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Carbon Offsetting and Sustainable Aviation

A study of contemporary and future sustainable aviation via carbon offsetting

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Abstract

The aviation industry stands for about 2% of the global CO_2 emissions and constitutes a large portion of what the individual can affect by their own decision making. A direct round-trip Stockholm to New York consumes about 50% of an individual's annual CO_2 budget. This paper studies what role carbon offsetting has in the transition towards sustainable aviation. Sustainable aviation fuels (SAFs), electrical aviation and abstaining from flying are also considered as potential approaches to making aviation more sustainable. The research method is both empirical and theoretical. Empirically, a Carbon Offsetting Assessment Framework evaluates airlines' and online travel agencies' (OTAs') work with carbon offsetting and SAF. This is done from a Sweden-centric perspective. The airlines BRA, KLM and SAS score highest. Theoretically, a discussion of the dynamics of the aviation industry's transition into sustainability is carried out through the multi-level perspective (MLP). Carbon offsetting is considered the best short-term solution for sustainable aviation due to availability and cost-efficiency. SAF is currently too expensive and the usage too low to yield significant emission reductions but is a promising mid-term solution. In the long-run, electrical aviation is the solution that has the potential to lower direct emissions to almost zero but it relies on major energy storage development and is not commercially viable today. The study also explains why carbon offsetting not should be used as a letter of indulgence but still is a good way to be certain that climate positive actions happen now and not are postponed or not happen at all.

Keywords: carbon offsetting, sustainable aviation, green aviation, Flexibility Mechanisms, sustainable aviation fuel, SAF, multi-level perspective, sustainability transition.

Sammanfattning

Flygindustrin står för ungefär 2% av de globala CO_2-utsläppen och utgör en stor andel av vad individen kan påverka genom sitt eget beslutsfattande. En direktresa tur- och retur Stockholm till New York konsumerar ungefär 50% av en individs årliga CO_2-budget. Den här studien undersöker vilken roll klimatkompensation har i en övergång mot hållbart flyg. Hållbart flygbränsle (SAF), elflyg och att avstå från att flyga har också utvärderats som potentiella tillvägagångssätt för att göra flyget mer hållbart. Studiens forskningsmetod är både empirisk och teoretisk. En modell för att empiriskt utvärdera flygbolags och onlineresebyråers (OTAs) arbete med klimatkompensation och SAF appliceras på en Sverigecentriskt urval av aktörer. Flygbolagen BRA, KLM och SAS får högst poäng. Vidare förs en teoretisk diskussion om dynamiken i flygbranschens övergång mot hållbart flyg genom "the multi-level perspective" (MLP). Klimatkompensation anses vara den bästa kortsiktiga lösningen för hållbart flyg eftersom det är tillgängligt och kostnadseffektivt. SAF är idag för dyrt och användandet för lågt för att resultera i betydelsefulla utsläppsminskningar men är icke desto mindre en lovande teknik på medellång sikt. På lång sikt är elflyg lösningen som har potential att minska direktutsläpp till nästan noll men det står och faller med avsevärd teknikutveckling inom energilagring och är inte kommersiellt tillgängligt idag. Studien förklarar också varför klimatkompensation inte borde användas som ett avlatsbrev men att det fortfarande är ett bra sätt att försäkra sig om att klimatpositiva handlingar sker idag och inte blir uppskjutna eller uteblir.

Nyckelord: klimatkompensation, hållbart flyg, grönt flyg, flexibilitetsmekanismen, hållbart flygbränsle, SAF, multi-level perspective, hållbarhetsövergång.

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Thank you Mattias Nyman and Flygresor.se for letting us fly under your wings (pun intended) during the spring of 2020. You may not be aware, but we are immensely grateful for you taking your time to care about two simple students during the COVID-19 inferno that has raged over the aviation industry. Thank you for the office small talks and the sustainable aviation big talks.

It is also expected of us to direct a thank you to our family and loved ones, which we are more than happy to do. Thank you. Your support is the underlying driver for everything we do. Let us now turn to the intricate subject of aviation and sustainability. And let us remind you of that aviation enables great freedom, possibilities and happiness but also that the question of sustainable development is dead serious and the greatest challenge of our time.

Kasper & Anton
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Abbreviations and Acronyms

ADLY	Averted Mortality and Disability Adjusted Life Years
AENOR	Asociación Española de Normalización y Certificación (The Spanish Association for Standardization and Certification)
AIC	Aircraft induced cirrus
ANT	Actor-network theory
CCS	Carbon capture and sequestration
CDM	Clean Development Mechanism
CER	Certified Emissions Reductions
CO_2e	Carbon dioxide equivalent
CORSIA	Carbon Offsetting Scheme for International Aviation
CPE	Cultural political economy
DNV	Det Norske Veritas
EASA	European Union Aviation Safety Agency
EU ETS	European Union Emission Trading System
FAA	Federal Aviation Administration
GDP	Gross domestic product
GHG	Greenhouse gas
GWP	Global warming potential
HEFA	Hydroprocessed esters and fatty acids
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICE	Internal combustion engine
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
LCE	Life cycle emissions
LEED	Leadership in Energy and Environmental Design
MLP	Multi-level perspective
NGO	Non-governmental organization
OPR	Offsets Project Registry
OTA	Online travel agency
REDD+	Reducing emissions from deforestation and forest degradation in development countries
RF	Radiative forcing
ROI	Return on investment
SAF	Sustainable aviation fuel
SAOL	Svenska Akademiens ordlista (Swedish Academy Dictionary)
SCOT	Social construction of technology
SDGs	Sustainable Development Goals
SDS	Sustainable Development Scenario
SMT	Social movement theory
TÜV	Technischer Überwachungsverein
TIS	Technological innovation systems
UNFCCC	United Nations Framework Convention on Climate Change
VCU	Verified Carbon Unit
VER	Verified Emissions Reductions
WBC	Water Benefit Certificates
WWF	World Wildlife Fund

1 Introduction

In this chapter, the topic of carbon offsetting and sustainable aviation will be introduced and related to climate change in general. The problem of transitioning the aviation industry into becoming more sustainable is introduced and is furthered narrowed down to study purposes and research questions. Study objectives, hopefully resulting in industry and academic contribution, are articulated. How does this study contribute to sustainable development within the aviation industry? Lastly, the remaining part of the study is briefly gone through in the outline section.

1.1 Preamble

Climate change is arguably the number one contemporary global challenge. The transnational Paris Agreement is the main measure against climate change with the goal of keeping the global temperature rise well below 2 degrees Celsius above pre-industrial levels. Global warming is mitigated by reducing greenhouse gas emissions. Often greenhouse gas emissions are referred to as carbon equivalent emissions or simply carbon emissions. Excess carbon emissions (are anthropogenic and thus) stem from almost all human activity and economic engagement. For example, Paul Hawken (2017) suggests that carbon reductions can be completed in the following sectors: buildings and cities, energy, food, land use, materials, transport and equality. These systems are complex and extensively interlinked but as formulated by Sterner et al. (2019) “the urgency is such that we cannot let complexity be an excuse for inaction”, regarding undertaking adequate measures to mitigate climate change. This study will focus on implicitly reducing the carbon emissions from the aviation part of the transport sector by financing carbon emission reducing activities in other sectors as energy, food and land use. The instrument for doing this is carbon offsetting.

Although only around 2% of the global CO_2 emissions stem from the aviation industry, the individual’s choice of flying or not is probably the single most impactful decision that affects each person's climate footprint when considering the share of the world population that are on an income level where flying is reasonable (ATAG, 2018). In 2017, the global average CO_2 emission per capita was 4.8 tonnes (Ritchie & Roser, 2017). A direct round trip flight Stockholm to New York gives rise to 2.3 tonnes CO_2 emissions per passenger (according to the calculation technique by Schennings et al. (2019)), i.e. 48% of the annual CO_2 budget per person (and this should be even higher if the budget would be consistent with the Paris Agreement). Flying thereby has a significant impact on each individual’s carbon emission bottom line. On the other hand, the possibilities of aviation are extraordinarily unique, the societal welfare and individual utility that it enables is almost unquantifiable. It thereby lies in the interest of society to solve this equation - making aviation sustainable. There is no all-encompassing solution today but several promising trajectories that utilize technology, behavior change and societal structures to achieve sustainable aviation. Some of these are abstaining from flying, electrical aviation, sustainable aviation fuels and carbon offsetting. This study will discuss all these trajectories but lays the most focus on carbon offsetting.

Carbon offsetting alludes to the idea of solving the global warming problem and reducing carbon emissions on a system level and to trust in intellectually created structures rather than solely trust emission reductions that occur right in front of our eyes. This is in line with the

United Nations Sustainable Development Goal 17: *Partnerships for the Goals*, as carbon offsetting relies on global cooperation allowing effective distribution of capital to where it has the greatest potential to reduce emissions. Carbon offsetting will be thoroughly explained later on but to give an example carbon offsetting could be to partly fund a wind power project in a place where the energy system now consists of coal-fired power generation. This will result in reduced carbon emissions which can be considered carbon offsets if the carbon emission reduction occurred because the project obtained carbon offsetting funding.
What role does carbon offsetting have in general and particularly in a transition into carbon neutral aviation? There are several policy tools and measures that push the aviation industry into undertaking carbon emission reducing actions: Intra-EU flights are encompassed by the EU ETS. Nations have different individual policies to tax carbon emission from flights, for example, carbon tax and flat seat tax. The CORSIA program aims to set a cap on international flights. On top of this, airlines carbon offset and use SAFs beyond these formal requirements on their own initiative. Also, incremental and disruptive aviation technology help in decreasing the carbon emission per passenger. All these initiatives contribute to emission reductions but there is reason to continue the efforts and there is room to do more. As argued by Hassler et al. (2018) it is more societally costly to set a too low carbon tax than a too high, analog to this it could be better too to have too high ambitions when reducing aviation emissions rather than too low. In general, setting too high ambitions is also a hedge against reaching spiraling effects, self-reinforcing feedback loops, climate tipping points and accelerating global warming (IPCC, 2019). Thus, there is room for carbon offsetting to reduce aviation industry emissions.

Due to the globality and complexity of carbon offsetting and aviation, there are multiple stakeholders and possible influential actors for carbon offsetting and sustainable aviation. Many of those will be gone through throughout this study. However, the starting viewpoint for the analysis is the flight ticket price comparison site Flygresor.se (Flygresor). It is their environment and their partners that will form the basis for both empirical and theoretical reasoning although the study scope is very much applicable generally. Flygresor is a meta-search engine that gathers price information from travel agencies and airlines and presents it to the user who then can click-out and book their ticket. Flygresor do not sell tickets. Flygresor has an engagement in transforming the aviation industry into becoming more sustainable. Since 2019 they offer carbon offsetting integrated into their price comparison interface. It is possible to show prices including carbon offsetting and the carbon offsetting cost will then be imposed upon the regular ticket price. However, if the airline or online travel agency (OTA) already carbon offset for their customers, no additional cost for the user at Flygresor will be imposed. In this way, the search engine dynamics will reward the airlines and OTAs who carbon offset for their customers by placing them higher in the search results (due to lower price). It is also possible to sort flights with respect to carbon emissions. The algorithm that is used to calculate carbon emissions is the one presented by Schennings et al. (2019). Except for the offering of carbon offsetting, Flygresor also facilitates a development towards sustainable aviation through donations to electrical aviation and participation in professional organizations promoting sustainable aviation (Nyman, 2020). In the context of this, Flygresor wants to build knowledge both in the field of carbon offsetting and sustainable aviation to improve its current carbon offsetting offering and future contribution to sustainable aviation.

1.2 Problem

In order for the aviation industry to cope with climate goals it needs to undertake several measures to reduce carbon emissions, it needs to undergo a transition into more sustainable aviation. The question is how this can and should be done. Sustainability transitions are special kinds of transitions for several reasons. Firstly, unlike many transitions that occur on regular markets sustainability is a normative goal that treats collective goods (Geels, 2010). The normative character of the problem means that the problem is full of disagreement and discussion of the relative importance of different subsections of the problem and of what the problem actually is. This leads to meta-discussions of ideology and values. Collective goods on the other hand may lead to the tragedy of the commons, a theory proposed by Garrett Hardin (1968), where each agent's individual utility maximization does not lead to utility maximization for the collective. This problem is very much applicable to carbon offsetting as a means to facilitate a sustainable transition in the aviation industry. For example, Higham et al. (2019) stress that aviation emissions that threaten everyone's well-being are difficult to stop with voluntary carbon offsetting and should be met by collective action. Analog to the tragedy of the commons each individual would be better off if there was a collective action plan to fight aviation emissions, for example, national or international policy, but each individual is worse off when offsetting only themselves. A concerned individual faced with the prospect of choosing whether to fly or not may feel that whichever they choose, their action will be inconsequential if everyone else does not act the same. This rationalizes flying as one gives up considerable benefits while not receiving anything in return when choosing not to fly. This is a problem that has to be encountered when trying to solve the aviation industry's sustainable transition with voluntary measures, which carbon offsetting partly is.

Another perspective of sustainability transitions that partly is addressed by Geels (2010) is who is responsible for deciding which pathways to take in a sustainability transition. This is certainly applicable to the transition into sustainable aviation; is sustainable traveling a responsibility of the government, scientists or the individual? Is it allowed to make decisions that limit the individual's freedom in order to achieve sustainability goals? Is it okay to introduce policies that limit low GDP countries from consuming aviation in the same excessive manner that has been done in the high-income countries the recent decades? These moral questions lead to the matter not being solely technical but also to a high degree political and ethical.

These kinds of value-based questions will however not be in the main problem treated in this study. This study will instead focus on the means to solve the issue of achieving sustainable aviation. The focus will be on the mean carbon offsetting, as it is complex but also promising since it is feasible technically and also relatively cheap. To understand this, it is important to acquire knowledge on the potential of different means to achieve sustainable aviation and what stage they are in the development phase. It is also important to understand how far the aviation industry has come today in its work with sustainable ways of traveling. Lastly, the complex, global, intangible, externality characterized environment that is sustainable aviation has a lot of stakeholders and agents that drive the sustainability transition. There is a problem in understanding this environment too.

1.3 Purpose and Research Question

This study has the purpose of investigating the current situation and the future transition of sustainable aviation, mainly by focusing on carbon offsetting. The study is conducted together with the flight ticket price comparison site Flygresor and the empirical and theoretical starting point in which this study is conducted is thereby their business partners which results in a Sweden-centric perspective but in the aviation industry, the scope still is very much global. The purpose of the study is to acquire knowledge of the current situation of sustainable aviation from this Sweden-centric perspective. The purpose is to especially investigate carbon offsetting but also to conduct an empirical study on sustainable aviation fuel (SAF) and to theoretically discuss electrical aviation and other relevant aspects in a transition into sustainable aviation. Further, the study has the purpose of extensively discussing the transition dynamics of sustainable aviation and especially focus on carbon offsetting's role in this multifaceted transition. These purposes lead to the following research questions:

1. What is the state of sustainable aviation today? From a Sweden-centric perspective with a focus on carbon offsetting and SAF.
2. What dynamics and most important agents characterize the transition into sustainable aviation?
3. How should carbon offsetting be considered as a means of achieving carbon emissions reductions? The answer will be discussed through the lens of aviation but could be generalized to assessing carbon offsetting generally.

1.4 Study Objectives

The goal is to understand the contemporary situation of sustainable aviation and acquire knowledge that can be used to continue a further transition into sustainability. Especially the goal is to build knowledge in the carbon offsetting field and what role it has in the transition to sustainability. If carbon offsetting is found to be useful in mitigating emissions, hopefully, the increase in knowledge leads to the goal of increasing the use of carbon offsetting which in turn leads to climate-positive effects. This aim also applies to SAF. These climate positive effects will in this study be occurring in the aviation industry but could easily be generalized to some extent in other industries and facilitate the adoption of carbon offsetting there too. The study aims to give knowledge and insights both to the price comparison site Flygresor regarding their approach to carbon offsetting and a sustainability transition in the aviation industry but also to airlines, other travel mediators, the academy and other stakeholders that are interested in sustainable aviation.

1.5 Limitations and Delimitations

The scope of a transition towards sustainable aviation is wide. It encompasses not only carbon offsets and SAF which are the center of attention in this study but also a plethora of other factors ranging from policy to improved aerodynamics. While these other factors are not at the core of the study it is important to keep them in mind to understand the reasoning used in order to explain the role of carbon offsets and SAF in the transition. These factors are not necessarily much elaborated on in the theoretical discussion and thus their explanations are kept brief limiting them to the aspects important for the understanding of the context in the theoretical analysis of the transitions towards sustainable aviation.

Further, the Sweden-centrism of the study does limit the reach of the quantitative framework used as the data only consisted of airlines and OTAs with large Swedish user bases. However, this does not imply that the theoretical analysis of the transition is limited to the Sweden-centric perspective as the analysis aims to establish a more comprehensive view of the transition globally.

Lastly, while airlines and OTAs were evaluated with the qualitative framework it was decided that it would not be done with travel meta-search engines due to the fact that there are relatively few operating on the Swedish market. It could possibly be conducted on a European or global level but this would make the results from meta-searches difficult to analyze side by side with the Sweden-centric results from airlines and OTAs.

1.6 Outline

Chapter one has introduced the area of carbon offsetting, its potential use in the aviation industry and how this could be a partial solution to the general challenge of climate change. In order to answer the stipulated research questions and carry out the intended study, the following chapters are articulated.

Chapter two will give an extensive background on multiple areas: policy and system measures for reducing carbon emissions related to the aviation industry, carbon offsetting certifications, technical aspects of aviation emissions and a theoretical lens to analyze the aviation industry's transition into sustainable aviation (the multi-level perspective). The background will facilitate both hands-on information and circumstantial understanding that will be useful for the reader to mentally participate in the result and discussion sections.

Chapter three describes the study's research method. The literature review and data gathering are gone through as well as one empirical and one theoretical method. The empirical method is called the Carbon Offsetting Assessment Framework and aims to map out the contemporary state of carbon offsetting and sustainable aviation fuels in the aviation industry from a Sweden-centric perspective. The theoretical method is called the multi-level perspective and aims to discuss the dynamics of the future transition of the aviation industry into becoming sustainable.

Chapter four presents the results of the Carbon Offsetting Assessment Framework. The framework yields the state of airlines' and online travel agencies' work with carbon offsetting and sustainable aviation fuels (SAF) via a scoring technique. The certification standard of carbon offsetting is reviewed and the airline results are related to a geographical area.

Chapter five constitutes an extensive discussion of the aviation industry's transition into sustainable aviation via the theoretical lens of the multi-level perspective (MLP). The discussion both encompass the current situation and transition dynamics for the industry's future development into sustainability.

Chapter six presents Conclusions regarding the role of carbon offsetting in the aviation industry brings up some dilemmas and suggestions for future studies.

2 Background

In this chapter, the necessary knowledge foundation is laid out in order to comprehensively and fairly analyze carbon offsetting and sustainable aviation. Relevant measures that can contribute to reducing aviation emissions are gone through. So is also certifications for carbon offsetting and technical aspects that play a role in aviation emissions. Lastly, the theoretical lens of the multi-level perspective that will form the discussion basis is described.

2.1 Overview of Measures for Reducing Carbon Emissions

There are several approaches to reduce carbon emissions related to the aviation industry. It could be systems of commitments where carbon emissions are traded as securities. It could be pure policy, voluntary commitments by organizations and individuals or it could be technological development leaps. The most relevant ones are described in this section.

2.1.1 Carbon Offsetting

Carbon offsetting (also referred to as climate compensation) is defined as "*compensation of greenhouse gas emissions, e.g. through tree planting or investment in renewable energy sources"* in the Swedish Academy Glossary (SAOL, 2015). In this paper, the term carbon offsetting will mainly be used instead of climate compensation and the term carbon equivalent emissions (or simply carbon emissions) will be investigated instead of the term greenhouse gas emissions. Carbon offsetting can then be defined as "*compensation of carbon equivalent emissions, e.g. through tree planting or investment in renewable technology*". Carbon emissions occurring in one place could be offset by reducing, avoiding or sequestering emissions at another place (Goodward & Kelly, 2010). The concept is simple and feasible but there are some common problems that could undermine the effect of carbon offsetting.

Carbon offsetting needs to fulfill five criteria in order to be legitimate according to Goodward and Kelly (2010). (1) *Real*, the carbon offsetting action should not cause a carbon emitting action. Reduced emissions in one place should not increase emissions in another. (2) *Permanence*, the carbon offset should consist over time and not go back to the original state after a time. This is particularly important when planting trees as a carbon offsetting. If the forest is shredded or burnt down, the climate positive action will not persist. An assurance that they will then be replanted or something equivalent needs to be in place. (3) *Additional*, a carbon offset needs to be an action that had not been completed if the offset had not been initialized. Additionality could be difficult to determine in advance of a project. It is a prediction of a potential future. There are regulating initiatives that attempt to ensure additionality so credit is solely given to the projects that would not have happened without someone investing in the carbon offsetting action. Additionality can be assessed either *project-specific* or according to *standardization criteria*. In a project-specific assessment, a business as usual scenario is developed for each project and additionality is evaluated. When using standardization criteria, a specification is met that is supposed to require additionality (Broekhoff & Zyla, 2008). (4) *Verifiable*, the carbon offset needs to be able to be monitored and verified by an independent third party. (5) *Enforceable*, it must be possible to enforce the unique ownership of each action so no double accounting is present where the same action is sold to more than one customer (Goodward & Kelly, 2010).

In general, a carbon offsetting action, for example, inefficient cooking equipment that is replaced with efficient equipment, generates so-called carbon credits that can be sold to offset purchasers. The issue of carbon credits could be completed either before or after the offsetting action is completed. Issuing the credit before the project, ex-ante (*carbon debt)* will enable more financial assurance for the project since they get secured payment upfront. Issuing the credit after the project is completed and real climate effects can be measured, ex-post (*pay upon delivery*) will on the other hand ensure that carbon offsetting is fully accomplished. In general, the pay-upon-delivery ex-post model is considered to be more legitimate (Tricorona, 2015). A third party is typically involved to authenticate the offset.

Essentially there are two different kinds of markets for carbon offsetting. Firstly, there are the compliance carbon markets. These markets are typically aimed at governments and companies that are mandated by law to account for a certain amount of carbon reductions, for example, the states that have commitments under the 1997 Kyoto Protocol but often people and corporations are also able to access these markets through different means. The second type of carbon markets is the voluntary carbon markets. These markets are meant to facilitate carbon credit trading for those entities, be it companies, states or other actors that are not mandated by law to mitigate emissions but choose to do so on a voluntary basis (Seeberg-Elverfeldt, 2010). As the two types of markets are aimed at different audiences the offsets found on the respective market types are different in that the compliance offsets generally are just concerned with the CO_2 reduction whereas the offsets found in the voluntary markets often include additional social benefits from the projects (Ecosystem Marketplace, n.d.). As of today, carbon offsets from both markets are commercially available for purchase by private individuals. One Swedish retailer is for example Go Climate Neutral who offers carbon offsetting to the price of 40 SEK/ton carbon offsetted emissions (GoClimateNeutral, 2020).

2.1.2 Flexibility Mechanisms

The Flexibility Mechanisms are measures defined under the 1997 Kyoto protocol to help countries reach their commitments stipulated by their ratification of the treaty. There are three mechanisms, the Clean Development Mechanism, the Joint Implementation and Emissions Trading Systems. They are designed to facilitate emissions reductions in a cost-effective way while stimulating sustainable development by encouraging the private sector and developing countries to contribute to emission reduction efforts (European Commission, n.d.).

2.1.2.1 EU Emission Trading System

The EU Emission Trading System (EU ETS) is an EU-based cap and trade system aimed to reduce carbon emissions in a cost-effective way. As it operates in all EU countries, Norway, Iceland and Liechtenstein it is the emissions trading system of interest from a Sweden-centric perspective and incidentally the world's largest (Reuters, 2020). The initiative covers around 45% of EU emissions and focus on limiting large emitters as heavy industry, power production. In the context of aviation, the EU introduced aviation to the EU ETS in 2012. The initial implementation stipulated that any flight arriving or departing from an airport located within the EU would be subject to the emissions trading scheme. However, this was immediately amended to only include flights within the European Economic Area (EEA).

The cap and trade system sets a ceiling on how much the whole system can emit and the ceiling is lowered over time so the overall emissions are reduced continuously. Practically, companies who want to emit 1 tonne of CO_2 equivalent emissions must have a 1 tonne CO_2 equivalent allowance certificate to be able to emit without substantial penalty fees. Companies receive or purchase emission allowances. Over the trading period 2013-2020, 57% of the emission allowances were bought on auctions. The allocation of free allowances decreases each year. The aviation industry has however received most of their allowances for free during the period 2013-2020 (European Commission, n.d.).

The EU ETS system has gone through three phases. Phase 1, 2005-2007, was a pilot period to learn how the implemented mechanisms work in reality. Emission allowances were only required from industries and power producers. The allowances were issued almost solely for free. Phase 2, 2008-2012, lowered the cap by 6.5% compared to 2005. The free allocation fell to around 90% and the penalty for emitting beyond your allowances was raised. On January 1st 2012, the aviation sector was brought into the EU ETS. The economic crisis in 2008 lowered the demand for emitting carbon profoundly which led to a surplus in emissions which affected the price of emission allowances in phase 2 (European Commission, n.d.). Phase 3, 2013-2020, introduced an EU wide cap instead of the previous national caps on emissions. A significantly larger portion of allowances was auctioned instead of issued for free. 300 million allowances are set aside in the New Entrance Reserve that will fund future renewable energy technology innovations and CCS initiatives (European Commission, n.d.). In January 2019 the Market Stability Reserve was introduced to improve the systems resilience against market shocks, mitigating situations like the financial crisis 2008. The reserve controls how many allowances that are available in the auctions. Allowances are taken from the market when the surplus is large and put back on the market when the surplus is small (Energimyndigheten, 2019). Phase 4 will be effective 2021-2030. In this phase, the pace of emission reductions will be increased to 2.2% annually. The Market Stability Reserve will also be further reinforced to make sure that the system is resilient against potential future shocks (Engström Stensson et al., 2014).

2.1.2.2 Clean Development Mechanism

The Clean Development Mechanism (CDM) is one of the three Flexibility Mechanisms defined under the Kyoto protocol. Since 2013 it is in its second commitment period which lasts up until the year 2020 after which it has to be revisited. It is a carbon offsetting program at its core and the idea is that industrialized countries are obliged to comply with emission reduction targets under the Kyoto protocol but not all reductions have to be endemic to the country itself. A share of these reductions can be achieved by purchasing Certified Emissions Reductions (CER). CERs are carbon credits awarded to greenhouse gas reducing projects in developing countries compliant with the CDM. The product itself, the CER, is a financial instrument commonly referred to as a carbon credit. One CER represents one metric tonne of CO_2 equivalent emissions and they can be traded much like any other financial instrument (Joshi, 2013). During the first commitment period 2008 to 2012, 9 out of 36 members had to utilize one or more of the three Flexibility Mechanisms in order to comply with their emissions reduction targets (United Nations Environment Programme, 2012).

In order to be awarded CERs, a project must fulfill a plethora of criteria. The most central is the one of additionality. What additionality entails is that projects that are carried out under the CDM are only carried out because of the CDM and would not have been carried out without the benefits and support received through the CDM. Most commonly, the additionality of the projects under the CDM is based on the projects not being financially viable on their own and in some cases they face barriers unbreachable without support. An important aspect of determining the additionality of projects is the baseline. Baselines are hypothetical scenarios of what the development would have looked like without a particular project and it is against this baseline the amount of CO_2 equivalents a project is deemed to mitigate is based on and subsequently what amount of CERs it is awarded. Different kinds of projects (power, waste, cookstoves etc.) require different scenarios and different baselines have different geographical limitations, for example, due to the energy mix in a particular energy grid.

As part of the compliance carbon markets, CERs can be used within the EU ETS. Under the rules of the EU ETS, certain actors are obliged to have emission allowances corresponding to some share of their emission, this is further detailed under the *EU Emission Trading System* chapter. However, EU emission allowances are not the only instruments that can be used to cover for emissions, to some extent international credits i.e. CERs or ERUs can be used in addition to EU allowances under the EU ETS. The use of international credits by an actor is regulated and thus limited to either a set number of credits or a percentage of verified emissions. Historically, the EU ETS actors have been the largest purchasers of international credits. During the second phase 2008-2012, the use of international credits rose from 83 million with ERUs constituting only a fraction, to 504 millions of which 284 were ERUs (Engström Stensson et al., 2014).

In its third phase from 2013, the EU ETS has cracked down on its use of international credits over concerns that they contribute to the large share of the surplus emission allowances the EU ETS has suffered from (Engström Stensson et al., 2014). Especially the use of CERs has been limited excluding reforestation and afforestation projects, nuclear projects and industrial gas destruction projects. Further to ensure that the use of CERs spurs on global sustainable development only projects in the least developed countries are permissible (European Commission, n.d.).

2.1.2.3 Joint Implementation

The Joint Implementation (JI) is the third Flexibility Mechanism. It is also a system of carbon offsets created through investments in carbon emission reducing projects, for example replacing coal plants with renewable energy, and shares most traits such as additionality with the CDM. The main difference is the list of countries eligible for projects. Compared to the CDM, the JI focuses carbon offset projects in Annex B countries i.e. the countries included in Annex I of the Kyoto protocol that is part of the OECD (United Nations Framework Convention on Climate Change, n.d.). While the CDM and JI essentially share criteria for recognition the nations that JI projects are conducted within are generally wealthier and more developed than nations where CDM projects are conducted. CERs and the JI:s equivalent Emissions Reduction Unit (ERU) are traded separately.

2.1.3 Carbon Tax

A carbon tax is another way to mitigate carbon emissions. Carbon equivalent emissions implicitly impose a cost on others than the emitter through global warming, i.e. a negative externality. A carbon tax aims to internalize the cost imposed on others. When the social cost of the emission is internalized, the tax is a *Pigouvian tax* (Pigou, A. C.,1920) which arguably optimizes welfare. Regarding carbon emissions, this optimization is difficult since the cost of emissions, in advance of global warming, is difficult to precisely quantify (Calmfors & Hassler, 2019). The uncertainty is both economical and natural scientific. Hassler et al. (2018) in “The Consequences of Uncertainty [...]” however conclude that the consequences of having a too passive climate policy are much more costly than having a too aggressive climate policy. A too high carbon tax (in regard to effectiveness) is better than a too low tax. In reality, this could for example mean that it is not that costly for the economy to use renewable power plants when coal-fired plants optimally should be used (setting a too high tax) but it is much more costly with the other way around.

The implication of undertaking a precautionary principle regarding carbon tax may be useful also when managing carbon offsetting. In the carbon tax case, there are two types of uncertainties as previously mentioned: economic and natural scientific. The natural scientific uncertainty, basically how carbon emissions translate into global warming and how this affects planetary systems, is also present when assessing carbon offsetting. One could interpret this as that it is better to overcompensate than to undercompensate, analog to the reasoning that it is not that costly for the economy to substitute a coal plant with a renewable plant when the coal plant is optimal but vice versa is very costly. However, the economical aspect is not the same for tax and offsetting since the theoretical tax is mandatory and offsetting often is not mandatory. Carbon offsetting will never be a firm instrument that prevents direct carbon emissions when there is a demand to emit but it could work as a soft instrument that alludes to companies’ and organizations’ CSR work and climate responsibility. This is not to be underestimated since it is conventional for large corporations to have extensive sustainability and climate action strategies. The insight of that the precautionary principle is important to meet climate change cost-effectively is perhaps an argument for companies and organizations to undertake ambitious carbon offsetting schemes.

A carbon tax is difficult to implement practically since the effects of carbon emissions are not limited to any nation or organizational borders. The tax level is difficult to set according to the reasoning above. It is also a challenge to assign the tax to specific sectors, should agriculture be subjected to a carbon tax for example? The aviation industry is special regarding carbon tax and emissions stemming from flights are generally excluded from tax schemes. In Sweden, there is no tax on carbon emissions or fuel associated with aviation.
The VAT on domestic flights is 6% and 0% on international flights (Naturskyddsföreningen, n.d.). However, Sweden today has a specific excise duty on flight tickets divided into three categories based on flight distance. The three levels are 60 SEK, 250 SEK and 400 SEK (Sveriges Riksdag, 2017). There is currently no carbon emission tax for aviation on EU level but nine states (Netherlands, Germany, France, Sweden, Italy, Belgium, Luxembourg, Denmark and Bulgaria) have in a joint statement asked the European Commission to consider a tax or another measure to combat emissions stemming from aviation (Barbiroglio, 2019).

There are no international agreements on how to tax aviation fuel. Essentially, the only regulation in effect is the Chicago convention from 1944 which prohibits taxing fuel already in aircraft upon landing in another country (Convention on International Civil Aviation, 1944). However, while there are no regulations that prohibit the taxing of aviation fuel in general for domestic purposes not a single EU country chooses to do so. They are instead choosing flat taxes as in the previously mentioned case of Sweden and in the similar case of the UK Air Passenger Duty (APD) (Her Majesty’s Revenue and Customs, 2019).

2.1.4 CORSIA

Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) is an initiative by the UN agency International Civil Aviation Organization (ICAO) intended to help the aviation industry meet its target of carbon-neutral growth, i.e. no net increases of annual emissions from 2020 (IATA, n.d.). Operational and technological improvements will contribute to decreased emissions but will not be enough to reach the goal of carbon neutral growth. CORSIA mandates airlines to mitigate emissions through carbon offsetting or SAF. Emission reductions in other sectors will be financed by airlines through carbon credits in order to bring down the net emissions of the aviation sector industry. CORSIA was decided upon in 2016 and take effect in 2021 (Transportstyrelsen, 2019).

ICAO only regulates international aviation and thus, so does also CORSIA. International aviation is responsible for about 60% of total emissions from aviation, excluding the non-CO_2 effect, which mainly occurs at high altitudes (Transportstyrelsen, 2019). Including non-CO_2 effects significantly decreases the reach of CORSIA. From 2021 to 2026 during its pilot and first phase CORSIA will be voluntary for states to participate in. In 2027 CORSIA will be mandatory, however, almost all states that will be encompassed in the mandatory contract 2027 have pledged to follow the voluntary start in 2021. In 2032, the system will be evaluated and decided upon if it should continue after 2035 or not.

In its first phase, the system is formed so that all airlines compensate the same percentage annually. How much all airlines will compensate is decided by how much the whole industry exceeds the 2019 emission baseline. This is a revised plan due to COVID-19. The original plan was to use average values from 2019 and 2020 but since the 2020 values are very low this will not be suitable for creating a baseline (IATA, n.d.). The equation for calculating the amount that operators should mitigate is the following:

$$OR_y = OE_y * \frac{SE_y - SE_{B,y}}{SE_y}$$

Where OR_y is operator's requirements in year y (from 2021), OE_y is operator's emissions covered by CORSIA in year y (from 2021), SE_y is sectoral emissions with route-coverage by CORSIA in year y and $SE_{B,y}$ is sectoral emissions in baseline (2019) with route-coverage by CORSIA in year y (ICAO, 2018). This means that there is some asymmetry in how much an airline will have to offset. Airlines that keep below their individual fictive baselines (i.e. do not increase emissions) will still have to offset as much as the industry exceeded the baseline while airlines that increase their emissions the most only have to offset according to the industry average. Therefore, there is no direct systematic incentive for the individual airline to lower its emissions, which could lead to a tragedy of the commons.

There are some nations that are excepted from the system, typically very poor nations, small island nations, nations without seacoast and countries with very few international flights. Additional exceptions for small aircraft, small airlines, medical, humanitarian and firefighting flights also exist. New actors on the market are also excepted from the system in their first three operating years.

The development of CORSIA has been undertaken together with the airline industry and the industry has in general been positive. IATA sees CORSIA as a cost-effective solution to emission braking instead of having a patchwork of national and transnational solutions. The climate and environmental movement is more skeptical. Some criticism exists on the ambition level being too low and that there is a risk for the carbon credits to be double accounted for by nations. It is also stressed that SAFs should really result in reduced life cycle emissions since they are eligible to use as a means to achieve the Carbon-Neutral Growth goals. CORSIA is not firmly established in a way that cannot be renegotiated, so if there is a consensus regarding an increased ambition level, it is possible to do so. The initiative as is today is massive and could have profound effects on global emissions. According to projections made in 2019 CORSIA could need as much as 1.6 to 3.7 billion carbon credits in the period 2021 to 2035 to mitigate the emissions exceeding the 2020 baseline. This could be compared with the 2 billion carbon credits used under the Kyoto protocol for its 2008 to 2020 crediting period (Warnecke et al., 2019).

2.1.5 Carbon Capture and Storage

As possibly the most hands-on measure for reduction of carbon emissions carbon capture and storage (sometimes carbon capture and sequestration or simply carbon capture) (CCS) is somewhat of a environmental grail. Being able to simply remove CO_2 from the atmosphere on demand is clearly a comfortable solution to our environmental woes (Senftle & Carter, 2017).

There are generally two approaches for CCS, either point source i.e. applying CCS at the site of emissions like a power or cement plant or direct air capture which involves the processing of atmospheric air to remove CO_2. The most common technology for separating CO_2 is amino scrubbing and has been around since the 1930s for sweetening i.e. purifying natural gas which naturally is mixed with CO_2. It has also been long possible to store CO_2 in geological formations, a technology used in enhanced oil recovery. However, CCS is yet to be applied on a large scale for the purpose of removing CO_2 from the atmosphere or at source (Smit, 2016).

For carbon offsetting purposes CCS is an attractive proposition as the measure of the CO_2 reduction is not dependent on some future scenario or methodology to be calculated thus eliminating uncertainties about the actual effect of the offset. So far, the high cost of CCS is a barrier to its implementation as there are cheaper alternatives in the quest for lowering emissions. For point-source capture, one of the most feasible approaches to CCS, Finkenrath (2011) suggests that the cost per avoided tonne of CO_2 emissions is 52 and 80 USD for coal and natural gas power plants respectively. This is considerably more costly than typical carbon offsets as of now. However, it still remains a promising opportunity in reducing global GHGs (Simon et al., 2011). Since the 2010 COP16 in Cancun, some applications of CCS can be allowed under the CDM (Al-Fattah et al., 2012) but as of 9th of March 2020 there are no registered CCS projects in the CDM project activities database.

2.1.6 Behavioral Change

Until now the measures for reducing aviation carbon emissions have been based on technology, legislation or formalized commitments. In this last section, the focus will be on how the individual’s choice and behavioral change can reduce carbon emissions. Behavioral change is an imperative measure to lower global carbon emissions. In the book *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming* (Hawken, 2017) several behavior change aspects with the potential to reduce global warming are presented. The behavior-related aspects are sorted out in and summarized in a report by the Center for Behavior & the Environment (Williamson et al., 2018). It identified 30 behavioral solutions for climate mitigation which are analyzed from 2020 to 2050. Accumulated these 30 solutions are assessed to be able to reduce 19.9% of anthropogenic carbon emissions (393 Gt CO_2 equivalents (CO_2e)) in a plausible scenario and 36.8% (729 Gt CO_2e) in an optimal scenario. The biggest mitigating action is assessed to be reduced food waste (70.5-93.7 Gt CO_2e) and plant-rich diets (66.1-87.0 Gt CO_2e). There is obviously a power to change in shifting behaviors. Relating to aviation, the same book assesses that “telepresence - using video-conferencing technologies in place of commercial flights” has the potential to reduce emissions by 2.0-17.2 GtCO_2e from 2020 to 2050. This could represent the potential of abstaining from flying voluntarily. However, the potential of flight abstaining is even larger since this “telepresence” behavioral change does not include vacation commercial flights, only professional.

Climate change mitigation by behavior change is dependent on the individual’s will to voluntarily undertake climate action. This is the connection between behavioral change and carbon offsetting, the individual’s will to carbon offset when it is not mandatory. The sentiment for undertaking climate action is different geographically, culturally, socio-economically, etc. and there are different reasons for people to undertake voluntary climate action. Since this study has a Sweden-centric perspective the most relevant manifestation of this is the movement behind Greta Thunberg who has achieved enormous attention even worldwide in the last years. She has affected people to change their behavior and go on school strikes on Fridays. Even though this does not have any direct carbon reducing effects it is an example of how public debate and discussion can lead to behavior change.

Climate anxiety is also an up-and-coming aspect that can drive behavioral change. Worries about global phenomena unmanageable on an individual level have been present for as long as global cognition. In that sense, climate anxiety is not a new phenomenon but an old heuristic of humans applied to a new threat, it is an existential crisis. The American Psychological Association (2017) defines the term “eco-anxiety” as “a chronic fear of environmental doom”. It is manifested by the multiple rallies held all over the world urging politicians and legislators to take action, not least the Fridays For Future rallies spearheaded by Greta Thunberg. The Swedish word for climate anxiety (*klimatångest*) became a word in the Swedish official dictionary SAOL already in 2007 but more recently and relevant to the aviation industry the word for “flight shaming” (*flygskam*) became a new word in SAOL in 2019. These aspects of behavioral change referrers to the individual’s changing behavioral patterns due to an aversion of doing bad rather than a will to do good.

In relation to the aviation industry, it is these kinds of mechanisms that change the individual’s behavioral patterns of traveling which are relevant to reduce industry emissions. It may lead to individuals changing their travel destinations, transport type, abstaining from flying or utilizing voluntary carbon offsetting.

2.2 Carbon Offsetting Certifications

When one is to carbon offset one will be met with a plethora of alternatives all promising the same thing, somehow reducing emissions. In this study, carbon offsetting in the context of the aviation industry is considered and thus the offset certifications found when examining the airlines are the main focus. Below the three certifications for the voluntary market most commonly found in the data are shortly presented and explained.

2.2.1 Gold Standard

The Gold Standard is a certification for carbon offsetting projects established in 2003 by environmental non-governmental organizations (NGOs), amongst them the World Wildlife Fund (WWF). It is administered by the Gold Standard Foundation, an NGO standards body. Its main governing organ is the Gold Standard Secretariat, supported by the Technical Governance Committee and the NGO Support Network (Gold Standard Foundation, n.d.). Since its inception in 2003 the Gold Standard has undergone three phases with the latest, "*Gold Standard for the Global Goals*" devised so that projects contribute to the 2030 Agenda for Sustainable Development.

The main activity undertaken by the foundation is proofing new methodologies and certifying projects that benefit sustainable development. They certify four types of projects, Certified Emissions Reductions (CER, for the compliance markets), Verified Emissions Reductions (VER, for the voluntary markets), Averted Mortality and Disability Adjusted Life Years (ADLY) and Water Benefit Certificates (WBC). In this project only CERs and VERs will be of interest as they concern carbon emissions reductions whereas ADLYs and WBCs do not.

The Gold Standard Foundation communicates that reduction of direct emissions is the primary measure to reduce climate impact that individuals and organizations should undertake but that carbon offsetting is an effective secondary way to reduce emissions (Gold Standard Foundation n.d.). The Gold Standard offers guidelines for how to engage problems frequently occurring in different contexts, for example, projects conducted in large-scale urban environments or interconnected ecosystems. Gold Standard projects set requirements to be sustainable beyond climate change and set requirements on social sustainability (Gold Standard Foundation, n.d.). The Gold Standard also undertakes a return on investment (ROI) perspective for projects and claim that initiatives including also social responsibility actually are more profitable on average when quantifying the social benefits (Gold Standard Foundation, n.d.).

There are several different varieties of projects that are eligible for Gold Standard: community-based projects, energy efficiency, forests, renewable energy, waste management and water (Gold Standard Foundation, n.d.). It may be useful to give an example of how a project is conducted and how the financing is turned over into climate positive effects. Conceptually, the aim of funding a Gold Standard project is to push the financials of a climate positive project from almost being profitable to being profitable. Let us look into a renewable energy wind power project.

Suppose that a company, that we can call India New Winds, wants to build a wind farm in Kerala, southern India. They have found a potentially suitable place for the wind farm and have made financial calculations for the project. There is a demand in the existing power grid for a wind farm and hopefully building a wind farm at this exact spot could prevent the usage and perhaps even prevent the construction of coal-fired power plants. However, India New Winds have analyzed the current market and unfortunately, the current prices of electricity do not justify the investment costs. It will simply not be a profitable investment. Now left to its own devices, India New Winds would have to abandon this project as they will only lose money. This is where Gold Standard carbon offsetting has a role.

In reality, it is not solely India New Winds who profit from the potential wind farm, the wind farm reduces CO_2 equivalent emissions and there are actors who are willing to pay for emission reductions. When the financials are almost profitable, India New Winds can contact Gold Standard and present how they are reducing carbon emissions through their initiative. If the initiative seems legitimate, The Gold Standard Foundation conducts a thorough assessment of the Kerala wind farm project in terms of feasibility, additionality and make sure that the project contributes to the UN Sustainable Development Goals (for example 7 Affordable and Clean Energy, 8 Decent Work and Economic Growth and 13 Climate Action) (United Nations, n.d.). Based on the power grid composition in the country and projection of power production from the wind farm a quantity of saved CO_2 equivalent emissions will be estimated.

These estimated emission reductions are equivalent to a certain amount of CO_2 credits (1 tonne CO_2 equivalent emissions translates to 1 CO_2 credit). These credits are typically produced when the wind farm has delivered electricity over a certain time and by this, has prevented carbon emissions since the electricity otherwise would have been produced by for example a coal-fired plant. The credits will be issued when a validation process is completed. This process is carried out by third-party observers from renowned independent quality assurance, organizations like Det Norske Veritas (DNV) and Technischer Überwachungsverein (TÜV).

When the CO_2 credits are received, they can be sold in an open marketplace. The credits are bought by broker companies who act as a middleman between the customers (who want to carbon offset) and the CO_2 savers (India New Winds in this case). When taking the income streams from selling CO_2 credits into account, the wind farm project becomes profitable. India New Winds will show their improved investment calculation to their financiers (for example a bank) and will hopefully be able to obtain a loan. This process pushes the carbon offsetting project to be completed and saves carbon emissions.

Gold Standard projects are in general viewed as one of the more legitimate forms of carbon offsetting. They could though be criticized, for example from a cultural political economy (CPE) view. Ina Lehmann (2019) investigate 22 Gold Standard-certified cookstove projects from a CPE perspective and uses the term “charismatic carbon marketing” to describe how the cookstove carbon offsetting projects are framed as “small scale, cute and cuddly carbon projects” (Ina Lehmann, 2019). It is found that the marketing makes particularly strong claims on improving family livelihoods, income generation and women empowerment while depoliticizing feminism concerns. Women are depicted as solely responsible for cooking and other related household work. Lehmann reasons that the cookstoves improved technology functions at the expense of a more integrated solution that also would encompass social equality aspects. But this sacrifice of social and gender-equal marketing enables this type of "charismatic carbon marketing" which may be the most effective way to promote carbon offsetting.

2.2.2 Plan Vivo

The Plan Vivo standard is a carbon offsetting certification concerned with land use in general and forestry in particular. The overall purpose of Plan Vivo is to reduce carbon emissions by either increasing an area's carbon sink or by lowering an area's emissions but the intended effects also include social benefits, and protection of biodiversity. This can be done through one of the following project interventions:

- Ecosystem restoration – By reverting land back to its previous state, the ecosystem is allowed to recover. The aim is to once again establish the previous structures, productivity and diversity that existed in the area before anthropogenic intervention. This process often involves planting trees which is where the projects' intended carbon sink is created.
- Ecosystem rehabilitation – In contrast to ecosystem restoration ecosystem rehabilitation does not involve reverting the land to its natural state but instead focuses on improving an incumbent ecosystem. This can be done by for example interplanting (i.e. adding) native tree species to restore soil functions of degraded agricultural land.
- Prevention of ecosystem conversion or degradation – Not improving land use but preventing poor use with the potential of degrading the ecosystem. Measures to do this could include reducing agricultural expansion into forest land or improved pasturing practices preventing grassland degradation.
- Improved land use management – Increasing the ecosystem services provided by an area in terms of carbon sinks through improvements in land use and management.

Plan Vivo, like most carbon offset initiatives relies on the principle of additionality to quantify and qualify the claimed emissions reductions. In order to calculate the additionality baselines are used and the difference in CO_2 emissions between the baseline scenario and the projected impact of the project is considered to be the carbon offset by the project. While land use projects are important in general and undeniably can have the effect of reducing emissions, they have some drawbacks when considered as carbon offsets to be bought and sold (Harper et al., 2007).

The main problem is the timescale on which land use projects take place. As the main carbon sink is the one achieved through the growth of trees it takes a long time for projects to come to fruition and sequester the planned amount of CO_2. This raises the question of ex-ante or ex-post. Plan Vivo accepts both models and stresses that upfront payments can be instrumental for the realization of projects in poorer, third world countries. Further, for the sake of ensuring that a certain amount of carbon emissions has been avoided, it is important to ensure that the land keeps its new improved status for long for the action to be considered permanent. The mechanism Plan Vivo relies on for land to keep its improved use is management objectives i.e. they are supposed to provide some ecosystem service that is valuable to the people working the land. This could for example be sustainable timber or fruits. The value of these is supposed to keep the land as intended under Plan Vivo. However, most carbon offset projects are monitored by a third-party validator. This is also the case for Plan Vivo which requires validation every five years by one of the five authorized organizations

AENOR, Aster Global, Control Union, Epic Sustainability or GHD in order to still be allowed to market Plan Vivo carbon credits (Plan Vivo, n.d.).

2.2.3 Verified Carbon Standard

Verra is an organization specialized in developing programs and standards to ensure quality in environmental and in social projects. They manage the Verified Carbon Standard the largest certification in the context of voluntary Carbon Offsetting (number issued of CO_2e emissions credits). Worth mentioning is that they also are an (out of multiple) administrator of the *Offsets Project Registry* (OPR), the compliance market registry for offsets eligible for use under California's cap and trade system equivalent to the EU ETS.

The Verified Carbon Standard's voluntary program for GHG reductions is the world's most widely used voluntary carbon offset program. The program allows projects in six sectoral scopes: (1) GHG emission reductions from fuel consumption, (2) GHG emission reductions for industrial processes (non-combustion, chemical reaction, fugitive, and other), (3) Land Use and Forestry, (4) Carbon, Capture, and Storage, (5) Livestock and (6) Waste Handling and Disposal. A credit issued under the Verified Carbon Standard is called Verified Carbon Unit (VCU) and represents one tonne of CO_2e emissions. As with the previously mentioned carbon offsetting certifications, the Verified Carbon Standard relies on the concept of additionality to determine how much carbon emissions are avoided by a project. Additionality is determined against a baseline scenario considering the outlook without the extra capital provided through the sales of VCUs. Like previously mentioned certifications the, VSC is quality assured through auditing third-party observers (Verra, n.d.).

While social aspects are considered in some VCS methodologies not all encompass these. Further the VCS methodologies include disputed project types like gas destruction projects. Gas destruction projects have been dropped from the CDM as it was found that awarding the destruction of cheap to manufacture gases incentivized increased destruction and thus increased the production (Schneider, 2011).

2.2.4 Other

There are too many other programs and certifications for carbon offsets to mention. In work during this study, many different programs and certifications were encountered but it was decided that only the most cited would be delved into. One honorable mention commonly quoted by airlines is the UN Reducing Emissions from Deforestation and forest Degradation (REDD+). However, mostly these REDD+ credits are certified by Plan Vivo or VCS and thus, in those cases, the guidelines regarding Plan Vivo or VCS are applicable and additional explanation is not called for.

2.3 Technical Aspects of Aviation Emissions

The aviation industry is not known for being carbon neutral. There are efficiency improvements which leads to reduced carbon emissions through higher technical and managerial efficiency. There are also several innovations that can take the aviation industry far along the road, primarily electric aviation and sustainable aviation fuels. The aspect of the non-CO_2 effect must however be considered.

2.3.1 Flight Efficiency

Reduced carbon emissions can be achieved through efficiency improvements related to the flights. Migdadi (2019) do for example suggest that one could reduce direct CO_2 emissions from jet fuel and ground support through improvements of aircraft design, fuel management, management of flight routes, maintenance and operational flights. It is also suggested that indirect CO_2 emissions and energy consumption could be reduced through improving engine design, the operation of engines, adoption of Leadership in Energy and Environmental Design (LEED) standards, upgrading of facilities, usage of sustainable energy and adoption of energy-saving actions. These efficiency improvements will not result in carbon neutral aviation but it could decrease the overall environmental footprint.

An example of an important aircraft design feature is the winglet. A winglet is typically a bend at the edge of the aircraft's wing that reduces the high-pressure air leakage from under the wing to above the wing. This results in reduced strength of the wingtip vortex. Tests on the Boeing 707 type airliner (a typical commercial airliner) have shown a decrease in fuel use of 6.5% when using winglets compared to not using winglets (NASA, 2015). This is one example of an incremental technical improvement that reduces carbon emissions.

Fuel efficiency is not solely important in regard to carbon emissions but is also a substantial cost post for airlines. Jet fuels stand for about 20% of aviation operating costs (Airlines for America, 2018) and there are therefore economic incentives for airlines to improve efficiency. From 1968 to 2014 the average fuel burn for a new aircraft has fallen approximately 45% or 1.3% annually (Kharina & Rutherford, 2015). The annual energy efficiency improvement pace was 1% in 2014-2016 (IEA, 2019). The International Energy Agency (IEA) has developed a Sustainable Development Scenario (SDS) that is necessary to follow in order to meet the UN Sustainable Development Goals (SDGs). In this scenario, the aviation industry needs to improve its energy efficiency by more than 3% annually until 2040 in order to succeed, furthering incentives for improving efficiency.

Other parameters that can affected environmental impact is seat configuration and seat occupancy i.e. how many persons fit in the aircraft and how many empty seats there are. On average, a business or first class seat takes up more space than an economy seat and therefore an aircraft with a high portion of economy class passengers emits less than one with the same seat occupancy (Schennings et al., 2019).

Looking forward, it will be difficult to achieve enough reductions in emissions in the aviation industry with incremental improvements of predominant technology. The current ruling technological paradigm is the turbofan engine and this technology will likely play a central role in the coming couple of decades too (Ranasinghe et al., 2019). There are turbofan innovations that have the potential to reduce emissions, some examples are combustion and thermofluidic enhancements, gearbox technology, lightweight materials and intelligent engine health management systems. But it is shown by Ranasinghe et al. (2019) that investments in turbofan technologies have experienced diminishing returns in terms of reduced emissions. In other words, when keeping investments constant, the amount of emission reductions has decreased over time. To technically reach carbon neutral aviation disruptive technologies, as electrical aviation, sustainable aviation fuels or new aerodynamic configurations are needed.

2.3.2 Sustainable Aviation Fuel

The most common fuels used in aviation today are Jet A or Jet A-1. There are a few minor differences such as freezing point but essentially, they both consist of an array of hydrocarbons (paraffins, olefins, naphthenes, and aromatics). The fuels are petroleum products derived from crude oil and are thus fossil (Fedorov et al., 2004). However, as knowledge of global warming and the depletion of oil reserves has grown so has the interest in renewable alternatives.

Biofuels are an important step towards a more sustainable energy supply. The term biofuel encompasses everything from biomass, its most basic form, to highly refined fuels found in the aviation industry amongst others. It has long been hailed as an example of a drop-in solution for internal combustion engines that can utilize a lot of the incumbent infrastructure while lowering CO_2 emissions compared to fossil alternatives. All biofuels are based on some form of biomass which is then processed to some degree. In the case of furnaces, the biofuel is often pure biomass and thus requires little or no processing.

Internal combustion engines usually require fuels with more specific compositions of molecules and thus tend to be more processed or refined. The characteristics of aviation fuel for commercial flight are standardized and fuels must fulfill the specifications stipulated in ASTM D1655 or Def Stan 91-91, standard specifications for aviation turbine fuels (IATA, 2015).

There are multiple methods and raw materials that can be used for the production of biofuels for use in the aviation industry. These particular biofuels are generally referred to as sustainable aviation fuels (SAF). As of 2019 there were six approved pathways for use of biofuels or SAFs in commercial aviation (see table 1). However, there are some hurdles for biofuel in aviation as while the technology to create the fuel is readily available albeit relatively expensive, the regulations on most fuels used in commercial flights stipulate that a maximum of 50% of the fuel mix can be biofuel and, in some cases, only 10%. (Prussi et al., 2019). Further, it is important how and what kind of feedstock i.e. what kind of biomass is used in the production. Early biofuels used human-grade food as feedstock but all the currently approved pathways can all make use of biowaste as feedstocks as well. The feedstock used is very important for the life cycle emissions (LCE) of the fuel. For example, Alcohol to jet fuel produced with corn grain as feedstock has an LCE comparable to that of normal Jet A fuel whilst hydroprocessed esters and fatty acids (HEFA) using used cooking oil as feedstock can lower the LCE by as much as 80% (ICAO, 2019).

Name/Pathway	Raw material	Allowed blend by volume %	Technology Readiness Level 1-9
FT-SPK (Fischer-Tropsch Synthetic Paraffinic Kerosene).	Biomass	50% with fossil jet fuel	6-8

HEFA (Hydroprocessed Fatty Acid Esters and Free Fatty Acid)	Lipid feedstocks such as used cooking oil vegetable oils, tallow, etc.	50% with fossil fuel	9
HFS–SIP (Hydroprocessing of Fermented Sugars - Synthetic Iso-Paraffinic kerosene)	Sugars	10% with fossil fuel	7-8
FT-SPK/A (variation of FT-SPK, where alkylation of light aromatics creates a hydrocarbon blend, which includes an aromatic part.	Biomass	50% with fossil fuel	6-8
ATJ-SPK (Alcohol-to-Jet- Synthetic Paraffinic Kerosene)	Iso-butanol	50% with fossil fuel	7-8
Co-processing	Lipid feedstock, biological origin (fats, oils and other residues) in fossil refining process	5% with fossil crude, bio-component can be 5% of resulting product	N/A

Table 1, SAF approved pathways (European Commision, 2019)

While the use of biofuel might be able to rid the aviation industry of fossil fuel dependence it might not reduce its CO_2 emissions to zero. The overall lifecycle emissions are however lower than conventional jet A-1. The exact number will inevitably vary depending on the different pathways and biomass used. SkyNRG who is developing the first European dedicated SAF production plant aims for an 80% reduction in CO_2 emissions for their fuel compared to conventional jet A-1 primarily utilizing waste as feedstock (SkyNRG, n.d.). For reference, Lokesh et al. compared SPK from three different sources of biomass (non-waste) in their 2015 study "Life Cycle Greenhouse Gas Analysis of Biojet fuels with a Technical Investigation into their Impact on Jet Engine Performance". They concluded that the carbon LCE reductions relative to jet A-1 are in the span of 58% to 70%. Further, while the use of biofuel might reduce the net CO_2 emissions stemming from aviation it will not lessen the inflight emissions considerably and will still give rise to non-CO_2 effects (Krammer et al., 2013).

SAF as a technology was first demonstrated in aircraft for commercial use in 2008 by Virgin Atlantic and was used on a commercial flight in 2011 by KLM. However, it still accounts for an infinitesimal share of aviation fuel used today on account of its high price and subsequent low production volume. For reference using SAF (synthetic kerosene with an 80% reduction rate) from Compensaid, the offsetting initiative used by the Lufthansa Group, it would cost 5206 SEK/tonne using the current (15/5-20) exchange rate of 10,66 SEK/EUR (Compensaid, 2020).

2.3.3 Electric Aviation

Electrical aviation is a possible way to fly with a low climate footprint. Solar cells, ultracapacitors, fuel cells and power beaming could play a future role in electrical aviation development. However, batteries are currently the most feasible technology. Electricity powered aircraft produce no emissions while in operation (IATA, 2019). The production of electricity is not emissions-free but leaves a smaller footprint than jet fuels. In the future, when electrical aviation potentially will play a larger role, the electricity mix will likely consist of more renewable energy and therefore give rise to even less carbon emissions (IEA, 2018). Electrical engines also require less maintenance than combustion engines. The Swedish company Heart Aerospace do for example claim that reliable electric engines reduce maintenance costs with 90% compared to turboprops (Heart Aerospace, n.d.).

Electricity can be used as the sole source of energy or as a hybrid solution. All-electric systems make rid of combustion engines and instead rely on energy storage and usage systems such as batteries or fuel cells. Hybrid-electric systems rely on gas turbine engines for propulsion and for charging batteries. Turbo-electric systems on the other hand do not have batteries at all but generate propulsion via electrical fans powered by turboshaft engine generating electricity rather than thrust (IATA, 2019). For all intents and purposes, “electric” will henceforth refer to all-electric systems if not specified.

There are split opinions on when electrical aviation will be available widespread commercially. From an optimistic market-based start-up perspective electrical aircraft with a capacity of 15-20 passengers could be available in 2023 and larger aircraft with around 100 passengers will be available soon after 2030. A more pessimistic view is that the 15-20 passenger aircraft will be available around 2030 and that a regional hybrid aircraft of 50-100 passengers will be available first around 2050, according to IATA (2019). The current problem with electric aviation is the power source. As previously mentioned, batteries seem to be the most viable option but as of now, they are not good enough. The elephant in the room is the specific energy i.e. energy density of batteries, they are simply too heavy in relation to the energy they can store. Lithium-ion batteries the best available battery technology of today, can only store about 1/50th of the energy the same mass of jet fuel could and as flying is a question of overcoming gravity, weight is a great disadvantage. Beyond weight, there are other concerns like safety and propulsion but they are essentially unimportant until the problem of weight is solved.

A first step in the adoption of electric aircraft could be air taxis, small aircraft that can transport passengers within cities. IATA depicts a potential future market development summarized in the following figure.

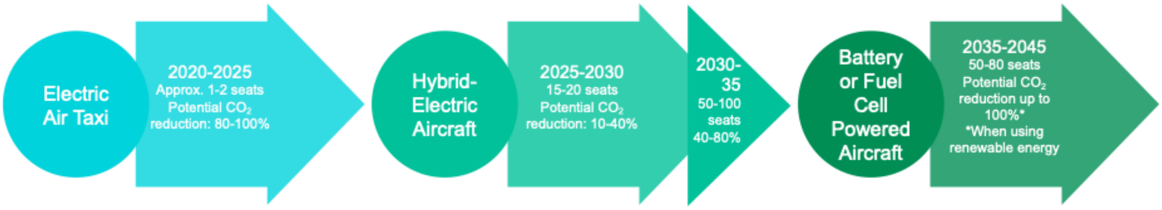

Figure 1, Market development projection for electrical aviation (IATA, 2019)

They also have created a timeline for an optimistic scenario development:

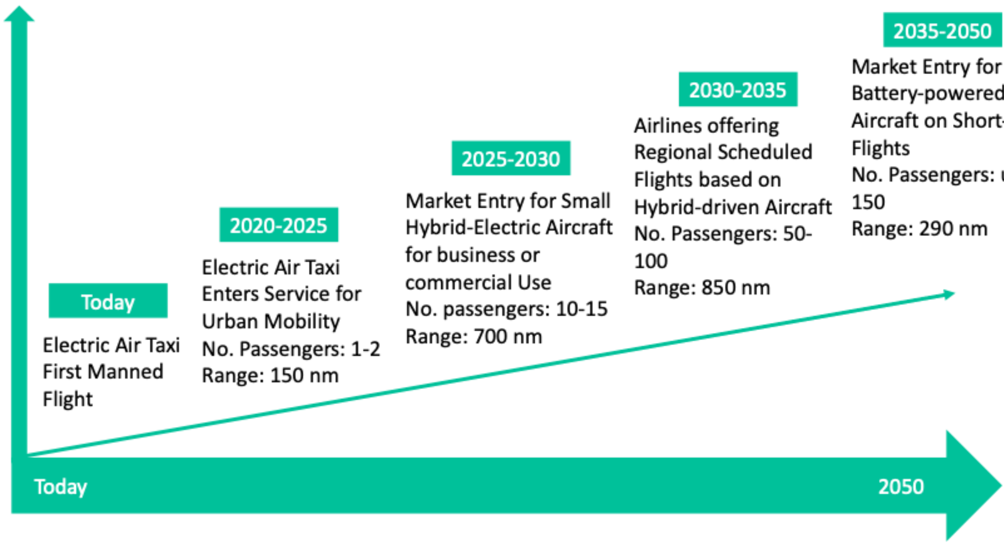

Figure 2, Timeline projection for electrical aviation (IATA, 2019)

Electrical aviation will likely have an important role in future reduced aviation emissions since it is the least emitting technology. According to the above timestamps, electrical aviation will not be the solution to prevent the aviation industry from increasing emissions after 2020. It will neither significantly lower the short term carbon emissions that are needed to meet the 1.5-2°C goal according to the projections.

2.3.4 Non-CO_2 Effects

When discussing the environmental impacts of aviation there is more to it than just CO_2 emissions. In addition to CO_2, internal combustion engines (ICEs) burning fuel, be it diesel or petrol, gives rise to nitrous oxides (NO_X), carbon monoxide (CO), sulfur dioxide (SO_2), water (H_2O) and soot particle emissions which like CO_2 can play a reinforcing role in the greenhouse effect warming the planet (Manning & Reisinger, 2011). However, the emissions from aviation have additional effects due to the environmental conditions at high altitudes. These effects are commonly referred to as non-CO_2 effects or sometimes high-altitude effects.

The metric on which greenhouse gases are evaluated is radiative forcing on climate. It is the difference between incident radiation and upwelling radiation from the Earth's surface and atmosphere i.e. how they affect the atmosphere's radiative ability. The relations of how the different gases and particles affect the radiative forcing (RF) of the atmosphere are rather complex. While for example, NO_X has a warming effect (increasing RF) in the troposphere by means of chemically creating ozone (O_3) it also has a cooling effect (lowering RF) stemming from NO_X chemically destroying methane (CH_4), another potent greenhouse gas (Akimoto et al., 2001).

Further, a component of global warming impact exclusive to aviation is the creation of contrails. More specifically contrail-cirrus clouds, often referred to as aircraft induced cirrus (AIC), are the clouds often seen in the wake of aircraft flying at high altitudes of 8,000 to 13,000 meters (cruising altitude for commercial flight). These are the only unnatural ice clouds (man-made) and have a warming effect (increasing RF) and are created by the engines ejecting hot gaseous and particulate matter into the cool ambient environment at high altitudes which forms droplets that freeze into ice crystals creating the clouds (Kärcher, 2018). Another important aspect of the non-CO_2 effects is the timeframe. While CO_2 is a long-lived GHG with an atmospheric lifespan of 20-200 years (Archer et al., 2009) the clouds have much shorter lifespans rather measured in hours or days than centuries (Kärcher, 2018). AIC together with NO_X emissions is what is most generally considered when discussing the non-CO_2 effect however it could include additional emissions and effects but for its further use in this paper, it only refers to AIC and NO_X.

While the fact that aviation at high altitudes gives rise to additional effects is generally accepted and has been for quite some time, the exact effects are deceivingly difficult to estimate (Lee et al., 2009). The sheer amount of factors that play a part, especially the timeframe, makes it nearly impossible to give a precise estimate of a particular flight's impact. A widely used metric to gauge emissions where time is a factor of great importance is global warming potential (GWP). It can be measured on different timescales the most common being 20 (GWP_{20}), 50 (GWP_{50}) and 100 (GWP_{100}) years, the latter being the timescale used in reporting GHG emissions under the Kyoto protocol. Lee et al. (2009)
concluded that the non-CO_2 multiplier effect on CO_2 equivalents for GWP_{100} ranged somewhere from 1.9 to 2.0 i.e. the total RF stemming from the emissions at high altitude are 1.9 to 2.0 times as much as the RF from the CO_2 emissions alone. The multiplier for GWP_{20} ranged from 4.3 to 4.8. In a similar study, Forster et al. (2006) estimated the multiplier for only NO_X to be 1.2 for GWP_{20} and 1.8 for GWP_{100}.

In this paper, the multiplier 1.9 for CO_2 emissions is used in order to cognitively percept the total impact of aviation emissions. It is the same multiplier used by Schennings et al. (2019) in their formula for calculating CO_2 equivalent emissions. It is important to keep this figure in mind when analyzing carbon offsets and SAF as means of lessening the environmental impact. They are both often used and focused on reducing a set amount of carbon dioxide emitted from a certain amount of burnt fuel, not focused on carbon equivalent emissions which also would include the non-CO_2 effect. This factor allows for analysis of carbon offsets by industry actors to be more critical and realistic.

2.4 Theoretical Lens

Until this point, the background has regarded facts and information about the reality of carbon offsetting and sustainable aviation. In this section, a tool for analyzing this reality will be introduced. The theoretical lens will help to analyze the dynamics of the aviation industry's transition into sustainability. Its aim is to contextualize the reality facts, show interlinkages and discuss future developments.

2.4.1 The Aviation Industry as a Socio-Technical System

If the current aviation industry is to curb its increasing emissions, reduce emissions and ultimately become carbon neutral it will have to undergo a radical transition. This is typical for sustainability transitions which often are cases of significant societal challenges where unsustainable patterns of consumption or production need to be intercepted and changed (Köhler et al., 2019). In order to describe the entire system of consumption and production patterns the term *socio-technical system* can be used. A socio-technical system constitutes the context of a technology and allows for a more profound understanding of how it operates. Technologies are very much interwoven with the people interacting with them, their lifestyles and practices, with complementary technologies' business models and value chains, and with regulation, institutions and political factors. These multiple factors together create the socio-technical system which itself exists in and interact with a complex environment (Hughes, 1989).

To encounter the sustainability challenges current socio-technical systems such as electricity, heating, buildings, and mobility are facing the need to undergo not just incremental changes or technological improvements but radical changes are necessary (Köhler et al., 2019). One could also view the aviation industry as a socio-technical system that needs to undergo such change in order to become sustainable.

2.4.2 A Multi-Level Perspective

To understand how socio-technical systems transform Geel (2002) and Rip & Kemp (1998) advocate the multi-level perspective (MLP). This proposes that the socio-technical system is a system on a meso-level influenced by the complex environment consisting of both micro- and macro-level components. The level above is a macro-level where long term sustainability questions can be discussed, such as climate change's overall planetary impacts, public vs. individual responsibilities or globalization and equality. The level below is a micro-level where the individual actors' actions can be observed, such as individual lifestyles or upcoming technologies and companies. The three levels are generally referred to as the socio-technical landscape - the macro component, the socio-technical regime - the meso-level and the technological niches - the micro component. The system boundary and scope of the MLP is flexible and thus can be used to observe system transitions on different empirical levels (Geels, 2011).

The socio-technical regime consists of ethereal and latent patterns of the socio-technical system, which is the measurable and tangible elements of the same object of study. The socio-technical regime is the cultures, symbolic meanings, strategic games, techno-scientific paradigms, heuristics, policy tradition, social norms and visions while the socio-technical system consists of market compositions, user preferences, infrastructure, sectoral policy and regulation. Generally, the alignment between the regime components is stable due to lock-in effects and path dependency stemming from the vested interest of the actors in the regime, sunk investments, existing infrastructure, and established regulation. It is however imperative to understand that they are not static in their positioning but in constant, if small, motion, a state of incremental innovation and predictable progress (Rip & Kemp, 1998; Geels, 2002; Geels, 2004; Geels & Schot, 2007). This motion is partly due to the interaction with the two other levels. Firstly, the macro-level socio-technical landscape which is the exogenous environment where the regime operates. It is characterized by rules that guide technical design, shape market developments and regulate said markets. The rules are not necessarily a decree but consist of factors like economics and political development on the macroscale and deeply rooted societal cultural phenomena (Geels & Schot, 2007). The typical way of analyzing the landscape is to focus on how it puts pressure on the regime and by that destabilizing and reforming it. However, the opposite could also take place where landscape pressure has a reinforcing effect, further stabilizing the regime. It is also possible that a socio-technical transition leads to the regime affecting and changing the landscape. This leads to a case of reversed causality where the regime transition is the dependent variable which reversely causes an effect on the landscape independent variable, which generally is used to predict and understand the regime and not a variable of interest (Geels, 2011).

The other interacting level is the niche micro-level. The niche level is where innovations and novelties that do not conform to the current state of the socio-technical regime can be sustained and developed. Geels (2004) argues that niches often emerge from protected spaces. These spaces are generally protected in the sense that they are allowed to avoid the selection-retention characteristics of markets through subsidies, public authority or by being investments of strategic importance, thus effectively not competing in any market. That said, niches considered inferior by the standards of the broader fully commercialized markets can still give rise to their own niche markets due to specific high performance (Levinthal, 1998). Previous scholars have identified three processes behind niche development: (1) Articulation of *expectations* or *visions*. (2) The building of social *networks* and the enrolment of more actors. (3) *Learning and articulation processes* on various dimensions. These three processes help explain how a niches gain momentum by (1) aligning with the expectations or visions of external actors and thereby attract consideration and capital, (2) by expanding social networks and thus expanding the resource base and legitimacy and finally (3) learn on all dimensions a niche will face on its way to the mainstream such as market business models, market demands and user preferences (Kemp et al., 1998; Schot & Geels 2008).

The main mechanism of transformation in the MLP includes all three levels in interaction. Changes in the socio-technical landscape puts the socio-technical regime under a transformative pressure, forcing it to reconfigure. At the same time, innovations and technologies in the niche-level are constantly probing the regime for market acceptance. In some cases, the transformative pressure loosens up and reconfigures the socio-technical regime in such a way that it allows for diffusion and breakthrough of niche novelties, it opens up a so-called window of opportunity (Geels, 2002). This kind of transformation of the regime is not exclusively limited to the two-pronged explanation in the MLP and other underlying dynamics can be found. One such dynamic can be found in Christensen's critically acclaimed *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (1997) where incumbent firms fall at the hand of newcomers that create a radical change without the transformative pressure from the landscape. Another could be Kuhn's paradigm shifts described in his 1962 book on the history of science, *The Structure of Scientific Revolutions* (1962) where paradigms rule the course of research until the discovery of anomalies within the research paradigm pressures the scientific community to ask new question creating a new paradigm (Geels, 2004).

The dynamics of the MLP could be interpreted as that change always starts in the niches, who push into the socio-technical regime, change it and ultimately changes the landscape. This bottom-up approach does seldom describe reality perfectly. Geels (2011) introduce four pathways that are alternatives to the bottom-up dynamic:

1. *Transformation* - Niches are not that developed. Incumbent actors adjust the innovation path when the landscape puts pressure on the regime.
2. *Reconfiguration* - Niches are more developed. If niches can co-work with the regime they can be adopted by incumbent actors when the landscape puts pressure on the regime. If the niches take place in the regime, it is likely that the regime will change in its foundations.
3. *Technological substitution* - Niches are well developed and competitive which allows for breakthroughs in the regime if the landscape exerts transformative pressure that creates a window of opportunity. An additional scenario where technological substitution can occur is when a niche gains internal momentum substantial enough to replace the regime without the aid of the landscapes transformative pressure.
4. *De-alignment and re-alignment* - The change process is initialized by the landscape putting so much pressure on the regime that it becomes turbulent and de-aligned. This creates window of opportunities for niches who parallelly will try to take place in the window. Ultimately, one innovation will win. This process is similar to the "dominant design" concept (Christensen, 1997).

2.4.3 Nuancing the Multi-Level Perspective

In this setting, the MLP will be used to analyze the aviation industry's transition towards being more sustainable and less carbon intensive. The MLP is just one of many possible models and frameworks that can be used, for example, Diffusion of Innovation (Rogers, 1962) or Large Technical Systems (Hughes, 1989), could potentially also be used to describe the transition. One could argue that solely using the MLP results in missing out on important aspects of the transition dynamics. The critique should be taken seriously and it should be kept in mind that MLP is not the framework to rule them all. As discussed by Frank W. Geels (2010) there have been several criticisms towards the MLP. For example, Smith et al. (2015) and Genus and Coles (2008) argued that the MLP could focus more on the power of agents in socio-technical transitions. Social construction of technology (SCOT), actor-network theory (ANT) and constructive technology assessment are also suggested. Markard and Truffer (2008) do further suggest that technological innovation systems (TIS) could widen the applicability of the MLP. Geels (2010) partly address this critique by examining seven general theories of social science in relation to the MLP, and also specifically applied to sustainability transitions. The general theories or ontologies are *rational choice*, *evolution theory*, *structuralism*, *interpretivism/constructivism*, *functionalism (system theory)*, *conflict and power struggle* and *relationism*.

It is argued that *evolution theory* and *interpretivism* are most compatible with the MLP. The evolution theory's selection and retention mechanisms remind of the MLP's treatment of niches that are or are not adopted into the socio-technical regime. In the MLP, the selection and retention process is however multifaceted incorporating market, regulation, social, cultural and political aspects and retention is not a question of what works (as in behaviorism theory) but a question of institutionalization in the regime via cognitive jostling and competition (Geels, 2010). The view of interpretivism is also compatible with the MLP and overlaps with the function of understanding how sense-making, social anchoring and cognition are important aspects of socio-technical change. For example, Levinthal (1992) suggests that change in organizational strategies and missions is preceded by knowledge and competence development within the relevant area. Belief systems and interpretive schemes usually also precedes actual strategy and mission change (Geels, 2010).

Another relevant expansion of the MLP framework is the function of *ambidextrous organizations* (Tushman & O'Reilly, 1996) which focus on the abilities of incumbent firms to exploit existing technology but at the same time explore new ones. The ambidextrousness of organizations explains some of the niche-regime interactions that might otherwise be overlooked when searching for dynamics on a niche–regime–landscape level (Geels, 2010).

Lastly, the socio-technical landscape and its interaction with niche innovations and the regime is complex and is dependent on deep societal structures. This could be dug in into infinitely but this is not the scope of the MLP. However, some further understanding could be acquired by consulting ontologies as *structuralism* and *conflict and power*. A structuralist view through cultural sociology and discourse analysis could help the description of how deep cultural patterns affect collective opinion and sense-making (Spillman, 2002). In the MLP, this analysis will occur mainly on a landscape level but it will have its implications on how the socio-technical regime evolves and what niches that relevantly will take place in the socio-technical regime after a transition. Public discourse (public debate, media, social media) is a debate between different discourse coalitions (Hajer, 1995) and is played out before different target groups. The discourse results in coalitions having different viewpoints of the discoursed subject, which leads to different priorities of social problems and technologies (Geels, 2010). This affects the landscape's public, political and financial support (Suchman, 1995; Lounsbury & Glynn, 2001) and thereby enable or disable niche innovations to find their place in the socio-technical regime. The public discourse could also be described by the *conflict and power* ontology with its causal agents being collective actors such as social movements similar to *structuralism's* social collectives and the conflict and power ontology can explain how the regime is formed and stabilized. When large and powerful actors stand in the way of change, stability exists. When the socio-technical regime adapts to social movements such as protests, incremental change prevails. When new entrants have won the public opinion and conquered the socio-technical regime, radical change and power shifts have occurred (Geels, 2010). Social movement theory (SMT) could further be relevant when describing how incumbent actors are affected by social movements who argues that the current regime is discriminating, ineffective or immoral. For example, normative questions of sustainability. As social movements usually start out as aliens to current regimes these movements employ non-institutionalized means of exercising power such as protest marches, strikes and petitions (Geels, 2010).

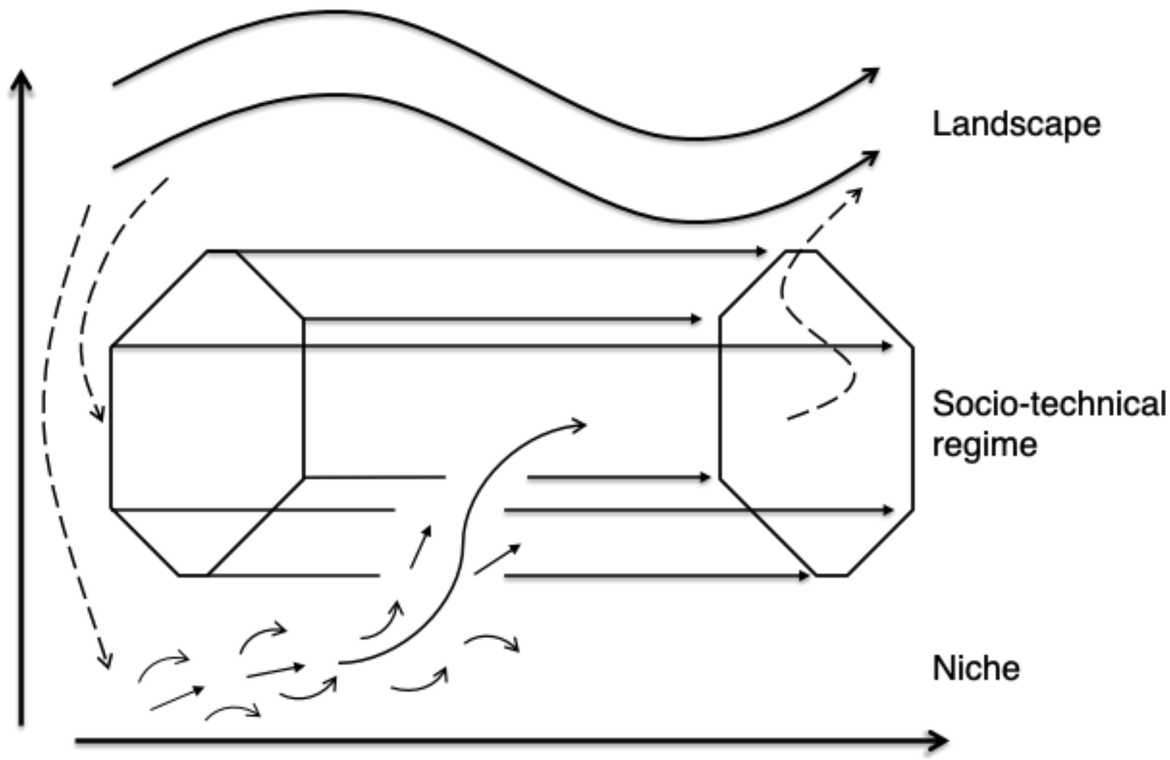

Figure 3, A schematic picture of the MLP dynamics

3 Method

The aim of this chapter is to thoroughly describe and provide insights into the design of the study. First, the general research process is described. This is followed by reasoning regarding what literature that was reviewed and what knowledge that was required in order to be able to progress. After this, the process of gathering data for and the development of the Carbon Offsetting Assessment Framework will be presented followed by a summary of the multi-level perspective.

3.1 Research Design and Process

The research method of this study is a mixed inductive-deductive qualitative method utilizing mainly secondary data but also primary data. The research process was exploratory and an important part of the project's method was orientating in the subject and defining the problem. Overall the research process started with defining the research purpose. This led to a need for exploring the carbon offset market, sustainable aviation and its underlying elements in order to understand research needs. This was also supplemented by a sample of interviews of relevant actors further described under *3.5 Semi-structured interviews*. When a better understanding of the carbon offset market was acquired in relation to the aviation industry, a relevant literature study was able to be conducted. The literature study contributed with information both on aviation, carbon offsetting and theoretical lens (MLP) that were used in the analysis. Data collection was conducted. An empirical framework (Carbon Offset Assessment Framework) for analysis was developed and it was used inductively in relation to the collected data. With the framework filled in and with a comprehensive problem understanding a discussion was deductively elaborated on through the MLP theoretical lens. Conclusions were drawn and future research was then suggested.

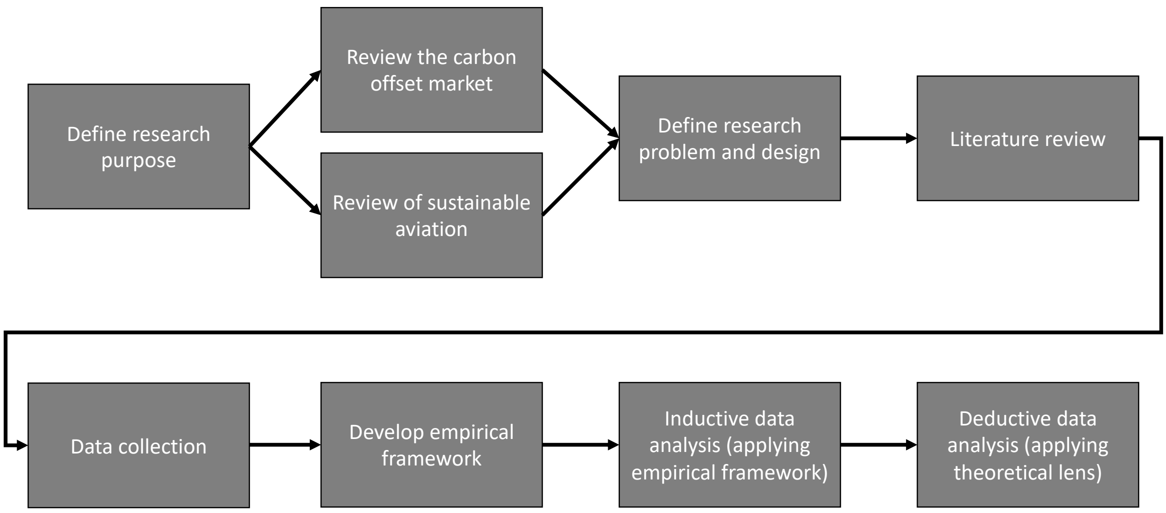

Figure 4, Schematic view of research design and process

3.2 Carbon Offset Market Review

Early on in the work, it became clear that performing a review of the carbon offset market would be helpful as carbon offsetting is a rather young and not well-known industry. Initial knowledge gathering and compiling was thus imperative in order to guide the research in the correct direction and formulate the right questions and the right research purpose.

This primary work consisted mostly of reading up on the subject at hand through online sources, mainly the UN through the IPCC, UNFCCC and the ICAO but also via the Gold Standard, Plan Vivo and other NGOs concerned with carbon offsets, intergovernmental organizations such as the IEA and aviation trade organizations such as the IATA. Further, continuous discussions with colleagues and an interview with Kalle Nilvér, the CEO of Go Climate Neutral (the main purveyor of Carbon offsets to the customers of Flygresor) gave great insights and understanding of the processes behind carbon offsets and the aviation industry. As an example, this knowledge gathering in the field of carbon offsets led to the understanding of how they work in practice, how carbon offsets can be so cheap and the controversies associated with them.

3.3 Literature Study

Literature was reviewed continuously throughout the process in an ad-hoc manner when more in-depth information was needed regarding certain aspects. Literature was also studied more systematically at some points in the process. When defining research purpose, problem and design a literature study on carbon offsetting, aviation emissions and green aviation was conducted. This was mainly done with searches on Web of Science, Google Search, Google Scholar, KTHB Primo. Some examples of keywords used are *carbon offset*, *green aviation*, *greenhouse gas offsets*, *sustainable aviation fuel* (*SAF*), *electrical flights*, *aviation biofuel*, *Gold Standard*, *Clean Development Mechanism* (*CDM*), *non-*CO_2 *effects*, *high altitude effect, Kyoto Protocol*, *EU Emission Trading System* (*EU ETS*), *carbon tax*, *CORSIA* and *Carbon Capture and Storage* (*CCS*). Additional literature on carbon offsets, climate change information and climate anxiety were distributed from Flygresor (Fores, Tricorona) and was also reviewed. Organically expanding from these information sources, a view on carbon offsetting, aviation emissions and green aviation was obtained. Further on, a study of more theoretical literature was conducted to form the multi-level perspective framework. Searches on Web of Science, Google Searches, etc. were also used there. Mainly, the work of Frank W. Geels was studied and used as origin for organic expansion of literature scope. Some material provided directly from KTH courses was also used.

3.4 Data Collection and Secondary Data Analysis

In order to understand and map the current state of carbon offsetting in the aviation industry, data was collected for the 30 airlines that receive the most clicks on the Flygresor site and from the at the time 33 active online travel agencies (OTAs). The data in question was primarily secondary data available through the internet. It was retrieved by completing a Google Search, by reading annual reports and by visiting respective websites for each company individually. The searches were formed according to *airline/OTA* + “sustainability”, *airline/OTA* + “carbon offset” and *airline/OTA* + “annual report”. Flights were also fictively booked so the customer offering of carbon offsetting or SAFs was revealed. While most of the 30 airlines of interest were publicly traded and thus had annual reports available some were state-owned or privately held. This caused some headaches as there was significantly less data available on these airlines. In these cases, the data gathered was obtained only through Google Search results and the fictitious booking except for the cases where through company contacts access to proprietary information was granted. As for the OTAs privately held companies was the norm and thus the data gathered relied more heavily on fictitious bookings and exploration of their respective websites. Also, in cases where access to proprietary information could be granted by the OTAs that data was used. Data retrieved from proprietary information was handled in the same way as the data retrieved from annual reports. In a few cases, airlines and OTAs were contacted directly via email to obtain some additional or clarifying information.

3.5 Semi-Structured Interviews

The interviews in this project have a rather small role and were mainly used to acquire anchoring knowledge and perspectives from reality. This contributed with a deeper understanding of the carbon offsetting and sustainable aviation in general and a confirmation of that the reality that can be observed behind a desk through a computer is a proper depiction. Three interviews or meetings were held and all were completed in the same manner. The idea was to have one perspective from each type of actor that is relevant to carbon offsetting: a carbon offset provider, an airline who undertakes green aviation measures and an institutional innovation actor. The interviewees where:

- Kalle Nilvér, Go Climate Neutral, CEO
- Lars Andersen Resare, SAS, Head of Environment & CSR
- Maria Fiskerud, RISE, Senior Project Manager
- Jonas Matthing, RISE, Researcher

The interviews were semi-structured and carried out in a group meeting setting as a focus group (Creswell & Creswell, 2018) which is useful since the interviewees needed to provide historical information and enabling follow-up questions when needed. The weakness of this setting is that it enables the interviewee to formulate their answers in a way adapted to the audience. As the interviewers, we, are engineering students in energy systems and sustainable development there could be a bias towards that the interview objects want to be perceived as more climate-friendly than they actually are. The data recording procedure was to use an *interview protocol* (Creswell & Creswell, 2018) with written notes on relevant information, explanations and opinions of the interviewees.

3.6 Carbon Offsetting Assessment Framework

The purpose of this study's assessment framework that is is referred to as the Carbon Offsetting Assessment Framework was to develop a standardized and comprehensive way of analyzing and quantifying the current state of carbon offsetting and SAF in the aviation industry. Relating to the MLP, this assessment framework is a way of mapping out the contemporary socio-technical regime components. Using the data collected according to the procedure found under *Data Collection and Secondary Data Analysis* some key aspects were collected for every airline and OTA. Since the data collected was of mainly qualitative nature and thus non-standardized it needed to be processed. One way in which this was done was to classify the data by categorizing as suggested by Saunders et al. (2015). The data that was collected was the following:

- Carbon offsetting work
- Specification of offsetting initiative
- Sustainable aviation fuel work

3.6.1 Carbon Offsetting Work

To narrow down the collected data the two main points of interest, the airlines and OTAs approaches to carbon offsets were divided into four categories each. The categories were *No offsets att all*, *Plans to provide offsets*, *Provides voluntary offsets* or *Offsets all or a portion of passengers*. An airline/OTA gets the tag *No offsets at all* if they do not engage in carbon offsetting in any way. An airline/OTA gets the tag *Provides voluntary offsets* if the customer purchasing a ticket is offered to carbon offset either in the check-out process or by some kind of linkage to the booking process. Often the offsetting action is associated with an emission calculation tool. An airline/OTA gets the tag *Offsets all or a portion of passengers* if they purchase carbon offsets for their flights in any way that does not result in an additional cost for the passenger. For example, an airline can compensate for all their domestic flights, all their bonus program passengers or for all their passengers. Lastly, an airline/OTA gets the tag *Plans to provide offsets* if they do not provide carbon offsetting in any way but somehow states that they intend to do it in the future. There should be a clear ambition to do so but there is no criteria for a formal commitment.

In the cases where an airline or an OTA offset flights on their own accord the question of how much they offset is raised. Some compensate for certain customer segments while others offset all flights across the board, thus the impact of their offsets varies greatly. Further, the question of the inclusion or exclusion of the non-CO_2 effect becomes relevant, along with some additional calculation details. Some actors who offset their customer's emissions specify what they compensate as a percentage of all their aviation related emissions. However, some actors do not disclose how large of a percentage they offset. They might instead specify a certain segment, for example, all domestic flights or all alliance customer flights. The aspect of how much is being offset was initially intended to be included in the framework. However, it was removed as the data that would be needed often is sensitive and thus disclosed by very few airlines.

3.6.2 Offsetting Quality

The airlines and OTAs use a wide assortment of initiatives for their carbon offset endeavors. In this study, the interest in the offsets is generally limited to what certification they fulfill and thus raw data is written and in cases where certification is not disclosed or missing, the best possible data available is used. General conclusions are drawn from the data, for example, portion Gold Standard.

It should be kept in mind that the stipulated standards for airlines and OTAs in this category do not take into account whether the actor provides this for the customer pro bono or if it only provides the customer with the opportunity to purchase carbon offsets on their own behalf. These have significantly different implications. An optional offering of an expensive premium product is profoundly different from providing the product to the customer free of additional charge.

3.6.3 SAF Work

The same structure as for carbon offsetting work was used for SAF: *No SAF*, *Plans to provide SAF, Provides voluntary SAF* or Purchases *SAF as a company*. The term “Purchases SAF as a company” is used since it is rather a matter of voluntary investing in SAF in general rather than purchasing SAF for a customer group which often is the case for carbon offsetting. SAF as a percentage of used fuel was initially of interest in order to evaluate the environmental work undertaken by the airlines and OTAs but as the amounts used were so insignificant it was scrapped as a data point.

3.6.4 Carbon Offsetting Score

The carbon offsetting score aims to encompass the overall extent and quality of each actor’s carbon offsetting work. Sustainable aviation fuel work is included in the carbon offsetting score since the usage of SAF is almost identical in its practical function to carbon offsetting. When travelers compensate with airlines, SAF is often communicated as equal with carbon offsetting but with another price tag.

The score is based on the factors “carbon offsetting work”, “offsetting quality”, and “sustainable aviation fuel work” and is calculated according to:

No offsets att all	0
Plans to provide offsets	1
Provides voluntary offsets	2
Offsets all or a portion of passengers	3

No SAF	0
Plans to provide SAF	1
Provides voluntary SAF	2
Purchases SAF as a company	3

No quality assured standard	0
A portion quality assured	1
Fully quality assured	2

Table 2, Carbon offsetting score

$$carbon\ offsetting\ score\ =\ carbon\ offsetting\ work * offsetting\ quality + SAF\ work$$

The maximum score is thereby 9. The idea of the multiplication of the offsetting quality with offsetting work is that the utility of undertaking carbon offsetting is strictly connected to the quality of the offsets. At the lowest level, there are no quality assurances for the offsets. This aims to target unserious or even greenwashing actors. The middle level has some serious quality certification but it could be that it is unclear how large portion that is quality assured or that it involves debatable projects. This could for example occur when they disclose that they use a mix of offsets but do not delve into detail about proportions. The fully quality assured score is given to the actors who only use high-quality certifications such as Gold Standard. There is no certification for SAF since SAF is straightforward when using it, either you use the fuel or not. This means that extensive high-quality carbon offsetting work is evaluated higher than extensive SAF usage. This could seem wrong since SAF is arguably a more reliable way of guaranteeing net emissions reductions than carbon offsetting, but it is suitable since the amount of SAF that is actually bought by airlines typically is very small in relation to the amount of carbon offsetting when companies claim that they offset.

3.7 Summary of the Multi-Level Perspective

The second part of the method structure is to observe carbon offsetting from a multi-level perspective. The findings from the Carbon Offsetting Assessment Framework are contextualized in the MLP and related to the topics discussed in the background section. At first, the MLP is used as a template where the relevant aspects of transition into green aviation are inserted. When this is done, the main actors and mechanisms for a transition into green aviation via carbon offsetting are present. It is important here to distinguish the MLP from a machine providing its users with answers but rather see it as a set of heuristic devices. MLP is a framework that consists of creative adaptations and not firm empirical causal investigations (Geels, 2011). Using the MLP as a narrative tool for explanation, it is now possible to draw conclusions regarding the current state of the industry and potentially learn about possible future outcomes for carbon offsetting and the other phenomena that could play key roles in green aviation (electrical aviation, SAF, flight abstaining). This methodological approach is used to facilitate a rigorous base for discussion regarding the multifaceted subject that is carbon offsetting and its role in a transition into green aviation. It will also be possible to draw some general conclusions regarding carbon offsetting that also will be applicable outside the aviation industry.

3.8 Reliability and Validity

The data collection process is dependent on the amount of public information available from the airlines and OTAs. Direct communication to collect data constitutes a small portion of the data collected. The dependency on public information can lead to carbon offsetting work not publicly disclosed being excluded from the data set. However, the risk is assessed to be rather small since our notion is that companies seldom remain silent about their sustainability commitments. To extensively communicate sustainability work can sometimes be more popular than actually going through with it.

The origin of the data is sometimes not uniform since some companies are publicly traded and have annual reports whilst some are not and thus lack. Information about carbon offsetting is often possible to disclose both if the company is publicly traded and not but the reliability of nuances in the information disclosed must be assessed with greater caution when retrieving information outside annual reports since in the annual reports, they have a legal obligation to tell the truth.

One should keep in mind that the data collected is cross-sectional, a snapshot of information during the spring of 2020. Airlines and OTAs attitude to carbon offsetting is changing due to strong macro-trends in sustainability. In general, one could say that the information stems from the 2019 and in a few cases 2018 annual reports and adjacent information. Also, the spring of 2020 obviously is characterized by COVID-19, which has shaken the aviation industry in its foundations. Due to COVID-19, we will see significant economic difficulties for the airlines which may alter their priorities to not prioritizing investments in carbon offsetting and SAF. Another perspective is that COVID-19 would facilitate a possibility for a “sustainable restart” when the economy returns from the pandemic negative shock.

Wet-lease operators are a particular type of actor within the airlines category. They do not operate under their own brand, instead, they operate a complete aircraft with crew and equipment under a lease to other airlines. The exact agreements between the wet-lease provider and the airline vary and are undisclosed, thus the data of interest is not available for wet-lease providers. However, as a wet-leased aircraft are most commonly operated as an aircraft in the lease recipients fleet most wet-leased flights are still accounted for. Among the 30 airlines that received the most clicks on the Flygresor website, two were wet-lease providers, City Jet and Regional Jet. These two actors were subsequently excluded from the carbon offsetting score leaving 28 actors with scores.

4 Framework Results

In the following section the results from the Carbon Offsetting Assessment Framework both applied to airlines and OTAs will be described and summarized. For example, scoreboards for the carbon offsetting score are presented along with geographical distributions for the airline results. Findings not observable quantitatively in the framework but that still has relevance to the results are discussed.

4.1 Airline Results

Applying the Carbon Offsetting Assessment Framework to the 30 most used airlines for Flygresor yielded the following results. *Table 3* below shows the complete results. Sorted from most to least used, the airlines have received scores in three categories which have then been summarized into a carbon offsetting score, explained under section "carbon offsetting score". The two wet-lease actors did not receive a score in any category as the potential scores are fully dependent on the leaser and thus it is impossible to score them and they are only included in *table 3*.

Airline	**Carbon Offset work**	**Offset Initiative**	**SAF**	**Carbon Offsetting Score**
SAS	3	1	3	6
Norwegian	2	2	0	4
Ryanair	2	1	0	2
Turkish Airlines	0	N/A	0	0
Lufthansa	2	1	2	4
BRA	3	2	2	8
British Airways	3	1	1	4
Qatar Airways	1	1	0	1
KLM	2	2	3	7
Easyjet	3	1	0	3
Finnair	1	1	3	4
City Jet	N/A	N/A	N/A	N/A
Vueling	0	N/A	1	1
Brussels Airlines	0	N/A	0	0
Thai Airways	2	1	0	2
Ukraine International Airlines	0	N/A	0	0
Czech Airlines	0	N/A	0	0
Wizz Air	0	N/A	0	0

Aeroflot Russian Airlines	0	N/A	0	0
Regional Jet	N/A	N/A	N/A	N/A
Air India	0	N/A	0	0
Pegasus Airlines	0	N/A	0	0
Eurowings	2	2	0	4
TAP Portugal	2	1	0	2
Ethiopian Airlines	3	0	0	0
Air France	3	1	1	4
Swiss	2	1	2	4
Austrian Airlines	2	1	0	2
Lot Polish Airlines	2	0	0	0
Air Baltic	0	N/A	0	0

Table 3, Carbon Offset Assessment Framework applied to airlines. N/A indicates that that particular data point was unavailable

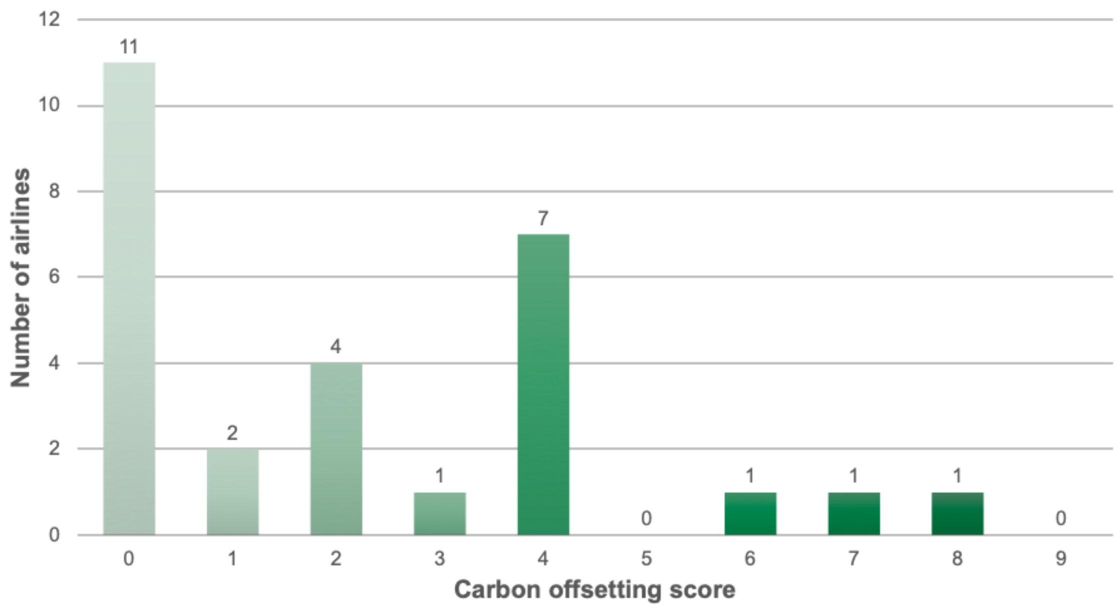

Figure 5, Carbon offsetting score. Number of airlines on the vertical axis and carbon offsetting score on the horizontal axis.

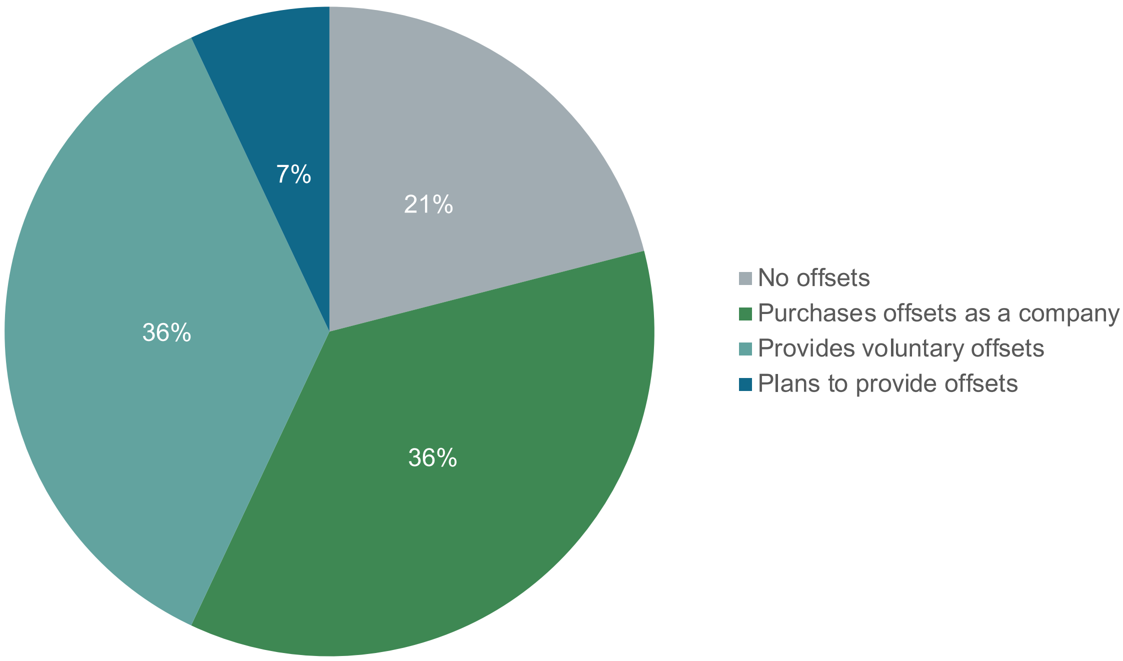

Figure 6, Airline carbon offset work

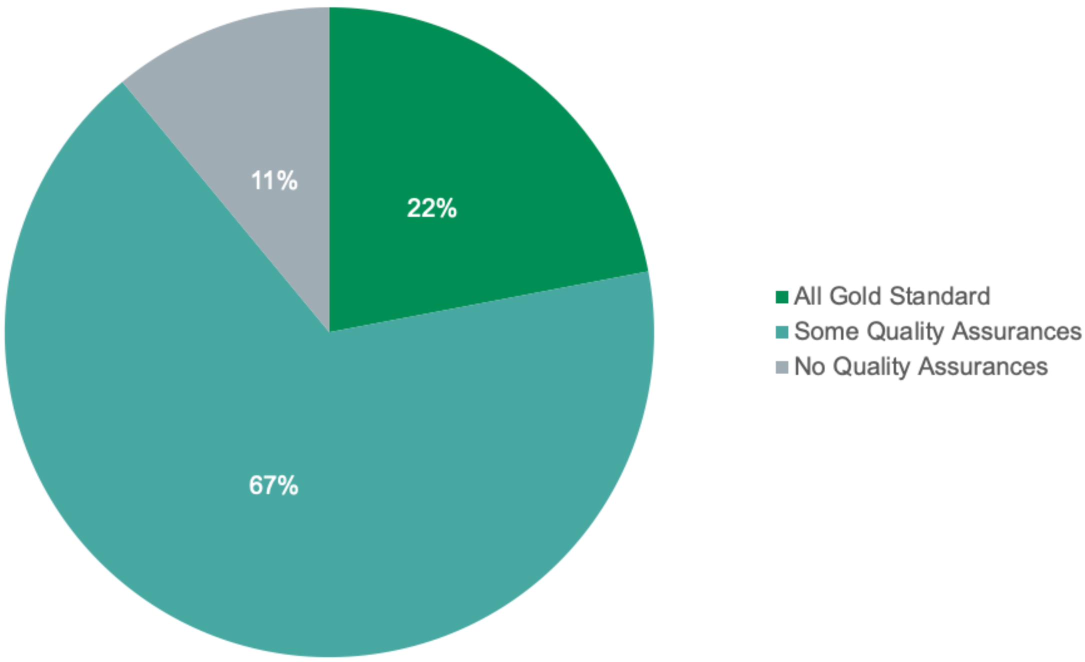

Figure 7, Offset initiative quality for airlines

Figure 5 shows the carbon offsetting score distribution, *figure 6* shows the distribution of carbon offset work and *figure 7* shows the distribution of offset quality assurances. As *figure 5* shows there is one airline with each of the scores 6, 7 and 8. BRA scores highest with 8, KLM comes in second with 7 and SAS comes in third place with 6. Further made evident by *figure 5* more than one third (39%) of the airlines do not engage in any valuable carbon offsetting activities or SAF work and thus receive the score 0. However, as seen in *table 3* most of the airlines do engage in some carbon offsetting or SAF activity. The reason for this dissonance in score can be seen more clearly when comparing *figure 5* and *figure 6*. A pattern can be discerned where a clear majority (72%) of airlines purchase offsets as a company or provide voluntary offsets but 39% of airlines receive a framework score of 0 due to them not purchasing or providing offsets with highly assured quality which can be seen in *figure 7*. This goes for actors in all score brackets, one could for example observe from *table 3* that SAS would have received a full score if it would have been possible to verify that they only use the best offset certifications. Only one of the airlines (BRA) achieved a full score in both the carbon offset and offset initiative categories.

Further*, figure 7* shows that an overall large portion (67%) have some assurance but not all top quality. About a fifth (22%) of the surveyed airlines have well-documented quality assurances and (11%) of the examined airlines do not have any assurance of quality. This could possibly be interpreted as greenwashing.

Further, *table 3* shows that carbon offsetting is generally more integrated into the airline industry as a way of reducing emissions than SAF seeing as only about one third (32%) of the surveyed airlines engage in work regarding SAF. Out of these only a third actively purchase SAF for use in their aircraft and another third only provides customers with SAF as an optional extra at the customer’s expense. The remaining third only expressed ambitions regarding SAF. *Table 3* also shows that all actors engaged in SAF except for one (Vueling) also engage in carbon offset work.

Airline	**Geographical area**	**Score**
BRA	NO	8
KLM	CONTW	7
SAS	NO	6
Air France	CONTW	4
British Airways	BI	4
Eurowings	CONTW	4
Finnair	NO	4
Lufthansa	CONTW	4
Norwegian	NO	4
Swiss	CONTW	4
Easyjet	BI	3
Austrian Airlines	CONTW	2
Ryanair	BI	2
TAP Portugal	CONTW	2
Thai Airways	APAC	2
Vueling	CONTW	1
Qatar Airways	ME	1
Aeroflot Russian Airlines	CONTE	0
Air Baltic	CONTE	0
Air India	APAC	0
Brussels Airlines	CONTW	0
Czech Airlines	CONTE	0
Ethiopian Airlines	AFR	0
Lot Polish Airlines	CONTE	0
Pegasus Airlines	ME	0
Turkish Airlines	ME	0
Ukraine International Airlines	CONTE	0
Wizz Air	CONTE	0

Table 4, Airlines sorted on their carbon offsetting score. Geographical division areas: Nordics (NO), Continental Western Europe (CONTW), British Isles (BI), Asia Pacific (APAC), Middle East (ME), Continental Eastern Europe (CONTE), Africa (AFR).

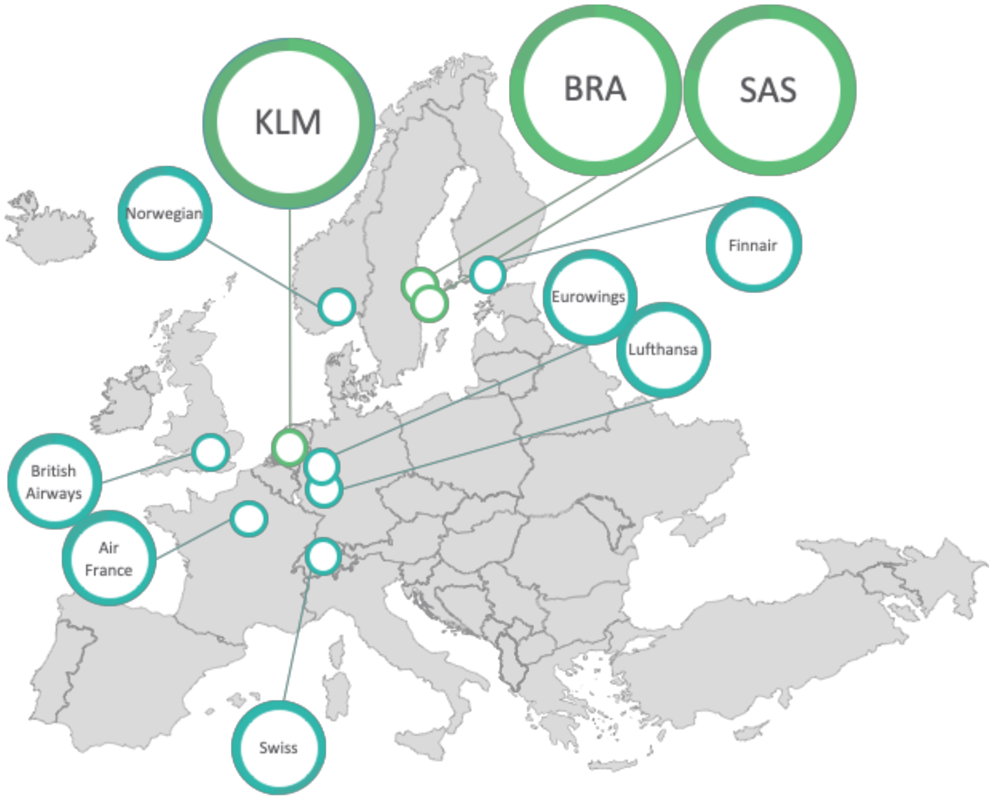

Figure 8, Geographical location of top performers (scores 4-9)

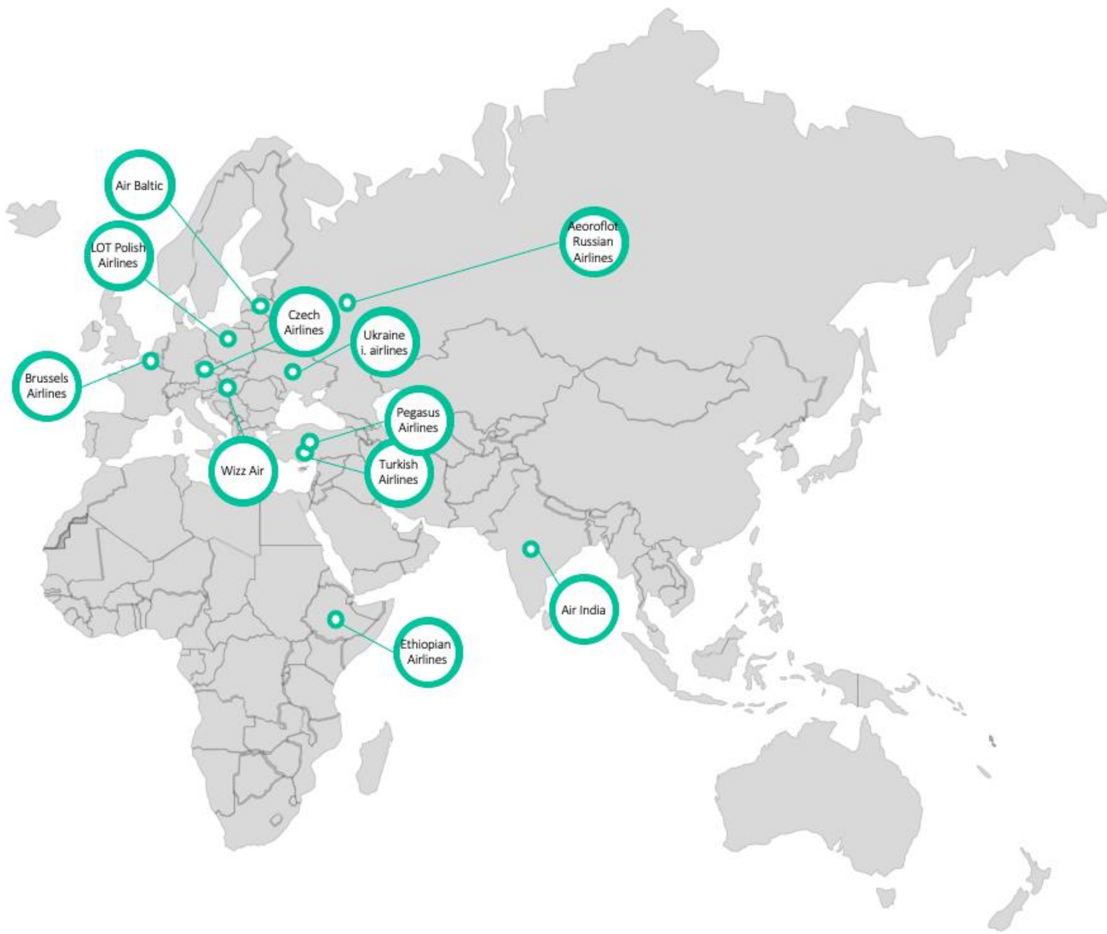

Figure 9, Geographical location of bottom performers (scores 0-3)

Table 4 shows the region of origin for the airlines and is sorted by their carbon offsetting score. The airlines have also been given a geographical designation based on where the airlines are headquartered. The airlines are sorted in alphabetical order within each scoring bracket and thus their positioning within a particular score bracket does not reflect any differences. The results show a clear skewness towards higher scores for airlines based in the Nordics, Western Europe and the British Isles. The two maps (*figure 8* and *figure 9*) display this geographical distinction between the actors who scored high and low respectively. Reasoning regarding what this implies can be found under in the Multi-Level Perspective Discussion section.

4.2 OTA Results

The results from the Framework applied to the OTAs yielded a rather different result from the airlines. The underlying reasons are plentiful and will be analyzed but the overall reason is that they are a much more heterogeneous group than airlines and are smaller actors with a less visible role. Further the OTAs are not meaningfully associated with a geographical location because they are not providing a physical value chain. The geographical analysis is therefore excluded.

In Appendix 1 a complete result from the Carbon Offsetting Framework applied to OTAs can be found. It is not included here as the complete results do not yield much useful information since most OTAs are not mature enough in their sustainable offerings to obtain meaningful framework result. Instead the few factors that yield interesting results are focused on.

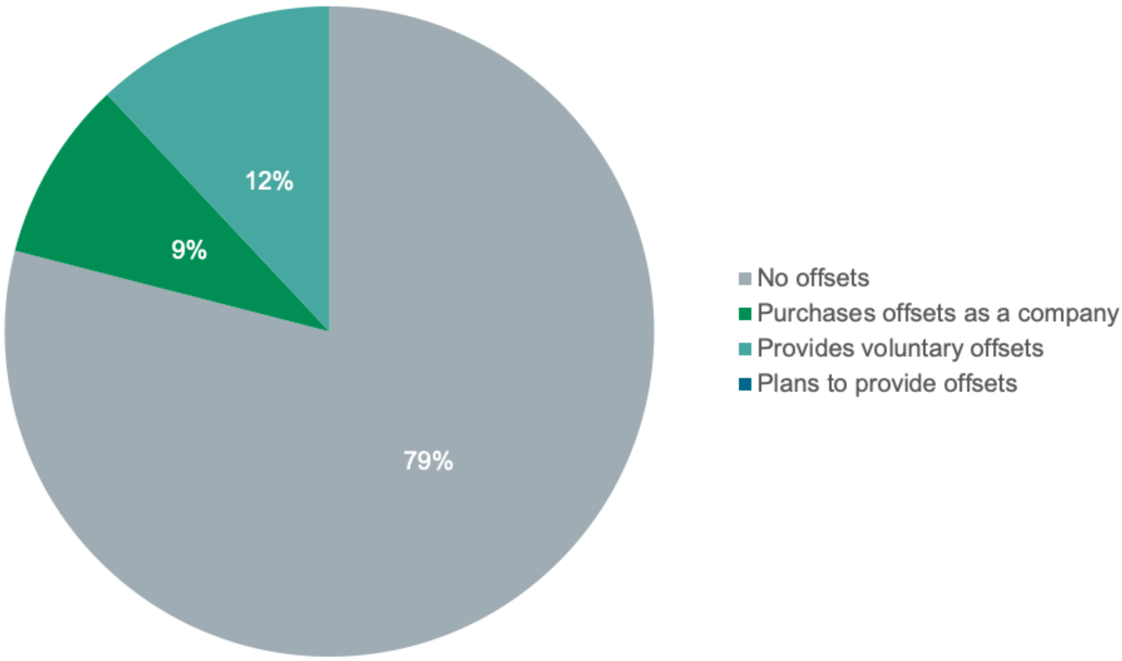

Figure 10, Availability of carbon offsets, OTAs

The selection of OTAs is also fully based on the OTAs who cooperate with Flygresor, which makes the selection a biased sample in contrast to airlines where almost all are represented. The analysis of OTAs does however yield some empirical implications that lay the groundwork for anecdotal evidence discussion. Out of the 33 OTAs, only four provided voluntary offsets compared to the 10 out of 30 airlines. Three OTAs offset all their customer's emissions by purchasing carbon offsets compared to six airlines. Notably, all OTA actors who either provide voluntary offsets or purchase them on their own accord received the highest rating for the offsetting standards whereas only 22% of airlines who bought, provided or planned to provide offsets received the highest rating.

Further, the use of SAF as a means of lessening environmental impact was very limited. Out of a total of 33 total actors 4 utilized SAF. Only one OTA offered customers to purchase SAF and in this case, the offering was dubious as it allowed customers to purchase an arbitrary amount of SAF for 100 SEK no matter what the actual flight booked was. One additional actor stated future plans to offer SAF to customers. Lastly, two OTAs are labeled with "purchases SAF as a company" which makes them score the highest in the framework. This becomes a bit misleading since the companies' intentions of purchasing SAF in these two cases turn out to be the purchasing of SAF for their employees' trips and not for the customers purchasing tickets from them. The framework becomes a bit misleading in this case but the complete results are kept in the appendix for consistency.

4.3 Findings Not Observable in the Framework

Lifting the perspective from carbon offsetting and SAF, there are several other factors that are important for the carbon footprint of aviation, for example, aircraft and operations efficiency. These are not included in the carbon offsetting assessment framework. Further, there are details about carbon offsetting and SAF that are not possible to observe in the framework. In the data gathering and assessment process nuances in the data emerged, for example, the amount of purchased SAF which is different in both absolute numbers and in percentage between the airlines that have been classified with "purchases SAF as a company". The resolution of the framework does not capture this. An insight from studying the amount of purchased SAF that should be added is that in general, the amount bought is profoundly low. One airline did for example purchase SAF roughly equal to one round trip flight Stockholm to New York according to our calculations. There was no airline that significantly exceeded that level. But of course, the important meaning of purchasing SAF at this stage is not to reduce carbon emissions but as a symbolic and facilitating action that will lead to considerable reductions.

Another relevant aspect that is not possible to observe in the framework is how carbon offsetting and SAF are offered to the customer when they are classified as "provides voluntary carbon offsets/SAF". This could be done well integrated as a checkbox in the check-out process or with an obscure link to another webpage that is not that obvious to find. In this stage, different companies also choose if they want to reveal the amount of emitted carbon or not and how transparent the calculations are in that case. One actor that for example should receive a gold star for their carbon offsetting and SAF tool is Swiss via Compensaid. The tool is user friendly and transparent and this is not reflected in the framework.

Further, an assessment of the quality of the carbon emission calculation is not included in the framework. Different actors state different emissions for the same trips since they make different assumptions and emission calculation methods. For example, one parameter that varies is which greenhouse gases are included as emissions. Especially, the framework does not consider whether the actors include the non-CO_2 effect (or the high-altitude effect). It is excluded from the framework as both the airlines and OTAs generally do not incorporate non-CO_2 effects in their emission calculation and when they do it is difficult to dissect how the calculations are made and on which assumptions they are made.

Lastly, one must keep in mind that the framework by no means aims to assess overall sustainability performance but only focus on carbon offsetting and SAFs. When reviewing the carbon offsetting work, it has been impossible not to observe that there are other very important aspects that affect the overall sustainability performance, which are also discussed in the background. For example, flight efficiency, green operations, usage of plastics and charity. A general comment is that the carbon offsetting work seemingly has a positive correlation with general sustainability work. There are some asymmetries though, for example, the low-cost carriers (Ryanair, Easy Jet, Wizz and Norwegian for example) over-performs in sustainability since they focus a lot on having a high load factor (high occupancy) and high capacity seating configurations which are two of many important keys to reducing emissions. They generally also have more modern fleets with features that increase efficiencies such as modern engines, weight-saving composite structures and winglets.

5 Multi-Level Perspective Discussion

This section will discuss and examine the findings obtained via the Carbon Offsetting Assessment Framework through the theoretical lens of the multi-level perspective. In the context of sustainable aviation, the macro-, meso- and micro-levels of the aviation industry and all their respective agents will be mapped out to give an all-encompassing overview of the state of the transition dynamics of sustainable aviation.

5.1 Defining the Socio-Technical Transition

The MLP analyzes socio-technical transitions. The socio-technical transition in this discussion is defined as the transition of the aviation industry into sustainable aviation. It is not the goal to analyze the whole socio-technical transition extensively. The main focus is to analyze the role of carbon offsetting within this greater socio-technical transition. However, this requires mentioning and discussing many transitional components since the system dynamics are complex.

MLP facilitates a cross-sectional time frame discussion but with implications for future trajectories. The most recently available information is used within the analysis which often is dated 2019 or early 2020. The spring of 2020 is however no ordinary spring due to COVID-19, especially not for the aviation industry. Many devastating repercussions will hit the aviation industry and many interesting effects will affect carbon emissions. The force majeure COVID-19 is not a part of this carbon offsetting MLP discussion. It is possible that that type of analysis will be possible to undertake in the retrospective of the virus and it is certain that COVID-19 will change some of the components in the MLP. This discussion's defined system that is analyzed is hopefully nevertheless useful since climate change and a demand for flying will persist as a conflict when the crisis is worked out.

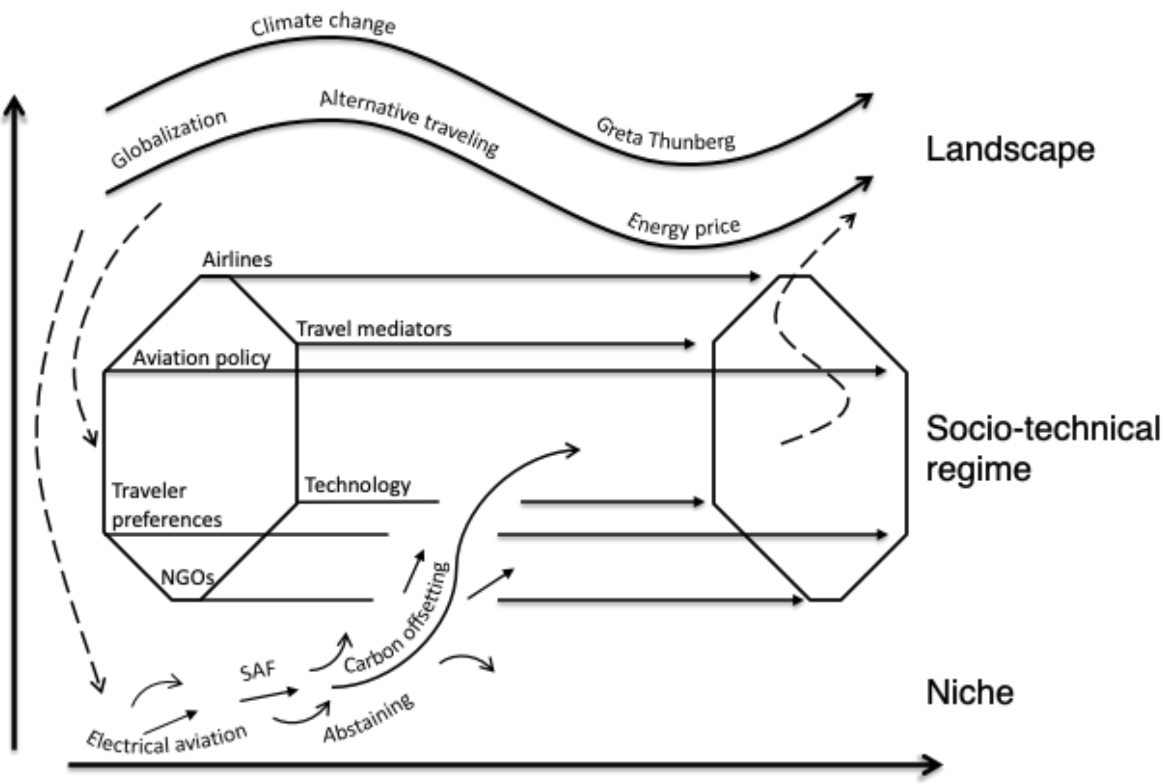

Figure 11, Sustainable aviation - MLP dynamics

5.2 Contextualizing the Socio-Technical Landscape (Macro-Level)

The exogenous environment to the sustainable aviation industry is global in every sense of the word as the negative externality of excessively emitting carbon into the atmosphere affects all people all over the world. As the socio-technical landscape is characterized by guiding rules for market and technical design, based on economic, political and cultural phenomena and the context in which the aviation industry at large operates in is worldwide, the socio-technical landscape can be both perceived as uniform and asymmetric in its pressure on the regime. A cultural phenomenon at the landscape level, as Greta Thunberg, is perceived differently in different contexts, i.e. parts of the socio-technical regime. Another pressure from the landscape is the climate change externality in general which different parts of the socio-technical regime treats differently, for example undertaking carbon policy measures. This is made evident for example by the introduction of a national flight tax in both the UK and Sweden while it lacks in other markets like for instance on a European level. The socio-technical landscape is in this analysis therefore thought upon as uniform in its structure and its elements but its effects on the regime are not uniform since the different regime parts are asymmetrically susceptible to landscape pressure.

5.2.1 Climate Change

Climate change as a landscape pressure is defined as the actual risks and consequences that can occur from global warming. The effects can be increased sea levels, more extreme weather, disturbed ecosystems, decreased access to freshwater and increased risk for diseases (for example mosquito-borne Malaria) (United Nations, n.d.; National Geographic, n.d.). Climate change is the main underlying driver in society to climate and sustainability movements. The climate change landscape pressure changes over time with the amount of temperature rise and the associated effects that continuously occurs. Climate change is an externality, as previously discussed. This means that it is in one sense voluntary to undertake measures or not undertake measures for politicians and influential agents. As discussed by Hassler et al. (2018) the cost of underestimating global warming effects is larger than overestimating them so the pressure that is exerted on the regime should according to this reasoning be so large that the ambition becomes to overachieve climate goals rather than to exactly achieve them. Whether this is an established truth or not is difficult to say but it should enforce the strength of this landscape pressure.

Climate change being an externality leads to the climate change pressure affecting the policy part of the regime the most, and the market actors less (airlines and OTAs). The reasoning is that policymakers by definition have a responsibility in handling externalities which the private actors do not have. There will of course be exceptions, market actors that undertake measures against climate change. However, the motives when market actors take action may be to follow public opinion and demand for sustainability. This will be the focus of the landscape pressure “Greta Thunberg”. Here, there is also a philanthropic aspect of climate change that leads to non-profit initiatives and incentives.

But what does this pressure lead to for carbon offsetting in reality? Climate change is the driver for policy change and policy change can affect carbon offsetting which will be discussed in the aviation policy section.

5.2.2 Greta Thunberg

Greta Thunberg is chosen as a symbol of the civil movement against climate change. During recent years she has received massive support and public attention for her communication regarding climate change. This affects people's awareness of sustainability questions and ultimately the demand side of sustainability products. While the climate change landscape pressures stand for the fact-based handling of the physical problem, this pressure represents the sentiment for behavioral and decision-making change. This significantly affects the socio-technical regime, altering the demand for sustainable aviation, which in turn leads to an adjustment on the supply-side of sustainable aviation. This distorts the regime and creates windows of opportunity for niches to enter the new demand for sustainable aviation products.

The Greta Thunberg landscape pressure can be difficult to grasp. As Geels (2010) proposes one could undertake a structuralist discourse analysis to understand the societal structures that underpin the dynamics of the MLP. The Greta Thunberg landscape pressure manifests itself on social public stages such as televised debates, social media and forums of public opinion like demonstrations and protests. The ongoing discussion, promotion and advocacy of different environmental questions and solutions are what the landscape pressure in essence consists of. This continuous debate is what in turn affects the individual attitudes in sustainability matters in general and sustainable travel preferences in particular.

This pressure is perceived differently by different markets both on the supply and demand side. Relating to the Carbon Offsetting Assessment Framework, it can be observed that the supply-side is geographically tilted towards Northern and Western Europe, with the top-three scorers coming from Sweden, Sweden and Netherlands. Of course, one should keep in mind that the selection of airlines is Sweden-centric. There are however no found implications that there should be many actors outside the selection of airlines that are at the forefront in their carbon offsetting work. One possible future of the Greta Thunberg-effect is that it will spread to other countries in the same manner as with many other cultural societal changes for equality and sustainable behavior that has started in wealthy, innovative and liberal countries as *avant-garde* to later trickle down to lagging countries. Will this occur for climate change it will lead to raised public awareness worldwide and an increase in demand for sustainable aviation, which in turn will lead to that the airlines operating in those lagging countries will offer sustainable aviation products (carbon offsetting or SAF).

5.2.3 Alternative Traveling

Alternative traveling refers to societal trends that change patterns and means for traveling. The alternative travel trend both encompass the use of other transportation means than aviation due to fundamental changes in physical and societal infrastructure and changes in the sentiment of preferences. The trends can result in for example that more people take the train instead of flying or people abstaining from flying in general, perhaps having a so-called *staycation* instead. There is an issue with understanding the causality here: is it the societal landscape changes that change customer preferences? Or is it the social movement against climate change that has affected the sentiment for traveling preferences in the socio-technical regime which in turn has affected the landscape level macro trends for alternative traveling? The answer is probably both, complexly interlinked. This does however result in changed patterns for traveling in the landscape. One Swedish example is the extensive promotion by the state-owned railway company to travel by train. Also, the expansion of railway infrastructure has been extensively debated in the political arena the recent years. One could also argue that electric cars partly affect the socio-technical regime of sustainable aviation since it can be a substitute for short-distance traveling.

How does alternative traveling affect the socio-technical regime of sustainable aviation? In general, one can say that a strengthened trend of alternative traveling results in a generally lowered demand for sustainable aviation. One big driver for the alternative traveling trend is the individual's demand for being able to travel sustainably, so the stronger that demand is, the more significant the trend will be. One should also keep in mind that the socio-technical regime regards *sustainable* aviation and not aviation in general. The alternative traveling landscape pressure does probably affect sustainable aviation more than aviation in general since the travelers that value a sustainable way of flying are more likely to also be open to alternative traveling since it generally is more sustainable than commercial aviation (assuming that the alternative traveling is not a private helicopter or such). There is also the case of reverse causality (Geels, 2011) where the landscape pressure of alternative traveling is mitigated by the socio-technical regime of sustainable aviation. More sustainable aviation weakens the trend of alternative traveling because if aviation does not give rise to carbon emissions, there is no need to change the transport type.

5.2.4 Globalization

Globalization is a landscape trend that puts pressure on sustainable aviation as well as on aviation in general. Globalization is the increase of physical and economical interactions between organizations and region which result in more interlinkages and exchanges. As globalization trends grow stronger, the demand for sustainable aviation increases. The landscape pressure globalization is also a counterweight to the other landscape pressures Greta Thunberg and alternative traveling since globalization emphasizes the demand for more and further travels while the other two works against long-distance traveling by aviation. In the MLP context, globalization suppresses the other landscape pressures that decrease the demand for aviation. One possible outcome is that these pressures act together at the same time. The Greta Thunberg effect and alternative traveling will put pressure on the regime that travels should be sustainable. They do not directly implicate anything about reduced traveling, only that it should be sustainable. Globalization however holds up or even increases the demand for traveling. This results in exclusively one solution: continued aviation but in a sustainable manner. This landscape pressure interaction creates a space in the socio-technical regime that can be exploited by niche innovations which is discussed below.

It is obvious that globalization has been an economic megatrend during the 20th century in general. Internet and digitization have enabled more internationally interconnected supply and value chains. But in recent years, there has been some profound setbacks for international trade flows with several examples of protectionism and deglobalization. Some examples are the USA's trade war with China and Brexit. But most recently the main antagonist to globalization is COVID-19. As argued by several economists, for example, Klas Eklund (2020), COVID-19 will not solely hamper trade flows during the pandemic in regard to disease control but the trend may also withhold after the pandemic with more localized markets that relies on more local trade flows. One explanation can be that the spread of COVID-19 obviously is dependent on a globalized economy and that the economy in the future will be reluctant to continue trade flows in that same way in the future. This deglobalization would overall decrease the strength of the landscape pressure of globalization through a lowered demand for aviation in general.

Another note on the globalization trend that does not have a direct connection to sustainable aviation is that the function of carbon offsetting would not be possible without a functioning globalized economy. The idea that an emission in one place can be offset by an emission-reducing or hampering action at another is completely based on a globalized network that can perform the action that has positive climate effects, that can verify the action, connect producers and customers and complete the affair. So, globalization is not just a term that is pivotal for sustainable aviation but also for the niche component carbon offsetting.

5.2.5 Energy Price

Energy price is included as a landscape pressure since the fuel cost is of such importance in the aviation industry. Fuel cost is not the single cost or market driver, but arguably the most important one. The demand for jet fuel is a similarity for all airlines and the market and the pricing are global. SAFs and electricity are also two potential energy sources to power aircraft. SAFs are more expensive than traditional jet fuel (IEA, 2019). Electricity is in theory and in general cheaper but the energy price is not the main issue for electrical aviation. The dynamics and development of the energy price does form the circumstances in which the socio-technical regime acts. A raised price on jet fuel, will decrease the profitability of traditional aviation and relatively increase the profitability of sustainable aviation. This does per economical definition affect the actors on the margin between providing traditional or sustainable aviation into being more willing to provide sustainable aviation. The scope of this project is not to digest the dynamics of energy pricing but one should keep in mind that it is likely that the results from the Carbon Offsetting Assessment Framework will contain more SAFs if the jet fuel energy price would be higher.

How does the energy price landscape pressure act on carbon offsetting? One could argue that lower energy prices would result in more use of traditional jet fuels and less use of sustainable fuels. In ceteris paribus, i.e. the demand for sustainable aviation is constant, this would result in an increased demand for carbon offsetting (if it is assumed that its price is constant with the energy price). This is the economical explanation. Another perspective could be that if the energy price would rise, this would facilitate an environment where there is room for more sustainable energy in aviation. Social and physical infrastructure will potentially be built up in an environment where sustainable aviation is the rule rather than the exception. In this scenario, carbon offsetting could obtain a larger role than previously thanks to positive spillover effects from for example SAFs and electrical aviation.

One should also keep in mind a reverse causality mechanism for landscape and socio-technical regime interaction (Geels, 2011). Here, reverse causality is meant to convey that it is not the energy price that independently changes which in turn gives rise to effects on the sustainability transition, but that it is the sustainability transition in the socio-technical regime that changes the landscape energy price. A more widespread adoption of sustainable aviation would lower the demand for traditional jet fuel, which in turn would lower the price.

5.3 Contextualizing the Socio-Technical Regime (Meso-Level)

Global commercial aviation has been instrumental in shaping the world we know today. It is a possibility thanks to the actors within the socio-technical regime and the patterns in which they are arranged. The actors can be reduced to six large groups explained below.

5.3.1 Airlines

Among the entities that comprise the socio-technical regime in the MLP of the transition towards sustainable aviation the first and foremost would be the airlines themselves. They are central to the notion of commercial aviation both domestically and internationally. They are very influential in the regime as they constitute the demands towards suppliers (aircraft manufacturers, fuel producers, etc.) found in the regime and thus dictate a lot of the technological developments. A famous example of this is the development, launch and subsequent cancellation of the Airbus A380, the world's largest airliner. It happened due to a dissonance in how Airbus and the airlines perceived the aviation industry. Airbus envisioned a hub-spoke system with connecting flights creating a role for a very large, low cost per passenger seat- aircraft while the airlines favored point to point flights demanding smaller aircraft (Business Insider, 2019). This shows how the airlines play a large role in the selection retention mechanism of the regime. Further, investments in aircraft in general also constitute a problem itself due to aircraft being very expensive. This leads to natural lock-in effects and rigidity which may hamper investments in new technologies, basically because the investments are too large and there is no financial room for them. For example, the list price for an A350-1000 is 366.5 million dollars (Airbus 2018).

In the Carbon Offsetting Assessment Framework, it was discovered that carbon offsetting was purchased or offered by some of the seminal actors. SAF was also offered but not to the same extent as carbon offsets. Thereby there is some permeance of carbon offsetting and SAF niches in the current regime but there is room for the niches to expand further. In a not insubstantial number of airlines examined, the carbon offsetting and SAF undertakings are provided to the customer on the behalf of the airline which indicates that they perceive this as a strategy to remain competitive in the market. On the other hand, the airline business is generally a low margin business and the actors want to cut costs as much as possible to maximize profitability. This could explain why they in most cases offer carbon offsetting and SAF for customers to purchase voluntarily as an added service instead of purchasing it on their own behalf as an altruistic action. The conclusion is that this is an action in response to altered travel preferences where the customer values sustainable traveling due to their own awareness of sustainability (obtained from the landscape pressure of changed public sentiment and awareness in the climate change question).

In order to realistically create a space for sustainable aviation to develop, the space must be created taking market mechanisms into consideration, i.e. the sustainable aviation alternatives must be feasible in cost for the airlines and price for the travelers. Airlines need to keep down the costs to compete with traditional aviation both internally and externally and at the same time meet the travel preferences of the customers and following prevailing policy boundaries. This leads to an adequate payoff situation which the airlines today handle differently. As seen in the assessment framework, some airlines have taken the strategic path of offering carbon offsetting and SAF while others have not. That said, it is not certain that all the airlines in the list would profit from working with carbon offsetting at this time, one possible explanation is that the travel preference part of the socio-technical regime is asymmetrical to the airlines in the regime which leads to different airlines trying to meet different customer group demands. A possible path in for the future development is that the landscape pressure of climate change awareness will affect a larger portion of the traveler preference part of the regime, which will lead to reformed traveler preferences that more widely values sustainable traveling, this puts pressure on more airlines to work more extensively with providing sustainable travels which creates a space for niches to facilitate airlines with these solutions to later be adopted by travelers.

5.3.2 Travel Mediators

One other group of agents found in the regime of commercial aviation are travel mediators who play a part in advertising, distributing and selling a large share of the flight tickets to consumers. This can for example be online travel agencies (OTAs), traditional travel agencies or price comparison sites as Flygresor. These together with the airlines are the agents in the regime that share the role of being the entities with which customers interact directly. Travel mediators are not as rigid as airlines since they have less fixed capital. This leads them to have less inertia to a change to sustainable aviation. For travel mediators, a change from traditional to sustainable aviation does not result in any significant change in business strategy or value flows.

On the other hand, travel mediators like OTAs create a smaller portion of value per sold ticket than airlines do, which means that they in absolute numbers make less profit per trip. This leads to smaller absolute profit per trip which can be problematic if they want to offer carbon offsetting or SAF for free to the customers. It is difficult to see a scenario where costs for carbon offsetting or SAF is so low or the margins so high that travel mediators are able to provide carbon offsetting or SAF along with ticket sales for free. The likely future scenario is rather that travel mediators will provide voluntary offsets for their customers, which is a rather small strategic step for them that does not encompass technical hurdles.

The notion that travel mediators having a harder time providing carbon offsetting and SAF is consistent with the empirical findings in the Carbon Offsetting Assessment Framework application to OTAs. OTAs are behind airlines in the offering and purchasing of carbon offsetting and SAF. While this is the general case for travel mediators it was also found that those who did purchase offsets only used the highest offset standards in comparison to airlines where only a fifth did. This would contradict the general theory of low margins preventing travel mediators from engaging in the purchasing offsets, especially those with high-quality assurances. The likely explanation for this dynamic in the socio-technical regime is that those OTAs that do provide the highest certification standard are the ones who offer package trips that for example include hotel stays and transfers which firstly ads additional value beyond the flight ticket and secondly makes their offerings more difficult to compare than just flight tickets. They, therefore, do not compete on price in the same ways as the other OTAs who solely mediate flight tickets and can thus simply include the extra costs of offsets in their price without losing competitiveness. These actors are the trailblazers of the OTAs and open up a window of opportunity for carbon offsetting and SAF to obtain a stronger position in the socio-technical regime. Notably, out of the OTAs that provided the highest standard offsets, two also choose to include the non-CO_2 effect in the amount which they offset. They are the sole actors to do this. An explanation for this could be that they as previously mentioned, do not compete on price in the same way as actors purely concerned with selling flight tickets.

But as mentioned there are other travel mediators than the OTAs which can be impactful to sustainable aviation. For example, meta-search engines who are not assessed in the Carbon Offsetting Assessment Framework have the opportunity to provide carbon offsets and SAF directly to the customer. This is done by Flygresor who according to the framework metrics are at the forefront with their carbon offsetting offering with Gold Standard carbon offsetting directly integrated in the booking interface. One can argue that the involvement of meta-search engines is even more important than the involvement of airlines and OTAs since they are more closely related to the customer offering.

5.3.3 Aviation Policy

The power of dictating policy is found across multiple actors who often work together or are otherwise interlinked. Among the actors, there are supranational unions, mainly the European Union, governmental organizations such as the Federal Aviation Administration (FAA) (USA) and Luftfartsstyrelsen (Sweden) and intergovernmental organizations as the International Civil Aviation Organization (ICAO) (UN) and European Union Aviation Safety Agency (EASA) (EU).

A lot of regulatory policy surrounding commercial aviation is tight and for good reason. Safety aspects of aviation are for obvious reasons not taken lightly and there is strict regulation concerning for example reliability, redundancy and safety. These regulations encompass everything from fuel composition to the ability to withstand bird strikes. On the other hand, non-safety related aviation policy could be considered lax. For example, the Chicago Convention signed in 1944 still prohibits taxing of fuel onboard inbound flights making it more difficult for individual countries to employ taxes in order to combat emissions. Also, the idea of individual countries taxing air travel is not well established in the regime among the airlines and their respective interest groups as they argue it would not be effective or fair competitively compared to say a global tax on CO_2. The pressure of climate change is, of course, a driving factor behind the initiatives that are undertaken but at the same time, the generally reinforcing landscape pressure of globalization has a destabilizing or inhibiting effect on policymaking. As argued by airlines and interest groups, taxes or duties levied locally on a global industry creates unfair competition and the risk of relocation for tax purposes.

The inclusion of aviation in the EU ETS is as of today the largest policy measure towards sustainable aviation encompassing all intra-EU flights. From a carbon offsetting perspective, the inclusion in the EU ETS has the interesting side effect of cementing the role of offsets in the context of aviation as some share of EU ETS emissions can be accounted for through the use of CDMs or JIs. This gives credibility and legitimacy to carbon offsets as means of further voluntary offsetting by travelers, airlines, or other regime actors who feel obliged to do their part in making aviation more sustainable as why should it be allowed under the EU ETS if it is not considered as a credible way of voluntarily reducing emissions?

Individual governments are also increasingly taking a more active role in creating policy to increase sustainability in the aviation industry, often against the wishes of airlines and some interest groups. The underlying reasons tend to be the landscape pressures of Climate Change and Greta Thunberg. Examples of this include the introduction of flight taxes in the UK and Sweden. While the global impact on emissions from the decisions made by these individual governments is small, in the case of the Swedish aviation tax it has shown to slightly decrease the demand for shorter flights while not affecting long haul in the same way. This is possibly due to the availability of alternative means of travel that results in a high price sensitivity on shorter distances (Transportstyrelsen, 2019). As Hassler et al. (2018) concluded it is from a sustainability perspective likely more beneficial to levy too high a tax than a too low which would reinforce the notion of local taxes being beneficial. However, policymakers must be aware of the potential of a patchwork of tax regulation to lessen the sense of urgency and responsibility, discouraging voluntary and collective initiatives.

Further, many regulatory bodies are undertaking initiatives to combat the aviation industry's environmental footprint, even regulatory bodies normally concerned with safety. While they generally are impervious to sustainability-related landscape pressures they can acknowledge that they are a hindrance to some developments that would benefit the industry and act accordingly. One example is the Federal Aviation Administration's amendments to the regulation concerning the certification of aircraft with 19 or less seats, amendments made in an attempt to simplify and thus speed up the development, certification and eventual deployment of electrically powered aircraft (FAA, 2016). Another, more direct example of a sustainability-related policy is ICAO's CORSIA. CORSIA has wide support from a range of regime actors including airlines and IATA. CORSIA's cap system limits emissions to 2020 baseline levels, forcing excess emissions to be offset through either SAF or carbon offsets. This can be seen as a first firm foothold globally for the niches carbon offsetting and SAF in the regime, to some extent guaranteeing their use as means of making aviation more sustainable. However, CORSIA does not encompass all emissions leaving room for further expansion of the niches carbon offsetting and SAF.

5.3.4 Travel Preferences

Customer demands for travel heavily dictate the path of the regime. The two main agents at work are culture and traveler preferences. The culture surrounding travel varies across the world with Swedes undertaking five times as many flights as the global average, traveler preferences vary along with the culture. All travelers want to travel in comfort, speed and at a low cost and some cultural differentiations also lead to some travelers wanting to travel more sustainably. Keeping in mind the Sweden-centrism of this study, the previous culture of unlimited consumption is being challenged by the culture of more responsible consumption. This shows in a lot of areas for example the rise in popularity of shopping second hand, carpooling and eating less meat. These are changes in consumer preferences which are analog to changed travel preferences to more responsible, i.e. sustainable, traveling.

The first commercially available aviation was a luxurious privilege for the wealthy few but with the advent of for example charters, it was brought to the broader masses, at least in the industrialized world. Further down the line, the broad demand for cheap flights has led to the emergence of the low cost, no-frills airlines that can be seen today such as Ryanair and Easyjet. While the demand for cheap flights will continue to rise globally as the poorer parts of the world play catch up economically, a demand for not only comfortable, fast and cheap but also sustainable flights will arise. This change in customer demand and corresponding offerings can be observed in the Carbon Offsetting Assessment Framework where it was found that both airlines and OTAs are offering SAF and carbon offset products to meet sustainable travel preferences.

5.3.5 Technology

Aircraft and fuel manufacturers are the two main providers of the technology and materials that make commercial aviation possible and thus play an important part in the transition dynamics towards sustainable aviation. One should keep in mind that they are by no means the sole technology actors but they are the two with the most potential in the question of shaping the transition of technology towards sustainable aviation. Other fields that could fit in technology are airport management, green operation of aircraft (as taxing using one engine) and reduction of single-use plastics.

The aircraft manufacturing industry for commercial aviation is characterized by large incumbent firms and high entry barriers, this clearly shows when considering that only two companies, Airbus and Boeing, jointly supply 91% of the global market for commercial aircraft and three engine manufacturers supply more than 50% of engines used (Forbes, 2020). Under oligopolistic market dynamics like this, firms sometimes end up falling victim to the fallacy of rigidity i.e. exploiting inherent strengths and neglecting exploration of new ones, be it for a lack of competence or trying. This could be viewed as a resilience to the landscape pressure of Climate Change, caused by a low level of competition and potentially stalls development. This also leads to these few and large actors having a proportionally large influence on the technological shaping of the socio-technical regime.

As aircraft technology goes, on the surface, not much has changed since the introduction of jet airliners. The big improvements have been incremental, increasing fuel efficiency by almost 45% between the years 1968 to 2014. These improvements have principally been driven by internal regime desire from the airlines to lower the cost of operating aircraft through the use of less fuel. The same can be said of the deployment of winglets and lightweight composites. This particular alignment and trajectory of technology within the regime has had the effect of making aviation gradually more sustainable but not until recently has the landscape pressure of Climate Change been a driving factor. However, the development of the current technological paradigm of the turbojet airliner is seeing diminishing returns in terms of emission reductions. This is somewhat expected for any technology but as of today, there is no feasible alternative to the jet airliner which means that there is not much potential for sustainable aviation from an incremental improvement aircraft technology perspective.

Producers of jet fuel are typically large international oil producers with refinery capacity. Generally speaking, jet fuel is not their main product, instead, it plays a small part (~10%) in a lineup of fuels and petrochemical products such as gasoline, heating oil and plastics. However, as the other industries, today supplied by these oil giants such as the automotive industry edge towards electrification, jet fuel's importance to the oil industry might increase (IEA, 2019). This could prove a hindrance, slowing down the transition as many producers might end up with a surplus of oil lowering the price of fuel thus increasing demand. However, one way for producers of jet fuel to comply with landscape pressure for more sustainable aviation can be SAF as still as of today by regulation requires at least 50% fossil mix and can utilize much of the incumbent infrastructure in its production and use due to its drop-in nature. As of now, SAF is in limited use because of its uncompetitive price and subsequently low production volumes and there are still concerns as to how the biomass can and should be sourced. The uncompetitiveness of SAF is however less of a problem for wealthier travelers whose preferences are to fly sustainably, thus enabling them to disregard the uncompetitiveness.

5.3.6 Non-Governmental Organizations

Beyond governmental and intergovernmental there are also non-governmental organizations (NGOs) relevant to the regime. While they generally have no power to dictate the state of policy in the regime, they can still play a part in influencing its direction.

The International Air Transport Association (IATA) is the world's largest aviation trade organization with more than 290 member airlines representing over 80% of the globally available seat kilometers (IATA 2016). They wield no legislative power but can in practice influence the policy surrounding aviation thanks to their wide reach and do so in multiple disciplines including sustainability. IATA is outright questioning the trend of taxation schemes aimed towards air travel among European countries, deeming them ineffective and damaging to the aviation industry. IATA instead favors ICAO's CORSIA citing it as an effective way of making amends while maintaining a level playing field within the industry (IATA, 2019).

Environmental NGOs are also pertinent actors. They tend to be aviation's most prominent opposition emphasizing the unnecessity of most commercial aviation and its high environmental impact (WWF, 2010). Most importantly for the regime, they are the most prominent advocates for the inclusion of non-CO_2 effects when discussing the aviation industry's carbon footprint (Naturskyddsföreningen, n.d.). While most if not all actors in the regime acknowledge that there is more to the environmental impact of aviation than the direct effects of CO_2 emissions i.e. non-CO_2 effects, they tend to disregard it when calculating the overall impact citing the uncertainty of its exact extent and urging for more investigating. This, from a sustainability perspective, is of course undesirable as the problem of global warming due to human activities is urgent and NGOs like the World Wildlife Fund and Naturskyddsförening do wield some power in influencing the public and decision-makers in matters like these.

5.4 Contextualizing the Niches (Micro-Level)

In this section, the niches in the MLP will be gone through. Niches are the seeds that grow and drive transitions or wither and die. As niches for driving a transition into sustainable aviation four niches are identified: abstaining, electrical aviation, SAF and carbon offsetting.

5.4.1 Abstaining

Abstaining from flying is defined as a niche in the MLP although it is not based in any specific technological innovation. Abstaining is the concretized action of the social movement against climate change and alternative traveling landscape sentiment. Abstaining from flying is free and can theoretically be adopted by anyone. In one sense it has the potential to affect the aviation industry significantly but it is not reasonable to think this will happen. The fundamental value of global commercial aviation is too large for the demand for flying to disappear. Abstaining has the potential power to affect the individuals who stand on the tipping point of flying or not flying due to not wanting to affect the climate negatively. In relation to the other niches, it is thereby not seen as a competitor, it is rather a parallel development that has taken and will take a position in the socio-technical regime. The question is the size of the position it will take.

When speaking of abstaining as a niche, the purpose is to discuss abstaining by people that more or less could afford to fly and has access to it. It is not a question of poverty, where flight abstaining is due to economic constraints. The individuals who choose to abstain not only have the choice to do so but actively do so even if it limits some of their welfare possibilities. This raises a problem of its own. When the population that does not fly due to economic constraints undergoes economic growth and increased economic living standards, it will also want to participate in the significant possibilities of flying and there will be a resistance to flight abstaining. This justifies the hypothesis that abstaining from flying will not be the all-encompassing solution to sustainable aviation. When abstaining has taken a market share (or rather eliminated a market share) for sustainable aviation there will be much room left for other sustainable aviation solutions for those who are not done exploiting the welfare opportunities associated with flying.

5.4.2 Electrical Aviation

Electrical aviation is an interesting niche that has the potential to take an important role in a long-term solution for sustainable aviation. There is internal support in the regime from some of the actors: airlines see it as an opportunity to reduce operating costs by reducing maintenance and eliminating their dependence on fuel. Incumbent aircraft manufacturers, who are the ones to overcome the technical challenges, see it as an eventual necessity for keeping their market position. Lastly, travelers see electrical aviation as a way to meet their demand for sustainable ways of traveling.

The niche is the least developed one of the niches and is far from maturity and market readiness. According to the time plans discussed in the background it will in the most pessimistic projections take until 2050 before electrical aviation can fully replace traditional aviation technologies. Electrical aviation will not get the first-mover advantage in sustainable aviation but this does not seem to be a problem for its innovation and development potential. Research and development actors do not communicate that they perhaps will favor SAF instead of electrical aviation and therefore will not develop electrical aviation technology. It is rather an environment of parallel development where both solutions seem needed along with other carbon emission mitigating measures. But electrical aviation has the potential to make carbon offsetting obsolete since electrically powered flight does not have any emissions directly associated with the propulsion and then there is nothing obvious to offset. As the time frame entails, this will not happen in several years, but when it does it will likely eliminate the intuitive function of carbon offsetting directly linked to individual flights.

There are some socio-technical circumstances that favor electrical aviation, especially the already positive societal view on a general switch from fossil fuels to electricity. An example is the expansion of renewable electricity production and investments in electric cars and batteries. This kind of general electricity promotion can result in an environment that facilitates positive spillover effects on electrical aviation. It is however not favored by the fuel manufacturers as it would make their role in the regime obsolete and thus far no regulatory body has approved any electrical aircraft for commercial use.

The technical niche development of electrical aviation is in part being driven by new entrants in the aircraft manufacturing industry, examples of this is the Swedish Heart Aerospace and the Israeli Eviation Aircraft. But as Geels (2010) discusses, it is also relevant to consider the incumbent firm’s ambidextrousness as organizations in the development of electrical aviation. Both Boeing and Airbus are developing their own electrical aircraft and are competing with pure niche actors. At the same time, it is important to understand that the reverse-salient technology to electrical aviation is not solely technology traditionally endogenous to the aviation industry. This may speak in favor of the pure innovator niche actors who are able to specialize in imperative matters as for example battery energy density.

5.4.3 SAF

SAF is a more mature niche innovation that is more ready for the market than electrical aviation. SAF has already adopted some space in the socio-technical regime since it is offered commercially if limited. The hurdle for SAF to enter the market more widely is the cost and does thereby rely heavily on technological improvements and improved economies of scale. Governmental and NGO subsidies for SAF will help it in taking a larger role in the regime. As shown in the Carbon Offsetting Assessment Framework SAF also can be voluntarily promoted by user travel preferences in the sense that some airlines offer the travelers to purchase SAFs to offset their emissions using SAF. The limited use is further reflected in the fact that globally, only five airports receive regular distribution of SAF. The airports are Bergen, Oslo (Gardemoen), Stockholm (Arlanda), Los Angeles and Brisbane (IEA, 2019). The geographical distribution of these airports is consistent with the overall score in the Carbon Offsetting

Assessment Framework in which the top scorers were located in northern or western Europe. Los Angeles and Brisbane are certainly not located in northwestern Europe but there are some obvious similarities between these areas and one could assume that the landscape pressures act relatively symmetrically on the travel preferences in these areas.

SAF will develop before electrical aviation and will therefore not compete with it extensively in the coming few years. But how will it interact with the carbon offsetting niche? One could argue that SAF and carbon offsetting are interchangeable and that the use of SAFs will combat with the use of carbon offsetting. This is a possible scenario. But as this study has discussed previously, SAFs do not reach almost zero operating emissions as electrical aviation does. Firstly, there is as of today no certified pathway that allows for more than a 50% SAF fuel mixture. Secondly, the non-CO_2 effect will still persist with SAF. Further, zero emissions will not be reached as the estimated lifecycle emissions of SAFs today vary between 50 to 80% reductions in life cycle emissions compared to regular jet fuel. It technically is not a problem with the low levels of use seen today but in order to change this new regulation on fuel must be passed. Until then, emissions that are not able to be reduced by SAF will still be reasonable to mitigate through carbon offsetting initiatives. This means that regardless of how much SAF is used, there will always be a remaining demand for carbon offsetting. These two are therefore assumed to be able to coexist.

The development of SAF is difficult to complete solely in the niche environment. The current actors that are producing and offering SAF are rather already present in the socio-technical regime. They partly consist of oil and petrochemical giants who even before the advent of SAF supplied the aviation industry with regular aviation fuel. This once again shows how the ambidextrousness of organizations allow for established regime actors to not only act within the regime but also interact with niche developments in ways that create an opportunity without destabilization of the regime. The development of SAF could also lead to couplings of the aviation industry and its regime with previously unrelated socio-technical regimes as forestry and agriculture as they develop interdependencies instead of the current interdependencies with the oil industry.

While SAF technically seems rather ready for the mass market (disregarding the need for the price to drop) the way it is produced is a more pressing question. First-generation biofuels used human-grade food as feedstock which was ethically questionable. In the context of the sustainable aviation MLP, this would not have been accepted as the user preference aspect would not view this as a socially sustainable practice. The user preference aspect demands a legitimate fuel production process, what in contemporary business language is known as “triple bottom line”, which takes environmental, social and economic aspects into account. However, the six as of today approved SAF pathways allow for non-food feedstocks and thus SAFs do not directly compete with human food supply.

5.4.4 Carbon Offsetting

Carbon offsetting has been touched upon throughout the whole MLP discussion but in this section, it will be the focal point. Carbon offsetting is a more easily adopted niche solution for sustainable aviation than SAF and electrical aviation. This can be seen in the Carbon Offsetting Assessment Framework where it is made clear that there are more actors who offer carbon offsetting than SAFs. In the assessment framework carbon offsetting certifications are also investigated and it is shown that the quality of offsets varies between the different actors. For carbon offsetting to further establish as a part of the socio-technical regime, it will need to develop more in its reliability status and the certification process and actors play an integral part there. In terms of the socio-technical regime, it is the traveler preferences that do not accept carbon offsetting when it is not legitimate presented, and sometimes even not when it achieves the highest certification standard. This is the toughest challenge for carbon offsetting, to get a reliable and credible reputation (meeting the criteria of being *real*, *permanence*, *additional*, *verifiable* and *enforceable* (Goodward & Kelly, 2010)).

Thus far carbon offsetting has found some roles in the regime. First and foremost, it is used to directly offset the emissions from a unique flight. In this application, whether it is actively purchased by the consumer or provided free of additional charge by an OTA or airline, it is aimed at consumers. The other way in which it has gained a role is through CORSIA and EU ETS. Under CORSIA and EU ETS, airlines that exceed their baseline emissions can use carbon offsets to bring their net emissions down. A plethora of emissions units are eligible for use but generally, afforestation, reforestation and industrial gas destruction projects are prohibited as they are the type of projects that generally have received the most criticism concerning their actual environmental impact. Here a slight difference in the use of carbon offsets can be discerned between offsets marketed at consumers and offsets used in the industry. Through the Carbon Offsetting Assessment Framework, it was found that many airlines that offer carbon offsets offer afforestation, reforestation and even whale conservation projects, projects that would not be eligible under CORSIA. It could be theorized that these types of projects are offered because they and their impact may seem more tangible and thus attractive to a consumer with very little or no insight into the actual workings of carbon offsets, attributes not as important in the context of CORSIA. This somewhat tie back to the notion of “cute and cuddly” carbon being more easily marketed. It also highlights one of the potential pitfalls of carbon offsetting, namely greenwashing. As there is a plethora of available supposed offsets it is very difficult for consumers to make fully informed decisions that leave room for less serious actors to capitalize on the good will of consumers.

A potential problem with carbon offsetting taking place in the transition into sustainable aviation is that carbon offsetting for some travelers becomes a letter of indulgence, and they continue flight habits (or even increase their amount of flights) that without the carbon offsets would not have been completed. One could ask why this is a problem, and there is certainly no easy answer. It is in one sense rational that one traveler that offsets his or her emissions should be able to travel unlimitedly. After studying the subject, the short answer to this is that the process of carbon offsetting is too complex to reason like this and that it is coupled with too large risks. One can remind oneself of the good old “precautionary principle”, which is assessed to be important after studying the question deeply.

In other respects, carbon offsetting has good prerequisites to be competitive in the socio-technical regime. The unique selling point is the price of carbon offsetting which today is significantly lower than the price of SAF. The path for the price of carbon offsetting in the socio-technical regime is however uncertain. One could argue that an increase in use of carbon offsetting would yield positive economies of scale and network expansion effects that result in lowered prices. But if carbon offsetting would take a significant role in the socio-technical regime another possible path is also that the demand for carbon offsetting will exceed the supply. This scenario is very dependent on carbon offsettings general development and spread across other sectors. The supply of carbon offsetting in for example the food industry utilizes the exact same value creation and underlying assets as in aviation. This would result in raised price tags for carbon offsetting and some travelers not being able to offset their flights even if they had wanted to at a lower price. It is a difficult calculation, but it is reasonable to think that on a system level it will be impossible to provide carbon offsetting to all people in the world's climate negative consumption that exceeds the Paris Agreement goals. Carbon offsetting will thereby hardly be the single solution to a transition into sustainable aviation.

However, one should keep the development of CCS technology as a way to carbon offset in mind. The technique solves the legitimacy problems of carbon offsetting since the carbon emission reduction is tangible. CCS is too expensive and low-scale today but in the future, it may become a solution that enforces the carbon offsetting niche and will increase its competitiveness against the other niches. But it is difficult to see an MLP dynamic where CCS is upscaled to a degree that makes SAF and electrical aviation obsolete.

5.5 Multi-Level Perspective Synopsis

The most important attribute of the MLP is to understand sustainable aviation, not only as isolated technologies and trends but as a whole, exposing the transition dynamics of sustainable aviation. The MLP is not a forecasting tool, but with caution one can attempt to analyze how the transition dynamics likely will interact and this will yield a future outlook, whether you like it or not. In this section, the key insights from the MLP will be gone through.

As discussed in the section above, there are some indicators of how the niches will develop. The abstaining niche has established partly in some geographical and social areas already and will likely spread to other segments as the world become more and more woke in the sustainability question. There is a cap though of how much it will spread because many people will not be willing to give up any travels for the climate and there are also many travels that cannot be replaced or omitted. There are no technical difficulties for abstaining, obviously, the hurdle consists of social obstacles in the idea of voluntarily abstaining from traveling.

Carbon offsetting is the niche that has the potential to develop the most in the coming years. If airlines and travel agencies continue the trend of increased offering and purchasing of carbon offsetting it will gradually obtain a larger role in the socio-technical regime. One hinder is the potential lack of supply of low-cost carbon offsetting projects. Another hinder is the legitimacy process, both to conduct the carbon offsetting projects in a legitimate way and to be able to communicate it to the travelers, meeting their traveling preferences. The carbon offsetting holy grail is CCS, but for sustainable aviation the question is whether the price of CCS technology will decrease faster than the price of SAF and electrical aviation and at the same time be able to scale up widely. Carbon offsetting will continue to be relevant when SAF has taken a larger role in the socio-technical regime since carbon offsetting can still mitigate the non-CO_2 effect of aviation. But it will take time for SAF (and electrical aviation) to take a major place in the socio-technical regime.

As of now, SAF does not reduce carbon emissions significantly but the niche has the potential to do so in the coming years. The main hurdle is the production cost, which needs to be significantly lower to compete with traditional jet fuel. Policy, for example a tax, that promotes

SAF relative to traditional jet fuel is one possible way to increase the speed of SAF's competitiveness. However, it is not favored by many regime actors. Another issue with SAF is the non-CO_2 effect that still persists. In the socio-technical paradigm, SAF could thereby be coupled with the complementary good carbon offsetting to handle the non-CO_2 effects. According to this MLP analysis, this co-work of carbon offsetting and SAF will be the best solution before a wide introduction of electrical aviation is available.

Electrical aviation is the eventual endgame if commercial aviation is to become carbon neutral and it has very wide support as it also promises decreased operating costs and quieter aircrafts. However, the technologies available today are not even close to fulfilling the hopes and expectations of its proponents and no one really knows when it will reach market readiness. The most critical reverse salient technology today is one not endemic to the aerospace industry: the energy density of batteries measured in relation to weight. As of today, the largest demand for high capacity battery technology is found in the automotive industry. The automotive industry values much the same attributes (i.e. light and high capacity) in batteries as the aircraft industry and this could lead to a future scenario of coupling of regimes much like the coupling of forestry/agriculture and aviation regimes. This could indicate that in order to further analyze electrical aviation's potential future one might need to widen one's analysis to not only look at the regime and niches of aviation but also other industries like for example the automotive industry.

To illustrate how the transition dynamics for sustainable aviation can interact and develop over time a schematic graph is created. The graph is shown with some reluctance because it is easy to criticize a projection of the future with time stamps. The illustration should be thought upon as a manifestation of the insights from the MLP where the aviation industry in general is heading in the direction of sustainable aviation. The projection is wishful but also assessed as feasible when the mentioned obstacles are encountered and treated.

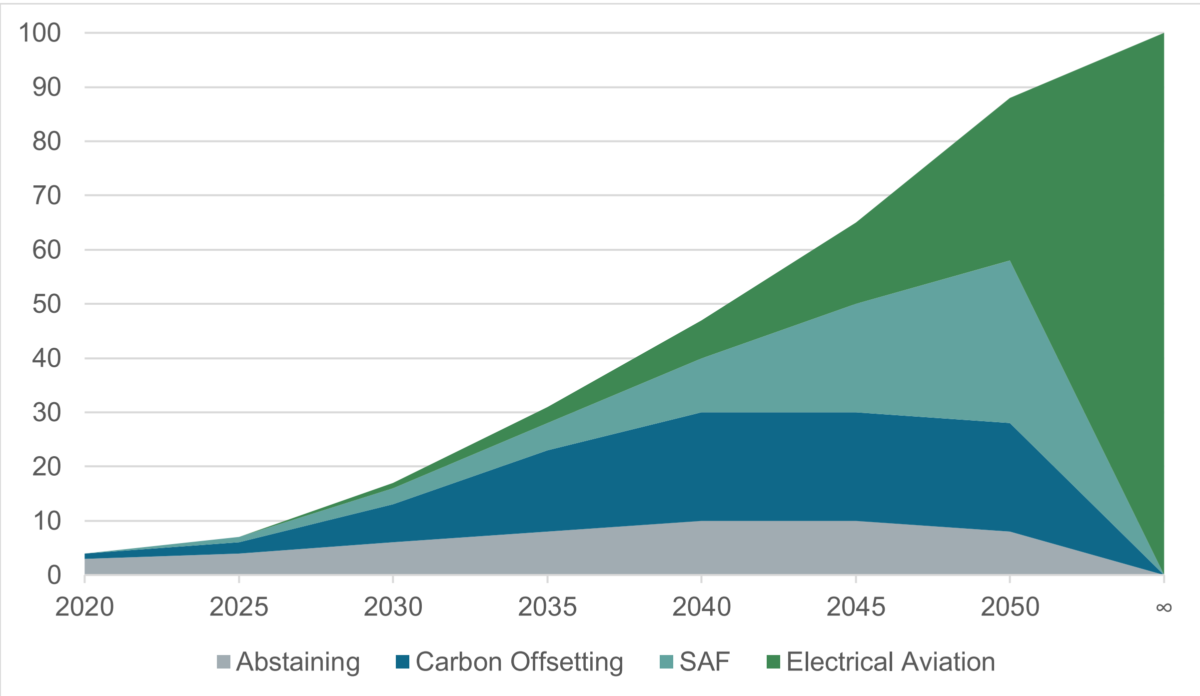

Figure 12, Sustainable aviation forecast

6 Conclusion

In this section, the role of carbon offsetting in future sustainable aviation is summarized. Carbon offsetting as a concept is revisited and further problematized in the light of the findings from the Carbon Offsetting Assessment Framework and the MLP. Guidance for further studies is proposed.

6.1 The Role of Carbon Offsetting in Future Sustainable Aviation

As of today, it is not possible to substantially reduce the gross emissions of aviation. This will not be possible until electrical aviation can replace the current turbojet engine. The MLP analysis showed that as the paths leading to more sustainable aviation goes, electrical aviation was by far the furthest from coming to fruition and entering the socio-technical regime.

In the anticipation of the advent of electrical aviation, the industries focus will rather be on reducing the net emissions through the use of sustainable aviation fuels and carbon offsets. The most obvious tell-tale of this is the widely accepted CORSIA program which will begin its first phase in 2021. It has, as of writing this, more than 60 signatory states for its voluntary pilot and first phase 2021-2027. Under CORSIA, airlines will have to mitigate any gross emissions exceeding the 2019 baseline through the use of either SAFs or carbon offsets. The program has the potential to boost the use of SAF as it could create a stable demand and market for it, even at relatively uncompetitive prices. It could also give rise to an increase in the global demand for carbon offsets and thus also run up the price. All in all, the program has the potential to limit the future increases but not tackle the industry's current emissions.

This leaves further room for carbon offsets and SAF to be used and purchased by both airlines and travelers. Voluntary purchases on behalf of airlines and consumers found through the Carbon Offset Assessment Framework confirms that there is a demand for this. However, the geographical distribution of these initiatives raises the question whether it is, on account of the airlines, due to a righteous strategy, profoundly aimed to take responsibility for their emissions or an adaptation stemming from changing traveler culture and preferences in shape of increased environmental awareness and subsequent demand for more sustainable travel, i.e. profit maximization. It is a very difficult question to answer but a potential hypothesis is that sustainable aviation is provided due to profit maximization through the airlines meeting a traveling preference demand for sustainable travels. The traveling preferences are reasonable to correlate with an extensive public discourse around sustainability. If there is such a correlation, then airlines would profit maximize by offering more sustainable aviation through carbon offsets or SAF. While it does not confirm the hypothesis, the results of the Carbon Offset Assessment Framework are in line with the hypothesis as the origins of actors receiving high scores were predominantly found in well-developed western European nations. In these nations, it is not unreasonable to assume there is a more extensive public discourse concerning sustainability than the global average.

Further, even if the aviation industry acknowledges the negative impact on the environment stemming from their activities, not a single airline examined in the Carbon Offset Assessment Framework who offered or bought offsets included the non-CO_2 effect. A few airlines did comment and acknowledge the fact that the non-CO_2 effect plays a role in the global environmental impact of aviation but chose not to consider it in their emissions or footprint calculations citing uncertainties. The only actors found to be including the non-CO_2 effect were two online travel agencies. One possible reason as to why these two actors include the additional effects in contrast to the airlines is that they sell packaged trips with flight transfers hotels etc. together all in one. When packaged trips are sold in this way it is more difficult to compare the prices of alternatives than just comparing flights, alleviating them from the cut-throat price competition that characterizes selling flight seats. This enables them the opportunity to include the non-CO_2 effect as the additional cost is not visible to consumers but the added sense of responsibility increases marketability.

6.2 Persisting Dilemmas with Carbon Offsetting

Hopefully, the principles of carbon offsetting have been made clear at this point - one can mitigate their carbon emissions at one place through the funding of a project that results in reduced carbon emissions elsewhere. What still may be difficult to understand is how carbon offsetting can be so relatively cheap. This has been explained but not problematized. The explanation is that you do not fund an entire carbon offsetting project through carbon offsetting initiatives, only the top-part that pushes the project over the threshold from being unprofitable to being profitable. However, the carbon emission reduction is not proportional to the top-investment that pushes it over the threshold. The attribution that is assigned to a carbon offsetting investment is rather for the whole project. This means that the carbon offsetting investor takes climate positive credit for a whole project but funds solely a small part of it. This leads to something that we would like to call “the attribution dilemma”. In carbon offsetting certification systems, there are restrictions that keep more than one carbon offsetting actor from taking credit for the same carbon offsetting project. This is necessary and good. But think of the energy system in for example India. If a carbon offsetting initiative has resulted in wind power being built instead of coal plants a change in the energy mix has occurred and it has become a little bit greener. This leads to a lowered incentive for India too, in the future, invest in sustainable power generation. This is the dilemma. If carbon offsetting was ideally handled, India is not allowed to take any credit for their improved energy mix, because this credit is already taken by the individuals who have bought the carbon offsetting. This problem is assessed to still exist when additionality criteria are taken into account since additionality is only possible to assess project-specifically or in a short time frame. It is not possible to prove long-term additionality for a whole energy system. Carbon offsetting thereby suffers from some implicit double accounting which is well known but has been accepted under the Kyoto protocol for well over a decade (Science, 2019). This could in the future arguably be solved with CCS technology but it is not a solution to rely on in the near future.

To assess the carbon offsetting impact on carbon emission reductions in a long-term, life-cycle all-encompassing perspective is immensely difficult. The standardization, verification and certification processes do help a lot in guaranteeing that actual positive effects emerge. The general viewpoint that has grown forward when studying carbon offsetting is that it has the potential to hasten carbon emission reductions and boost a transition into a low-carbon economy faster than the regular market would have done. Carbon offsetting is an intelligent reallocation of resources where low hanging fruit is harvested. The long-term problem is that in time the fruit hanging in the middle, or even in the top of the tree, also needs to be picked in order to stop global warming. Why, is a bit of a puzzle. Think of the world as one energy system that has a cap on its emissions in order to handle climate change and global warming. In order for this system emit within its cap, every sub-system of the whole system must emit so little that when all the sub-systems are accumulated the whole system's emissions are still below the cap. For example, if Sweden exceeds its cap, India must compensate it with an equal amount. This is the principle for carbon offsetting. But what happens when emissions per capita rise in the sub-systems, countries that today have low carbon emissions per capita due to low GDP? There is not certain prognosis for this to happen, a so-called leapfrog development can be discussed, but it is quite reasonable to assume that some increase in emissions per capita will occur when GDP in the future increases (Cederborg & Snöbohm, 2016). So, if the emissions per capita rise over time with GDP, in *ceteris paribus*, there will be an increased demand for carbon offsetting since more countries exceed their individual cap. This is not a sustainable situation because there is a limit to how large the supply of carbon offsetting projects can be. An increase in demand and supply that do not cope with the development will also drive up the price tag for carbon offsetting. This kind of development due to a more structuralized utilization of carbon offsets is not improbable. As previously mentioned in the background the CORSIA initiative will potentially consume 1.6 to 3.7 billion carbon credits during its first 14 years comparable to the 2 billion used under the Kyoto Protocol in the last 12-year period. Utilization on this kind of scale has the potential to be a large price driver in the global carbon offset markets. A deficit in supply will lead to that each sub-system must oversee what they can do to keep within their cap in the long-term. Turning back to aviation, one can say that carbon offsetting is an effective and feasible solution in short-term but that in the long run, it will not be enough to cut emissions. The long-term solution is SAF and electrical aviation.

This discussion seems to undermine the impact of carbon offsetting, and perhaps it does, but carbon offsetting is still assessed to be an effective short-term solution for sustainable aviation if stop flying is not an option. And to stop flying completely is not a desirable or feasible option as previously discussed in the abstaining niche. The upsides and possibilities of flying are too large. People will not voluntarily stop consuming aviation broadly due to traditional negative externality dynamics.

Another perspective is the question of "do something or do nothing?" It is reasonable that a lot of individuals view abstaining from flying not to be an option and that SAF currently is too expensive, then there is one current option left for sustainable aviation and that is carbon offsetting. The traveler may be aware of the disadvantages of carbon offsetting but still consider it as the best option. The alternative may be to do nothing at all and keep flying as usual, which is significantly worse than to use carbon offsetting. Especially when recalling the reasoning of Hassler et al. (2018) who argues that it is more economically effective to undertake too extensive measures than too small. With this reasoning, it is better to carbon offset even if it is not perfect. A perspective that also needs to be kept in mind is the low cost of carbon offsetting compared to the alternatives for sustainable aviation. One price example of carbon offsetting is 40 SEK/tonne CO_2 while one for SAF, which is the only current other option for sustainable aviation, is 5206 SEK/tonne CO_2. Making the carbon offsetting about 130 times cheaper than SAF. This is a significant price difference and one may say that SAF is better than carbon offsetting, but is it 130 times better? It is a well-known fact that a bird in the hand is worth more than two in the bush but is it worth more than 130 in the bush? Probably not. But in the future, the price tags are likely to converge and it will have to be reconsidered.

6.3 Further Studies

One limitation of this study is the selection of airlines and OTAs that are Sweden-centric and based on Flygresor's partners. Although it is believed that the sample is representative and relevant for studying the main components of carbon offsetting, the study would be richer if a larger and more worldwide sample were used. It is believed that a wider study of the state of carbon offsetting in the aviation industry would be fruitful in the future, but the suggestion is to wait a few years until the concept, and sustainable aviation in general, is more widespread. It is assessed that conducting a wide study at this point would not yield any additional radical results since carbon offsetting and sustainable aviation is that immature globally.

Further, a common theme found through the annual reports and other material that was read to gather data for the Carbon Offset Assessment Framework was the multifaceted term "green operations". This included everything from taxing with one engine to reducing single-use plastics. These different initiatives did not make sense to evaluate in the given the purpose of evaluating sustainability in the context of carbon offsets and SAF as they are more linked to the use of fossil fuels but they surely also have sustainability implications and could be of interest when evaluating the overall sustainability of aviation.

While this study focuses on the use of carbon offsets and SAF as a means of reducing the aviation industry's emissions one should not neglect the importance of other factors as well. The calculation method for calculating the amount of carbon emissions to offset will be increasingly relevant in the future if carbon offsetting becomes more widely used. For example, the load and freight factor of a flight have a great impact on the CO_2 emissions per person kilometer and the different spaces needed to accommodate economy, business and first class results in large differences in per-person emissions as well. While it does not fall within the scope of this study these factors also have an effect on how carbon emissions should be offset as they affect the impact of an individual's flight. Examining these parameters will both be a matter of technical challenge and ethical trade-offs. Although this is important, getting all these details perfect and become flawless in the emissions calculations is not assessed to be the most urgent matter. As argued before, it is more important to be approximately right, not underestimate and to act now rather than postpone the acting until technicalities are perfect.

6.4 Any last words?

Use carbon offsetting because it is a feasible and relatively cheap option to hasten a transition into a sustainable energy system. Do not use carbon offsetting as an excuse to consume more, rather a way to try to make up for the carbon emissions that are currently emitted and already have been emitted. The responsibility is bound to states and NGOs but also to individuals; carbon offsetting is part of rigorous legal obligations and covenants but also a voluntary option for individuals. In order to ensure sustainable carbon emission reducing actions, the carbon offsets must be of high standards and certifications. The more rigorous standard, the larger the positive impact. Carbon offsetting is an excellent tool to hasten sustainable development but is not an underlying solution, it is rather a carbon reducing derivative that can be purchased in order to guarantee that carbon reducing actions are undertaken now and not later, or not at all.

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Appendix

Appendix 1
Carbon Offsetting Assessment Framework scores for OTAs.

OTA	Carbon Offset work	Offset Initiative	SAF	Carbon Offsetting Score
Supersaver	0	0	3	3
Resecentrum	0	0	0	0
Ticket	2	2	0	4
Travelstart	0	0	0	0
Kiwi	0	0	0	0
Flygcity	0	0	0	0
Seat24	0	0	0	0
Flightsearch	0	0	0	0
Bravofly	0	0	0	0
Sembo	0	0	0	0
Tripmonster	0	0	0	0
Travelgenio	0	0	0	0
Airngo	0	0	0	0
Travel2be	0	0	0	0
Mytrip	0	0	3	3
Aobtravel	0	0	0	0
Budgetair	0	0	0	0
Travellink	0	0	0	0
Travelstore	0	0	0	0
Flightfinder	0	0	0	0
Resia	0	0	2	2
Airtours	3	2	0	6
Flyhi	0	0	0	0
Ving	3	2	0	6
Tui	3	2	1	7
Flighttix	2	2	0	4
Flygpoolen	0	0	0	0
Loltravel	0	0	0	0
Opodo	0	0	0	0

Lucky2Go	0	0	0	0
Travelpartner	0	0	0	0
Kilroy	2	2	0	4
Skytours	2	0	0	0

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