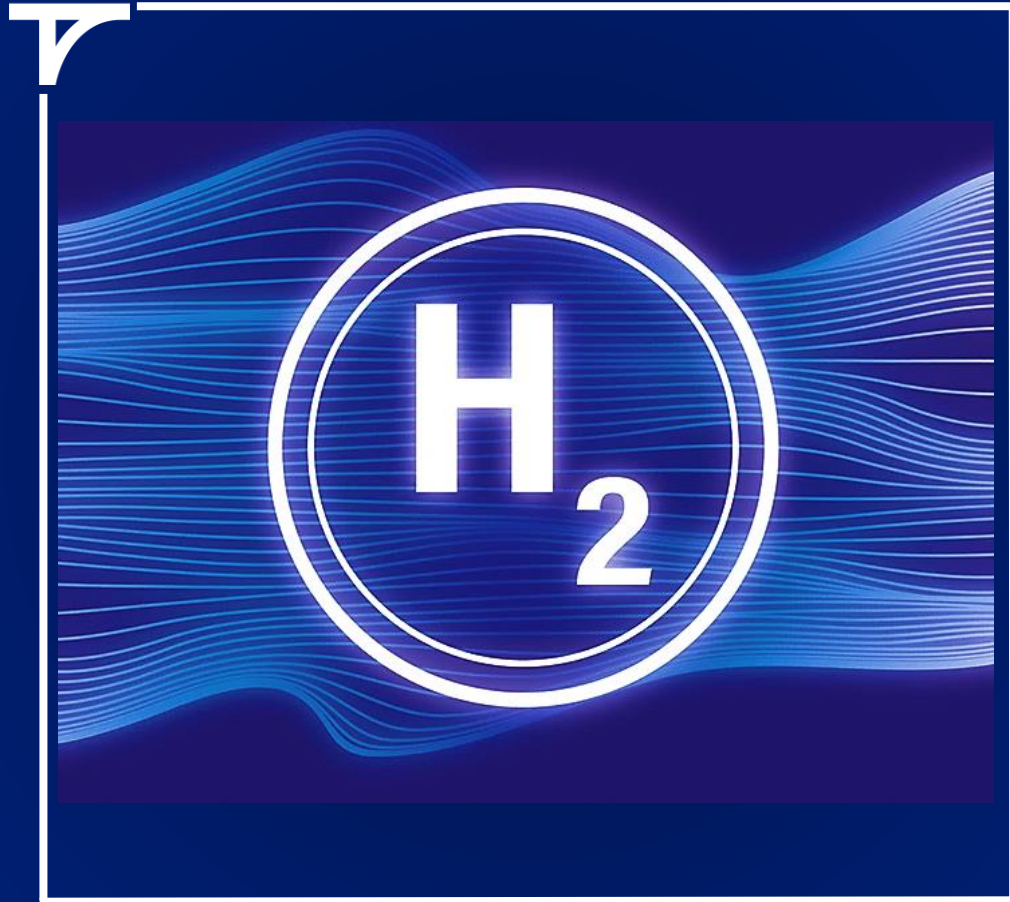


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## Global pathways that India can follow for building a robust hydrogen ecosystem

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01

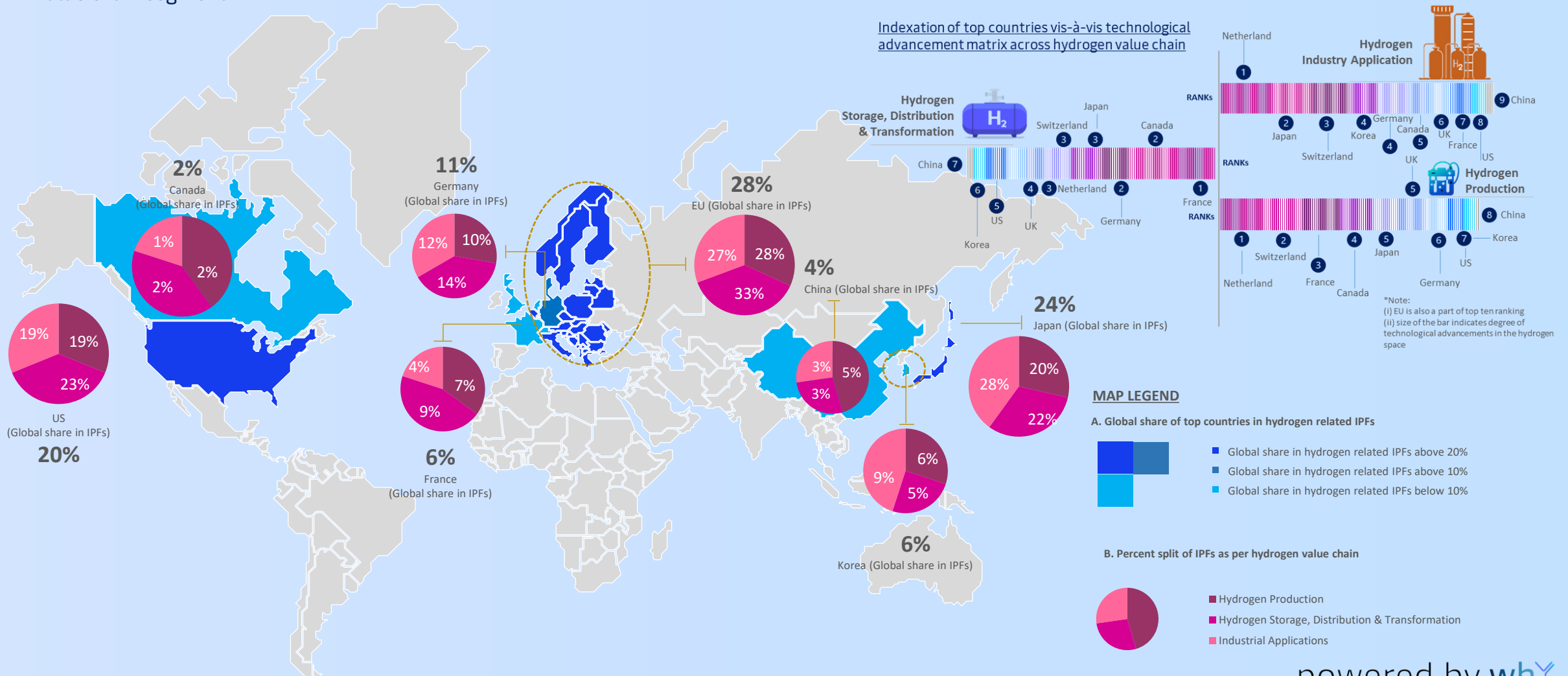
## Developing a culture of setting innovation clusters

### For boosting R&D across hydrogen value chain, globally countries are encouraging culture of innovation clusters

Globally, countries are developing innovation clusters for boosting R&D activities. Innovation clusters are such geographic locations that have large & rapidly growing number of intellectual property facilitation (IPFs). These clusters provide a perfect ecosystem that allows well established industry players, start-ups, new entrants & technical colleges/universities/public research institutions (PRIs) to work cohesively on scaling technological advancement for hydrogen value chain segments. For example, in Europe Munich & Paris have such clusters that are led by mature industry players as well as by universities & PROs. Also, the players are encouraged to develop integrated value chain & cross value chain solution offerings. **In Paris, nearly 72% of the technology development on hydrogen is commanded by industry players , while 28% is supported by the universities & PRIs.**

# Global Hydrogen Development & Deployment Indexation, Top 10 countries

Exhibit 01: Hydrogen IPFs Infomap - Status of the share of top 10 countries in revealed technology advantages for hydrogen technologies by value chain segment



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02

**Universities/Public research institutions are actively involved in scaling R&D**

## Globally, universities & public research institutions are developing technologies for industry use across hydrogen value chain

**Universities and public research institutions across the globe generated nearly 14% of all hydrogen-related IPFs in the period 2011–2021\***. They were particularly active in hydrogen production technologies with 18% of IPFs in that field, compared with 13.3% for storage, distribution and transformation technologies and only 7.1% for end-use applications. Some of the top institutions leading the R&D are from France & Korea. A snapshot of top institutes to have maximum number of patents across hydrogen value chain is indicated in Exhibit 02.

\*indicates information as of Jan 2021

Three French institutes and two Korean research centers are leading the R&D activities. . Interestingly, there is no Japanese research institution among the top ten, although Japanese companies are well represented in the list for corporate patenting.

Exhibit 02: Snapshot of top public research institutions (PRI) to file maximum number of patents b/w 2011-2021\*

PRI	Country of Origin	Production	Storage, Distribution & Transformation	End use applications
CEA	France	119	32	08
IFPEN	France	78	12	31
CNRS	France	36	16	08
KIER	Korea	53	04	10
KIST	Korea	29	09	10

\*indicates info as of Jan 2021



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03

## More innovation taking-off in liquid hydrogen storage and vehicle refueling

### Globally more patents are getting locked for storage & transportation of gaseous & liquid hydrogen

The EU bloc led patenting activities in most areas of hydrogen storage and distribution in the period 2011–2021\*. The EU shows a particularly strong lead in established technologies supporting the storage and transport of pure hydrogen, with half of published IPFs in **liquid storage, 38% for gaseous storage, 39% in refueling and 32% in networks and related equipment**. The EU is also ahead in the field of low-emission hydrogen-based synthetic fuels and solid hydrogen storage by adsorption. The share of EU countries shrinks to 20% in the field of hydrides.

\*indicates information as of Jan 2021

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04

**Integrated project development at play by national oil & gas companies**

## National oil & gas companies can leverage their strong cross-value-chain positions for developing hydrogen ecosystems

This play is a good fit for oil companies with advantaged access to energy resources, such as hydrocarbons and green energy, as well as advantaged geography, a broad set of energy off-taker relations, and substantial local demand driven by local industries over the long term. **Shell's hydrogen and CCS project in UK called Acorn , led by Pale Blue Dot Energy is a perfect example . Using existing oil and gas infrastructure at the St Fergus gas processing terminal, the project will reform North Sea natural gas into decarbonized hydrogen. The hydrogen produced would then be used in transport, in the gas grid to decarbonize heating in homes, and in heavy industry**

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05

## Hydrogen guarantees of origin (GO) certificates

### Netherland has started “hyXchange exchange platform initiative to provide renewable hydrogen guarantees of origin (GO) certificates

The issue of green Guarantees of Origin for hydrogen in the Netherlands has started as of October 2022. Netherlands is the first country in Europe with such a system. The associated system was evaluated in recent months in a pilot by hydrogen exchange initiative HyXchange in cooperation with Vertogas, the certifying body for biogas, now also for green hydrogen. A total of eighteen market parties participated in this successful pilot (practical test). **HyXchange aims to rapidly expand certificate and hydrogen trading, aimed to also facilitate trade between European countries and hydrogen imports from countries outside the EU.**



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# 06 Green ammonia consumption to see uptake by power generation & shipping sector

## Global demand for low-carbon hydrogen to produce ammonia for offtake in power generation & shipping sector likely to grow to 75 MT by 2050

This anticipated demand would be 50% higher than the market for all hydrogen for chemicals today. **In Japan, the largest power generation company, JERA, issued a tender in 2022 for up to 0.5 Mt of low-emission ammonia to replace 20% of the coal at a large power plant unit from 2027.** Growing targets for patenting in this area include electrically-heated reactors for ammonia synthesis that reduce the need for fossil fuel combustion and have the potential to eliminate fossil fuels on-site if the hydrogen is sourced from water electrolysis. Europe dominated patenting in these fields over the period 2011 to 2020, with 34% and 48% respectively of IPFs in the production of ammonia and methanol.

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07

## Automotive & aviation to see more adaptability of hydrogen in the transport segment

### For automotive and aviation, the innovation is mainly driven for hydrogen fuel cells

Since 2021, Zero Avia, a start-up founded in 2017, has raised USD 78 million to develop a fuel cell aircraft with up to 100 seats. However, for longer distances, the higher power of turbines and the greater energy density of hydrogen-based fuels are expected to be more competitive. Universal Hydrogen, a start-up founded in 2020, has raised over USD 80 million for hydrogen turbine drivetrains. **From 2011-2021\*, nearly 235 hydrogen fuel cell & 61 hydrogen ICE patents have been locked for the automotive sector.** While aviation segment has observed 71 fuel cells patents in the same period.

\*indicates information as of Jan 2021

Hydrogen could be a critical part to the journey to net zero as it can be used in end use industry applications ranging from power generation- transportation- refining- fertilizers-steel making. Clean hydrogen is anticipated to play an important role for India to meet its decarbonizing goals especially for the hard-to-abate sector such as heavy industries & long-haul transport. **For the hydrogen vision to materialize & the market to scale in India ,the key areas that will need to be addressed are –** (i) encouraging R&D across hydrogen value chain, (ii) identifying value & developing right plays in value chain (iii) focusing on more integrated solutions, (iv) encashing value for cross value chain with existing infra, (v) scaling competitive supply; (vi) stimulating local demand; (vii) facilitating corporations across value chains, customers, and countries, (viii) increasing participation of Indian states for development & deployment of hydrogen. The states should be encouraged to come out with dedicated hydrogen policies & roadmap for establishing **“hydrogen innovation cluster (HIC)”**. **These clusters could provide a perfect ecosystem that allows well established industry players, start-ups, new entrants & technical colleges/universities/public research institutions (PRIs) to work cohesively on scaling technological advancement for hydrogen value chain segments. Also, production of low carbon hydrogen & its deployment for end use industry application should be mandate in these clusters.** To measure the performance of Indian states regards low carbon hydrogen development, the central government can introduce a **“hydrogen development & deployment (HDD) index”** & a subsequent incentivization structure could be prepared to reward the best performers.



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