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HYDROGENZJU
浙江大学氢能研究院

Hydrogen Activities in the Asian Region

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Convenor of ISO/TC197/SC1/AHG 2 H_2 and high H_2 content blends pipelines

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1. China: Policies

中华人民共和国国家发展和改革委员会
National Development and Reform Commission

Guidelines on promoting the green innovation and high-quality development of the oil refining industry, 2023

- Promote the integrated development of the oil refining industry and renewable energy, and encourage enterprises to vigorously develop hydrogen production from renewable energy.
- **Support the construction of demonstration projects for green hydrogen refining, promote the replacement of green hydrogen, and gradually reduce the amount of hydrogen produced from coal in the industry.**
- Encourage strengthening the selectivity of hydrogenation process, implement the integration and optimization of hydrogen network system, and reduce the carbon emissions of hydrogen production units.

Implementation Plan for Green and Low Carbon Advanced Technology Demonstration Project

- **Low-cost (off grid, interruptible load) renewable energy hydrogen production demonstration**;
- **advanced safe and low-cost hydrogen storage, transportation equipment research and development, manufacturing, and demonstration application**;
- Hydrogen fuel cell research and development, manufacturing, and large-scale demonstration application;
- Pure burning and mixed burning hydrogen gas turbines research and development, manufacturing, and demonstration application;
- Hydrogen electric coupling demonstration application, etc.

1. China: R&D

中华人民共和国科学技术部
Ministry of Science and Technology of the People's Republic of China

The Ministry of Science and Technology (MOST) continue to strengthen research and strive for key breakthroughs in hydrogen energy and fuel cell technology, so as to provide strong technical support for the development of China's fuel cell commercial vehicle industry. In 2023, MOST launched 19 projects and subsidized 340 million yuan.

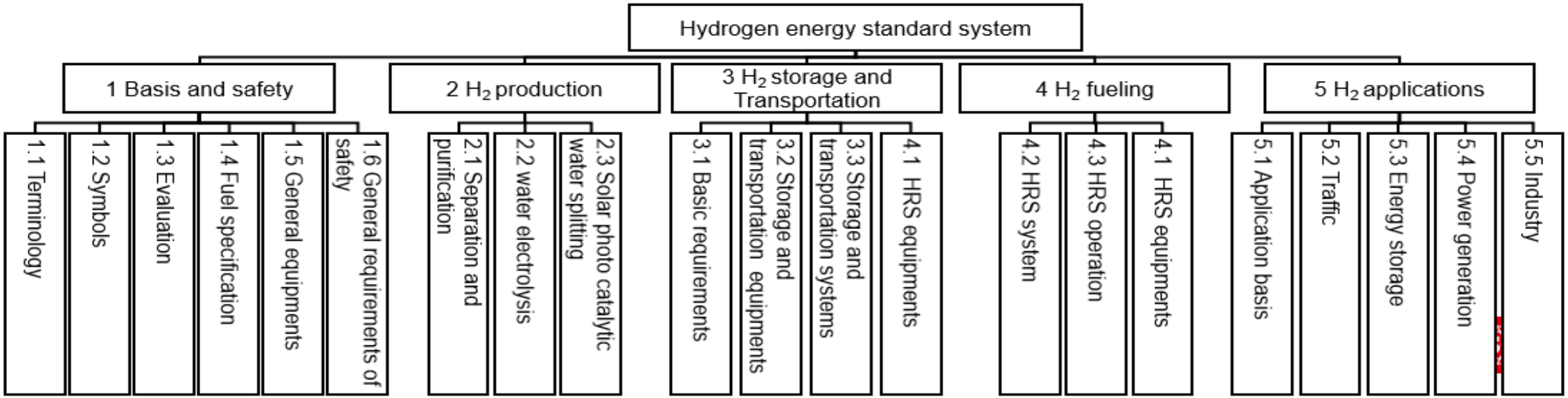
- **Green hydrogen production and scale transfer system**
- **Safe storage and rapid transmission and distribution system**
- **Convenient hydrogen upgrading and efficient power system**

1. China: Standards

国家标准化管理委员会
standardization administration

Guidelines for the Construction of Hydrogen Energy Standard System，2023

The hydrogen energy standard system includes **five sub-systems: basis and safety, hydrogen production, storage and transportation, fueling, and application**. According to technology, equipment, system, safety and testing, 20 secondary sub-systems and 69 tertiary sub-systems have been constructed. **There will be 145 national standards and 13 industrial standards . Among them, about 112 are in use, the others will be prepared and published in the next three years.**



10 National H_2 Standards published in 2023

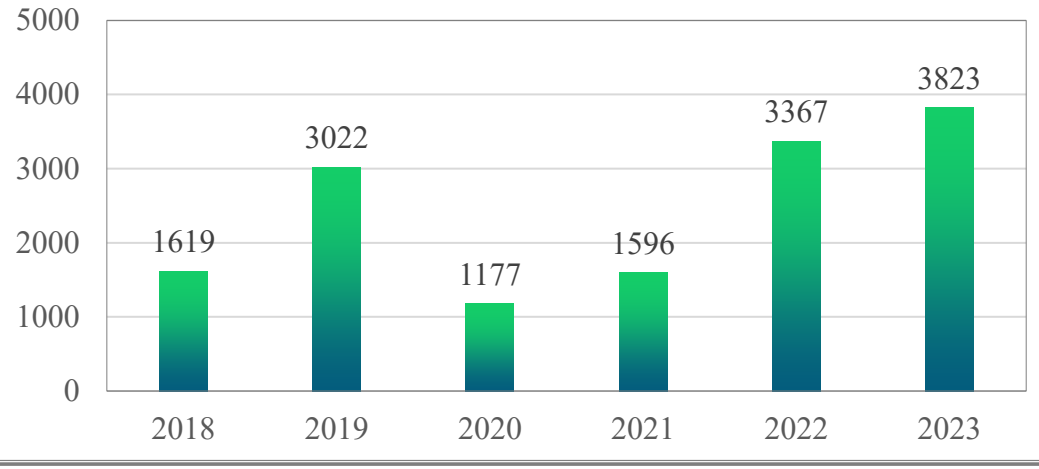
Hydrogen compatibility	• **GB/T 42610-2023 Test method for evaluating hydrogen compatibility of plastic liner of high pressure gaseous hydrogen cylinders**
Hydrogen cylinder	• **GB/T 42612-2023** Fully-wrapped carbon fiber reinforced **cylinders with a plastic liner** for the on-board storage of compressed hydrogen as a fuel for land vehicles • **GB/T 42626-2023** Periodic inspection and evaluation of fully wrapped fiber reinforced **composite gas cylinders of compressed hydrogen** gas for automotive vehicles
Valve	• **GB/T 42536-2023 Assembly valve** on high pressure hydrogen storage cylinder for vehicles • **GB/T 42177-2022** Technical requirements and test methods for **gaseous hydrogen valves** used in hydrogen fueling stations(adoption of ISO 19880-3)
Hydrogen safety	• **GB/T 29729-2022 Essential requirements for the safety of hydrogen systems**(refer to ISO/TR 15916)

Update on activities in the region

Fueling protocols	• **GB/T 42855-2023** Technical requirements of fueling protocols for hydrogen fuel cell vehicles
Hydrogen purification	• **GB/T 42857-2023** Safety of pressure swing adsorption systems for hydrogen purification(adoption of ISO/TS 19883)
Hydrogen refueling station	• **GB/T43674-2024** General requirements of hydrogen fueling stations (adoption of ISO 19880-1)
Hydrogen Pipelines (Under Development)	• **Technical requirements for hydrogen delivery system** • **Hydrogen Transmission Pipelines** • **Test method for hydrogen compatibility of welded joints of hydrogen pipelines** • **Method for evaluation of repurposing natural gas pipeline for transportation of hydrogen blended natural gas**

1. China: Applications（HRS and FCVs）

total **417** *only* **262** **in operation**



1. China: Applications（Pilot Projects）

Sinopec Xinjiang Kuqa Green Hydrogen Pilot Project

China Petroleum & Chemical Corporation announced that **the Green Hydrogen Pilot Project entered into commercial operation**. The Project takes advantage of the wealth of photovoltaic resources in Kuqa to achieve **20,000 tons per annum** of green hydrogen by using solar power to electrolyze water, along with the capacity to store **210,000m^3** of hydrogen and transport **28,000m^3** per hour.

The Project supplies hydrogen to Sinopec's Tahe Refining & Chemical to remove its fossil fuel-based electricity used for hydrogen production, which is expected to help it reduce 485,000 tons of carbon dioxide emissions annually.

1. China: Applications（Demonstration project）

Ningbo Cixi hydrogen-electricity coupling DC micro-grid demonstration project

- Hydrogen-Electricity-Heat combined energy system: hydrogen production ~100 kg /d, heat ~ 120 kW/d
- 4MW solar photovoltaic power, 0.2MW wind power
- 400kW water electrolyze, 10 DC charge for EV
- 3MWh energy storage battery and 240kW fuel cell
- The project can support the operation of the grid when the grid is urgently needed

2. Japan: Policies

2017 Japanese government released its Basic Hydrogen Strategy, the world's first national hydrogen strategy.

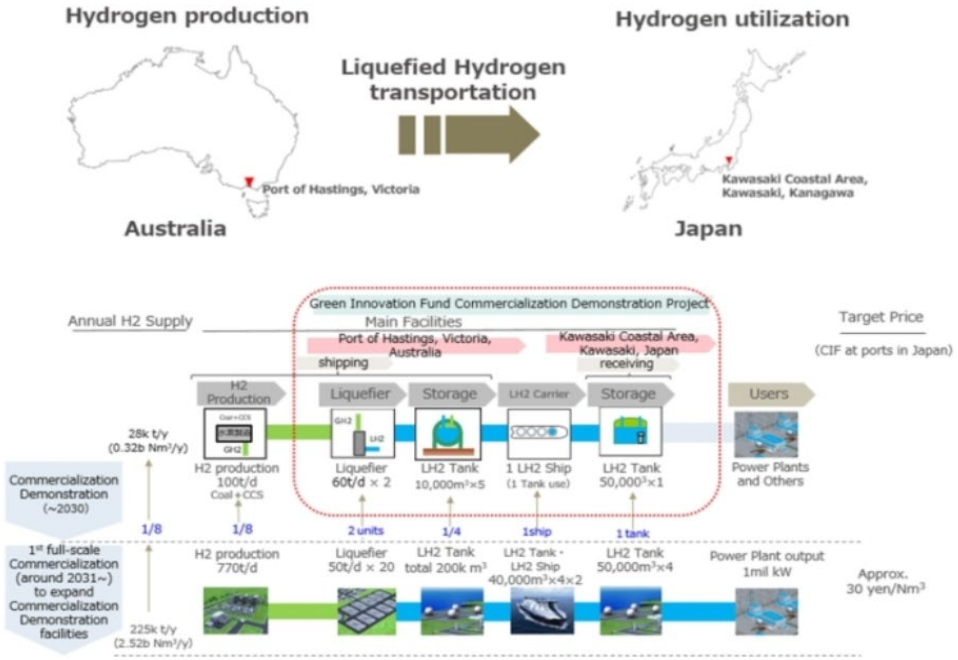
2023 It was revised with a goal: $3/kg by 2030 & less than $2/kg by 2050.

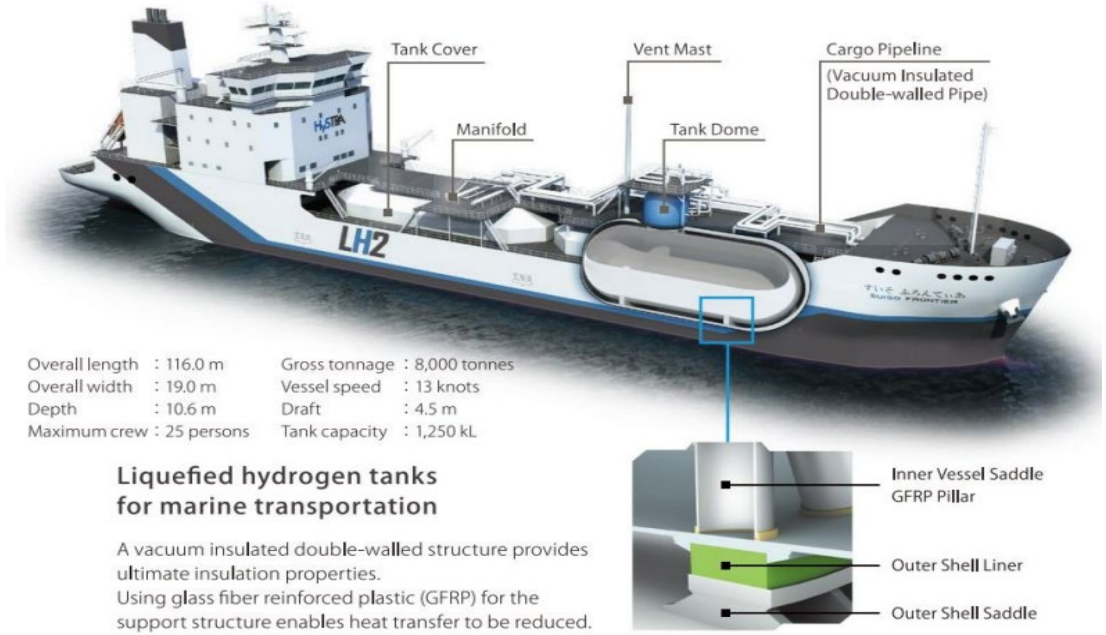
Three new features of the refreshed strategy:

- **New targets** Hydrogen production: 12 million tons per annum by 2040 / Electrolysis: a 10% for Japanese companies' share);
- **A "pathway" to low-carbon hydrogen** aiming for 3.4kg of CO_2 emissions or less for 1kg of hydrogen produced;
- **Strengthening industrial competitiveness** JPY 15 trillion Public-Private investment for H_2 supply chain next 15 years; Prioritizing nine strategic areas(Electrolysis, Hydrogen Supply Chain, Fuel Cells, Power Generation, etc.)

2. Japan: Liquefied Hydrogen Supply Chain Commercialization Demonstration

The project is to establish marine transportation technologies of liquefied clean hydrogen, aiming to achieve the Japanese Government's objective of a hydrogen supply cost of 30 JPY/Nm3 in 2030 at the point of arrival in Japan.





2. Japan: Applications

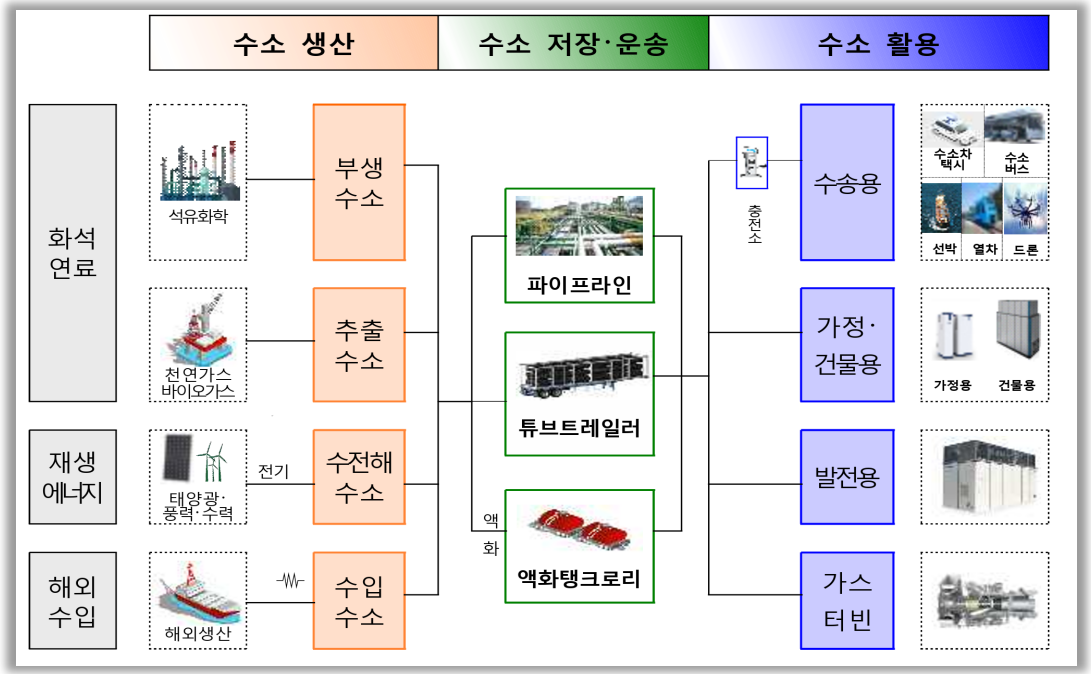
Current status（as of Feb.203)

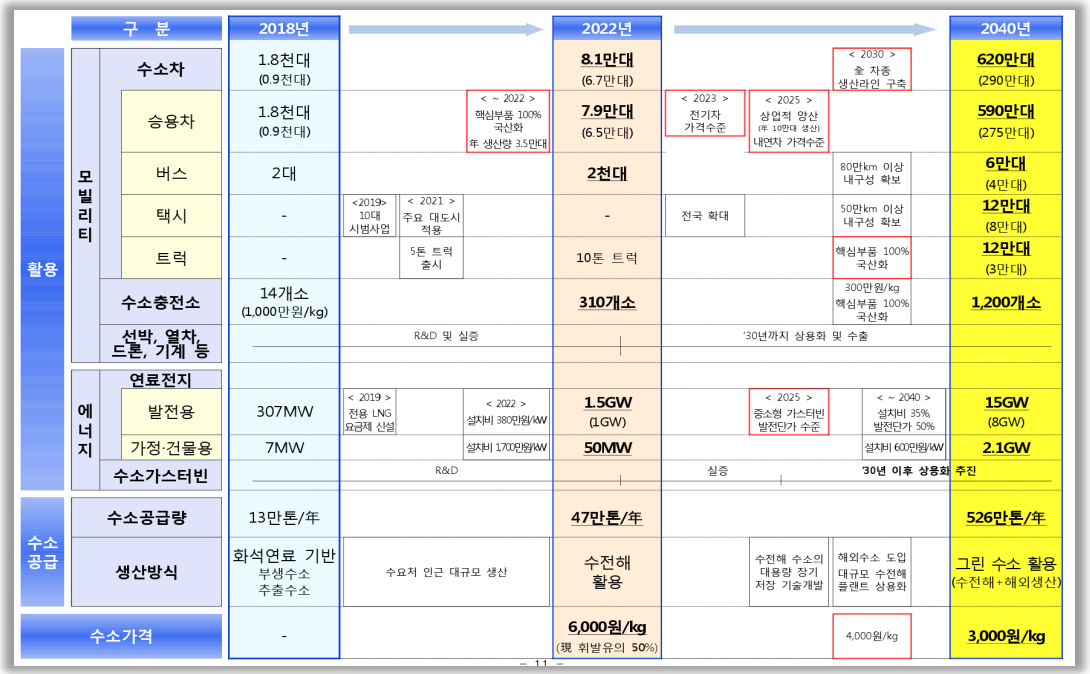
Stationary Fuel Cell	**480,373(Mar. 2023)**
Mobility	
Passenger Vehicles	**7692**
Fuel Cell Buses	**132**
Forklift	**397**
HRS	**167(Mar. 203)**

3. South Korean: Policies

2019 **Hydrogen Economy Roadmap and Ulsan's Future Energy Strategy,** South Korean's first strategy, released;

2020 National Assembly passed the Hydrogen Economy Promotion And Hydrogen Safety Management Act (**Hydrogen Act**), was the world's first national hydrogen law.

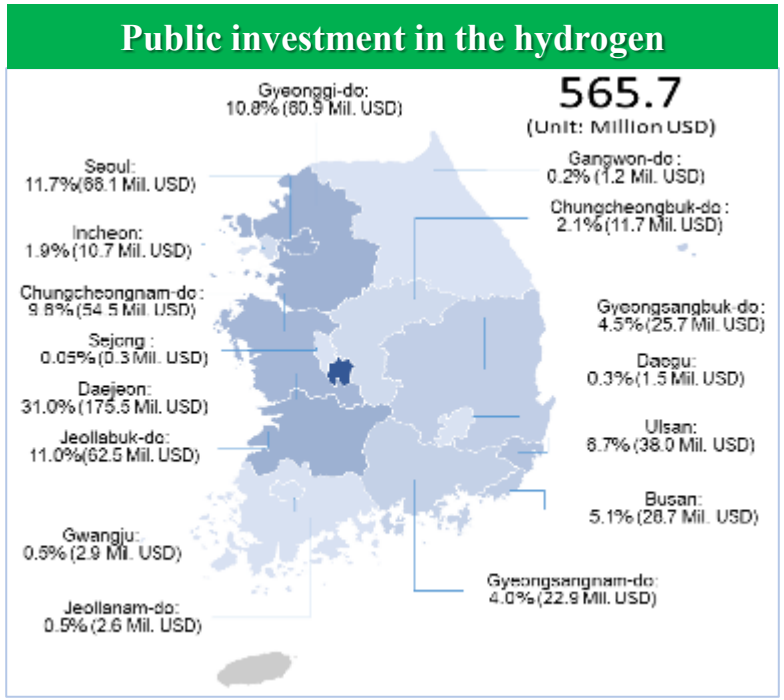


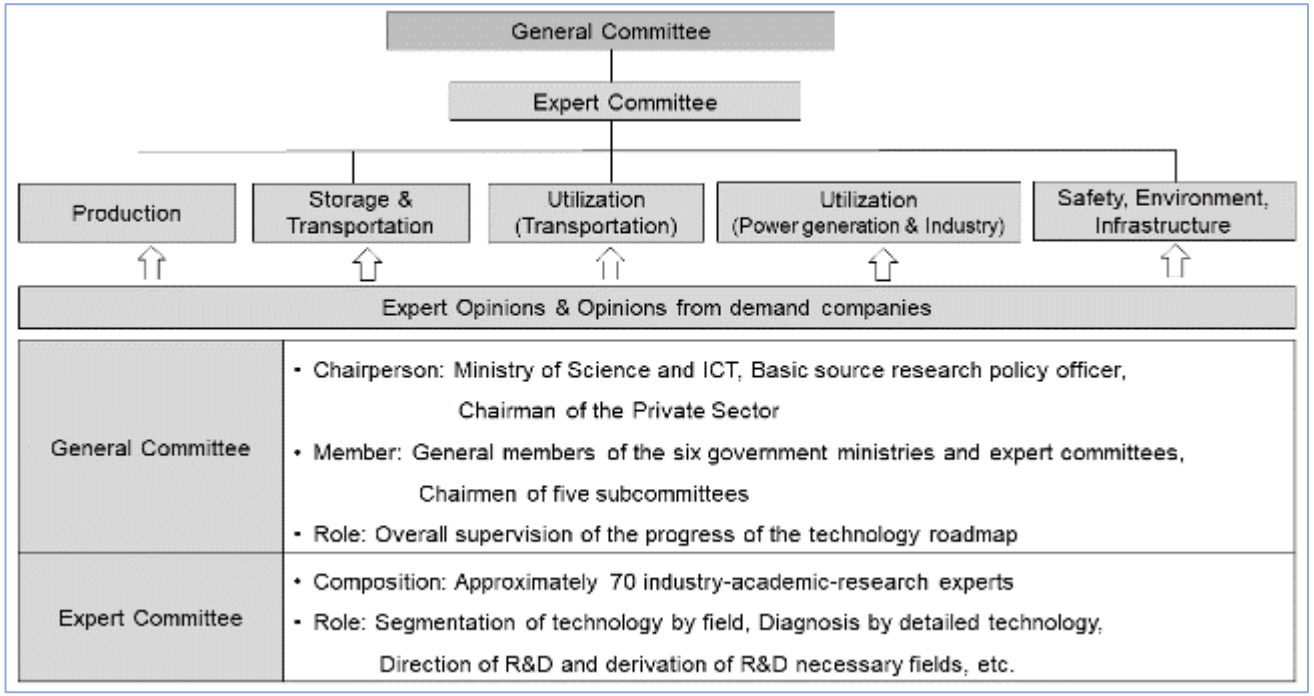


구 분		2018년	2022년	2040년
활용	모빌리티 수소차	1.8천대 (0.9천대)	8.1만대 (6.7만대)	620만대 (290만대)
	모빌리티 승용차	1.8천대 (0.9천대)	7.9만대 (6.5만대)	590만대 (275만대)
	모빌리티 버스	2대	2천대	6만대 (4만대)
	모빌리티 택시	-	-	12만대 (8만대)
	모빌리티 트럭	-	10톤 트럭	12만대 (3만대)
	수소충전소	14개소 (1,000만원/kg)	310개소	1,200개소
	선박, 열차, 드론, 기계 등	R&D 및 실증	'30년까지 상용화 및 수출	
	에너지 연료전지 발전용	307MW	1.5GW (1GW)	15GW (8GW)
	에너지 연료전지 가정·건물용	7MW	50MW	2.1GW
	에너지 수소가스터빈	R&D	실증	'30년 이후 상용화 추진
수소 공급	수소공급량	13만톤/年	47만톤/年	526만톤/年
	생산방식	화석연료 기반 부생수소 추출수소	수전해 활용	그린 수소 활용 (수전해+해외생산)
수소가격		-	6,000원/kg (現 휘발유의 50%)	3,000원/kg

Update on activities in the region

2023 Korean government deliberated and passed "The List of Critical and Emerging Technologies (draft)," officially confirming the selection of "12 Critical and Emerging Technologies." Hydrogen is one of them.





Reference: Doyeon Lee, Keunhwan Kim. Sustainability 2021, 13(19), 10686;

3. South Korean: Applications（Demonstration project）

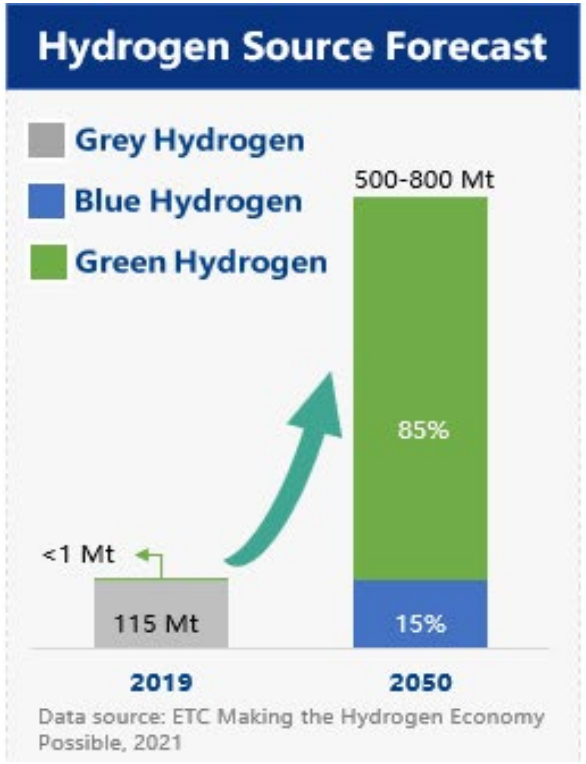
Comprehensive ecosystem of the clean hydrogen lifecycle spanning production, transportation, and utilization (Jeju Island, The Ministry of Trade, Industry, and Energy)

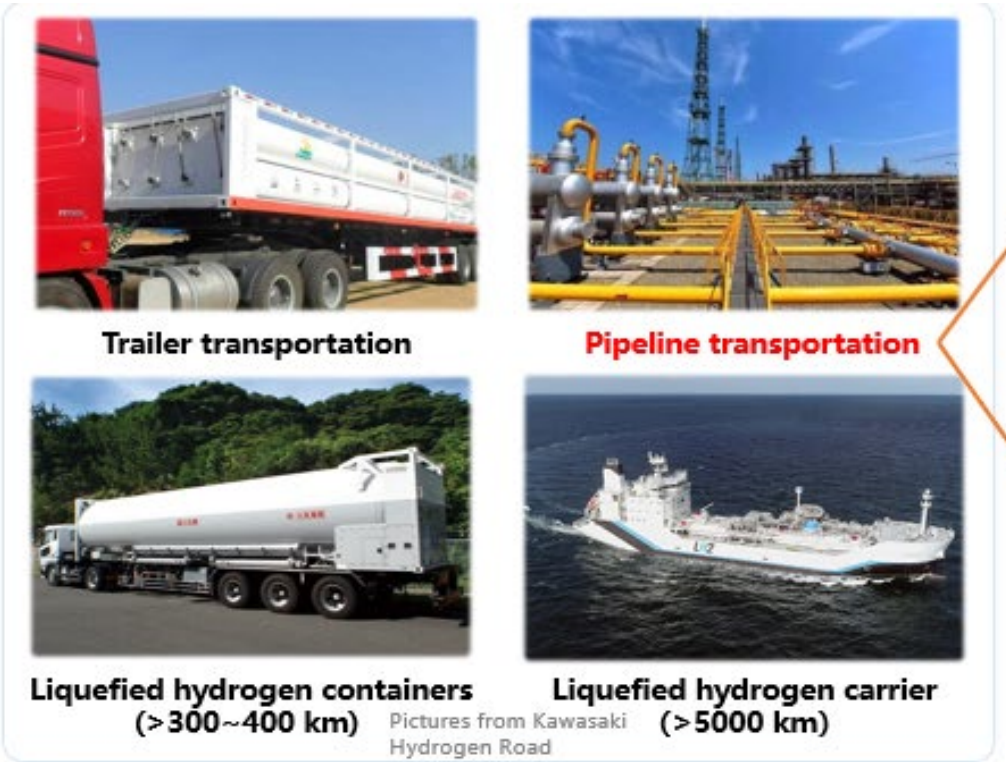
- **Seawater electrolysis demonstration project** connected with renewable energy, approximately 200kg of hydrogen is produced daily. Plans are underway to augment daily hydrogen production to up to 1 t.
- Increasing the number of refueling stations to five (currently one) by 2025
- Deploying 300 hydrogen buses (currently nine) by 2030
- Continuously strengthen policy support
- The project can support the operation of the grid when the grid is urgently needed

Contents

A hydrogen pipeline network ultimately needed to meet a net-zero emission goal

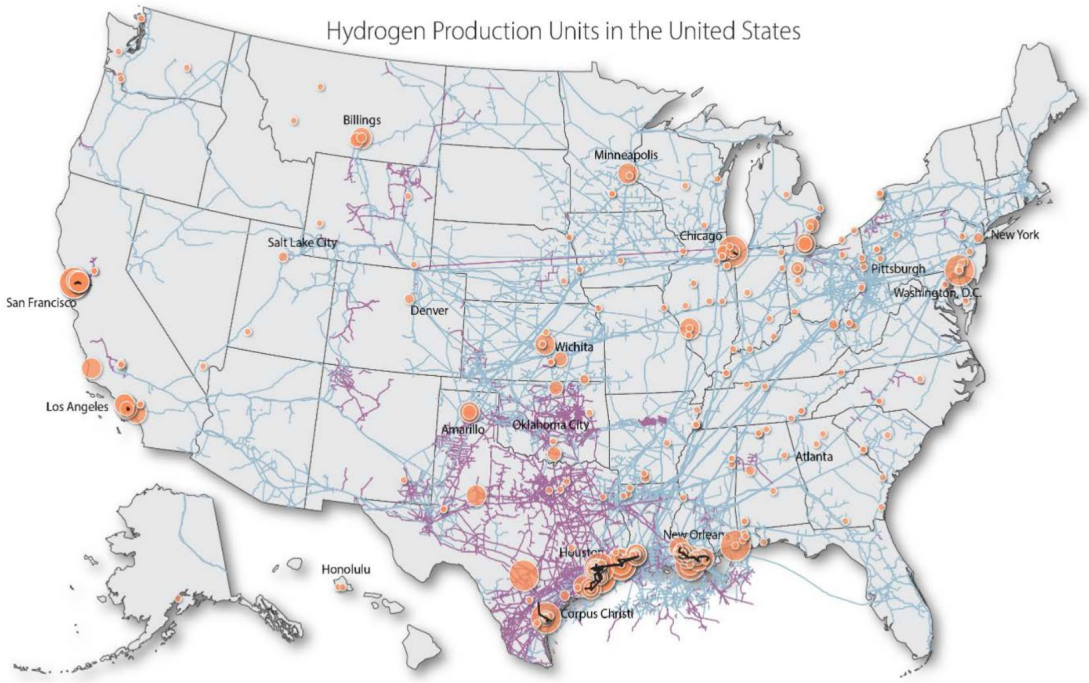
- Delivering hydrogen to widely scattered facilities—such as power plants, industrial sites, and vehicular fuel distribution hubs—**require the development of an expansive hydrogen pipeline network**.
- **Pipeline is the most energy-efficient way for large scale (>kt/day), long distance (>1000 km), and long duration (15~30 years) hydrogen supply.** Hydrogen delivery by pipeline is an integral part of hydrogen energy strategies of countries like USA, Europe, and China.





Hydrogen pipelines in USA

As of December 2020, there were 1,608 miles of active hydrogen pipeline in the United States. Over 90% of these pipelines are located along the Gulf, primarily serving refineries and ammonia plants in the region.



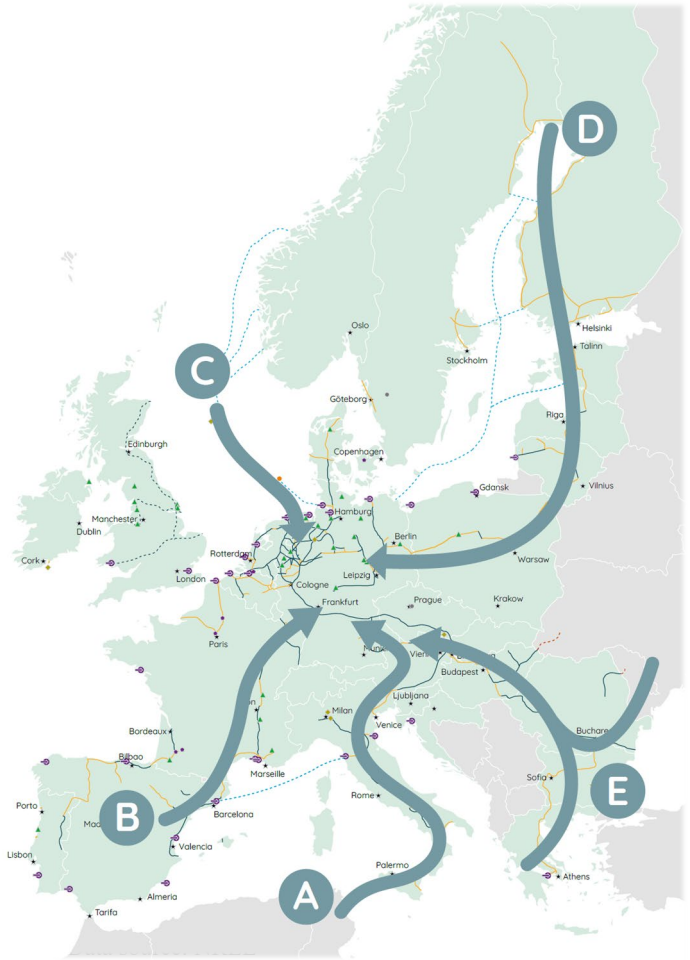
Hydrogen production units and pipelines for hydrogen and natural gas in the US (hydrogen pipeline in black)

Data source: NREL

Organization	Time	Research content
NASA	1969	Effects of high pressure hydrogen on metals at ambient temperature
BNL	1984	Hydrogen degradation of pipeline steels
Sandia National Labs	1981	Hydrogen compatibility of structural materials for energy storage and transmission
NREL	2010	Blending Hydrogen into Natural Gas Pipeline Networks
US DOE	2017~	**H2@Scale:** advance affordable hydrogen production, transport, storage, and utilization to enable decarbonization and revenue opportunities across multiple sectors
Sandia National Labs	2018~	**H-Mat:** focuses on understanding the effects of hydrogen on the performance of polymers and metals used in hydrogen infrastructure and storage
NREL	2021~	**HyBlend:** aims to address technical barriers to blending hydrogen in natural gas pipelines

Europe hydrogen backbone

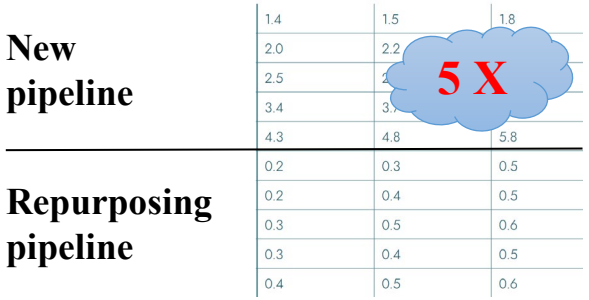
Plans for the expansion of hydrogen that have been developed in Europe highlight the need for use of existing pipeline infrastructure to make substantial progress in a reasonable timeframe.



European Hydrogen Backbone

2030: 5 hydrogen corridors

- Corridor A: North Africa & Southern Europe
- Corridor B: Southwest Europe & North Africa
- Corridor C: North Sea
- Corridor D: Nordic and Baltic regions
- Corridor E: East and South-East Europe



Data source: European Hydrogen Backbone

2040: 53000 km pipeline (60% repurposing vs. 40% new pipeline)

Name	Length (km)	Year	Pressure(MPa)	Materials
Portugal, Spain and France - H2MED *	450	completed by 2030	2 million tonnes/year	Partly undersea
Germany: flow-hydrogen *	1100	operational by 2025	/	converting the gas pipelines
France	290	1966~	6.5~10	Carbon steel

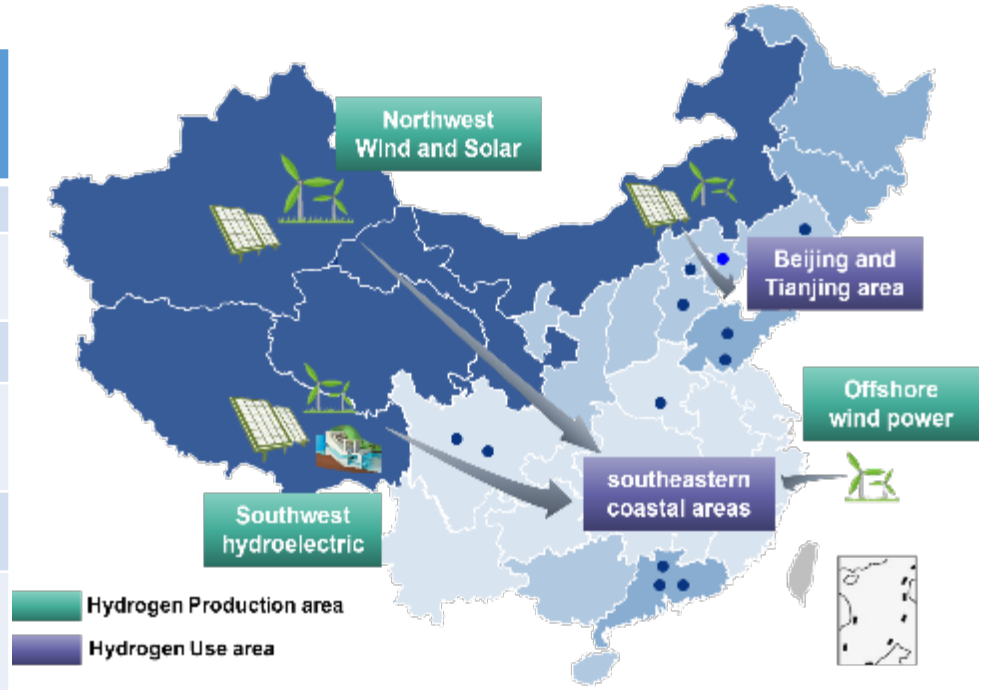
* is Hydrogen pipeline under planning

Hydrogen pipeline in China

China's hydrogen pipeline construction is still in its infancy and is mostly used to supply hydrogen to chemical industries. More than 3,000km of long-distance hydrogen pipelines are expected to be built by 2030.

Name	Length (km)	Diameter (mm)	Design pressure (MPa)	Pipeline materials
Jinling-Yangzi	32	325	4	20#
Baling-Changling	42	457	4	Cracked carbon
Jiyuan-Luoyang	25	508	4	L245 Seamless
Wuhai – Yinchuan*	217.5	610	3	L245 Longitudinal welded
Yima-Zhengzhou*	194	426	2.5	SM400C Spiral Weld
Inner Mongolia Ulanqab - Beijing Yanshan	400	In the design phase, the design conveying capacity is 100,000 tons/year		

* is Coal gas hydrogen blending transmission pipeline



Low pressure, Low strength, Less experience

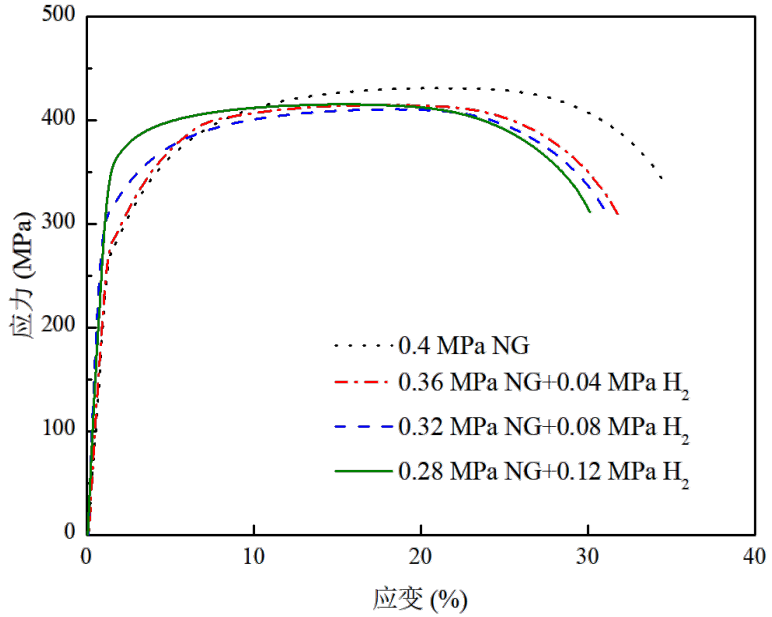
Hydrogen Transport from West to East

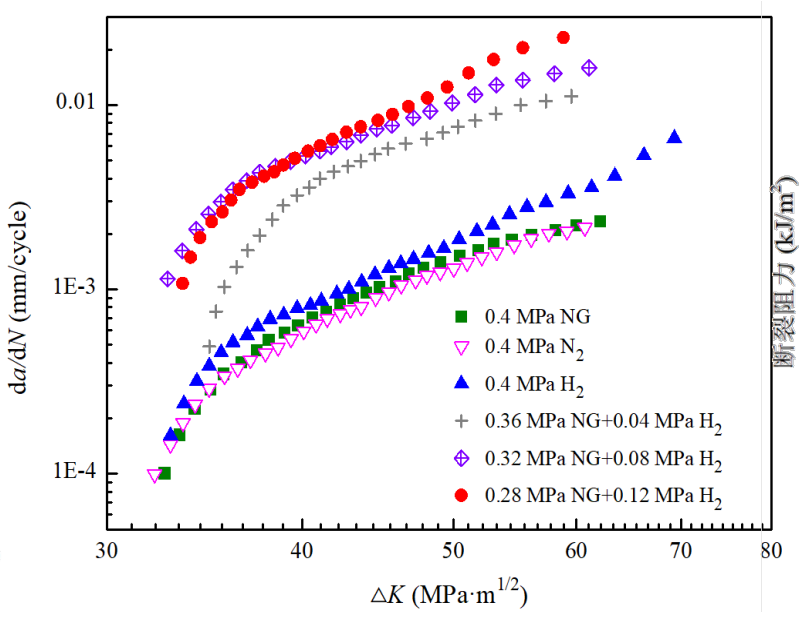
Hydrogen Delivery from Sea to Land

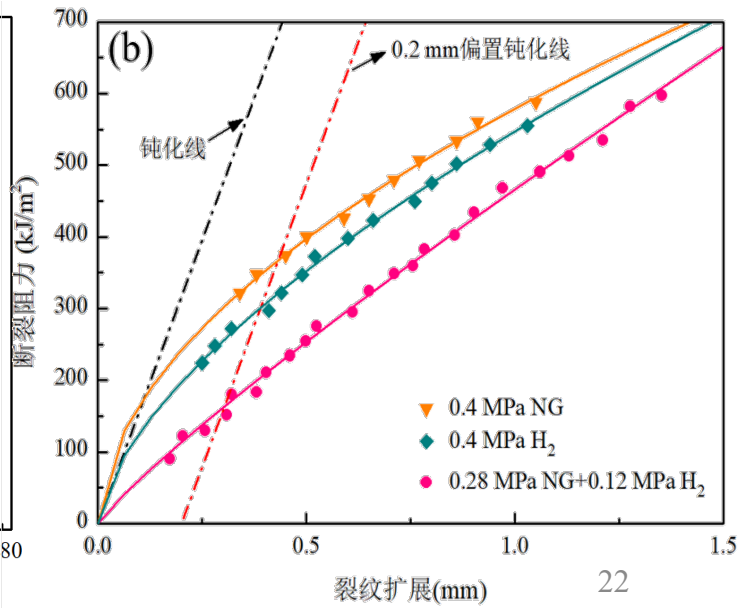
Data Source: China Hydrogen Energy Industry Infrastructure Development Blue Book

Hydrogen energy requires a new generation of pipeline

- Shipping hydrogen by dedicated pipeline is not new all over the world, but the existing hydrogen pipeline infrastructure, the majority of which are **constructed from lower strength steels up to pressure of 4MPa**, is small compared to that of the natural gas and oil pipeline systems.
- The hydrogen pipeline network required to support a hydrogen-based energy strategy would **need to be much larger in diameter, higher in pressure and with much broader geographic reach** than that in place today.
- Establishing a national network of dedicated hydrogen pipeline infrastructure, or reconfiguring existing natural gas systems to carry hydrogen**, poses numerous challenges related to technology, regulation, siting, and economics**.







Key technical challenges of hydrogen pipelines

- **Low cost, high strength, hydrogen resistant pipeline steel** are needed to reduce pipeline wall-thickness and thus reduce cost for construction
- Design Method in ASME B31.12 based on material performance factors, brings excessive conservatism and leads to higher costs and limits the transport efficiency of pipelines. **Design methods based on failure mechanism and material performance in hydrogen environment are needed.**
- How to effectively establish **the process parameters (such as hydrogen velocity etc) for hydrogen pipeline operations** given the substantial differences in physical characteristics between hydrogen and natural gas?
- Hydrogen compatibility of key equipment (e.g. valves, compressors, pipeline pigs);
- Due to the reduced flaw tolerance of pipeline steels in the presence of hydrogen, **advances in the detection, sizing and characterization capabilities of inspection may be needed**

Key challenges of high hydrogen content blends pipelines

- The influence mechanism of gas impurities on hydrogen embrittlement is still unclear, and **the interaction of multi-component gases is rarely studied.**
- **How to evaluate the hydrogen compatibility of existing pipelines, especially welded joints**? The cost of extracting samples from CNG pipelines for destructive testing is too high, and the subsequent operation of pipelines will be affected
- **Technologies for hydrogen blending and separation**
- **Analysis of life-cycle greenhouse gas and criteria pollutant emissions of blending**
- **How to determine blend limit by comprehensively considering**
  - hydrogen compatibility of pipelines and equipment
  - functional reliability of equipment
  - applicability of pipeline network process
  - failure risks of pipelines leakage and explosion,
  - adaptability of terminal equipment replace of CNG with hydrogen

Key technologies for long-distance pipeline transportation and application of hydrogen and hydrogen blended natural gas

Principle Investigator: Jinyang Zheng

Lead Organization: Zhejiang University

Implementing time: 2022.12~2026.11

2022 National Key R&D Program

Objectives

- **Develop science-based strategies to design the microstructure of high strength materials for improved resistance to HE.**
- **Develop damage mechanism-based design method, welding technology, risk management for hydrogen long distance pipeline.**
- **Develop a tool that evaluates the opportunities and costs of blending hydrogen into natural gas.**
- **Develop hydrogen blending and separation technology.**
- **A comprehensive test platform will be built for technical validation.**

ISO/TC197/SC1/AHG2

ISO/TC197/SC1/AHG2 was activated to promote coordination of standardization on H_2 and high H_2 content blends pipelines.

Targets:

(1) Discuss and research on literatures, technologies and standards for hydrogen and high content hydrogen blended natural gas pipelines, develop a report on state of the art and research priorities in hydrogen pipeline

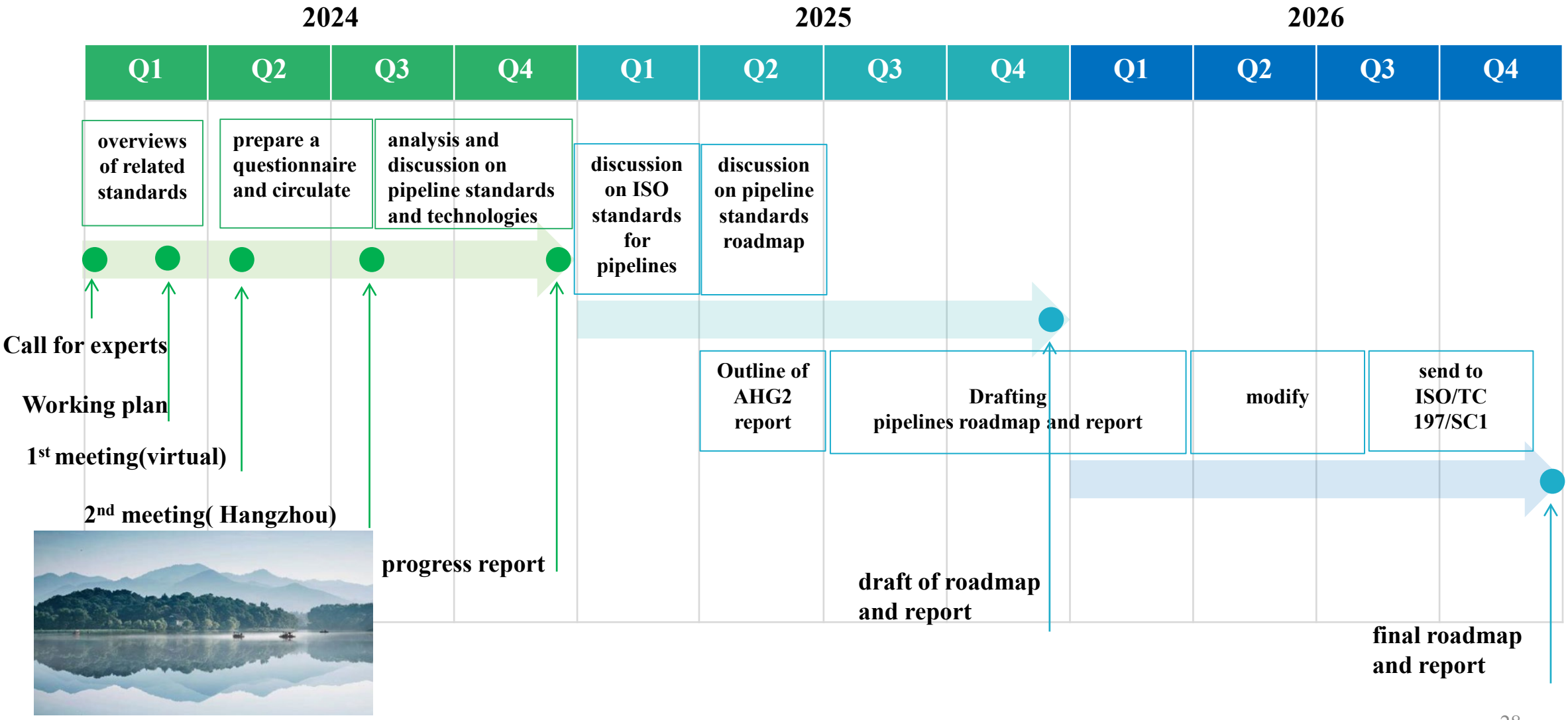
(2) Develop a roadmap for future hydrogen pipeline standards development

Convenor: Prof. Jinyang ZHENG

Secretary: Dr. Yanmei YANG, Dr. Zhengli HUA

Experts(10): SAC x2, ANSI x2, DS(Danemark) x1, SABS(South Africa) x2, EIGA x1, DIN x1, JISC x1

Working Plan



Current Progress

Finished literature review of hydrogen pipeline

Finished survey of standard related to hydrogen pipelines

Setters	Number	Title	Content
ASME	ASME B31.12–2023	Hydrogen piping and pipelines	H_2 and H_2 blend pipelines
	ASME STP-PT-006-2007	Design guidelines for hydrogen piping and pipelines	Design guidelines
CGA	CGA G-5.6-2005 (R2013)	Hydrogen Pipeline Systems	H_2 pipelines
AIGA	AIGA 033-14	Hydrogen Pipeline Systems	H_2 pipelines
DVGW	DVGW G 464	Fracture-Mechanical Assessment Concept for Steel Pipelines with a Design Pressure of more than 16 bar for the Transport of Hydrogen	Material Assessment
IGEM	IGEM/TD/1 Edition 6 Supplement 2	High pressure hydrogen pipelines	H_2 pipelines
ISO	ISO 13623:2017/DAM 1	AMENDMENT 1: Complementary requirements for the transportation of fluids containing carbon dioxide or hydrogen	H_2 blends pipelines

Current Progress

Large movement has been made in the hydrogen pipeline industries. With the increase in pressure and transportation quantity, users of the current standards find that increased costs have not led to safer services.

It is necessary to find a way to balance between security and economics through technical innovation.

Current status

Excessive conservatism in design

Material performance factor which are not technically justified

Non-specialized evaluation methods

- 1 mile to extract samples for destructive testing;
- Over prescriptive sampling and testing requirements that are not risk or system based

Gaps

Performance-based design method

Based on material properties in the gaseous hydrogen or blends with pressure not less than operating pressure

Methods for assessment of repurposing natural gas pipeline for transportation of blends

- Economical and safe sampling method;
- Establish a database for materials performance

No International Standard for hydrogen pipeline

Thanks for your attention !