BE GREEN, KEEP FLYING !

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INTRODUCTION

Global warming and its accelerated evolution are concerning issues. Civil aviation is responsible of 2.6% [2] Carbon Dioxide (CO_2) emission per year. A 4% [3] year gross is assumed and without any improvement this will lead to triple the emissions and this without even taking other emitted gas such as Nitrogen Oxides (NOx) into account. The aeronautical domain is aware of its ecological impact and is already changing with the challenge to have a zero-emission aircraft by 2050 [2].

In the meantime, while writing this document, the aviation industry is facing the COVID-19 pandemic, its weaknesses are showing up [4], sometimes stopping s research programs, as the E-Fan X project [5], that could have given significant results for future aircraft . What if this situation was just the premise of what could happen to the industry if no 'green aircraft' were designed on time to face global warming? The pandemic increases the urge of not only going towards but actually creating an eco-friendly aircraft and making sure it is going to be the most common aircraft used in the future.

Starting with a critical appraisal to determine the pros and cons of new technologies used to reduce energy consumption and help define a more environmentally friendly future aircraft, operation of those aircraft with current measures and infrastructures show some issues that will need to be resolved. Eventually, changes in aircraft domain will have some social, political, and financial changes.

1. Considering the importance of going green, new technologies are all mobilized to help create an eco-friendly aircraft that certainly will change the course of history.
2. However, our current infrastructures and implemented measures are causing some issues in the fulfilment of our objective.
3. If we manage to go through these different obstacles, the society might go through major changes (be it political, social or financial changes).

NEW TECHNOLOGIES FOR INCREASED AIRCRAFT PERFORMANCES

Aircraft are complex vehicles and are mainly constituted of a single fuselage and wing, a propulsion system under the wings or at the rear of the fuselage, with a tail plane and an empennage. Current aircraft are already highly optimised but new solutions can certainly help improve the change needed to both go green and keep flying.

New propulsion energy (Fuels)

Since the beginning of aviation, propulsion emissions drastically decreased as their efficiency improved [6]. As an example, the Leap is consuming 15% less fuel than its predecessor [7]. Nevertheless, despite all the progress made, fuel extraction is decreasing in the world as its stock of fuel are running lower and lower [8][9]. Therefore, new solutions need to be adopted.

A way of reducing emissions during flight can be achieved with a new propulsive energy, that is to say by changing the fuel used. Two new energies are emerging: Biofuels and Synthetic Electrofuels, with biofuels already used in test flights [10]. Biofuels are made from compostable waste and biomass, while Synthetic Electrofuels (e-fuels) are created with use of electricity creating a liquid hydrocarbon out of CO_2 and water, acquired from human emissions activity for instance [11] Using unwanted material to create energy is promising.

Biofuels and Electrofuels, the last one being considered as a Renewable Fuels of Non-Biological Origin (RFNBO), are fuels allowing them to be used in current aircraft and can be used as a complete substitute of fuel. Small powerplant system changes might have to occur to keep in consideration safety of operations, but in terms of cost, using the same aircraft with the new fuels is economically attractive. Comparing fuels on an energy density base, 100% use of Biofuels has less energy than current jet fuel [12] while Electrofuels are planning to obtain an energy density of 32 MJ/kg of fuel [13], which is slightly under the current energy density of Jet A-1 turning around 46 MJ/kg [31].

Despite the fact those solutions have a lower energy density than current jet fuel, it could help the industry reduce its environmental footprint. Research on Biofuels and Electrofuels are still ongoing, and progress is made to increase the energy density [14].

A second solution to reach the ultimate zero-emission during flight would consist in using electrical energy instead of fuel [15]. Even if electrical motors are more efficient than jet engine - a ratio of 3 - if considering a brushless motor technology, batteries energy capacity (195 Wh/kg at highest [16]) are too low compared to jet A-1 (10,000 Wh/kg [17]). Moreover, Lithium-ion batteries are made of pollutant that can't be recycled or reused yet [18], transferring the carbon footprints on a different life cycle stage for long-range aircraft [20]. Li-Air therefore help reduce batteries footprints.

A way to use electrically driven aircraft without Lithium-ion would be to use Nano-electrofuel [16] or to have a hybrid configuration. Nano-electrofuel is interesting as it is an electrically charged liquid (positively or negatively charged), used like a fuel and place in tanks separated by a membrane where the electricity will be retrieved. The liquid used can be recycled and this technology is expecting to achieve an energy density of 575 Wh/kg.

Hybrid configurations can be, for instance, a generation of electricity combining fuel cells and Liquid Hydrogen (LH_2) [22] or the use of a high-by-pass ratio using LH_2 as an on board generator. LH_2 is considered as the 3rd lowest-carbon fuel according to Safran [23] as it has a rather high energy density of 120 MJ/kg [6] and emissions stay only 50 years in the atmosphere [3]. Main issues are regarding its production and bigger pressurised storages at a temperature of 20 Kelvin which is incompatible with current aircraft configuration [6].

	Propulsive Energy Type					
	Jet A-1 fuel	Biofuel	Synthetic Electrofuel	Batterie	Nano Electrofuel	Liquid Hydrogen
Energy Reference	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**
Energy density [MJ/kg]	46	Un-known	32	0.702	2	120

Table 1: Energy Density Comparison

Several solutions of Propulsive Energy are summarised in Table 1 with their respective Energy Density. Those Propulsive Energy can lead to 'zero emission flight' if the process of energy production is renewable. Let's take Electrofuel, it was estimated that its use in aviation in Europe by 2050 would increase the use of electricity by 24% [11].

Aircraft structure improvements

Aircrafts have been using the same single fuselage-wing shape for years as it was the ideal shape for the propulsive systems used. Now, these systems and new technologies are improving aircraft structures to reduce Drag, Weight, Powerplant and Noise, decreasing the fuel penalty and finding optimum shapes for different propulsive systems [24].

Two concepts of aircraft have a lower drag generated during flight: Box-Wing (PrandtlPlane - PP) and Blended Wing body (BWB) aircraft. Box-Wing aircraft have two superposed wings and a fuselage [25]. A Sea configuration is possible with a hybrid or LH_2 propulsive energy [27] increasing the number of commercial routes. A configuration using the Open rotor could help reduce noise and fuel consumption even more [28].

The BWB, also called a flying wing, has only a single trailing edge reducing the induced drag. The length and a wide fuselage are suitable for LH_2 circular tanks. Those configuration are more fuel efficient than a conventional commercial aircraft with the same capacities [26], reducing tip wing drags and allowing a fuselage increase for the Box-Wing and a better lift to drag ratio [29] for the BWB. Powerplant on top of the fuselage configuration can also help decrease the noise thanks to the fuselage acting as a sound barrier.

The use of those aircraft concepts can be combined with new propulsive systems. The Open Rotor is consuming 30% less fuel than the CFM56 while reducing the noise [30]. The Open

Rotor can only be used with fuel, a hybrid configuration could lead to further application of this engine in the future. LH_2 High-by-pass ratio (HBPR) are estimated to be very efficient turbofan for long range aircraft with good performances and noise reduction [31]. Distributed propulsion using several electrical ducted fans could be easily implemented at the rear of the fuselage/wing to create a boundary layer, decreasing the fuselage drag [32].

Some research can help increase aircraft performances. For instance, golf balls are using a determined geometry surface to create a turbulent boundary layer to go further [33] : this could be used to achieve a natural turbulent boundary layer on aircraft surfaces. Another example is the following : whale tails have protuberances reducing by 8% the drag and increasing the Angle of Attack by 40% [34]. Surfaces create drag, morphing wing could reduce drag without using joints [35] or as in project demon demonstrated that mobile surfaces could be avoided to control the dynamic of the aircraft [36], reducing in parallel aircraft radar signature and noise.

New airframe structures configuration in line with new powerplants and propulsion system will definitely help to build a more performant aircraft, allowing lower particles emissions and a better aerodynamism. Technologies are still being characterized, but proof of efficiency are already present.

Systems

In line with new airframe structures, systems in the aircraft have an important role to play in making aircraft more environmental. Depending on what propulsive energy being used, secondary power for systems will have to adapt.

Batteries are not efficient yet and studies are helping to create a More Electric Aircraft (MEA). New generation aircraft have more electrical power on-board and are equipped with electrically powered actuators powered like Electro Hydrostatic Actuator (EHA) and Electro Mechanical Actuator (EMA) which increasing the efficiency and safety of systems [37]. For example, EHA is a localised hydraulic circuit. The power needed to keep the pressure at the required level for actuation is lower as hydraulic losses are less to happen.

MOE could also help use the OLED screens [38] and replace traditional windows and cockpit. Fake windows will allow a smoother structure, reducing drag and weight created because of structure reinforcement around window. This technology offers a low electrical consumption while being lightweight, but concerns should be made on the reliability of this technology and human trust and comfort in aircraft if this technology were to be used.

E-taxi and regenerative landing gear is interesting as the fuels to move the aircraft on the ground are energy-consuming, why not use aircraft inertia at landing to recharge batteries and reverse this energy to perform aircraft taxi [39]. Being an interesting concept, complexity of this technology will add weight to the structures combined to poor batteries efficiency to stock the energy produced and could increase fuel consumption instead.

An alternative of e-taxi could be to remove landing gear systems and assist the take-off and landing of aircraft with a maglev electromagnetic rail. Removing landing gears weight, this concept can reduce aircraft weight by 9.3% and fuel consumption by 18.1%, as well as reducing the noise during take-off up to 64% [40].

Systems are being designed and are focusing on electrically powered system. Systems will change the way of how people fly as well as helping reduce aircraft consumption.

Conclusion

A critical appraisal performed on new technologies to increase aircraft performances showed us the implication of aircraft industries to make aircraft 'greener'. Several promising technologies and research have been made, allowing us to better understand the future of aircraft. In, new technologies were given a number between 1 and 5, with the following signification (1: Totally not suitable; 2: Feasible but not recommended; 3: Already in use; 4: Suitable, need more clarification; 5: Totally suitable).

Numbers were influenced by different parameters such as the life cycle of the Aerospace

Vehicle, a military aircraft will not have the same life cycle compared to a civil aircraft, the immediate use of the new technology, does the structure need to be change, and the feasibility of a new technology if it is still in a research stage, and will be developed in the next section.

		Energy (cf. Table 1)						Systems			
		E1	E2	E3	E4	E5	E6	EHA/EMA	OLED	E-taxi	Gabriel
References		E1	E2	E3	E4	E5	E6	S1	S2	S3	S4
Military	Unmanned	3	4	4	2	2	5	3	1	4	5
	Fighter	3	4	4	1	5	5	3	4	5	5
Commercial Aircraft	LR (HC)	3	4	4	1	1	5	3	5	2	5
	LR (LC)	3	4	4	1	1	5	3	5	2	5
	SR (HC)	3	4	4	4	4	5	3	5	2	5
	SR (LC)	3	4	4	5	5	5	3	5	2	5
Cargo Aircraft	LR	3	4	4	1	1	5	3	1	2	5
	SR	3	4	4	5	5	5	3	1	2	5

		Aircraft Structure Improvements								
		Shape		Propulsion			New technologies			
		BWB	PP	Open Rotor	LH_2 HBPR	Ducted fans	Golf Ball	Whale Tail	Demon Project	Morphing wing
References		ASI1	ASI2	ASI3	ASI4	ASI5	ASI6	ASI7	ASI8	ASI9
Military	Unmanned	5	5	2	5	2	5	5	5	5
	Fighter	4	4	2	5	2	5	5	5	5
Commercial Aircraft	LR (HC)	4	4	5	5	5	5	5	4	5
	LR (LC)	4	4	5	5	5	5	5	4	5
	SR (HC)	4	4	5	5	5	5	5	4	5
	SR (LC)	4	4	5	5	5	5	5	4	5
Cargo Aircraft	LR	5	4	5	5	5	5	5	4	5
	SR	5	4	5	5	5	5	5	4	5

Table 2: New technologies for increased aircraft performances
(SR – Short Range, LC – Low Capacity, HC – High Capacity)

OPERATIONAL CHANGES OF NEW AIRCRAFT

New technologies to increase aircraft performances were established in the previous section. New aircrafts mean new ways of operating them. An aircraft life cycle can be summarised in 5 steps [41] starting from the Design, followed by the Manufacture, the Operation, the various Maintenance/Repair/Altercation to achieve Continued Operational Safety. For this challenge, we are going to have a look at the Maintenance, aircraft Operations and end of life changes resulting from new green technologies in aircraft.

Flight Operations

In previous section, several new aircraft configurations could be adopted. Amongst them, a short range with low capacity import electrical aircraft was found to be a solution for a future aircraft. Short range aircraft are mostly affected to regional routes with a short turn times and high numbers of flight a day. A major issue encounter would be charging the batteries in a short time enough to have a relevant economic model to make companies earn money. Fast charging of batteries is creating heat and can damage the cells if not performed right while increasing the weight to withstand the heat generated by using this methodology. In CS 25, section 1353 'Electrical equipment and installations' [42], it is stated that batteries temperature and pressure need to be the same at any time when used. More easily controlled in the air with ram air cooling, it is more challenging on the ground. An external cooling system will need to be found in order not to increase the weight of the aircraft during flight. Nevertheless, nanoelectrofuel could get rid of this issue by loading two types of fluid, 1 electrically positive and 1 electrically negative charged fluid on the aircraft as a traditional batterie.

Concerning aircraft using LH_2, first point should be made on the certification process. No mention of LH_2 in CS-25 is present, making an aircraft impossible to have an airworthiness certificate yet. Lack in CS-25 could be explained by the different issues that are still up to date. LH_2 are transported in a 2-bar-pressurised tank with a temperature achieving in this state 20 K (– 253°C). Moreover, it was established that to increase fuel efficiency, the inlet temperature should be around 150 K at least (-123)[6]. Despite the fact that small changes on aircraft could allow the use of LH_2 in aircraft, temperature and pressure are the limiting factors, increasing thermal cycle and compromising safety of operation. During refuelling or a parking overnight, what are the condition required due to the usage of LH_2? Tank are highly isolated, but a constant temperature would need to be achieved to limit dilatation of it that could damage the structure of the aircraft during an overnight parking.

As part of LH_2 tank, BWB or PP could be used with their upgraded performances. Choosing the PP configuration, if a distributed propulsion system made with ducted fan is used on the trailing edge of the wing to increase the boundary layer, a new emergency evacuation process will need to be redefined as emergency exit from the wing will not be possible.

Looking at military application and usage of new technologies to fulfil the demanding life cycle of combat and unmanned aircraft, batteries were not recommended if operational force is needed quickly, but nanoelectrofuel could still resolve this issue. OLED technology could be of use for combat aircraft only and if this technology is resistant enough, why not imagine a counter parallel OLED screen that could help hide aircraft from its enemy. Last but not least, E-taxi with an auto guided electrical vehicle could help save fuel for more mission flight time and also increase the time to displace aircraft if an urgent operation is needed. As military have dangerous missions, choice of propulsion should be chosen for spying or combat abilities.

Operation of flights are going to be deeply changed by new aircraft. Choose of a new technology in accordance with emission diminution policy should be chosen in accordance with safety of Operation.

Airports infrastructure changes

The aviation industry can go greener if we take into consideration all the chain that involve an aircraft. Airports are also buildings that involve various form of pollution from both aircraft and daily commuting cars. How an airport can help aviation to be more environmentally friendly?

Green airports can lead to several benefits such as an increase in biodiversity and ecosystems, improve water quality, conservation, and restoration of natural resources. Plants and microbes help to degrade chemical pollutants and organic wastes. The presence of plants attracts pollinators which provide economic benefits to the agricultural ecosystem as it can increase the productivity of food crops as well as giving a good natural environment for passengers.

Airports can help reduce aircraft particles emission and noise emission using building materials working as noise protection barriers or encourage people use public transportation. Alternative or renewable energy sources should be implemented and could also be combined with use of intelligent energy control equipment for lighting, heating walkaways, and escalators. These initiatives impose the installation at airports of wind turbines, biomass power plants and intelligent energy systems, recycling facilities, and so on.

As well as other resources, Airports consume a lot of water to maintain their infrastructures operational. Installation of rainwater harvesting program, polluted water storage and treatment, water recycling and reuse, and other systems will help to save water. Recycled water is sufficient for airport operations because mainly used in non-potables activities such as floor and aircraft washing, air conditioning systems for instance. Airports using recycled water demonstrate that it is economically and technically feasible and helps the environment [43].

Waste management should also be improved. Lot of materials are used for the reconstruction of runways or by consumers.

Thus, recycling can contribute to landfill pressure relief and reduces the demand for materials extraction. Use of recycled pavements could allow a rapid reopening with the material being already on the field for instance. Implementation of waste incineration will help reduce unnecessary waste such as packaging while producing energy.

Airport configuration changes should take in consideration aircraft of the future. LH_2 facilities combining production and stocking would need to be added, as well as a Maglev rail for the GABRIEL concept. A Maglev rail should allow aircraft with landing gears to take-off and land as not all aircraft might use this concept. On a military side, use of GABRIEL concept might be useful on the next generation aircraft carrier of for French operational force. Electromagnetic rail can help propels aircraft with a high velocity and could allow space combat aircraft to achieve its high location more quickly with less fuel burned during flight.

The global air transport is expected to continue its rapid growth. At airport level, changes can definitely be put in place to reduce environmental, social, and economic impact and help the use of environmentally friendly aircraft.

Maintenance and end of life

Maintenance is compulsory to maintain aircraft airworthy and are highly related to the end of life as dismounting process are similar.

Recycling of aircraft will help reuse material, reducing raw material extractions impacts caused by use of chemicals and transportation. Aircraft material or products are reuse at first, recycled at second and disposed or burned at third [17]. Most valued part of the aircraft are the engines and the avionics and are mainly sell for a second use on a flying aircraft.

Previously, aircraft were constituted of 70% of Aluminium for the A330 and now tendency are with Composite with the A350 using 70% of it in its structure [17], to reduce structure weight and fuel penalties. Nowadays, 90% of the aircraft are valued during end of life but Carbon fibre are the missing part of this process. This material might save several amounts of fuel during flight, but recycling of it is not possible yet compares to Aluminium. New technologies might save energies and cost during flying, but the overall life cycle of an aircraft should be considered.

New technologies such as LH_2 tanks and batteries, while considered on a maintenance phase, can be less attractive. Use of LH_2 for end of life can be compared as use of Jet A-1 in a way considering that fuel when used only will left the tanks to take care off, but maintenance of them are complicated due to the low temperature and pressure, and a direct eye check will not be possible to perform, therefor integrity of tanks will need to use adapted micro camera instead. Batteries are complicated to maintain and to recycle. High power used in batteries are harmless to human and dismantling it need to get rid of the total stocked electrical energy. Moreover, and bad maintenance could create cells malfunction leading to a potential fire.

To help reuse and recycle aircraft, aviation stakeholders launched the Process for Advanced Management of End-of-Life Aircraft (PAMELA) project including research in three stages: decommissioning, disassembly, and smart and selective dismantling. An Aircraft Fleet Recycling Association (AFRA) was co-founded by BOIENG to set-up new standards for aircraft dismantling, being responsible of 150 aircraft recycled every year.

Aircraft manufacturers are taking maintenance and end of life of aircraft seriously, showing good results and progress, and working in collaboration with ICAO Committee on Aviation Environmental Protection (CAEP) to support aircraft sustainability development.

FLYING IN THE FUTURE, A HUMAN CHALLENGE

Previous sections showed that technologies consistency and viability are progressing very quickly. What could precipitate the use of those technologies, what role does politics and consumer have and what will social, financial, and political impacts be?

Immediate improvements, an economical motivation

Major technological changes are still on progress. Despite the urgent times, several immediate improvements can be applied on current aircraft.

Improvements on electrification can be done on aircraft but also on software or onboard connected system. Development of the latter can help acquire real time information. Knowing the weather is useful for the optimization of altitude in order to use less fuel. Indeed, the optimal altitude of a plane changes along with the flight as it consumes fuel, thus its weight will decrease. Air France are working on flight road optimisation using digital information to have better precision and reliability. OpenAirlines developed a software based on data analysis from the flight recorder, meteorological data and flight plan that enable companies to save fuel. Pilots can use the software called MyFuelCoach to replay his flight in 3D and have information about the use of fuel in real time and see the different impacts when he leaves the landing gear, deploys flaps and other manoeuvres and learn how to decrease its fuel consumption. Taxiing can now be performed with one engine only.

Thales is working on a flight management system to optimize aircraft trajectories. Ironically, thanks to the support plan due to the COVID-19, research are accelerated. Pureflyt is developed to calculate in real time, new trajectories for optimization flight through a permanent exchange of data between the aircraft, the ground components, the airline, and the air traffic control transmitted by satellite constellations. For instance, if there is a storm, indication of it will appear on screen before the onboard flight radar allowing the calculator to propose an improved and more efficient new trajectory helping save fuel.

Aviation used to be a linear economy, that is to say: it takes the resources, makes the latest product, keeps it for a couple of years and then, disposes of it in landfills. The linear economy is not sustainable because it consumes a lot of finite resources and generates a significant amount of waste, pollution, and greenhouse gas emissions. Whereas, the circular economy works to reduce waste, reusing and recycling rather than wasting resources, it tries to keep materials as long as possible. The 3 main actions are known as 3R: Reduce, Reuse, Recycle and companies like Air France-KLM group started to adopt this strategy in their flight operations.

Applying the circular economy to aviation means a focus on designing and operating for sustainability, a design for reusability, a maximization in asset utilization, and better recycling. Therefore, it aims to reduce as much as it can, the environmental and social impacts, as well as to reduce economical costs and create jobs. The circular economy increases customer satisfaction by increasing a response to a sustainability challenge. This strategy can lead to a total modification of the supply chain, from product design to end-of-life management. Some breakthroughs such as 3D printer are yet helping aviation to transit toward a circular economy but there are still improvements that can be made to leave the linear economy. According to the ICAO report, 3D printing helped to reduce up to 90 percent of raw material consumption.

If we apply circular economy on airports, the easiest thing that we can do is to redesign waste management as Gatwick airport did in 2016. This led to several positives results such as reducing operation cost from saving of onsite energy and water, up to £750,000 for Gatwick. Thanks to its efforts, in 2018, this airport became the first to achieve the Carbon Trust's Zero to Landfill certification which recognise companies that have successfully achieved zero waste to landfill.

Immediate changes mainly concern flying and operations methods. Education of aeronautical worker is the first step to reduce fuel emissions and economical saving directly come out from this state of mind.

Keep flying, social and political choices

More and more, human environmental consciousness is rising. Despite the fact that global warming was already known in 1970s, real actions are recent. Sustainability is now a state of mind, a way of leaving and a political direction.

The aeronautic domain is facing what can be called as 'aeronautic shaming'. A radical approach would definitely be to not travel or buy products from others country, but attractivity in trips and exotic items are high. Some companies started to propose an additional green increased price to compensate the flight particles emissions. It was proven that consumer are ready to pay an extra price, but willingness is a factor of gender, flight range and gas reductions [45]. Women were more willing to pay than men. The higher the gas reductions were, the more likely the consumers were to pay this extra price with a limit of 15% the initial ticket price. Willingness to pay an increased ticket price to reduce gas emissions is encouraging as it will help compensate the high cost of a sustainable aircraft.

Consumers have a high power to make things change if united, but political have the same power too on a different scale. Political collaboration is the key to the future. Starting on a local scale in France, usage of Nuclear energy to produce electricity can help perform the energy revolution to a more efficient way of energy production as the International Thermonuclear Experimental Reactor (ITER) is trying to prove. Nuclear energy is creating debate as thought unsecure and radioactive, but this technology is not creating huge amount of CO_2 during energy production. The Fessenheim Nuclear power station was set out of service in 2020, results of this was the increase of imported electrical energy produced through coal-fired power station. ITER will be tested in 2035 and low CO_2 emission and constant energy will start in 2100 [46].

Changing scale and moving to the Europe Union (EU), Airbus was created to concurrence Boeing. Several countries are working together daily, and Airbus proved more than once its capacity of achieving a good product from several collaborations. Batteries were found to be very low efficient and not that much useful for future aircraft, but a political call was made to create the 'Airbus of batteries'. This collaboration will make several countries works on batteries and hope would be that an efficient, sustainable, and moral [47] battery is created. The world need batteries, but moral and pollution coming from them should not be part of making a better future world.

Improvements can be made in the EU also by merging airspace. EU planned to reform Air Traffic Management (ATM) because of the growing traffic. The de-fragmenting of Europe airspace will increase safety, reduce the aviation environmental footprint, and reduce costs related to service provision. Indeed, today, due to inefficiencies in European ATM, companies are facing unnecessary delays and aircraft are producing more CO_2 emissions than they should. This project is named Single European Sky (SES) and was launched in 2000 by the European Commission. Thanks to this initiative, companies can plan freely their flight path, allowing more direct routes, saving cost, and reducing CO_2 emissions. SES concerns civil aviation, but military organizations demonstrated their interest in it because it will enable them to have a better access to European airspace for training and operational purposes without major constraints. It represents 25% [48] of all flights operating in European airspace.

EU has the power to act and define new rules in accordance with a sustainable world policy, but concerns should be made on worldwide political stability. In 2016, the Brexit was pronounced. Now the pandemic is striking the world and how countries are dealing with the pandemic shows the different policy of different countries. Collaboration are important to combine and share knowledges, but economic and politic interest, if not human and sustainable centred, could create damaging issues for the good of operations. Gross Domestic Product (GDP) gross is one of the major objectives to have jobs and a good country economy, but Jancovici [8] proved that diminution of resources is not compatible with GDP growth. Decision to maintain stability in countries will definitely come from energy independency. Production of new energies such as Biofuel or Synthetic fuel for instance will need more biomass or electricity input. Biomass can be increased with additional farming on another country soil, but choice of the country to feed its people or to increase its economy will then create moral issues.

Flying was created by and for human being. The world is answering to a well-known economical scheme, interests first. Consumers proved that they are ready to help in performing the sustainable transition and should be supported or outdistance by politics, keeping moral integrity and human dignity while doing it.

Future of transportation

In this document, information was mainly concerning the aeronautic sector. In fact, future of transportation can be split between air, road, or marine transports.

Electrical Vertical Take-Off and Landing (e-VTOL) aircraft are considered as the new urban way of transportation in cities [49]. Ducted fans or propellers e-VTOL aircraft are favoured in urban mobility because structure footprints are rather small as it does not need a specialized equipment for take-off and landing. We just have to put the ducted fan on the ground, and it takes off vertically. Electricity is easy to install allowing the use of electric engine, lowering the noise which is a must if we want to use e-VTOL in urban areas without disturbing people. UBER plans to develop an urban air taxi network using e-VTOL to transport people from one place to another by a ride-sharing system. They aim to create a quiet, fast, clean, efficient, and safe transportation system that is affordable for all [50].

The issue that they meet is again the low energy density of lithium-batteries which held up long distances flight. Different actors from different sectors: aerospace companies (i.e. Airbus, Boeing, …), automotive companies (i.e. Audi, Honda, Toyota, …) and technology leaders and investors (i.e. Google, Intel, Uber, …) are developing high performance lightweight batteries and hybrid-electric systems. Such an implication of some world's largest companies shows that the e-VTOL might be the future of aviation and transportation. During the COVID-19 pandemic, Air Force was deployed to transport a patient from a hospital to another, we saw the importance of aviation in daily life. The use of e-VTOL might be very useful and convenient. E-VTOL can be a promising technology for future aviation if it can pass through technological and regulation challenges standing in his way.

E-VTOL can replace cars and what can replace trains and short-range flights? The hyperloop, a project initially imagined by Elon Musk might be a response to this question. This concept relies on magnetic levitation pods, propelled at speeds of up to 760 miles per hour [51] in a low pressure tube. With this speed, it can connect major cities rapidly. This new way of transportation can help to reduce congestion in airports and is more environmentally friendly with its low energy consumption. Furthermore, it will use solar energy using photovoltaic panels placed on the tube and batteries will be recharged during the braking of the train. Thanks to the high speed, hyperloop can glide using passive maglev energy and will use only 10% of energy to initiate final velocity in the whole path. If hyperloop has a lower impact on climate change, it can have a negative effect on socioeconomic. Indeed, hyperloop especially plans to connect two main cities together. People living far from the station will not really be involved in by this new technology, whereas, they will contribute to the network through taxes. In addition, they will not benefit from the influence of the Hyperloop network, places where can attract more business and tourism.

Hyperloop can be useful to transport passengers from one place to another but for products, airship can be a good substitute too. Airship does not have a good image in our mind because of the Hindenburg accident in 1937 due to hydrogen leak but today, new technologies can help to avoid this problem such as the use of very resistant materials. Airship does not require polluting energy for the elevation because it uses helium or hydrogen, fuel is used only to propel the ship forward. Thus, this way of flying will generate only 10% [52] of the CO2 emissions of a commercial aircraft. It can be used in the case where helicopters or ships could not land because of earthquakes for instance as airship can land even in an unstable land and without specific infrastructure. The comeback of airship might be a good thing for the economy as it is a cheaper and cleaner transport than plane or boat.

After the return of the very slow heavier than air, the return of supersonic can rekindle the flames of all aviation lovers. Boom, an American start-up company is trying to create a greener supersonic. In terms of energy, they plan to use alternative fuels to lower their impact on climate change, tests were handled in 2019 and results show a positive way for this energy.

Noise is the big concern for a supersonic aircraft and they also have to reduce the sound of the boom when they exceed the speed of sound which can be reduced if they adopt an optimal shape for the aircraft. It can be a promising technology because some companies such as Virgin Group or Japan airlines have already invested in this project [55]. Boom affirms that they can reduce the cost of supersonic flights by 75% [55] so the price of the ticket will be equivalent to a business class ticket.

CONCLUSION

Global warming and its accelerated evolution are concerning issues and aeronautic stakeholders are definitely involved and actively participating in developing sustainable aircraft shown with several technologies and research to achieve this goal. New propulsive energy and new structures might take over traditional aircraft in a near future.

It was found that depending on the operations, propulsive energy and propulsion systems would have different applications (cf. table 2). Propulsive energy was found to be the most complicated issues in terms of technology, energy production and density in general being low to compensate Jet A-1. Using renewable energy and oil substitute are not enough for worldwide transportation demand, energy will be more expensive increasing economic and social split. Economy priority will allow rich people to fly in supersonic business aircraft while average human would stop fast travels.

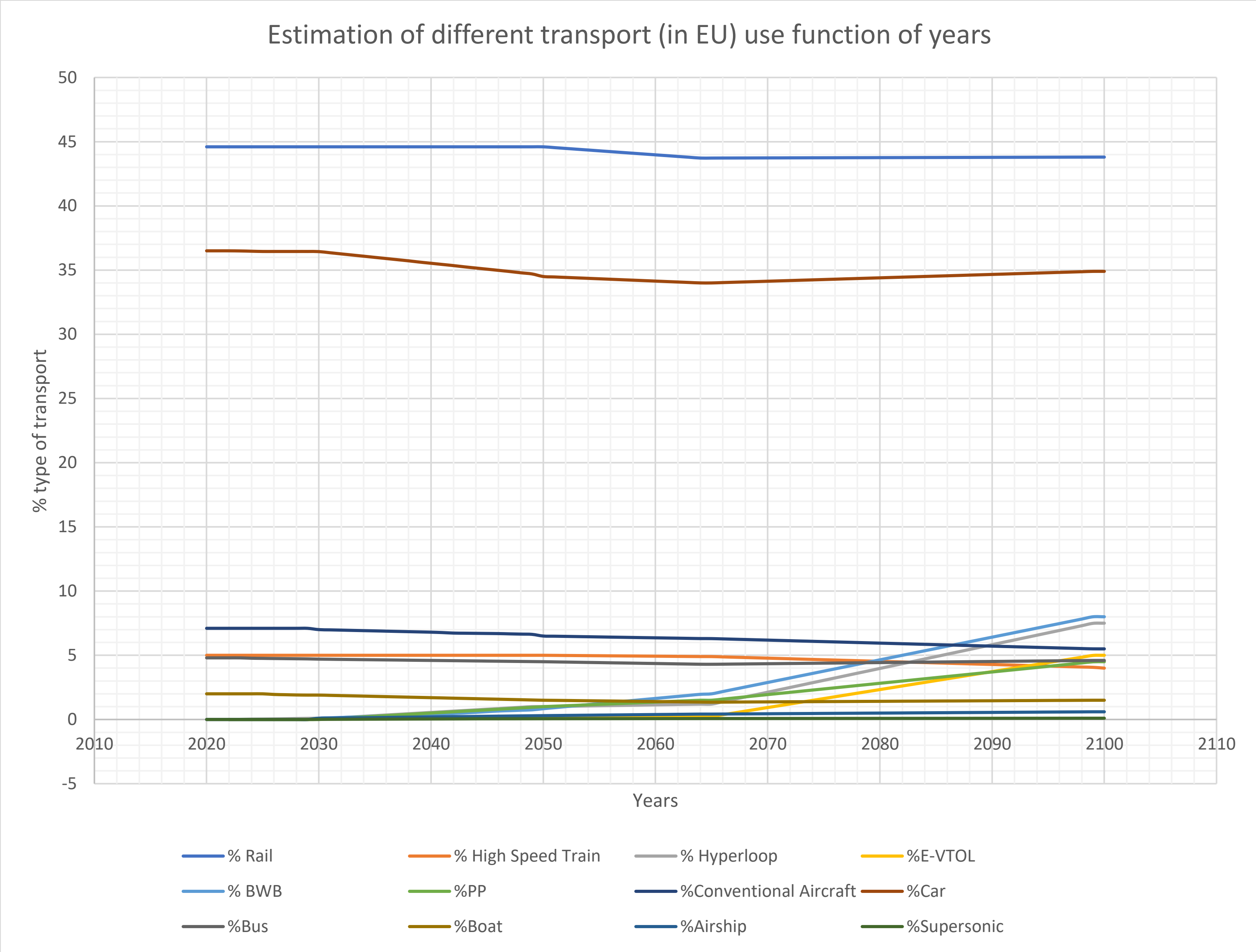
Political stability, consumer passion and worldwide partnerships are a way to help this transition to lower particle's emissions. Clear and Transparent knowledge sharing in collaborations will allow further progress. Global warming and energy production should be the next priority if we want to keep human travelling. Note that runways for aircraft have a lower impact in terms of carbon footprint than the other transport as they need roads or rails to circulate.

Supposing an optimistic approach with ITER technology working in 2100 in the world with sustainable batteries acquired from the 'Airbus of Batteries', transportation will face lack of fuel until 2100, decreasing common transportation system and digging social inequalities while using the existing energy, the transport sector will live again in 2100 with more hydrogen and electrical vehicles summarised in Table 3.

Transports	Previsions												Application	
	2030			2050			2065			2100			Freight	Pax
	Trend	%	Social	Trend	%	Social	Trend	%	Social	Trend	%	Social		
Rail	→	44,6	Average	→	44,6	High Income	↓	43,725	High Income	↑	43,8	Low Income	Yes	Yes
High Speed Train	→	5,15	Average	→	5,15	High Income	↓	4,6	High Income	↓	4	Average	Yes	Yes
Hyperloop	↑	0,1	High Income	↑	1	High Income	↑	1,3	High Income	↑	7,5	High Income	Yes	Yes
E-VTOL	↑	0,05	High Income	↑	0,20	High Income	↑	0,28	High Income	↑	5	Average	Yes	No
BWB	↑	0,1	Average	↑	0,84	Average	↑	2,3	High Income	↑	8	Average	Yes	Yes
PP	↑	0	Average	↑	1	Average	↑	1,65	High Income	↑	4,5	Average	Yes	Yes
Conventional aircraft	↓	7	Average	↓	6,5	Average	↓	6,3	Average	↓	5,5	High Income	Yes	Yes
Car	↓	36,44	Average	↓	34,5	Average	↓	34	Average	↑	34,9	Average	No	Yes
Bus	↓	4,7	Average	↓	4,35	Average	↓	4	Average	↑	4,6	Average	No	Yes
Boat	↓	1,9	Average	↓	1,5	Average	↓	1,35	Average	↑	1,5	Average	Yes	Yes
Airship	↑	0,1	Average	↑	0,3	Average	↑	0,42	Average	↑	0,6	Low Income	Yes	Yes
Supersonic	↑	0,01	High Income	↑	0,06	High Income	↑	0,075	High Income	↑	0,1	High Income	No	Yes
Energy used	Oil, Gas, Synthetic Electrofuel, Electric, Hydrogen									Hydrogen, Electric, Nano-Electrofuel				

Table 3: Estimation of different transport (in EU) use function of energy progress (graph in appendix)

Appendix



Estimation of different transport (in EU) use function of years
% type of transport
50
45
40
35
30
25
20
15
10
5
0
-5
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
Years
% Rail
% High Speed Train
% Hyperloop
%E-VTOL
% BWB
%PP
%Conventional Aircraft
%Car
%Bus
%Boat
%Airship
%Supersonic

References

[1] N.A.S.A. (July 2020). Climate Change: How Do We Know?, https://climate.nasa.gov/evidence/ , last consulted 08/07/2020

[2] May 2020, Hydrogen-powered aviation, *A fact-based study of hydrogen technology, economics, and climate impact by 2050*, Clean Sky 2 JU

[3] Loïc Chauveau. (2020). Pourquoi l'avion propre est un défi difficile à tenir, https://www.sciencesetavenir.fr/nature-environnement/climat/le-defi-hasardeux-d-une-aviation-propre_145599, last consulted 18/07/2020

[4] Jen Mills. (July 2020). British Airways retires entire fleet of 747s due to drop in people flying, https://metro.co.uk/2020/07/17/ba-retires-boeing-747s-drop-passengers-due-coronavirus-13002222/, last consulted 18/07/2020

[5] John Excell. (April 2020). Rolls-Royce and Airbus cancel E-Fan X project, https://www.theengineer.co.uk/e-fan-x-project-cancelled/, last consulted 18/07/2020

[6] Egbert Torenbeek (2013), Advanced Aircraft Design, *Conceptual Design, Analysis and Optimization of Subsonic Civil Airplanes*, John Wiley & Sons, pp. 186

[7] The Leap Engine, CFM International, https://www.cfmaeroengines.com/engines/leap/, last consulted 20/07/2020

[8] (2019). Lecon inaugural de Jean-Marc Jancovici – rentree 2019 de Paris, Sciences Po, https://www.youtube.com/watch?v=h9SuWi_mtCM&t=6270s, last consulted 20/07/2020

[9] L'épuisement des ressources, https://www.edf.fr/groupe-edf/espaces-dedies/l-energie-de-a-a-z/tout-sur-l-energie/le-developpement-durable/l-epuisement-des-ressources, last consulted 30/07/2020

[10] Ahmed Sherrif. (August 2018). India's First Biofuel Aircraft Takes Off Successfully: Will Air Travel Get Cheaper? https://www.thebetterindia.com/157200/india-first-biofuel-aircraft-spicejet-delhi/, last consulted 20/07/2020

[11] Carlos Calvo Ambel. (November 2017), Electrofuels - what role in EU transport decarbonisation? Transport & Environment

[12] (March 2020). Ben Custard. What is biofuel? What are the advantages and disadvantages?, https://www.carbuyer.co.uk/tips-and-advice/168179/what-is-biofuel-what-are-the-advantages-and-disadvantages, last consulted 20/07/2020

[13] (2010). Electrofuels Programm Overview, https://arpa-e.energy.gov/sites/default/files/documents/files/Electrofuels_ProgramOverview.pdf, last consulted 20/07/2020

[14] Singh, Lakhveer & Rana, Supriyanka & Thakur, Sveta & Pant, Deepak. (2020). Bioelectrofuel Synthesis by Nanoenzymes: Novel Alternatives to Conventional Enzymes. Trends in Biotechnology. 38. 469-473. 10.1016/j.tibtech.2019.12.017.

[15] (November 2019). Cranfield Aerospace Solutions (CAeS) announces £9m UK Government grant for the development of electric flight, https://www.cranfield.ac.uk/press/news-2019/cranfield-announces-uk-government-grant-for-the-development-of-electric-flight, last consulted 21/07/2020

[16] J. A. Lechniak, M. Salazar, J. Morello, A. Waddell, K. V. Papathakis (January 2020), AQUIFER Nano-electrofuel Energy Economy and Powered Aircraft Operations, retrieved from https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20200000417.pdf

[17] (March 2020). Sustainable Aircraft: Fantasy or reality? https://www.facebook.com/watch/live/?v=2738083132936452&ref=watch_permalink, last consulted 21/07/2020

[18] Ryan Morrison. (November 2019). Electric cars could be causing a pollution CRISIS - with thousands of tonnes of unprocessed battery waste being DUMPED by drivers in the UK, study warns, https://www.dailymail.co.uk/sciencetech/article-7655977/Electric-vehicle-battery-pack-waste-lead-damaging-pollution-problem.html, last consulted 21/07/2020

[19] B.J.Brelje, R.R.A.Martins (2019), Electric, hybrid and turboelectric fixed-wing aircraft : A review of concepts, models, and design approaches, retrieved from www.elsevier.com, Elsevier

[20] João Ribeiro, Frederico Afonso, Inês Ribeiro, Bruna Ferreira, Hugo Policarpo, Paulo Peças, Fernando Lau. (October 2019). Environmental assessment of hybrid-electric propulsion in conceptual aircraft design. In: Journal of Cleaner Production, retrieved from www.elsevier.com, Elsevier

[21] N.Hansson, M.Bradley, M.Campbell, De'Andre J. Cherry, K.Cox, D.D'Angelo, J.Gonzalez, C.Moore, J.Zee (2018) Environmental Impacts of Aerospace Batteries

[22] Dave Calderwood. (June 2020). ZeroAvia makes first UK flight with electric Malibu. https://www.flyer.co.uk/zeroavia-makes-first-uk-flight-with-electric-malibu/, last consulted 22/07/2020

[23] Bill Read. (May 2020). Turning aviation green, https://www.aerosociety.com/news/turning-aviation-green/, last consulted 22/07/2020

[24] Mistry S, Smith H & Fielding JP (2008) Novel design concepts for aircraft with reduced noise and global warming characteristics. In: 26th Congress of International Council of the Aeronautical Sciences, 2008, Anchorage, 14 September 2008.

[25] Paul O Jemitola, John P Fielding (2012) Box wing aircraft conceptual design. In: 28th Congress of International Council of the Aeronautical Sciences, 2012, September 2012

[26] Alexander Somerville, Matthew Marino, Glenn S. Baxter, Graham Wild (March 2016) Understanding Box wing aircraft: essential technology to improve sustainability industry, Vilnius Gediminas Technical University

[27] Aldo Frediani, (June 2005) The Prandtl Wing

[28] Colmenares Quintero, Ramon & Smith, Howard & Seresinhe, Ravinka. (2011). APPLICATION OF THE OPEN ROTOR IN A BOX WING AIRCRAFT: A FEASIBILITY STUDY.

[29] R. H. Liebeck, M. A. Page, B. K. Rawdon (1997) Blended Wing Body Subsonic Commercial transport, In: 36th Aerospace Sciences Meeting and Exhibit, 1998, January 1998, American Institute of Aeronautics and Astronautics

[30] Safran celebrates successful start of Open Rotor demonstrator tests on new open-air test rig in southern France, https://www.safran-group.com/media/safran-celebrates-successful-start-open-rotor-demonstrator-tests-new-open-air-test-rig-southern-france-20171003, last consulted 22/07/2020

[31] I. Dincer, A. Hepbasli, A. Midilli and T. H. Karakoc (2010) 'Global Warming: Engineering Solutions', Green Energy and Technology. New-York: Springer.

[32] Ziang Gao, Howard Smith (2020) Blended wing body with Boundary layer Ingestion conceptual design in a multidisciplinary design analysis optimization environment, American Institute of Aeronautics and Astronautics

[33] Gilbert Barfield. (April 2003) Golf ball dimple structures with vortex generators, US6547678B2

[34] Biomimétisme & aérodynamisme : une evidence,.https://www.bioxegy.com/biomimetisme-aerodynamisme, last consulted 22/07/2020

[35] FlexFoil Morphing Wing Technology Could Reshape the Future of Wing Design – AINtv, https://www.youtube.com/watch?v=Lvlucywvtd4&t=3s, last consulted 22/07/2020

[36] Developing the next generation of Unmanned Aerial Vehicles (UAVs) with BAE Systems, https://www.cranfield.ac.uk/Case-Studies/research-case-studies/FLAVIIR, last consulted 22/07/2020

[37] Craig Lawson (2019), Airframe systems lessons, Cranfield University

[38] Jay Singh. (January 2020). Are OLED Screens The Future Of In Flight Entertainment?, https://simpleflying.com/oled-in-flight-entertainment/, last consulted 24/07/2020
[39] (2012) Engineers confirm feasibility of aircraft regenerative braking from landing gear, https://www.greencarcongress.com/2012/02/epsrc-20120227.html, last consulted 24/07/2020
[40] Daniel Rohacs, Jozsef Rohacs (2016) Magnetic levitation assisted aircraft take-off and landing (feasibility study – GABRIEL concept), In: Progress in Aerospace Sciences 85, 2016, pp 33-150, retrieved from www.Elsevier.com, Elsevier
[41] FAA. Commercial airplane certification process study: an evaluation of selected aircraft certification, operations, and maintenance processes. Washington DC: Federal Aviation Administration (2013).
[42] European Union Aviation Safety Agency (July 2019), CS 25 - Amdt. 23
[43] S.L.B.Santa, J.M.P.Ribeiro, G.Mazon, J.Schneider, R.L.Barcelos, J.B.S.O.A.Guerra. (2020). A Green Airport model: Proposition based on social and environmental management systems
[44] Circular economy, https://aviationbenefits.org/environmental-efficiency/circular-economy/, Air Transport Action Group, last consulted 24/07/2020
[45] C. Rice, N. K. Ragbir, S. Rice, G. Barcia. (2020), Willingness to pay for sustainable aviation depends on ticket price, greenhouse gas reductions and gender, retrieved from http://www.elsevier.com/locate/techsoc
[46] ITER,c'est quoi ?, https://www.iter.org/fr/proj/inafewlines,https://www.iter.org/fr/accueil last consulted 30/07/2020
[47] S. Lémeret. (July 2020) Production des batteries de voitures électriques: L'ONU met en garde, Retrieved from https://www.20minutes.fr/economie/auto/2816647-20200707-production-batteries-voitures-electriques-onu-met-garde
[48] European Defence Agency. (2017). The military in SES/SESAR, retrieved from https://eda.europa.eu/docs/default-source/brochures/2017-eda-sesar-wac-brochure_a4--final
[49] Claude Le Tallec, Christophe Maury, Fabrice Cuzieux, Sylvette Canard-Caruana, Stéphane Beddok, Pierre-Marie Basset. (2018). Distributed electric aeropropulsion architectures for VTOL drones and urban air-taxi vehicles. In: AHS Technical Conference on Aeromechanics Design for Transformative Vertical Flight, 2018, San Francisco, January 16-19. AHS International
[50] Uber elevate, Uber, https://www.uber.com/us/en/elevate/, last consulted 27/07/2020
[51] R.Walker. (2018). Hyperloop: cutting through the hype. https://trl.co.uk/papers/hyperloop-cutting-through-hype, last consulted 27/07/2020
[52] Contributor. (2015). Return of the Zeppelin – The Greener (And Slower) Way To Travel, retrieved from https://suitcasemag.com/travel/stories/return-of-the-zeppelin-the-greener-and-slower-way-to-travel/, last consulted 27/07/20
[53] M. Piesing. (2019). Airship lost out to conventional aircraft after a series of disastrous crashes. But now safer technology could be the key to their return, retrieved from https://www.bbc.com/future/article/20191107-how-airships-could-return-to-our-crowded-skies, last consulted 27/07/20
[54] T.Radford. (2019). Airship's return can boost hydrogen economy, retrieved from https://climatenewsnetwork.net/airships-return-can-boost-hydrogen-economy/, last consulted 27/07/20
[55] A.Gray. (2018) Supersonic jets are making a comeback, retrieved from https://www.weforum.org/agenda/2018/02/supersonic-jets-are-making-a-comeback/, last consulted 27/07/20