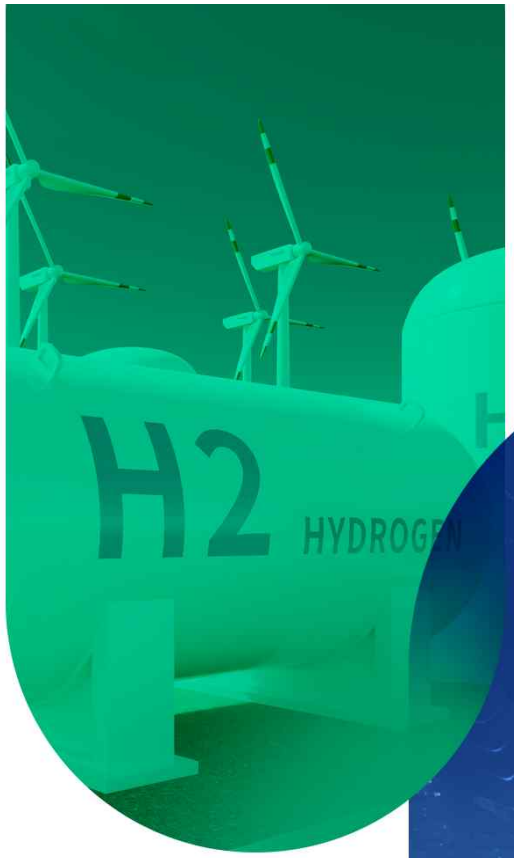
Nuclear Hydrogen

2024. 4. 26.



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Introduction

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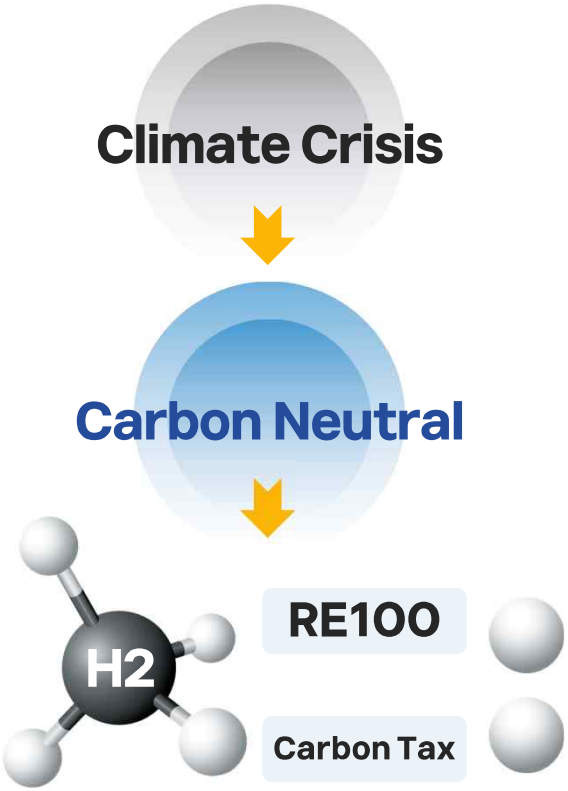
Hydrogen Economy

Advent of Hydrogen Economy



Global Hydrogen Demand

2018 → 70 million Mt

- Steam Methane Reforming (SMR)
- Refining of fossil fuels, Ammonia production

2050 → 600 million Mt

- Water Electrolysis (85%)
- Existing demand + Future demand*

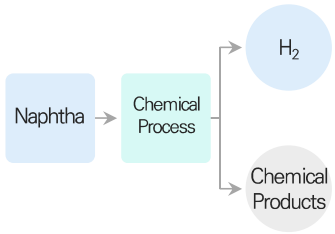
* Metal Refining, Transportation, Power Generation, etc.

Types and characteristics of hydrogen

	Gray	Blue	Green / Pink
Feed	Fossil Resources (Coal, NG, etc.)	Fossil Fuels (NG)	Water (Renewable/Nuclear)
CO_2 Emissions	10 ~ 15 kg	3 ~ 4 kg	< 1 kg
Equipment	Steam Methane Reformer, etc.	Steam Methane Reformer CO_2 Capture & Storage	Electrolyzer

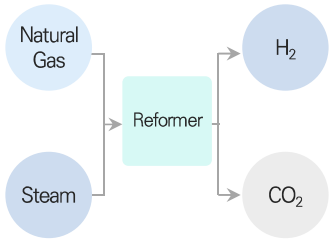
IRENA 2021

By-product



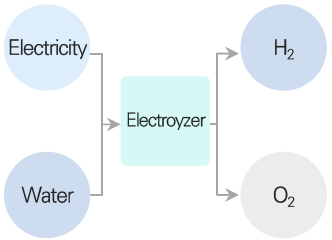
- CO_2 Emission
- Cost-effective

SMR



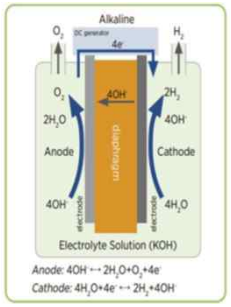
- CO_2 Emission
- Low Cost

Electrolysis

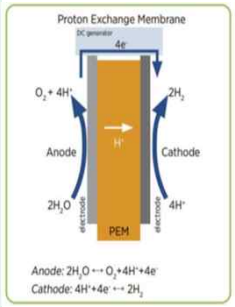


- Carbon Free
- High Cost

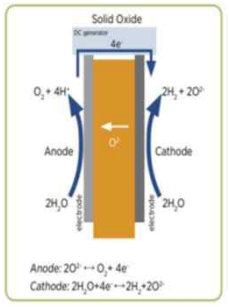
ALK



PEM



SOEC



Clean Hydrogen Certification

Clean Hydrogen Certification Guidelines

If greenhouse gas emissions during hydrogen production and import processes are below a certain level,
It can be certified as Clean Hydrogen eligible for administrative & financial support

Criteria

◆ **Emission Scope**
Well-to-Gate

◆ **Emission Criteria**
≤ 4kgCO_2eq / kgH_2

Grade

◆ Grade of Clean Hydrogen

(Unit : kgCO_2eq / kgH_2)

Grade 1	Grade 2	Grade 3	Grade 4
0~0.10	0.11~1.00	1.01~2.00	2.01~4.00

Domestic Clean Hydrogen Utilization Plan

Projected Clean Hydrogen Demand for 2030 : At least 800,000 tons or more

G

Power Generation

→ 800,000 tons for Co-firing

T

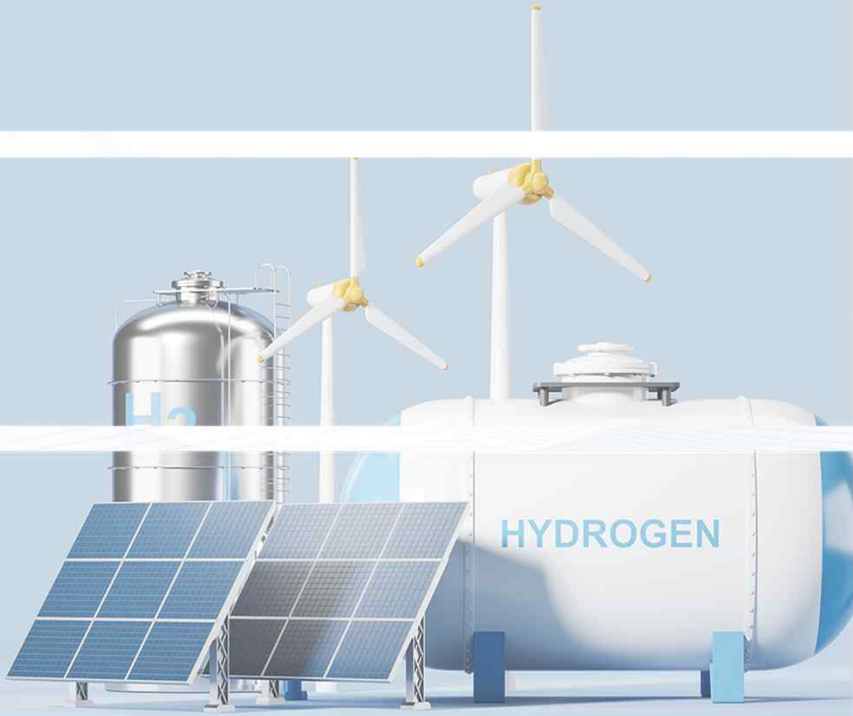
Transportation

→ 400,000 tons for Hydrogen vehicle

I

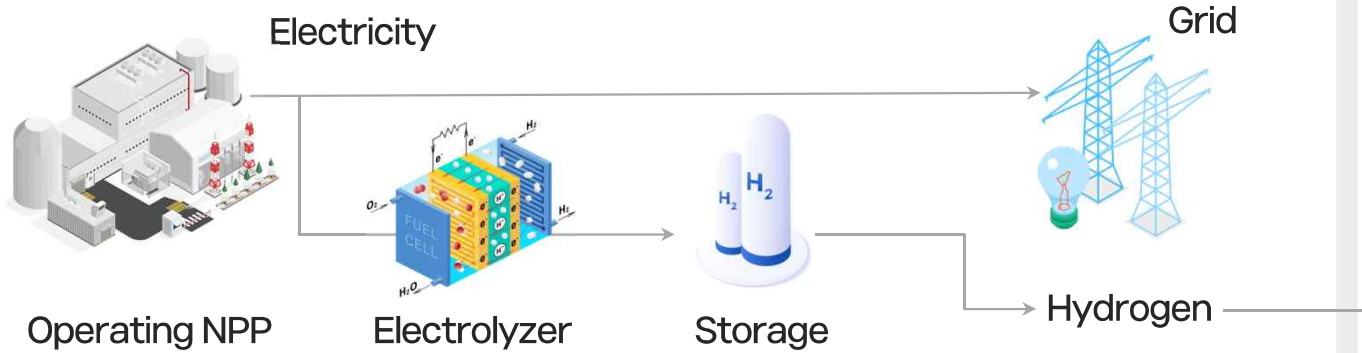
Industry

→ 90,000 tons for metal refining

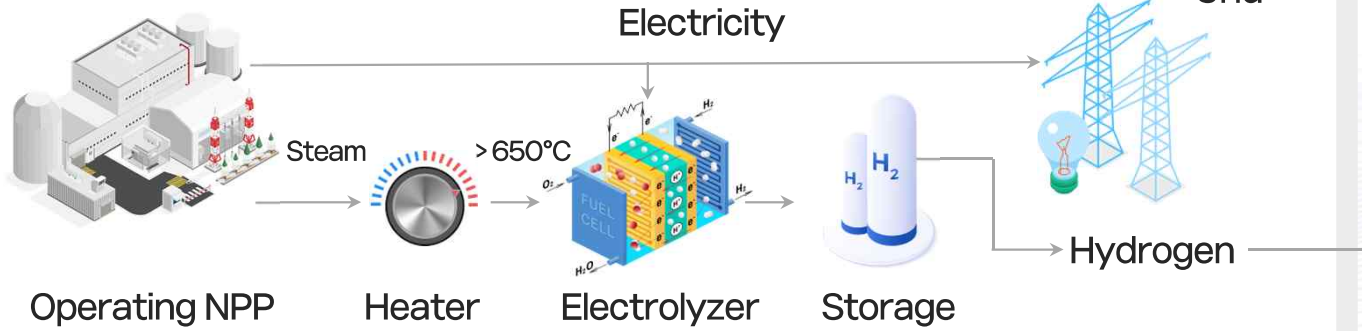


Nuclear Hydrogen with an Operating NPP

LTE



HTE



Clean Hydrogen Market

Motivation for Nuclear Hydrogen

Low-carbon Energy

IPCC AR5 Climate Change 2014

Power Source	Nuclear	Wind	Solar	Hydro
g CO_2eq/kWh	12	11 ~ 12	27 ~ 48	24

High Capacity Factor

IAEA / IRENA Renewable Power Generation Costs In 2021

Power Source	Nuclear	Wind	Solar	Hydro
Capacity Factor (%)	**85**	39	17	45

Low Electricity Cost

KPX Information System (Feb 2024)

Power Source	Nuclear	Wind	Solar	Hydro
Electricity Cost (₩/kWh)	51	115	121	141

Thermal Energy Use

Power Source	Nuclear	Wind	Solar	Hydro
Thermal Energy	O	X	X	X

Motivation for Nuclear Hydrogen

Changes in Power Grid

- Increase in renewable energy generation, decrease in fossil fuel generation, Grid Constraints
- Increased grid variability, NPP output limitation due to surplus power generation

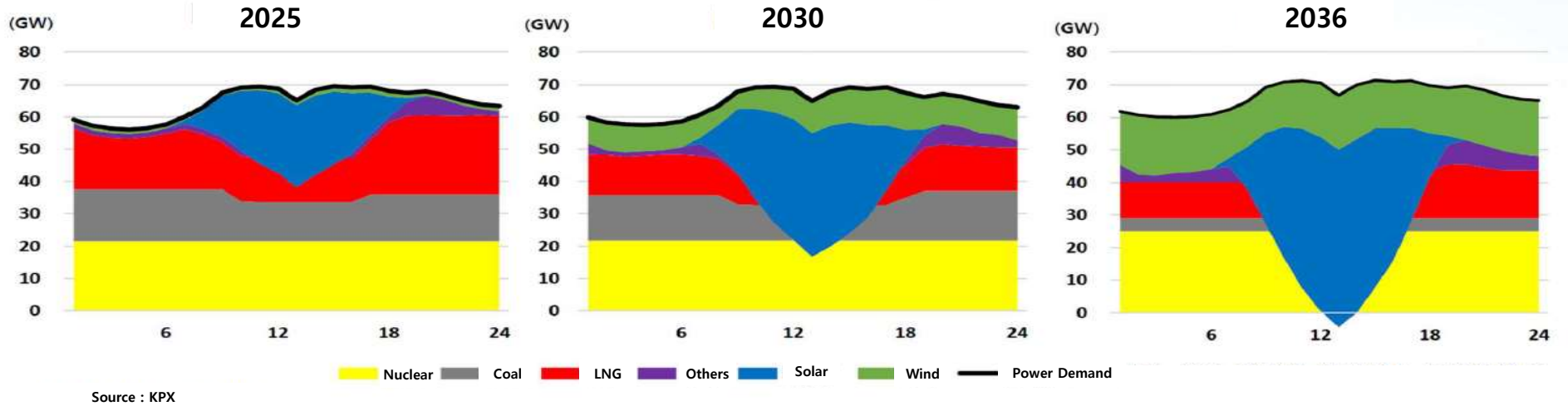
<The 10th Basic Plan for Electricity Supply and Demand>
Comparison of power generation shares by power source (%)

Year	Nuclear	Coal	LNG	Renewable	Co-firing	Others	Total
2018	23.4	41.9	26.8	6.2	-	1.7	100
2030	32.4	19.7	22.9	21.6	2.1	1.3	100
2036	34.6	14.4	9.3	30.6	7.1	4.0	100

Motivation for Nuclear Hydrogen

Future Power Mix Change

Example of Daily Generation Pattern



Source : KPX

Multiple use of operating NPPs with hydrogen plant

- Demand response operation of the electrolyzer contributes to the stability of the power grid
- Domestic clean hydrogen production contributes to carbon neutrality and energy security

II

Considerations

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Technical Considerations – Hydrogen Island

Electrolyzer Selection

IREA Report, 2020

Parameter	2020			2050 Target		
	LTE		HTE	LTE		HTE
	Alkaline	PEM	SOEC	Alkaline	PEM	SOEC
Efficiency [kWh/kg H_2]	50~78	50~83	45~55	< 45	< 45	< 40
Lifetime [hours]	60,000	50,000~ 80,000	< 20,000	100,000	100,000~ 120,000	80,000

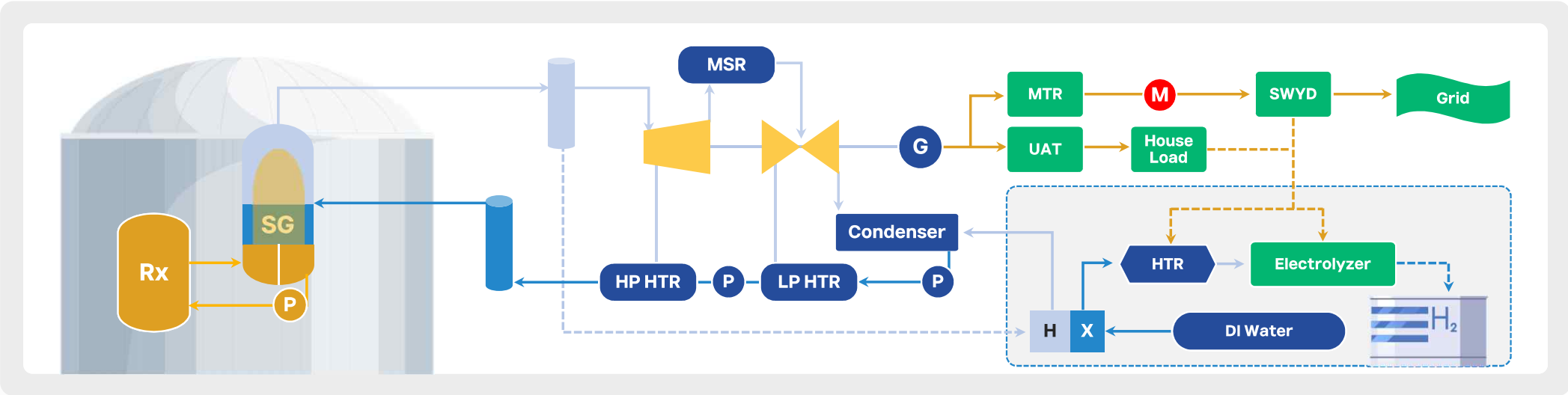
Location & Space

- **Closer physical proximity** Shorter connections, more hydrogen hazards
- **Space availability** 5,400 m^2 for 10 MW ALK Plant (More area for scaling up)

Storage

- Determined by plant scale, operation profile, end uses
- Compression, liquefication or conversion

Technical Considerations – Nuclear Island



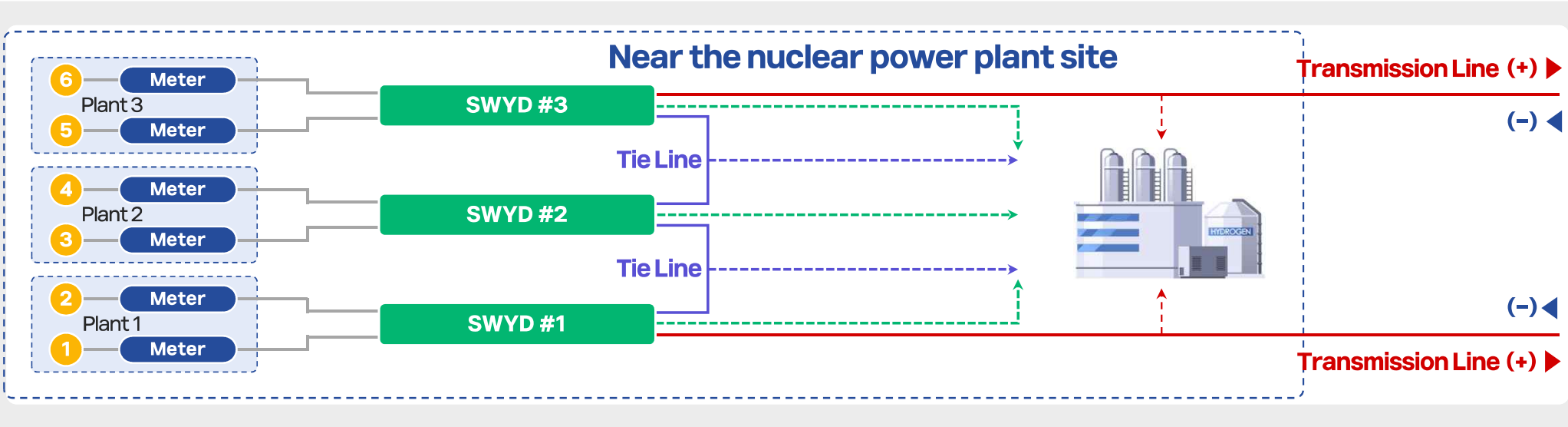
Electrical Integration

- **Connection Point** Before / after the meter
- **Impact to plant electric systems** New electrical transients

Thermal Integration

- **Diversion Point** Main / Auxiliary steam system or Extract steam line
- **Impact to the TBN Cycle** New normal operation, new thermal transients

Technical Considerations – Electrical Integration



Clean Hydrogen **With the utilization of multiple units generation at the site, continuous clean hydrogen production is possible**

Stable and economical clean hydrogen production and supply to nearby industrial complexes are possible through the baseline operation of the hydrogen plant

Grid Stability **Large-capacity hydrogen plants can be constructed for each nuclear power site to enable demand response operation**

Utilizing as a flexible resource for the power grid, it can contribute to resolving output limitations of nuclear power plants and expanding renewable energy

Safety & Regulatory Considerations

Hydrogen Facility Safety

- **Hydrogen ignition** Purge, ventilation, leak detection, etc.
- Hydrogen piping and pipelines, Storage, etc.

Impact on Nuclear Safety

- **Hydrogen Explosion** Hydrogen hazard analysis
- **Electrical Transients** LOOP (Loss of offsite power)
- **Thermal Transients** SLB (Steam Line Break)

Operating License

- FSAR (Final Safety Analysis Report)
- Plant Operation Programs (Severe Accident, Fire Protection, Physical Security, etc.)

Economic Considerations

Project Cost / Expenses

- **Capital Cost** Electrolyzers, BOP, Nuclear Modification, etc.
- **Operating Cost** Feedstock (Electricity, water,…), Maintenance, etc.

Sale Price

- **Sale Price** (Production cost + Delivery cost)
- **Cost of hydrogen production** Dominated by the cost of electricity
- **Cost of delivery** Proximity to consumption points, Large/small consumers

Biz Model

- Hydrogen “Hubs” or “Valleys”
- CF100 Industrial Complex

R&D Roadmap & Status

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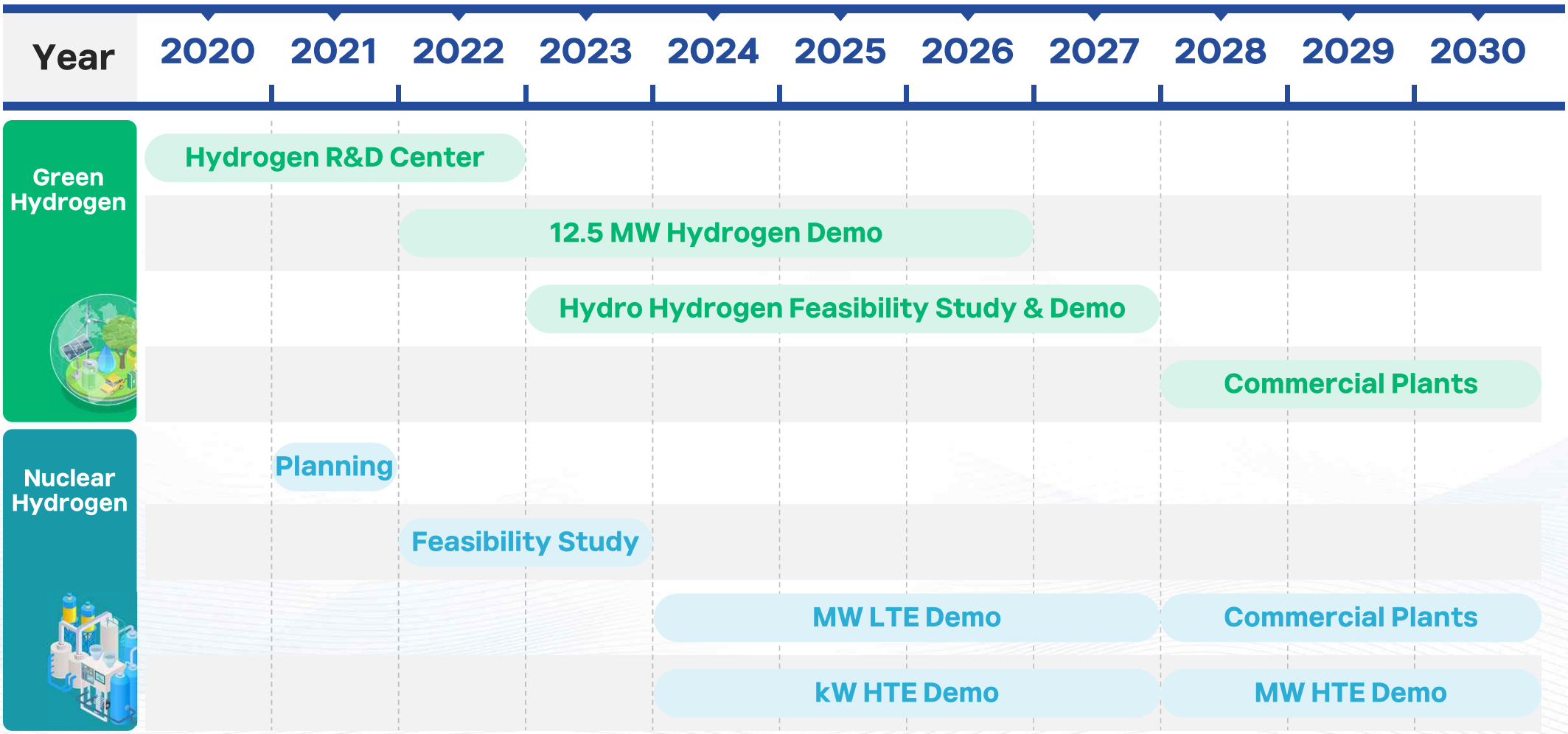
R&D Roadmap


Year
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Green Hydrogen
Hydrogen R&D Center
12.5 MW Hydrogen Demo
Hydro Hydrogen Feasibility Study & Demo
Commercial Plants
Nuclear Hydrogen
Planning
Feasibility Study
MW LTE Demo
Commercial Plants
kW HTE Demo
MW HTE Demo

R&D Status

Feasibility Study ($ 5 Million, April 2022 ~ July 2024)

Site Investigation	Hydrogen Plant Design	Nuclear Island Integration	Safety & Regulatory Requirements	Legal & Economic Analysis

Demo Plan ($ 61 Million, April 2024 ~ March 2028)

Design, construction, and operation of a 10 MW LTE clean hydrogen Production plant connected to NPPs

Nuclear Hydrogen R&D

Carbon-Free Clean Energy Leader

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