

Doosan Fuel Cell

Advent of Hydrogen Society & Doosan Fuel Cell's Vision



Disclaimer

Forecasts and projections contained in this material are based on current business environments and management strategies, and they may differ from the actual results upon changes and unaccounted variables.

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Contents

- Advent of Hydrogen Society
- Doosan Fuel Cell Strategy and Vision



Advent of Hydrogen Society

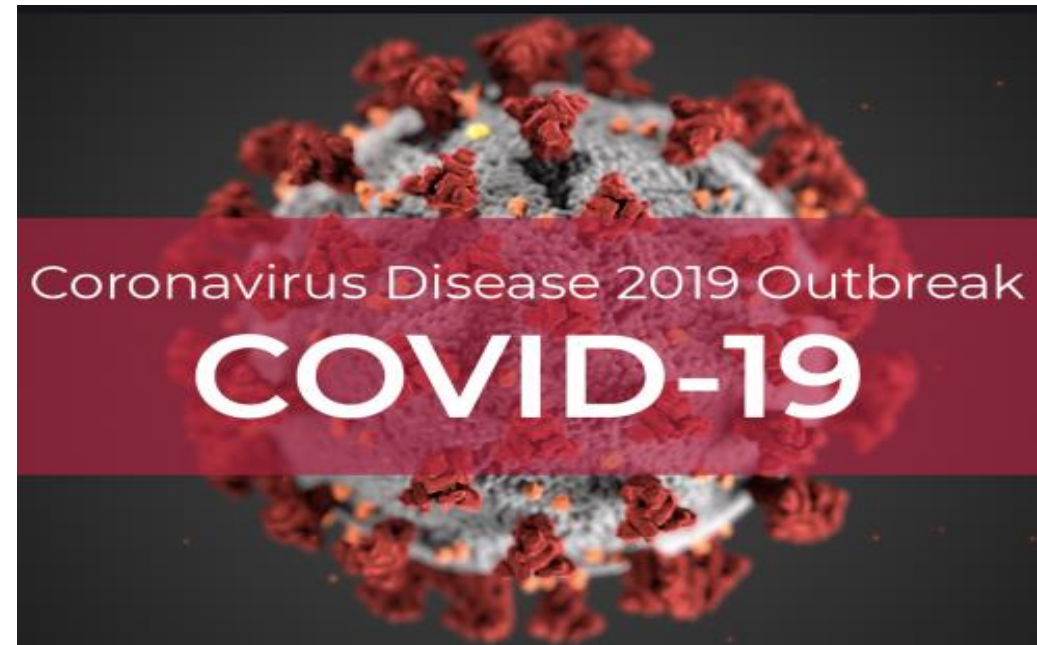
- Climate Crisis
- Net Zero Pledge to Combat Climate Change
- Net Zero: How Can It Be Achieved?
- Why Hydrogen?
- Why Now?
- Korea, the First Mover in H₂ initiatives
- Companies Rushing into Hydrogen

Climate Crisis

- ✓ Australia's Devastating Wildfires
19 fall - 20 spring



- ✓ COVID-19 Pandemic
170 million confirmed cases¹⁾



* As of end of May 2021

Net Zero Pledge to Combat Climate Change

Since 2015 Paris Agreement, countries have announced Net Zero around 2020 to cut carbon dioxide emissions

✓ Paris Agreement(2015)



Source: Getty Images

✓ Nations Moving to Net Zero

- ✓ 44 nations and EU
- ✓ Representing 70 % of global carbon dioxide emissions

By 2050



Nov 2018



Oct 2020



Oct 2020



Dec 2020
After Biden
was elected

By 2060



Apr 2021

Net Zero: How Can It Be Achieved?

According to IEA, 'Hydrogen electrolyzer' is key technology to Net Zero by 2050

Net Zero by 2050: A roadmap for the global energy system

International
Energy Agency

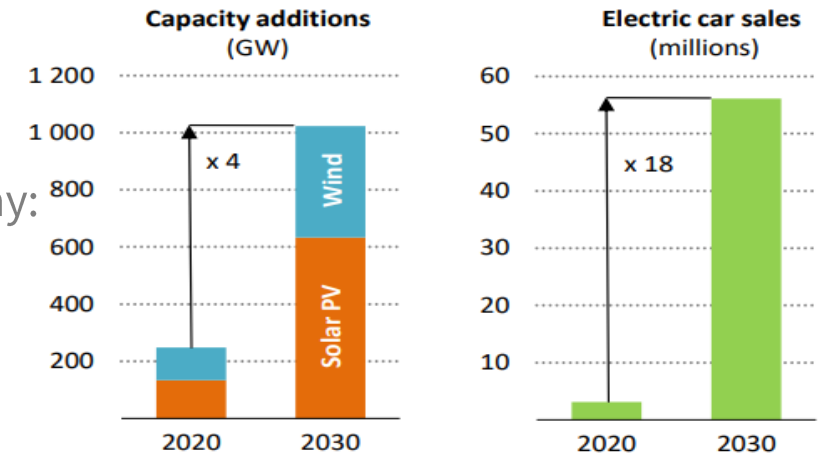
- ✓ Energy sector accounts $\frac{3}{4}$ GHG¹⁾
 - Need to change ways to generate, transport, and consume energy
- ✓ Urged to all governments to significantly strengthen and implement energy and climate policies



Source: IEA (International Energy Agency), May 2021
1) Green House Gas

~ 2030

Technologies
Available Today:
Solar, Wind
and EVs



2030~2050

Innovative
Clean Energy
Technologies

- 1 Advanced batteries
- 2 **Hydrogen electrolyzers**
- 3 Direct air capture and storage

Why Hydrogen?

1 Ubiquitous

Hydrogen is the most abundant element in the universe, accounting for 75 % of its normal matter
If there is technology, it is to improve energy independence and security

2 Green Energy

Carbon-free energy

3 High Energy Density

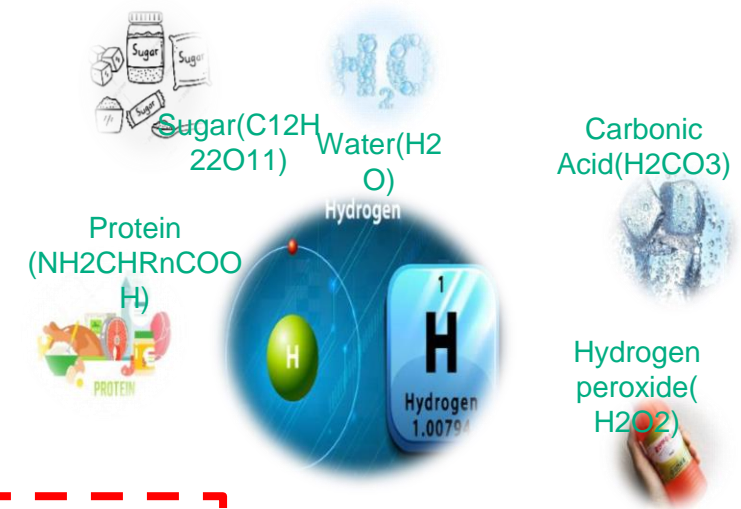
142kJ/g; 4x of gasoline, 3x of natural gas

4 Energy Carrier

Renewable energy accounts for 55% of total energy in 2050¹⁾

Renewable energy can be stored as H₂ (“Green H₂”) and transported

1) Source: IEA 2021



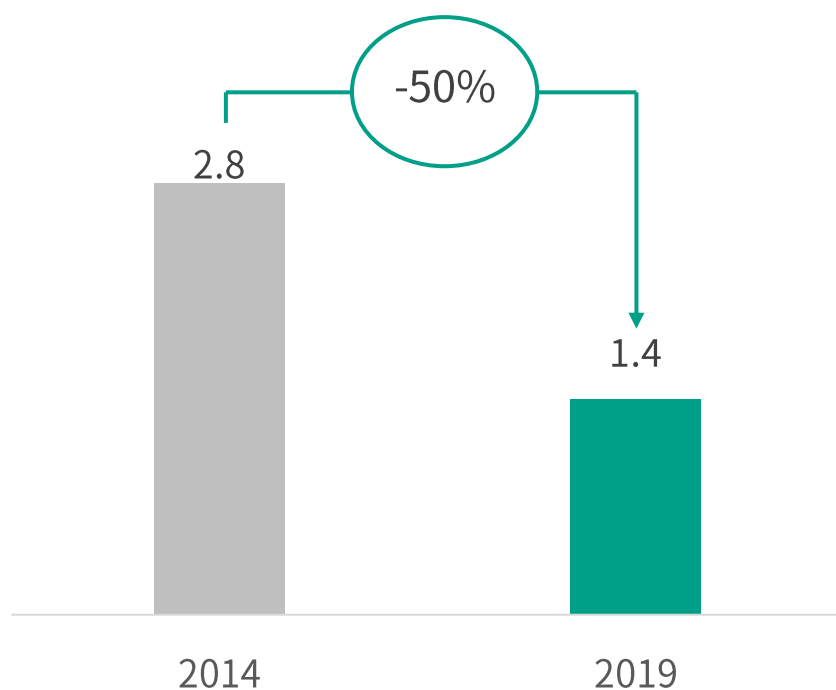
Why Now? (1) Tech Innovation and Renewable LCOE¹⁾

H₂ technology advancement and decline in renewable LCOE open the door to H₂ Society

✓ H₂ Tech Advancement

CAPEX of PEM electrolyzers

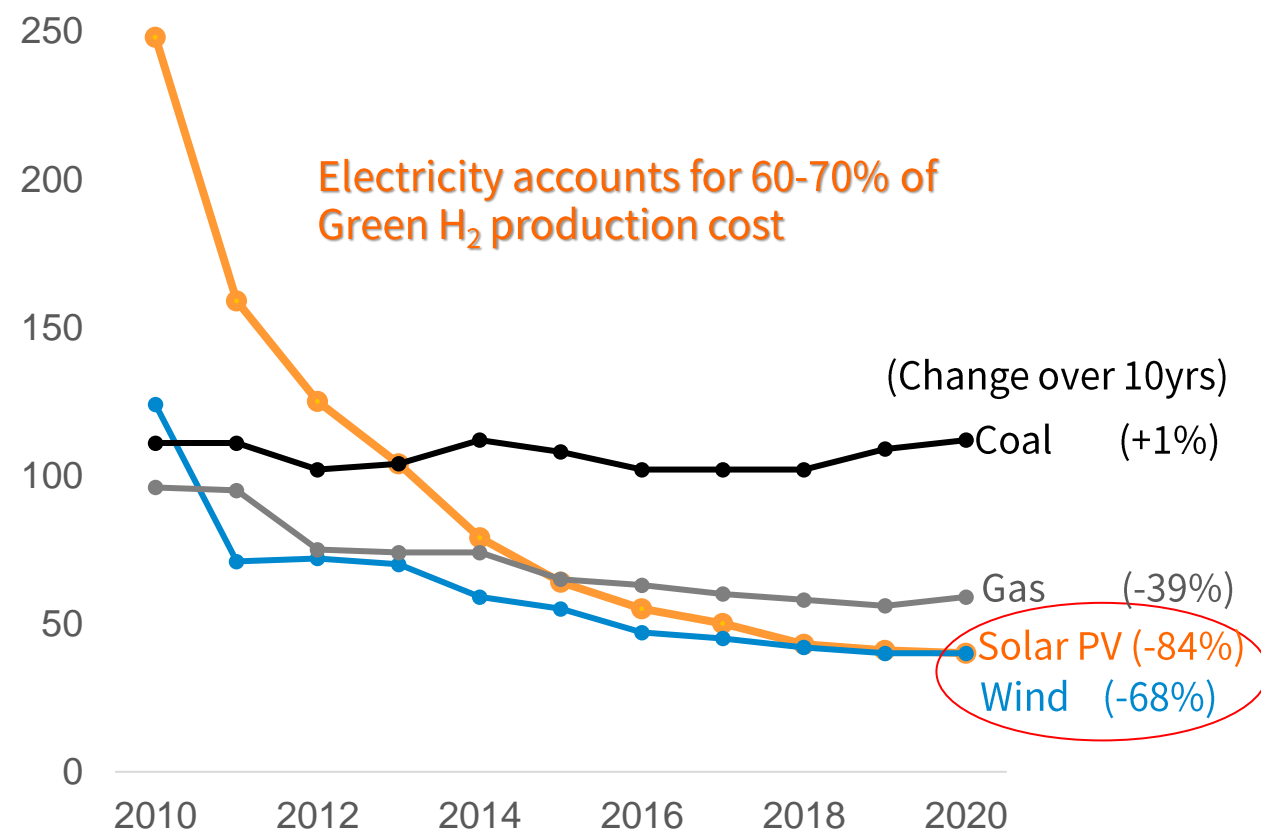
(Unit: USD/W)



Source: BNEF (Western-made electrolyzers)



✓ LCOE of Renewables



Source: Lazard (October 2020)
1) Levelized Cost of Electricity

Why Now? (2) Strong Global H₂ Policies

Ushering into H₂ society arising from strong political drive

Nation

Hydrogen Initiatives



EU

H₂ initiative announced in 2020

- 40GW target for electrolyzers by '30 (up to EUR 470bil investment)



Germany

National H₂ strategy announced in 2020

- 5GW target for electrolyzers by '30



Australia

Target announced in 2016 to be green H₂ exporter

- H₂ export based on abundant renewable energy sources



Japan

H₂ roadmap announced in 2020

- Technology development for large scale H₂ import and transport



US

H₂ roadmap announced in 2020

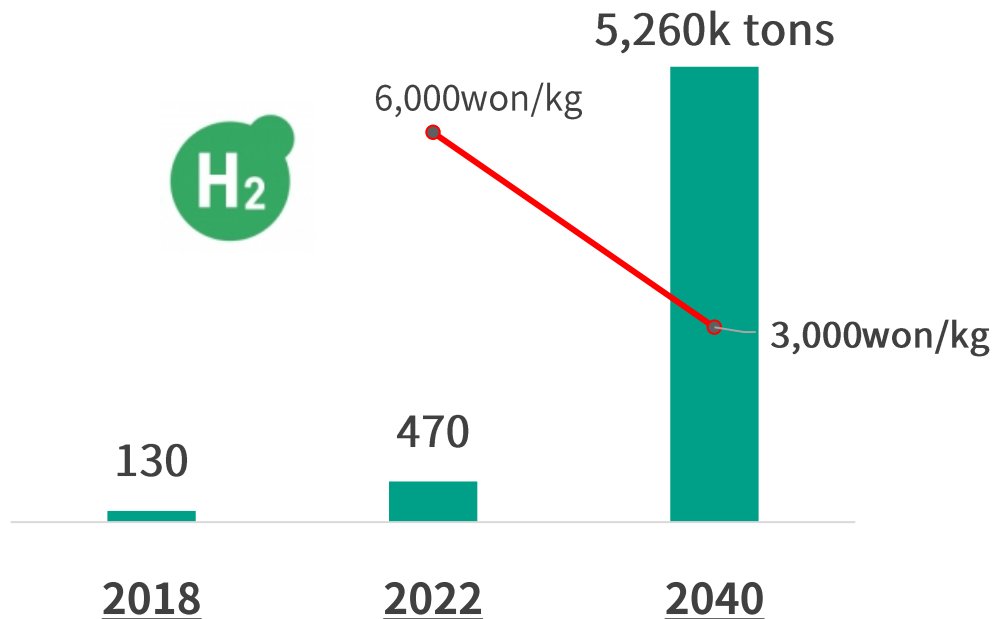
- \$1.28~2.16/kg H₂ cost target by '30

Korea, the First Mover in H₂ initiatives

Korean government already declared H₂ economy roadmap in 2019 prior to other nations and it implemented H₂ act first in the world in 2021

✓ Korean H₂ economy roadmap

(1) H₂ production and cost



(2) FCEV¹⁾/charging stations



2018

2022

2040

18K
14 EA

81K
310 EA

6,200k
1,200 EA

(3) Stationary fuel cells



307MW

1.5GW
(Korea:
1GW)

15GW
(8GW)

(4) Fuel cells for residential/building

RPS²⁾ → HPS³⁾



7MW

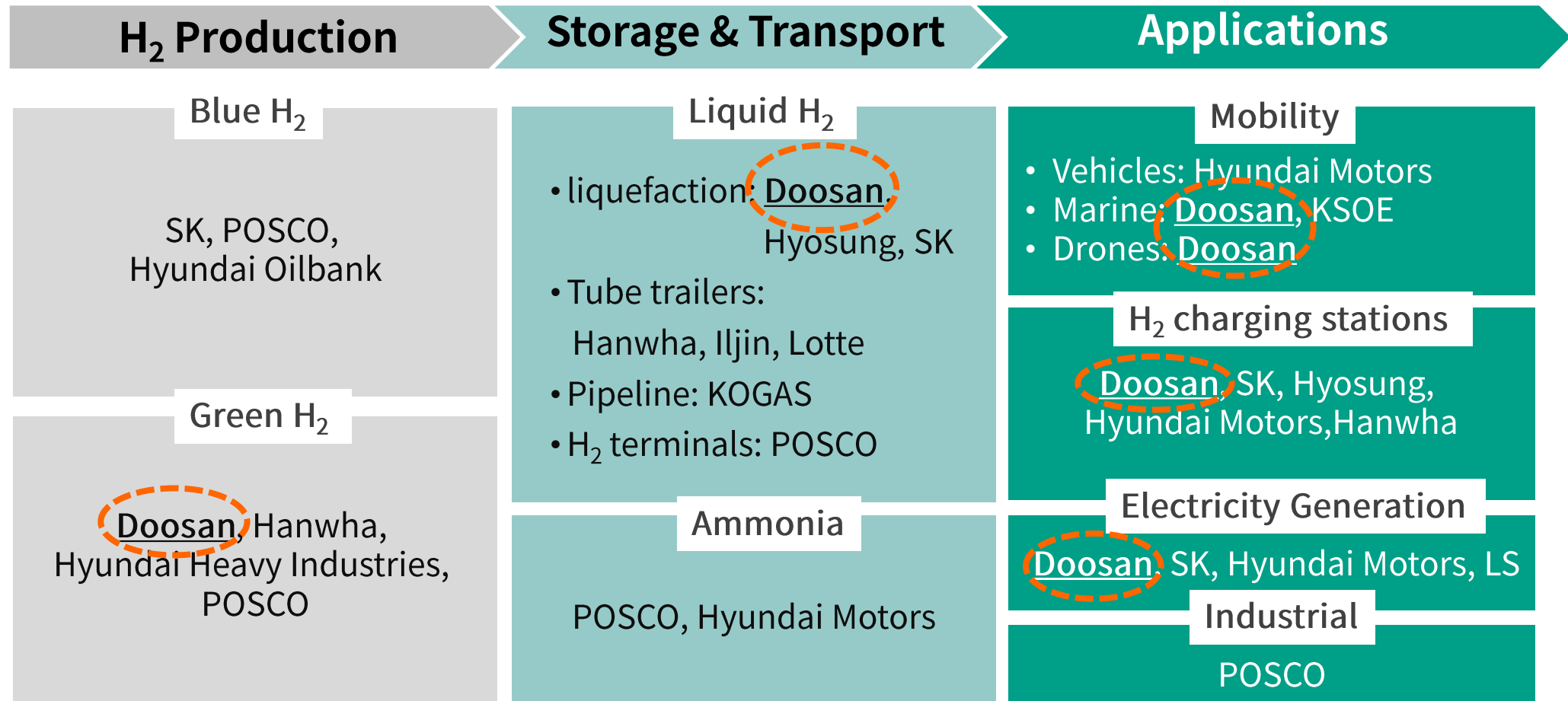
50MW

2.1GW

- 1) Fuel Cell Electric Vehicle
- 2) Renewable Portfolio Standard
- 3) Hydrogen Portfolio Standard

Companies Rushing into Hydrogen

Doosan and other Korean companies have announced H₂ investment plans to take the lead in the sector





Doosan Fuel Cell Strategy and Vision

- Who We Are
- What is a Fuel Cell?
- Key Advantages of Fuel Cells
- Expansion PAFC applications
- Technology Competitiveness
- New Growth Engine
- Technical Roadmap
- Doosan Fuel Cell Vision

Who we are

Overview

- Business : fuel cells, long-term service, H₂ generator installation & management, FCEV charging stations and etc.
- Assets : 769.4 bn won¹⁾
- Employees : 405¹⁾

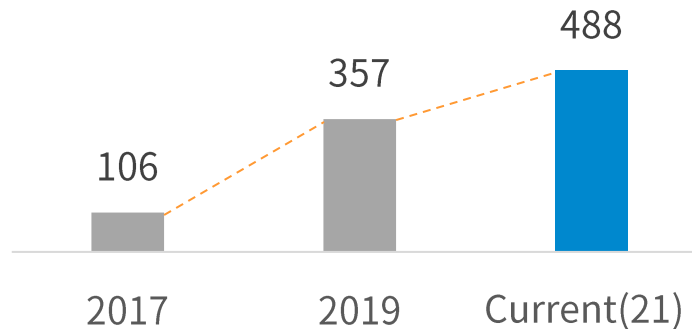
History



Performance

Accumulated orders received (MW)³⁾

Korean No. 1 in 3 consecutive years



Footprints

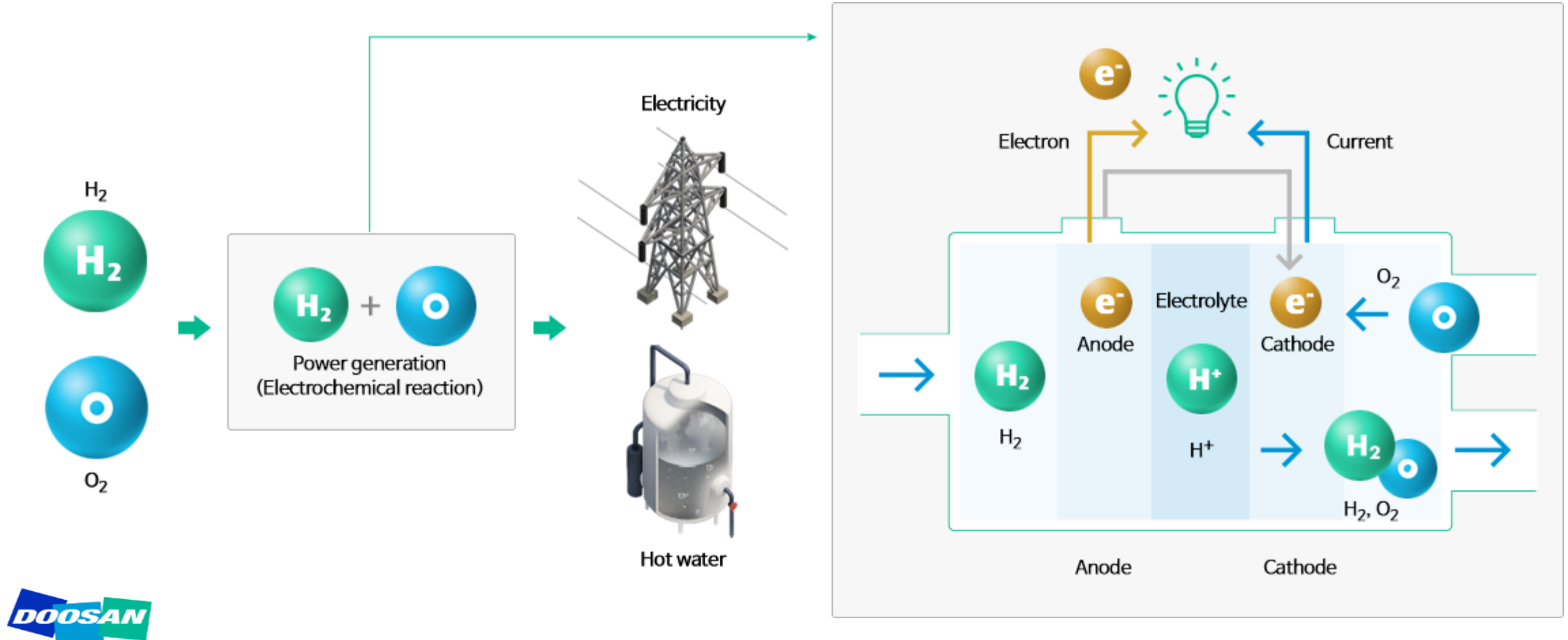
- ✓ 344MW installed in 34 sites
- ✓ 144MW installation underway in 9 sites



What is a Fuel Cell? –(1) how it works

Fuel cells are efficient and **green energy generation** technology which leverages the **electrochemical reaction** of hydrogen and oxygen

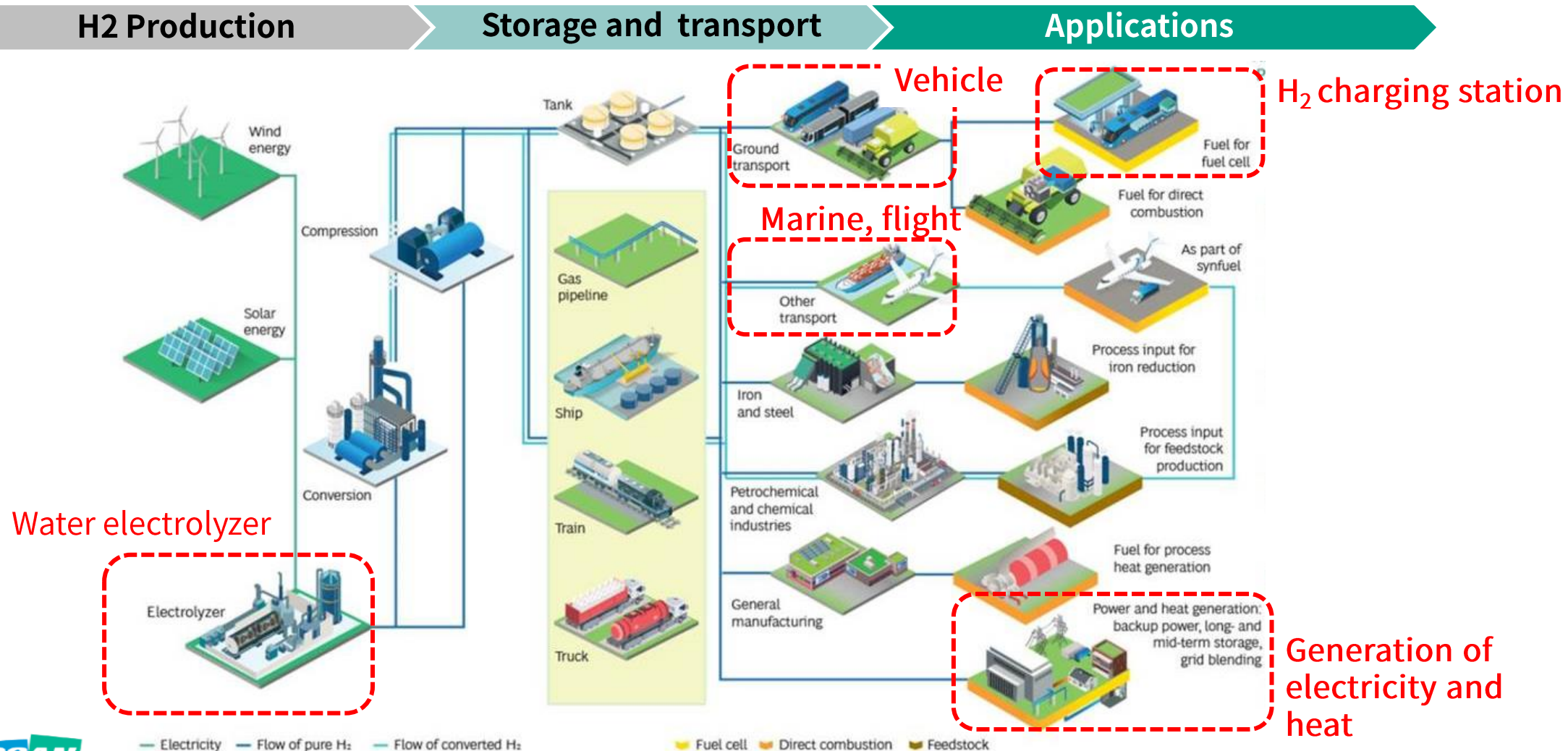
✓ How fuel cells work



What is a fuel cell? –(2) Roles in Net-Zero era

Fuel cells technology is an enabler of producing and using hydrogen

 Fuel cell tech applications

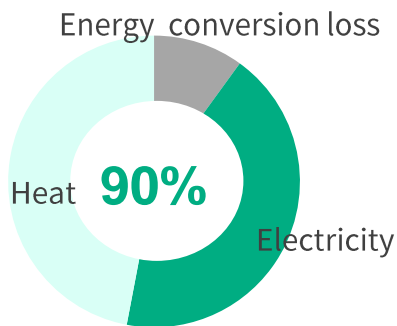
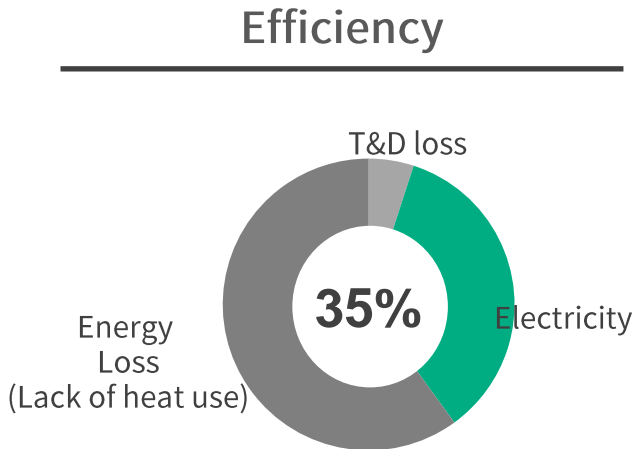


Key Advantages of Fuel Cells–(1) vs. Carbon Fired Conventional Energy Sources

✓ Distributed Energy

Centralized Generation

Distributed Generation



✓ Green Energy



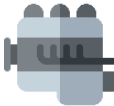
M400 Hydrogen



M400 NG



Gas Turbine

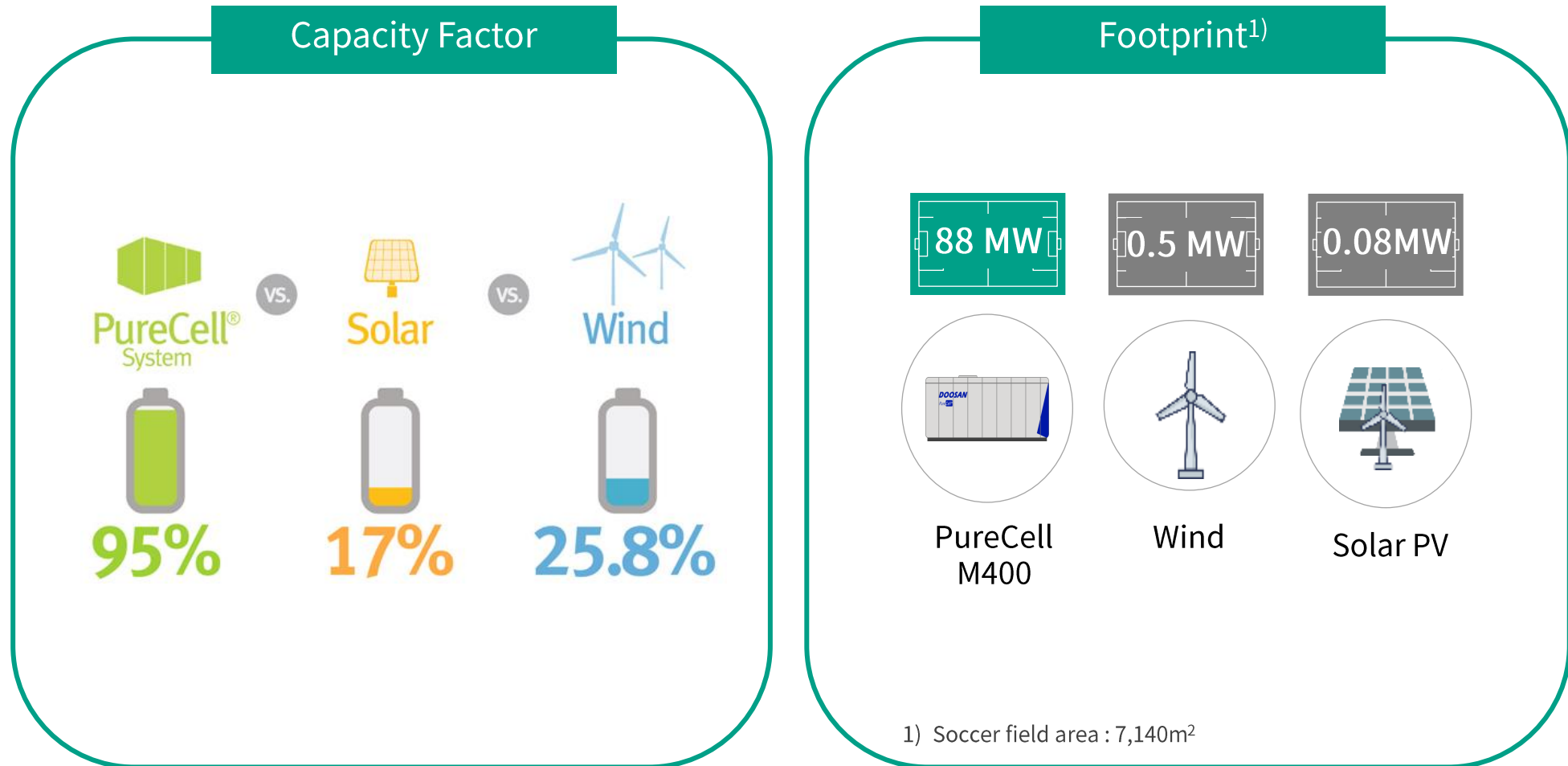


Gas Engine

	Emissions	
	NOx (ppm)	CO2(g-c/kWh)
M400 Hydrogen	0	0
M400 NG	1~2	111
Gas Turbine	~42	233
Gas Engine	~100	171

Key Advantages of Fuel Cells –(2) vs. Renewable Energy

Fuel cells with high capacity factors and small footprint complement the features of renewables



Key Advantages of Fuel Cells–(3) PAFC Technology

PAFC has (1) high flexibility due to low operating temperature and (2) easiness to transform to H₂ model

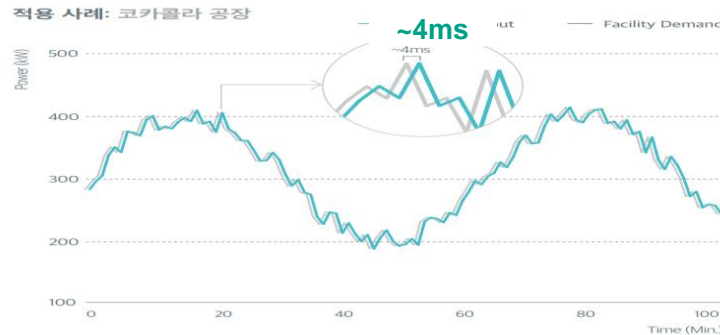
✓ Flexibility: load following & base load



US fuel cell cases

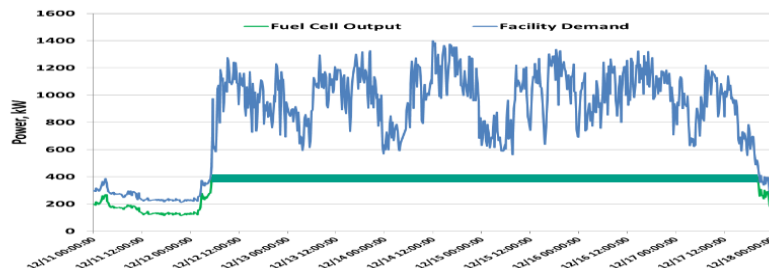
Load following

• East Hartford, Connecticut



Base load

• Elmsford, New York



✓ High H₂ Electricity efficiency and various fuel choice

M400 NG model
Natural gas



M400 LPG/NG model
LPG + NG



M400 Hydrogen
Hydrogen



“Hydrogen Ready”
Easily transforming to
H₂ model

First commercialized
H₂ model for
“Green H₂ era”

LPG/NG Dual Model



Fuel cell power generation plant in Guangju (12MW)

Source: SK gas

- Global first LPG/NG dual model
- Received an order of 12MW for the power plant in Gwangju (Q4 '20)

Implication & applications

- ✓ Improving economics from various fuel options
- ✓ Using LPG in areas with low access to electricity and city gas infrastructure, electricity and heat are supplied
- ✓ Targeting remote area in the overseas market without sufficient electricity generation

Hydrogen Model

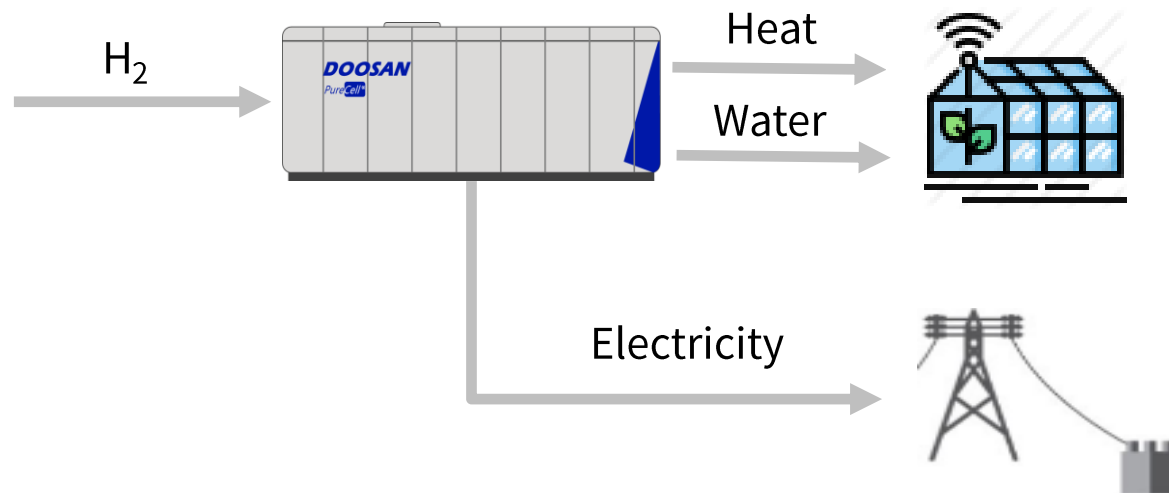


- Electricity generation with H₂
- Higher efficiency(50%) than NG model
- Commercialized H₂ model for the world's first and largest byproduct H₂ power plant in 2020

Implication & applications

- ✓ Using byproduct H₂ from petrochemical and steel industry
- ✓ 100% green energy source
- ✓ Fit into green H₂ policy in a timely manner
- ✓ Convertible to H₂ model when H₂ infrastructure is available

Smart Farm

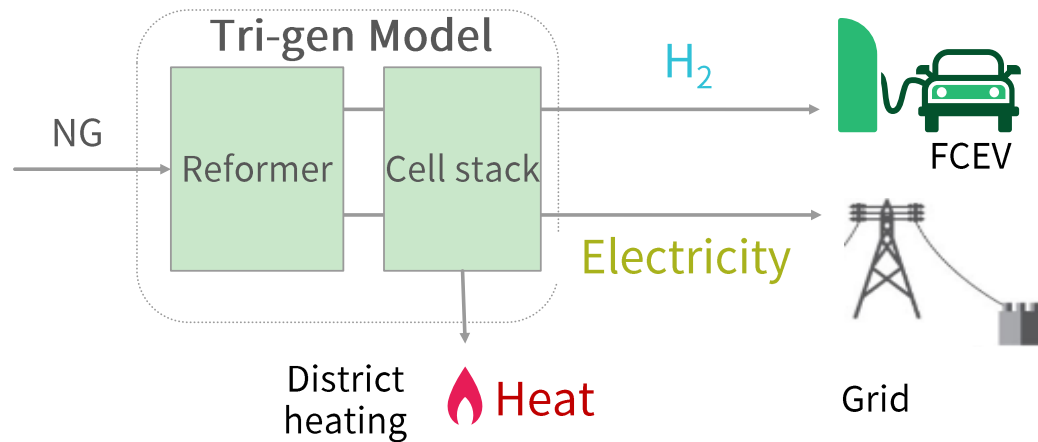


- Fuel cell applied to heating and cooling for smart farm
- MOU for Korea-China Smart Farm project (April 2021)

Implication & applications

- ✓ Supplying cooling and heating for smart farms and electricity can be sold to add values
- ✓ Fuel cell generated water will be used as agricultural water (4ton/day per unit)
- ✓ Applicable to areas where the agricultural climate is barren

Tri-gen Model



- On-site H₂, electricity, heat supply
- Economical H₂ supply
 - Large and high-pressure tube trailers not required
- Commercialization in '22

Implication and applications

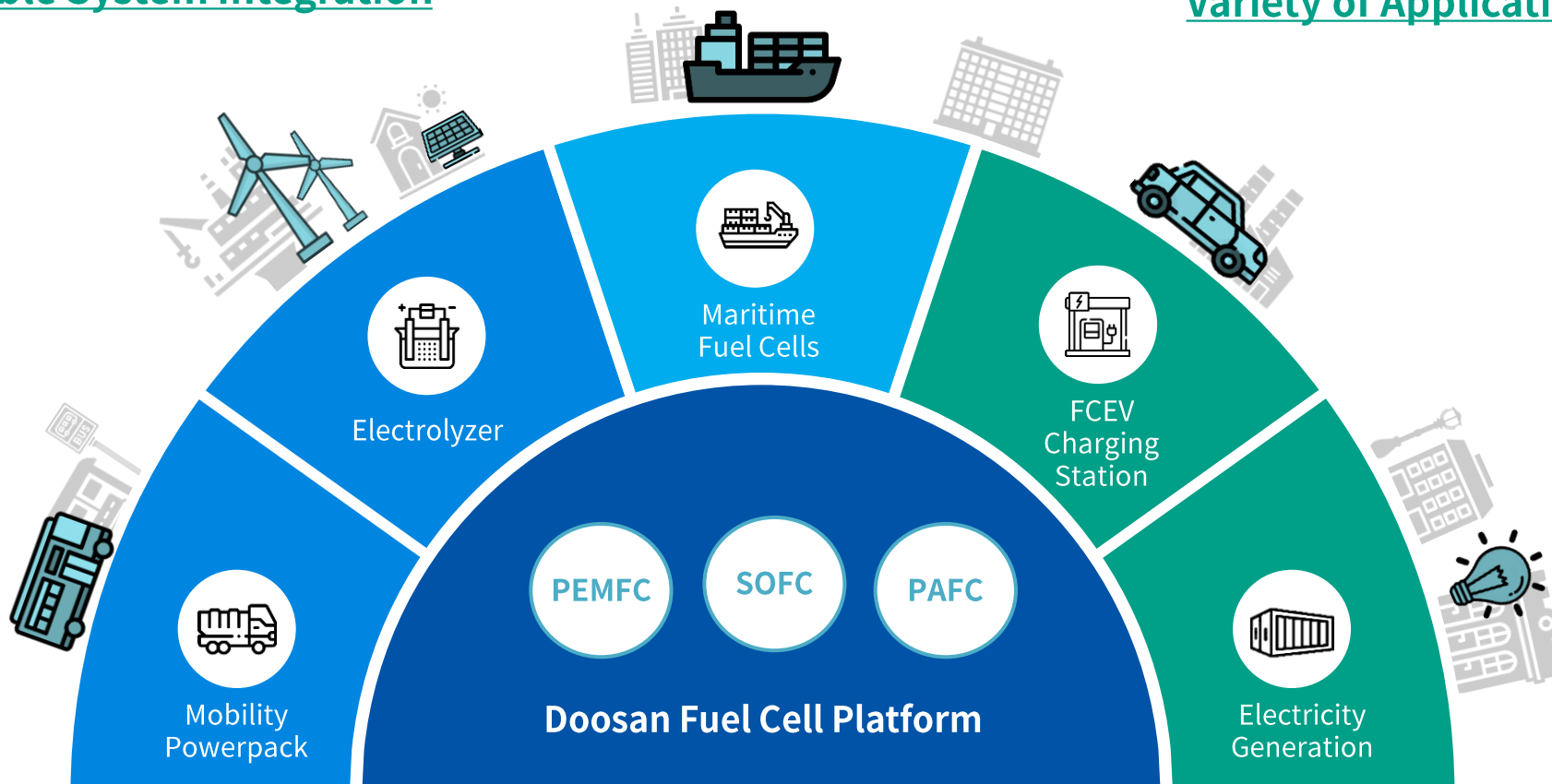
- ✓ Expanding business area to H₂ production
- ✓ Being supplied to FCEV and EV combined charging stations
- ✓ Meeting the government target to deploy charging stations

Technology Competitiveness

Based on PAFC capabilities, we will develop SOFC and PEMFC technology to expand our business area

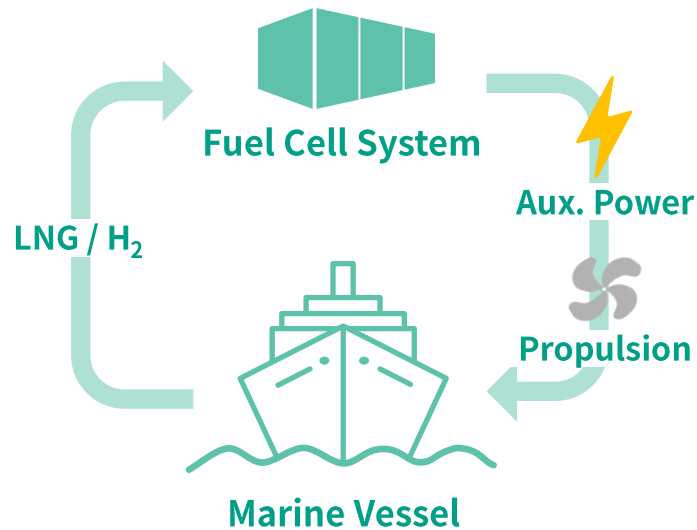
“Flexible System Integration”

“Variety of Applications”



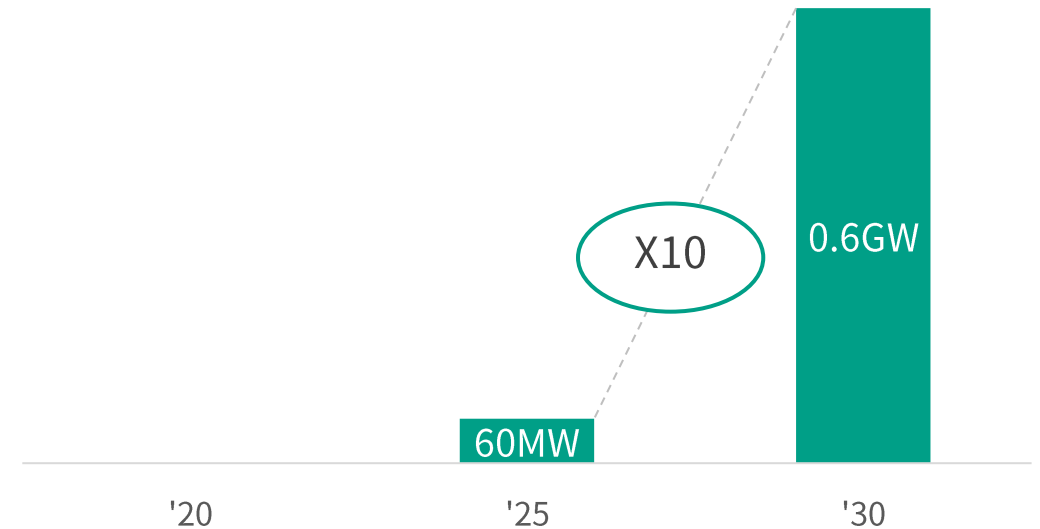
Eco-friendly fuel for maritime is required to comply with regulation

Drivers for Maritime Fuel Cell



- IMO¹⁾ regulation to meet GHG emission target
- Planning to advance into the market with natural gas fueled fuel cells and move to H₂/NH₃ fuel cell according to future strengthening restrictions

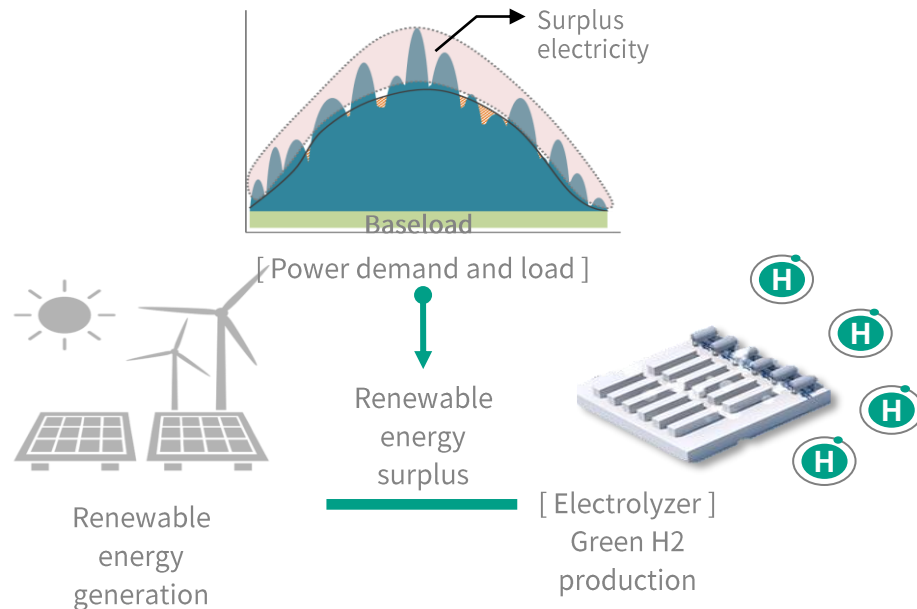
Market Outlook for Maritime Fuel Cell



- As all vessels will fall under the restriction in '50, expected to see SOFC fueled vessel market formation around '25
- Oligopoly anticipated
→ need to focus on AIP²⁾ standardization for market lead

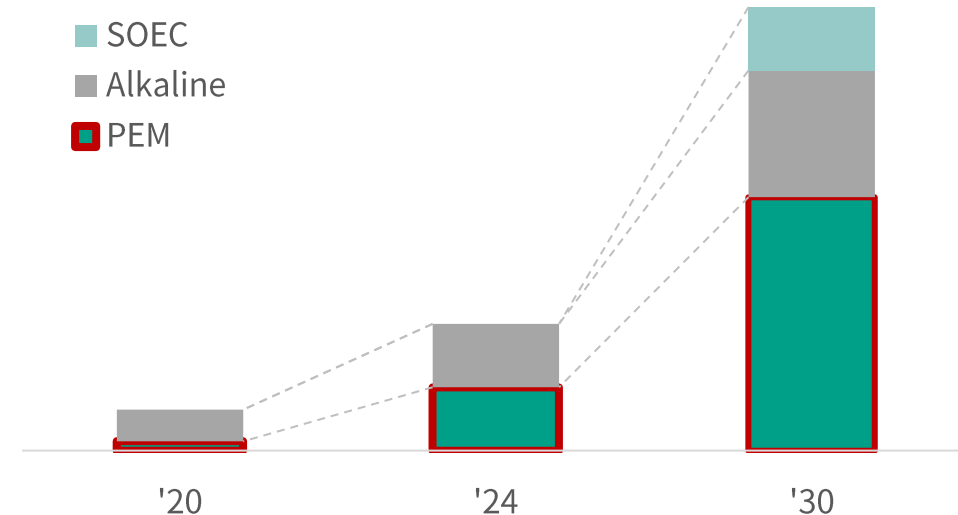
Strong Green Hydrogen policies will accelerate electrolyzer market growth

PEM electrolyzer market driver & Biz model



- Renewable energy creates a large amount of surplus electricity
- Net-Zero expanding H₂ needs
- Low H₂ charging stations penetration

Market outlook by electrolyzer technology



- PEM electrolyzer market growth expected driven increasing renewables and transport infrastructure, high purity, eco-friendliness
- Electrolyzer would be expanded first in nations with abundant renewable energy sources

1) Variable Renewable Energy, VRE ratio = (Wind+Solar PV)/Total Energy
Source: IEA

New Growth Engine(3)

Marine Fuel Cell

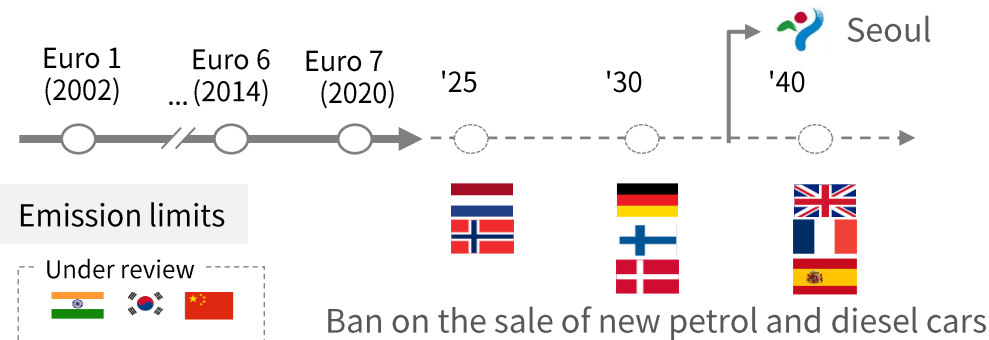
Electrolyzers

Mobility

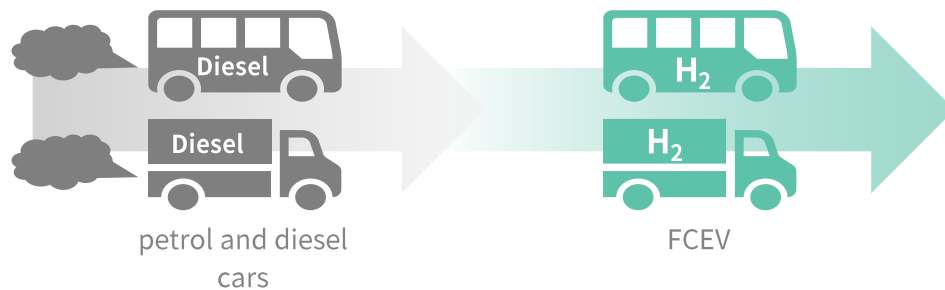
Advance into heavy commercial vehicle market where FCEV is more competitive than battery EV(“BEV”)

Driver for Mobility Powerpack

- Emission limits & ban on the sale of internal combustion cars



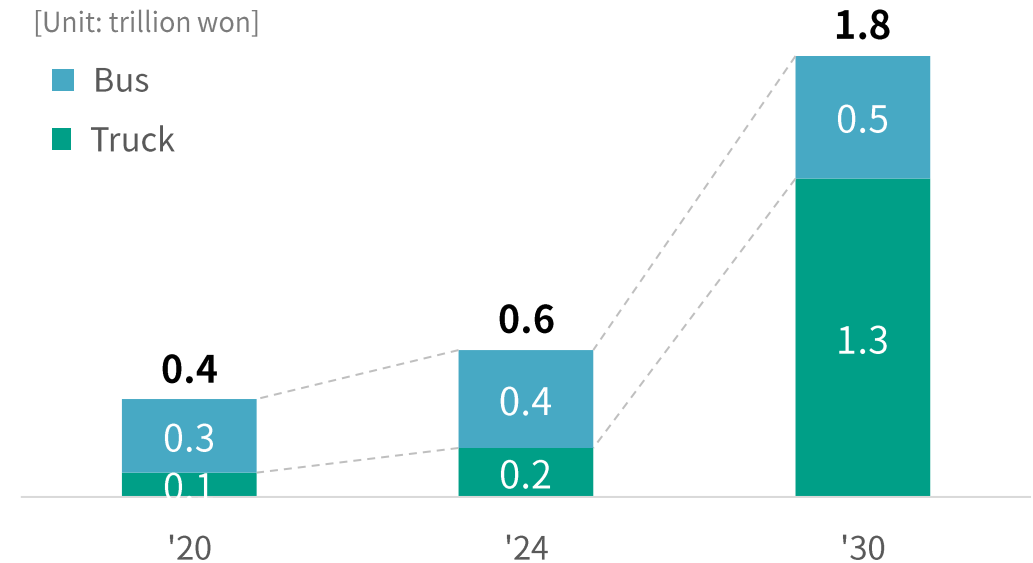
- High energy density of FCEV drives demand for fuel cells
- Battery's low energy density limits advance into heavy commercial vehicles¹⁾



Market Outlook for Truck/bus Power Pack

[Unit: trillion won]

■ Bus
■ Truck

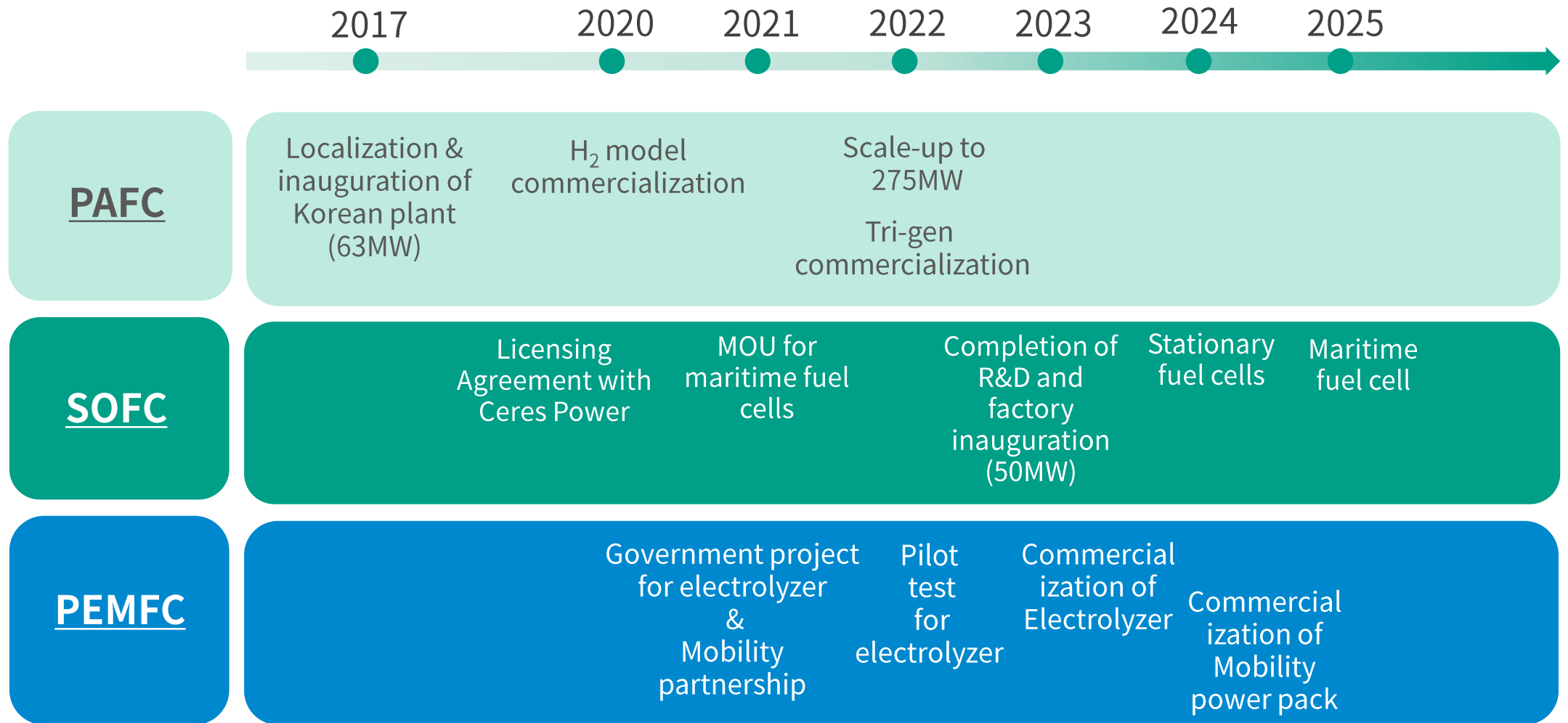


- Expected to form large and stable market around heavy trucks and long-distance buses where BEV can't penetrate
- Anticipated FCEV deployment in new truck market in '30 driven by restrictions and policies

1) Heavy commercial vehicles : medium and large trucks and long-distance buses

Source : Mckinsey_Route 230-A Regional View of Truck Industry Profit Pools/E4tech

Technology roadmap



■ 수소 ■ 전기 ■ 연료 ■ 열 ■ 냉수

Q&A Session

