

# Is Hydrogen a Crime Against Thermodynamics?

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WorleyParsons Group

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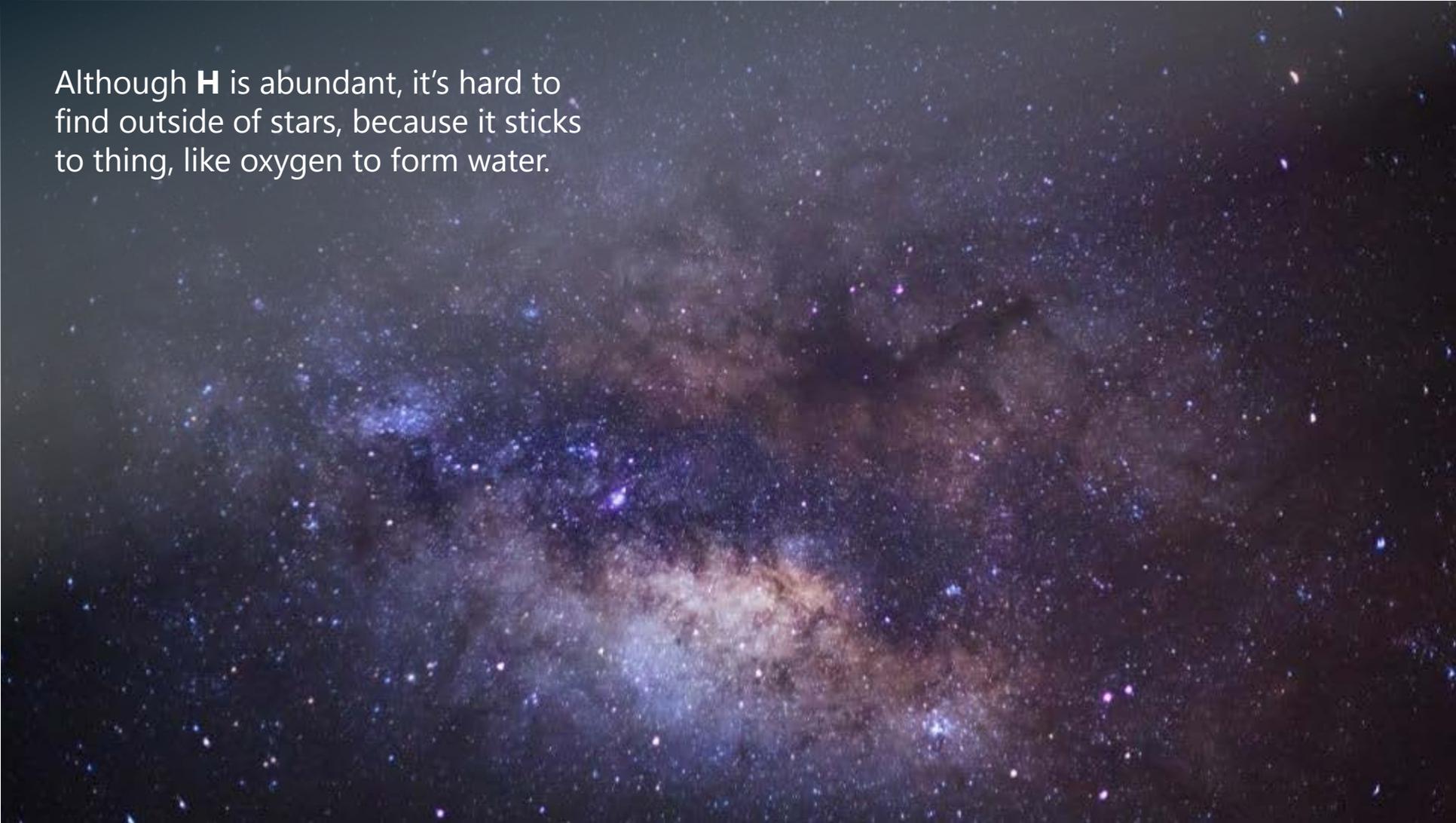


Anyone who has ever watched a rocket launch will have seen hydrogen (**H**) in action.

**H** = highest energy per unit mass of any element.



Although **H** is abundant, it's hard to find outside of stars, because it sticks to things, like oxygen to form water.

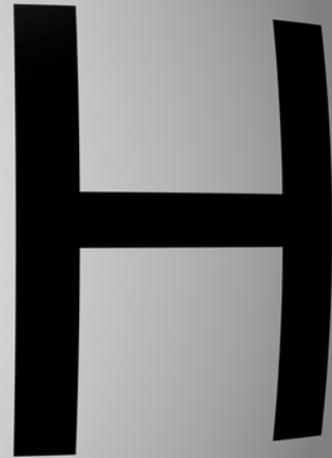


**H** isn't even considered a fuel, rather an energy carrier, because it's so hard to find.



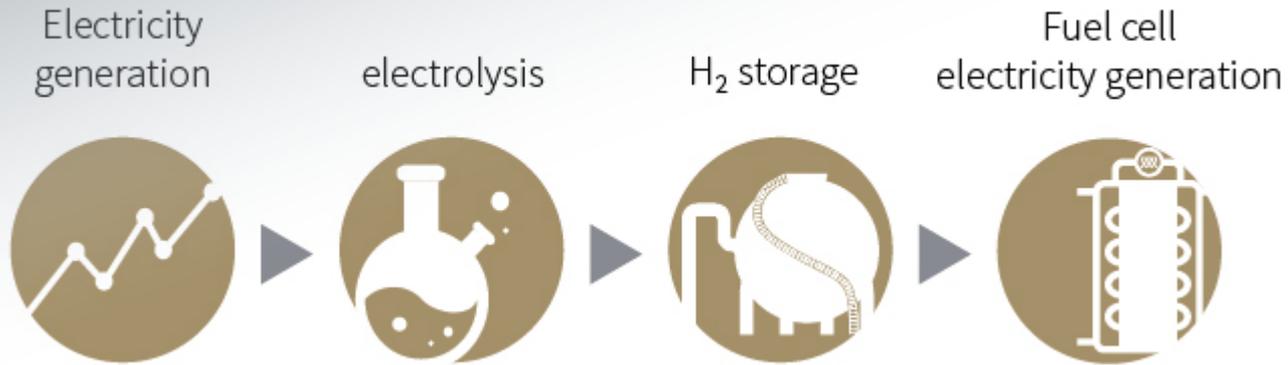
So how do you make this simple, carbon-free molecule?

Let's focus on the electrolysis of water using renewable electricity.



Electricity is passed through water to split it into **H** and oxygen.

Ensure the electricity input is low carbon  
= low emissions (green hydrogen).



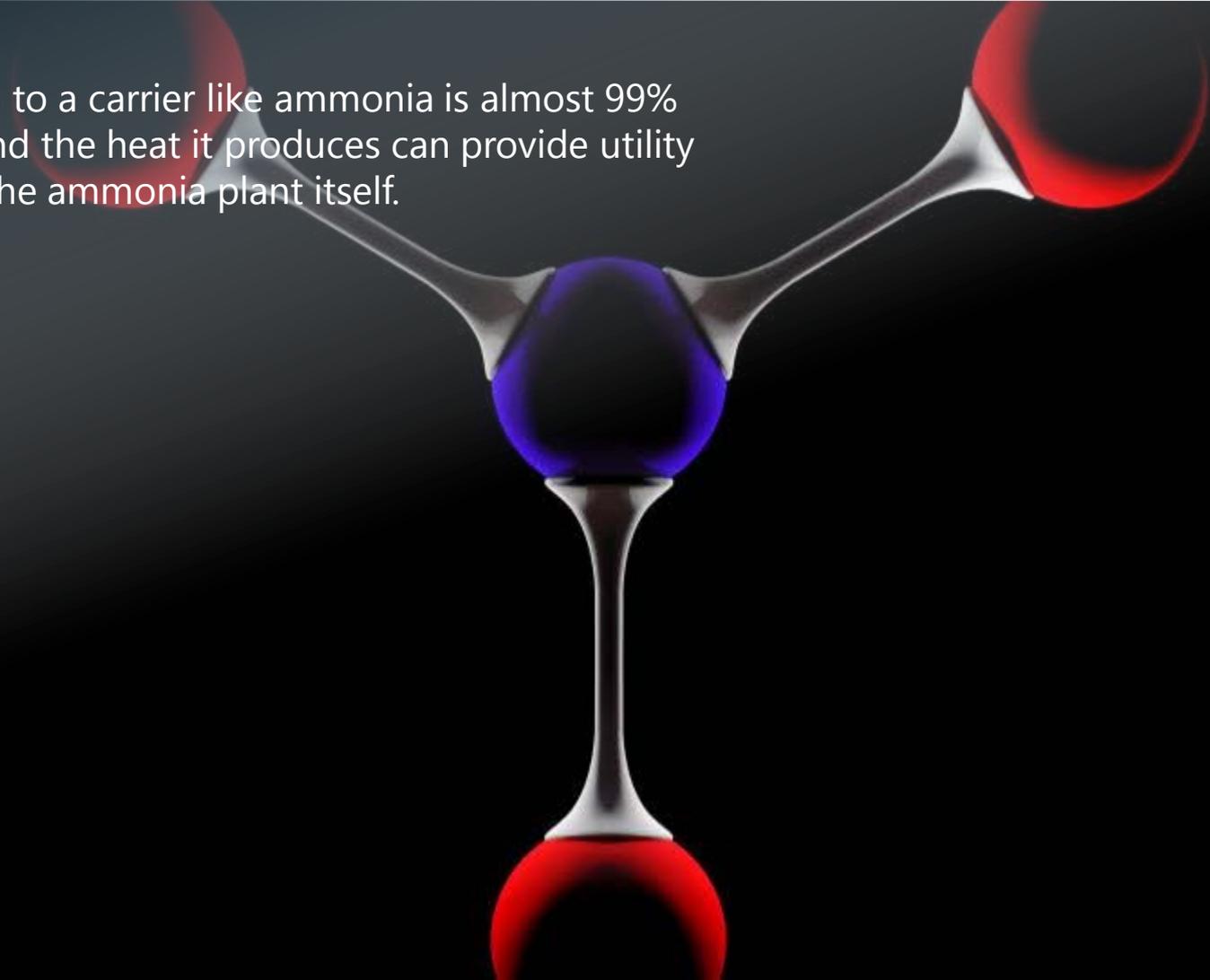
Compress the **H** or transform it (taking up less volume),  
you have a renewable electricity export vector  
that can be transported



Industrial scale electrolysis loses almost 30% efficiency, but it does produce hydrogen gas – which needs to be converted so it can be transported.



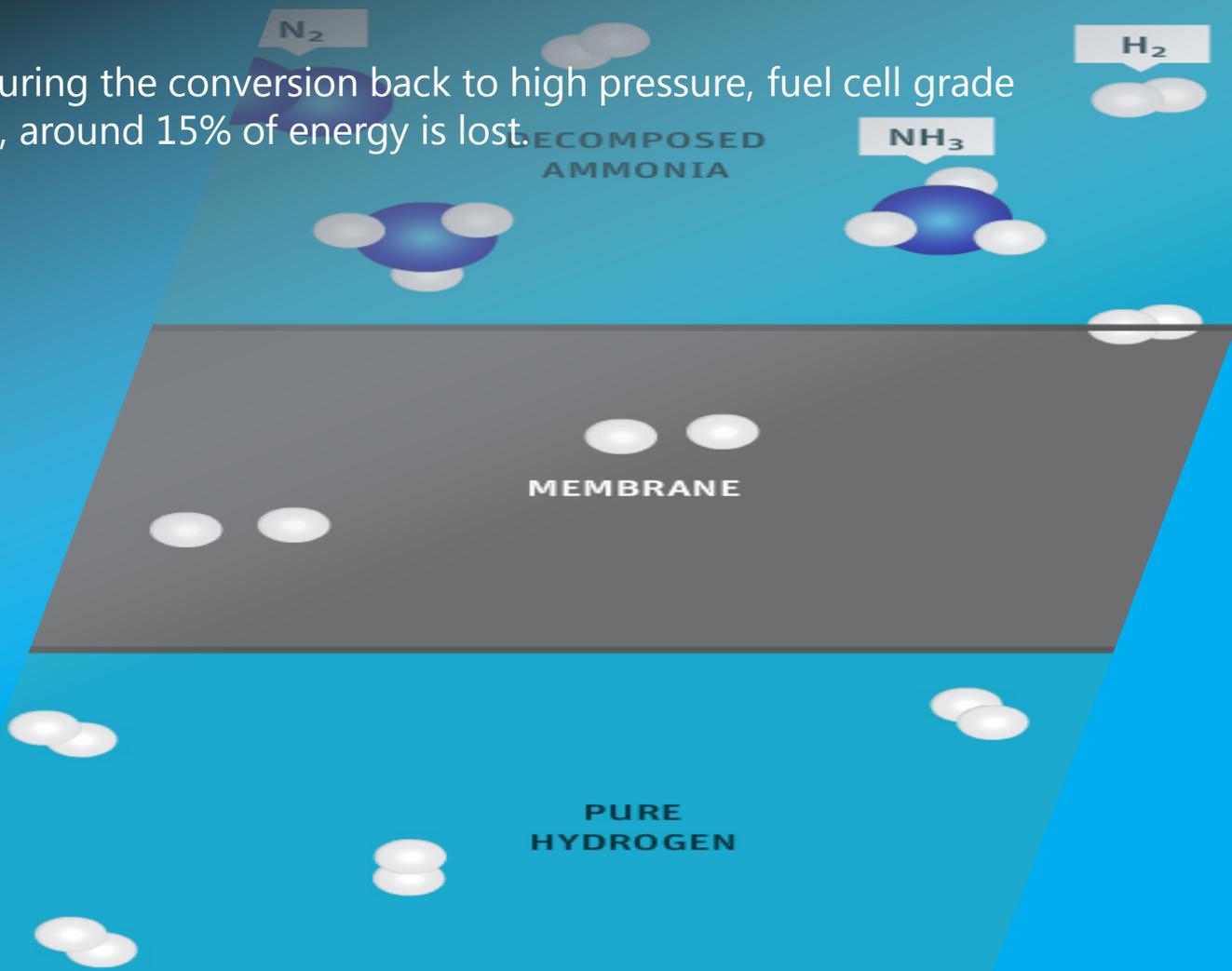
Conversion to a carrier like ammonia is almost 99% efficient, and the heat it produces can provide utility needs for the ammonia plant itself.



Ammonia then needs to be shipped, where it loses a small amount of energy. It then needs to be converted back to **H**.



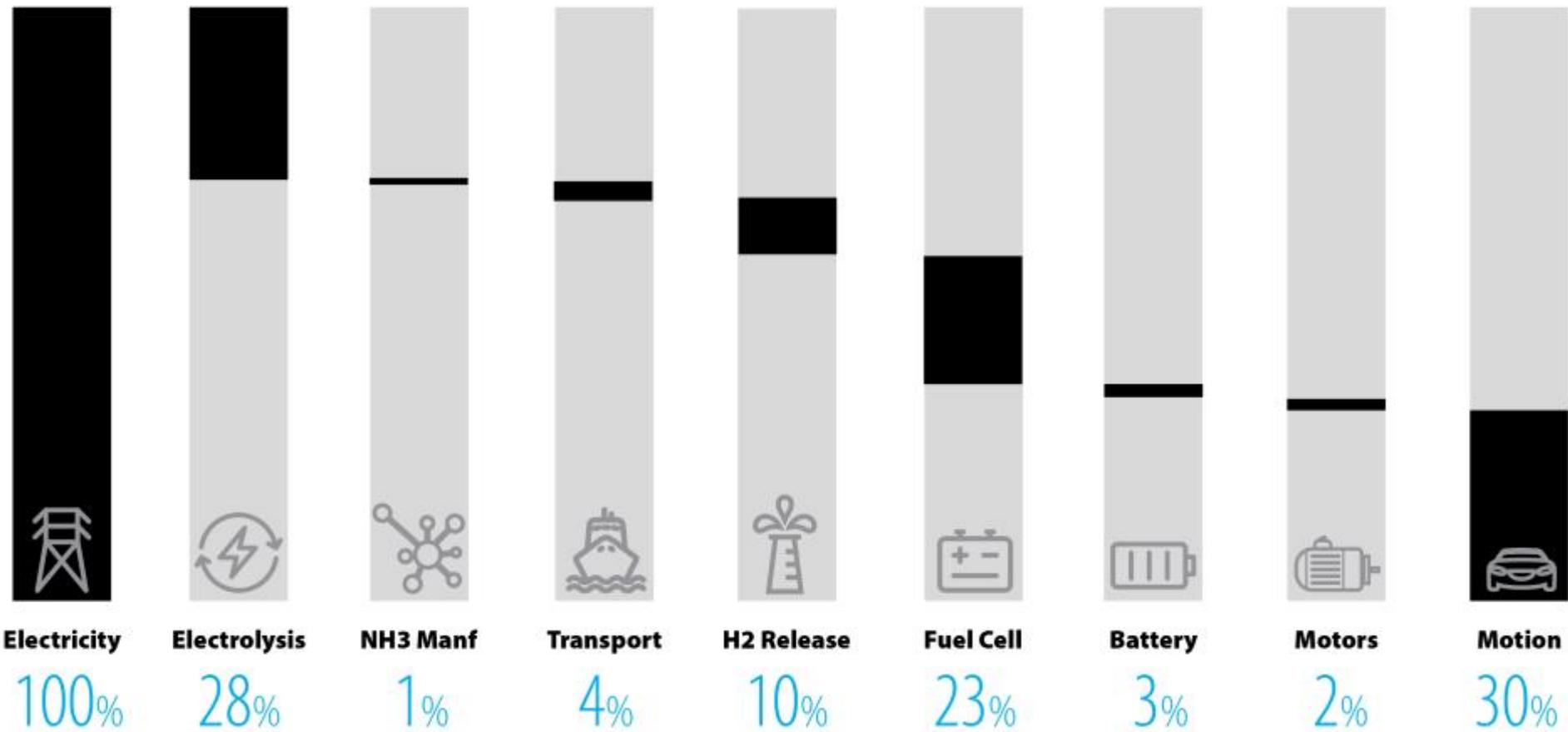
During the conversion back to high pressure, fuel cell grade **H**, around 15% of energy is lost.



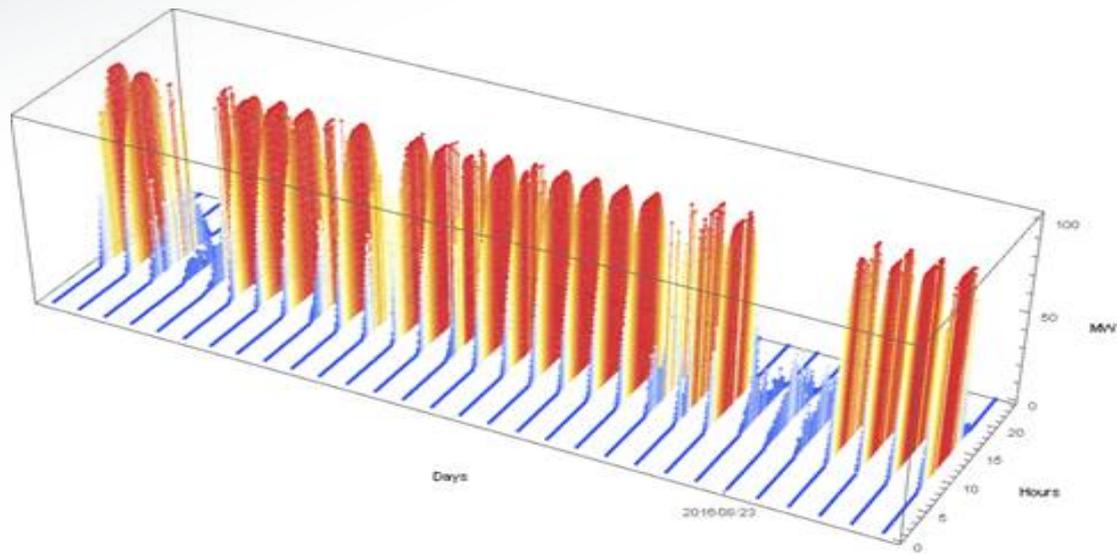
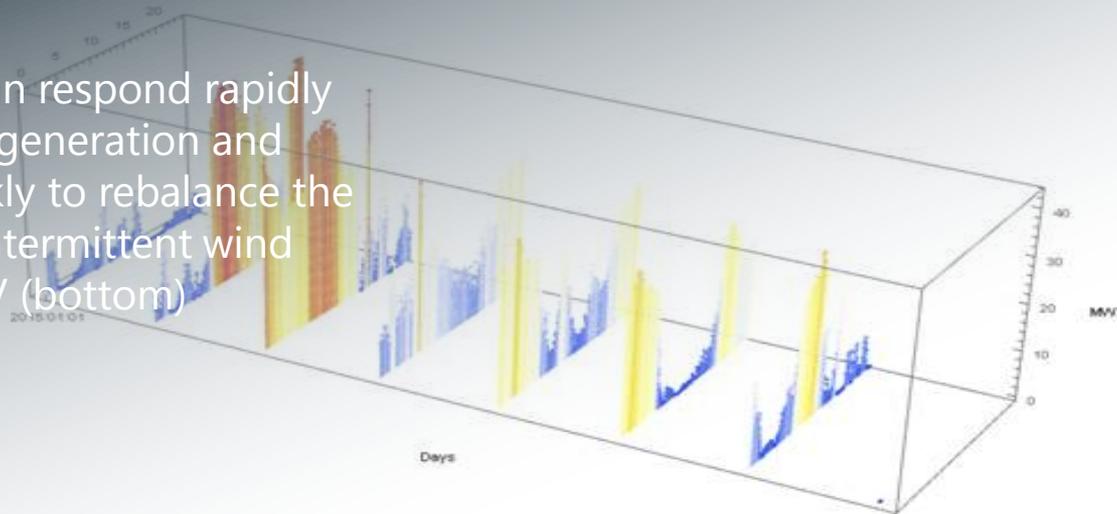
Fuel cell vehicles use **H** combined with oxygen in the air to make water, and electricity to charge the battery; meaning they're battery electric vehicles with an on-board charger.



Only 30% of the energy from the electricity generated makes it to provide motion to a fuel cell vehicle



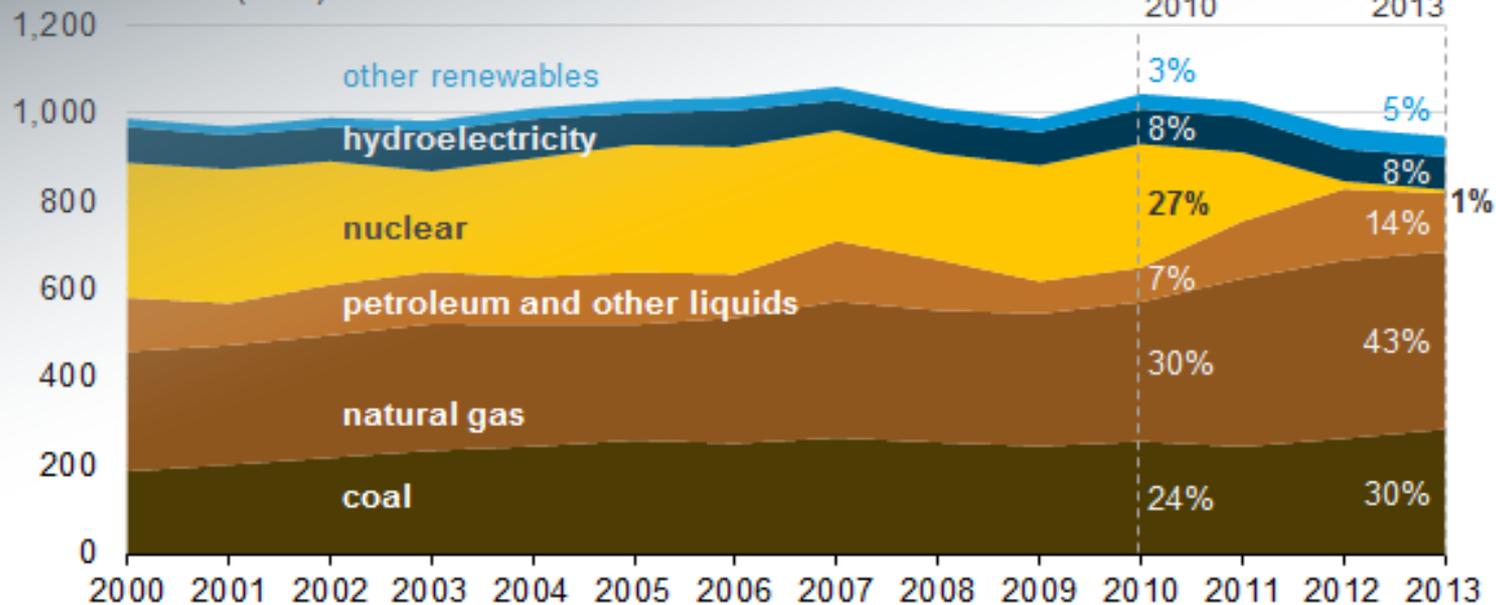
**H** electrolyzers can respond rapidly to absorb excess generation and reduce load quickly to rebalance the grid to support intermittent wind (top) and solar PV (bottom) generation.



Some countries must import energy; H can provide a lower carbon source.

Japan's net electricity generation by fuel, 2000-2013

terawatthours (TWh)

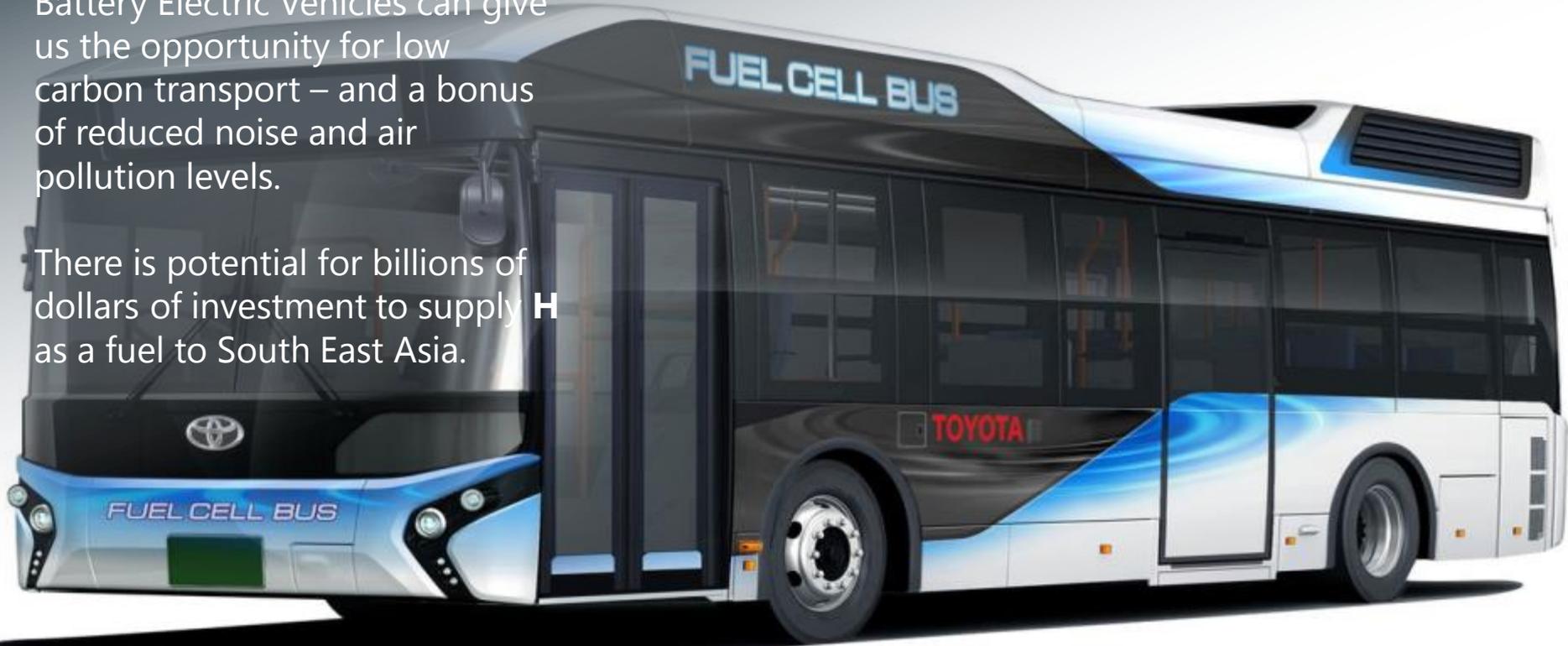


Fukushima  
March 11, 2011



In transport, **H** fuel cell and Battery Electric Vehicles can give us the opportunity for low carbon transport – and a bonus of reduced noise and air pollution levels.

There is potential for billions of dollars of investment to supply **H** as a fuel to South East Asia.



In the stationary energy space, coal and natural gas dominate.

However if a number of key factors i.e. electrolyser efficiency, etc. improve then **H** could become the low carbon, low cost energy export fuel.



Maybe it could even undercut the delivered price of LNG in South East Asia?

Now that would be an industry that could take off!



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