Hydrogen Will Not Save Us. Here's Why. The trouble with Hydrogen?
https://www.youtube.com/watch?v=Zklo4Z1SqkE&ab_channel=SabineHossenfelder

Today I want to talk about something light. Hydrogen. Hydrogen is one of the currently most

popular alternatives to fossil fuel in transport. Many companies and nations have put money into

it. In 2021, the number of hydrogen-fueled passenger cars bought in the UK was 12.

Does that sound like a booming business? Not exactly. Indeed,

a report from the British Science and Technology Committee that just

appeared last month warned that “we do not believe that [hydrogen] will be the panacea

to our problems that might sometimes be inferred from the hopes placed on it”.

Ouch. So what’s the deal with hydrogen? Hope or hype? That’s what we’ll talk about today.

Hydrogen is the first element of the periodic table. If you mix it with
Hydrogen Basics

oxygen and put fire to the mixture you get water. This reaction releases energy,

so if you do it under controlled conditions, you can drive a motor or turbine with it. The

only exhaust you get is pure water, no carbon dioxide, no nitrogen oxides, no particulates,

no radioactive waste, no chopped-up birds. It’s really difficult to complain about pure water.

But let’s not give up that easily, certainly we can find something to complain about. For example,

hydrogen is a gas that, at normal atmospheric pressure and temperature,

takes up a lot of volume, and it’s somewhat impractical to drag a zeppelin behind your

car. That’s why to store and transport hydrogen, one compresses it by putting it under a lot of

pressure. Typically, that’s something like 700 bar, or about 700 times atmospheric pressure.

At that pressure, the energy that one gets out of one litre

of hydrogen is one sixth of the energy one gets out of one litre of gasoline.

This means if you power a car with hydrogen, one needs more litres of hydrogen than one

needs litres of gasoline to cover the same distance. But litres are a measure of volume.

The amount of energy you get out of hydrogen per mass is about twice as high as what you get from

gasoline. Then again, since the hydrogen must be kept under high pressure hydrogen tanks tend to be

heavy compared to gasoline tanks. When everything is said and done, hydrogen–powered cars end up

being somewhat heavier than gasoline–powered ones, but it’s not such a big difference.

Okay, but how do you get the energy out of the hydrogen?

The technology for this isn’t new, it’s been around for more than 200 years. The

first hydrogen fuel cell was developed by William Grove in 1839 but it was only in

the 1960s that two engineers at General Electric proposed a smart way to go about

it. They developed what’s now called a Proton Exchange Membrane. Those keep

the hydrogen and oxygen largely separate and allow chemical reactions only at the

membrane. That way it’s much easier to control the reaction which also makes the system safer.

Those hydrogen fuel cells were then further developed by NASA. One of the first uses was

on the Gemini spacecraft, which was launched in the mid-1960s. They were

later also used on the Apollo spacecraft that carried astronauts to the moon and

for the space shuttle. The International Space Station uses hydrogen fuel cells

to generate electricity and also to produce drinking water for the astronauts on board.

So, hydrogen fuel cells have been around for a long time, but they’ve never been particularly
The Hydrogen Market

popular. One of the reasons has certainly been that there was simply no need for them, because

fossil fuels are considerably more convenient. Unfortunately, they have side-effects, which is

why companies like Hyundai and Toyota have been selling hydrogen-fuelled cars for about a decade.

BMW, Ford, and other automobile giants have plans for hydrogen cars, and some governments

are looking at hydrogen to power their transit systems, for example Scotland and Germany.

The UK with its measly 12 sales in 2021, I admit, is a particularly sad example. For one thing,

that’s only passenger cars. They also put about 50 hydrogen-powered

busses on the road. And globally the market doesn’t look quite as dire.

In total, about 16 thousand hydrogen powered cars were sold in 2021,

about three thousand 500 of those in the US. The total number of new cars sold in

2021 was about 67 million, so at the moment it’s about one in four thousand

new cars that’s hydrogen powered. It’s a small market, but it’s an existing market.

Some plans are extremely ambitious. For example, in May last year, the European

Union rolled out a strategy called REPowerEU, with the goal of replacing up to 50 billion

cubic meters per year of imported Russian gas with hydrogen. This’d mean replacing almost 10

percent of the EU’s total gas consumption with hydrogen power. That’s substantial.

It's not only Europe. Many other countries are also investing in hydrogen production

facilities, that includes Japan, Canada, Egypt, China, and the United States. For example,

in March last year, the company Green Hydrogen International unveiled plans

to create a plant in Texas that'll use 60 Gigawatt of electricity from solar and

wind to produce 2 point 5 billion kilograms hydrogen per year. It'll be called Hydrogen

City. And Individual companies are investing in it, too. Microsoft, for example, wants to

use hydrogen fuel cells as climate-friendly backup generators for their data centres.

As you see, hydrogen is booming. But.
The Colours Of Hydrogen

The first "but" that might spring to your mind is But where does the hydrogen come from? Now,

hydrogen is the most abundant element in the universe. Indeed,

three quarters of all normal matter in the universe is hydrogen,

but you normally can't buy it in the supermarket. So where do you get it?

Naturally occurring geological deposits of pure hydrogen are rare on Earth. Most of the

hydrogen we have is bound, either in water or in methane. And this is where the problem begins.

Because you have to break those chemical bonds to get the hydrogen and that requires energy.

Hydrogen is therefore not really a source of energy, but a storage system. You use energy

to create it in its pure form, transport it, and then you release this energy elsewhere.

How environmentally friendly this is depends strongly on where the hydrogen

comes from. To keep track of this, scientists are using a colour scale. You all know this,

but this is YouTube, so I have to say this anyway The hydrogen itself has always the same colour,

which is transparent. This colour scale is just a way of keeping track of the production method.

On this colour scale, the rare, naturally occurring hydrogen is white. Hydrogen obtained

from water using coal or lignite has the colours black or brown, respectively. Its production emits

carbon dioxide and methane; both are greenhouse gases. Gray hydrogen is derived from methane and

water; this also produces carbon dioxide and usually some of the methane escapes.

At the moment, almost all hydrogen is produced in one of those ways by using fossil fuels. According

to the World Energy Council, in 2019 more than 95 percent of the hydrogen worldwide was assigned

one of those colours, black, brown, or grey. This releases about 830 million tons of carbon dioxide per year. That’s 2 percent of the total global emissions and about the same as air traffic.

But there are more colours on the hydrogen rainbow. Next there is

blue. Like grey hydrogen, blue hydrogen is made from methane,

but the carbon dioxide is stored underground and does not escape into the atmosphere.

This method is currently only used for1 percent of hydrogen production, but it could be expanded.

The industry association Hydrogen Council has touted blue hydrogen as a climate-friendly

initiative. It’s not entirely irrelevant, so let me mention that this council was created by the

oil and gas industry. Many of its members have a financial interest in switching from natural

gas to hydrogen produced from natural gas. So maybe one shouldn’t take their argument

that blue hydrogen is climate-friendly for granted. Hasn’t someone looked into this?

Well, since you asked, in 2021, two American researchers calculated the amount of greenhouse

gases released by grey and blue hydrogen technology. They not only took carbon dioxide into

account, but also methane, which is a much more potent greenhouse gas. To make comparisons easier,

the greenhouse effect from methane is usually converted to a carbon dioxide equivalent, which is the amount of carbon dioxide that would have the same effect.

They came to the conclusion that grey hydrogen has a carbon dioxide equivalent of about 550

grams of carbon dioxide per kilowatt hour and blue only slightly less, 486 grams. That's about

the same as the emissions you get from using natural gas directly to generate electricity.

Part of the reason blue hydrogen performs so poorly is that not all the carbon dioxide from

hydrogen production is captured and stored. Another reason is that the process of storing

the carbon dioxide also requires energy and leads to carbon dioxide emissions. The authors estimate

that under the most favourable conditions, it might be possible to reduce those emissions

to around 200 grams of carbon dioxide per kilowatt hour by using renewable energy sources.

So blue hydrogen doesn’t help much with climate protection. Then there

is green hydrogen, which is produced from water using renewable energy.

Again that sounds good, and again, it’s not that simple. According to a calculation by researchers

from Australia, greenhouse gas emissions from green hydrogen produced with solar energy are

ideally about a quarter of those from grey hydrogen. Under realistic conditions, however, they find that emissions are comparable, particularly due to fluctuations in solar

radiation that make hydrogen production inefficient. There is neither data nor

any study for hydrogen production from wind but you expect this method to suffer even

more from fluctuations because wind is far less reliable than sunlight.

And since these methods are inefficient, they are also expensive. Indeed, producing

hydrogen with solar and wind is pretty much the most expensive way you can do it,

according to a review in 2019. Now maybe those costs will go down a bit

as the technology improves. But seeing that the biggest problem is that energy input

fluctuates I doubt it’ll become economically competitive with the “dirty” hydrogen.

This problem can be fixed by using nuclear power to generate hydrogen

which has been assigned the colour pink and purple. A few projects for

this are underway but it’s early days and nuclear power isn’t exactly popular.

Ok, so we have seen that it isn’t all that clear whether hydrogen is climate friendly,

and also, it’s expensive. And this is only the production cost. It doesn’t include the entire

infrastructure that’d be necessary to fuel a fleet of hydrogen cars. Remember you have to

keep the stuff at several hundred bars and you can’t just use a normal gas station for that.

Let’s move on to the next problem that might come to your mind where do we get the water
Water Supply

from? From a distance, the world has no shortage of water, but freshwater can be scarce in certain

regions of the planet. According to estimates from researchers at the University of Delaware,

however, water supply issues probably won’t stand in the way of a hydrogen economy. They

looked at a scenario in which we replace 18 percent of fossil fuels with hydrogen,

and found that this would require about 2 percent of the amount of freshwater that’s currently used

for irrigation. Watch out, this figure has a logarithmic scale. You also see on this figure

that using fossil fuels requires freshwater too, for cooling, mining, hydraulic fracturing,

and refining, and it’s currently actually more than the projection for hydrogen.

That’s 2 percent on the global average,

but in some regions the fraction can be higher. For example, estimates for

Australia are that you'd need about 4% of the water amount used for irrigation.

So that seems a manageable amount,

but it's something to take into account if you want to make this work.

Another problem with water is that it can freeze. This is why you shouldn't leave

the beer in the car in the winter. And it's also why hydrogen fuel cells like

it warm. If the temperature drops more than a few degrees below zero,
The Cold Start Problem

the water that the fuel cells create at start will freeze immediately, which swiftly degrades

the membranes and tubes. It's known as the "Cold Start" problem of hydrogen fuel cell. And, no, you

can't just pour antifreeze (not an "ai) into it, remember the water is created in the fuel cell.

So, you'll either have to stay in California or keep your car warm.

The solution that manufacturers pursue at the moment is pre-heating systems.

But the biggest problem for a hydrogen economy may be making
Rare Metal Shortages

those proton exchange membranes to begin with. It's not because it's so difficult,

but because they're made of platinum and iridium. Platinum you may have heard of, it’s an expensive noble metal that’s also used for jewellery. The reason it’s expensive is that

it’s rare. Iridium is also a noble metal. It’s so rare that most people have never heard of it.

Both of those metals are difficult to replace with anything else in the hydrogen fuel cells.

That’s a problem because it means that the entire hydrogen economy hinges on the availability of

those two metals. There’s only so much of those in the world and they are only in very specific

geological formations. Almost all the platinum and iridium supply comes from only three countries

South Africa, Russia, and Zimbabwe, and colonies have gone out of fashion recently.

China, which has invested heavily in hydrogen technology is already feeling the consequences.

And we’ve only just barely begun with building the hydrogen economy. This issue has been highlighted

recently in reports from various international organizations including the International Energy

Agency and the World Bank. According to the business consulting group Wood Mackenzie,

the increased demand for platinum might be manageable in the near future,

but it looks like by 2030 demand for iridium will be several times

higher than the supply. I don’t know much about trade, but I think this isn’t good.

It’s possible to make fuel cells somewhat more efficient and decrease the demand

for those rare metals. But this situation isn’t going to change

and iridium isn’t going to move to the US even if you ask it really nicely.
Hydrogen Embrittlement

One final problem that’s worth mentioning is that hydrogen is just nasty to deal with.

Hydrogen is the smallest molecule. If you squeeze it into a tank,

it’ll creep into the walls of the tank. That destroys the chemical structure of the

material and makes it brittle. It’s called “hydrogen embrittlement”. For this reason,

hydrogen tanks must be thick and specially coated, which makes them both heavy and

expensive. Like the cold start problem, this one’s basic chemistry and isn’t going to go away.

And the need to keep the hydrogen under pressure makes the stuff inconvenient to

handle. The city of Wiesbaden in Germany, for example, recently retired its six new hydrogen

powered busses because the filling station broke down, sinking a few million Euro.
Summary

In summary, hydrogen production at the moment has a high carbon footprint because it’s almost

exclusively done using fossil fuels. Reducing the carbon footprint of hydrogen production seems difficult according to estimates, but at the moment there’s basically no real-world data.

Hydrogen produced by wind and solar will almost certainly not be economically competitive with

that derived from fossil fuels but using nuclear power might be an option. Building infrastructure

for a transport-system based on hydrogen would eat up a lot of money. It seems that rare metal supply

for hydrogen fuel cells is going to become a problem in the near future which won’t help making

the technology affordable. Keeping hydrogen stored and under pressure [[under pressure]] adds to the

cost and makes those systems heavy which isn’t great for transport. And finally,

hydrogen-powered cars don’t like cold temperatures.

So. Well. It seems to me that the British Science and Technology committee is right.

A hydrogen economy isn’t a panacea for climate change. Indeed, the French have

a similar committee that likewise concluded “l’hydrogène n’est pas une solution miracle”.

I must admit that I was considerably more upbeat about hydrogen before I

started working on this video. How about you? Did

you learn something new? Did you change your mind? Let us know in the comments.

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