Sustainable Alternative Fuels For Consumer Automobiles

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⟙ *Introduction* ⟙

As consumers move to alternative fuel sources for their automobiles with a goal of zero emissions, there is no single solution that is feasible for all drivers around the world. Factors such as affordability and access to supplies will help determine the best alternative for each to choose.

Zero emissions is a target that has become a commonly advertised goal among automakers. It entails the release of zero environmentally unfriendly greenhouse gasses through the production, operation, and destruction life cycle of a vehicle. Forward progress must be made now in the undeniable move away from gasoline and towards other options in order to obtain zero emission. Developing nations, farmers, and tropical islands will not be able to deal with the effects of climate change caused by greenhouse gas release for much longer. A world with dramatically lower automobile emissions provides a greater chance of survival for these groups, as well as time to develop and work out solutions for other climate issues. The technology needed to slash emissions exists, and is available for purchase, though American roads are still traveled over 90% of the time with gasoline powered passenger cars and trucks.[1] Many options exist in the realm of alternative consumer automobile fuels, and it is time for them to be explored.

Governments around the world will pay their citizens to buy this car. It gets from a full stop to 60 miles per hour in under two seconds, all without making a sound. On top of this, it can fit five people and go 400 miles without having to stop, all while

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[1] Cartier, Mathilde. "Gasoline-Powered Vehicles in the United States- Statistics & Facts." *Statista*, 15 Oct. 2021, https://www.statista.com/topics/4580/gasoline-powered-vehicles-in-the-united-states/.

emitting no direct carbon and being on the cutting edge of style and technology.[2] It never needs to fill up on gas, get an oil change, or see a mechanic. The Tesla Model S, as described above, is a remarkable vehicle that has revolutionized the consumer automobile market. However, a society maintaining zero emissions perfection is still out of range. A world full of these electric Teslas would be no better for the environment, proving it is critical for the industry to research all fuel options that promote sustainability before moving forward.

⟙ *The Climate* ⟙

Climate change is identified by the United Nations as one of the world's most critical issues, and it is no secret that modern transportation is a major player in worsening it.[3] Wildfires, mass flooding, devastating storm seasons, droughts, and the disappearance of the Arctic are all effects that have already appeared and will continue to attack the Earth and humanity.[4] For example, if the world stays at its current carbon production pace, the city of Miami is projected to be underwater and uninhabitable by 2035.[5] The United States Environmental Protection Agency (EPA) has deemed transportation as the culprit behind 29% of the country's total greenhouse gas emissions, meaning United States transit has emitted over 500,000,000 pounds of carbon in just one year, 58% of which was directly emitted from light-duty, consumer

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[2] "Tesla Model S Plaid." *Tesla Incorporated*, https://www.tesla.com/models.
[3] "Global Issues." *United Nations*, https://www.un.org/en/global-issues.
[4] "The Effects of Climate Change." *NASA*, https://climate.nasa.gov/effects/.
[5] Castro, Alejandro. "Rising Sea Levels in Miami." *Miami Underwater*, 22 Dec. 2020, https://storymaps.arcgis.com/stories/80d2465cd19c405f933e9afcfe1fdf83.

automobiles.[6][7] This problem is mirrored in Europe, where consumer automobiles are responsible for 16% of total carbon emissions.[8] Clearly, change must be brought to the consumer automobile field, or the world will continue driving down a road that is one way to self destruction. Numerous partial solutions that advertise "zero emissions," which often cannot actually fully achieve them, exist in the automobile market already, but a legitimate commitment from the industry to researching methods which actually fulfill this promise, from production to destruction, is an essential step in securing the Earth's future. Carbon offsetting, mining for materials, and the production of fuel are numerous processes hidden by manufacturers in order to maintain an appearance of "zero emissions". However, there is no singular route that will move the world closer to this milestone, nor is there a current method that can fully achieve it, though numerous fields exist where significant progress can be made. The alternative fuel automobile market has exploded over the past few years, and presents an individualized way for governments and individuals alike to act in a way that will benefit the Earth's future.

← *Electricity* →

Thomas Edison invented the electric light bulb in 1879, changing the illumination of the world forever. It is less known, however, that in 1914, he contracted with Ford Motor Company to produce the first electric car. "Electricity is the thing", Edison said, as he built nickel-iron batteries into early Model T's that could reach 70 miles per hour and

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[6] "Fast Facts on Transportation Greenhouse Gas Emissions." *United States Environmental Protection Agency*, https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions.
[7] "Climate Change Indicators: U.S. Greenhouse Gas Emissions." *United States Environmental Protection Agency*, https://www.epa.gov/climate-indicators/climate-change-indicators-us-greenhouse-gas-emissions.
[8] "Cars- CO2 Emissions." *Transport and Environment*, https://www.transportenvironment.org/challenges/cars/. Accessed 20 Jan. 2022.

travel 85 miles on a single charge.[9] As time went on, though, Henry Ford drew his company away from Thomas Edison in order to streamline production on his gas vehicles, killing the electric car market until its recent resurrection.

Today, electric cars have made an incredible shift from a fringe concept for environmentalists to a mainstream market. The Ford F-150 has long been the top selling automobile in America, and it will soon be passed by an electrified version of itself. Over 200,000 orders for the F-150 Lightning, an electric version of the truck, have already been placed, though it has not yet even reached production.[10] An exponential rise in the popularity of electric vehicles, exemplified by the Lightning, has occurred in recent years, and its promotion by governments and major corporations ensures that it will continue to increase. This was seen in the fiscal year of 2020, when, despite a 16% decrease in total car sales, electric car sales rose by 50%. Companies such as Tesla and Rivian have come to fruition because of this electrified market, while existing giants such as Ford, GM and Volkswagen have shifted their focuses to keep up. Though they all target different existing sectors of the automobile market, all the vehicles developed by these companies are similar due to their power coming from the lithium-ion battery.

This battery type utilizes a liquid solution as an electrolyte to create electricity out of stored energy from charging. An electric car can gain its power by simply being plugged into a residential wall outlet, though this process takes about 8 hours. Lithium-ion batteries contain lithium, nickel, cobalt, manganese, graphite, and other rare materials, making them too pricey for many consumers.[11] These materials all must be mined from natural deposits scattered across the world, and then shipped to

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[9] McKenzie, Hamish. *Insane Mode*. Penguin Random House, 2018.
[10] Welch, Craig. “The Future Is Electric.” *National Geographic*, 2021, p. 38–64.
[11] Welch “The Future Is Electric.” 2021

manufacturing facilities where the batteries are assembled. This sequence of mining, shipping, and producing emits large amounts of CO_2, contributing to the same issue electric cars aim to solve. The "zero emissions" facade that electric cars maintain is false, as it ignores the 8-10 metric tons of CO_2 that are emitted during battery mining and production of each individual car.[12] More importantly, the emissions produced by coal and gas power plants, which create the electricity to fuel these cars, are far from being "zero emissions". Despite this, though, electric cars have become a common symbol of environmentalism and innovation. Over 12 million electric cars have recently been sold, 90% of which were dealt in the United States, China, and Europe.[13] These developed areas lead the way, while cheaper electric conversion kits have become popular in many nations with older automobiles and public transport. Despite the high initial cost of electric cars, they maintain a cost of ownership of about 2 cents per mile, relative to 12 cents per mile of internal combustion cars, meaning these kits are highly economical for drivers in developing nations.[14]

Clearly, electric cars must be considered when trying to move forward into a world of net-zero emissions. The United Nations has agreed this net-zero figure must be achieved by 2050, though this term is a loose regulation, as it means still producing carbon, but offsetting it through actions which are calculated to benefit the environment a certain amount.[15] Driving an electric vehicle does remove all emissions from the

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[12] Sykes, Nolan, "Are Electric Cars REALLY Better For The Environment?", Youtube, Donut Media, 20 Apr, 2020, https://www.youtube.com/watch?v=G67j_Z8ukD4

[13] Welch "The Future Is Electric." 2021

[14] Wilberforce, Tabbi, et al. "Developments of Electric Cars And Fuel Cell Hydrogen Electric Cars." *International Journal of Hydrogen Energy*, vol. 42, no. 40, Oct. 2017, p. 25695–25734, *Science Direct*, https://wlv.openrepository.com/bitstream/handle/2436/621478/AAM-A%20Baroutaji-%20Developments%20of%20electric%20cars%20and%20fuel%20cell%20hydrogen%20electric%20cars-Wire.pdf?sequence=8

[15] UN. "Net Zero." *United Nations*, https://www.un.org/en/climatechange/net-zero-coalition#:~:text=With%20science%20affirming%20a%20shrinking,reach%20net%20zero%20by%202050.

action of driving, though it places greater burden on battery and electricity production. It takes at least two and a half years of electric vehicle ownership for its lifetime to produce less emissions than the average internal combustion car.[16] This means that 2 year leases of electric vehicles, a common method of new car ownership, will actually hurt the planet more than it will help. Any time less than the 30-36 months calculated for an electric vehicle to surpass internal combustion in its minimization of environmental impacts, and the increased emissions during its production simply outweighs those emissions produced by gasoline.

The supply of electricity to power these cars is also a major factor in their possibility for implementation. Too sharp of an increase in consumers with electric vehicles would overrun the power grid, meaning new infrastructure would have to be built rapidly, which comes with an environmental cost. Electricity production is the key concept for how effective electric cars can really be for the environment. Solar power, wind power, and hydroelectricity are common ways to gain sustainable energy, though none are popular enough at this time to create all electricity. Over 80% of American electricity is still generated from non-renewable fossil fuel sources, meaning true zero-emission ownership of an electric vehicle is far away for the majority of the country.[17] Individuals who have direct access to renewable electricity, such as roof-mounted solar panels, are target customers for electric vehicle companies. Not all citizens can afford this technology, though, and natural circumstances can also hinder the possibility for electric vehicle ownership. Commonly cloudy areas such as the

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[16] Sykes, “Are Electric Cars REALLY Better For The Environment?”, Donut Media
[17] “Renewable Energy.” *Center for Climate and Energy Solutions*, https://www.c2es.org/content/renewable-energy/.

American Pacific Northwest, as well as northern Great Britain, cannot generate much power off of solar technology.

Even with sufficient electricity production, electric vehicles are far from ideal for individuals who often travel long distances due to their lengthy charging time and limited ranges. To increase the ownership duration of electric vehicles to the point where they really help, automotive manufacturers must ensure that their EV's are sold to consumers who are aware of their limitations, and that they do not sell a one size fits all model. Battery electric vehicles will not create an emission free world alone. However, they are beneficial in many consumer scenarios. Individuals who reside in cities and suburbs, particularly those provided with renewable electricity, should seriously consider their next vehicle being electric. Home charging overnight is easy, and populated areas are commonly outfitted with supercharging stations at shopping and fuel facilities.

Electric vehicles can generate more torque than most gas vehicles due to their single gear motors that do not need to shift or engage, meaning intense weather is not a limiting factor for their feasibility. This is important because harsh climates, such as areas with heavy snowfall, do not pose a problem for electric vehicle use.

Figure 1 shows a map of America, with a green dot representing each public electric charging station.[18] Clearly demonstrated in the map is the fact that populated city and suburban areas are surrounded by charging stations. Rural areas, however, are sparsely covered. Along with this, the issue of battery mining and production still exists. As of now, 2021, few technologies are in place that can improve battery efficiency by reducing emissions through production and use. The future is bright,

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[18] "Alternative Fueling Station Locator." *United States Department of Energy*, https://afdc.energy.gov/stations/#/find/nearest.

though, as solid-state batteries are said to be ready for use by 2025. These batteries utilize fewer rare earth materials, and are more energy dense. Due to a solid electrolyte design, compared to a lithium-ion's liquid one, they have many benefits, including a longer life, smaller form factor, and more power and range. Solid state batteries are predicted to last five times as long as the average lithium-ion, though the perfect material for maximum efficiency has not yet been found.[19] In the near future, the implementation of these batteries, along with an increase in sustainably generated electricity, will cause electric vehicles to become more and more effective for reducing emissions. Electric vehicles are, indeed, a feasible partial solution for the world's shift to sustainable consumer automobile power.

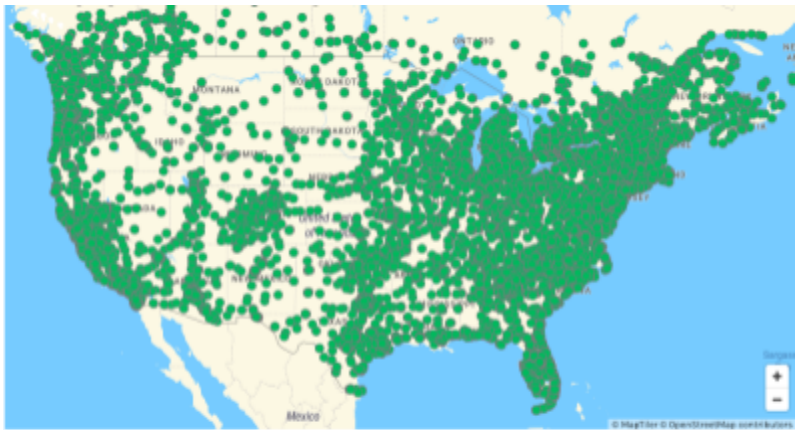

Figure 1

Hydrogen

Hydrogen fuel cell vehicles (FCEV), though currently far rarer than their electric counterparts, present another option to move the consumer transportation world towards zero emissions. Within the United States of America, these cars, and their

[19] DeWith, Cameron. "Do Solid State Batteries Have the Potential to Make Combustion Engines Obsolete?" *Future Science Leaders*, https://www.futurescienceleaders.com/blog/2021/02/do-solid-state-batteries-have-the-potential-to-make-combustion-engines-obsolete/.

required infrastructure, are scarce, though countries such as South Korea, Japan, China, and Great Britain have all invested great amounts to increase their development.[20] Hydrogen is the most common chemical element in the universe, meaning it will not run out, unlike current fossil fuels.[21] In fact, hydrogen suitable for fuel cell power can be derived directly from water or natural gas. Influential brands such as Toyota, Hyundai, and Honda have realized the potential of such a resource, and produced competitive automobiles that run on fuel cells. Major players in hydrogen often invest heavily, such as the United Kingdom's recent 23 million Euro package to increase hydrogen vehicle and infrastructure development.[22] Within the United States, the state of California has essentially been the only promoter of hydrogen fuel cells, maintaining 41 of the nation's 43 refueling stations.[23] These investments are critical, because unlike synthetics and electrics, hydrogen power requires its own grid.

Hydrogen on earth does not exist as an element individually, meaning it all must be derived from molecular sources such as water, nuclear power, and natural gas.[24] This process is often completed at energy production facilities, or on the site of the refueling station. Either way, advanced transport systems, such as pipelines or trucks, are required to move the product. Currently, the majority of hydrogen used for fuel cell vehicles is taken from natural gas, which is notably not a renewable energy source, and

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[20] International Energy Agency (IEA), Clean Energy Ministerial, and Electric Vehicles Initiative (EVI) (2021-04-29). "Global EV Outlook 2021: Accelerating ambitions despite the pandemic". International Energy Agency, https://en.wikipedia.org/wiki/Fuel_cell_vehicle#cite_note-GlobalEVOutlook2021-4

[21] "An Introduction To Hydrogen Vehicles." *Hydrogen Hub*, https://www.hydrogenhub.org/2017/10/31/introduction-to-hydrogen-cars/. Accessed Nov 12, 2021

[22] "An Introduction To Hydrogen Vehicles." *Hydrogen Hub*

[23] "Alternative Fueling Station Locator." *United States Department of Energy*, https://afdc.energy.gov/stations/#/find/nearest.

[24] Wilberforce, et al. *Developments of Electric Cars And Fuel Cell Hydrogen Electric Cars*. 2018

processed at the larger facility.[25] The hydrogen taken from the gas is vaporized and compressed into H35 or H70, numbers which symbolize the pressure of the gas.[26] Higher numbers mean higher compression and increased range, similar to the function of premium and standard gasoline. A hydrogen refueling station looks quite similar to a modern gas station, though it features above ground tanks and costs over 1.5 million dollars to build. These tanks are cooled to control the hydrogen and ensure it is compressed with maximum efficiency. The movement of hydrogen from the tank to fill a FCEV takes about three to five minutes and will provide upwards of 300 miles of range, meaning that little lifestyle change would need to occur in processes of storage, refueling, and driving distance if switching from a gasoline to hydrogen vehicle.[27]

Once inside the vehicle, though, hydrogen functions differently. Fuel cells utilize the hydrogen to produce electricity, which drives the motor in a similar structure to a battery EV. Compressed hydrogen is fed into the fuel cell as demanded by the throttle. The energy is produced as the hydrogen passes through a membrane and mixes with oxygen blown into the fuel cell by a fan, hereby forming H2O, which leaves the exhaust as the only byproduct in the form of vapor.[28] This process is quiet and clean, though it is

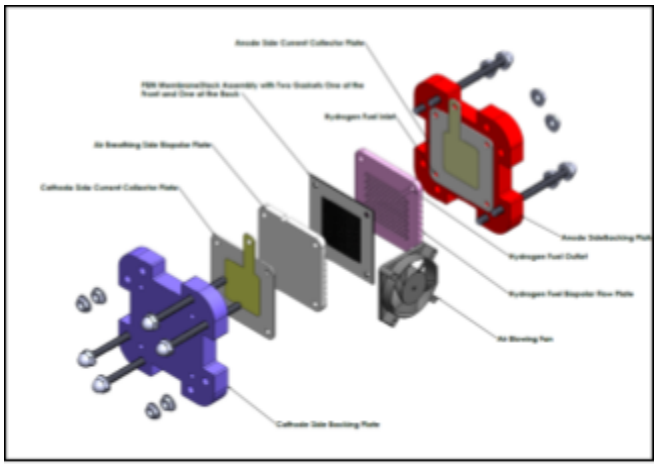

Figure 2

[25] California Air Resources Board. “Hydrogen Fueling Overview.” *DriveClean California*, https://driveclean.ca.gov/hydrogen-fueling. Accessed Nov 12, 2021
[26] Car and Driver, “How A Hydrogen Filling Station Works.” *Car and Driver*, 1 Feb. 2017, https://www.caranddriver.com/features/g15376667/how-a-hydrogen-filling-station-works/.
[27] California Air Resources Board. “Hydrogen Fueling Overview.” *DriveClean California*
[28] Wilberforce, et al. *Developments of Electric Cars And Fuel Cell Hydrogen Electric Cars*. 2018,

notoriously slow. The Toyota Mirai, arguably the most prominent and best performing FCEV, goes from 0-60 in a dull 9.2 seconds, and this is one of the fastest times on an available fuel cell model.[29] This fact hinders fuel cell success, as it draws automotive enthusiast interest towards other sustainable fuel methods. Another obstacle is the cost of FCEV infrastructure. Few government denominations can afford to invest millions of dollars into a field that has not had the opportunity to prove itself. Hydrogen implementation is currently only possible in areas with high levels of existing infrastructure and wealth, as the pipelines, trucks, processing facilities, and stations are costly and difficult to construct. FCEV's cannot currently boast complete zero emissions results, either, as the energy required to separate hydrogen from natural gas and then move it to a refueling site is significant. In fact, the "well to wheel" emission of a FCEV is still about 50% of what a modern gas engine produces, signifying it is currently not a complete zero-emission solution.[30] However, as renewable electricity becomes more common, and extraction methods become more efficient in coming years, this figure may improve dramatically.

Hydrogen fuel cell vehicles present yet another alternative fuel source that can drive the world forward with fewer emissions. However, despite the illusion of only water exiting the tailpipe, they are not emission free. On top of extraction, production, and transportation of fuel cell-grade hydrogen, which all contribute to emissions, the mining of the rare element platinum, a critical ingredient in fuel cells, produces significant environmental damage. However, aside from these processes, which all have room for improvement in the near future, FCEV's are a viable partial solution to

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[29] Lim, Brandon. "2021 Toyota Mirai First Drive." *MotorTrend*, 16 Dec. 2020, https://www.motortrend.com/reviews/2021-toyota-mirai-first-drive-review/.
[30] California Air Resources Board. "Hydrogen Fueling Overview." *DriveClean California*

reduce consumer transport emissions. They require no change in lifestyle and cost about the same or less to own and refuel as internal combustion vehicles. In fact, many hydrogen cars are sold with multiple years of free refueling, as well as government tax incentives of up to seven thousand dollars.[31]

The real cost of these vehicles falls not on the consumer, but on companies and governments who must develop them, as well as their accompanying infrastructure. Right now, though, this infrastructure does not yet exist. Figure 3 shows all the hydrogen refueling stations in America, and it is obvious that FCEV ownership is only feasible in a select few areas.[32] The hesitancy to invest on the part of governments and fuel corporations is the driving factor that limits FCEV ownership. Granted, this map would look more optimistic in select other countries due to their higher levels of investment in fuel cells, but as the supposed world leader in innovation and automobile production, the United States must set a stronger precedent. Hydrogen fuel cell technology is young, though, and actions of the near future will determine if it will develop into a leading solution, or fall as a fluke alternative.

Figure 3

← *Synthetic Fuel* →

[31] Wilberforce, et al. *Developments of Electric Cars And Fuel Cell Hydrogen Electric Cars*. 2018
[32] "Alternative Fueling Station Locator." *United States Department of Energy*

Sustainability and fuel saving were concepts first commercially promoted in the early and mid 2000's. One of the first forms of synthetic fuel was used restaurant vegetable oil, which could be purchased by the barrel and burned as fuel in slightly modified diesel engines. Conversion kits and how-to articles flooded the internet as individuals searched for a way to power their cars and trucks that utilized already existing materials, thus helping the environment. Nowadays, synthetic fuels have matured, and are a target fuel method for many major automobile corporations. The potential solution synthetic fuels pose is often overlooked by environmentalists who believe radical change is necessary, however, within the automotive and political communities where the change will occur, synthetic fuels are being heavily considered. Unlike all other methods, synthetic fuels can be fully implemented without changing refueling infrastructure or taking away the function of vehicles already on the road.[33] The instant processing facilities are constructed to produce synthetic fuel, they will be able to produce, and provide a more sustainable way to power currently driven gas cars. Even if synthetic fuel is not utilized as a long term solution, the short term implementation of it would cut carbon emissions drastically. Porsche, the major corporate catalyst for synthetic fuel, stated that its use in internal combustion engines, when sustainably produced, cuts emissions by 85%, which, if true, would be a similar figure to the well-to-wheel emission cuts of an electric vehicle.[34] However, in research completed by Transport and Environment, an independent organization, it was found that electric cars will only be 40% more efficient than synthetic fuel-powered vehicles, all

[33] Morris, James. "Synthetic Fuels Won't Save The Planet, So Don't Say They Could." *Forbes*, 27 Mar. 2021, https://www.forbes.com/sites/jamesmorris/2021/03/27/synthetic-fuels-wont-save-the-planet-so-dont-say-they-could/?sh=3f978e2369a4.

[34] Kitman, Jamie. "Faux Fuel: Can Chemistry Save Internal Combustion?" *Car and Driver*, 25 Sep. 2021, https://www.caranddriver.com/features/a37419222/synthetic-fuel-porsche-bmw/.

while costing 43% less throughout ownership.[35] It is important to note, however, that the statistics proposed would each benefit the parties which privately completed the studies and presented the data, and until synthetic fuel is commonplace on roadways, it will be difficult to test their exact efficiency.

In partnership with Siemens, Porsche has begun construction on a 24 million dollar synthetic fuel plant in Chile, which will be ready to produce commercially sometime in 2022.[36] The plant exists in a windy location in order to gather as much wind power as possible sustainably, thus reducing the emissions released from the production of the fuel. Many other major brands, such as BMW, McLaren, and ExxonMobil have begun investing in synthetic fuel alongside Porsche.[37] The production process Porsche plans to use in their new factory utilizes air, salt water, renewable energy, and CO_2 collected from the atmosphere to produce its synthetic fuel product.[38] This process means that carbon already in the atmosphere will be reduced

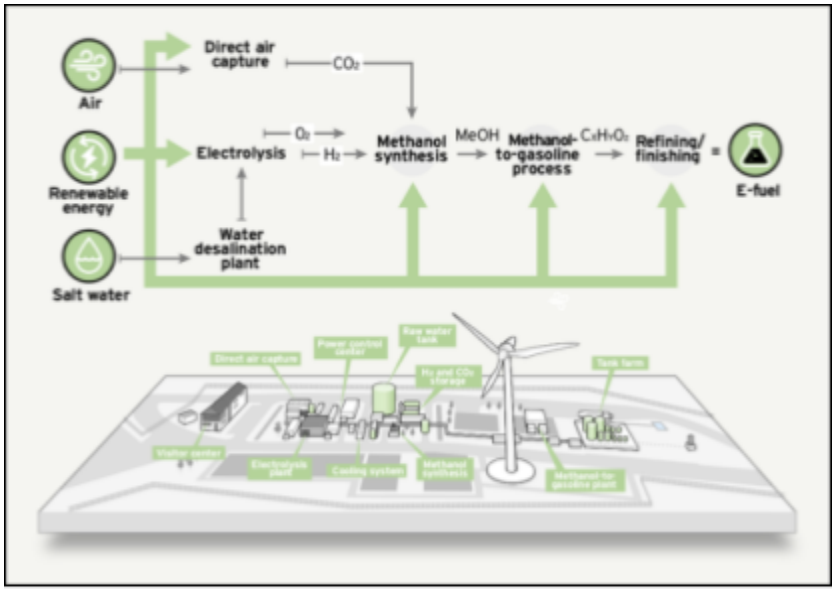

Figure 4

[35] Edelstein, Stephen. "Study: Synthetic Fuels Cost More Money and Cause More CO2 Emissions vs. Batteries." *Green Car Reports*, 4 Apr. 2021, https://www.greencarreports.com/news/1132136_study-synthetic-fuels-cost-more-money-and-cause-more-co2-emissions-vs-batteries. Accessed 20 Jan. 2022.
[36] Kitman, Jamie. "Faux Fuel: Can Chemistry Save Internal Combustion?" *Car and Driver*
[37] Morris, James. "Synthetic Fuels Won't Save The Planet, So Don't Say They Could." *Forbes*
[38] Kitman, Jamie. "Faux Fuel: Can Chemistry Save Internal Combustion?" *Car and Driver*

through the production of power, though this process costs energy, and occurs at a rate that will have next to no effect. The cost of this fuel, once produced, is projected to be about twice that of normal gasoline.[39] However, the performance and similarity to modern gasoline that synthetic fuel maintains could be a critical aspect in at least temporarily reducing vehicle emissions until technology is accessible for true zero emissions.

Synthetic fuel is a polarizing resource in the quest for sustainable consumer automotive power. It provides a more sustainable solution for car enthusiasts with vintage vehicles they still desire to drive, while also requiring almost no change to modern infrastructure. Perhaps the greatest benefit of synthetic fuel, though, is the fact that it can be effective in locations with any basic gas station, enabling access to sustainable automotive power that other options cannot provide due to costliness. Per gallon, the fuel is more expensive than typical gasoline, but as states within the US follow California's lead in the banning of internal combustion vehicle sales, synthetics will become critical.[40] Specialist vehicles, such as the military, as well as motorsport, could greatly benefit the environment by utilizing synthetic fuel over typical gas, as organizations such as Formula 1 already have. No other sustainable fuel method offers a transition as easy as synthetics. However, as with these other methods, synthetic fuel is not perfect, and of the three discussed in this paper, it may likely land the world the furthest from zero emissions if fully implemented. Princeton University estimates that a full switch to synthetic fuels would only reduce emissions by 50%, while costing over a

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[39] Morris, James. "Synthetic Fuels Won't Save The Planet, So Don't Say They Could." *Forbes*

[40] "Governor Newsom Announces California Will Phase Out Gasoline-Powered Cars & Drastically Reduce Demand for Fossil Fuel in California's Fight Against Climate Change." *State of California*, 23 Sept. 2022, https://www.gov.ca.gov/2020/09/23/governor-newsom-announces-california-will-phase-out-gasoline-powered-cars-drastically-reduce-demand-for-fossil-fuel-in-californias-fight-against-climate-change/. Accessed 20 Jan. 2022.

trillion dollars in factory construction which would last over 30 years in order to provide a proper supply.[41] Even Porsche's own CEO stated, "Our goal is and remains electric mobility. This is the future. It must be emphasized that we do not see the use of e-fuels as an alternative, but as an addition to the all-electric drive." Synthetic fuels, similar to regular gasoline, are four times less efficient than battery power.[42] Production of the fuel is slow, and Porsche's factory will not be able to meet any need much more than specialist motorsport groups whom they contract with and a supply to power their own vehicles. The process which produces synthetics consumes large amounts of energy, and in locations unlike Chile where renewable electricity is not abundant, it will become wasteful if done at large scale. Supply and implementation location provide no obstacles in the path of synthetic fuel, but the impossibility of true zero emissions that comes with it is a detriment to its potential short term promise.

⌐ *In Conclusion* ¬

Despite these three promising methods of powering cars while cutting emissions, no accessible method currently exists that can guarantee zero emission consumer automobile use immediately. However, many options are present that promise to cut emissions by at least 50%, which is progress that must be made soon. Over 55% of the world's energy consumption is from the transport industry, with consumer automobiles being the primary force in the field.[43] Right now, there is no complete solution to cut emissions from all consumer automobiles, but partial developments that come quite

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[41] Kitman, Jamie. "Faux Fuel: Can Chemistry Save Internal Combustion?" *Car and Driver*
[42] Morris, James. "Synthetic Fuels Won't Save The Planet, So Don't Say They Could." *Forbes*
[43] Wilberforce, et al. *Developments of Electric Cars And Fuel Cell Hydrogen Electric Cars*. 2018

close show that it will soon be possible. A greater investment, by governments and major vehicle corporations alike, must be placed into research and implementation of sustainable fuel options. A vehicle powered by either electricity, hydrogen, or synthetic fuels would individually help the majority of the world population towards the net zero goal. Electric cars, for those living in densely populated areas, are an excellent option, which will only become better with the future development of solid state batteries and an expansion to the renewable electric power grid. Vehicles gathering power from hydrogen fuel cells are equivalently efficient at reducing overall emissions, and they will also gain prominence through investments and exposure from major influential groups as time goes on. Synthetic fuel, though similar to gasoline, requires no change in consumer infrastructure, benefitting less developed regions, while also pulling carbon directly out of the atmosphere through its production.

It is complicated. None of these sustainable alternatives will be the ideal solution for everyone, rather, the near future must shift into a hybrid world in which a variety of sustainable consumer automobiles must be heavily promoted and implemented, offering a chance to save the climate and humanity. As consumers move to alternative fuel sources for their automobiles with a goal of zero emissions, there is no single solution that is feasible for all drivers around the world. Factors such as affordability and access to supplies will help determine the best alternative for each to choose.