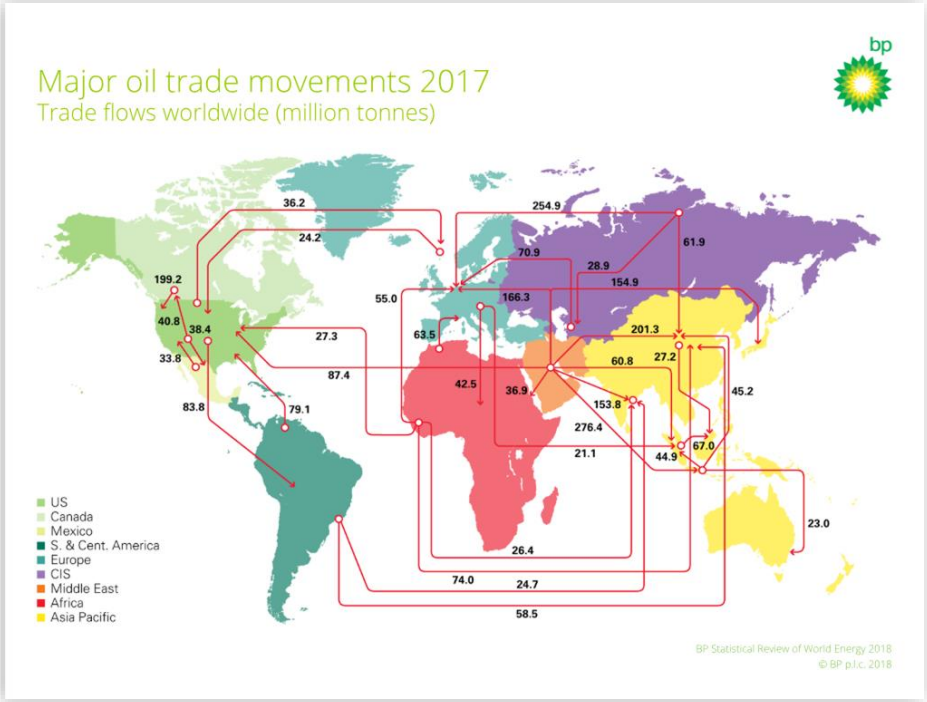
Hydrogen Council

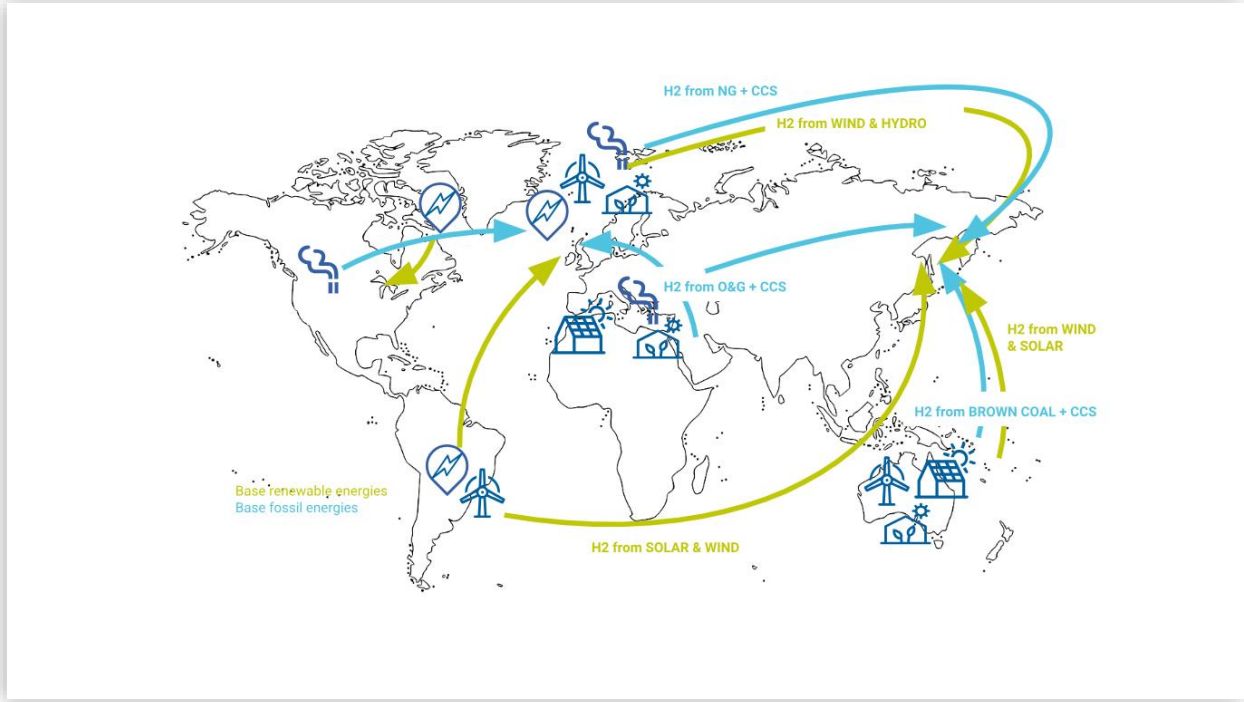
MISSION INNOVATION HYDROGEN VALLEYS

26 March 2019

VISIONS FOR HYDROGEN ENERGY IN 2050 ?

Hydrogen, the possible energy vector of tomorrow





Today

Oil & Gas

Possible end-game?

Hydrogen & Electricity

HYDROGEN VALLEYS DEFINITION – HYDROGEN COUNCIL

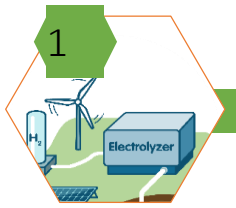
- Creation of relevant eco-systems around one or several H2 applications
- Synergies across sectors - such as sectoral integration - or across segments of the value chain to allocate risks efficiently and accelerate scale-up of H2 markets

- Mobility applications as early cases
  - Existing replicable cases
  - Mobility at the core of national and local issues (health + GHG)
  - Aligned with local alternatives for H2 production & logistics

"ARCHETYPE" PROJECTS ACROSS HYDROGEN DIFFERENT ROLES

Production

Enable large-scale renewables integration



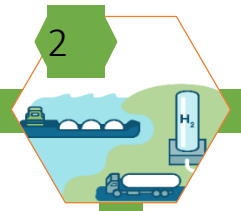
1A. Large-Scale Electrolysis

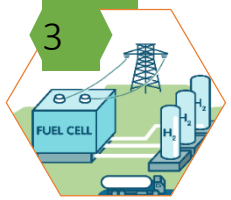
1B. Large-Scale SMR + CCS

System / Infrastructure

2. LH_2 Transport

Distribute / transport energy across sectors and regions

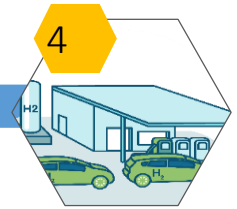




Act as a buffer to increase system resilience

3. H_2 Storage and Transmission

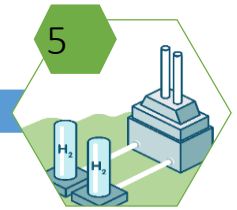
Decarbonise end uses



4A. Refueling Infra for FCVs
4B. FC Train Deployment

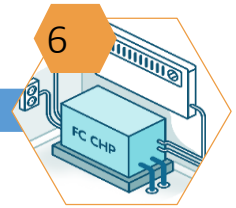
Decarbonise transportation

4C. Infra for Truck Fleets
4D. Infra for Captive FC fleet



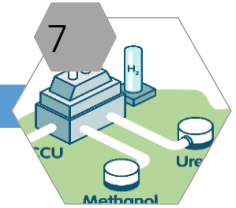
Decarbonise industry energy use and power generation

5. Clean Power Production



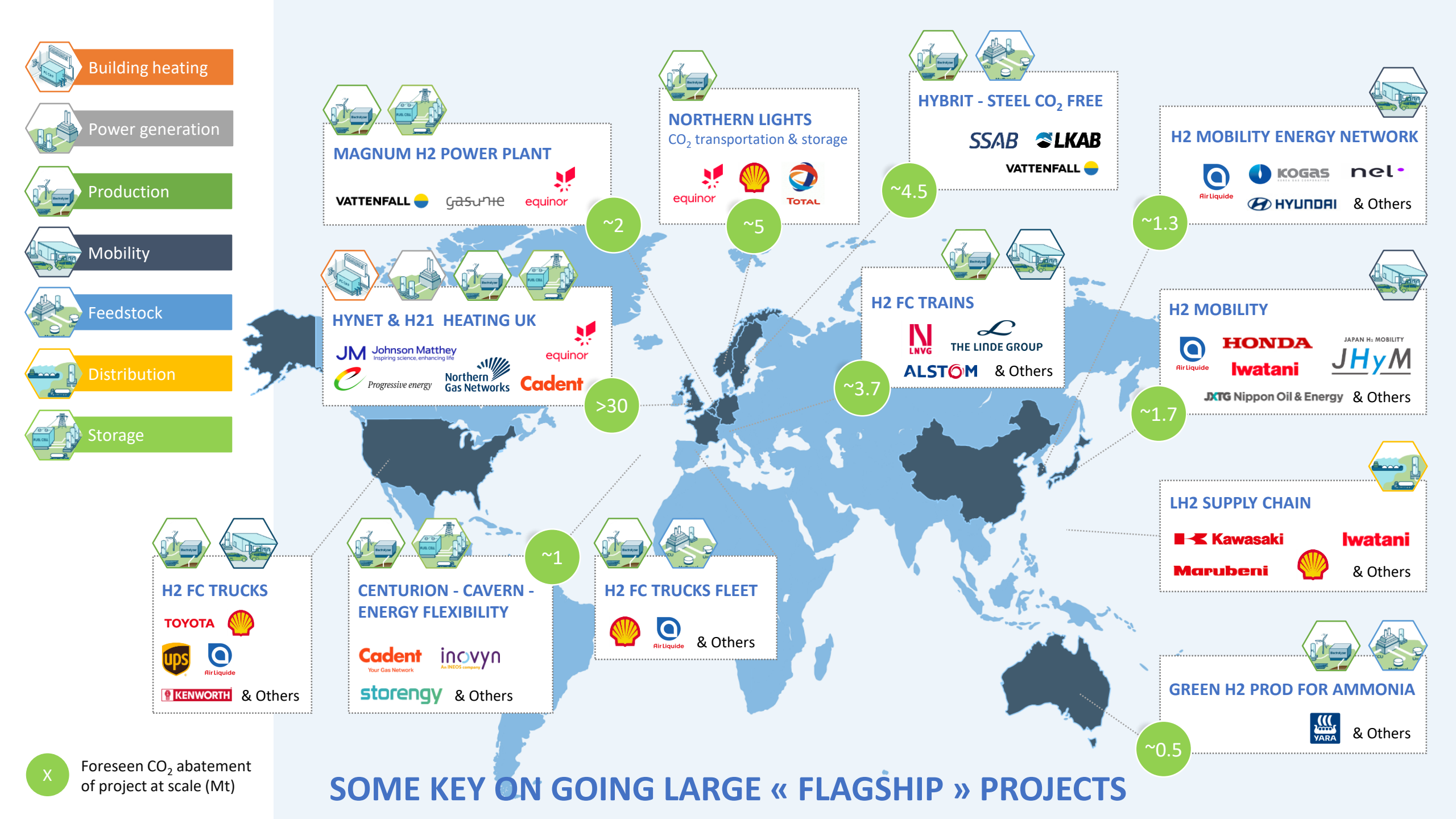
Decarbonise building heating and power

6. H_2 Heating



Serve as clean feedstock for industry

7. Industry Feedstock


Building heating
Power generation
Production
Mobility
Feedstock
Distribution
Storage
MAGNUM H2 POWER PLANT
VATTENFALL
gasunie
equinor
~2
NORTHERN LIGHTS
CO_2 transportation & storage
equinor
TOTAL
~5
HYBRIT - STEEL CO_2 FREE
SSAB
LKAB
VATTENFALL
~4.5
H2 MOBILITY ENERGY NETWORK
Air Liquide
KOGAS
nel
HYUNDAI
& Others
~1.3
HYNET & H21 HEATING UK
JM Johnson Matthey
Inspiring science, enhancing life
equinor
Progressive energy
Northern Gas Networks
Cadent
>30
H2 FC TRAINS
LNVG
THE LINDE GROUP
ALSTOM
& Others
~3.7
H2 MOBILITY
Air Liquide
HONDA
Iwatani
JAPAN H2 MOBILITY
JHyM
JXTG Nippon Oil & Energy
& Others
~1.7
LH2 SUPPLY CHAIN
Kawasaki
Iwatani
Marubeni
& Others
H2 FC TRUCKS
TOYOTA
ups
Air Liquide
KENWORTH
& Others
CENTURION - CAVERN - ENERGY FLEXIBILITY
Cadent
Your Gas Network
inovyn
An INEOS company
storengy
& Others
~1
H2 FC TRUCKS FLEET
Air Liquide
& Others
GREEN H2 PROD FOR AMMONIA
YARA
& Others
~0.5
X
Foreseen CO_2 abatement of project at scale (Mt)
SOME KEY ON GOING LARGE « FLAGSHIP » PROJECTS

FULL LIST OF FLAGSHIP PROJECTS – *as of 2019.01.24*

1. Centurion Large-Scale Electrolysis Project, UK
2. Fukushima Renewable H_2 Project, Japan
3. Acorn (Aberdeenshire) Clean H_2 production, UK
4. Hydrogen to Magnum (H_2M), Netherlands and Norway
5. Northern Lights: CO2 transportation & storage Project, Norway
6. HyNet Northwest Project, UK
7. HyNetherlands Project, Netherlands
8. H-Vision Project, Netherlands
9. H21 NoE Project, UK
10. Liquefied H_2 Supply Chain Project, Japan and Australia
11. H2 Mobility Deutschland
12. HyNet H_2 Project, South Korea
13. JHyM (H_2 Mobility) Flagship Project, Japan
14. Hype Taxi Fleet, France & EU
15. Zero Emission Valley Project, France
16. Pan-European Fleet of Trucks
17. Fleet of Trucks in California
18. FC Train Project, Germany
19. Low Cost Carbon Fiber for H_2 Tanks (FORCE), France
20. Ene-Farm Flagship Project, Japan
21. Green H_2 Production & Conversion to Green Ammonia, Australia
22. Reallabor GreenHydroChem Project, Germany
23. HYBRIT fossil-free steel production, Sweden

Transport-ation

HyNet, South Korea (Hydrogen Energy Network)

KOGAS · HYOSUNG · Woodside · HYUNDAI · 코오롱인더스트리 · SPG · Bumhan · ECO BIO · Air Liquide · nel · 덕양 DEOKYANG · Valmax · JNK Heaters Co., Ltd.

Objective

Build 100 new Hydrogen Refuelling Stations (HRS) by 2022 in South Korea to help reach government goal of 310 HRS and 16k FCVs by 2022

Building blocks

H_2 supply | HRS | FCEVs

	Market	Technology	Regulatory
Risks / Barriers[1]	▪ Near zero IRR ▪ Too few FCVs ▪ H_2 production cost too high	▪ H_2 supply shortage or quality issues ▪ HRS fails	▪ None identified
Mitigation measures[1]	▪ Government funding (HRS, FCV subsidy)	▪ Experience of consortium members	▪ Government participation

Systemic impact

- Large-scale CO_2 abatement
- Replicable, will establish H_2 supply organisation and pathway to 2023 target and 2030 goal (which is 630k car, truck and bus FCVs; c. 720 HRS)
- Will assist the government's plan to reduce overall CO2 output by 37% by 2030 vs BAU

[1] Non-exhaustive

Capital Investment[2]

- **Phase 1: 100 HRS = $320m**

- **Phase 2: 210 more HRS by 2022 = $Unknown**
  Higher proportion of private funding by financial institutions likely. Government plans to subsidise 50% of capex
- **Phase 3: c. 410 more HRS by 2030 = $Unknown**
  Yet higher proportion of private funding by financial institutions likely

Policy Ask

- **Establish environmental value of H_2 (i.e. CO_2 abatement value) to support long-term business case**

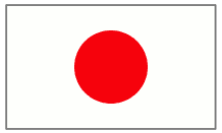
[2] Excludes H_2 production infrastructure cost and FCV cost

Transport-ation

JHyM (H_2 Mobility) Flagship Project, Japan

HONDA JXTG Nippon Oil & Energy Iwatani TOYOTA Air Liquide

+ 14 others in JHyM



Objective

Build 80 new Hydrogen Refuelling Stations (HRS) throughout Japan by March 2022, on top of the c.100 already operating. Consortium JHyM will provide 5-10% capex funding; public sector and HRS operators will provide the rest

Building blocks

H_2 supply | HRS | FCVs

Risks / Barriers[1]

Financial/Market	Technology	Regulatory
▪ Unprofitable due to low H_2 demand (i.e. lack of ZE policies & FCV product; high H_2 production cost)	▪ H_2 supply shortage or quality issues ▪ HRS failure	▪ Permissions (unmanned HRS, HRS siting in urban areas, difficulty in finding suitable sites)

Mitigation measures[1]

▪ Government ZE policies (HRS opex subsidy, FCV subsidy, guarantee mech-anisms); government H_2 Strategy to develop FCV/ H_2 market; opex support by JHyM; key value chain represented in JHyM	▪ 100 HRS already operating in Japan, experience of JHyM consortium members	▪ Government adherence to and support of its H_2 Strategy

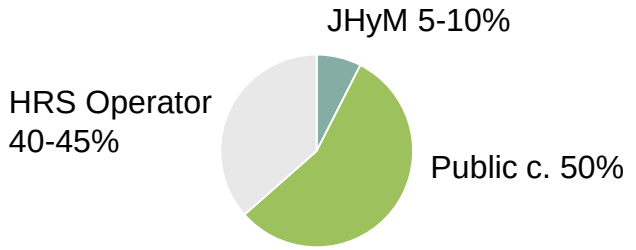
Systemic impact

- Multi-sector cooperation for large scale deployment of HRS
- Replicable; will support the government's H_2 Strategy to i) increase the number of HRS to 160 by 2020 and 320 by 2025, and to make HRS independent by the 2nd half of the 2020s; and ii) increase the number of FCVs to 40k by 2020, 200k by 2025 and 800k by 2030

[1] Non-exhaustive

Capital Investment[2]

- **Current Project (80 HRS by 2022) = $350m**



- **Future Roll-out (300 HRS over 2022-28) = $660m**
- Scheme will be discussed around 2020 (Government support is necessary)

Policy Asks

- **Financial support will be necessary till the late 2020s**
- **Regulatory adjustment will be necessary for cost reduction**

[2] 2018 prices. Excludes H_2 production infrastructure cost and FCV cost

CHINA

China's FCEV Development Milestone
2016-2020 medium power fuel cell mixed with large capacity power battery as technology feature. It is expected to realize large scale fuel cell vehicle demonstration in the public vehicle services in certain area.
2021-2025 large power fuel cell mixed with medium capacity power battery as technology feature. It is expected to realize fuel cell vehicle large scaled mass commercial application.
2026-2030 full power fuel cell as technology feature. It is expected to realize private passenger vehicle and large commercial vehicle million unit commercial promotion. The hydrogen energy supply system is mainly sourcing from renewable energy which will support fuel cell vehicle development.

Foton 8,5M Bus

- FC=30kW
- Battery= 40kWh

Foton 8 ton Truck

- FC=30kW
- Battery= 40kWh

China – Infra Development Roadmap

		2018	2020	2030	2050
OBJECTIVE	Dedicated to Energy H2 Production	70b m3/yr	72b m3/yr	100b m3/yr	H2E plays a key role in the energy mix
	H2E maturity		Complete industry chain demo	As an new pillar of economic growth and an important part of the energy strategy	H2E industry becomes an important part of China energy structure
ENERGY SAVING & CARBON REDUCTION		Fully use surplus clean energies to produce H2: abandoned solar, wind and water; gradually replace fossil fuel like coal, petrolem and nature gas; efficiently use coal for clean energy production.			
EQUIPMENT & MANUFAC-TURING	# of HRS	~10	100	1,000+	Full HRS network
	FC Power	30 kW	200 kW	Covering all pertinent useage cases	
	# of FCEV	1,000	5,000	1,000,000	10,000,000
POLICIES		**Gradually improve related policy system (regulations) to support H2E industry**			
		Standards & regulations	Inspection & Certification	Related tech. promotion	.....
		Fiscal policy	Quality & Safety	Platform for the industry development	

IHFCA H2 Bluebook -> H2E Infra Development Roadmap

10

CHINA: developments all over the country

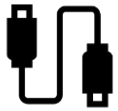
Source: Chinabuses.com

HYDROGEN DEPLOYMENT FRAMEWORK MATRIX

THEMES	CLEAN HYDROGEN TO MARKETS	UPSTREAM SUPPLY CHAIN	TRANSPORT	TOPIC DEVELOPMENT APPROACH
RULES / REGULATIONS	Pathways / Rules *(Europe lead - Certifhy)*	Maritime rules *(Japan/Australia lead)*	Infrastructure & supply chain regulations *(Lead Japan)*	Public / private workshops *(CEM/IPHE support)*
R&D	Private sector driven	Public / Private	Private sector driven	Public / Private effort *(MI support)*
MARKETS	All	Energy	Heavy duty, public transport & intensive usage for light duty vehicles	n/a
EDUCATION	Communication channels & events (public-private driven – CEM?)			n/a
SAFETY	Public / Private			n/a
SUPPORTING SCHEMES	Policies / Contract For Difference / CO2 Price	Large demonstration schemes	Policies & guarantee mechanisms	Public / private workshops - *Hydrogen Council lead*

SCALING UP HYDROGEN MULTILATERAL COLLABORATION

H2 production pathways
(including permitting)



Supply Chain

HRS
(including permitting)

Maritime codes and rules
(TBC – if requested by governments)

Hydrogen Council

Thank you for your time!

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