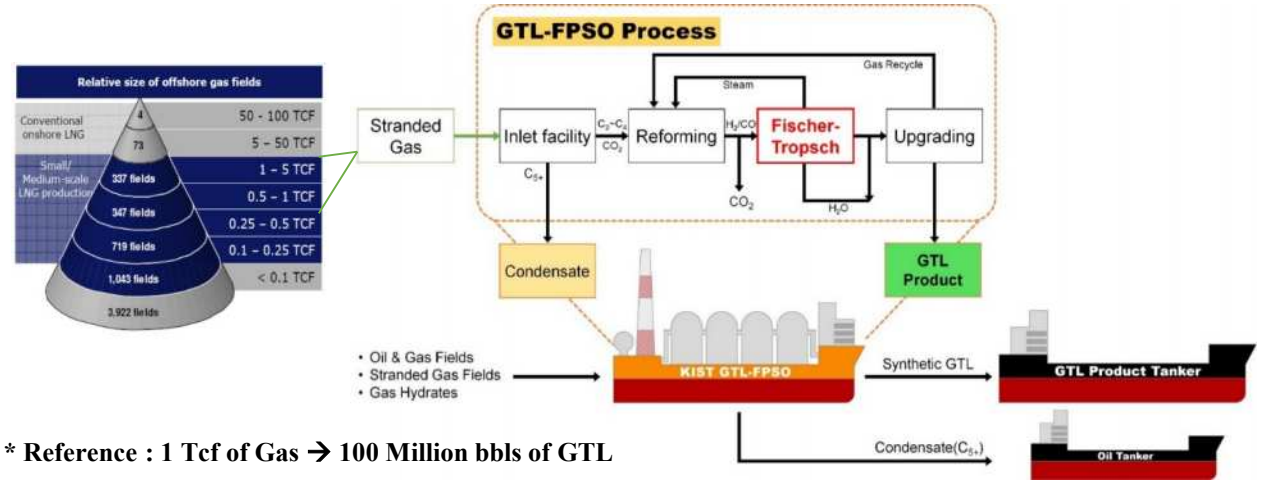
Stranded Gas

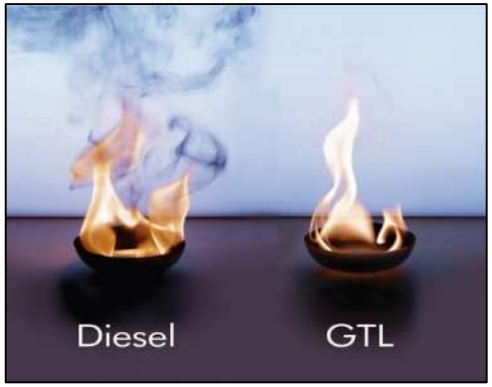


*** Reference : 1 Tcf of Gas → 100 Million bbls of GTL**

KIST GTL(MeOH)-FPSO & Small Scale GTL Process

using CO_2 Rich NG, Associated Gas & Flared NG [Moon et al., KP 10-1152666 B1 and USP 9475995 B2]





*** Reference : 1 Tcf of Gas → 100 Million bbls of GTL**

Markets Status on Clean Fuels

Status on GTL, GTL-FPSO Plants for Clean Fuels

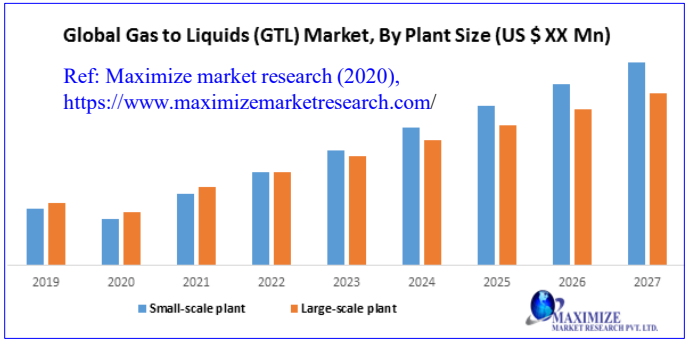
Plant	Stage	Institution	Reforming	FTS	Upgrading	CO_2-Neutral
Onshore GTL	Comm.	SASOL	ATR	SBCR(Co)	Iso-Cracking	WO
	Comm.	Shell	POX	FBR	Hydrocracking	WO
	Demo	Rentech	ATR	SBCR(Fe)	Hydrocracking	WO
	Demo	JOGMAC	SCR	SBCR(Co)	Hydrocracking	WO
Offshore GTL	Pilot	KIST-DSME	SCR	MCFBR(Co)	-	W/WO
	Pilot	KIST	SCR	MCFBR	-	W/WO

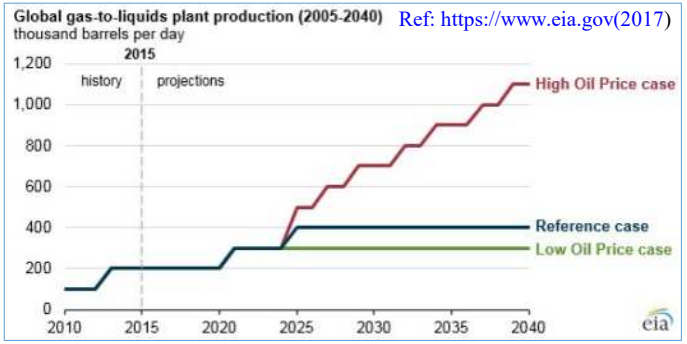
Markets & Industry Analysis on Clean Fuels

- Due to the carbon neutralization, there are many chance to monetize small scale GTL using biogas, flared gas, off gas, CO_2 and stranded gas w/wo H_2 produced by water electrolysis using surplus electricity.

- Not expect any other large-scale GTL plants to be built or expanded through 2040. Large GTL plants are capital intensive, and their economics depend on the price of crude oil relative to natural gas.

- Due to the limitation of onshore natural gas, there are many chance to monetize small scale GTL-FPSO process using flared gas, associated gas and stranded gas in offshore.





Markets Status On H_2 Station

Status on H_2 Station for FCPVs

Country	Institution	Key studies	Retention skill level
Japan	Osaka Gas	30, 100, 300 N ㎥/h NG- H_2 Reformer	30 N ㎥/h , H_2 Prod. Eff. 62.5% (LHV) 100 N ㎥/h H_2 Prod. Eff. 71% (LHV)
USA	H_2Gen Innovation	53, 80, 268 Nm³/h NG-H_2 Reformer	50N ㎥/h H_2 Prod. Eff. 67.4% (HHV)
Germany	Ws Reformer GmbH	Madrid H_2 Station reactor	50 Nm³/h H_2 Prod. Effi. 60–65%
Germany	Mahler AGS	H_2 Station Equipment	100 N ㎥/h H_2 Prod. Effi. 70%
Denmark	Haldor Topsoe	Comm. modified catalyst	Large renovation process over 1,000 N ㎥/h
Germany	Sud Chemie	Comm. modified catalyst	Large renovation process over 1,000 N ㎥/h

Markets & Industry Analysis on H_2 Stations

- Due to the limitation of by-produced H_2 from refinery plants, and the production costs of H_2 from H_2O electrolysis using solar and wind powers, the construction of LNG-H_2 station is important to enter into the hydrogen economy society with the carbon reduction and neutralization.

- World H_2 station markets : At the end of 2019, 470 hydrogen stations(HSs) were in operation worldwide, an increase of more than 20% from 2018.

- In Sep. 2019, 35 countries and inter. institutions attending the 2nd H_2 Energy Ministerial Meeting agreed to the Global Action Agenda included a target to reach 10 million H_2 vehicles and 10 000 HSs in ten years to encourage the use of H_2 and fuel cells in mobility.

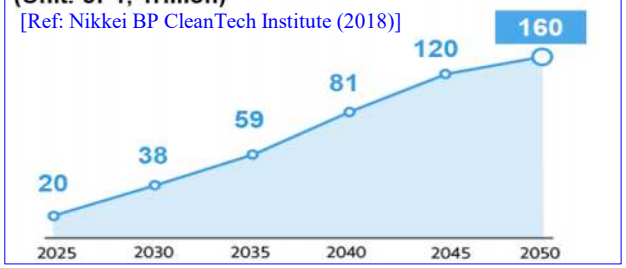
[Ref: IEA(2020), Hydrogen, IEA, Paris; https://www.iea.org/reports]

Global FCPV Distribution 2030

[Ref: Hyundai motor group (2020), https://www.hyundaimotorgroup.com/]

Global hydrogen infrastructure market size forecast (Unit: JPY, Trillion)

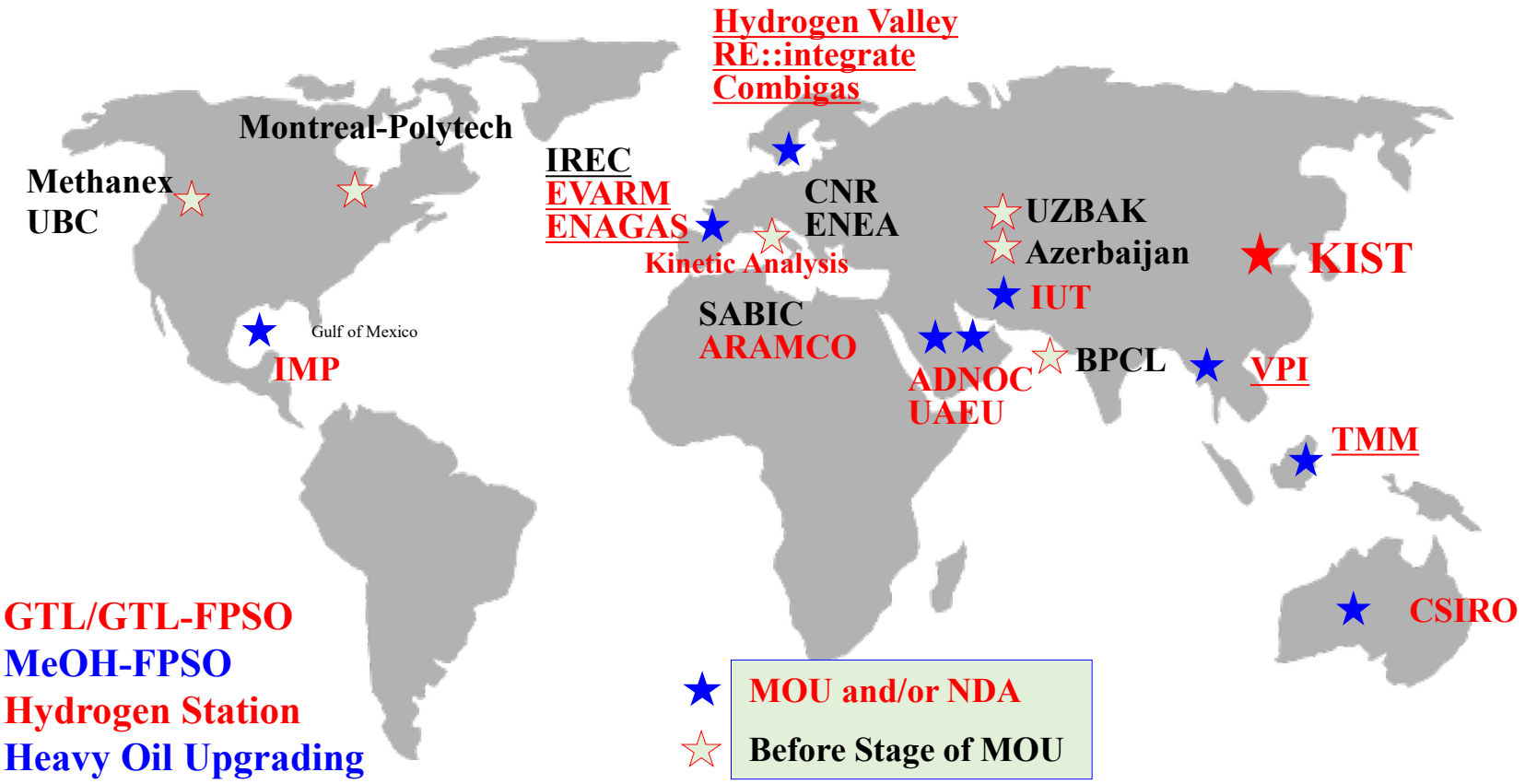
[Ref: Nikkei BP CleanTech Institute (2018)]



Dr. Moon's Inter. Collaboration

Inter. Collaboration Status of Dr. Moon's Group

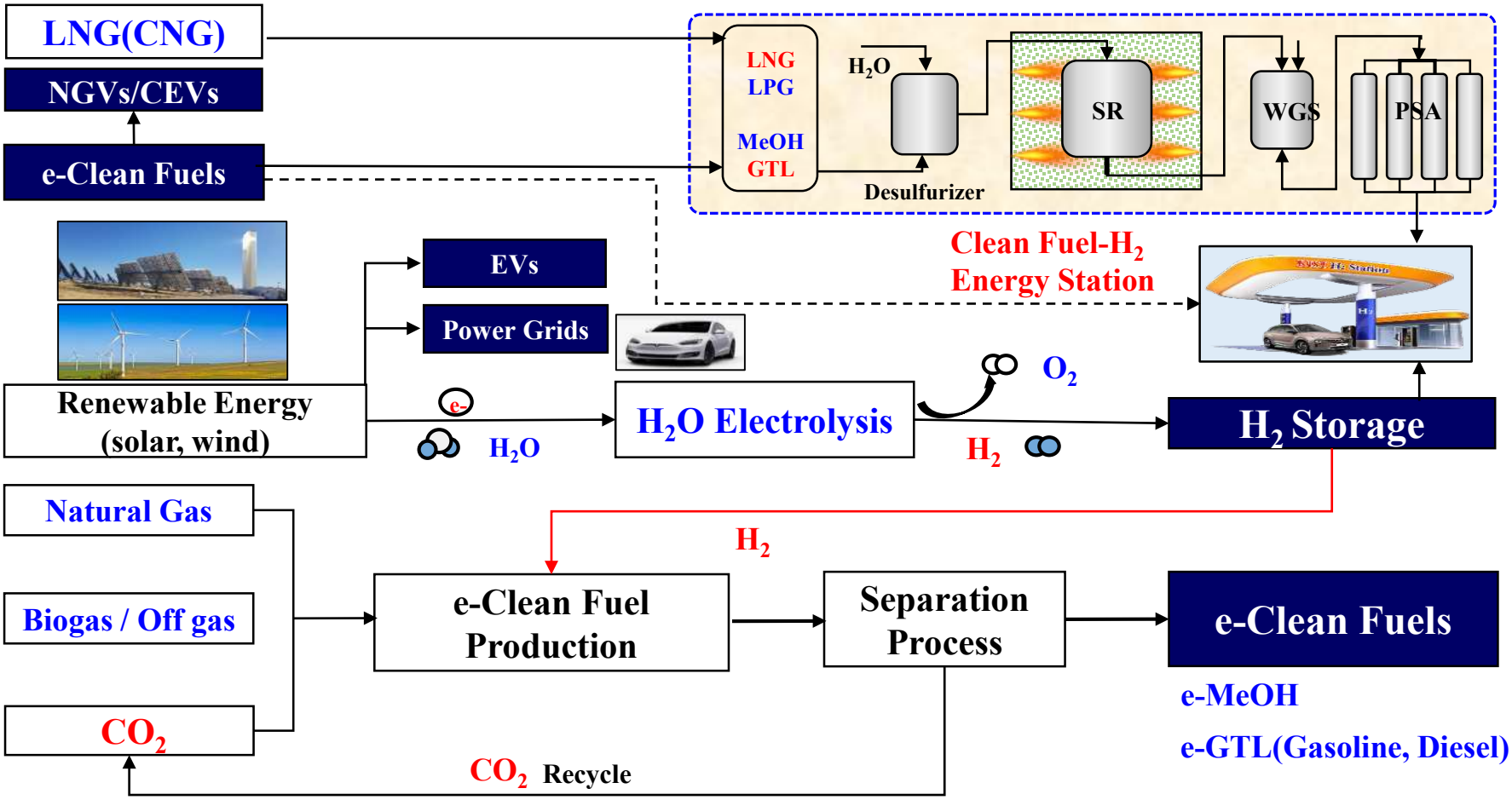
(MOU/NDA with 9 countries and 15 entities since 2014)



KIST Promotion Technology

What is e-Clean Fuels-H_2 Hybrid Energy Station ?

e-Clean Fuels-H_2 Hybrid Energy Station is a Clean Energy Solution integrated with LNG, e-clean fuels and H_2. Clean fuels can be produced from NG, biogas, associated gas and CO_2 neutralization. H_2 can be produced by water electrolysis using surplus electricity and reforming of LNG and e-Clean Fuels.

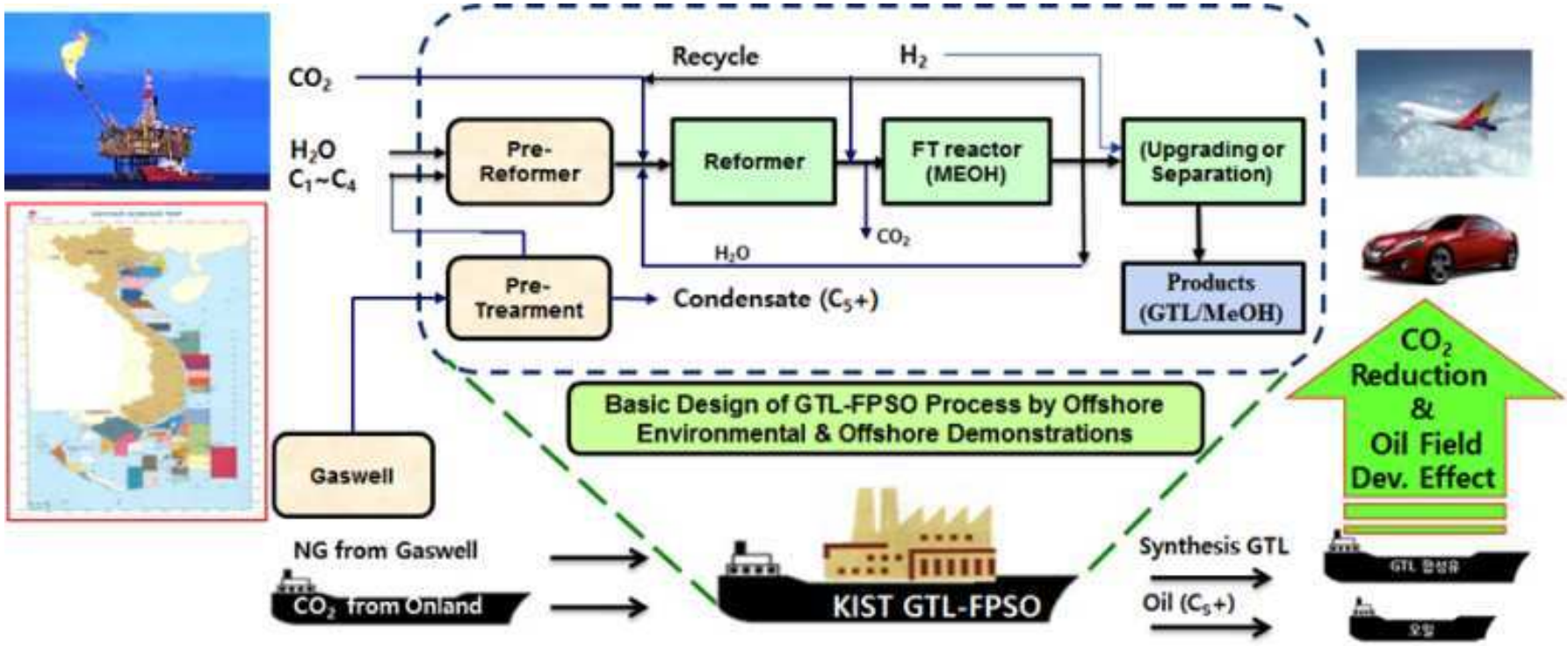


[Ref. : KP 10-2245416 B1(2021), D. J. Moon et al.]

KIST PromotionTechnology

1. GTL-FPSO Process

- **KIST GTL-FPSO & Small Scale GTL Plant**



[Ref. : USP 10046290 B2(2018), D. J. Moon et al.]

[Ref. : KP 10-1694221 B1(2017), D. J. Moon et al.]

- **Commercialization after Demonstration (1 bpd) at Vietnam offshore**

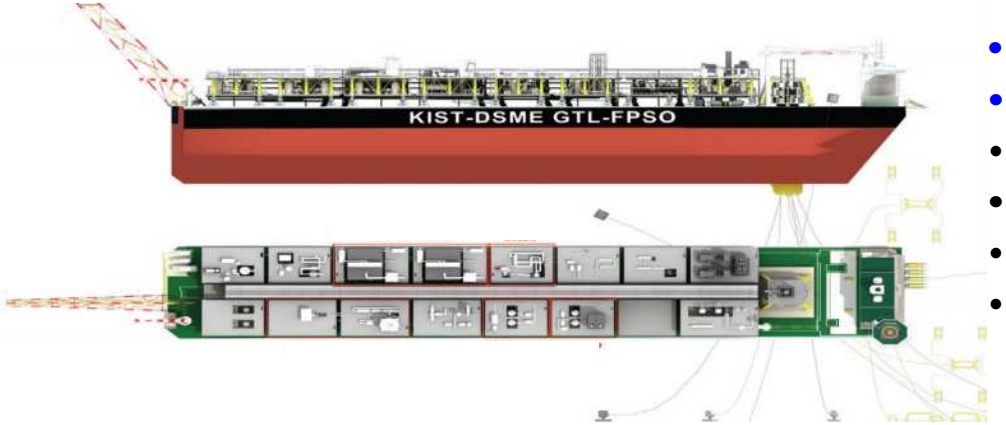
KIST GTL-FPSO Plant(1st Stage)

Key Technology of KIST GTL-FPSO Process






KIST GTL-FPSO Plant Mock-Up



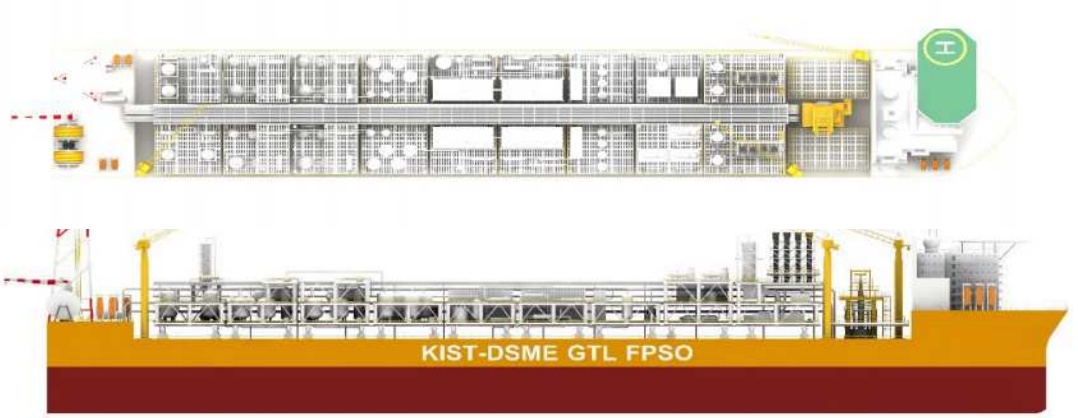
GTL-FPSO Plant Size/Specipication

- **N. G. : 200 MMSCFD Stranded Natural Gas,**
- **H_2O Feed : 126.8 Nm^3/D**
- CO_2 Feed : CO_2 Rich Natural Gas(0 ~ 30 %)
- **Clean Fuel Production Capacity : 20,000 bpd**
- GTL-FPSO Hull Dim.(m) : 310(L)x60(B)x32(D)
- Clean Fuel Cargo Storage Capacity
  : 1,500,000 BBL (240,000 m3).

KIST GTL-FPSO Plant(2nd Stage)

● KIST Sloshing GTL System

● Design & Demonstration of GTL-FPSO Process



● Mock-Up of KIST GTL-FPSO Process

PRINCIPAL PARTICULARS	
Length O.A.	370m
Length B.P.	362m
Breadth	60m
Depth	32m
Draft Operating	22m
Draft Scantling	23m
Tank Capacity	292,000m^3

Design of Commercial Catalyst

KIST Catalyst Manufacturing System

er

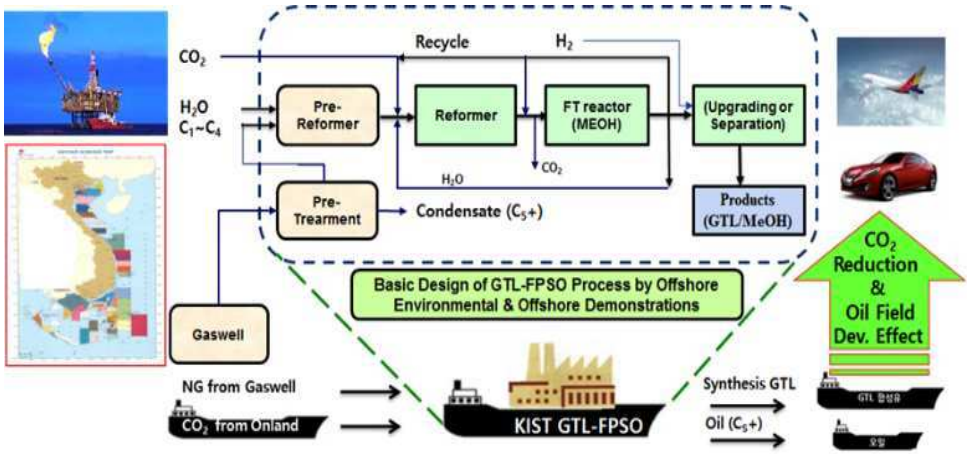
Pelletizer

Pilot Scale Catalyst for Hydrogen Station

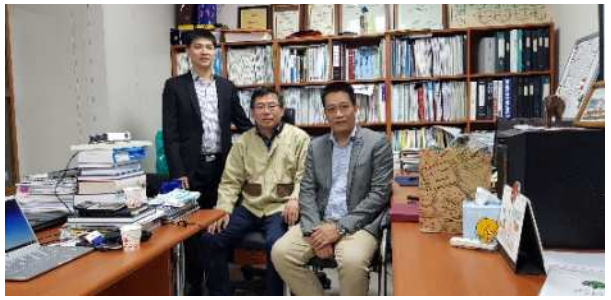
KIST Dr. Moon's Group

KIST-VPI GTL-FPSO Project

- **KIST-VPI GTL-FPSO Demonstration Project**



Diesel GTL



KIST GTL-FPSO Milestone

"Compact GTL-FPSO Plant (Technology and Leader)" was selected "The Future 100 Technologies for leading Korea Industries in 2020's" (NAEK, 2013.12)

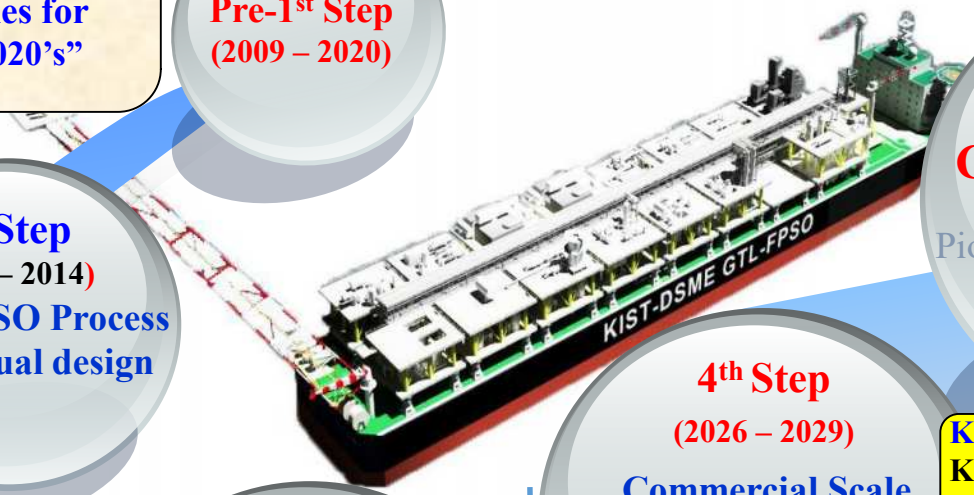
KIST Consortium Project (KIST with 5 Industries) Conceptual Design of GTL-FPSO Process

Pre-1st Step (2009 – 2020)

KIST-CSIRO MOU (2014.4)

1st Step (2011 – 2014) GTL-FPSO Process Conceptual design

KIST-VPI MOU (2017.2)
KIST-IMP MOU/NDA (2017.4)
KIST-ARAMCO NDA (2017.4)



GTL-FPSO Commercialization
Pioneer of Global market for Clean Fuel Production

We are here

2nd Step (2014 - 2016) Mini-Pilot Plant (0.01 BPD) Pre. Basic Design(I)

3rd Step (2022 – 2025) Pilot Scale Demonstration Planning (1 BPD) Pre. Basic Design(II)

4th Step (2026 – 2029) Commercial Scale Demonstration (100 BPD) Basic Design

KIST-IUT MOU(2018.01)
KIST-UAEU MOU(2018.3)
KIST-ADNOC MOU(2018.)

KIST-SABIC (2014. 11~)
KIST-BPCL (2017.5~)
KIST-IREC (2017.10~)
KIST-METHANEX (2017.9~)
KIST-ENEA/CNR(2017.8~)
KIST-ShimT-TMM(2020.9.~)

▶ Mini/Sloshing GTL Plant(5y)
Demonstration of 0.01 BPD

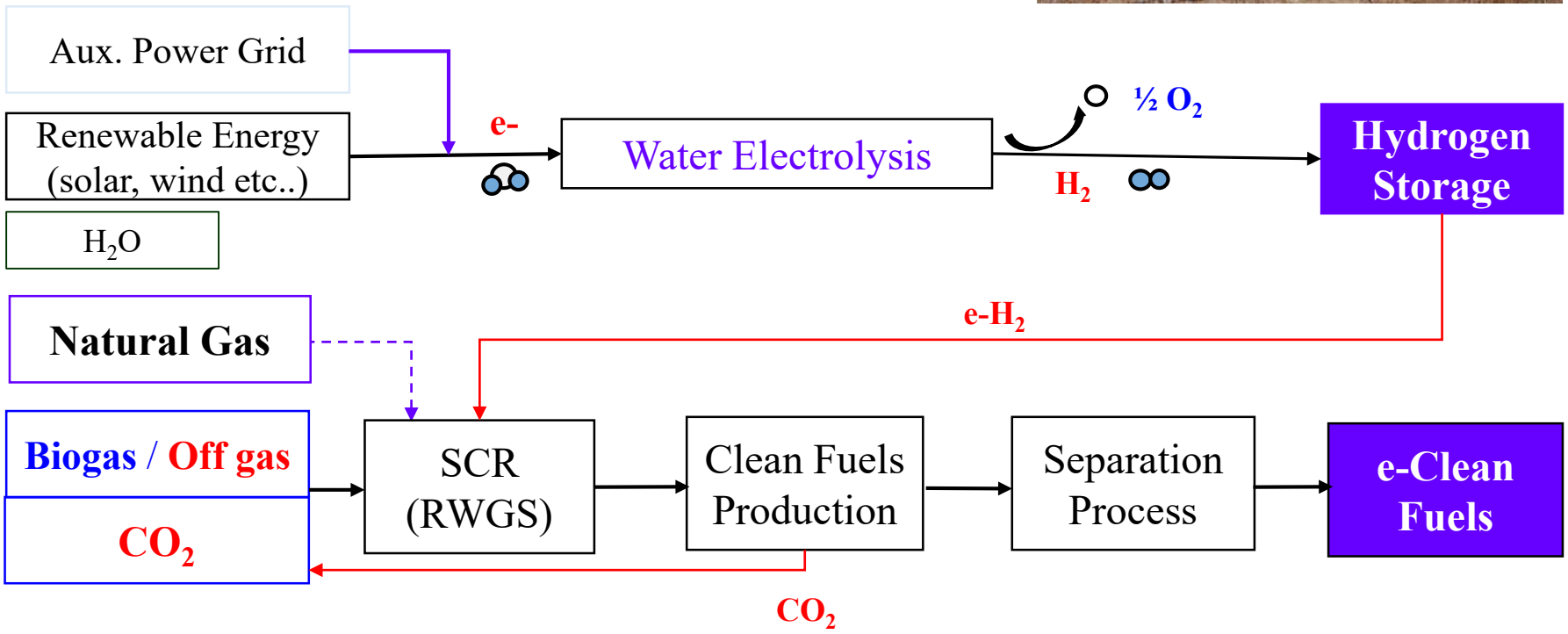
▶ Offshore Env. Demon.(4y)
Demonstration of 0.2~1 BPD

▶ Offshore Demonstration(4 y)
- Foundation of "KOGTL Consortium"
- Demonstration of 20-100 BPD Plant in offshore stranded gas fields.

KIST Promotion Technology
2. Small Scale GTL Technology

- **Small Scale GTL Process with Carbon Neutralization**

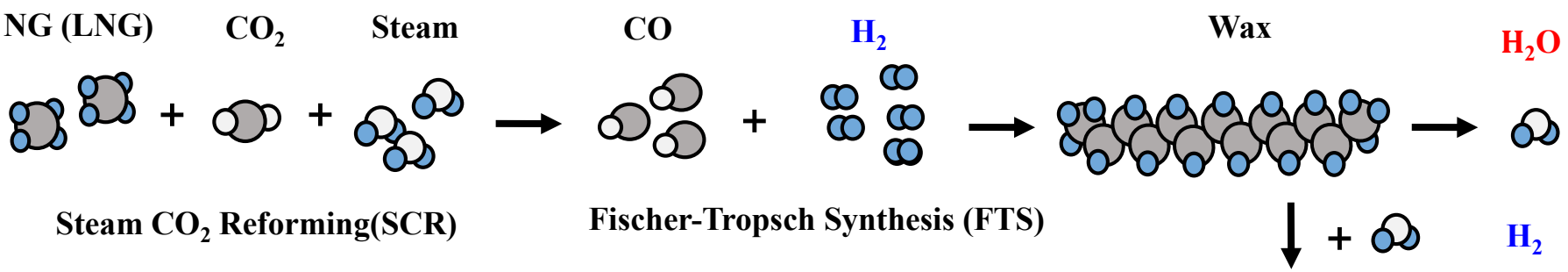




[Ref. : KP in application (2021), D. J. Moon et. al.]

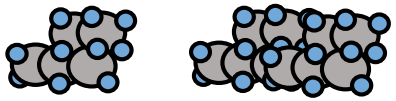
Clean Fuel with CO_2 Neutralization

1. Clean Fuel Prodution (Small Scale GTL)



(1) SCR reaction: $2CH_4 + CO_2 + 3H_2O \rightarrow 3CO + 6H_2$ $(+CO_2)$

(2) FTS reaction : $CO + 2H_2 \rightarrow -(CH_2)- + H_2O$ $(+CO_2)$



Gasoline Diesel

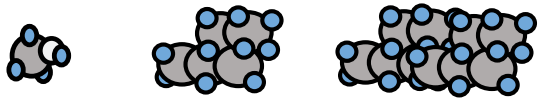
Upgrading Process

2. e-Clean Fuel Production

: Using surplus electricity(solar & wind powers)

(1) $H_2O \rightarrow$ e-H_2 $+O_2$ (water electrolysis)

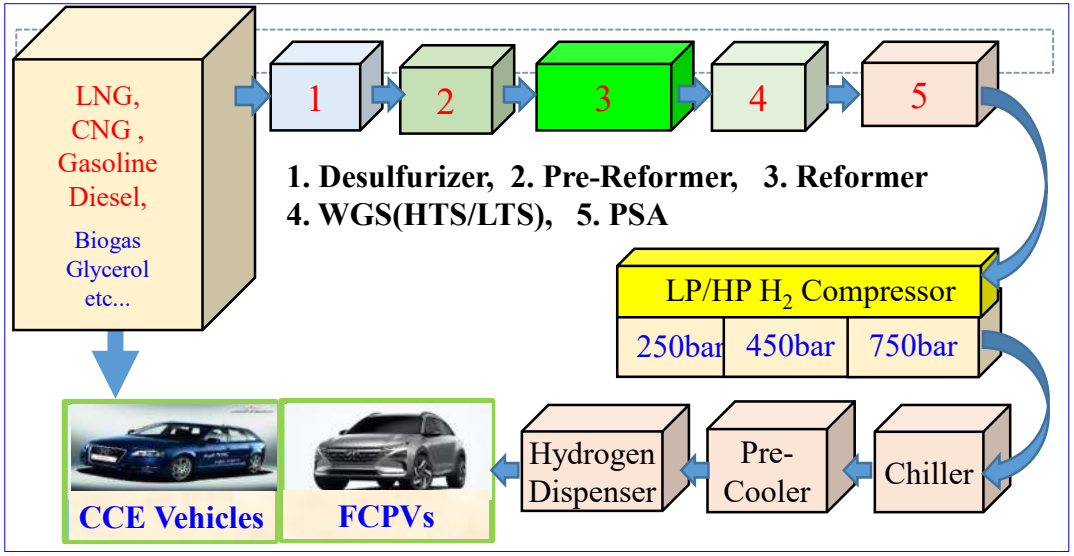
(2) CO_2 + e-$H_2 \rightarrow$ e-Clean Fuels



e-MeOH e-Gasoline e-Diesel

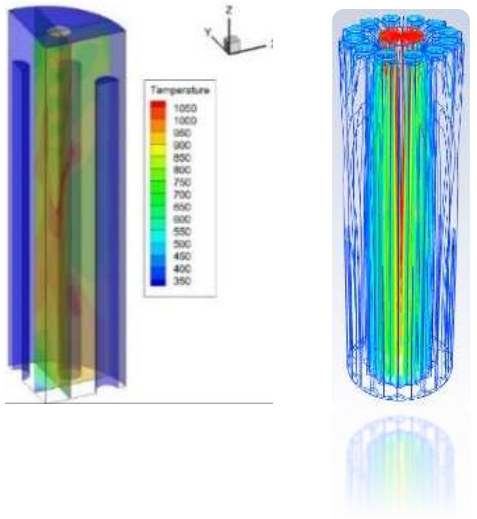
KIST Promotion Technology
3. LNG-Hydrogen Station

- **Design of Reformer & Hydrogen Station**



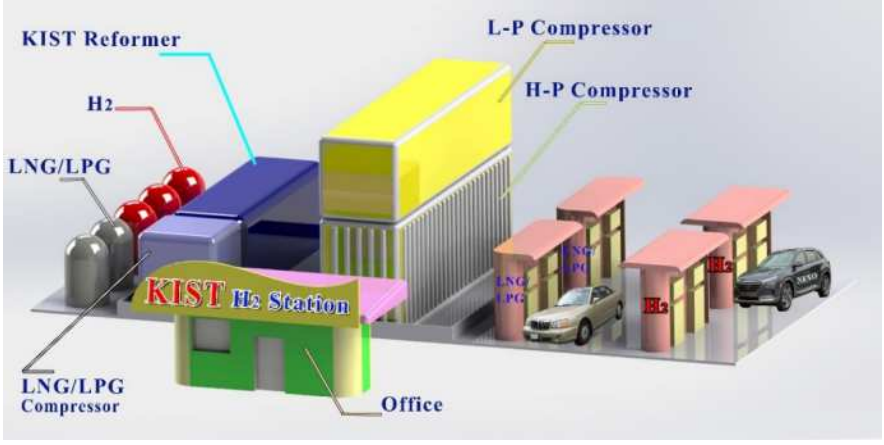
[Ref. : KP 10-2245416 B1(2021), D. J. Moon et al.]

- **Design of Fuel Processor**



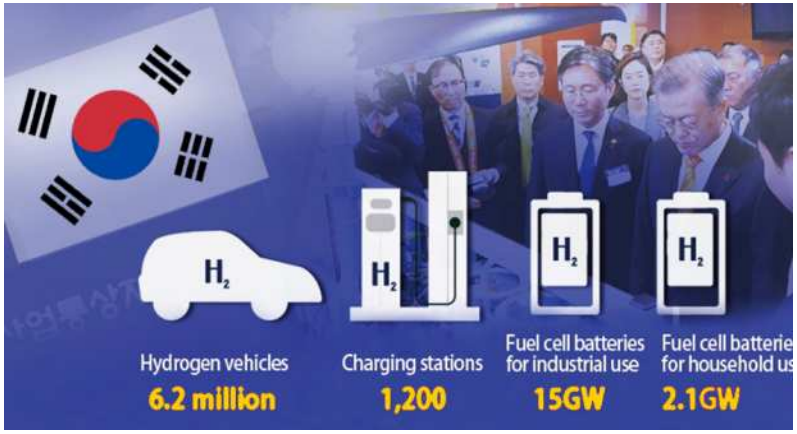
- **KIST Multi-Fuel H_2 Station**

- **KIST LNG-H_2 Station**



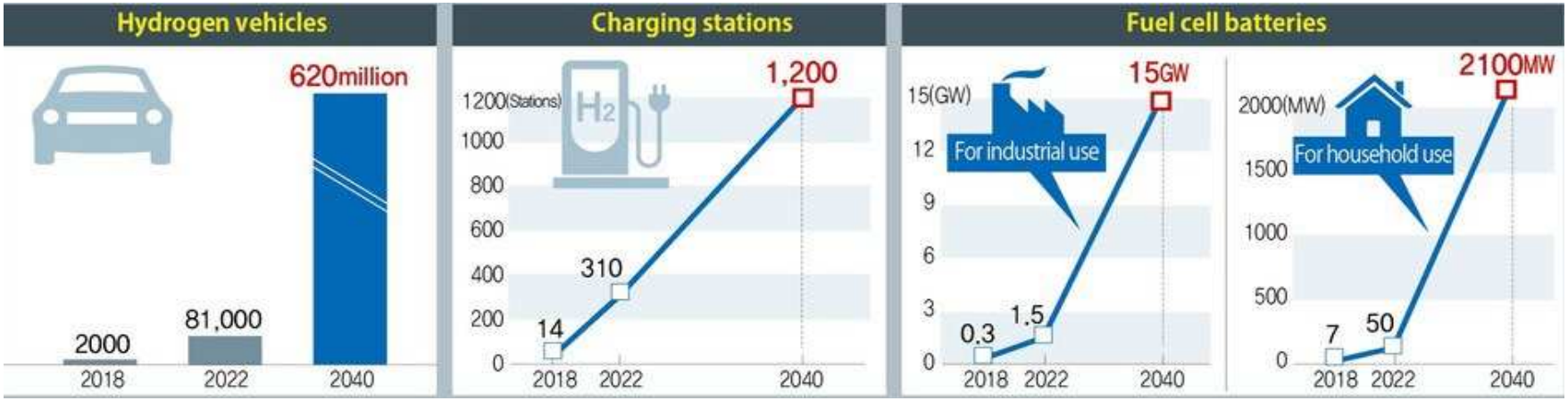
Hydrogen Economy at Korea

Hydrogen Roadmap in Korea(2019)



H_2-powered Hyundai's eco-friendly *Nexo 2019*

The roadmap for the H_2 economy released by Korea government on Jan. 2017 with mid- & long-term objective using H_2 as a major energy source!

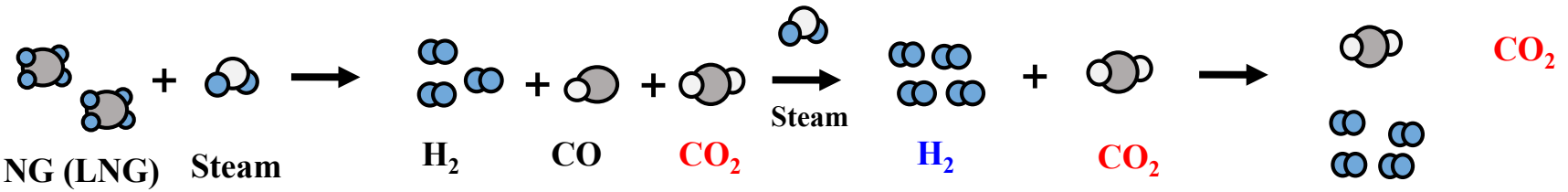


Ref: http://english.hani.co.kr/arti/english_edition/e_business/879097.html

KIST Promotion Technology
4-1. Clean Fuels-H_2 Station

- **What is Clean Fuels-H_2 Station with Carbon Neutralization ?**

1. Hydrogen Station



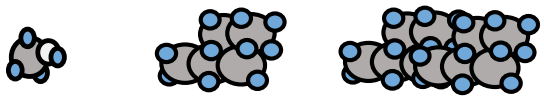
(1) SMR reaction : $CH_4 + H_2O \rightarrow CO + 3H_2 + CO_2$

(2) WGS reaction : $CO + H_2O \rightarrow H_2 + CO_2$

2. e-Clean Fuel Production

(1) $H_2O \rightarrow$ e-H_2 $+O_2$ (water electrolysis using Surplus Electricity)

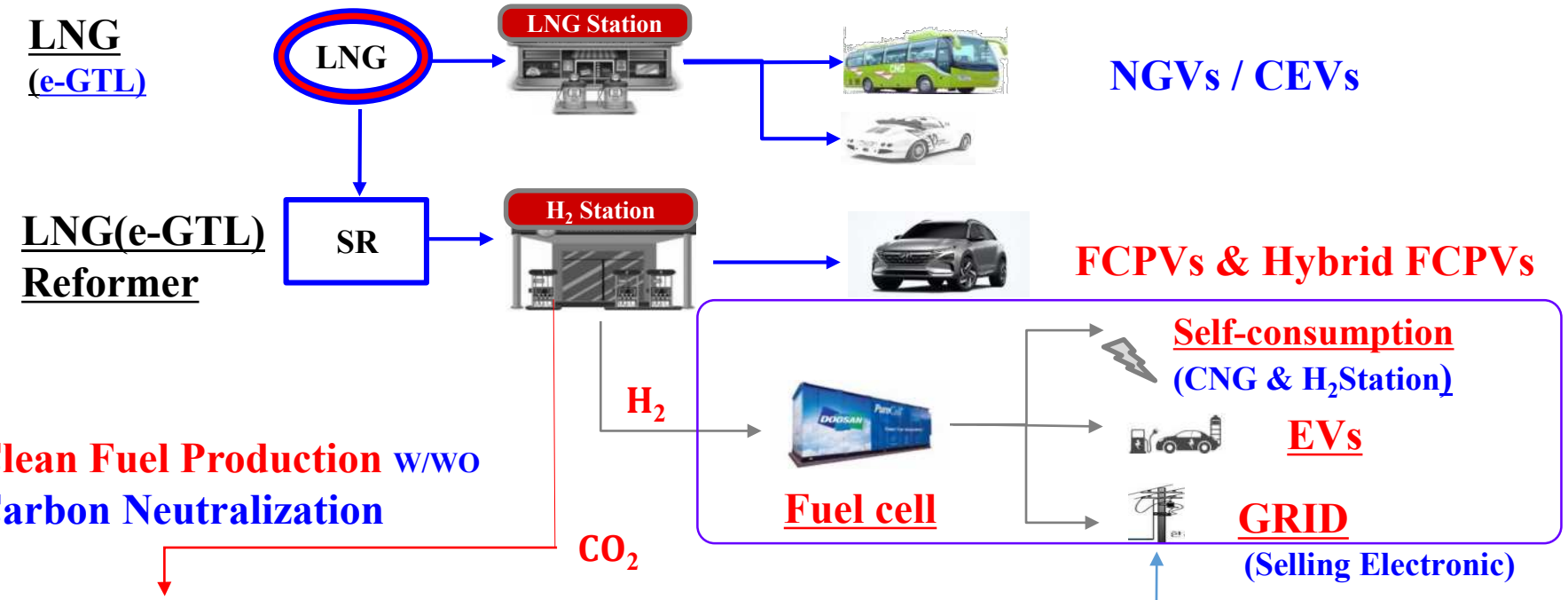
(2) CO_2 + e-$H_2 \rightarrow$ e-clean fuel (e-MeOH, e-GTL, etc)



e-MeOH e-Gasoline e-Diesel

KIST Promotion Technology
4-2. Clean Fuels-H_2 Energy Station

- **KIST Clean Fuels-H_2 Hybrid Energy Station**



- **Clean Fuel Production** w/wo **Carbon Neutralization**

(1) CO_2 + e-H_2 ⟶ e-Clean Fuel (e-MeOH, e-GTL)

(Direct & Indirect Fuel Production)

(2) H_2O ⟶ e-H_2 +O_2 (Water Electrolysis)

[Ref. : KP 10-2245416(2021), D. J. Moon et al.]

Surplus Electricity

THE KIST, Making New History

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KIST-Spain H_2-Station Project

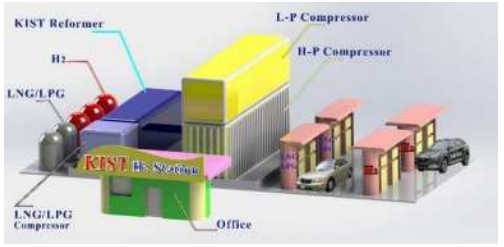
● NST-Catalonia Collaboration Project

○ **KIST** :
H_2 reformer/station development experience

○ **EVARM : Bi-fuel & Dual-fuel engine technology**
○ **ENAGAS : Holding CNG & Diesel supply market**

KIST-Spain, MOU & NDA & CA (2018. 07)

- **Korea (KIST) :** Small LNG-H_2 Reformer System
  LNG-H_2 Station Design Package development
- **Spain (ENAGAS & EVARM)** : H_2-based Bi-fuel & Dual-fuel fuel Supply system and securing market and solving legal regulations.



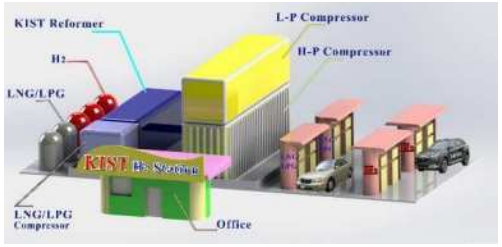
Joint Commercialization Strategy

Business Strategy between KIST and EU Partners

Technology Transfer

Joint Demonstration

Joint Venture



Small Scale GTL
Clean Fuel Production
Carbon Neutralization
Using CO_2, Biogas, Offgas & Flared gas

Business Strategy between KIST and EU Partners

Small Scale GTL & GTL-FPSO Plant w/wo Carbon Neutralization
Hydrogen Station & Energy Station w/wo Carbon Neutralization
Design of Catalyst, Reactor and Sustainable Chemical Process
Energy and Environment-Friendly Chemical Process
KIST can collaborated with Korean EPC Company

Technology Transfer → **Joint Venture** → **Global Markets Leading**

THE KIST, Making New History

Korea Institute of Science and Technology

Thank you

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