CLIMATE LEAP

How water could be the future of fuel

A new generation of fuels could power planes and ships without warming the planet.

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Photos and videos by Mark Felix for The Washington Post

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CORPUS CHRISTI, Tex. — The tangle of pipes at this industrial plant doesn't stand out in this city built around the carbon-heavy business of pumping oil and refining it into fuel for planes, ships, trucks and cars.

But this plant produces fuel from a different source, one that doesn't belch greenhouse pollution: hydrogen. Specifically, hydrogen made from water using renewable electricity, also known as green hydrogen.

The plant feeds water through machines that pull out its hydrogen atoms.

The hydrogen is then chemically transformed into diesel for delivery trucks.

This process could represent the biggest change in how fuel for planes, ships, trains and trucks is made since the first internal combustion engine fired up in the 19th century. In his 1874 science fiction novel “The Mysterious Island,” Jules Verne predicted that “water will be the coal of the future.” This plant, one of the first in the world to transform water into fuel, shows what that looks like on the ground today.

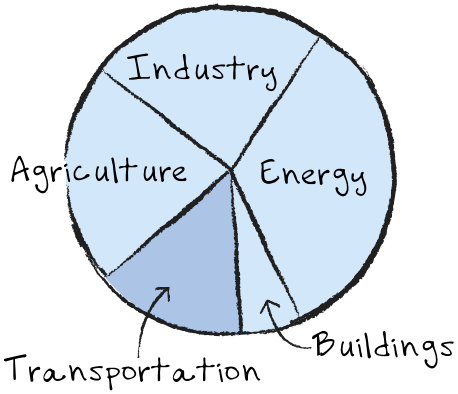
Turning hydrogen into liquid fuel could help slash planet-warming pollution from heavy vehicles, cutting a key source of emissions that contribute to climate change. But to fulfill that promise, companies will have to build massive numbers of wind turbines and solar panels to power the energy-hungry process. Regulators will have to make sure hydrogen production doesn’t siphon green energy that could go towards cleaning up other sources of global warming gases, such as homes or factories.

Climate Leap

Although cars and light trucks are shifting to electric motors, other forms of transport will likely rely on some kind of liquid fuel for the

A series examining the next batch of cutting-edge technologies to displace the world's biggest sources of global warming emissions.

This story focuses on transportation.



Global emissions by sector, IPCC report

e. Batteries are too heavy for planes and too bulky for
harging times could be an obstacle for long-haul
rail lines may be too expensive to electrify. Together,
resent roughly half of emissions from transportation,
t source of greenhouse gases.

s off oil, companies like Infinium, the owner of this
to churn out hydrogen-based fuels that — in the best
close to net zero emissions. They could also pave the
chnology, hydrogen fuel cells, to power planes, ships
second half of this century. For now, these fuels are
most no one makes them, so the U.S. government,
ilanthropists including Bill Gates are investing
to build up a hydrogen industry that could cut
of the most stubborn, hard-to-remove carbon

r how the world could avoid the worst effects of
nvision hydrogen cleaning up emissions in
transportation, as well as in fertilizer production and steel and chemical refining.

But if they're not made with dedicated renewable energy, hydrogen-based fuels could generate even more pollution than regular diesel, creating a wasteful boondoggle that sets the world back in the fight against climate change. Their potential comes down to the way plants like this produce them.

Here's what you need to make green hydrogen-based fuel:

Here it all starts with water.

The first step to make green hydrogen is opening the tap. Infinium makes hydrogen by splitting water molecules.

It's not an entirely new idea: Scientists discovered how to do this in the 18th century. By 1900, there were 400 industrial machines turning water into hydrogen to make fertilizer – but companies abandoned almost all of them when they discovered how to cheaply extract the gas from fossil fuels. It's now about three times cheaper to make hydrogen from fossil fuels than water.

This is a simplified representation of the way most hydrogen is produced now:
You take natural gas …

… and heat it up to separate it into carbon and hydrogen.

Those leftover carbon atoms combine with oxygen to create carbon dioxide, which vents into the atmosphere.

But to make green hydrogen, you take hydrogen from water and all you have left is pure oxygen.

Why use hydrogen as a fuel?

It's the most abundant element in the universe and its molecules store a lot of energy. It takes a lot of energy to bind two hydrogen atoms into a molecule — and once they're connected, the bond is very unstable. The hydrogen atoms are itching to break apart and release all their energy the moment there's enough heat and oxygen to kick off a chemical reaction.

That's a useful property inside an internal combustion engine, which uses tiny explosions to turn a crank that spins the wheels of a truck or the propeller of a boat.

Green hydrogen could also cut carbon pollution beyond transportation, as an ingredient in fertilizers or to refine steel, chemicals and oil. Today, making hydrogen out of fossil fuels for those industries generates 2 percent of global carbon emissions. Overall, plants that make hydrogen out of water — or make it out of fossil fuels and capture carbon — could cut 4 percent of global carbon

emissions by 2050, according to the International Energy Agency, an advisory group that represents 44 countries.

To make transportation fuel, Infinium plant operators first pull the hydrogen out of water.

This transformation happens in a nondescript beige container at the center of the plant. Inside is an electrolyzer.

Electrolyzer

4. Infinium keeps the hydrogen and vents the oxygen into the atmosphere.

1. Water is piped in, cooled and filtered.

2. An electric current breaks water molecules.

3. A filter separates the hydrogen from the oxygen.

The two electrolyzers here are rare specimens outside of research labs and small-scale pilot projects. Manufacturers are still perfecting the machines' designs and they're just starting to build big factories that can turn out lots of electrolyzers at low cost.

David Eaglesham, who co-founded the billion-dollar electrolyzer startup Electric Hydrogen, imagines a world where companies can buy electrolyzers off the shelf and run them in plants that produce tens of thousands of tons of hydrogen a year. That's still years away as companies like his start to open factories.

But cheap electrolyzers alone aren't enough to produce the amount of green hydrogen needed to fuel heavy transportation. "If the [electrolyzer] stack was free, you wouldn't solve the problem," Eaglesham said. It takes a lot of energy to split water molecules and force the hydrogen atoms to bond with one another.

Water
Electricity

The other all-important ingredient to make green hydrogen is cheap, green energy. Without a massive amount of renewable electricity, clean hydrogen-based fuels are a fantasy.

On the horizon surrounding the Infinium plant, renewable electricity is starting to materialize in the shape of towering wind turbines. They’re part of one of the fastest-growing networks of wind and solar power in the United States.

Nearby wind turbines
feed the Texas grid,
which powers the plant.

But even here, only about 40 percent of the power on the electric grid is from renewables, with the rest coming from natural gas and coal, according to state data. That grid energy is what flows through the power line into the Infinium plant.

The danger of using grid power for hydrogen production is that, across the United States, just like in Texas, 60 percent of that energy comes from fossil fuels. Making hydrogen from electricity that dirty is worse than simply making it from fossil fuels, according to an April 2023 analysis from Energy Innovation, a clean energy think tank.

Experts say that for green hydrogen to be truly clean, it has to be made at a plant hooked up to its own dedicated wind turbines and solar panels, or follow strict rules for using newly added renewable electricity from the grid. Federal officials are setting clean power rules that will decide which hydrogen plants qualify for billions of dollars in tax credits.

The stakes are high: If the rules are too lax, the government could subsidize hydrogen production that adds as much as 60 million extra tons of carbon to the atmosphere each year, according to an Energy Innovation analysis published in

February.

“Unless those Treasury rules are strict and rigorous … then we’re going to be in a very perverse place of paying hundreds of billions of dollars of public money to increase emissions from hydrogen production,” said Rachel Fakhry, policy director for emerging technologies at the Natural Resources Defense Council.

The Infinium plant follows the rules regulators have proposed so far, and CEO Robert Schuetzle says the plant will make any changes necessary to follow the final rules. For now, the company says it pays extra to certify that, over the course of each year, recently built wind turbines and solar panels produce as much electricity as the plant uses.

Water
Electricity
Carbon

Once they separate hydrogen from water, plant operators still need to put it through one last step before the fuel they produce can be pumped into a vehicle's tank. They mix it with carbon.

Most vehicles today can't handle pure hydrogen, and neither can the network of fueling stations for planes, ships and trucks.

Hydrogen is the least dense substance in the universe. It's so light that if you released it into the air it would float into space. To store it and use it, you have to cool it below -253 degrees Celsius and compress it until the air pressure is

several hundred times higher than our atmosphere. Even then, it takes up much more space than other fuels, which makes it expensive to transport on ships and trucks. The best way to move it is by pipeline, and hundreds of miles of hydrogen pipelines already exist in Texas, but expanding that network will be time-consuming and costly.

One day, heavy transportation may shift to fuel cells that run on pure hydrogen and emit only water vapor from their tailpipes. But planes, ships and trucks have decades-long lifespans, meaning every vehicle built to use fossil fuels is likely to keep running for a long time.

So for now, carbon remains a necessary ingredient in hydrogen-based fuels, which still release CO2 from the tailpipes of vehicles that burn them.

Infinium produces chemical copies of existing fuels made with crude oil — which are all some combination of hydrogen and carbon.

Diesel, for example, is .

Instead of rearranging the molecules in crude oil ...

... Infinium makes its fuel by combining captured carbon with
green hydrogen.

Those carbon atoms arrive at the plant in the form of carbon dioxide pumped in from six nearby oil refineries. Typically, those facilities would let that CO2 — released when distilling crude oil into gasoline, jet fuel, diesel and other products — waft into the air.

Pipes carry in water and carbon dioxide from nearby refineries.

Carbon dioxide

Water

Instead, Infinium combines that CO2 with hydrogen in a series of steel tanks that heat the gases, cool them, change their pressure, and set off a chain of chemical reactions that turns them into a mixture of diesel and naphtha, which is used in making plastic.

CO2 gets mixed
with hydrogen ...

... that mix gets
transformed
into diesel.

The final fuel gets

... and transported
out of the plant
in trucks.

Infinium won’t say how much it charges, but a 2022 study from Ford and researchers in Sweden and Denmark suggests this kind of diesel could cost around $9 per gallon to produce, more than double current U.S. prices. The diesel goes to clients such as Amazon, which will use it to fuel trucks carrying packages on long-haul routes across the country. (Amazon founder Jeff Bezos owns The Washington Post.) Factories elsewhere will turn the naphtha into household goods.

Infinium's fuel is chemically identical to regular diesel made from oil. When a truck driver steps on the accelerator, this hydrogen-based fuel will release just as much carbon dioxide from the tailpipe.

But proponents say there's a key difference: Burning fuel made from oil takes carbon that had been stored underground for millions of years and releases it into the atmosphere.

On the other hand, capturing carbon from the air or factory smokestacks, turning it into fuel and then releasing it again recycles carbon that was already floating around. It doesn't put any new carbon into the atmosphere.

A truck running on diesel made from hydrogen using only renewable electricity would create 89 percent fewer greenhouse gas emissions over the course of its lifetime than a truck burning diesel made from petroleum, according to a 2022 analysis from the European nonprofit Transport & Environment.

Today, the Infinium plant is a blip of green fuel production among the miles of oil and gas refineries that sprawl along the coast near the Port of Corpus Christi. To avoid climate disaster, those fossil fuel facilities would have to be replaced by wind turbines, solar panels, biofuel refineries and plants such as this one, which turn water — not oil — into fuel.

About this story

We spoke to more than 20 experts — scientists, hydrogen producers, electrolyzer manufacturers, fossil fuel executives, energy analysts and climate watchdogs — about the state of the hydrogen industry and its carbon-cutting potential.

José Miguel Bermúdez Menéndez, a hydrogen analyst at the International Energy Agency; Martin Tengler, head of hydrogen research at BloombergNEF; and Nikita Pavlenko, who heads the fuels program at the International Council on Clean Transportation, walked us through the models that predict hydrogen's role in avoiding the worst effects of climate change. Dan Esposito, the manager for electricity policy at Energy Innovation, explained how electricity regulations will determine whether hydrogen becomes a climate solution or a climate problem. Mijndert Van der Spek, an associate professor of chemical engineering at Heriot-Watt University in Edinburgh, Scotland, broke down the emissions differences between making hydrogen from water vs. fossil fuels. Our illustrations of the chemical processes behind hydrogen production were informed by Naomi Boness, co-managing director of the Stanford Hydrogen Initiative. All the illustrations are simplified representations of the chemical processes described.

522 Comments

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