

The ideal fuel still doesn't exist, but hydrogen is closing in

The ideal fuel debate revolves around identifying an energy source that is high-calorific, affordable, low-emission, and easily available. Natural gas and LPG are currently favoured as cleaner, efficient, and practical options. However, the transition from fossil fuels to alternatives such as biofuels and green energy continues to spark debate, particularly around issues like food versus fuel, land use, and scalability.

In aviation, Sustainable Aviation Fuel (SAF) and hydrogen are emerging as complementary solutions for decarbonisation. SAF is viewed as the primary near-to-medium-term option, offering a "drop-in" replacement compatible with existing aircraft engines and infrastructure. Hydrogen, by contrast, is a long-term, zero-emission solution, likely to be limited to short-haul flights due to storage and infrastructure constraints, or used indirectly to produce synthetic fuels such as power-to-liquid (PtL) SAF.

As of 2026, the automotive market is steadily transitioning toward cleaner alternatives. Electric vehicles (EVs) offer the lowest operating costs, approximately ₹0.80 per kilometre in India, along with zero tailpipe emissions. Hydrogen fuel-cell electric vehicles (FCEVs) provide rapid refuelling within 3-5 minutes and long driving ranges. Despite these advances, petrol and diesel vehicles continue to dominate due to their deeply entrenched infrastructure.

Compressed natural gas (CNG) and LPG are widely regarded as bridge fuels. They are generally cheaper than petrol and diesel but still emit greenhouse gases, limiting their long-term role in decarbonisation.

Hydrogen vehicles generate electricity on board by using hydrogen gas in a fuel-cell stack, emitting only water vapour as a by-product. This allows for fast refuelling, comparable to conventional fuels, and long driving ranges, making them particularly suitable for long-distance and heavy-

duty applications. However, the lack of refuelling infrastructure remains a major hurdle.

Hydrogen is the most abundant element in the universe and is present in water and organic matter. It is this abundance that technology developers are now trying to harness at scale.

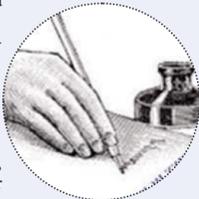
The process of producing hydrogen can be straightforward: electricity is used to split pure water into hydrogen and oxygen through electrolysis. The hydrogen is then compressed or liquefied and stored for use in vehicles. When produced using renewable electricity, the process avoids fossil fuels entirely, meaning the only emission from the vehicle's exhaust is water.

However, much of today's industrial hydrogen is produced using natural gas, resulting in what is known as "blue hydrogen". While this still lowers emissions compared to conventional fuels, it is not fully carbon-free.

A full tank of hydrogen can deliver a driving range of around 400 miles, though access to refuelling stations remains limited.

Hydrogen fuel-cell vehicles convert chemical energy into electricity far more efficiently than internal combustion engines. Fuel cells typically achieve around 60% energy conversion efficiency, compared with 20-30% for petrol engines. While EVs lead with efficiencies of up to 90%, they are constrained by battery capacity, charging time, and grid availability. Hydrogen vehicles also perform reliably across extreme weather conditions, from freezing winters to intense heat, adding to their appeal.

For the hydrogen sector, 2026 marks a shift away from distant promises toward real-world execution. The focus is no longer only on long-term climate goals, but also on immediate priorities such as energy security, industrial competitiveness, and system resilience. This signals a maturation of the industry, from a niche climate solution to a central arena of global economic and strategic competition.



Cuba has outlasted every US embargo, but Trump's may be the harshest yet

A sweeping blockade and threats to third countries are pushing the island into dangerous territory

JAMES TRAPANI

AFTER toppling Venezuela's leader earlier this year, the Trump administration has turned its sights on Cuba. The near-total blockade of the island is now posing the greatest challenge to the government since the Cuban missile crisis in 1962. Cuba is quickly running out of oil, creating a dire political and economic crisis for the island's 11 million residents.

US President Donald Trump's embargo has prevented any oil tankers from reaching the island for months. A ship carrying Russian fuel is now reportedly on the way to the island to attempt to break the blockade, but the US has seized other ships that have previously tried. The Trump administration has also threatened tariffs on any nation that tries to send Cuba fuel, putting Latin American leaders in an uncomfortable position. Mexican President Claudia Sheinbaum has called out the embargo as "very unfair", but she's been careful not to antagonise Trump by putting an emphasis on the Cuban "people", not the government. This is not the first time the US has isolated Cuba, or coerced Latin American leaders to take part.

Cuba has been under a US embargo for the past 66 years, which has stunted its economy and caused widespread human suffering. The island has always found a way to get by, but can it survive this new round of American pressure? Animosity grows in the 1950s. The Cuban Revolution caught the United States by surprise in 1959. During the Cold War, the US had supported dictatorships in Latin America, such as Cuba's Fulgencio Batista, with political, financial and military support, creating widespread anti-US activism across the region. After com-

ing to power, revolutionary leader Fidel Castro instituted modest reforms to land tenure and infrastructure to support the impoverished people.

Then-US President Dwight Eisenhower opposed these moves because of their impact on US commercial interests on the island. This opposition turned into a US embargo of Cuban sugar imports in 1960. In response, Castro looked to the Soviets as an export alternative. Eisenhower retaliated by refusing to ship oil to Cuba, leading Castro to sign an oil deal with the Soviets and eventually nationalise American and British refineries. In 1961, Castro declared his adherence to "Marxism-Leninism". Castro and Cuba were hugely popular throughout Latin America.

When the Cuban military defeated the CIA-trained force of exiled Cuban fighters at the Bay of Pigs in 1961, Castro was lauded for standing up to the US, though few knew of the military and intelligence support coming from the Soviets. And when President John F. Kennedy began the campaign to remove Cuba from the Organisation of American States (OAS) in 1961, most Latin American democracies moved to block it. To bring those leaders to his side, Kennedy used a carrot-and-stick approach. He proposed an "alliance for progress" to meet the "basic needs of the [Latin American people for homes, work and land, health and schools".

But his government also passed the Foreign Assistance Act, which established a total blockade of the island and prohibited US aid to any country providing assistance to Cuba.

The OAS removed Cuba as a member the following year and, in 1964, voted to embargo all trade to Cuba, except food and medicine.



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Life under the embargo

The embargo prevented Cuba from reaching the modern technological age. Instead, it existed in socialist bubble, emphasising the care of its people over economic development.

Nonetheless, Cuba's Cold War economic growth was comparable to its neighbours. In 1970, the nominal GDP per capita for Cuba was US\$645 (A\$900), slightly lower than Mexico and about double the Dominican Republic. By 1990, it was US\$2,565 (A\$3,600), about 80% of Mexico's and more than triple the Dominican Republic's. Cuba was not industrialised, but the country did reach full literacy before any other Latin American nation and extended health care to all Cubans. Cuba then exported its teachers and doctors throughout Latin America, and beyond. However, life on the island was still difficult, especially after the collapse of the Soviet Union. With no clear replacement for Soviet

imports and subsidies, the economy began to buckle. From 1990 to 1994 (a time known as the "Special Period"), food production decreased by 40%, leading to food rationing, malnutrition and other health issues. Protests broke out across the island in 1994 and some 35,000 Cubans fled on boats for Florida.

Cuba and the US after the Cold War

However, the end of the Cold War brought newfound sympathy and assistance from Cuba's neighbours. Venezuelan President Hugo Chavez, for example, provided Cuba with oil in exchange for Cuban doctors. Then, in 2009, the OAS voted to readmit Cuba and allow for regional trade and tourism again. US President Barack Obama followed suit in 2014, saying the US embargo of Cuba had "failed". His administration then initiated what would become known as the "Cuban thaw". Then-President Raul Cas-

tro visited Washington in 2015 and, the following year, Obama became the first US president to visit Cuba since 1928. Obama did not end the embargo, but he did open the door to US tourism, providing a lifeline for Cuba's economy.

Why is Trump punishing the island again?

Now, Trump is reimposing the Cold War-era embargo on the island and ramping up the pressure on President Miguel Diaz-Canel's government.

The White House claims Cuba presents an "unusual and extraordinary threat" to the United States, saying the island is cooperating with "dangerous adversaries" on intelligence activities, chief among them Russia and China. Russian President Vladimir Putin has condemned Trump's embargo, saying "we do not accept anything like this". If Russian oil makes it to Cuba, more aid could follow. If that eventuates, the US will have invited Russia into its backyard again, laying the foundation for another Cold War-style stalemate, with the Cuban people once more trapped in the middle.

(The writer is an Associate Lecturer in History, Politics and International Relations at Western Sydney University, Australia)

Science pokes holes in the 'ghost gun' myth

3D-printing filaments carry chemical signatures that could make illegal guns traceable

GEORGINA SAUZIER

3D-printed guns are a growing threat to public safety. The blueprints used to make these firearms can be found online, making them easily accessible. With a relatively cheap 3D printer and a quick web search, anyone could print their own unlicensed gun. These guns have been called "untraceable". Research is now putting this claim to the test. Our new study, published in the journal *Forensic Chemistry*, has found some filaments the materials used in 3D printers have distinct chemical profiles that could help link seized 3D-printed guns to their source.

The threat of 'ghost guns' Last October, an Australian Border Force operation uncovered 281 3D-printed firearms or components. 3D-printed components can be combined with common hardware store parts to create "hybrid" weapons, increasing their strength and durability. Both fully 3D-printed and hybrid 3D-printed guns can be just as lethal as factory-made firearms. Recent events have led to calls for retailers to help stem the flow of 3D-printed guns. Suggestions have included placing blocking technology on 3D printers or flagging the purchase of items that could be used to make hybrid firearms.

But what can be done about the weapons already circulating in the community? 3D-printed guns have earned the nickname of "ghost guns", as they are difficult to trace through standard firearms analysis. With law enforcement struggling to trace the source of seized ghost guns, it falls to researchers to find an alternative solution. Chemical analysis of



the filaments used to print these weapons may be the ticket to ending their "untraceable" reputation.

What are 3D-printing filaments?

3D-printing filaments are made up of various polymers, or plastics. The main polymer used in at-home 3D printing is polylactic acid or PLA, a bioplastic used to make compostable waste bags. Other common filaments are those made from ABS the main material used to make LEGO bricks due to its toughness and PETG, a flexible polymer found in sports water bottles. Some specialist filaments are made by combining different polymers. Many also have additives extra ingredients to improve toughness, flexibility or appearance.

As 3D-printing filaments are usually patented to protect their individual formulations, additives and other minor ingredients are typically not listed on the product packaging. It is these ingredients that could hold the key to tracing ghost guns.

The mix of ingredients used in 3D-printing filaments gives each type of filament a particular chemi-

cal signature. We can identify these signatures using a method called infrared spectroscopy, which records how the filament absorbs infrared light. This pattern of absorbance an infrared profile changes based on what molecules are present in the filament.

What we found

In our research, conducted in collaboration with ChemCentre a statutory forensic laboratory in Western Australia we analysed more than 60 filaments sourced from the Australian retail market.

We discovered that many of these filaments could be distinguished using their infrared profile, despite looking identical to the eye. Filaments made of PLA, ABS and PETG can be easily set apart due to large differences in the chemical make-up of each polymer. However, we were also able to separate some filaments made of the same polymer, due to minor additives creating differences in their infrared profile.

In one filament for example, we found signs of a compatibiliser an additive that helps two polymers to mix together. This ingredient was not found in other

filaments of the same base polymer, meaning it could be a distinct part of the brand's formulation. It also suggests this filament contained two different polymers, despite only one being listed on the packaging. These findings highlight why chemical analysis of filaments is useful, despite them being a widely available consumer product.

Tracing the seemingly untraceable

Being able to distinguish or identify different 3D-printing filaments could allow forensic investigators to create links between a seized gun and seized filament, or guns seized from different cases. These links can help lead law enforcement to the suppliers of these guns, ultimately disrupting supply chains and future production. While our research shows some 3D-printing filaments could be distinguished, this was not the case for all filaments.

We are now conducting further research using more analytical techniques that will provide complementary information, such as the elements contained within the filaments.

Combining different techniques will allow us to complete a full chemical picture of each filament. We hope this information will help us to make links between a seized 3D-printed firearm, the filament it was printed from, and the 3D-printer used to print it. By tracing the chemical fingerprint of 3D-printed guns, criminals can no longer feel safe under their "untraceable" veil.

(The writer is a Senior Lecturer in Forensic Chemistry, Curtin University, Australia)

One of the universe's largest stars may be about to explode

Astronomers observe dramatic changes in WOH G64, hinting at a possible pre-supernova phase

SARA WEBB

ONE of the largest known stars in the universe underwent a dramatic transformation in 2014, new research shows, and may be preparing to explode. A study led by Gonzalo Munoz-Sanchez at the National Observatory of Athens, published in *Nature Astronomy* today, argues that the enormous star WOH G64 has transitioned from a red supergiant to a rare yellow hypergiant in what may be evidence of impending supernova. The evidence suggests we may be witnessing, in real time, a massive star shedding its outer layers, shrinking as it heats up, and moving closer to the end of its short life.

A very special star

WOH G64 was first discovered in the 1970s as a star of interest in the Large Magellanic Cloud, a dwarf galaxy orbiting the Milky Way. It turned out the star was not only extremely luminous, but also one of the biggest ever discovered: more than 1,500 times the radius of the Sun. In 2024, WOH G64 was the first star beyond our galaxy ever photographed in detail, thanks to the Very Large Telescope Interferometer. The image showed a clear dusty cocoon around the central giant star, which confirmed it was losing mass as it aged.

From supergiant to hypergiant, big is big

WOH G64 is a young star in the grand scheme of the cosmos, with an estimated age of less than 5 million years old. Unlike our Sun (currently about 4.6 billion years old), WOH G64 is destined to live fast and die young. WOH G64 was born big, forming from a huge cloud of gas

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and dust collapsing until the pressure made it ignite. Like our Sun, it would have burned hydrogen in its core by nuclear fusion. Later it would have expanded and burned helium, becoming what is called a red supergiant.

Not all supergiants become hypergiants. It's been theorised that hypergiants form when very large stars quickly burn and evolve from burning hydrogen to burning helium. During this transition, these stars start to shed their outer layers, while their cores begin to shrink inwards. Once a star becomes a hypergiant, it is destined for a quick death in the fiery explosion of a supernova.

What has caused this change seen in WOH G64?

So what happened to WOH G64 in 2014? The new study proposes that a large part of the original supergiant's surface was ejected away from the star. This may have been due to interactions with a companion star, which the authors have confirmed exists by looking at the spectrum of light from WOH G64.

Another theory: the star is getting ready to explode. We know stars this big will inevitably go kaboom, but exactly when it will happen can be hard to determine in advance.

One possible scenario is that the transition we're seeing is due to a pre-supernova "superwind" phase. This is theorised to occur due to strong internal pulsations as the fuel in the core is spent quickly.

Only time will tell

Most stars live for tens of millions or even tens of billions of years. It was never a given we would witness and be able to document so much transformation in a star, let alone one outside our galaxy. If we are lucky, we will see the death of WOH G64 in our lifetimes not only providing an incredible intergalactic spectacle but also helping scientists complete the puzzle of this fascinating star.

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