The making of Hydrogen – Definition and acceleration of a sector over 2017-2021

Issues at stake at horizon 2030 – Executive summary

Joël Ruet, Baudouin Becker, Antoine Goutaland, Xieshu Wang,

Executive Summary – key moves since mid 2018 and forecasts 2030 on H2 as energy and H2 for mobility

H2-Energy Structuring Horizon 2025 – In 2 years, H2 as Energy jumped by what we anticipated to see in 5 years

New modes: EU: Multi-country projects, gas-power grids coordination, World: Mission innovation 1 GW Electrolysis

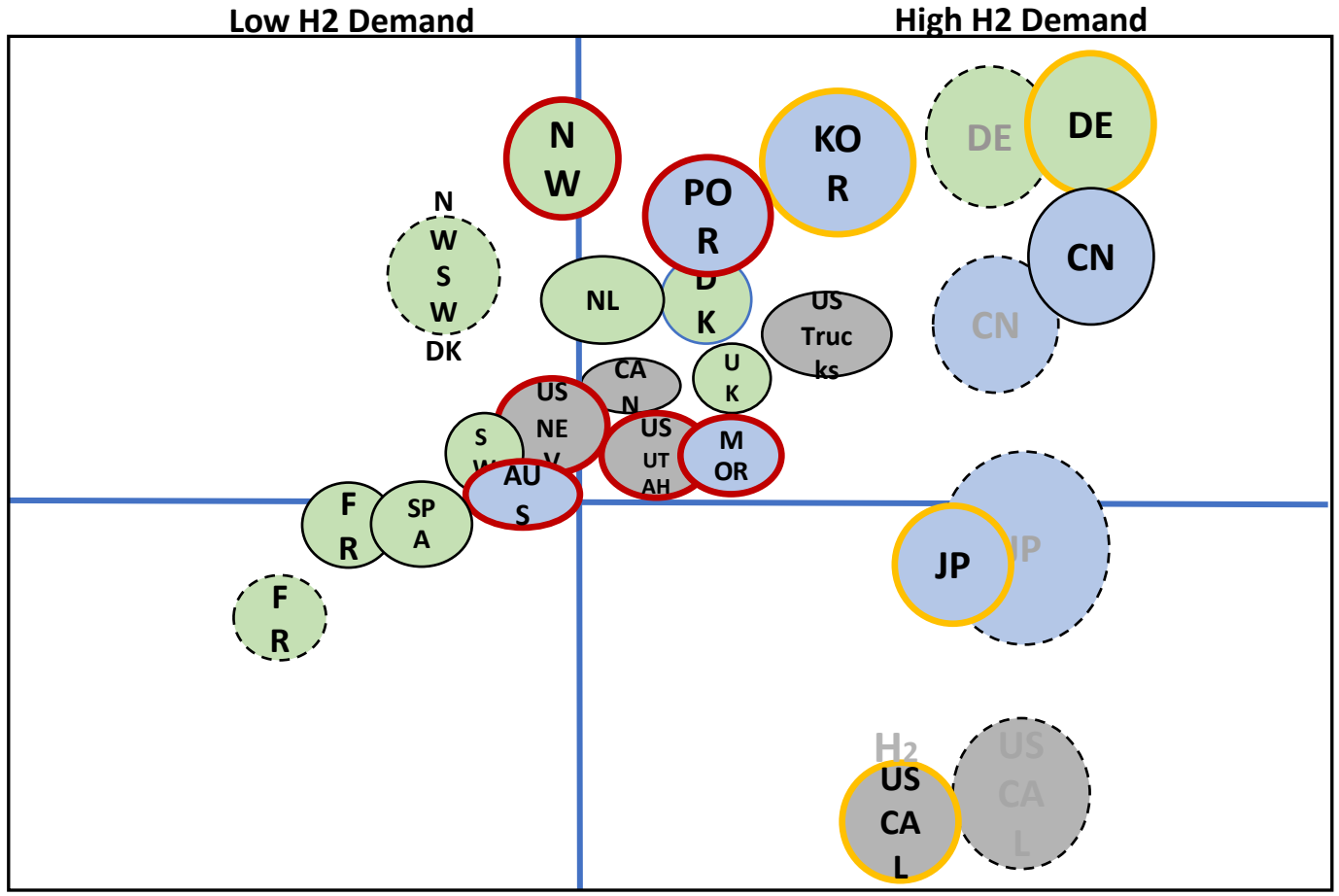
"Free H2 commodity market" missing by 2025: H2 as by-product, dedicated project, or sector silo
2 contrasted country groups: Low-High coherence &development: based on production-demand "coupling"
2 geographies: Europe Industry-driven, State backed, Asia State-driven and pushing towards Industry structuring

H2-Mobility unfolding by segments, Horizon 2030-35 - Deployment of H2 stations half speed of 2018 expectations

Partial Greening of H2 production by 2030 but unequal geographies

A phased deployment of H2-Energy needed ahead of H2-mobility: upstream prior to mobilities; HDV way before LDV
First mobility markets may not be future scaling markets :
Learning on H2 Mobility: from where to learn, where to later deploy? The need for national/regional monitoring

In 2 years, H2-Enegry coupling jumped by what we anticipated would happen in 5 or more



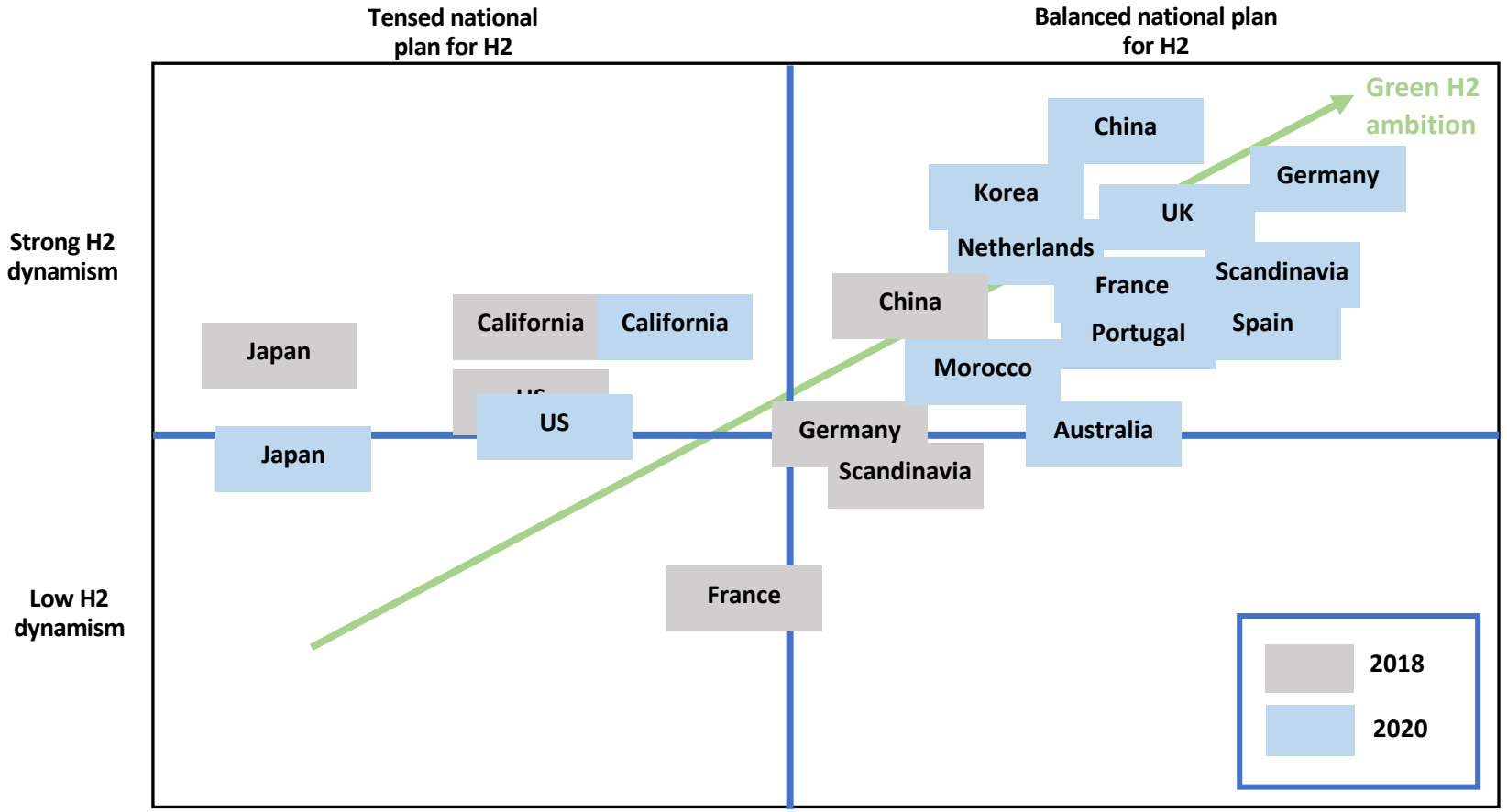
Structuring over two years
Germany, France, Scandinavian countries considerably improved their plans, China confirms it and delivers, S. Korea & NL have clear plans, while long term concerns persist in Japan& USA, including California

"Coupling" towards "free H2" market by 2030: those with an integrated plan towards a share of free H2 for market, vs. **de-coupled ones** this is lacks credibility.

Our view in 2018
Green H2 plan
Blue H2 plan
Grey H2 plan
Imports dependent countries
Exporting countries

- **Imports dependent countries (Japan, US California, Germany, S-Korea)**
- **Exporting countries (Australia, US-Nevada & Utah, Norway, Morocco, Portugal)**
- Global market room is limited, will rely on strong H2 strategy & policies coherence to move forward in the transition (and shipping technology progress)

Ecosystem coherence & deployment: 2 contrasted countries groups



3 Industrial dynamics

Transition chemistry/coal to H2: China, Korea, "Japan+Australia"

RE-to-grid integration / H2-to-gas: Europe & Chine

Industry belts transition: UK, China (Shanxi province), Netherlands

Greening H2 production by 2030-35 – only few countries are credible on large greening

Scenario perspective of Type of H2 and its availability

Country\Horizon	Current	2025	2030
China	22Mt 100%grey H2	↗ 32Mt 95%grey H2	↗ 41Mt 50%green" H2/H2
Japan	0,2Mt 100%grey H2	↗ Prod multiplied by 19 H2	↗ Prod multiplied by 74 H2?
California	100%grey H2	= H2	= H2
Germany	est.1-2Mt 95%grey H2	↗ H2/H2	H2
Scandinavia	est.0,5-1Mt 95%grey H2	↗ H2/H2	H2
France	1Mt 95%grey H2	= H2	? H2/H2

China: **50/50 very likely -** 50% green for additional capacity
Japan: high risks - Greening depends if sourced from Scandinavia or Australia
California: **unlikely at scale -** dependent on plants from other States

Germany/Scandinavia: credible greening but blue will remain large: check RE P2G (wind+electrolysis) & CCS

France: Low Carbon H2 needs peg on nuclear plants, as RTE study suggests

H2 : The main production/imports is considered as grey

H2/H2 : Probable transition shift to green hydrogen

↗ Important increase of H2 production either importation

= No sign of increase or stagnation of H2 production either importation

H2: Probable scenario of a move towards a majority mix of green hydrogen, available in large quantities

Proof of concepts still underway on green H2 profitability: explore optimising/expanding RE, scaling horizon 2030

Global H2 economics improved on (i) electrolysis cost techno-economics, (ii) role for carbon pricing rather than subsidies.

H2 mobility at a slower starting point: distinct trajectories but an "Asia-EU race"

H2 ≠ H2

Light passenger H2 mobility does not follow H2 economy's pace & remains at the starting point

National Plans for light passenger H2 mobility @2025 & 2030:

Most advanced countries :

		Japan	China	California	Germany	South Korea
FCV	2025 total in thousands % FCV/stock pass. cars	200 *** 0,3%	50-100 *** 0,04%	50-100 ** 0,3%	100* 0,2*	81 **
	2030 total in thousand / %FCV/stock pass. cars % FCV/sales pass. cars	800 ** 1,15% ** 8% #	1000 *** 0,5% *** (select zones)	190 * 1% * 8% #	400 * 1% 8% #	850 *

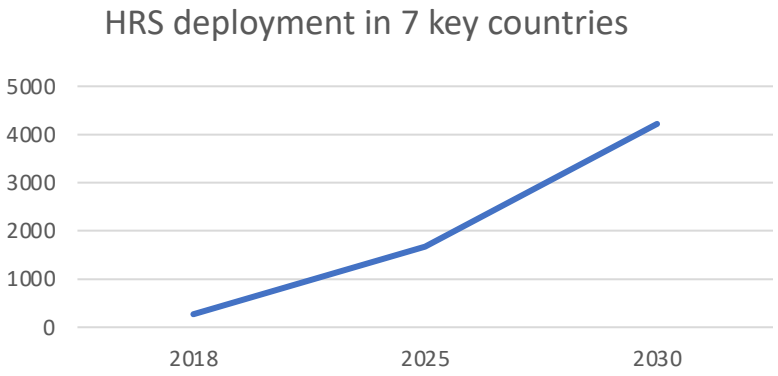
Non-homogeneous data quality:
*** Very Reliable
** At decoupling risk:
- Unreliable lobby data
- # Hydrogen Council Report

France: no real strategy for light passenger H2 mobility, focus on H2 HDV

By 2025, California, Germany & Asia have articulate plans (Norway not much on mobility)

By 2030, Only China & Japan have foreseeable & articulate ambitions for H2 mobility but Japan is upstream dependent

HRS Deployment: slow deployment mainly destined to H2 HDV:



Total HRS in 7 key countries (Japan, China, California, Germany, France, Norway, S-Korea):
- **2020:** 270
- **2025:** 1,670
- **2030:** 4,220

For comparison, total ICE stations in 2020 in those 7 countries: 191,300

The need for national/regional monitoring: recent EU policy push is promising; Chinese market. Industrial rivalry.

H2 Mobility: from where to learn vs. where to later deploy?
Japan, California, Korea, China good to learn; scaling (2030) more likely in China, EU-for HDV

China
State-led, + large firms

- China has 15 years track record on renewable energies
- China has a 10 years old focus on new energies mobility

→

- **Wish to be *the* lead market** for both generic H2 and H2-mobility

Japan
State + Tokyo Gas led
Phased but complex policy

- **Driven not by mobility but large generation projects**
- Heating feedstock drive: risk to create a disbalanced ecosystem

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- Take-off of mobility as a 2nd step from other energy-urban sectors; dynamic car firms and techno leaders

North West Europe
Increasingly holistic & green : territories integration

- **Moving from pilots to scale in H2 energy, but not in mobility**
- **H2-equipment Technology investment leaders esp. Germany**

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- Might become the 3rd / even 2nd 2030 market for H2 HDV –but on LDV missing steps so far
- **H2-energy greening grids and industry first**

USA California vs. rest
CAL; largest H2 LV market so far
US Firms lead in logistics / heavy duty storage

1st market for cars now but served by a Japanese company
Model at risk (subsidies for green elec) even today & US grey H2

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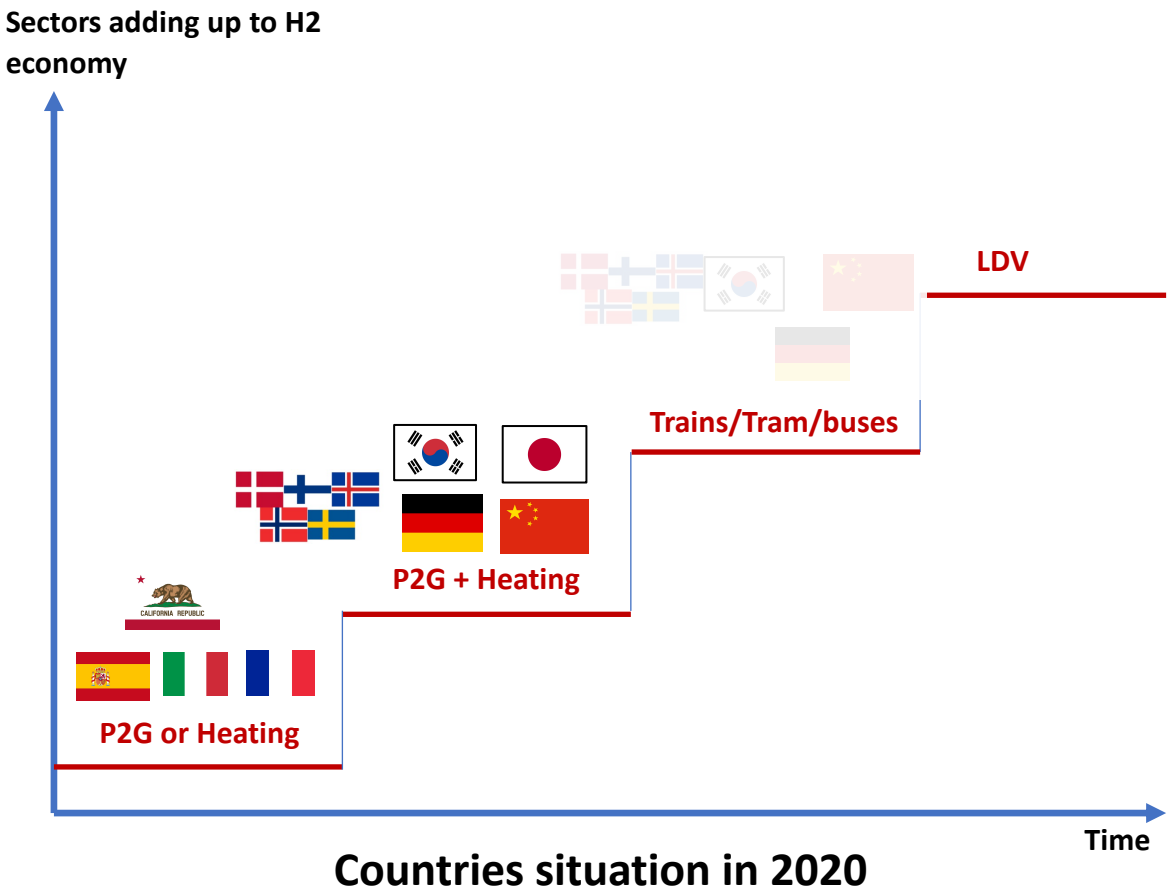
- Risk to be dependent market both on technology and green-H2

	H2 Ecosystem coherence	H2 Light Passenger Mobility plan	Deployment of H2 infrastructure for mobility	H2 Infrastructure cost	H2 imports dependency
N-W Europe	***	*	**	*	*
China	***	**	**	*	*
Korea	***	*	**	**	**
Japan	*	**	*	***	***
US California	*	*	**	***	***

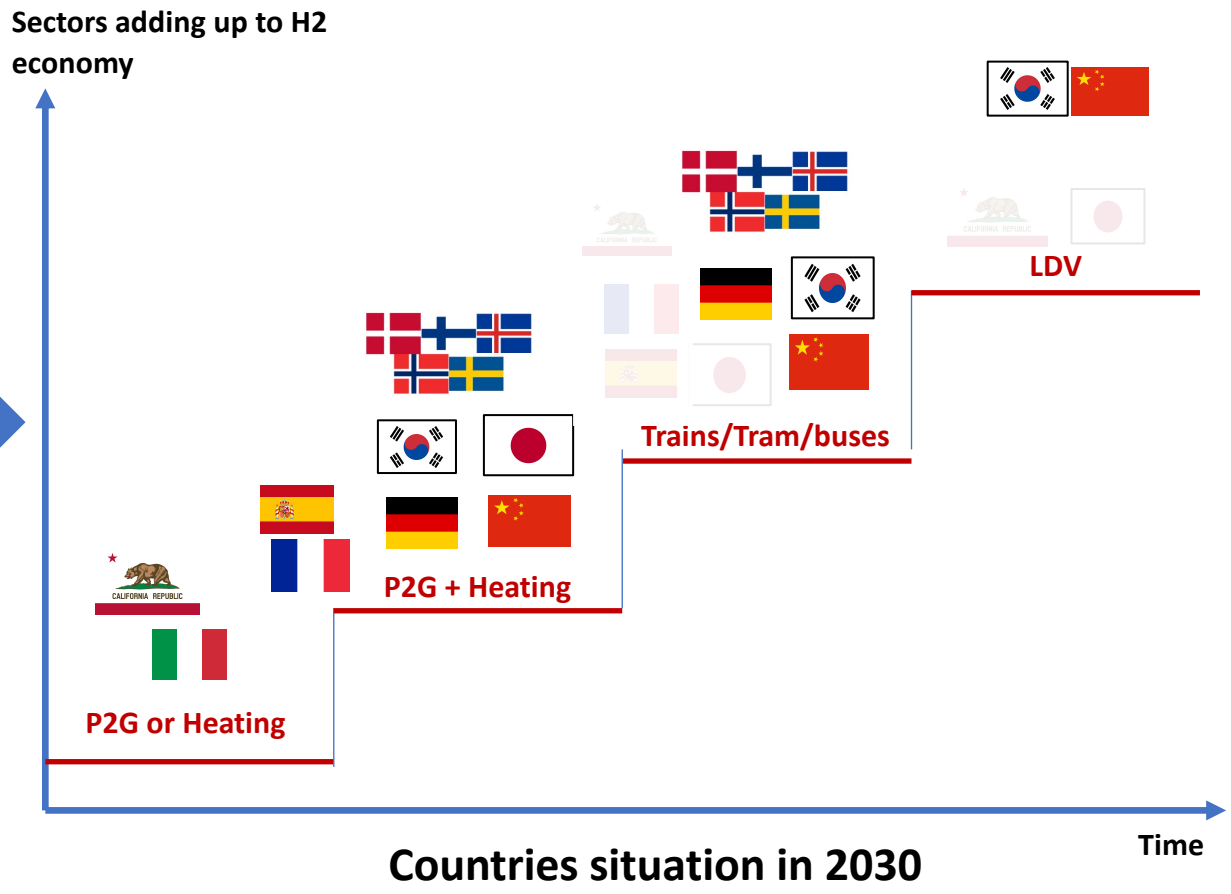
- **China 2025, THE first ecosystem to fully complete**
- **Japan 2nd market on mobility may be overtaken by Europe as Infra rises HDV 2025 – check Fuel Competition**
- **California: a learning place today, at high risk 2030 and even by 2025**

CONCLUSION

From H2-Energy dynamism to H2-mobility constraints scenarios –
H2-mobility scaling up needs a prior H2-Energy ecosystem; HDV learning path; few LDVs until 2030



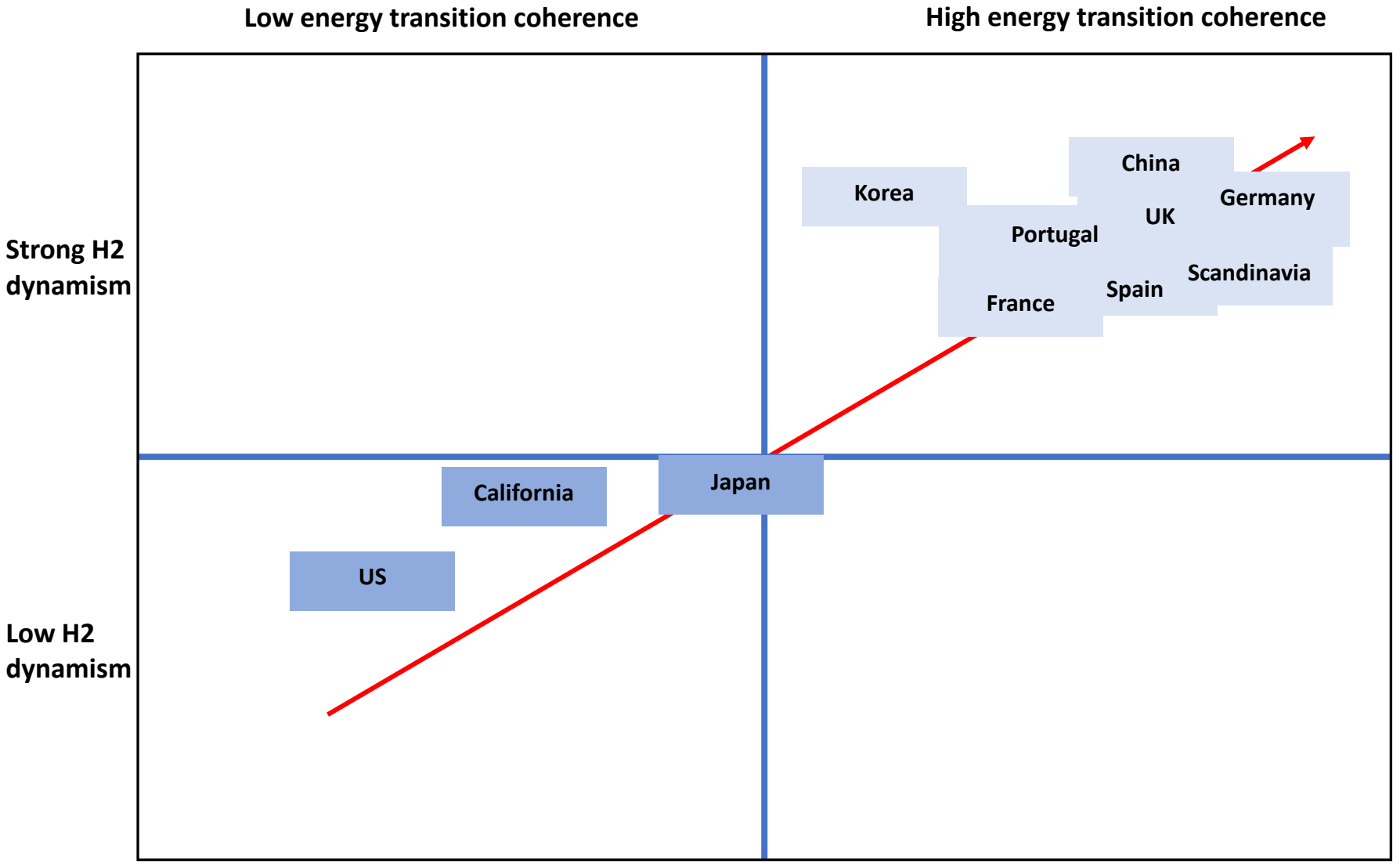
Countries situation in 2020



Countries situation in 2030

H2-mobility requires an infrastructure than can only be amortized if a multi-sectorial H2-economy is based on upstream industry …
2 risks: upstream / other sectors capture – electricity mobility first scaling advantage for LDV

H2 ecosystem coherence matches energy transition coherence; H2 not in pure silo



Matching H2 dynamism - country energy transition coherence

Still, H2 remains at decarbonization challenges level @horizon 2030; not achieving Paris COP21 objectives yet

ANNEX

Light Passengers Hydrogen mobility Plans by country – 1 / 2
some early adopters by 2025, unclear massification by 2030

		Japan	China	California	Germany	France	Scandinavia	South Korea
FCV	**2018** total in thousands % FCV/stock pass. Cars	2 *(2020: 30)* 0,0032%	1,4 (2019: 6,2) 0,0007%	3 (2019: 8,3) 0,006%	0,2 0,0004%	0,1 0,0003%	<0,2 0,001%	0,9
	2025 total in thousands % FCV/stock pass. cars	**200** *** **0,3**%	50-**100** *** **0,04**%	**50-100** ** **0,3**%	**100**** **0,2****	5 (2023) ** (commercial)	**50**-187* **0,4**-1,5% *	81 **
	2030 total in thousand / %FCV/stock pass. cars % FCV/sales pass. cars	800 ** 1,15% ** 8% #	1000 *** 0,5% *** (select zones)	190 * 1% * 8% #	400 * 1% 8% #	20-50 (2028) * (light commercial)	NA	850 *

Very non-homogeneous data quality…
*** Very Reliable
** Depends on:
- effective deployment (Japan & China 2030)
- or at risk because of week H2 Capacity-demand coupling
- Unreliable lobby data For FCV (to nuanced their figure, we propose an approximate range)

Hydrogen Council Report

By 2025, California, Germany and Asia have articulate plans (Norway mostly not for mobility)

By 2030, Only China and Japan have foreseeable and articulate ambitions for H2 mobility

Light Passengers Hydrogen mobility Plans by country – 2 / 2 -Inconsistencies remain for HRS deployment by 2030 **– Scandinavia & France have too low a FCV/HRS ratio**

	H2 – LPV – HRS	Japan	China	California	Germany	France	Scandinavia (Norway)	South Korea
FCV	**2018** total in thousands % FCV/stock passenger cars	2 0,0032%	1,4 0,0007%	3 (2020: 7) 0,006%	0,2 0,0004%	0,1 0,0003%	<0,2 0,001%	0,9
	2025 total in thousands % FCV/stock passenger cars	**200** *** **0,3%**	50-**100** *** **0,04%**	**50-100** ** **0,3%**	**100** ** **0,2%** **	5 (2023) ** (commercial)	**50**-187* - NW fuel for 100 **0,4**-1,5% *	81 **
	2030 total in thousand / %FCV/stock passenger cars % FCV/sales passengers cars #	800 ** 1,15% ** 8% #	1000 ** 0,5% **	190 ** 1% ** 8% #	400 * 1% 8% #	20-50 (2028) * (light commercial)	NA	850 *
HRS	**2018** total stations **2020** total stations (nb. of FCV per station)	90 160 25	20 100 72	31 60 (2019) 96	60 100 33	20 >40) 5	25 8	24 (2019) 37
	2025 total stations (nb.of FCV per station)	320 *** 625	300 *** 166	200 *** 500	400 *** 1250*	100 (2023) * 50	40 *** NA	310 **
	2030 total stations (nb.of FCV per station)	900 ** 890	1000 ** 1000	NA	1000 * 1000	400-1000 * 20 (2028)	100 ** NA	520 *
ICE	**2020** total stations	30,000	110,000	10,000	15,000	11,000	4,300	11,000

*** Very Reliable ** Depends on industrial conditions * Unreliable lobby data