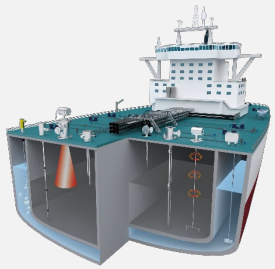
All Colors Hydrogen Generator

(SMR, ACS)

PANASIA

| Intro

· Marpol Annex 1
· USCG-39.20-7
· Exxon mobile Rule



Measurement & control system

IMO Marpol
73/78 Annex
VI NTC 2008

De-NOx SCR system

IMO
BWM
Convention

Ballast Water treatment system

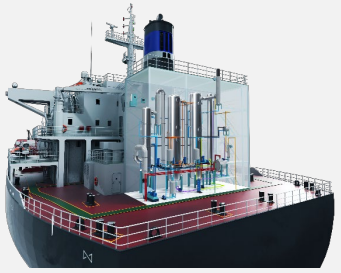
IMO
Sulphur cap
2020

De-SOx Scrubber System

GHG EMISSION

**Ammonia Cracking
Hydrogen generation system**

Hydrogen generation system



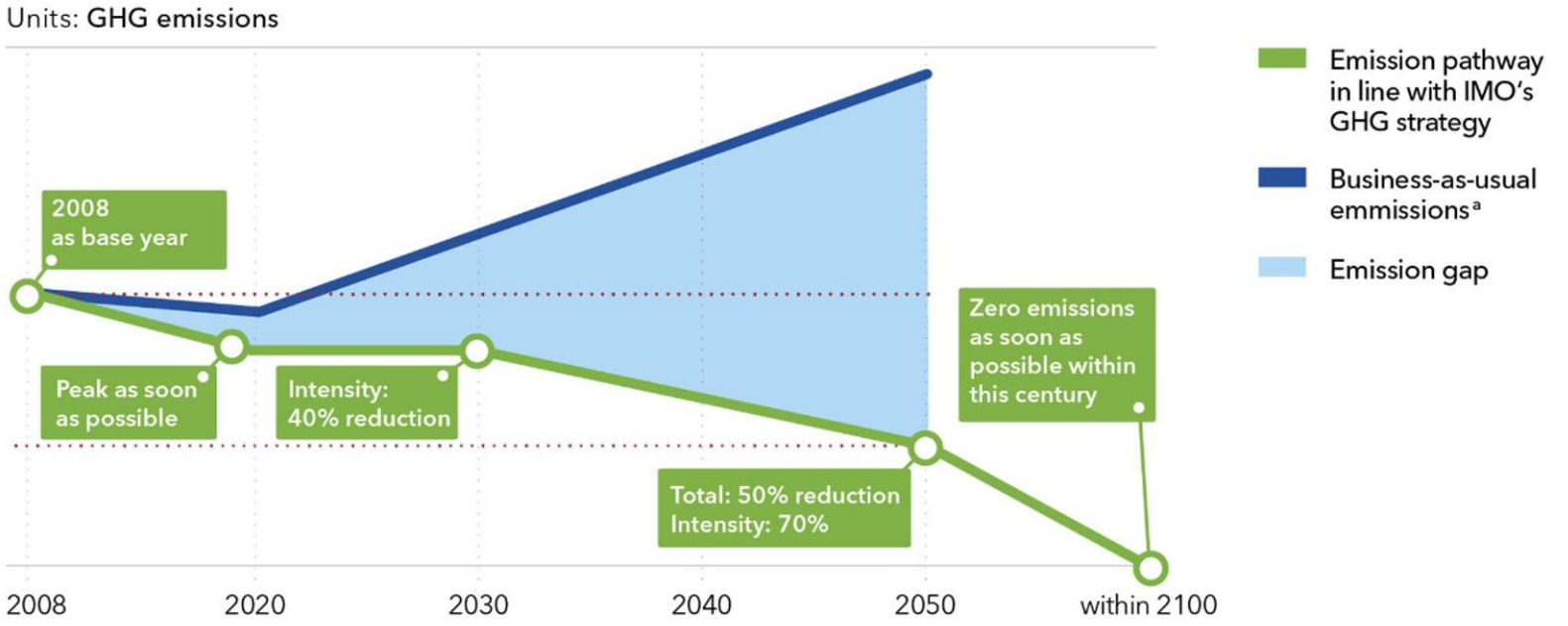
**Carbon Capture and
Storage system(CCS)**

PANASIA is a trustworthy solution provider to environmental regulations

| Maritime GHG Emission Regulations

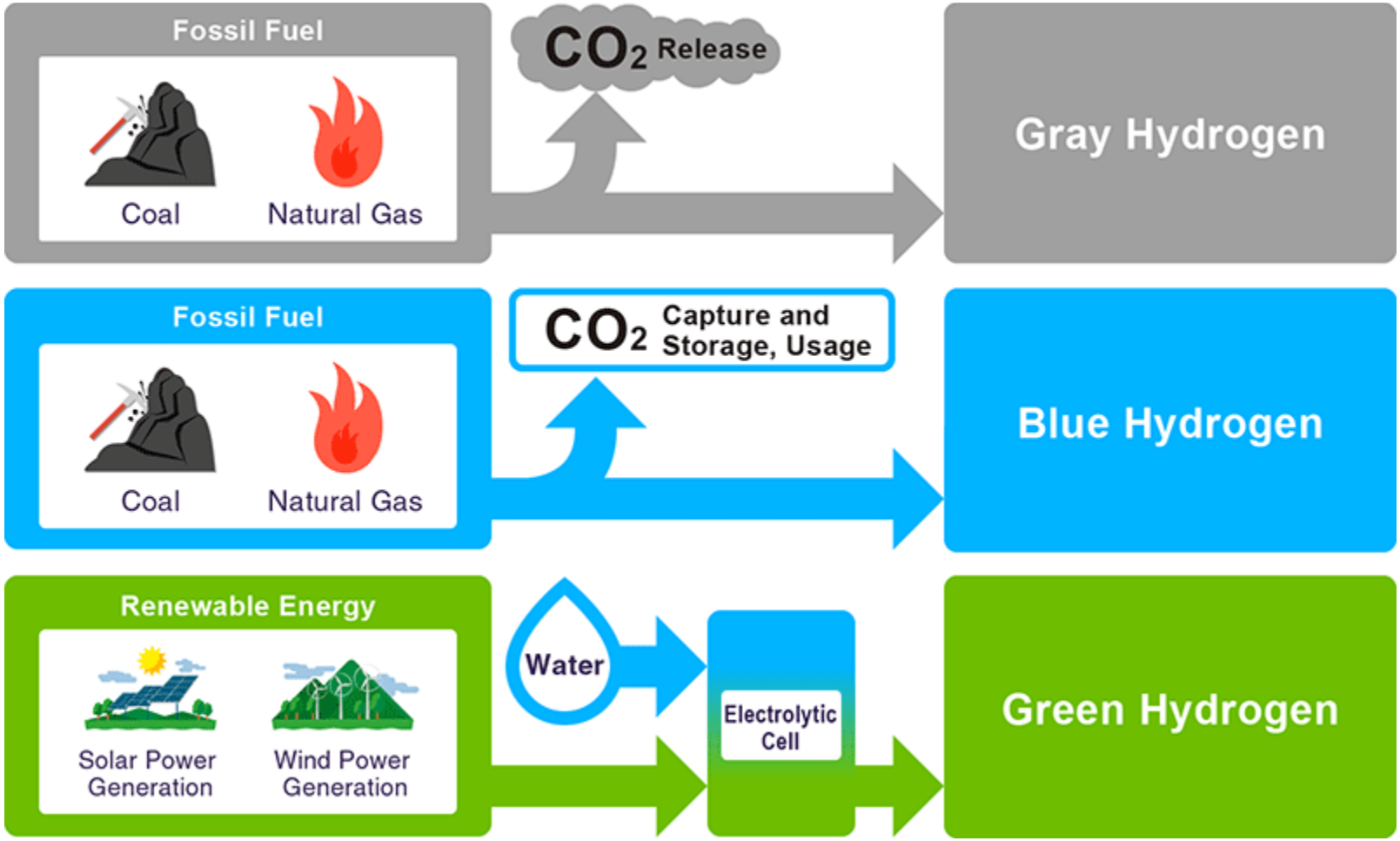
The International Maritime Organization (IMO) has introduced rules aimed as GHG emissions from ships.

IMO Strategy for major reductions in GHG emissions from shipping



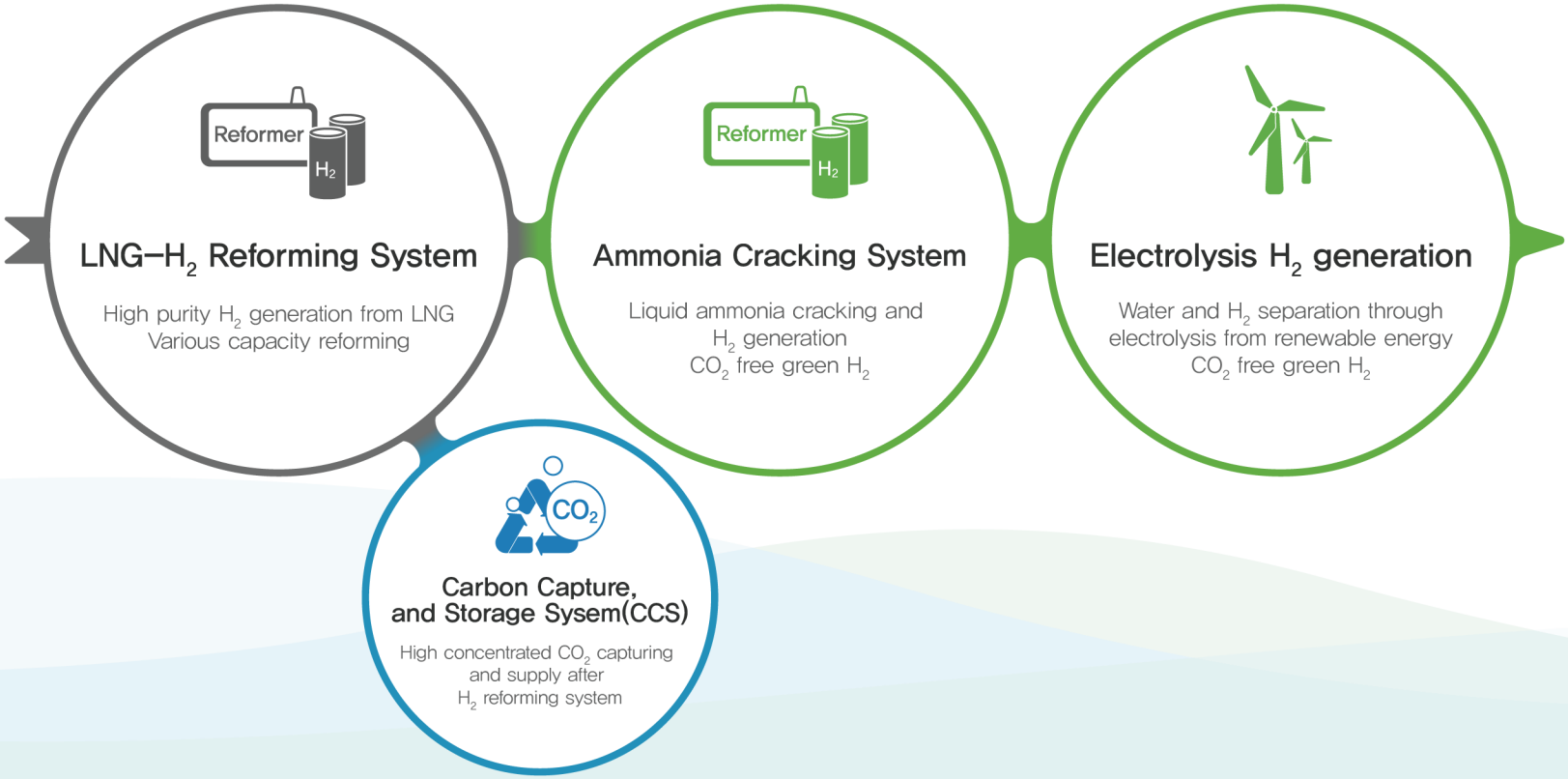
Source : DNV GL

| Maritime GHG Emission Regulations



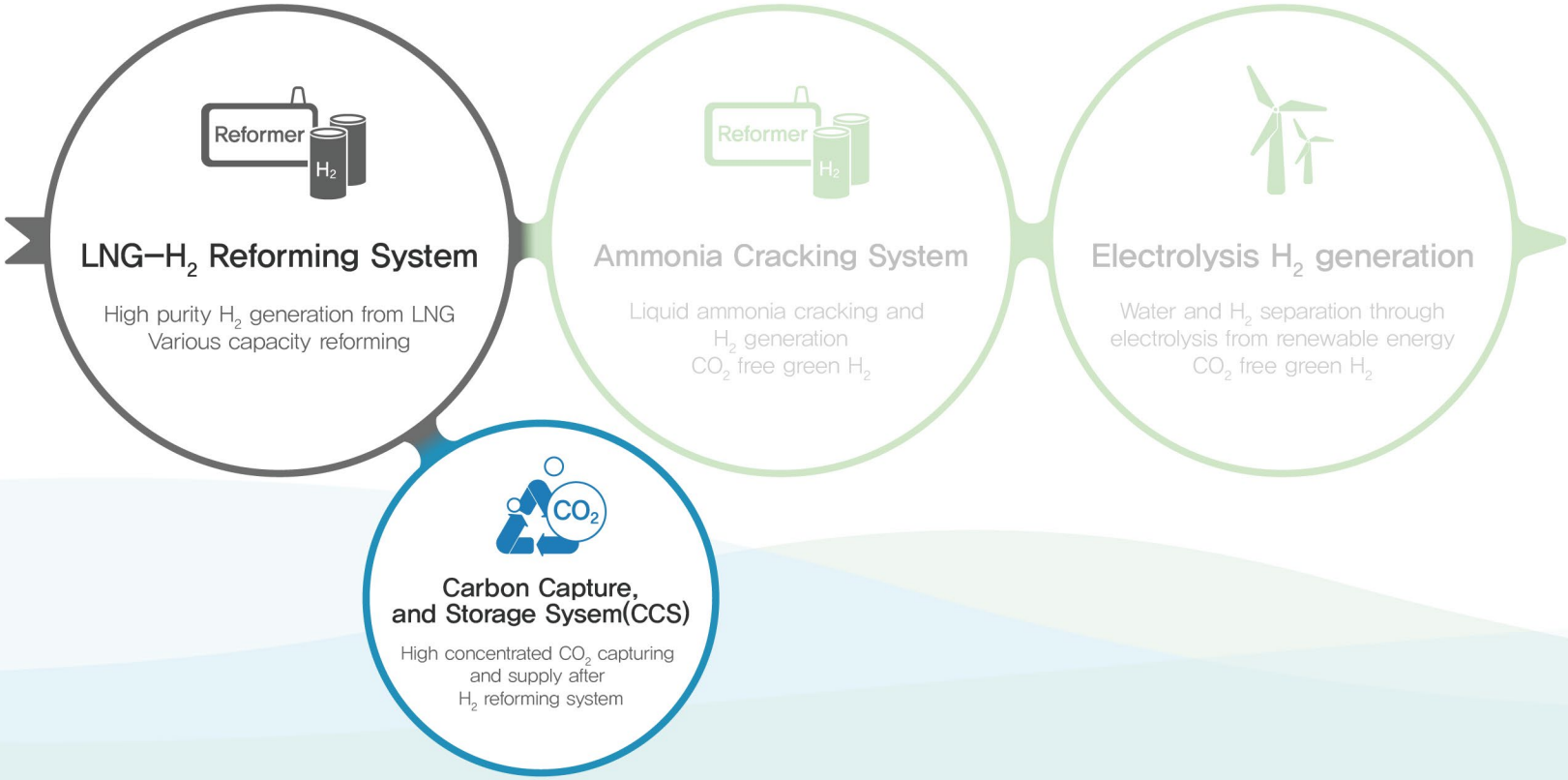
PanaGen

Hydrogen Generation System



PanaGen

Hydrogen Generation System



PanaGen Line-up

Line up		PanaGen ™-30	PanaGen ™-100	PanaGen ™-250	PanaGen ™-500	PanaGen ™-2300
Output(product)						
Product(H2)Flow	Nm3/hr	~30	~	~	~	~2300
	kg/day	~60	~200	~500	~1000	~4600
Purity	%vol			99.999		
Pressure	bar.g	~6.5	~6.5	~6.5	~6.5	~20
Electricity generation						
Power Source		380VAC 3phase 60Hz				
Electricity	kWh	~14	~30	~60	~150	~300
Dimensions						
Size(WxDxH)	Meter	6.2 x 2.4 x 3.4	6 x 3 x 3.5	8.5 x 3 x 3.5	14 x 3.2 x 3.8	15 x 25x 18
		H : Vent Stack Height Excluded				

- Applications


Hydrogen Station


Fuel Cells


Chemical Industry

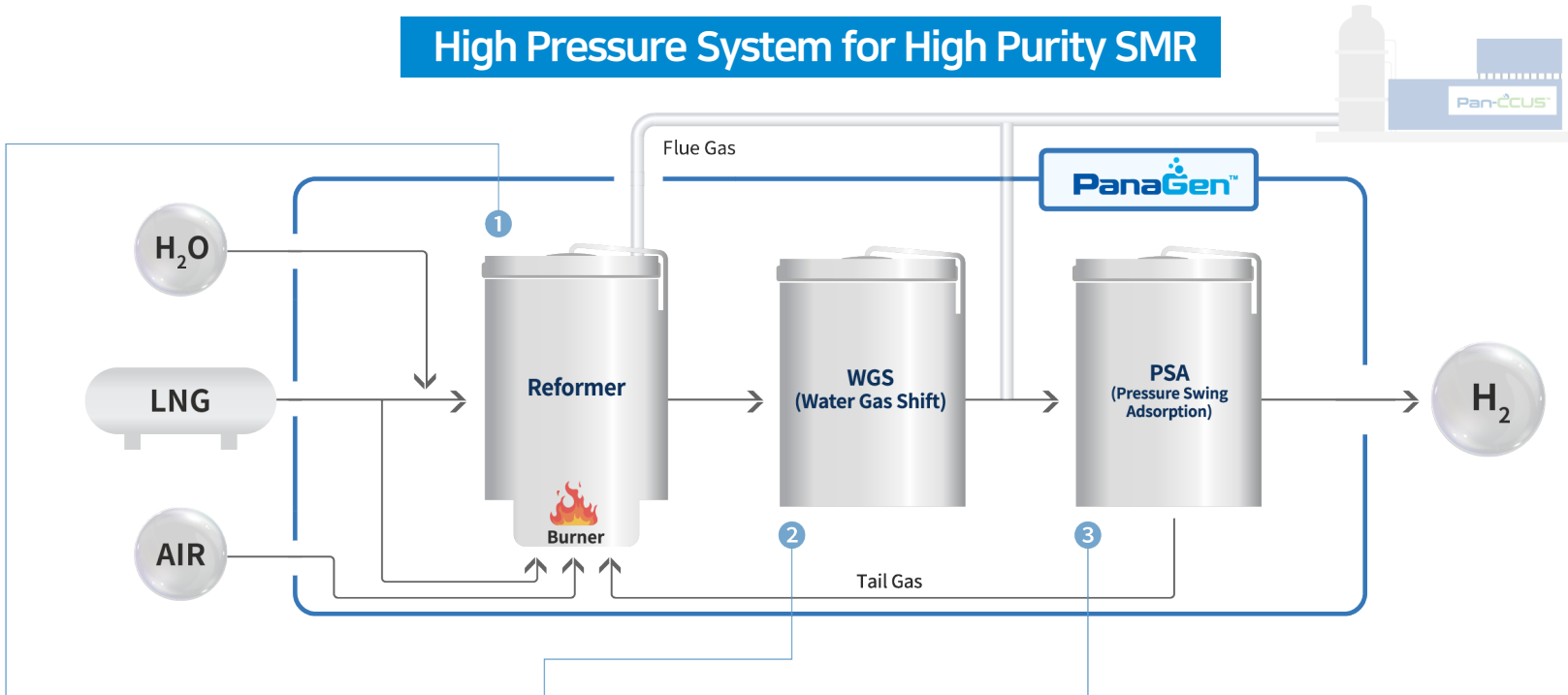

Photovoltaics


Ships


LEDs


H2 Gas Turbine

PanaGen System Diagram



1 Reforming($CH_4 + H_2O \rightarrow 3H_2 + CO$)

Hydrogen is produced by the reforming reaction of natural gas and water.

2 Water-Gas Shift($CO + H_2O \rightarrow CO_2 + H_2$)

Through the water-gas shift(WGS) reaction of CO_2 inside the syn-gas, additional hydrogen can be produced.

3 Purification(PSA : Pressure Swing Adsorption)

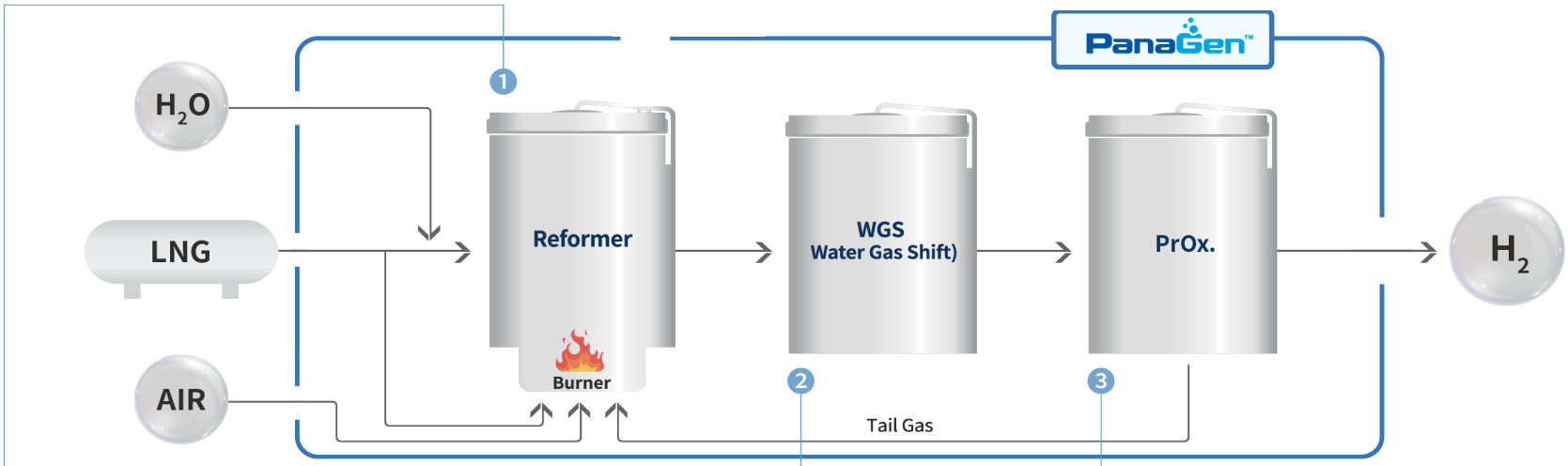
Through the PSA purification process, which utilizes the adsorption difference caused by pressure, pure hydrogen (99.999%) is separated. The remaining impurities, including H_2, CO, CO_2, and CH_4 (tail gases) are supplied to the burner so they can be used as sources of heating.

Specifications

Feed Gas	Pressure	Product(H2)		
		Capacity	H2 Purity	Pressure
Natural Gas	8.5~30bar.g	Customized	99.999%	20 bar.g

PanaGen System Diagram

Low Pressure System for High Purity SMR



1 Reforming($CH_4 + H_2O \rightarrow 3H_2 + CO$)

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2 Water-Gas Shift($CO + H_2O \rightarrow CO_2 + H_2$)

Through the water-gas shift(WGS) reaction of CO_2 inside the syn-gas, additional hydrogen can be produced.

3 PrOx. (Preferential Oxidation)

In order to get rid of remained CO in the reformec additional oxygen is supplied to selectively oxidize.

- Specifications

Feed Gas	Pressure	Product(H2)		
		Capacity	H2 Purity	Pressure
Natural Gas	0.3 bar.g	Customized	80%	ATM

R&D Status

30Nm3/h Hydrogen Generation System

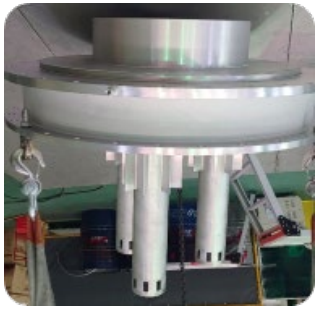
Item	Value	Unit	Remark
Efficiency			
Reformer(CH4 conversion)	85	%	
WGS(CO conversion)	90.00%	%	
PSA(H2 recovery)	85	%	
Output (product)			
Normal output	~30 ~60	Nm3/hr kg/day	
Hydrogen Purity	~99.999	%	
Pressure	~6.5	bar.g	
Typical Consumption data			
NG flow	~12	Nm3/hr	
NG Pressure	9~10	bar.g	
DI Water	33	L/hr	
Comp. Air	Required		
Electricity	14	kWh	
Dimensions			
Size(LxWxH)	6.2 x 2.4 x 3.4	Meter	For experiment
Weight	14,000	Kg	For experiment

- **Applications**

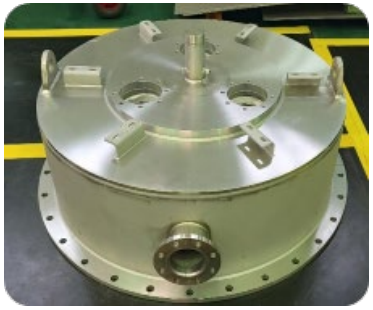
  Mid-small SMR system for Industrial use

< Burner/Dummy Test >

< PSA >



< Reformer >



R&D Status

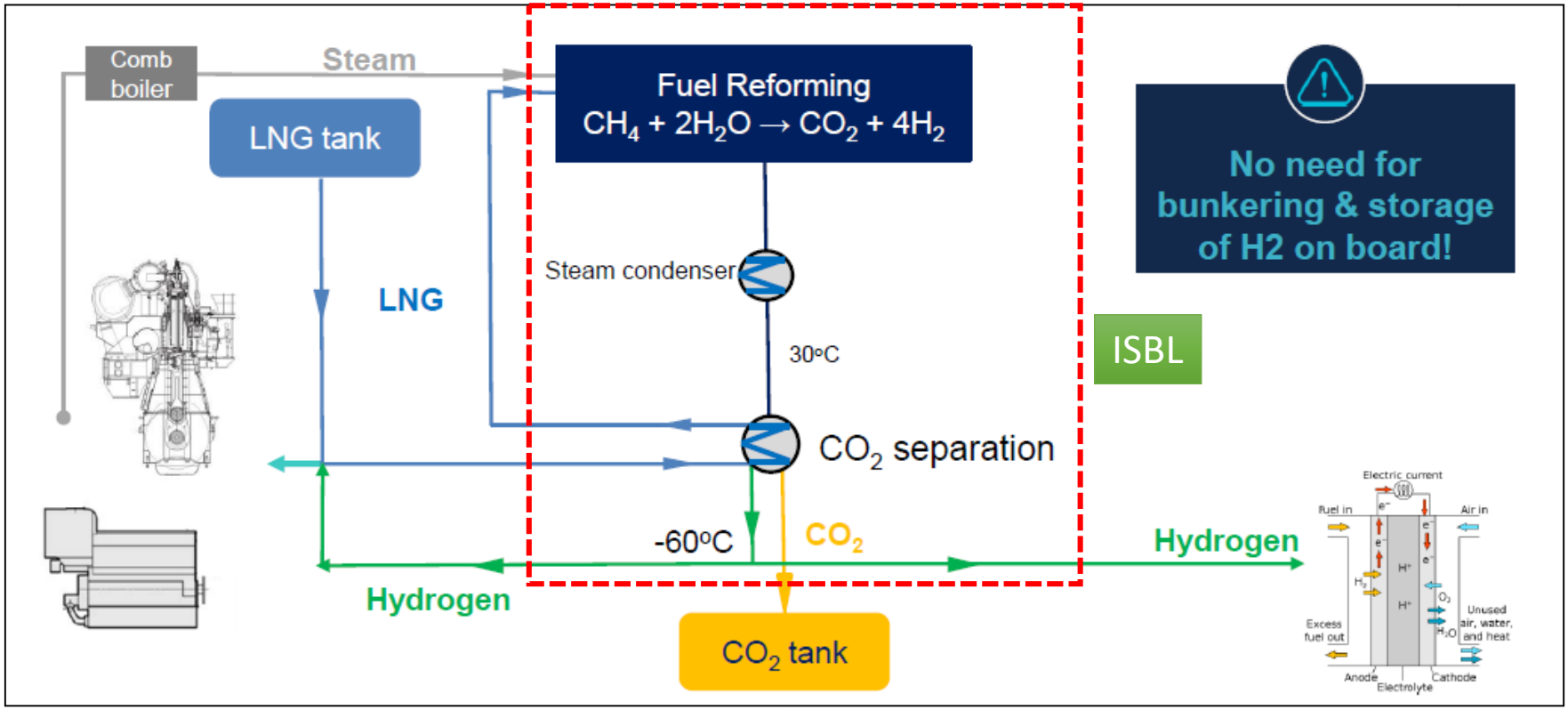
250Nm3/h Hydrogen Generation System

Item	Value	Unit	Remark
Efficiency			
Reformer (CH4 conversion)	85	%	
WGS(CO conversion)	90.00%	%	
PSA(H2 recovery)	85	%	
Output (product)			
Normal output	~250 ~500	Nm3/hr kg/day	
Hydrogen Purity	**~99.999**	**%**	
Pressure	~6.5	bar.g	
Typical Consumption data			
NG flow	~100	Nm3/hr	
NG Pressure	9~10	bar.g	
DI Water	250	L/hr	
Comp. Air	Required		
Electricity	~60	kWh	Estimated
Dimensions			
Size(LxWxH)	8.2 x 3 x 3.5	Meter	Estimated

- **Application**

  Industrial Mid-small SMR system for H2 gas station

| Reference - Joint Development Project for E/Fuel Cell vessel



Engine : 4stroke LNG mixed with hydrogen engine

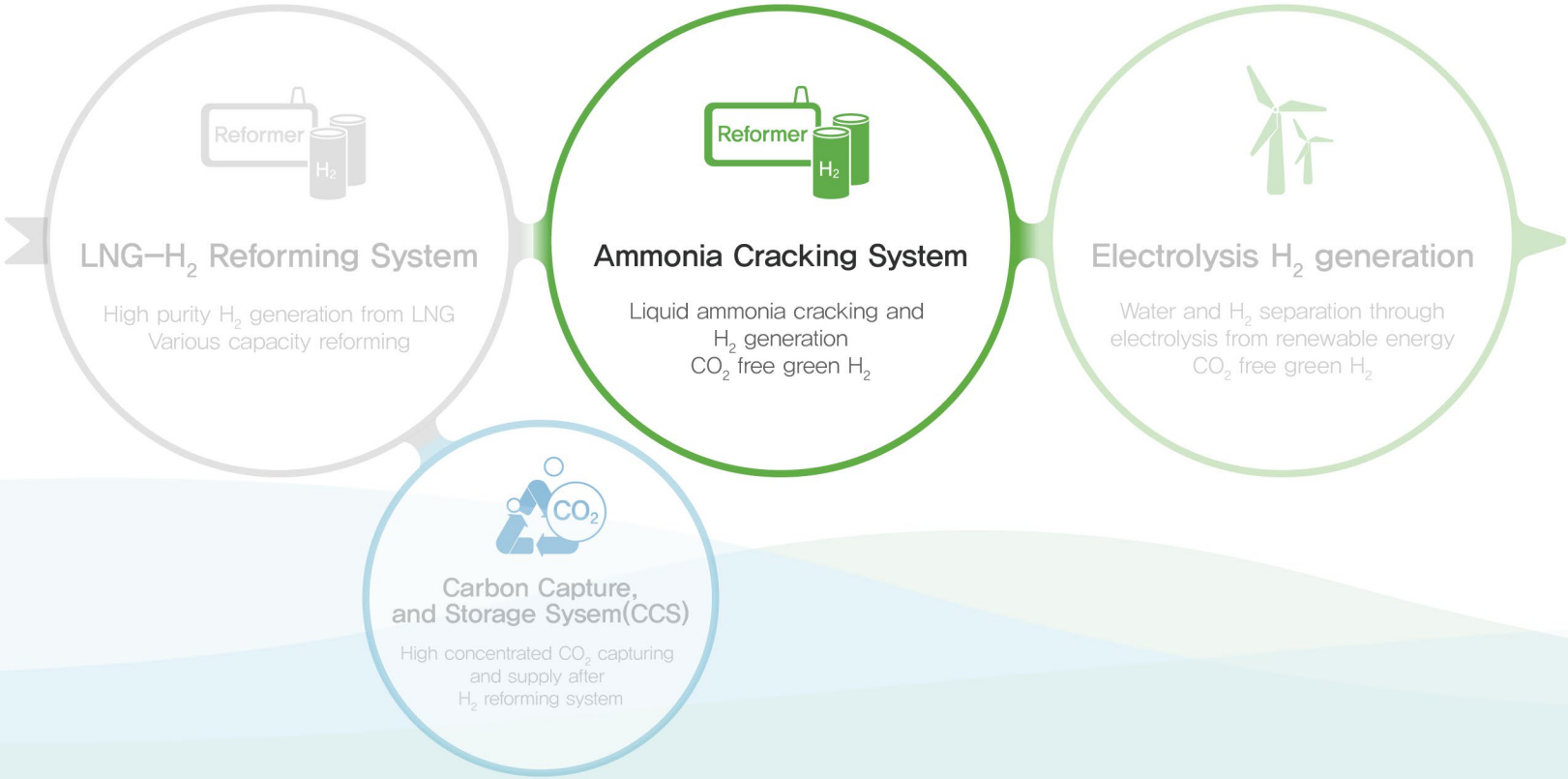
Hydrogen generator : PANASIA

CCUS : PANASIA

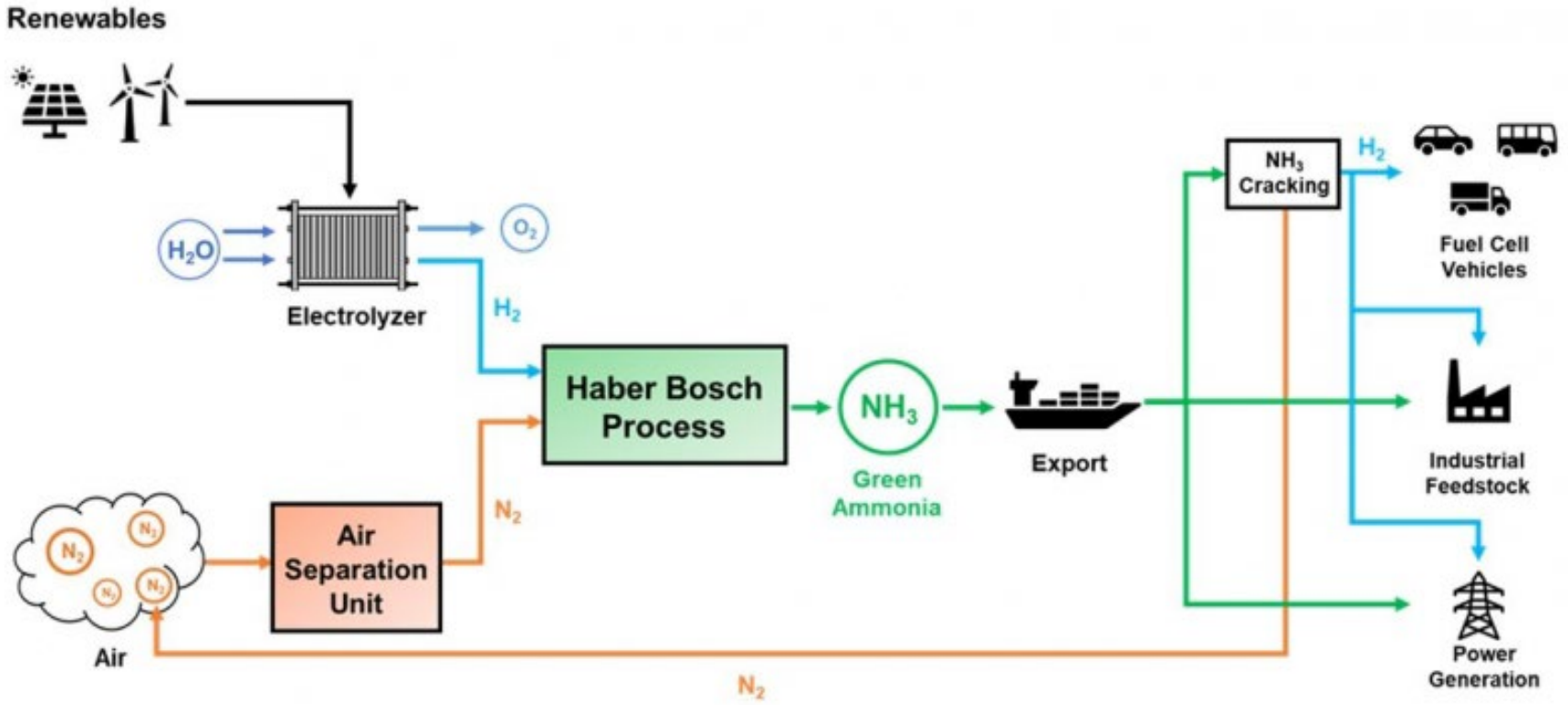
Fuel cell : TBD

PanaGen

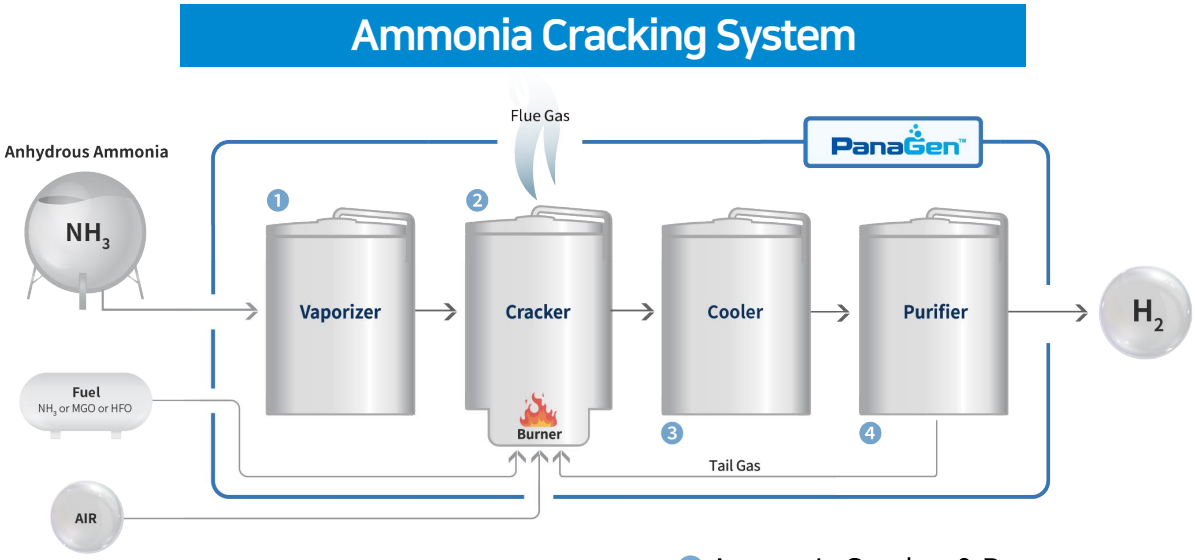
Hydrogen Generation System



How to produce Green Ammonia



PanaGen System Diagram



1 Vaporizer

The process of vaporizing liquefied ammonia, converting it into gas, and preheating the gas for a efficient reaction.

2 Ammonia Cracker & Burner

The process by which ammonia decomposes into nitrogen and hydrogen through the decomposition of ammonia gas.
($2NH_3 \rightarrow N_2 + 3H_2$)

3 Cooler

The process of cooling generated gas at room temperature to prepare for the purification process.

4 Purification(PSA & TSA)

The process of separating and absorbing non-reactive ammonia and the generated nitrogen to increase the purity of hydrogen.

*TSA(Temperature Swing Absorption : Unreacted NH3 treatment
*PSA(Pressure Swing Absorption) : Increase H2 purity

- Specifications

Feed Gas	Pressure	Product(H2)		
		Capacity	H2 Purity	Pressure
Ammonia	~10 bar.g	Customized	Above 99.97-8% (NH_3<0.1 ppm)	6 bar.g

| Development

5Nm³/h & 50Nm³/h NH_3 Cracking System

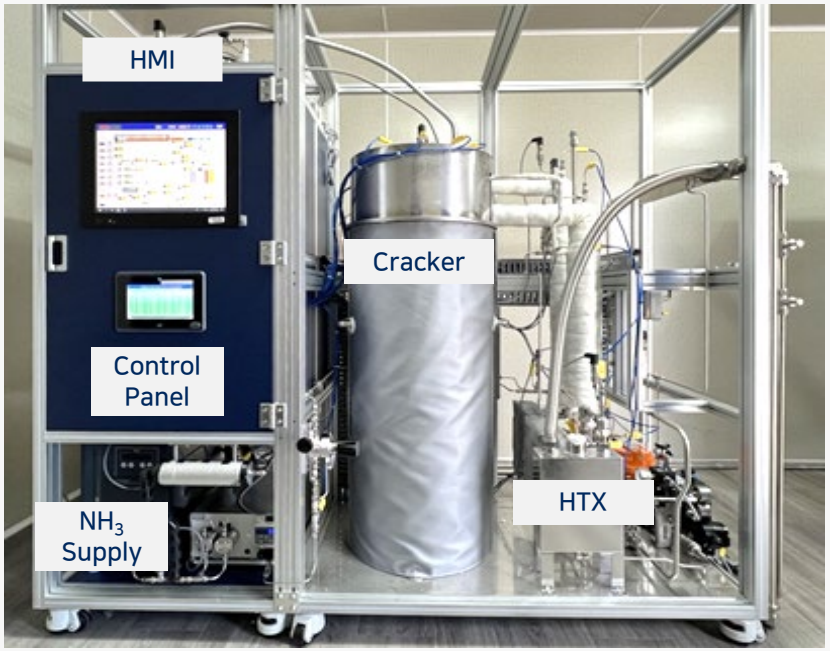
Type	5Nm3/h NH4 Cracking System	50Nm3/h NH3 Cracking System
Cracking type	High Pressure	High Pressure
H_2 Capacity	5.0Nm3/h	50Nm3/h
H_2 Purity	Above 99.97-8%	Low : above 99.97-8%
Residual NH_3 concentration	Below 0.1 ppm	Below 0.1 ppm

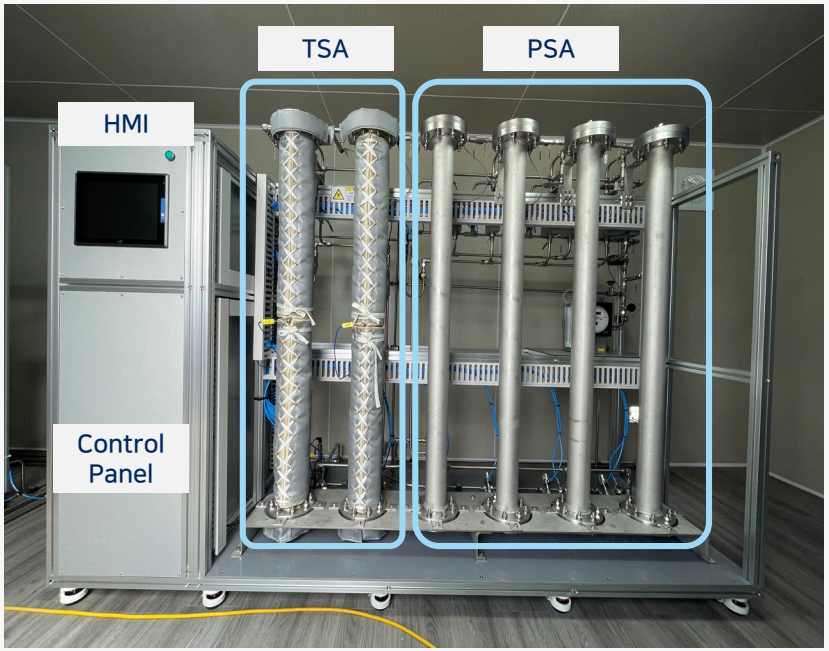
| Development

5 Nm^3/h NH_3 Cracking System

- Performance Satisfied -

5 Nm^3/h **NH_3 Cracking System**

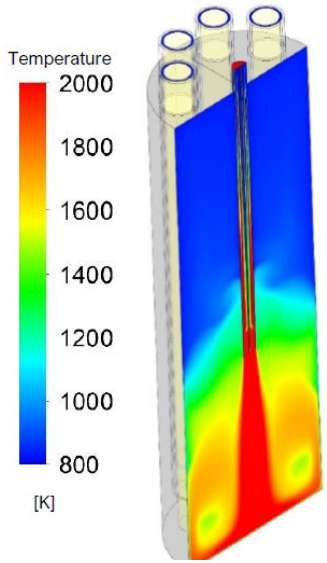




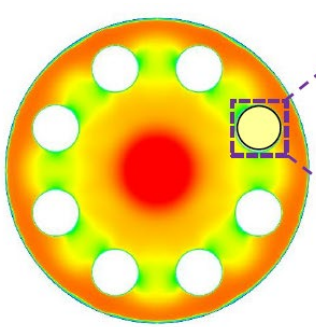
| Heat distribution sample

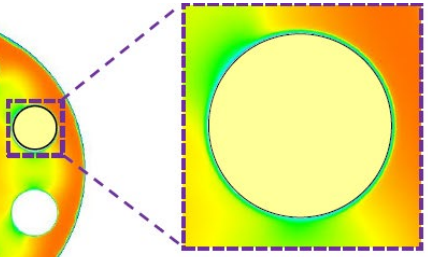
Features of NH_3 Cracking System

Heat distribution sample

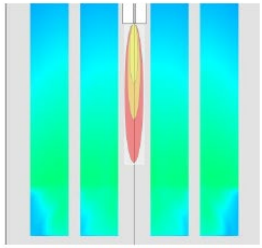


Heat distribution
of cracker section





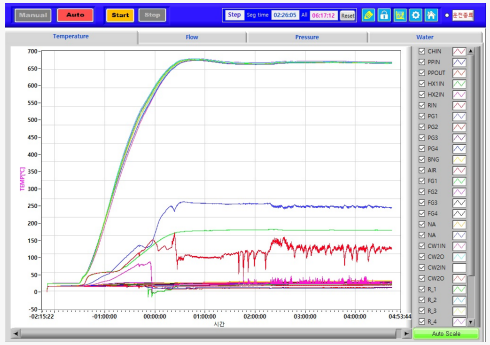
Heat flow on cracker



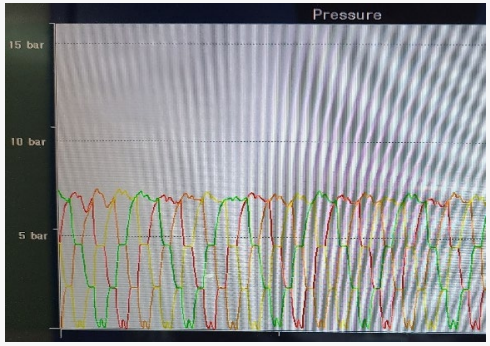
**Heat distribution
on the surface**

| Development

5 Nm^3/h NH_3 Cracking System Test Result

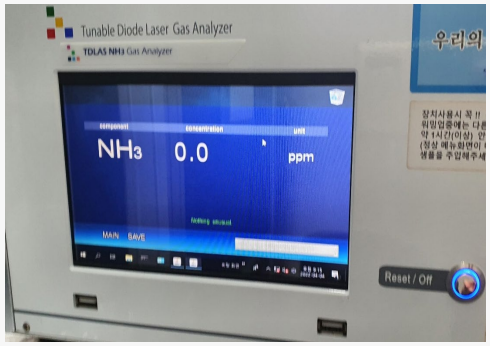


Cracker tube inside temp. trend



PSA Pressure trend

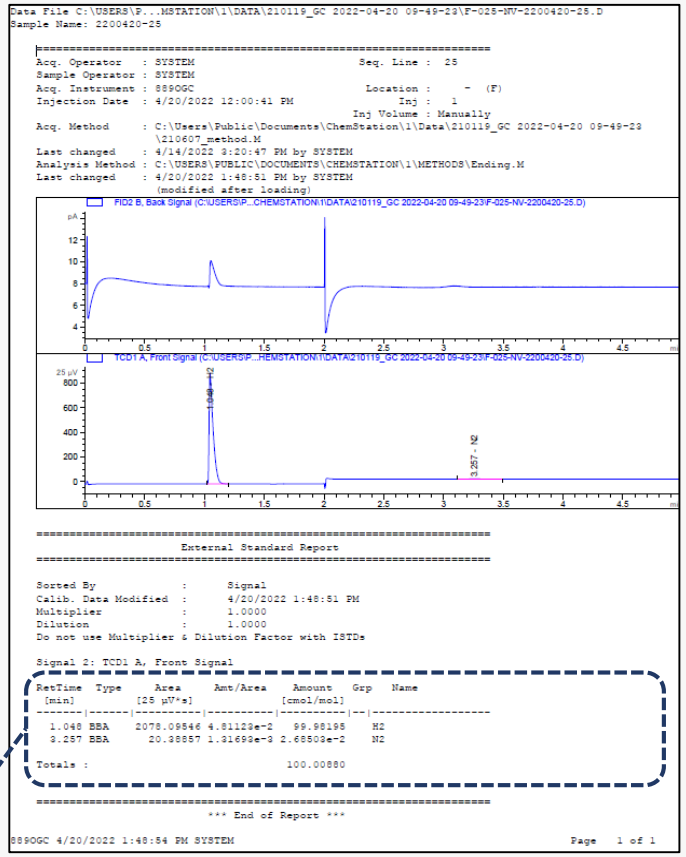
NH3 conc. Cracker outlet



NH3 conc. PSA in/outlet

N_2	2.68503E-02	0.026848%
H_2	99.981950	99.97315%

Purity analysis result using Gas Chromatography



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Sample Name: 2200420-25

Acq. Operator   : SYSTEM                        Seq. Line :  25
Sample Operator : SYSTEM
Acq. Instrument : 8890GC                        Location :   -  (F)
Injection Date  : 4/20/2022 12:00:41 PM            Inj :   1
                                                Inj Volume : Manually
Acq. Method     : C:\Users\Public\Documents\ChemStation\1\Data\210119_GC 2022-04-20 09-49-23
                  \210607_method.M
Last changed    : 4/14/2022 3:20:47 PM by SYSTEM
Analysis Method : C:\USERS\PUBLIC\DOCUMENTS\CHEMSTATION\1\METHODS\Ending.M
Last changed    : 4/20/2022 1:48:51 PM by SYSTEM
                  (modified after loading)

FID2 B, Back Signal (C:\USERS\P...CHEMSTATION\1\DATA\210119_GC 2022-04-20 09-49-23\F-025-NV-2200420-25.D)
TCD1 A, Front Signal (C:\USERS\P...HEMSTATION\1\DATA\210119_GC 2022-04-20 09-49-23\F-025-NV-2200420-25.D)

                        External Standard Report

Sorted By             :      Signal
Calib. Data Modified  :      4/20/2022 1:48:51 PM
Multiplier            :      1.0000
Dilution              :      1.0000
Do not use Multiplier & Dilution Factor with ISTDs

Signal 2: TCD1 A, Front Signal

RetTime  Type     Area      Amt/Area    Amount   Grp   Name
 [min]           [25 µV*s]              [cmol/mol]
-------|------|----------|----------|----------|--|------------------
  1.048 BBA     2078.09546 4.81123e-2   99.98195    N2
  3.257 BBA       20.38857 1.31693e-3 2.68503e-2    N2

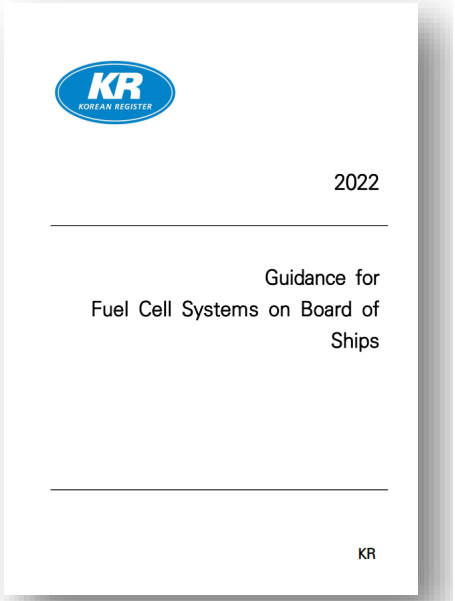
Totals :                                100.00880

                        *** End of Report ***

8890GC 4/20/2022 1:48:54 PM SYSTEM                          Page   1 of 1
```

| Development

Class looks into rule set up



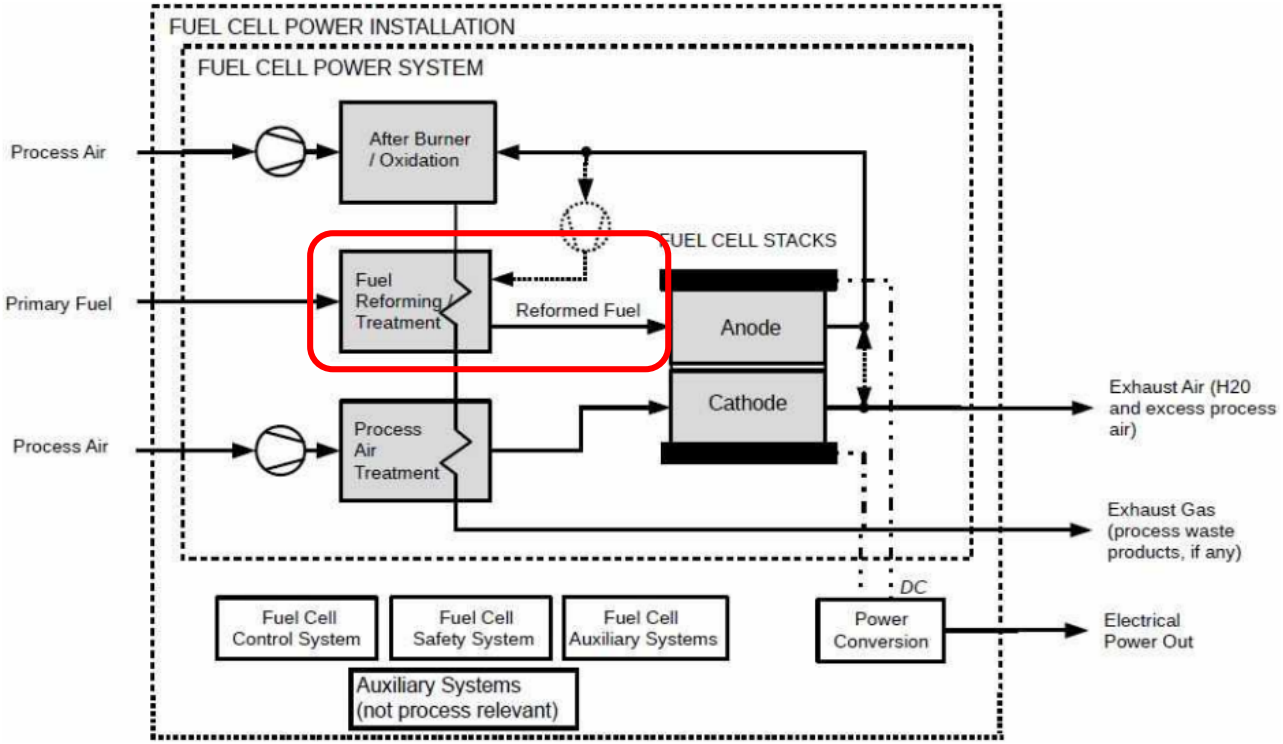


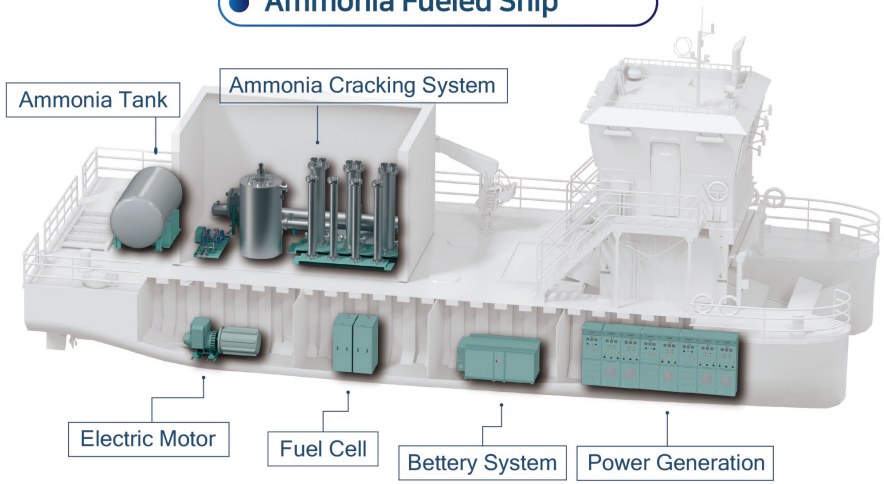
Fig 1.1 Components of Typical Fuel Cell Power Installation

| Development

「Busan Ammonia Eco-Energy Business」 50 Nm^3/h NH_3 Cracking System Manufacturing / Task

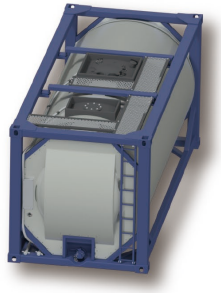
Assignment Period	2022.01.01 ~ 2023.12.31
Host / Participant	PANASIA / 11 Companies(KR, Lotte Chemical, Dong il shipyard, etc.)
Subject	Ammonia based Fuel cell Hybrid Eco-friendly Ship Test (100t)

● Ammonia Fueled Ship



● Ammonia Bunkering Station

● ISO Tank



| Panasia competitiveness

50Nm^3/h Ammonia Cracking System

Being tested at 2nd Factory, completion in Aug. 2023

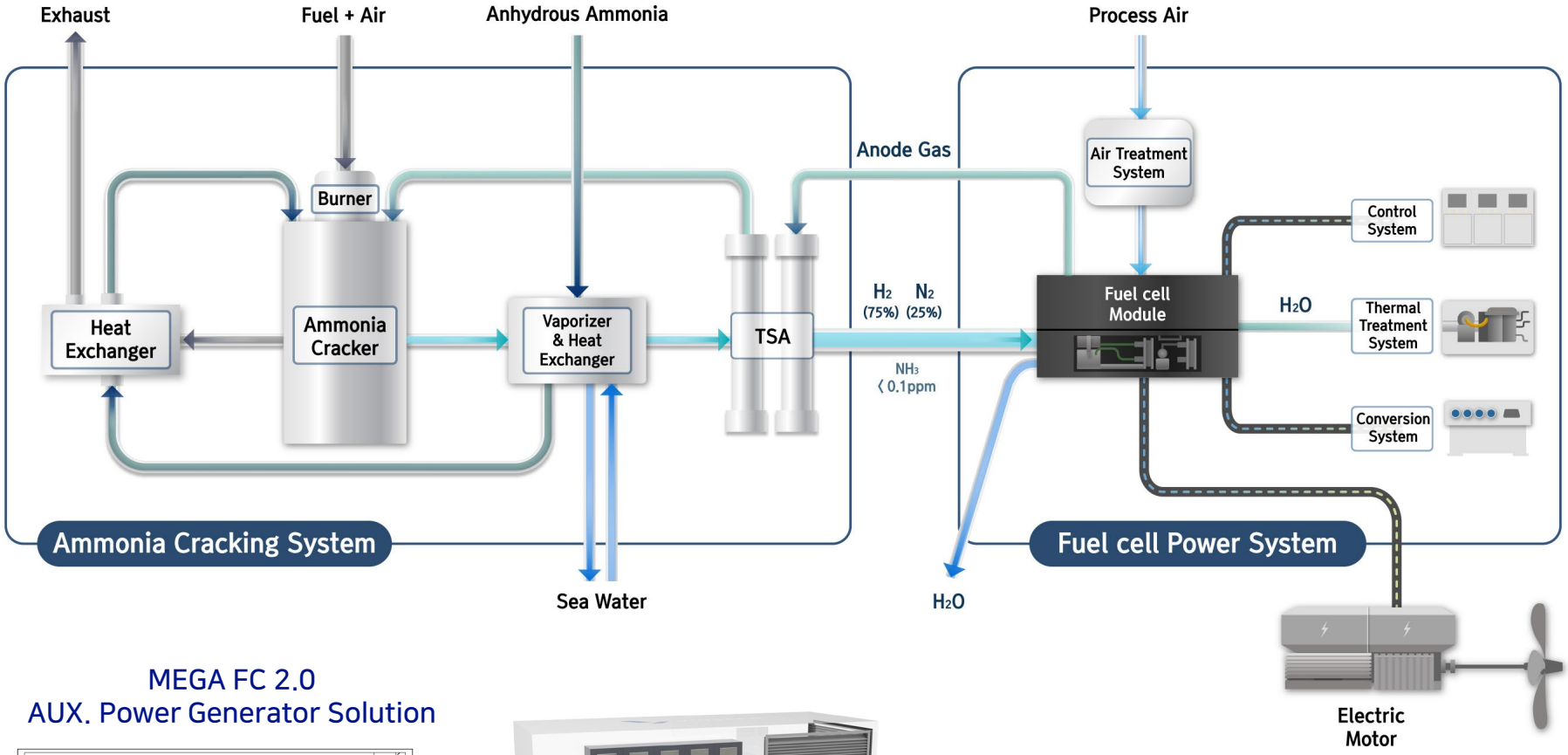
| Ammonia Cracker & Fuel Cell System for Vessels

Vinssen & Panasia Sign MOU for Hydrogen Fuel Cell Propulsion System for Vessel

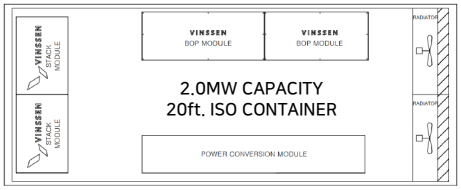
Vinssen and Panasia announced on the 2nd that they have signed a business agreement on a hydrogen fuel cell propulsion system for environmentally friendly ships.
As a result, the two companies promised mutual cooperation in various fields, including research into electric propulsion systems for environmentally friendly ships, promotion of joint projects, public relations, and human resource development.

In addition, Vinssen plans to develop a hydrogen fuel cell power system for large vessels by adding Panasia's ammonia hydrogen extractor to the hydrogen fuel cell module and to proceed with type approval. Ammonia has a higher energy density than liquid hydrogen, and is known to be suitable for large ships because it liquefies at -33℃ compared to liquid hydrogen cooled to -253℃. Last year, the International Energy Agency (IEA) also chose ammonia as the most efficient method of transporting hydrogen.
A Vinssen official said, "If the two companies, which have strengths in environmentally friendly technology, meet and the completed hydrogen fuel cell power generation system for large ships completes the formal approval process, South Korea's environmentally friendly ship technology will dominate the global market." I can lead," he said. It will also lead to the revitalization of the shipbuilding industry, which has become a major industry.

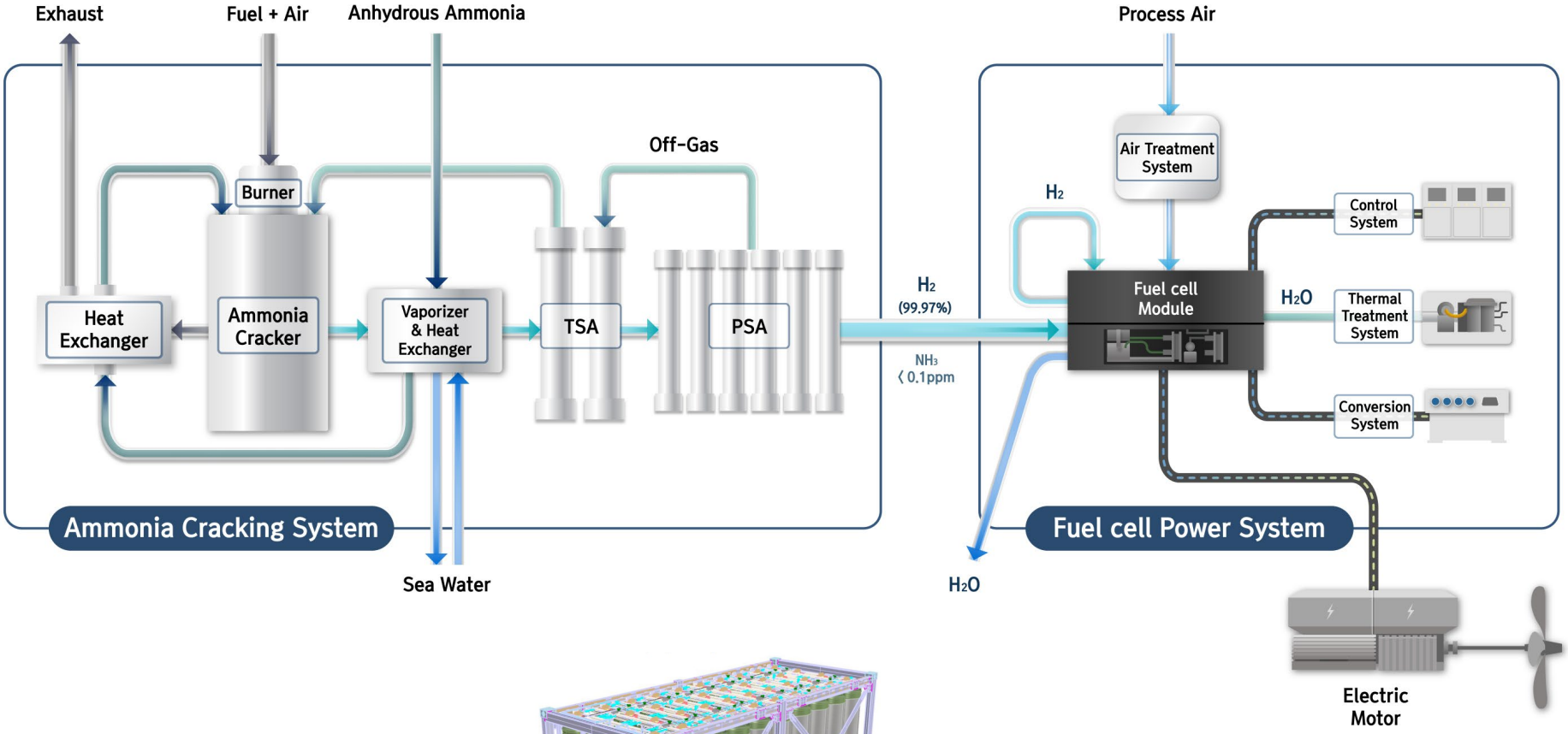
System Flow (PSA exclude)



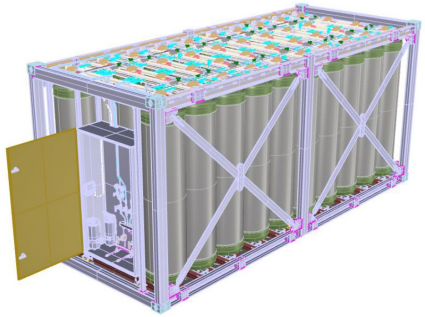
MEGA FC 2.0
AUX. Power Generator Solution



| System Flow (PSA include)



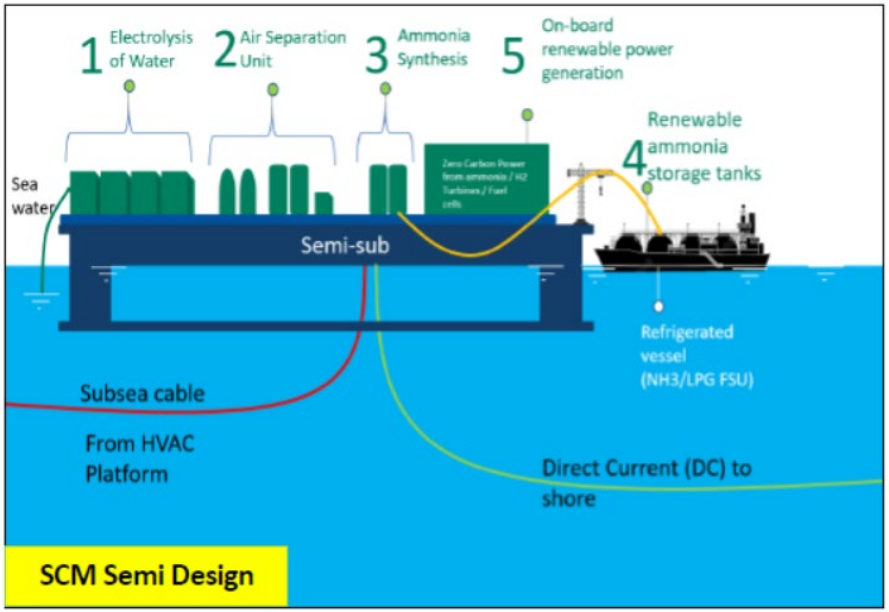
20ft Containerized Hydrogen Storage Tank



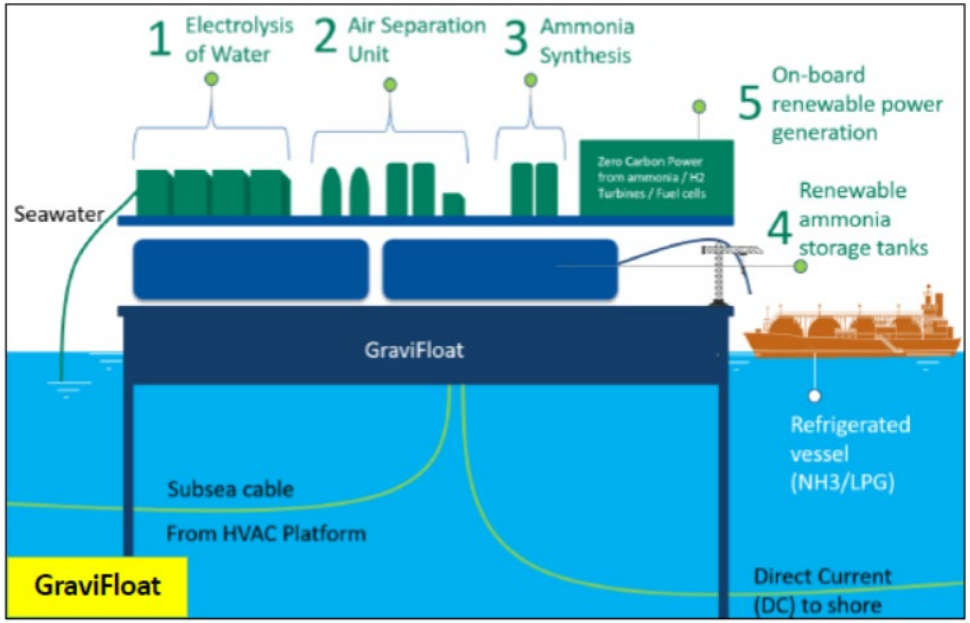
| On-going Fuel Cell Power System In Maritime Projects

Hydrogen Power Application On the Sea : Overseas

Deep Water Solution (Floating)



Shallow Water Solution (Fixed)



PANASIA

CASE STUDY

1. Oil Carrier
2. 115K Class_Crude Oil Tanker(LR2)
3. 50K PC(MR)

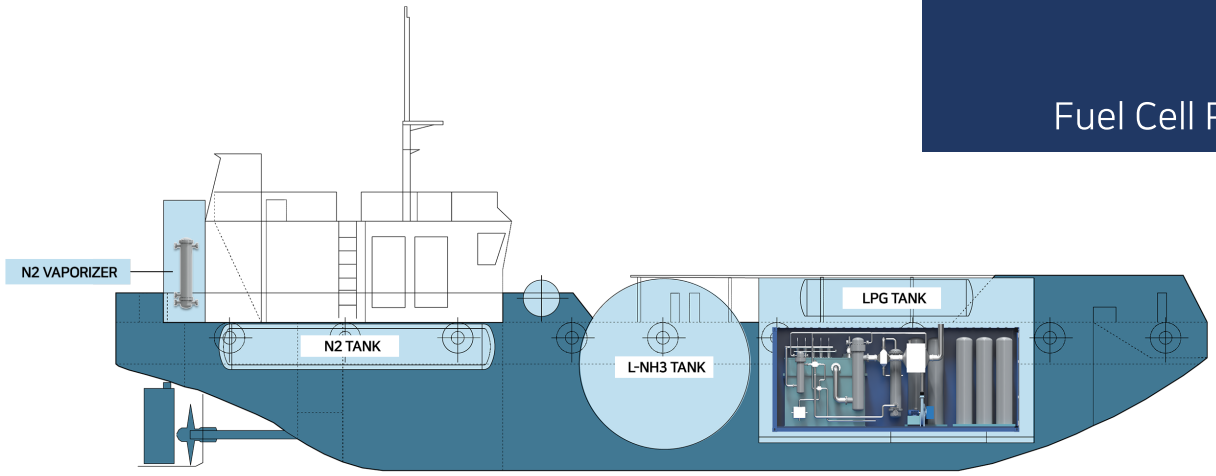
CASE 1_MPV

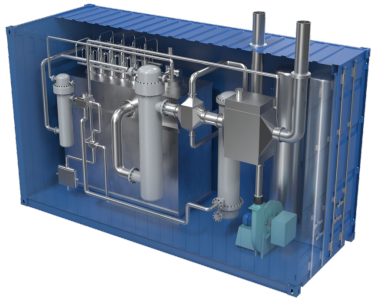
Concept

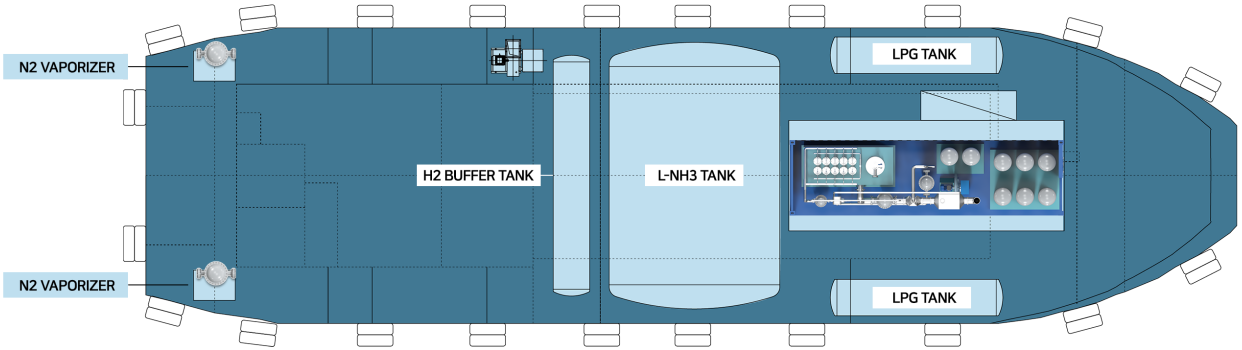
Ammonia Cracking System **400Nm3/hr**

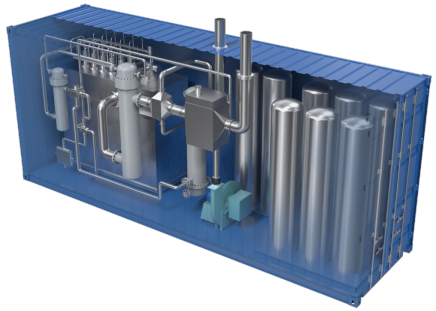
+

Fuel Cell Power System **500kw**

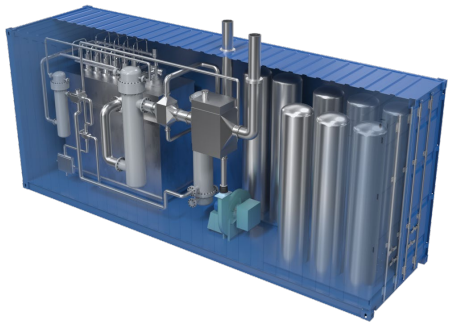


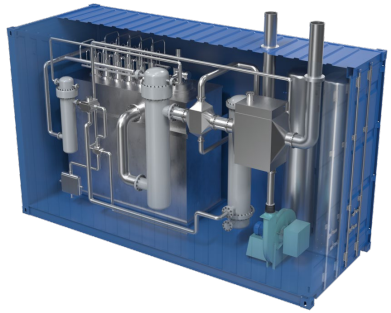






| CASE 1_MPV





Ammonia Cracker Model	PSA Include		PSA Exclude	
	ACSP 400	ACSP 800	ACST 400	ACST 800
Anhydrous Ammonia Input (kg/hr)	296	594	235	472
Anhydrous Ammonia Input Pressure (bar)	9.5	9.5	9.5	9.5
Anhydrous Ammonia Input Temperature (℃)	20	20	20	20
Product Gas Output (Nm3/hr)	416	832	588	1176
Product Gas Output Pressure (bar)	6	6	6.6	6.6
Product Gas Output Temperature (℃)	60	60	60	60
H2 Purity (%)	**99.7**	**99.7**	**75**	**75**
Product Gas Capacity (Nm3/hr) - H2	414.75	829.5	441	882
- N2	1.25	2.5	147	294
Power Consumption (kwh)	20	35	15	25
Explosion proof class	Ex d II C T1	Ex d II C T1	Ex d II C T1	Ex d II C T1
Dimensions (mL x mW x mH) _ NH3 Cracker	8.6 x 2.4 x 3.8	12 x 2.8 x 4.2	6 x 2.4 x 3.6	8.5 x 2.8 x 4

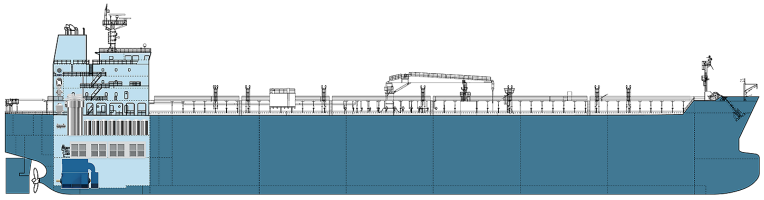
| CASE 2_50K PC(MR) - ACS

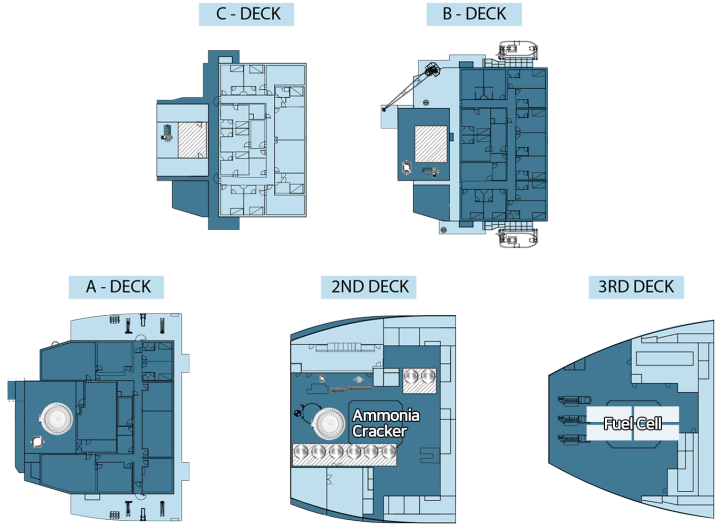
Concept

Ammonia Cracking System **6,000Nm3/hr**

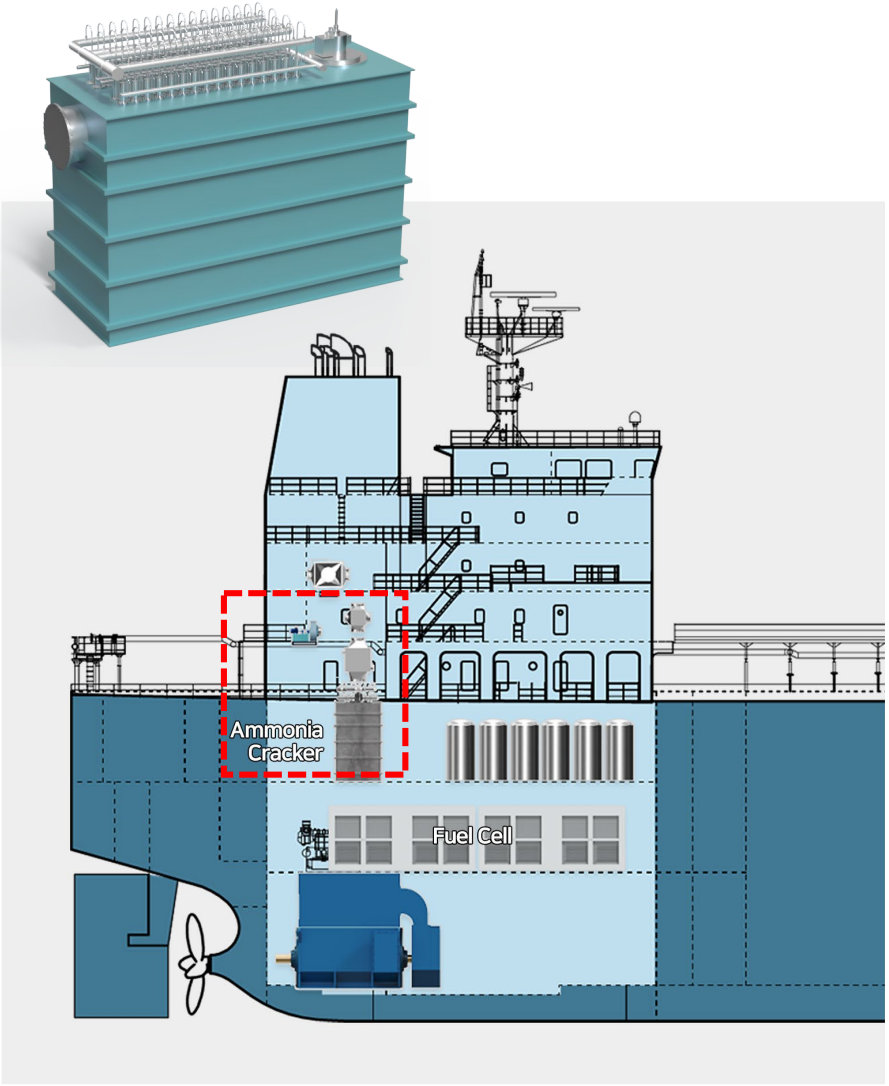
+

Fuel Cell Power System **7.5MW**





| CASE 2_50K PC(MR) - ACS

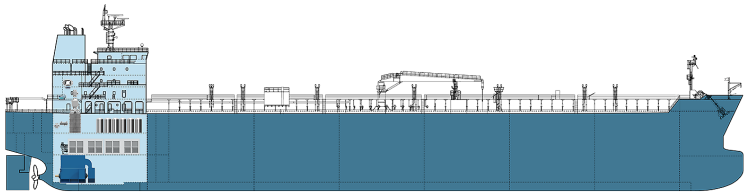


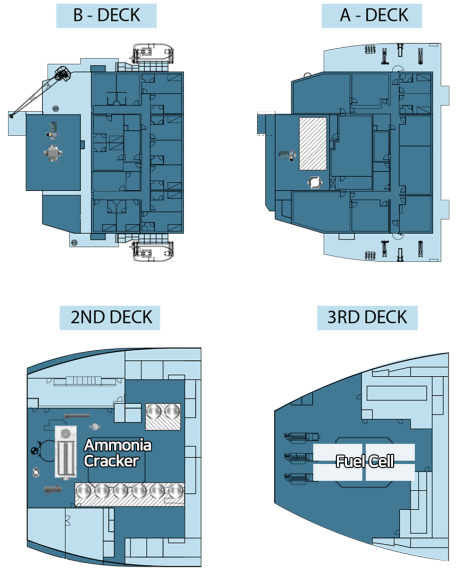
Concept

Ammonia Cracking System **6,000Nm3/hr**

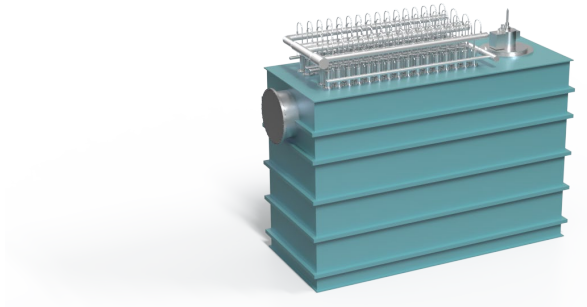
+

Fuel Cell Power System **7.5MW**



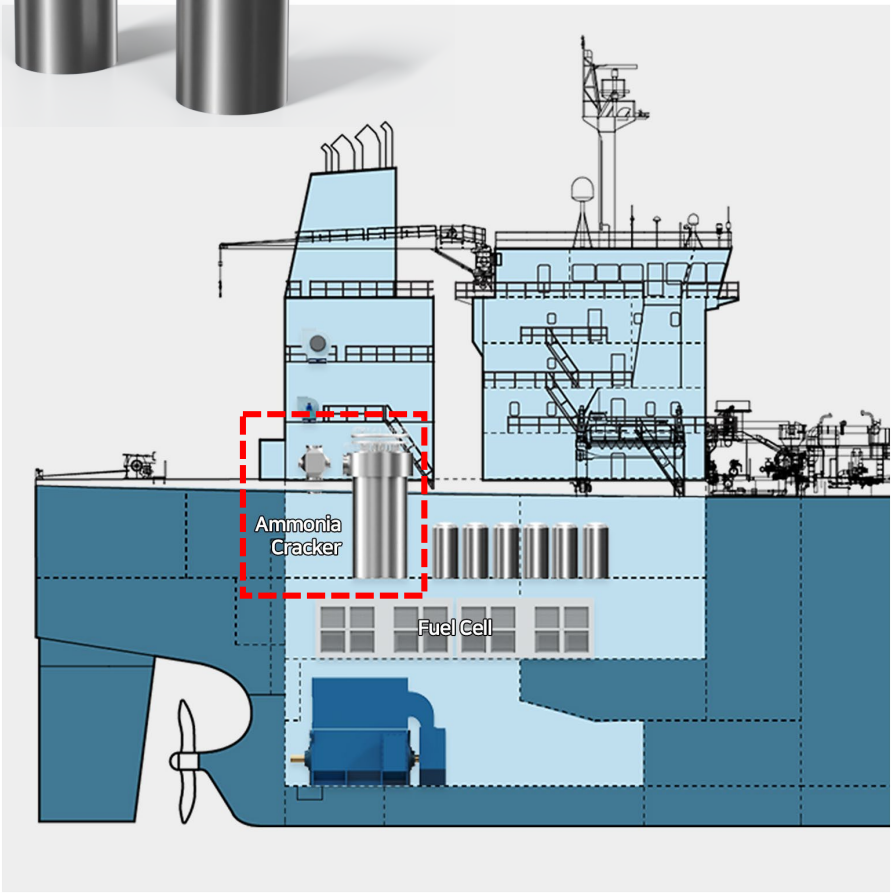


| CASE 2_50K PC(MR)



Ammonia Cracker Model	ACST 6000 D	ACSP 6000 D	ACST 6000 R	ACSP 6000 R
Anhydrous Ammonia Input (kg/hr)	3559	4332	3559	4332
Anhydrous Ammonia Input Pressure (bar)	15.5	15.5	15.5	15.5
Anhydrous Ammonia Input Temperature (℃)	20	20	20	20
Product Gas Output (Nm3/hr)	8865	6063	8865	6063
Product Gas Output Pressure (bar)	10.8	10.3	10.8	10.3
Product Gas Output Temperature (℃)	60	60	60	60
H2 Purity (%)	75	99.7	75	99.7
Product Gas Capacity (Nm3/hr) - H2	6648	6045	6648	6045
- N2	2216.25	18.19	2216.25	18.19
Power Consumption (kwh)	80	100	80	100
Explosion proof class	Ex d II C T1	Ex d II C T1	Ex d II C T1	Ex d II C T1
Dimensions (mL x mW x mH) _ NH3 Cracker	5.1 x 5 x 10.6	5.1 x 5 x 10.6	8 x 3.2 x 6.4	8 x 3.2 x 6.4

| CASE 3_115K Crude Oil Tanker(LR2) - ACS

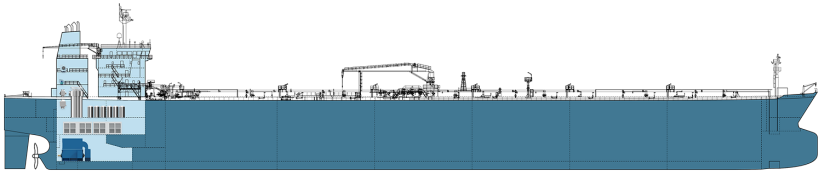


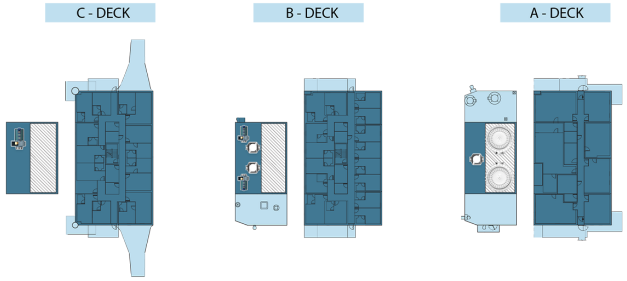
Concept

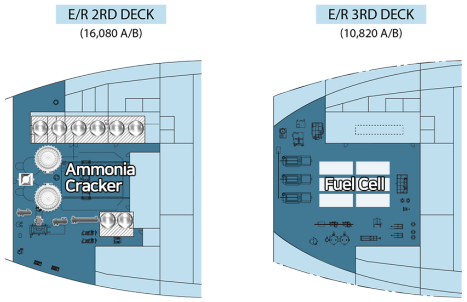
Ammonia Cracking System **12,000Nm3/hr**

+

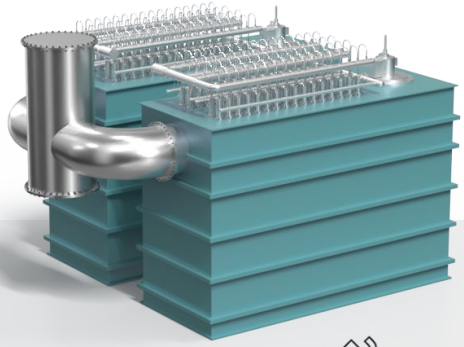
Fuel Cell Power System **15MW**

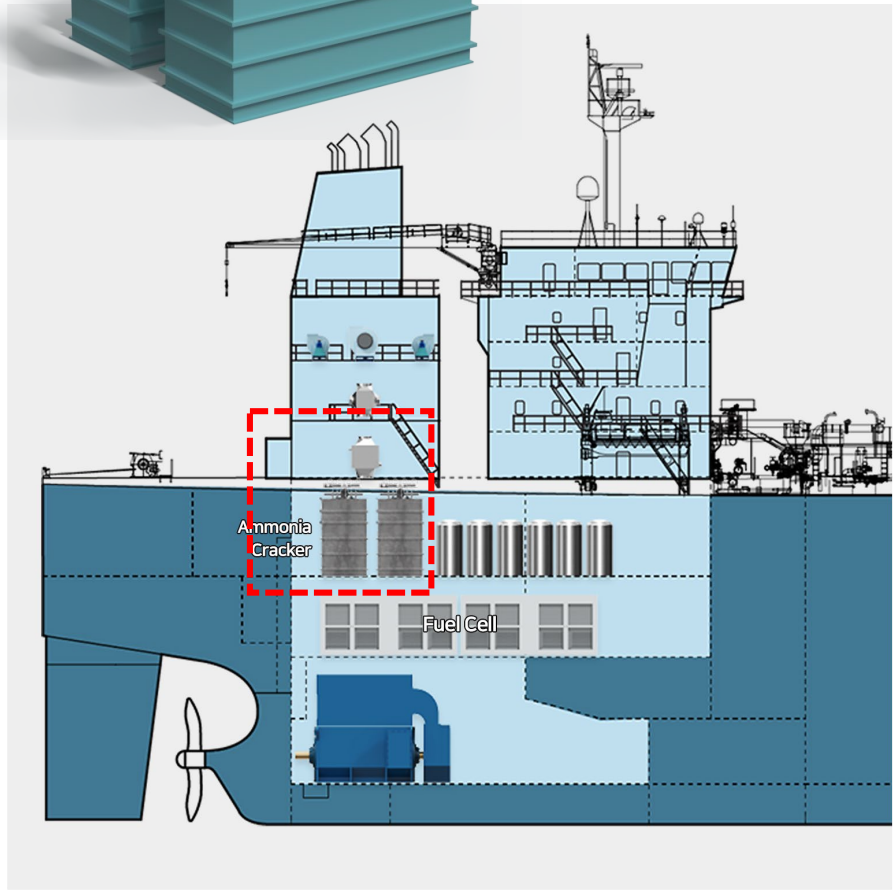






| CASE 3_115K Crude Oil Tanker(LR2)



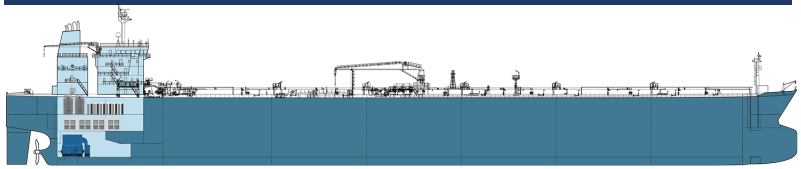


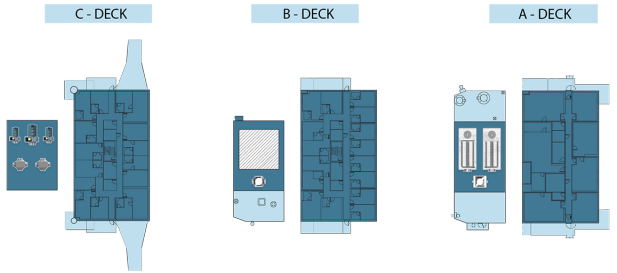
Concept

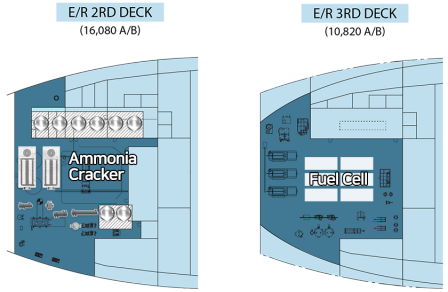
Ammonia Cracking System **12,000Nm3/hr**

+

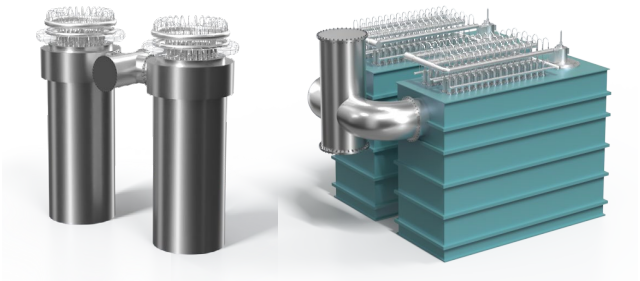
Fuel Cell Power System **15MW**







| CASE 3_115K Crude Oil Tanker(LR2)



Ammonia Cracker Model	ACST 12000 D	ACSP 12000 D	ACST 12000 R	ACSP 12000 R
Anhydrous Ammonia Input (kg/hr)	7083	8663	7083	8663
Anhydrous Ammonia Input Pressure (bar)	15.5	15.5	15.5	15.5
Anhydrous Ammonia Input Temperature (℃)	20	20	20	20
Product Gas Output (Nm3/hr)	17640	12127	17640	12127
Product Gas Output Pressure (bar)	10.8	10.3	10.8	10.3
Product Gas Output Temperature (℃)	60	60	60	60
H2 Purity (%)	**75**	**99.7**	**75**	**99.7**
Product Gas Capacity (Nm3/hr) - H2	13230	12090	13230	12090
- N2	4410	37	4410	37
Power Consumption (kwh)	150	185	150	185
Explosion proof class	Ex d II C T1	Ex d II C T1	Ex d II C T1	Ex d II C T1
Dimensions (mL x mW x mH) _ NH3 Cracker	12.5 x 5 x 10.6	12.5 x 5 x 10.6	10.3 x 7.7 x 6.8	10.3 x 7.7 x 6.8

R&D Facility

H_2 Production Technology R&D Center

Reforming System Test Bed (5, 30, 50, 250Nm3/h)

* SMR for house & building
* H_2 gas station, H_2 power plant

Utility & Gas

* Gases
* Air
* etc..

Control & Analysis Room

* System control/test
* Gas Monitoring & Analysis
* G/C analysis(purity)

CCS Test Bed

* Amine type CCS
* SMR CCS
* Multi- absorber tower

Test Barge

Test barge (14m x 44m , WT 344ton)

* Ballast system
* De-SOx, SCR system
* CCS system

5L 23/30H STX MAN Engine

* 650kW
* 720 rpm
* Diesel / HFO Operating

Control Room

* Engine & CCS system Control

DeSOx Scrubber

* CCS quenching tower

| Panasia competitiveness

Technology Independence

Cost reduction by localizing

PSA development

[30Nm3/h 급 PSA]

Sequence optimization for high purity

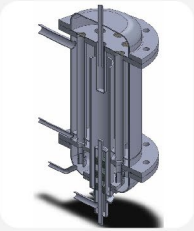
- PSA sequence improvement
- PSA line up(30, 100, 300, 500 Nm3/hr)

Catalyst development

Key element of Reforming process

- Obtaining Core technology
- Nickel : Mid/Large size of SMR
- Ruthenium : Small SMR or ACS system

Membrane technology

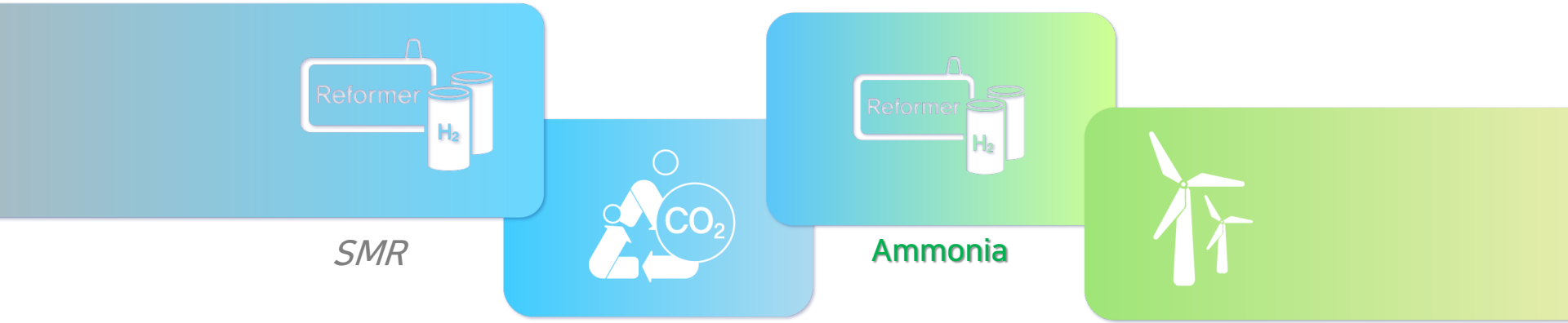


- All in one type(WGS, PSA, Chiller etc.)
- Energy saving (850->400~450 Degree C.)
- CO2 Capture for high concentration

Smart control center

- Real time monitoring
- Fault diagnosis
- Big data based replacement alarm
- Troubleshooting

Different color, same goal



SMR

CCS

Ammonia

Electrolysis