The Aviation of the Future and Its Challenges

Jordan SUAREZ

Economics and International Business, Romanian-American University, Romania

Abstract

While all sectors are transforming to be more environmentally friendly. What about the future of aviation? Aviation is one of the most polluting sectors, and with the expected growth in air traffic, there is an urgent need to make this sector more environmentally friendly. Companies are trying to innovate with new projects with the aim of reducing the carbon footprint of their aircraft. This paper examines two projects, their challenges, and issues.

Keywords: ecology, aeronautics, hydrogen, Bio jet fuel

Introduction

In 2020, 1.8 billion passengers flew, the same level as in 2003, which represents a 60.2% decrease compared to the 4.5 billion who flew in 2019. The aviation sector has been particularly affected by the Covid-19 pandemic. Industry experts estimate a return to 2019 levels by late 2023, early 2024. And then reach 5.6 billion passengers by the end of the decade, with annual growth of 3.9% between 2025 and 2030.

For some years now, with forecasts of fairly significant growth in terms of traffic and therefore, in fine, of the carbon footprint, many questions have been raised about the compatibility between aeronautics and ecology. To better understand these questions, we will look at the example of France.

Air transport is responsible for 7.3% of France's carbon footprint and is increasing. Without major changes, emissions from the aviation sector will continue to grow, even though national and

international commitments require a drastic reduction in greenhouse gas emissions. The entire effort needed to bring France onto the carbon neutrality trajectory would be destroyed by the aviation sector if it were to continue to grow.

Emissions from the aviation sector would represent the equivalent of France's carbon budget established by the National Low Carbon Strategy in 2050. “The only credible way to maintain a reasonable trajectory from a climate point of view is to reduce air traffic”. In order to comply with the Paris Agreement and not exceed 2°C of climate change, a decrease in passenger numbers of between 2.5% and 4% per year is necessary. In other words, the number of annual passengers should be halved within a maximum of 20 years.

So, we can ask ourselves whether growth and carbon footprint are achievable simultaneously? In view of certain reports and people, we can think that no, "Air travel is sad, but it should no longer be a child's dream today" Léonore Moncond'huy.

We don't know how to anticipate innovation. All projections and quantitative analyses that are made under the assumption don’t anticipate innovations. So yes, if we assume that there are zero innovations, whether in industrial processes and/or in terms of technology, we won't be able to have more flights, so people should stop flying.

But then, is there a future for aviation? And if so, is the aviation of the future exclusively ecological?

To answer these questions, we will study a concept from Airbus as well as biofuel with algae. This paper will present a new vision of these two projects and a new perspective for biofuel with algae. A survey was also conducted to better understand the expectations of passengers for the aviation of the future.

ZEROe Concept Aircraft

Manufacturers are setting up new and innovative projects, most of which attempt to address environmental issues. One of the most popular projects is that of Airbus.

Airbus carried out several studies to choose the best energy between methane, butane, ethanol, methanol, ammonia, and other energies. They concluded that hydrogen was the most promising

energy. So, in 2020 they presented three concepts for aircraft using hydrogen: the Turboprop, the Turbofan, and the Blended-Wing Body.

The Airbus hydrogen aircraft project would operate via 2 systems:

- Fuel cell: The fuel cell reacts hydrogen with oxygen to produce electricity and power the aircraft's electric motor, then the heat from the fuel cell must be managed. At a certain power level, it becomes difficult to manage the removal of this heat. The fuel cell is therefore more suitable for small aircraft (figure 1).

- Hydrogen engine: A cryogenic tank and an air compressor are used to supply the engine with air, which is then burnt to produce water and heat, which is used to propel the aircraft (figure 2).

Figure 1. Fuel cell

(https://www.youtube.com/watch?v=1wZ6HcjGR3s&t=3s)

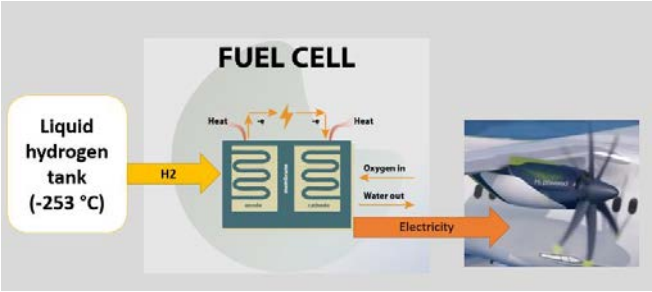
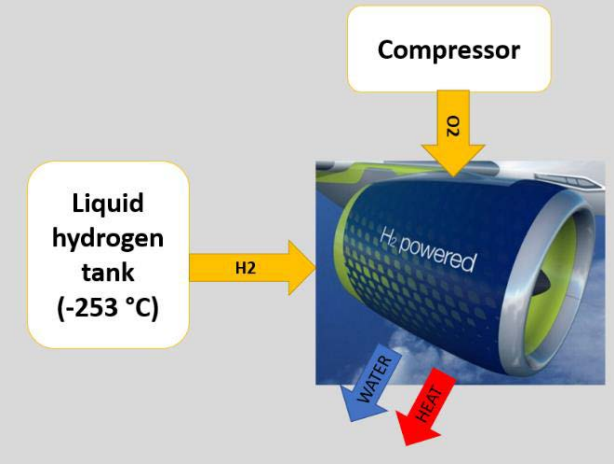


Figure 2. Hydrogen engine

(https://www.youtube.com/watch?v=1wZ6HcjGR3s&t=3s)



Hydrogen powered aircraft is technically possible, and the Tupolev Tu-155 is proof of this. The test flight on 15 April 1988 with three engines, one of which ran on liquid hydrogen, was a success, but the fall of the Soviet Union in 1991 put the project to rest.

As we have seen, hydrogen is possible and would present real advantages in terms of meeting the ecological challenge, since hydrogen-powered aircraft don’t emit any pollutants into the atmosphere. However, several constraints cast doubt on the idea that hydrogen aircraft will replace the current fleet of aircraft for several reasons:

Hydrogen takes up much more volume (4x more) than jet fuel, which implies supply and storage difficulties. To be stored in liquid form, hydrogen must be cooled to -253°C. Storing such a large volume of hydrogen at -253°C and maintaining it at this temperature will require the use of a cryogenic system, new materials that don’t exist today and a liner that is tight enough to prevent the hydrogen from leaking". The main problem concerns the structure of the hydrogen tank: "it will have to combine three properties, including static strength at low temperatures, thermal insulation and resistance to vibration and shock". Taken separately, these properties have been mastered. "The challenge is to combine them in a single material to be invented". Cryogenic tanks must also be cylindrical or spherical in shape to withstand the pressure, which makes their integration more complex.

Europe is not starting from scratch. With the space engines of the Ariane launchers, it has experienced the hydrogen fuel chain in the space sector, including refuelling and tanks. But specialists in the commercial aviation and transport sector are more nuanced. Luis Le Moyne, director of the higher institute of automobile and transport, explains that, as it stands, the "technology is not mature enough to be used in commercial aircraft" (Decourt, 2020). The development of a hydrogen engine, "whether it is a fuel cell that produces the electricity needed to drive a propeller or one that burns hydrogen in a turbojet engine", faces several technical and hydrogen production problems "requiring a massive increase in the production of wind and solar energy".

While the idea of flying a carbon-neutral commercial aircraft in 2035 seems feasible, there is also the question of the economic model that we wish to apply to this type of commercial aircraft. However, with oil being cheap and likely to remain so for a long time to come at very competitive

levels, hydrogen looks like a fairly expensive fuel to manufacture, especially as all the stages of its production will have to be decarbonised. All of this is more complicated than pumping oil and refining it.

In terms of GHG emissions, hydrogen will not avoid all the non-CO2 effects, although it does contribute to them. More worryingly, the vast majority (96%) of hydrogen manufactured today is produced by steam reforming of hydrocarbons: an extremely emissive process since to obtain one tonne of hydrogen, 10 to 11 tonnes of CO2 are produced and generally emitted into the atmosphere. Thus, although CO2 is not emitted during the flight phases, it is emitted upstream.

The reason for the interest in hydrogen is that it is possible to obtain hydrogen by electrolysis of water (green hydrogen). Thus, the production of hydrogen consumes electricity, which is a great opportunity from a climatic point of view, particularly for France, whose energy mix is decarbonised.

A democratisation of hydrogen requires a significant production of electricity in addition to the current use of electricity. This would require the installation of additional capacity to produce electricity dedicated to the electrolysis of water, either by increasing the current nuclear fleet or by developing numerous new renewable electricity production facilities. This solution requires a lot of energy. A team of researchers in Toulouse has estimated that it would take between 10 and 18,000 wind turbines (or 5,000 km^2), 1,000 km^2 of solar panels or 16 nuclear reactors to replace the jet fuel at Paris-Charles-de-Gaulle airport alone (representing about 37% of traffic in France).

These figures raise the question of the feasibility of the energy transition of the aviation sector, especially in a context where the sector is expected to double every 15 years.

We are touching on another sensitive point for the future of air transport, namely the competition with other sectors for available resources. It will certainly not be possible in the next 20 years to develop the electrical capacities that will allow us to maintain the use of electricity that we currently have in our way of life and at the same time to switch all transport (rolling, flying and even floating) to electric. For example, the energy demand of a decarbonised aviation sector using hydrogen is estimated at 21,000 TW·h in 2050, or 84% of the renewable energy available in 2040 according to the best scenario for renewable energy development in the World Energy Outlook 2019 (25,000 TW·h). Therefore, if hydrogen were to be used in air transport in the next 20 years, the fuel used

would come primarily from the steam reformation of hydrocarbons. And even if we Assume that enough green hydrogen can be produced, by electrolysis of water with renewable electricity. Filling the hydrogen tanks is a problem. The hydrogen still must be liquefied, which is a costly and energy-intensive operation. Then transporting it in a liquid state to airports by rail or truck would be an economic and energy disaster: a 38-tonne truck only carries 4 tonnes of liquid hydrogen! Knowing that in 2050, the hydrogen needs for aviation would amount to 40-50 million tons per year. "We could deliver the compressed hydrogen by pipeline or produce it by electrolysis and liquefy it on site at the airport. Then fill the tanks slowly, keeping the temperature incredibly low and avoiding boiling. But, of course, this will have to be done away from the public and in the open air, as any leakage in an enclosed space represents a major risk, as hydrogen can explode at low concentrations.

Airports should therefore have sufficient storage space to supply aircraft with paraffin and hydrogen. Hydrogen tanks can be up to 100 times more expensive than tanks for other gases. So, the economic equation is not yet solved.

It should also be noted that today, these zero-emission aircraft would only have a range of 3,500 km at best. Hydrogen is not being studied for long-haul flights, which account for about 48% of France's CO_2 emissions. It would a priori be a substitute solution restricted to short- and medium-haul flights.

There is also the problem of the average life span of aircraft (around 18 years), which means that this technology could not be sufficiently widespread to become significant before 2050.

While Airbus plans to launch its first hydrogen-powered commercial aircraft as early as 2035, the materials, tanks, distribution systems and air conditioning are all uncertainties that need to be resolved, as everything must work with hydrogen and not jet fuel.

We have here an ambitious project, which theoretically would work, but realistically this project and all that it implies is likely to be very complicated to implement soon.

Combining aviation and ecology a utopia or is it realistic?

Alternatives, algo fuel the best solution?

As we have seen, to be able to truly propose a solution that is feasible, sustainable, and integrated into our lives, the project must meet both ecological and economic needs.

The most promising solution, in my opinion, is the bio jet fuel solution.

Aviation biofuel could help decarbonize medium- and long-haul air travel generating most emissions and could extend the life of older aircraft types by lowering their carbon footprint. Biofuels are biomass-derived fuels, from plants or waste; depending on which type of biomass is used, they could lower CO_2 emissions by 20–98% compared to conventional jet fuel. The first test flight using blended biofuel was in 2008, and in 2011 blended fuels with 50% biofuels were allowed in commercial flights. Aviation biofuel can be produced from plant sources like Jatropha, algae, tallows, waste oils, palm oil…

So, we have an alternative, with biofuel that has already been working since 2008. In 2010, Airbus managed to get a plane off the ground using fuel derived entirely from algae. Algae offer promising possibilities for CO_2-neutral flights. They release as much dioxin as they absorb during their development phase. 100 kilos of algae are needed to produce 21 litres of biofuel and at the same time absorb 182 kg of CO_2.

According to an expert from Total, biofuels could account for 45% of global consumption by 2050. The solution could well be found in algo fuels, because of their excellent energy and ecological efficiency throughout their life cycle.

However, to impose biofuels, manufacturers must reduce their cost. This remains the main obstacle to the development of biofuels. Production costs are currently between three and ten times higher than for jet fuel. But mass production would reduce this gap.

Here too we have a project that is feasible and promising, but the financial aspect is a barrier to its widespread use.

Even Airbus says: "the ideal solution is to recycle the CO_2 emitted by industry in order to accelerate the growth of algae for conversion into biofuel" (Brimont, 2019).

What if economics were a lever rather than a barrier?

If companies were to grow algae, they could have an extraordinary biological balance sheet as it would create ecological niches for fish as well as ultimately allowing them to fly on biofuel.

Owning these algae crops for a company would be very relevant. Obviously, this would have a cost for the companies, but with the cultivation of algae other sources of income could be envisaged. With seaweed we can now make alginates, fisheries and many other activities that can be derived from seaweed cultivation, cultivating bivalves like scallops whose shells can be transformed into bioplastic and whose flesh can be eaten.

This is what Gunter Pauli explains through the Blue Economy, called the cascading value chain. The Blue Economy allows everything that is produced while manufacturing to be reused. Thus, what could be considered as waste becomes a source of energy to produce something else. It is opposed to the current economic model which produces a lot of waste and recycles very little.

With the cultivation of algae for biofuel and everything else we can do with algae we have a cascading value chain. Algae fuel could even be "FTP" Free to produce for companies. Understand that the algo fuel business from algae would cover the expenses, this may be optimistic but even if this were not the case the cost of their algae biofuel would be very affordable. Obviously, we still need to innovate on large scale industrial processes, realistically this solution is possible faster than the hydrogen aircraft because we already have enough knowledge to exploit this model.

At a time when we have already successfully flown 100% biofuel aircraft, or biofuel aircraft have received the international certification required for commercial flights. The hydrogen aircraft project is still in the conceptual phase, Airbus will not conduct any tests before 2025 and the objective is to launch its first aircraft on the market only in 2035. Algo fuel has a real advantage here.

Investments? Yes

When a €800 million "France 2030 plan" was developed to develop the aircraft of the future. When we see that the state has helped Air France to the tune of 4 billion euros, but that nothing has been done to allow biofuels and algae to be developed on a large scale, we can ask ourselves if we are really going in the right direction because the bio jet fuel project needs investment. So yes, in the long term, hydrogen-powered aircraft will be able to replace current aircraft, but given the need to reduce CO_2 emissions now, it is unfortunately not enough.

According to the IPCC's 2022 report, by 2050 about one billion people could be living in coastal areas threatened by rising sea levels and marine submersion during storms.

The report by UN climate experts (IPCC) "is a compendium of human suffering and a damning indictment of the failure of leaders to tackle climate change said Mr Guterres (UN Secretary-General)" (Climat: les experts du GIEC s'alarment des conséquences énormes d'une planète en péril, 2022). Any "further delay" in tackling climate change will miss the small chance of securing a "liveable future" for humanity, the UN's climate experts (IPCC) have warned. "The mounting scientific evidence is unequivocal: climate change is a threat to human well-being and the health of the planet" (Climat: les experts du GIEC s'alarment des conséquences énormes d'une planète en péril, 2022), underlining the need to act both to reduce greenhouse gas emissions and to prepare for further disasters. The need to reduce emissions by almost 50% by 2030 in order not to exceed +1.5°C.

So, I ask you the question, this hydrogen aircraft project which will only see the light of day from 2035. That between 2021 and 2040 Airbus estimate to build about 35,000 aircraft (a320 family) with a production of about 600 aircraft per year (considering an increase in productivity in future years). Understand that even if the hydrogen aircraft is a success, launched in 2035 it will be in insufficient quantity to allow the aviation sector to achieve its objectives in terms of ecology. Is this hydrogen aircraft project sufficient to reduce the effects of global warming?

My answer is no! It is too late because we must act now! Solutions while waiting for the hydrogen planes of the future have not been taken. There is nothing to prevent us from seeing a near future with planes running on bio jet fuel gradually taking the place of traditional paraffin planes and in a more distant future seeing the aircraft fleet shared between these two solutions, i.e., algo fuel planes and hydrogen planes.

Conclusions

To the question, do you think aeroplanes and ecology are compatible? 70.6% answered yes and 28.4% answered no. This percentage shows that about a third of the respondents doubt or think that we cannot reconcile the two. This is therefore a question that one has every right to ask

Even if we have focused exclusively on aviation from the point of view of ecology, the aviation of the future must also face different challenges and must address the concerns and expectations of passengers. For more than 60% the first concern when they fly is safety, followed by reliability and comfort. Ecology is the least chosen answer (no one chose ecology as a first concern). Yet 43.1% of people expect the plane of the future to be more ecological. The rest are divided between faster (25.5%), safer (11.8%), more connected (9.8%) and more comfortable (7.8%). One might think that these results are rather paradoxical, as ecology is the last expectation of passengers, but they see the plane of the future as more ecological. However, these results make sense on the one hand because ecology is a subject that is being discussed more and more and when we research or talk about the aeronautics of the future, we only find results on solutions, on projects that make this sector more ecological. So, it is normal that people have come to terms with the idea that the aircraft of the future will be more ecological. However, 58.8% have never heard of biofuel for aircraft or hydrogen aircraft, only 41.2% have heard of at least one of these two projects. Why is it that more than one in two people are not aware of these projects, is it due to a lack of information on these projects? Is it due to a lack of interest in the aviation sector or in the ecology? This is a question that makes sense because when 82.4% answer that they don’t think about their carbon footprint when they fly, we can wonder if people are sufficiently aware and informed.

In conclusion, it is important to be interested in the aviation of the future and we need to understand the issues and the projects but also their consequences. As we have seen, a project must not only reconcile the ecological aspect but must also be organised so that it is economically viable but also respond to the time constraint.

In this article we are interested in the two projects that I think are the most ambitious and feasible: the Airbus hydrogen aircraft project and the algae biofuel project. There are other projects such as Boeing's Sugar Freeze aircraft or TU Delft's Flying-V.

These projects will provide greener aviation, which will contribute to the fight against climate change, which is now a major objective. However, as we have seen, although the Airbus project is interesting from every point of view, the production of green hydrogen will not be sufficient, which raises questions about the relevance of the project. While bio jet fuel via algae is already a technology and a process that we know and master, certainly there is still a lack of investment and

innovation in this sector, but this project is more quickly accessible, in a certain precariousness of the environment that accelerates from day to day, month to month, year to year it is fundamental to act as quickly as possible.

References

aeronewstv, (2021, March 4). Retrieved from Youtube: https://www.youtube.com/watch?v=V3zVOxHchqU

Airbus teste des moteurs d'avions à hydrogène. (2022, February 22). Retrieved from Capital: https://www.capital.fr/entreprises-marches/airbus-teste-des-moteurs-davions-a-hydrogene-1429213

Avion à hydrogène: les deux possibilités. (2021, August 31). Retrieved from https://www.youtube.com/watch?v=1wZ6HcjGR3s&t=3s

Bouveret, T. (2013, April). Retrieved from https://www.larevuedelenergie.com/wp-content/uploads/2019/03/Micro-algues-energie-propre-XXIe.pdf

Brimont, G. (2019). Le biocarburant dans le secteur aérien : vers des vols plus verts ? Retrieved from TransportShaker: transportshaker-wavestone.com/le-biocarburant-dans-le-secteur-aerien-vers-des-vols-plus-verts/

Climat: les experts du GIEC s'alarment des conséquences énormes d'une planète en péril. (2022, February 28). Retrieved from nations unies: https://news.un.org/fr/story/2022/02/1115262

DÉCARBONER L'AVIATION. (n.d.). Retrieved from Corac: https://aerorecherchecorac.com/decarboner/avion-du-futur/

Decourt, R. (2020, June 24). Les Airbus de demain voleront-ils à l'hydrogène? Retrieved from yahoo finance: https://fr.finance.yahoo.com/actualites/airbus-demain-voleront-%C3%A0-l-073000041.html

echos, L. (2020, October 12). L'hydrogène va-t-il révolutionner l'énergie? Retrieved from Youtube: https://www.youtube.com/watch?v=2N6GwxEDmEQ

EMISSIONS DU TRANSPORT AÉRIEN : LA FAUTE AU LONG-COURRIER. (2021, February 17). Retrieved from Air Journal: https://www.air-journal.fr/2021-02-17-emissions-du-transport-aerien-la-faute-au-long-courrier-5226055.html

Feuvre, P.L. (2019, March 18). Are aviation biofuels ready for take off? Retrieved from iae: https://www.iea.org/commentaries/are-aviation-biofuels-ready-for-take-off

Flying-V. (n.d.). Retrieved from tuDelft: https://www.tudelft.nl/lr/flying-v

Fortin, P. (2021, April 26). AVEC ZEROAVIA L'AVION À HYDROGÈNE PREND SON ENVOL. Retrieved from Les echos planete: https://planete.lesechos.fr/solutions/avec-zeroavia-lavion-a-hydrogene-prend-son-envol-8920/

Gliszczynski, F. (2020, January 14). Airbus table sur une production record d'A320 dès 2023! Retrieved from La tribune: https://www.latribune.fr/entreprises-finance/industrie/aeronautique-defense/airbus-table-sur-une-production-record-d-a320-des-2023-871966.html

Global Market Forecast. (n.d.). Retrieved from Airbus: https://www.airbus.com/en/products-services/commercial-aircraft/market/global-market-forecast

L'AVION À HYDROGÈNE, NÉCESSAIRE MAIS PAS SUFFISANT POUR DÉCARBONER L'AVIATION. (2022, January 26). Retrieved from bfmtv: https://www.bfmtv.com/economie/entreprises/transports/l-avion-a-hydrogene-necessaire-mais-pas-suffisant-pour-decarboner-l-aviation_AD-202201260020.html

L'avion à hydrogène, nécessaire mais pas suffisant pour décarboner l'aviation, selon une étude. (2022, January 26). Retrieved from Geo: https://www.geo.fr/environnement/lavion-a-hydrogene-necessaire-mais-pas-suffisant-pour-decarboner-laviation-selon-une-etude-208081

Le nombre de passagers aériens retrouvera son niveau d'avant-crise en 2023. (2021, May 26). Retrieved from La presse: https://www.lapresse.ca/affaires/economie/2021-05-26/estimation-de-l-iata/le-nombre-de-passagers-aeriens-retrouvera-son-niveau-d-avant-crise-en-2023.php#:~:text=Sur%20le%20long%20terme%20(2019,passager%2Dkilom%C3%A8tre%2C%20sera%20moindre

Les biocarburants peuvent-ils vraiment améliorer le bilan écologique des avions ? (2021, June 24). Retrieved from le monde: https://www.lemonde.fr/les-decodeurs/article/2021/06/24/les-

biocarburants-peuvent-ils-vraiment-ameliorer-le-bilan-ecologique-des-avions_6085511_4355770.html

Michaut, C. (2021, February 2). Biofuels, an alternative that is still too expensive. Retrieved from Polytechnique insights: https://www.polytechnique-insights.com/en/braincamps/planet/zero-carbon-aviation/biofuels-an-alternative-that-is-still-too-expensive/

PLAN FRANCE 2030: 800 MILLIONS D'EUROS POUR DÉVELOPPER L'AVION DU FUTUR. (2022, March 15). Retrieved from bfmtv: https://www.bfmtv.com/economie/entreprises/industries/plan-france-2030-800-millions-d-euros-pour-developper-l-avion-du-futur_AD-202203150079.html

Réchauffement climatique: ce qu'il faut retenir du dernier rapport du GIEC. (2022, February 28). Retrieved from Geo: https://www.geo.fr/environnement/rechauffement-climatique-le-giec-sort-un-nouveau-rapport-208564

Tamburelli, L. (2020, September 27). The Tupolev which flew on hydrogen 32 years ago. Retrieved from Private jets blog: http://blog.privatejetfinder.com/tu-155-hydrogen/

Thouverez, P. (2020, December 15). L’hydrogène sauvera-t-il le secteur aérien ? Retrieved from Techniques de l'ingenieur: https://www.techniques-ingenieur.fr/actualite/articles/airbus-hydrogene-emissions-86095/

Transport aérien, voyageurs transportés. (n.d.). Retrieved from La banque mondiale: https://donnees.banquemondiale.org/indicator/IS.AIR.PSGR?end=2020&start=1970&view=chart

UAF/FA. (n.d.). Retrieved from https://www.aeroport.fr/uploads/documents/rapport_2019.pdf.pdf

Zhao, S.S. (2020, July 10). Bio-aviation Fuel: A Comprehensive Review and Analysis of the Supply Chain Components. Retrieved from Frontiers in energy research: https://www.frontiersin.org/articles/10.3389/fenrg.2020.00110/full