IT'S VERY ENERGY-INTENSIVE —

Synthetic gasoline promises neutral emissions—but the math doesn't work

E-fuels sound like a panacea, but there's not enough spare electricity to make them.

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Synthetic fuel promises to put gasoline back in our future. Motorsport will be using it in 2026, and European Union law is using it as a stay of execution for the combustion engine. Advertising promises that a future without fossil fuels doesn't need to be one without gasoline. But burning petrochemicals, wherever they come from, is still burning petrochemicals, and synthetic fuels come at a cost their supporters aren't talking about.

We live in perilous times. The annual Intergovernmental Panel on Climate Change report has become blunter with every edition. The sixth, published this March, described the steps we need to take to "secure a livable future." Not a *good* future filled with an abundance of resources and biodiversity,

just a *survivable* one. We're in this situation because we've spent the better part of two centuries digging up fossil fuels and burning them, putting carbon and other greenhouse gases like methane into the atmosphere and causing significant global warming.

But even though there's a domino effect to climate change—drought breeds drought as the land cooks and water seeps into the sea, for instance—mathematically, there is still time to act.

However, it's become clear that we can't be trusted to do the right thing. As the precipice we're wobbling on gets thinner with every misstep, some solutions that may have been on the table 30 years ago aren't great options for our current situation.

Synthetic fuel is one of those solutions.

What is synthetic fuel?

There are many types of fuel that carry the "sustainable" label, meaning they're made from a smaller percentage of—or are entirely free from—fossil fuels. They range from things like reusing cooking oil as a diesel replacement to molecularly constructing and then refining methanol.

Synthetic fuels are the latter. In theory, the process is a high school class on organic chemistry: Hydrocarbons are strings of hydrogen and carbon, so you break them apart and put them back together until you have the right one.

The synthesis could be done with any old carbon and hydrogen you happen to have—you could even get them out of fossil fuels if you wanted to needlessly complicate refining crude oil or natural gas. The process of creating synthetic fuel doesn't care where the carbon and hydrogen come from, and there's no purity advantage to them being sustainably generated; it's just the only justifiable way of doing it.

In theory, to make a synthetic fuel, you capture carbon from the air and generate hydrogen from electrolysis of water using clean and renewable electricity. You then jumble the carbon and hydrogen up and put them through a series of processes that ultimately lead to a drop-in gasoline.

When the fuel burns, it's just petrol, and it will re-release the captured carbon into the atmosphere. But it won't have taken any more out of the ground, which is why advocates for synthetic fuel refer to it as carbon-neutral.

It sounds too good to be true: carbon-neutral, guilt-free, renewable fuel for all our existing, beloved cars, planes, and ships. But the process of making synthetic fuel is real and possible.

We can (and in some places, already do) capture carbon from the air. We make hydrogen from electrolysis, though it accounts for just 4 percent of hydrogen generated worldwide. The Fischer-Tropsch process for turning methanol to gasoline exists, and there are catalysts and existing technologies that can make it happen.

Although the process is a very nerdy way of making gasoline, it's not confined to a laboratory stage, and there are companies—more each year—making fuel this way. Porsche opened an enormous new facility in southern Chile at the end of 2022 and generated its first barrel of all-synthetic fuel; it plans to release nearly 11,000 more gallons in 2023.

Germany just pushed the European Union to give a stay of execution to new combustion engine cars in 2035. The condition is that these cars must run only on synthetic fuel (or its more online-sounding synonym, e-fuel). Of course, that may sound like a transparent play to influence emissions restrictions toward the interests of, at the least, the VW Group.

Formula 1 is moving to 100 percent synthetic fuels by 2026, with its feeder series Formula 2 and 3 already steadily increasing the percentage of sustainably sourced gasoline in their Aramco-supplied fuel. There's no shortage of petrochemical companies that want to be part of the shift to gasoline that can wear a carbon-neutral badge.

There's a "but," though: synthetic fuel probably isn't a workable solution.

The energy equation

Fossil fuels are a great source of concentrated energy. They exist as a finite but abundant resource because millions of years of time and energy went into transforming the organic matter they're made of into gas, oil, and coal.

We didn't have to generate any of that. It was done fairly passively by the planet through gravity, pressure, and time. But no one running a synthetic fuel company will be able to turn a profit using the same method. Fuel has to be made quickly and by a series of processes that all have significant energy losses involved.

Take direct air carbon capture. For a fuel to claim it's carbon neutral, carbon capture has to be the source of the "C" in the H-C chains it's made of. Carbon capture needs to happen to help us pull back the amount in the atmosphere. But the process is not as straightforwardly miraculous as it sounds, as it's enormously energy-intensive.

At the same time that we need to switch to renewables to generate the power we already use, there will be hugely increased demands. Last year, edicts went out across Europe that limited air conditioning in summer and outdoor heating in winter. It's now illegal for a mall or bar in Spain to set its air conditioning below 80°F (27°C,) and in Paris, anyone enjoying a coffee on a charming table outside a bistro will find the bar heaters are turned off by law.

Some of that is due to an ongoing energy crisis across Europe, which was partially caused by Russia's invasion of Ukraine. Climate change is another significant cause, however; low water levels in rivers are shutting down energy generation by cutting off fuel supplies to power stations in Germany or

France's ability to use river water to cool its nuclear reactors.

Germany didn't have enough energy to run normally in 2022, with industry limited by high prices and citizens being encouraged to limit production. A new liquid natural gas pipeline has brought some relief, reducing inflation from 7.9 to 6 percent, but with no surplus capacity or significant price decreases coming in the near future. And even before the current energy crisis, spare energy-generation capacity would only be sufficient to synthesize a week's worth of gasoline.

On the other side of the Atlantic, creaking power grids have left people cut off. We've seen the casing of power lines literally melting off in Oregon and huge blackouts in Texas caused by ice storms. We don't have a surplus of energy or infrastructure to make synthetic fuel right now, and that will present a very serious challenge. The only way out of our current situation is going to need a lot of it, and it can't come from our reliable old fossil supply.

Short of a nuclear fusion boost in the very near future, meeting energy demands in the next decade will be very hard. So the fact that new processes like carbon capture will demand more energy presents an even bigger challenge.

Capturing carbon, only to then subject it to another energy-intensive process and ultimately release it right back into the air, doesn't make sense. Thirty years ago, this process may have been a messy, still-energy-intensive option to prevent more fossil carbon from getting into the atmosphere, but now, it's taking the tools we need to fix our problems and bludgeoning us with them.

That's just the carbon. Making hydrogen from electrolysis also requires energy; the process runs at about 75 percent efficiency, so we need to use a quarter more energy to make hydrogen than we get out of it, even if it's used in a fuel cell car. Fuel cell cars run at about 60 percent efficiency, which is stil an advancement over combustion's peak of around 40 percent.

Most battery-electric vehicles run at over 85 percent efficiency. So if we used the energy to directly charge a BEV instead of engaging in a convoluted process, there would be a lot more to go around. It takes about 50 kWh of energy to make 1 kWh of lithium-ion cell storage, but those numbers break even pretty quickly in a regularly used car.

Once hydrogen and carbon have been sourced, they are combined to form methanol or synthesis gas, aka "syngas." Optimistically, reaching that point for 246 gallons (931 L) of methanol takes about 10–11 MWh of energy. That's a year's worth of energy for the average American home.

A Mobil process (for methanol) or the Fischer-Tropsch process (for syngas) is then employed to refine the methanol or syngas further into something like gasoline. All those steps require resources, including catalytic metals and energy to power machinery. By the time the synthetic fuel hits a barrel, a lot of energy has gone into making it.

Because it's fuel, some of that energy will be turned into power in the combustion process, and the rest will be lost. At the end of the process, there are just tailpipe emissions and a return to the pump for another tank of the same, hopefully once again cycling the carbon it will release out to the

atmosphere first.

Neutral parties

Given the required energy and resources, all of which come with some kind of carbon cost, calling this process "carbon-neutral" is simply marketing speak. "Carbon-cycling" would be more accurate. If more carbon was being captured by synthetic fuel programs than was going back into creating the fuel and subsequently being released into the atmosphere, it would be easier to justify. But there's still a bit of finger-crossing going on here.

It's easy to think one's way into believing that efficiencies can rapidly improve. They might, but synthetic fuel is unlikely to ever require as little energy as the current method of sucking oil out of the ground and distilling it into gasoline. Combustion's low thermal efficiency—few engines exceed 40 percent—means that even a perfectly efficient process to make the fuel (also not something afforded by the reality of physics) would mean an ultimate majority loss.

The fuel is just gasoline when it gets to a vehicle's fuel tank, not magic. It's poorly understood, and there's not much effort being made to change that. Getting into the details is where the case for synthetic fuel's promises start to fall apart.

Take the amendment that Germany has pushed the European Commission to provide to allow combustion car sales so long as the car can only run synthetic, carbon-neutral fuels. That's not possible, since the car can't tell the provenance of the liquid it's being given (although I'm sure someone somewhere is rubbing their hands together at the idea of using the blockchain to try to make it look like it is possible).

It's theoretically possible to require the use of an additive with synthetic fuels, without which the car would not run. But there's no reason that additive couldn't go into fossil gasoline.

Side effects

A strange runoff effect of the prospect of synthetic fuel is that it makes hydrogen look a lot more sensible. Right now, almost all hydrogen used industrially is generated from fossil fuels, but efficiencies are improving in electrolysis, and there's been promising research this year that has shown it can be generated from brine rather than the freshwater we're running increasingly short of. There are improvements in electrolysis efficiency, too, that are starting to promise rates as good as 95 percent, at which point it becomes a much more serious proposition.

Getting diesel cars off roads has become a public health priority, especially in cities. The emissions the automotive industry has hid have been proven to severely affect us and our environment. But scrapping all the cars we were being incentivised to buy just a few years ago is a wasteful nightmare, even beyond the cost to individual drivers.

Toyota has been messing around for a couple of years now with a diesel Corolla it replaced a couple of valves in and turned into a hydrogen combustion race car. Hydrogen combustion has some issues, including that it produces some of the same particulates as diesel combustion if it burns hot enough. Plus, hydrogen is a relatively low-energy fuel to burn, but its big advantage is that if it's done correctly, it has effectively zero negative emissions.

Hydrogen is being pushed by fossil fuel companies as part of the clean energy future, and it's right to be skeptical about it. But if efficiencies really do mean that it can be made by electrolysis on a significant scale, we might not need to go all the way through the synthetic fuel process to have something we can drop into cars and instantly reduce emissions.

Synthetic fuel could have been a '90s fad, but back then, we were still getting around to banning leaded gasoline in most of the world. Now, we need more challenging solutions for harder times. Sure, synthetic fuel can keep race cars and old classics running, and I'm certain every gallon produced will find a home in a fuel tank. The aviation industry uses 60 billion gallons of fuel per year, and people who want to keep using their private jets are likely to be price-insensitive enough to lap up every liter.

But in terms of mitigating the disaster we're in, synthetic fuel is just a very expensive side quest.

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sophisticated racing AI. Beginning with the original Drivatar AI in Forza Motorsport for XBOX in 2005, Greenawalt and his colleagues experimented with computer learning, refining their methods from iteration to iteration. It was once the AI system was unshackled from local hard drives and placed online in Forza Motorsport 5, however, that the floodgates truly opened. As the AI rapidly evolved, producing unexpected new behaviors, the Forza team quickly learned how challenging it would be to wield this two-edged sword in creating realistic opponents.

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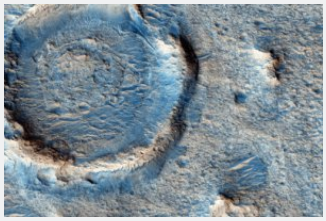

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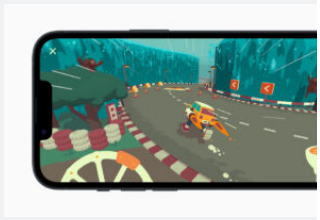

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