Plastics and decarbonization energy

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Korea Research Institute of standards and Science, Seung Hoon Nahm

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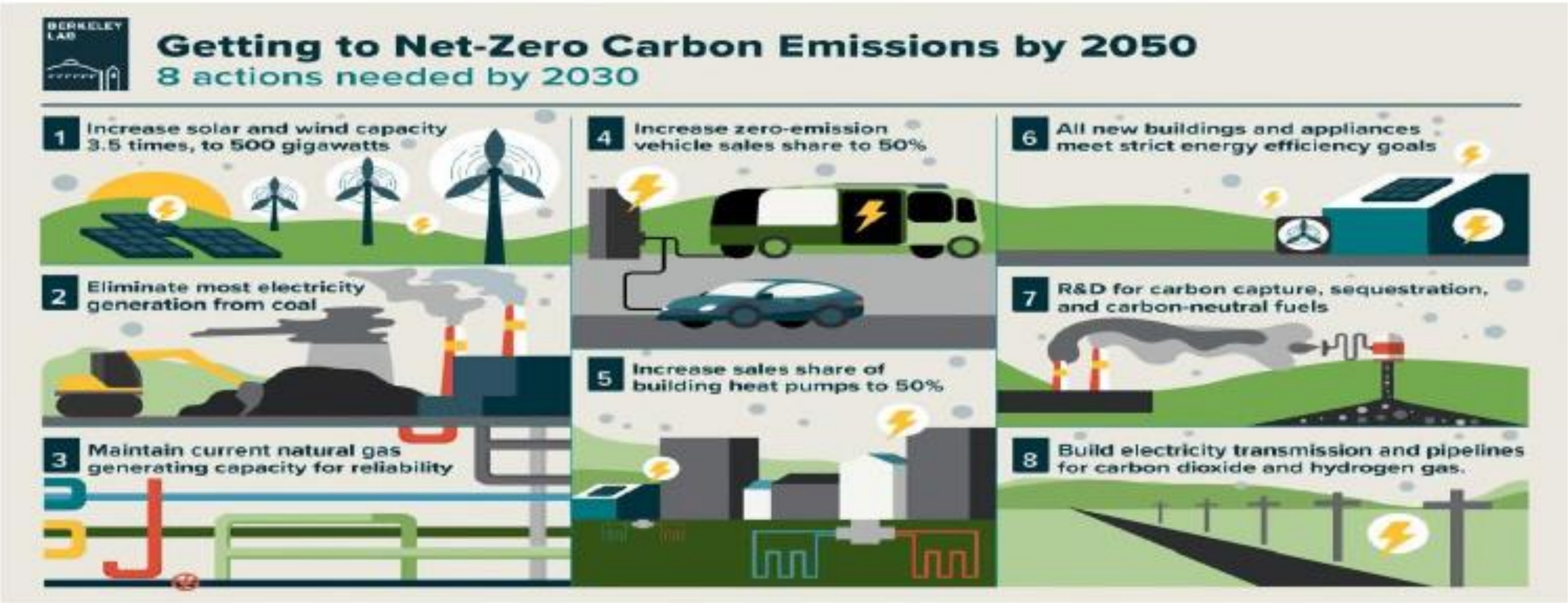
Net Zero & ESG

Carbon neutrality spotlight: 2050(USA/EU/Korea/Japan), 2060(China), 2070(India)

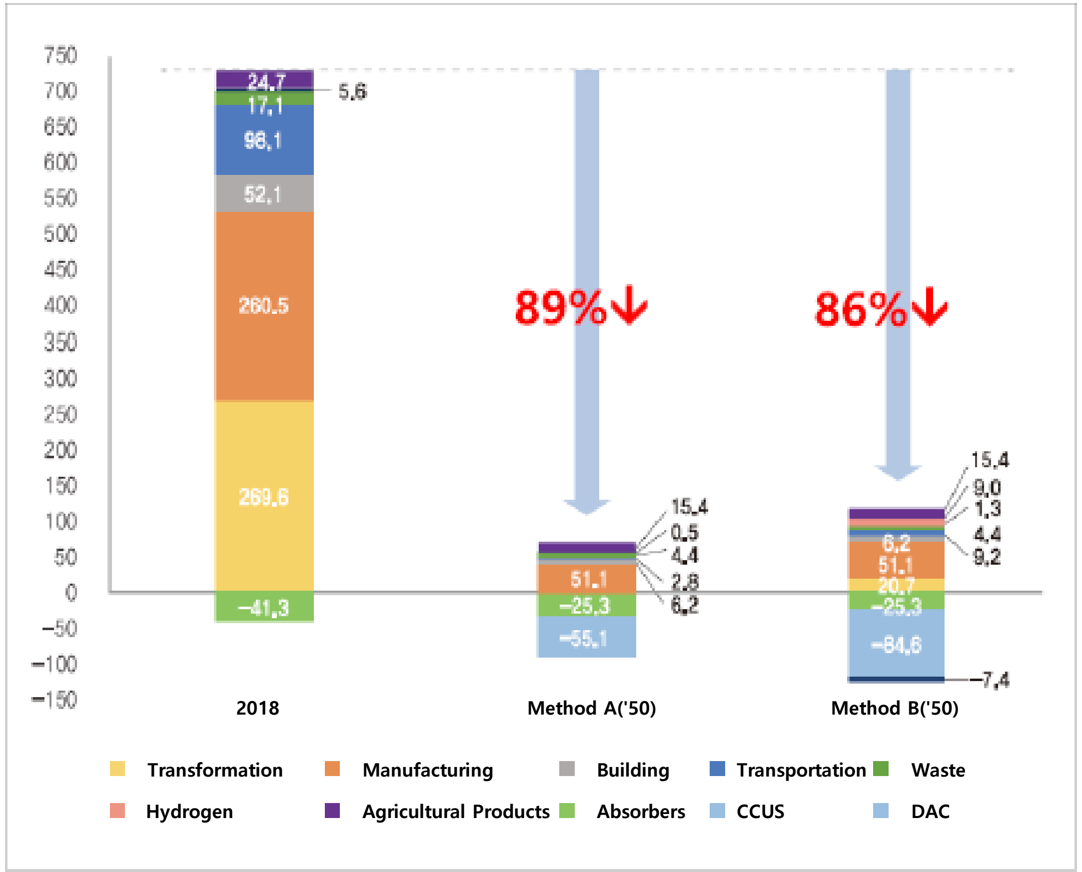


(Source : Carbon Neutral Pathways for the United States - SDSN, Berkeley Lab)

Responding to environmental/trade regulations
→ ESG Management, Industrial Reshaping/Low-carbonization

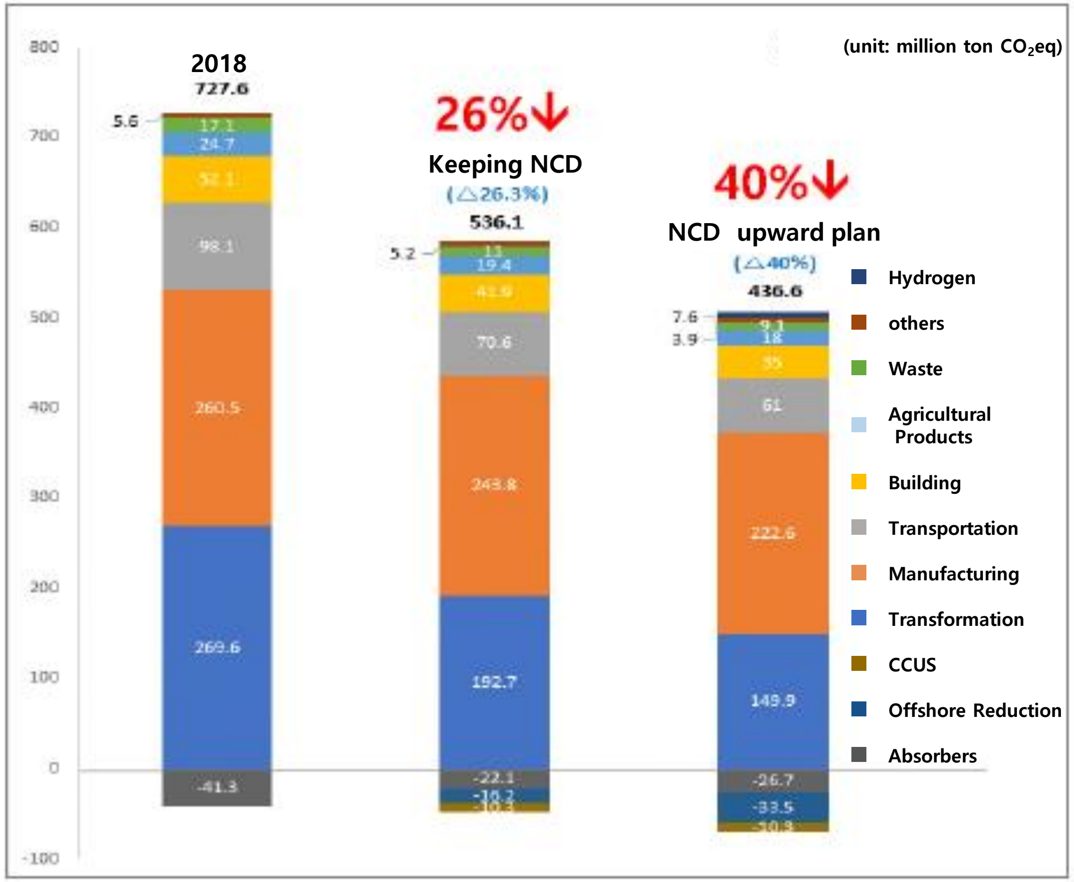
Scenario for 2050 Net Zero

2050 Long-term low greenhouse gas Emission Development Strategies(LEDS)



Method A : Fully shutting down thermal power, zero-emission vehicles, and green hydrogen production
Method B : Maintain some LNG generation, produce some gray-blue hydrogen, use e-fuel

2030 Nationally Determined Contribution(NDC)



Source: Carbon Neutrality Council (2021.10)

Greenhouse Gase Emissions by Industry

Greenhouse gas emissions by Industry in Korea and global

(unit: million ton CO_2eq)

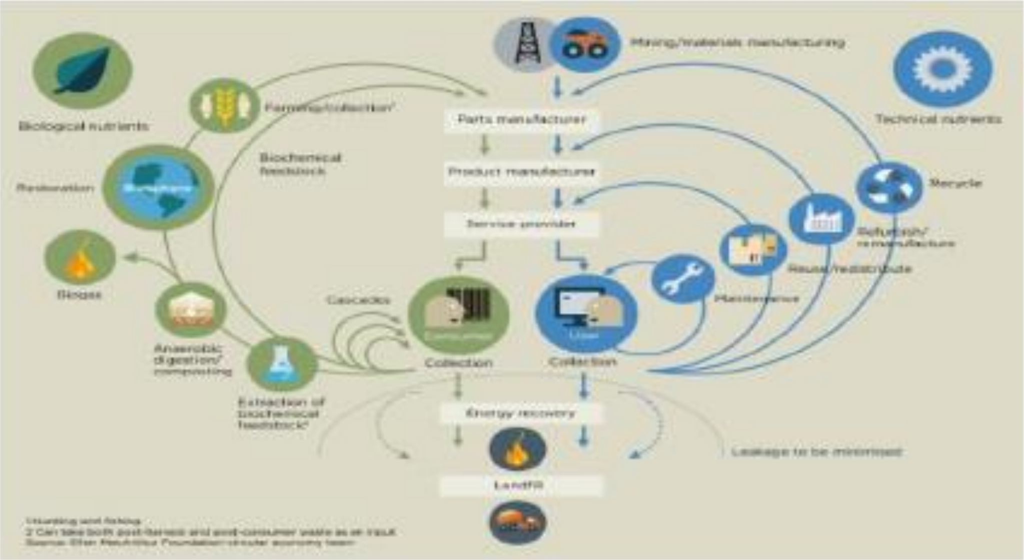
Industy	Korea (Direct and precess emissions)		Global (Direct and precess emissions)	
	Emission amount	Fraction(%)	Emission amount	Fraction(%)
Transformation (Power generation)	269.6	37.0	13,700	27
Manufacturing	260.5	35.8	15,810	31
Building (Heating, cooling)	52.1	7.2	3,570	7
Transprotation	98.1	13.5	8,160	16
Agricultural Products	24.7	3.4	9,690	19
Waste	17.1	2.3		
others (Felling)	5.6	0.8		
Total	727.6	100.0	51,000	100.0

* source : GIR·Korea Energy Agency (2018), How to Avoid a Climate Disaster (Bill Gates, 2021)
* Directly comparisons between Korean and global data are not recommended due to possible differences in criteria

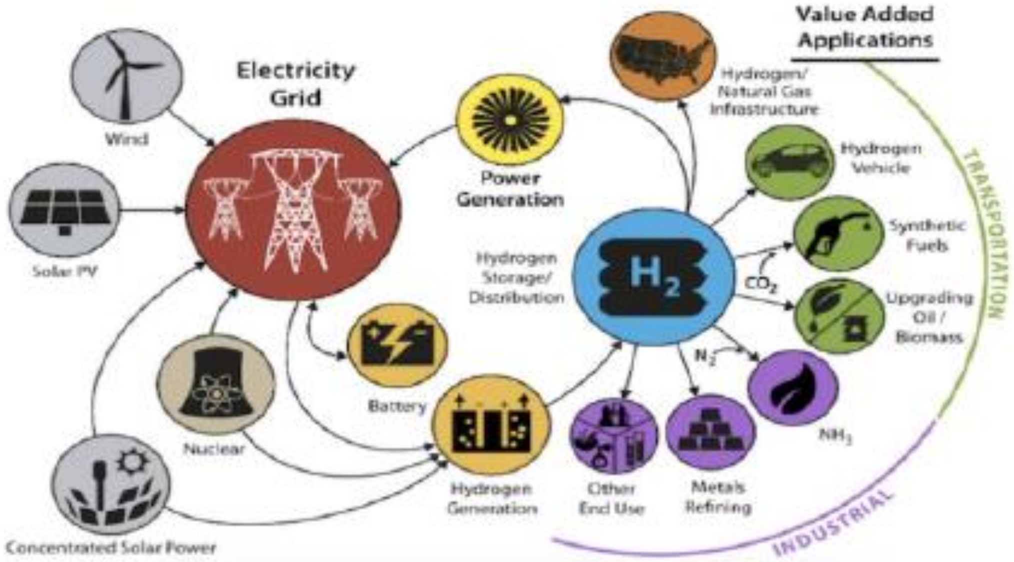
Net Zero Policy

RE100 → + Nucleation Power Genration → CF100

(Source : Ellen MacArthur Foundation)



(Source : US DOE)



Circular economy —— **Hydrogen economy**

Global Policy for Reducing Waste Plastics

Reduce

- Korea : 20% reduction in plastic waste (~’25)
- EU : Introducing plastic tax, phase-out of single-use products('21~)
- USA : Single-use products bans by state(‘15~)
- China : Single-use products phase-out(‘21~)

Recycle

- Korea : Increased recycling rate to 70% (~’25)
- EU : Achieve 100% recycling rate (~’40)
- Japan : Achieve 100% recycling rate (~’35)

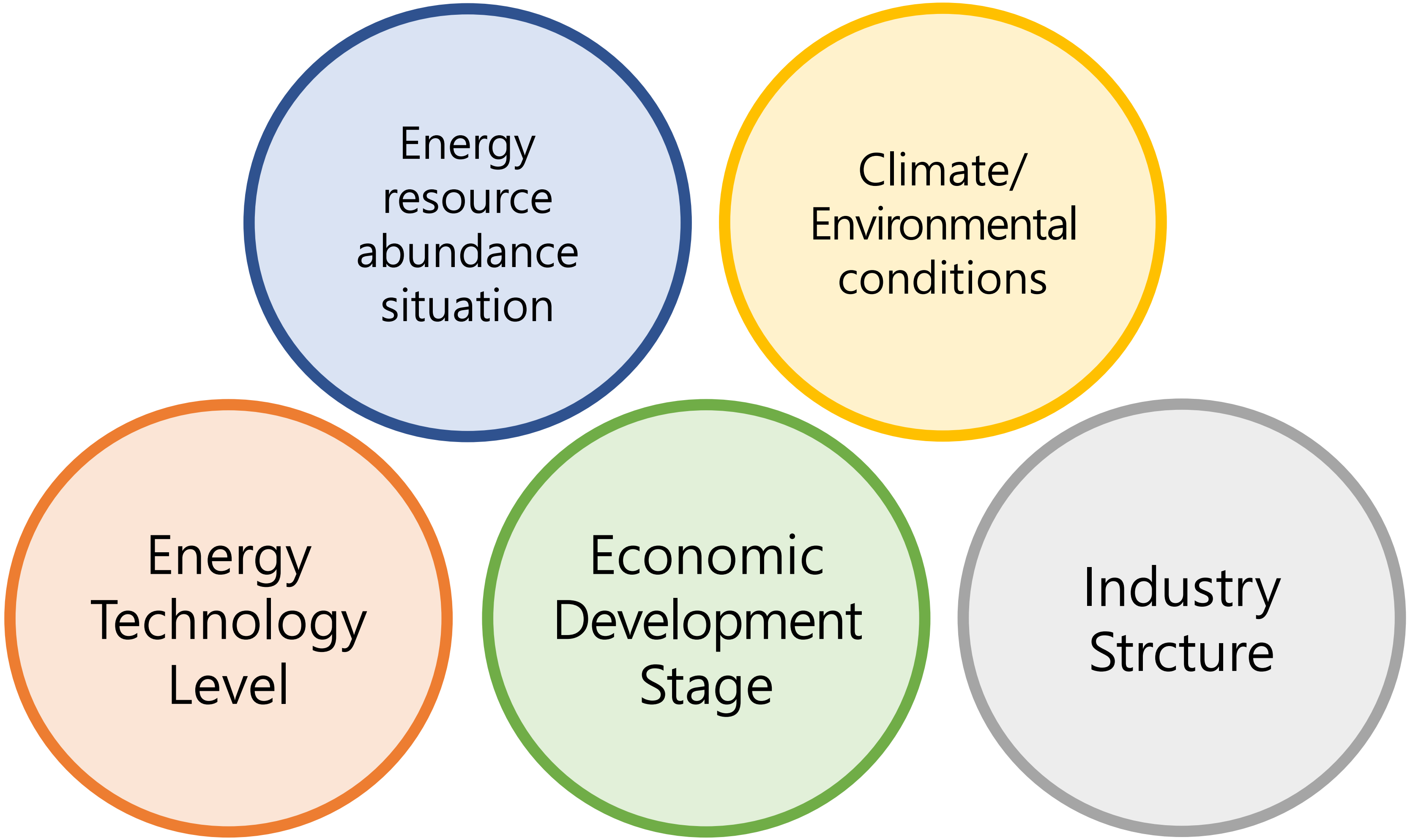
Replace

- Korea : Phasing out to bioplastics (~’50)
  - Limited use of mixed bioplastics (~’30)
  - 100% bioplastic replacement (~’50)

Waste Plastics in the Circular Economy

(Source : BASF)

Create an Energy Policy



Carbon Neutrality & Energy Challenges

| Science & Technology Innovation for Alternatives to Fossile Fuel

- Energy mix (energy harmony): Renewables + Nuclear as the mainstay
- Re-establish energy plan: Optimizing energy mix.
  - Renewable Energy Technology Independence & Innovation
  - K-Nuclear Power: SMR & Nuclear Waste Disposal
  - ESS (Energy scarcity in the energy transition)
  - Smart Grid(by Power Source Diversification)
- Hydrogen Energy & Hydroelectrolysis: Process Improvement Technology
- Waste to Energy
- Carbon capture, storage, and landfill technologies
- Transition to a low-carbon energy industry
  - Industrial Restructuring: Low efficiency energy Industries → High efficiency Industries

Analyze the Economics of Hydrogen Adoption Overseas

Key Factors in Green Hydrogen Production Economic Analysis: Hydroelectrolysis Facility Costs & Renewable Energy Generation Costs

- Port Headland, Australia: solar \$30/MWh, wind \$40/MWh
- Aqaba, Saudi Arabia: solar \$23/MWh, wind \$36/MWh
- Hydroelectricity application: Saudi Arabia 59.6% (36.1% wind + 23.5% solar), Australia 60.7% (38.9% wind + 21.8% solar)

Liquid hydrogen (Synthesizing Transporters)

- Primary cooling: compression to 13→30 bar, utilizing liquid nitrogen refrigerant
- Secondary refrigeration: Cooling to -253 ℃, utilizing helium refrigerant
- Large energy input for secondary cooling, 1/3 electricity input for hydrogen energy
  - Electricity input: 10~12 kWh/kgH_2 today, 6 kWh/kgH_2 in 2050

Liquid hydrogen

2030 Liquid hydrogen Adoption Price

- (Scenario 1) Liquid Input Power 8 kWh/kgH_2, Renewables
  - * Saudi Arabia: \$5.8/kgH_2 & Australia: \$5.5/kgH_2

Ammonia Fuel Application

Ammonia CI Engine

- Compression Ignition Engine
  - Low energy density of ammonia
  - Low performance cost compared to fossil fuels, requiring a lot of ammonia
  - Ammonia combustion characteristics: low cetane number
  - Ammonia Flammability: Improve with Combustion Accelerator

* Combustion Accelerators: diesel, gasoline, hydrogen, ethanol...

Improvement for ammonia's slower flame speed and ignition requirements

- Ammonia + hydrogen mix ratio: 10 % hydrogen is optimal

Ammonia Fuel Cells

- Direct Ammonia SOFC (Solid Oxide Fuel Cell) System
  - Converting ammonia chemical energy directly into electrical energy using an electrochemical reaction
  - High power generation efficiency (>60%) + CO_2 free power production

Use ammonia directly as a fuel

- More economical than using cracked hydrogen as fuel

Ammonia-Hydrogen-LPG Fuel Physical Properties Comparison

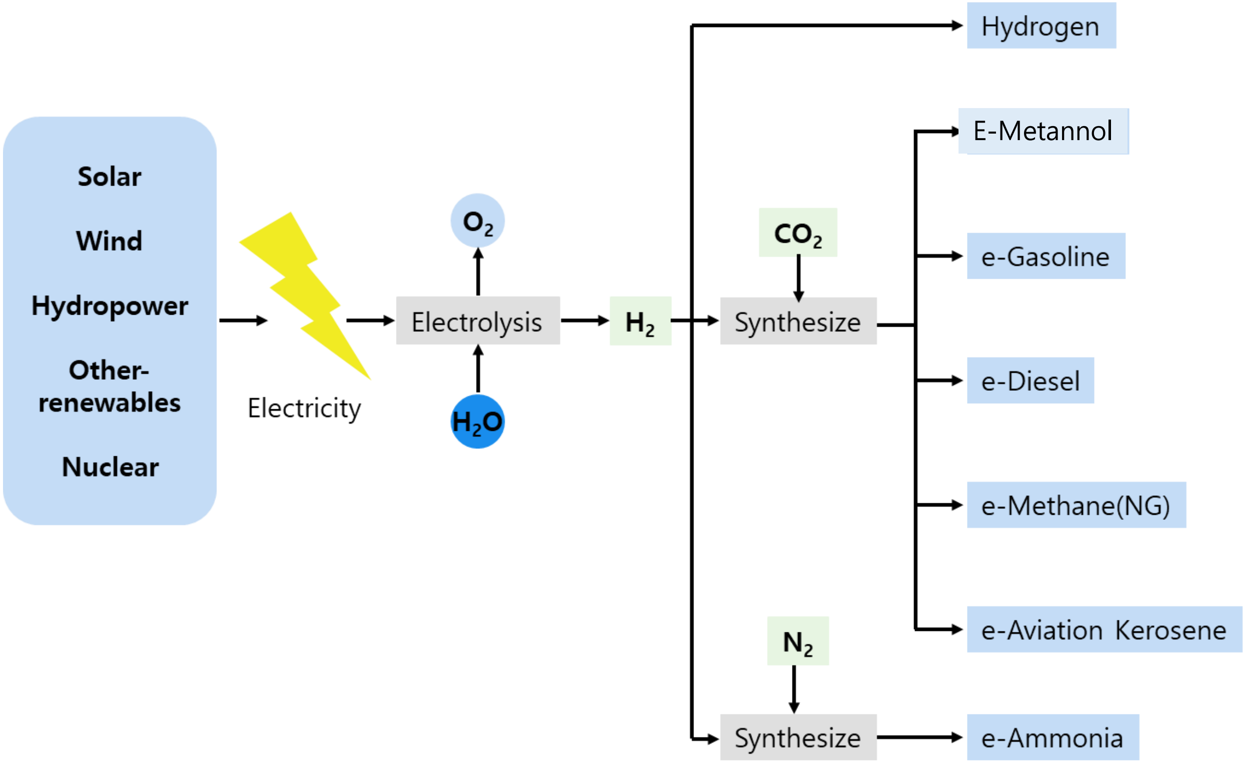
Attributes	Ammonia	Hydrogen	Natural Gas	Propane
Flash Point	-	-150	-188	-105
Spontaneous combustion	651	535	595	459
Ignition Energy	1,910,767	2,627	66,877	59,711

Attributes	Ammonia	Hydrogen	Natural Gas	Propane
Combustion Range	15~28	4~75	5~15	2.2~9.5
Combustion Rate	12	312	40	46
Critical pressure	132.4	-239.9	-82.95	96
Boiling point	-33.5	-253	-82.95	-42

e-fuel Concept

- European Union decides to phase out internal combustion vehicles, including gasoline-powered diesel cars, by 2035
  - Allow internal combustion vehicles that run on man-made synthetic fuels, "e-fuels," instead of petroleum.

◆ e-Fuel is an acronym for electricity-based fuel, which literally means “fuel produced by electricity”.
  - Hydrogen (H_2) produced by hydroelectrolysis, the electrolysis of water using renewable energy sources such as solar or wind.
  - Carbon dioxide emitted from chemical and refinery operations or carbon dioxide captured directly from the atmosphere, such as DAC (Direct Air Capture).
  - Refers to liquid hydrocarbons synthesized through gasification reactions (catalytic reactions) in plants at high temperatures and pressures.



- e-fuel uses hydrogen from the electrolysis of water and carbon dioxide captured from the natural world to create energy.
  - e-fuel is carbon-neutral energy, where carbon dioxide emissions and absorption are equal.
  - Currently, e-Fuel development technology is based on the Fischer-Tropsch process, which is an early stage of development.
  - Current production cost: around 5,000 KRW/L

THANK YOU

NO PAIN NO GAIN!