Green hydrogen, how is it made, and will it be the fuel of the future?

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Cigre Egypt Site:

https://cigre.moere.gov.eg/

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- Hydrogen is the chemical element with the symbol H and atomic number 1.
- With a standard atomic weight of 1.008, hydrogen is the lightest element in the periodic table.
- Hydrogen is the most abundant chemical substance in the universe, constituting roughly 75% of all baryonic mass.
- Hydrogen is a non-toxic colorless gas, even when it's referred to as green hydrogen.

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How is hydrogen generated?

- There are no natural hydrogen deposits on earth, it must be extracted from other compounds by a chemical process.
- Most of the industrial hydrogen is currently produced from natural gas through a process known as steam methane reforming or SMR.
- Producing hydrogen in this way is sometimes referred to as brown or grey or even blue hydrogen!

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What is blue hydrogen?

- Blue hydrogen is when natural gas is split into hydrogen and CO_2 either by Steam Methane Reforming (SMR) or Auto Thermal Reforming (ATR), but the CO_2 is captured and then stored.
- As the greenhouse gasses are captured, this mitigates the environmental impacts on the planet.
- The 'capturing' is done through a process called Carbon Capture Usage and Storage (CCUS).
- **What is green hydrogen?**
- Green hydrogen is hydrogen produced by splitting water by electrolysis.
- This produces only hydrogen and oxygen.
- We can use the hydrogen and vent the oxygen to the atmosphere with no negative impact.

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What is grey hydrogen?

- Grey hydrogen has been produced for many years.
- It is a similar process to blue hydrogen – SMR or ATR are used to split natural gas into Hydrogen and CO_2.
- But the CO_2 is not being captured and is released into the atmosphere.

What is pink hydrogen?

- Similar to green hydrogen, pink hydrogen is made via electrolysis, but using nuclear energy as its source of power.

What is yellow hydrogen?

- Another type of hydrogen made by electrolysis is yellow, where electrolysis is achieved solely through solar power (unlike green which could use a combination of renewable energy sources such as wind or solar).

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This is how we come to all the different shades of hydrogen:

- brown hydrogen is produced using coal where the emissions are released to the air
- grey hydrogen is produced from natural gas where the associated emissions are released to the air
- blue hydrogen is produced from natural gas, where the emissions are captured using carbon capture and storage
- green hydrogen is produced from electrolysis powered by renewable electricity

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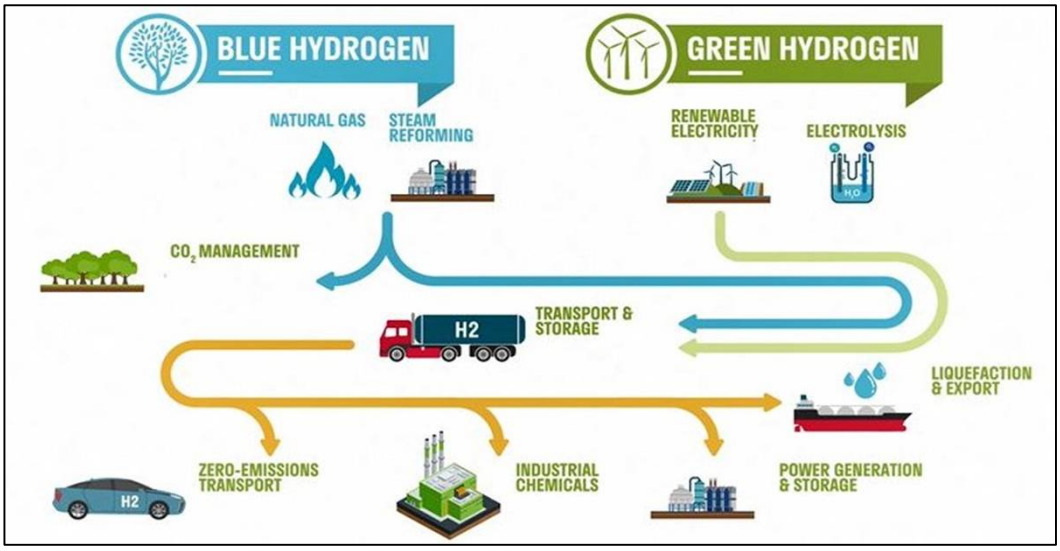

A comparison of production process for the "blue" and "green" types of hydrogen.

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Is the future multi-coloured?

- The future is a transition from grey, through blue, to green hydrogen.
- One thing that is clear is the important role hydrogen will play in energy transition.
- To meet the global energy demand, while achieving the national and global energy efficiency targets, the industry is looking at every potential technology.
- There is great potential in both the blue and green hydrogen and both will play an important role in energy transition.

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What are the by-products of hydrogen generation?

- Steam methane reforming (SMR) reacts the methane in natural gas with high-temperature steam in the presence of a catalyst.
- This produces hydrogen, and ultimately carbon dioxide, CO_2.
- As natural gas is relatively cheap, the hydrogen produced is also relatively cheap.
- The standard SMR process has the considerable disadvantage of releasing large quantities of CO_2 into the atmosphere, CO_2 is well known to be a highly significant greenhouse gas.

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- It’s less well known that methane itself has a global warming potential that is 85 times higher than CO_2.
- Any small gas leakage of methane from its source and on through the process is also a significant contributor to climate change.
- The unlimited production of hydrogen using SMR is a major issue in our attempts to avoid climate disaster.

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Carbon Capture and Storage – CCS

- Versions of steam methane reformation where the CO_2 is captured and stored in a stable form elsewhere.
- (Carbon Capture and Storage – CCS) has been proposed as a better alternative.
- CCS may well be workable, however there are doubts around our ability to manage and finance the storage of captured carbon through future decades and probably centuries or even millennia.
- Unfortunately, we don't have a good track record for managing the massive captured carbon deposits we've inherited.

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"green hydrogen" — hydrogen made without fossil fuels

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What is green hydrogen? How can it be used?

- There is a cleaner way of getting hydrogen: a strong electrical current passed through a tank of water splits the molecule into its two constituent elements.
- This is called electrolysis.
- Hydrogen atoms form hydrogen molecules (H_2) and oxygen molecules pair up too.
- Each can then be bottled up.
- If the electricity is generated from renewable sources such as solar or wind, production of hydrogen in this way emits no greenhouse gasses.

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Green hydrogen production

- Green hydrogen represents a real opportunity to revolutionize the way we produce and use energy.
- We continue to strive towards becoming more environmentally friendly by reducing carbon emissions.
- Hydrogen can also be produced by the electrolysis of water (using an electric current to break water, H_2O, into its component elements of hydrogen and oxygen).
- If this electric current is produced by a renewable source (e.g. Solar PV or a wind turbine), the clean hydrogen produced is known as green hydrogen.

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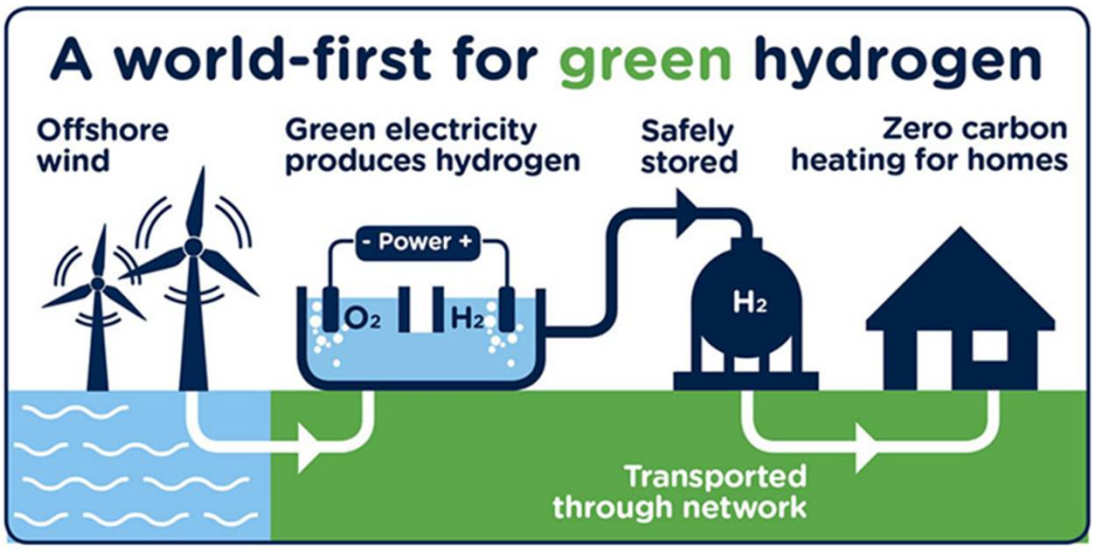

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Green hydrogen

- Our ability to produce large quantities of green hydrogen will play a major role in providing an alternative to fossil fuels.
- We work towards a clean, healthy environment.
- With electric cars becoming more and more popular, we need to rethink our strategy for electricity generation if we are going to support the increased amount of EV drivers that will be on the road needing to charge their electric cars.
- Through the use of green hydrogen, we can foresee a sustainable future in handling this increased demand.

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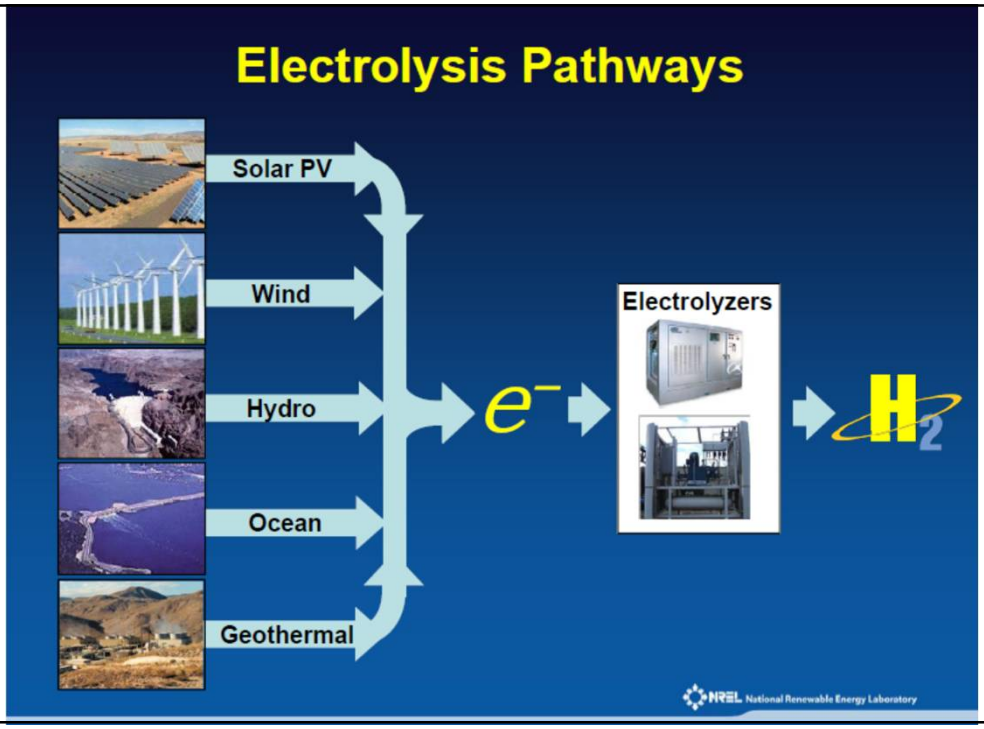

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Why Renewable Hydrogen?

- Virtually any primary energy source can be turned into hydrogen opening the possibility of hydrogen becoming a universal fuel.
- Renewable Hydrogen contributes to our National energy objectives

➢**Energy Security**

➢**Environmental Stewardship (protection)**

➢**Economic Competitiveness**

- Using hydrogen as an energy vector helps mitigate the intermittency of renewable energy sources by providing opportunities for storage.

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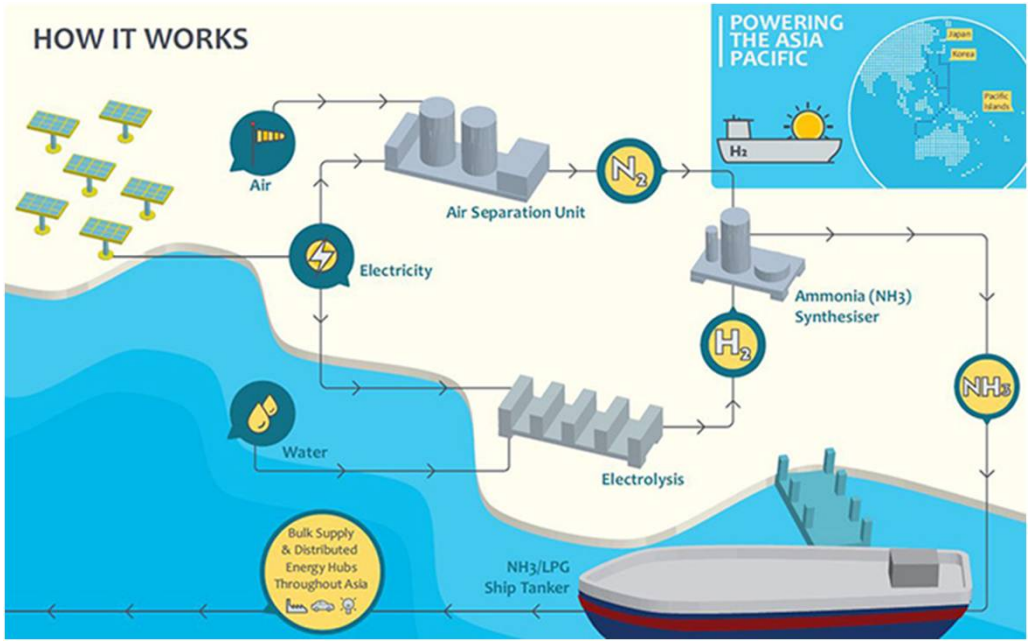

How renewable hydrogen is produced

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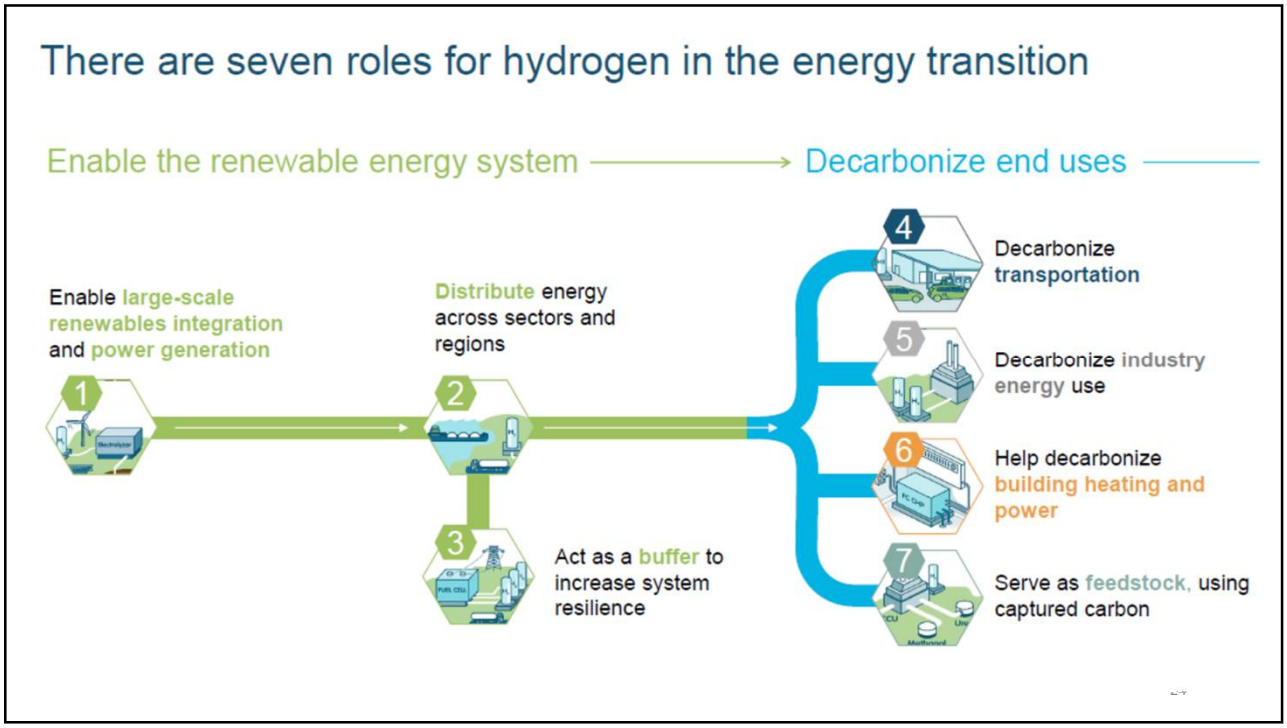

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Important milestones can be reached already in 2030

- **10-15 million** fuel-cell **vehicles** on the road, including private cars, taxis, vans and light commercial vehicles

- **3.5 Mt** hydrogen used for **high-grade heat** in first large-scale projects

- **50 million households** connected to a network safely blending hydrogen and natural gas

- **50 Mt CO_2** converted to chemicals and intermediates such as **methanol** using hydrogen

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Hydrogen benefits energy systems, environment and business

13%
of total energy demand in 2050

7.5 Gt
annual CO_2 abate-ment in 2050

USD 4,000 bn
annual sales in 2050 (hydrogen and applications)

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Hydrogen as the fuel of the future

- Abundant, cheap and clean-burning, hydrogen has long been described as the fuel of the future.
- That future has never quite materialized, however, due to hydrogen's disadvantages.
- It's difficult to transport, it can make metal brittle and it's 20 times more explosive than petrol.
- In recent years, has been identified as the clean energy source that could help bring the world to net-zero emissions.

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- Billions of dollars of investment capital and taxpayer support has flowed into the industry, and company share prices have soared.
- This has accelerated in recent months, driven by the rising adoption of zero-emission vehicles, a deadline set by many countries to go carbon-free by 2050.
- The European Union plans to scale up renewable hydrogen projects and invest a cumulative amount of 470 billion euros ($740 billion) by 2050.

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"Where green hydrogen is almost inevitably going to work is where green energy is going to be almost free,"

A large solar array in Karnataka state in India, a country that has some of the largest solar arrays in the world.

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How can green hydrogen be used?

Hydrogen can be used in broadly two ways.

- It can be burnt to produce heat or fed into a fuel cell to make electricity.

A 2018 Australian report outlines several potential applications for hydrogen:

- fuel-cell hydrogen electric cars and trucks
- container ships powered by liquid ammonia made from hydrogen
- "green steel" refineries burning hydrogen as a heat source rather than coal
- hydrogen-powered electricity turbines that can generate electricity at times of peak demand to help firm the electricity grid
- as a substitute for natural gas for cooking and heating in homes.

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A few big caveats (warnings)

- Like any gas, hydrogen can be compressed and stored in tanks, then used as needed.
- However, the volume of hydrogen is much larger than that of other hydrocarbons; nearly four times as much as natural gas, for instance.
- Its storage requires compression to 700 times normal atmospheric pressure or refrigeration to minus 253 degrees Celsius, which is near absolute zero.
- It's estimated that the cost of doing this could add anything from 60 cents to $7 per kg, making it less competitive with other fuels.
- On top of the cost of storage, there's a problem with pipes.

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- Hydrogen atoms under pressure are small enough to slip through solid steel, meaning natural gas plumbing often cannot be easily converted for pumping hydrogen.
- Appliances set up for natural gas, like stoves and heaters, would also need to be replaced or refitted to handle hydrogen.
- Given that's the case, in many cases it might be easier to simply use electricity.
- "However, there are certain things you might not be able to directly electrify, or there might be some places where you're not able to generate renewable energy".
- "In these places, having a liquid fuel is a very useful thing.
- "That's where green hydrogen could be a very useful part of the puzzle."

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- One solution to transportation problems is converting the hydrogen into ammonia (where three hydrogen atoms bond to a nitrogen to make NH_3).
- Unlike hydrogen, ammonia can be relatively cheaply stored under pressure or refrigerated as a liquid at -33C at normal atmospheric pressure.
- For many applications, once it arrived at its destination, the ammonia would then have to be converted back into hydrogen.
- With each conversion — from water to hydrogen to ammonia and back to hydrogen — energy is lost.

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- Electric vehicles have 'won' transport: experts say.
- Because of these shortcomings, hydrogen will struggle to compete with electricity in most situations.
- "Creating a whole new hydrogen grid will take decades and why bother when we already have an option that will be cheaper than gasoline and diesel in the 2020s?"
- Hydrogen will have a more niche role and be used for industry in regional and rural areas.
- Electric vehicles powered by lithium-ion batteries have "won" the battle for transport.
- "They're clearly the better option. We just need to roll it out."

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NREL Hydrogen Technology Thrusts

- Hydrogen production
- Hydrogen delivery
- Hydrogen storage
- Hydrogen manufacturing
- Fuel cells
- Technology validation
- Safety, codes, & standards
- Analysis

NREL: National Renewable Energy Laboratory

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Thank you

"Vision without action is a daydream. Action without vision is a nightmare."

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