Carbon-recycling and other technologies to decarbonize energy intensive industries

Summary of the report

July 2021

Contents of the study report

1. Germany
(1) Hydrogen direct use and natural gas blending

Connecting the dots

- National Hydrogen Strategy (2020) outlines
  - industry as a priority sector for the application of hydrogen
  - utilization of hydrogen prioritized over natural gas blending

- Focus on green hydrogen

- Current and future hydrogen demand
  - Today: 55 TWh
  - 2030: 90-120 TWh (NHS 2020)
  - 2050: 94-145 TWh (w/out chemicals, Robinius et al. 2019)

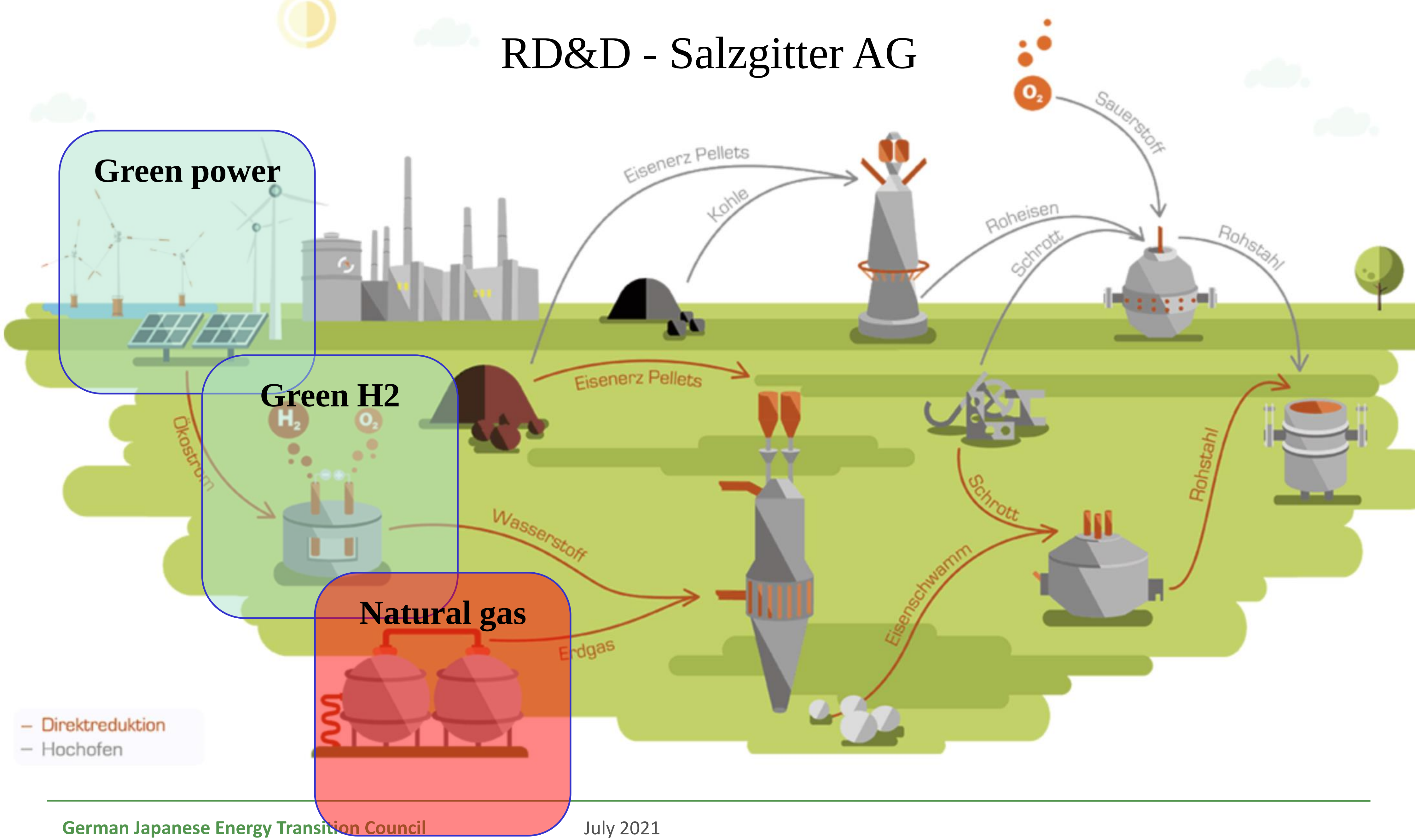
- Strategic orientation: domestic capacity development of electrolyzer capacities and import from European and Non-European partners

- Comprehensive RD&D in all sectors and along value chains

1. Germany

(1) Hydrogen direct use and natural gas blending

RD&D - Salzgitter AG



1. Germany

(1) Hydrogen direct-use and hydrogen natural gas blends

Issues	Hydrogen direct use	Hydrogen natural gas blends
Economics	• High costs of hydrogen production • Upfront investment	• Exchange of equipment of sensitive users
Technology	• Technology demonstration incl. product impacts • Ship imports	• Impacts on product quality • Membrane technology
Infrastructure	• Energy infrastructure planning	• Energy infrastructure planning • Questions regarding a gradual increase of H2 concentrations
Regulatory framework	• Certification	• Advance regulatory guidelines

Source: METI

1. Germany
(2) CCUS

Connecting the dots

- Carbon capture seen as a means to achieve carbon neutrality for some sectors (cement) for which substantial amounts of RE are needed

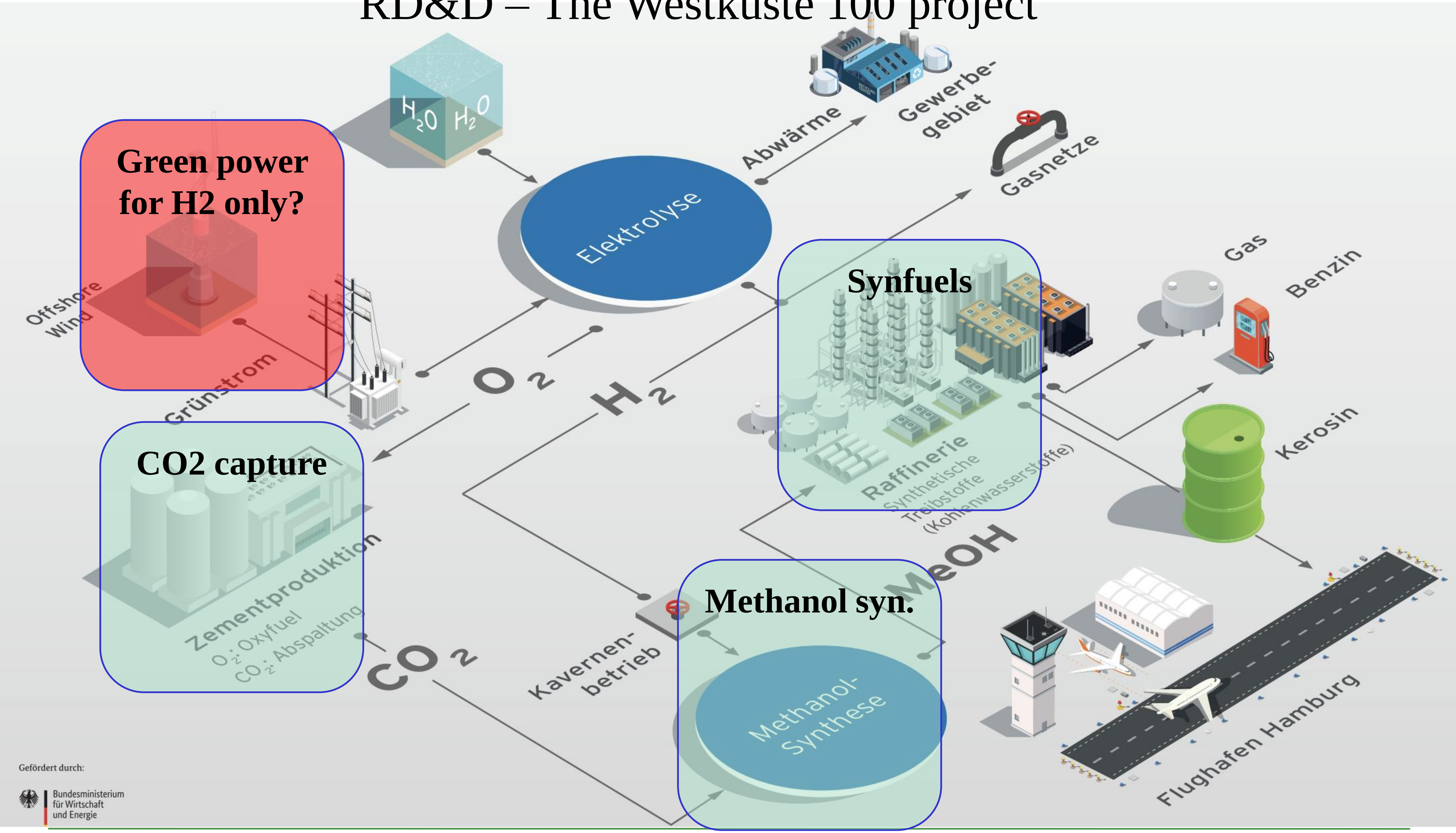
- Storage
  - Onshore storage unlikely to happen
  - Today, discussions focus on offshore storage

- Utilization
  - Various options on the table, but not uncontested

1. Germany

(2) CCUS

RD&D – The Westküste 100 project



1. Germany
(2) CCUS

Issues	Carbon capture and storage	Carbon capture and utilization
Economics	• High costs • Higher costs for offshore storage	• High costs if green hydrogen involved • Limited amount of valid business cases
Technology	• Increase energy efficiency of the capture technology • Advance technologies to reduce costs • Investigate upon uncertainties (storage)	
Infrastructure	• Lack of relevant infrastructure to transport CO_2 • Expand RE	
Regulatory framework	• CO_2-storage act for onshore storage	• Development of LCAs for measuring the environmental impact holistically
Acceptance	• Onshore storage not accepted	• Questions on durability of CO_2 removal from atmosphere and net GHG balance

Source: METI

2. Japan

(1) Hydrogen direct-use and hydrogen natural gas blends

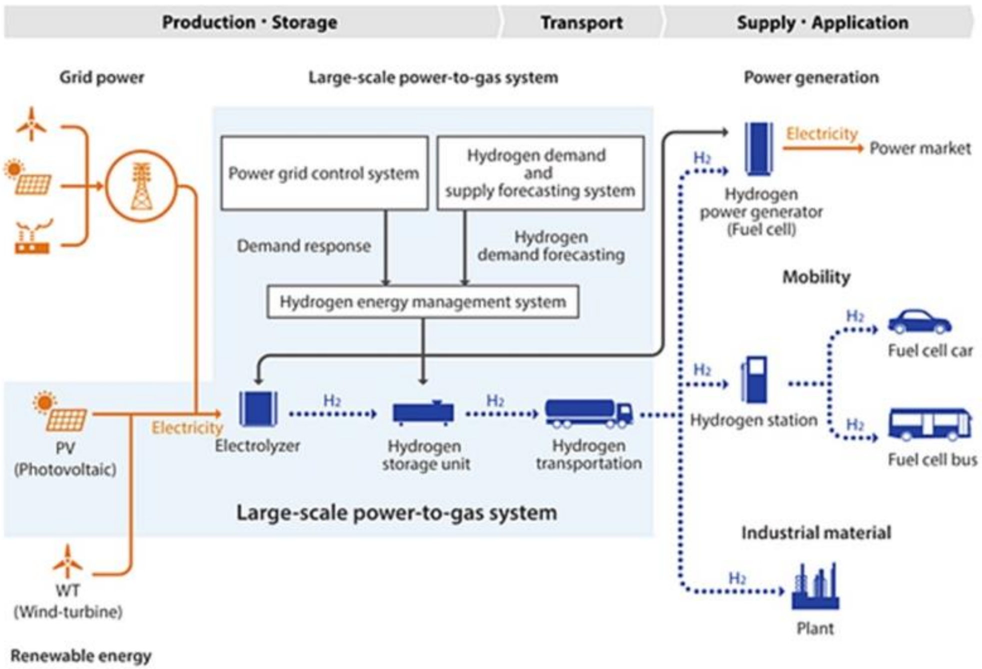
◆ Strategy

- The Hydrogen and Fuel Cells Strategic Roadmap (2014, revised in 2016 and 2019) and Hydrogen Basic Strategy (2017) focus more on hydrogen power generation, FCVs, and Enefarms. Not much description about hydrogen applications in the industry sector, though the latest version mentions its importance.
- The Green Growth Strategy (December 2020) estimates that clean hydrogen supply will be around 18-23 million tons/year by 2050, of which the industry sector occupies 7 million tons/year.

◆ RD&D

- The Ministry of Economy, Trade and Industry supports primarily large-scale hydrogen demonstration projects.
- The Ministry of the Environment conducts a hydrogen demonstration program in cooperation with local governments to support small-scale hydrogen production and hydrogen's application in local communities.

The Fukushima Hydrogen Energy Research Field (FH2R)



Source: NEDO

Figure: The largest green hydrogen project in operation
- 20MW solar PV plant, 10MW-class water electrolysis, hydrogen production 1,200Nm3 per hour
- Applications in the industry sector is included.

2. Japan

(1) Hydrogen direct-use and hydrogen natural gas blends

◆ Challenges

Issues	Hydrogen direct use	Hydrogen natural gas blends
Economics	• Cost reductions in hydrogen production and in new delivery infrastructure	• Competition with other low carbon gases (e.g. biogas and carbon-neutral methane)
Technology	• Possible changes and new technologies in application to utilize hydrogen, instead of fossil fuel	• Unknown technical readiness of natural gas pipeline for hydrogen blending • Possible impacts on specific application (e.g. specific industrial applications, gas engine, and fuel cell)
Infrastructure	• Needs for development of new infrastructure	• Limited motivation for gas suppliers, as benefit to gas suppliers (decarbonization) is limited, due to low calorific value of hydrogen.
Regulatory framework	• Certificate of carbon footprint and origin of clean hydrogen	• Firstly, detailed feasibility study needs to be conducted.

2. Japan

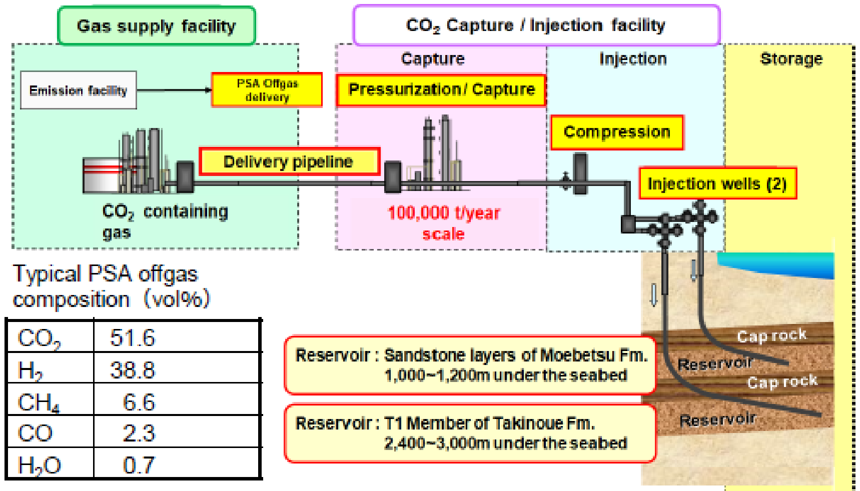
(2) CCUS

◆ Strategy

- CCS, CCU and Carbon Recycling have been encouraged by the government through various policies.
  - ✓ The 5th Strategic Energy Plan(July 2018)
  - ✓ The Long-term Strategy under the Paris Agreement (June 2019)
  - ✓ The Roadmap for Carbon Recycling Technologies (June 2019)
  - ✓ The Environment Innovation Strategy (January 2020)
  - ✓ The Green Growth Strategy (December 2020)

◆ RD&D

Tomakomai CCS demonstration project



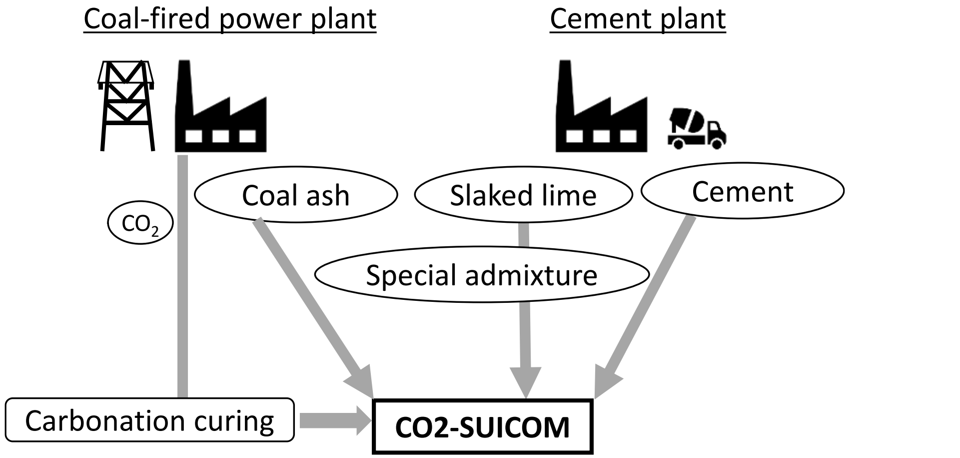
Typical PSA offgas composition (vol%)

CO_2	51.6
H_2	38.8
CH_4	6.6
CO	2.3
H_2O	0.7

Source: METI, NEDO and Japan CCS (2020)

The first large-scale CCS demonstration project in Tomakomai, Hokkaido, was conducted (FY2012-2020). CO_2 injection reached the target amount of 300,000 tons in November, 2019.

CO2-SUICOM
(a commercialized concrete product utilizing CO_2)



Source: based on Kajima Corporation

Two processes to reduce CO_2 emissions
1) Instead of cement, a special admixture is used for CO2-SUICOM.
2) CO_2 captured from exhaust gases of coal-fired power plants is utilized for carbonation curing.

2. Japan
(2) CCUS

◆ Challenges

Issues	CCS	CCU and Carbon Recycling
Economics	• Uncertain commercial feasibility	• Cost reductions - CO_2 capture process - Decarbonized hydrogen
Technology	• Technology development of CO_2 capture • Identifying feasible CO_2 storage sites • Efficient operation of CO_2 injection • Technology to enhance safety and reliability of CO_2 storage • Monitoring to detect CO_2 leakage	• Some processes require substantial energy to capture CO_2 and synthesize products → Life cycle assessment
Infrastructure	• Difficult to develop CO_2 transport infrastructure due to uncertainty	
Regulatory framework	• No specific rules for CCS • Unclear long-term liability for a storage site	• $LCCO_2$ evaluation • Attribution of decarbonization impact
Acceptance	• Low awareness and knowledge about CCS	

Major findings

A) Hydrogen direct-use

- **Germany** is more advanced in large-scale RD&D projects on hydrogen direct use.
  In **Japan**, demonstration projects on large-scale direct use of hydrogen are limited in the industry sector and small-scale projects of hydrogen applications focus more on the transport and residential/commercial sectors in local communities.
- For **both countries**, scenarios suggest an enormous demand for hydrogen in industry. However, costs for domestic production and for (ship) imports will remain a key challenge.

B) Hydrogen natural gas blends

- In **Germany**, industry favors the development of pure hydrogen (and supply chains), while the gas sector has an interest in blending; various issues need to be overcome.
- **Japan** has not addressed much this topic due to lack of a comprehensive natural gas infrastructure network, detailed evaluation of hydrogen blending impact to the existing infrastructure and technologies, and the long-term strategy.

C) CCUS

- As much as CCU is expected, **both countries** recognize opportunities but also challenges, such as life cycle assessment of CCU, market readiness of products derived from CCU and development of CO2 infrastructure.
  CCS could be an option but acceptance for storage in Germany is low.

Thank you for your attention!

Wuppertal Institute

The Institute of Energy Economics, Japan