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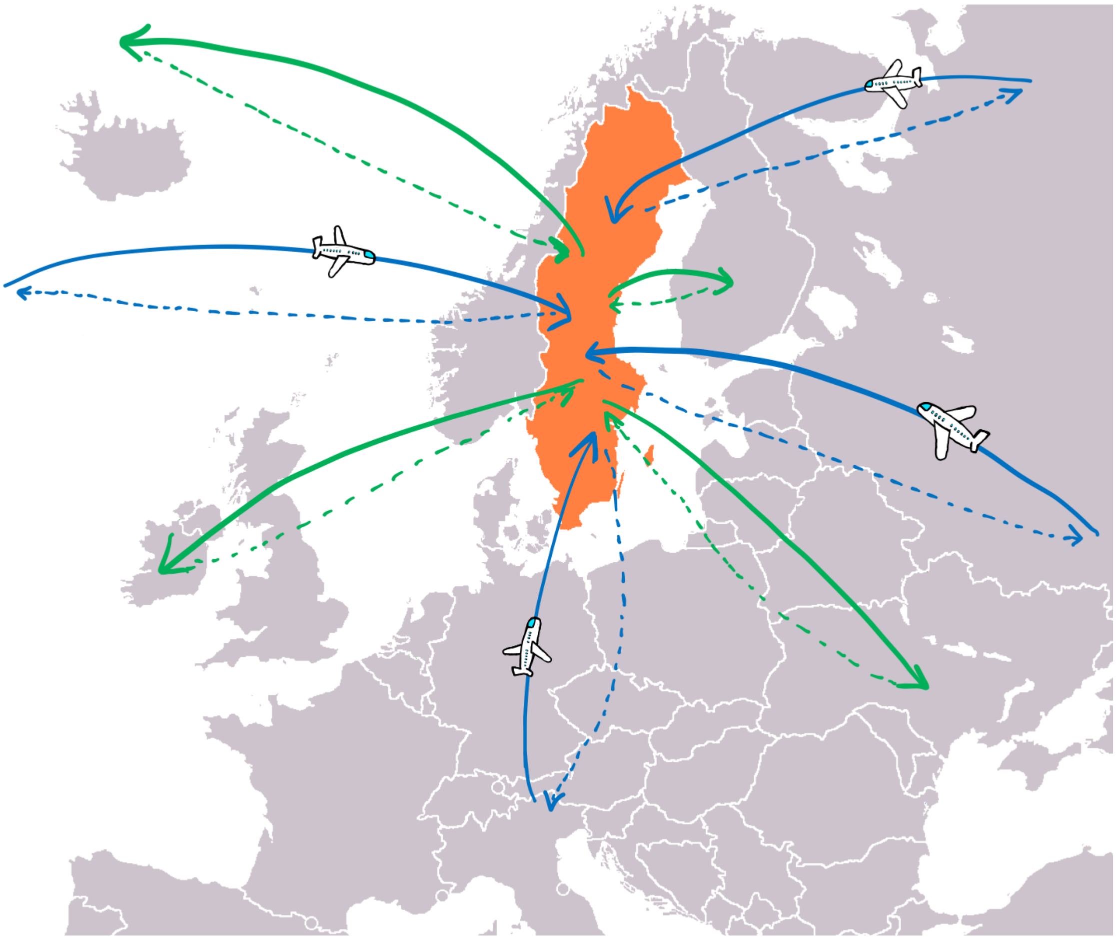

Aviation’s Climate Impact from Inbound Trips to Sweden

Quantifying the Historic Emissions and Creating Future Emission Scenarios Including the Effects from the COVID-19 Pandemic

Master’s thesis in Industrial Ecology

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Department of Space, Earth and Environment
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020

MASTER'S THESIS 2020

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Cover: Conceptualisation of inbound and outbound trips, picture taken from Wikimedia Commons and edited. The blue color represent inbound trips and the green color outbound trips. For more information about inbound/outbound tourism definition, consult section 2.1

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Abstract

Aviation is a carbon-intensive sector which is growing in Sweden partly due to increasing international tourism. Sweden aims at working proactively with their climate footprint simultaneously as they aim for growth in inbound tourism which is driven by air travel. The climate impact from these international inbound air travellers has not yet been quantified and this gap is filled in this report. The calculations follows a robust method, which incorporates the variables: average CO_2eq per p-km, number of inbound trips by non-residents and average distance. The variables are calculated through available official data. The results showed that the climate impact from air travel have increased with 29% 2014-2018, which is ten times more than the increase from outbound trips by Swedish residents in the same time period. Scenarios were also created to look at future trends for aviation climate impact until 2030, to incorporate the impacts from the ongoing COVID-19 pandemic. Two key variables impacting the future development of global air travel were identified: the length of the pandemic effects on society and whether the recovery would incorporate elements of globalisation or national priorities. This resulted in four scenarios named Resurrection, Tourism Depression, Staycation and Tourism Redefined. The scenarios showed a wide variance of future climate impact, concluding that the travel and tourism industry can be disrupted by the effects from the COVID-19 pandemic. Whether it will result in long-term green house gas emission reductions is uncertain. Nevertheless, a holistic approach towards the climate impact from both inbound and outbound travellers is needed, with an extended responsibility to include inbound tourism when creating future climate policies. An efficient way to reduce inbound trips climate impact is strategic marketing by focusing on closer areas to the destination and stop marketing far away. Such a measure would ensure a more sustainable tourism sector and resilience to future crises.

Keywords: aviation, emissions, tourism, COVID-19, sustainability, scenario planning, air travel

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Maija Happonen, Gothenburg, April 2020 &
Lisa Rasmusson, Gothenburg, April 2020

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Abbreviations and Acronyms

AIC	-	Aviation Induced Cloudiness
AJF	-	Alternative Jet Fuels
CCS	-	Carbon Capture and Storage
CO_2eq	-	CO_2 equivalents
COVID-19	-	Coronavirus disease 2019
CORSIA	-	Carbon Offset Reduction Scheme for Aviation
DMO	-	Destination Management Organisation
EOP	-	End of Pipe
ERF	-	Effecitve Radiative Forcing
EUA	-	EU Allowance (in EU ETS)
EU ETS	-	European Union Emission Trading Scheme
EWF	-	Emission Weighting Factor
GCD	-	Great Circle Distance
GHG	-	Green house gases
GWP	-	Global Warming Potential
IATA	-	International Air Transport Association
ICAO	-	International Civil Aviation Organization
ICCT	-	International Council on Clean Transportation
ICSA	-	International Coalition of Sustainable Aviation
IEA	-	International Energy Agency
IPCC	-	Intergovernmental Panel on Climate Change
IRTS	-	International Recommendations for Tourism Statistics
ITF	-	International Travel Forum
MLP	-	Multi-Level Perspective
Mt	-	Million Tonnes
Non-residents	-	Foreigners, people not living in Sweden
p-km	-	passenger-kilometers
RED	-	Renewable Energy Directive
RF	-	Radiative Forcing
SAF	-	Sustainable Aviation Fuel
SDGs	-	Sustainable Development Goals
UN	-	United Nations
UNEP	-	UN Environment Program
UNFCCC	-	United Nations Framework Convention on Climate Change
UNWTO	-	UN World Tourism Organisation

1

Introduction

With 8 billion people sharing one Earth, humanity share global opportunities and problems. Today we are connected and can travel to every far, remote corner in the world, something taken for granted in most developed nations. Travelling connect people from different cultures and bring them closer together, it enhances global cooperation and enriches people with new experiences. The last ten years tourism has also been a major driver for the global economy, as international arrivals have outpaced the growth of the global GDP (UNWTO, 2020). However, travelling has side-effects, especially one which is part of a vast problem; global warming.

The global mean temperature is rising and there is a wide-spread consensus among experts that man-made emissions of CO_2 and other greenhouse gases (GHG) are the cause of this human-induced climate change (Cook et al., 2016). The risks and effects from climate change are enormous, as it would affect for example fresh water resources, crop yield and increase likeliness for extreme weathers such as droughts, wildfires and cyclones (IPCC, 2014). Climate change could change the way we travel forever, as sensitive eco-systems are destroyed and popular destinations become uninhabitable. To combat climate change and other global issues the United Nations in 2015 created the Sustainable Development Goals (SDGs) 2030, a unified world approach to strive for sustainable development (United Nations, 2015). To be able to reach the SDGs stopping climate change is vital, and the UN urge all sectors to contribute. In result, the United Nations Framework Convention of Climate Change (UNFCCC) created the Paris agreement in 2015, ratified by a big majority of countries worldwide. The aim of the agreement is to keep global warming below plus 2°C from pre-industrial level, but with the ambitious goal below 1.5°C (UNFCCC, 2015).

In 2005, the tourism sector was responsible for 5% of all man-made CO_2 emissions (UNWTO & UNEP, 2008). Simultaneously, travelling and tourism have been identified as important means to achieve many of the SDGs, as it also brings many positive effects. It currently employs about 10% of the world population and contributes to about 10% of the global GDP as well as strengthen partnerships (UNWTO, 2019c). However, the tourism industry needs to become environmentally sustainable first and that includes one of the main drivers of GHG emissions; the transportation to the destination. Transport-related tourism GHG emissions grew 63% 2005-2016 (UNWTO & ITF, 2019).

Aviation alone accounted for 40% of the total CO_2 emissions from the tourism sector in 2005, without regarding the non-CO_2 effects of aviation caused by e.g. NO_x, contrails and cirrus clouds (UNWTO & UNEP, 2008). UNWTO and ITF (2019) further predict that the CO_2 emissions from aviation will nearly double until 2030 compared to 2005 levels, even with efficiency improvements of aviation. Projection from Cames et al. (2015) moreover showed that in a baseline scenario aviation alone could stand for 20% of total man-made CO_2 emissions in 2050. However, if these predictions will be the future is currently uncertain due to the COVID-19 pandemic which has had a major impact on the tourism and aviation industry (UNWTO, 2020d; B. Pearce, 2020b). Either way, measures need to be implemented to counteract the negative effects of tourism and especially all GHG emissions from aviation. These must be realised on all governing levels, from international agreements to local policies.

With growing international tourism dependent on air travel the negative effects from the sector are also increasing, which is also the case for Swedish tourism. Sweden has seen an increase in both inbound and outbound tourism in the last decade (Swedish Agency for Economic and Regional Growth, 2019). International inbound tourism in Sweden is dependent on aviation (Næss-Schmidt et al., 2019), thus air travel is responsible for a significant part of the global warming contribution from the tourism sector in Sweden. Outbound air travel by Swedish residents is also carbon-intensive, recently calculated to be 9.6 million tonnes CO_2-equivalents (Mt CO_2eq) in 2017, roughly as much as the CO_2 emissions from the Swedish population's car travel (Kamb & Larsson, 2019).

Sweden has a climate goal of reaching net-zero GHG emissions in 2045 (Environmental Protection Agency, 2019a) and aims at working proactively to meet this goal (Swedish Department of Finance, 2019). To reach the emission goals there have been social movements and media attention directed towards Swedish residents to take responsibility to fly less and shorter distances, limiting the outbound tourism. At the same time, Sweden's government through Visit Sweden has marketing campaigns aimed at far-away, growing markets such as India and China, which actively tries to attract more inbound tourism to Sweden (Government Offices of Sweden, 2015). No previous study has looked at how large the GHG emissions are from inbound international air travellers to Sweden, and whether they should be taken into consideration when developing Sweden's national strategies. This presents a gap between national tourist plans and climate mitigation goals in Sweden. It is a common goal conflict for aviation policies, where growth in for example tourism is sought together with a decline in aviation's GHG emissions (Elofsson, Smedby, Larsson, & Nässén, 2018). This conflict can inhibit sustainable development and a low-carbon society in the future.

The first step toward bridging this gap is quantifying the climate impact from inbound aviation and bringing this to the national agenda. The second step is to estimate how these will develop in the future, and which policies could be necessary. However, the future is uncertain due to the COVID-19 pandemic, an unprecedented crisis which in early 2020 already had large impacts on the tourism and travel industry. How the future will look for inbound tourism in Sweden is thus highly uncertain, but nevertheless important to consider.

1.1 Aim and Research Questions

This thesis has two main aims; to investigate the amount of GHG emissions from inbound air travel to Sweden by foreign travellers not living in Sweden (hereby non-residents) both historically and in future scenarios, as well as the implications this climate impact have for Swedish strategies and goals. The scenarios will focus on the development of the tourism and aviation sector after the COVID-19 pandemic to provide a broad spectrum of how the future might develop. These two aims are translated into the research questions:

- What is the climate impact from aviation due to inbound non-resident travellers to Sweden 2014-2018 and in different scenarios until 2030?
- What are the implications of these results on Swedish climate impact reduction policies and national tourism strategies?

1.2 Limitations

This report will only consider non-residents in Sweden that travel to Sweden by aviation. The climate impact calculations will be done between the years 2014-2018, as some of the data points were constricted within this interval. Travellers that get to Sweden by any other mode of transportation than air travel have not been taken into consideration, even if there are other possible ways to get to Sweden. Looking at all options would entail a too extensive scope for this report, and aviation is the biggest sole contributor to climate change within the tourism sector, thus justifying this decision.

Only international aviation will be discussed in the report and not domestic aviation. Possible transfers to reach the final destination will not be considered, only the direct flight path to Sweden from the traveller's origin country is accounted for. Furthermore, the calculations will only look at the geographical middle point coordinates in a country rather than airport to airport. These limitations are due to lack of data of which airport a traveller flew between. The calculations will not take a life-cycle perspective of the GHG emissions from flying and will thus not include upstream GHG emissions, i.e the GHG emissions from producing the fuel. The calculations includes the non-CO_2 impacts, to give the total climate impact not only CO_2 emissions.

1.3 Challenge Lab Context

The research questions for this thesis was formed through a collaborative backcasting process in Challenge lab (`https://www.challengelab.chalmers.se/`). Challenge lab exists to enable sustainability transitions and create master theses' that are connected to reality and work towards a sustainable future in collaboration with stakeholders. It is a multi-disciplinary approach to create a momentum of change. The theme of the 2020 edition was "mobility". For a further explanation of Challenge lab and the initial process that lead to the formation of the aim, consult Appendix I.

2

Theory

2.1 Tourism

Tourism as a phenomenon has been present in human history since the classical era, but tourism as we know it today took form in the 18th century. However, our modern travelling habits with charter trips, weekend trips, and adventure trips as well as long-distance trips to different continents, are still relatively new (Nationalencyklopedin, n.d.). Today, a traveller is defined as a tourist if they are a visitor who stays overnight for no longer than a year in a place outside their usual environment for any main purpose (business, leisure, personal), except to be employed in the place visited, see figure 2.1. A visitor can be either domestic, inbound or outbound according to the definition in the International Recommendations for Tourism Statistics (IRTS, 2008, 2.9,2.13).

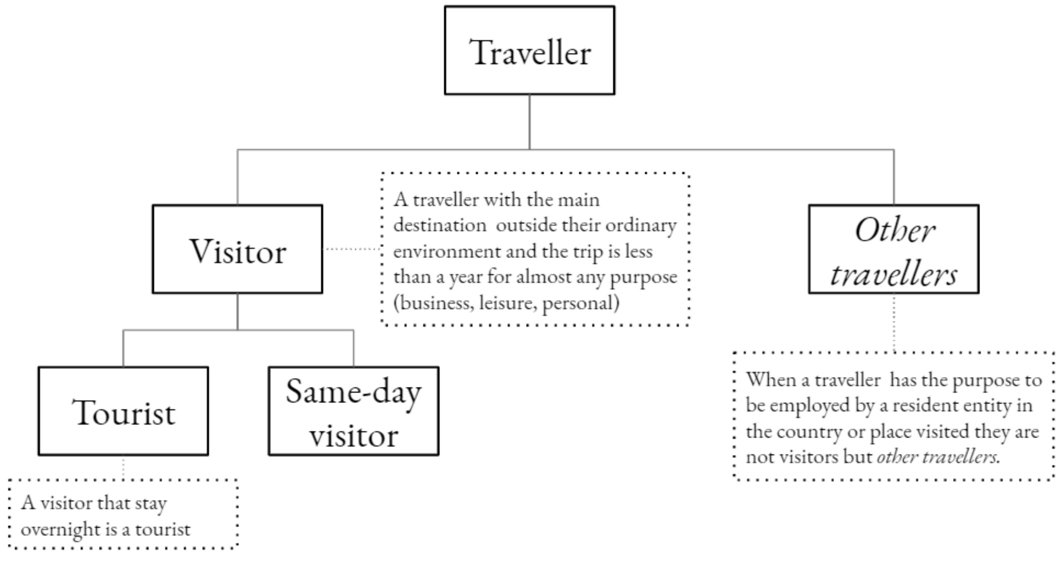

Figure 2.1: Definition of visitor and tourist adapted from IRTS (2008).

There are several frameworks that aim to describe the motivation behind tourism and travel. The purpose of tourism has been widely mapped out, but to find out *why* someone is travelling is more difficult, as it is often subjective in nature. Nevertheless, according to the push and pull theory, two factors are needed to explain why someone travels to a specific place (Dann, 1977). The push phenomena are factors that make the individual tourist prone to travel, while the pull factors are what attracts tourism to a specific destination. These will be explained in detail in this section, together with the concepts of overtourism and sustainable tourism.

2.1.1 Travel Motivation

Two commonly used frameworks that build upon each other and which are focused around push factors for tourism is the "travel career ladder" and "travel career pattern". They build upon the Maslow's needs-hierarchy of motivation and the first framework mentioned present the factors in a ranking system while the other one focuses on none hierarchical patterns (P. L. Pearce & Lee, 2005). Both theories argue that there is a difference in motivational factors between tourists that have a lot of accumulated travel experience and those who only have a little experience or none. This is referred to as one's travel career and which step you are on does not only depend on your amount of travel experience but also on other factors such as finances and health. Some motivational factors, that can be seen as the backbone of the motivation behind travel is not dependent on which step in the travel career you are on. These are: novelty seeking, escaping/relaxation, relationships and self-development. For people that has come further in their travelling career, factors such as; self-development through nature and host-site involvement is more important. People with less travelling experience considered stimulation, security, nostalgia, personal development, self-actualisation, relationship (security), romance and recognition as more important according to P. L. Pearce and Lee (2005). See figure 2.2 for a graphical representation of the travel career pattern motivations.

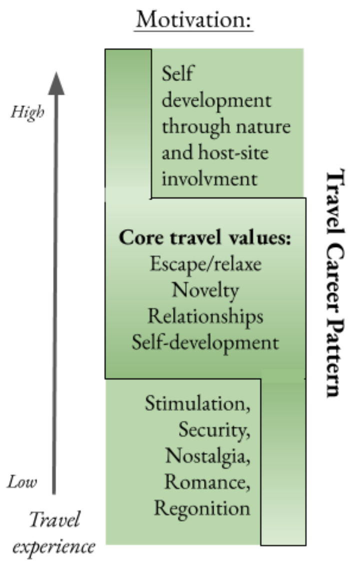

Figure 2.2: Travel career pattern with travel motivations depending on travel experience, adapted from P. L. Pearce and Lee (2005)

One note to consider when looking upon these models is that most of them, if not all, were conducted on tourists from western countries. There are studies made that indicate that people from different cultures have somewhat different motivations for travelling (Kim & Prideaux, 2005).

2.1.2 Destination Offerings

Destinations brand themselves to make tourist visit them and not other locations. Most countries and larger cities have something called Destination Marketing Organisations (DMOs) that is responsible for this. Their primary role is to increase the destination's competitiveness as there are many similar destinations out there (Pike & Mason, 2011). This has an important part in the pull effect in the push and pull framework by Dann (1977). The main roles of a DMO in destination marketing is as information provider, community brand builder, convener and facilitator, catalyst, funding agent, partner and team builder and lastly a network management organisation (Wang & Pizam, 2011).

There has been a lot of interest in how a destination should position themselves and in recent years brand identity has gotten a lot of attention. Branding is more than just a slogan or a name, it includes perceptions that can or cannot be in line with the market segments view of the destination (Pike & Mason, 2011). For example, Pike and Mason (2011) investigated how the market perceived the sunshine coast in Australia compared to the intended view by the DMO. They showed that the views were congruent and that this played an important part when a visitor decided to visit the destination. Furthermore, Séraphin et al. (2019) has looked into different branding strategies for 139 destinations around the world and it shows that most destinations have a strategy to attract a maximum amount of people.

DMOs have a mission to not only market a destination but also to develop the destination. They work as an important enabler for cooperation between different actor that in some cases are highly competitive, but need to collaborate to bring visitors to the region as a whole (Wang & Pizam, 2011). One way for DMOs to influence the number of visitors to their destination is by attracting more direct flight lines to the region. Direct flight lines to a destination have a direct link to the amount of international visitors a region have (Halpern, 2008). Furthermore, a location can develop their destination by creating major attractions such as the Eiffel Tower and Disneyland. Historically, destinations have put a lot of money into this (Weidenfeld, 2010). Although, how sustainable it is to draw tourists to a few hot-spots have been questioned. According to Becken (2005) these attractions pull travellers to the same location and if one country has a few disperse major attractions many tourists travel long distances between them. This may be resource-intensive and it also limits the possibility for tourism development at secondary locations in the region.

2.1.3 Overtourism

There are many definitions of overtourism, one according to UNWTO et al. (2018) is: "the impact of tourism on a destination, or parts thereof, that excessively influences perceived quality of life of citizens and/or quality of visitors experiences in a negative way". The word overtourism was created and gained attention in 2016. However, the issues it is representing have been known and managed before that. The term is closely related to the carrying capacity of a destination which UNWTO defines as the "the maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic and socio-cultural environment and an unacceptable decrease in the quality of visitors' satisfaction" (UNWTO et al., 2018). The opposite of overtourism is according to Responsible Tourism Partnership (n.d.) responsible tourism, which is about using the tourism industry to make a better place to live and visit.

According to UNWTO et al. (2018) overtourism is caused by mainly three factors; too many visitors, too much negative visitor impacts and too much physical impact on the location's economy. The first factor, too many visitors, relate to the absolute number of visitors as well as seasonality, that a lot of people come at the same time. According to Séraphin et al. (2019), branding strategies for destination can be one major force that contributes to this factor, but it is not the sole reason. The second factor relates to too much perceived negative impacts such as noise, congestion and rowdiness. The physical impacts on the local economy are related to why the services in the area aim towards tourists and not locals. It is worth noting that it can be difficult to distinguish when these factors are caused by tourism in itself since the tourism actors are placed in the setting of the local community and use the same resources and infrastructure as the residents. Therefore, it is important to take a wide array of factors into account when looking at the source of the negative consequences of tourism.

Overtourism has also lead to a growing anti-tourism movement in Europe as locals in popular tourist locations have become more interested in their quality of life rather than the income generated by the industry (Seraphin, Sheeran, & Pilato, 2018). This movement is a global phenomenon but in Europe it has been most apparent in Spain and Italy, but also notable in England and Croatia. Venice is a city that has been a popular tourist cite for a long time and the anti-tourism movement has grown strong there. In an article by Seraphin et al. (2018) the case of Venice is investigated and it is concluded that a forced exit from the tourism industry would not be an option. The impacts on the local economy would be too significant. One suggested way to limit the issues in Venice is to not include the city in any promotion material, and to rethink the role the city has in Italy's Destination Management Plan. This measure was taken by India to preserve the cultural importance of Taj Mahal.

2.1.4 Sustainable Tourism

Tourism is a large sector and therefore has the possibility to contribute to all sustainable development goals either directly or indirectly. It has been directly included in the three SDGs 2030; 8 "Decent Work and Economic Growth", 12 "Responsible Consumption and Production" and 14 "Life Below Water" (United Nations, 2015). Two targets in these goals consist of the ambition to device and implement policies that promote sustainable tourism as well as to develop tools to monitor the sustainable development impacts from sustainable tourism. In goal 14 there is a target to increase the sustainable use of marine resources, and this includes having a sustainable management of tourism.

The UNWTO currently has an ongoing project to develop a tool to measure impacts from sustainable tourism, in line with the target mentioned above. They are developing a framework to measure sustainable tourism to include economical, social and environmental indicators to complement the current statistics, called the Measuring Sustainable Tourism (MST) framework (UNWTO, 2019a). When the framework will be finished is not specified. Right now tourism is often measured in a Tourism Satellite Account (TSA), which aims to quantify the economic contribution from tourism in a country (UNWTO, 2019a). This makes it possible for countries to get standardised comparable data such as tourism contribution to GDP. However, it does not include any other dimension than an economical one.

2.2 Aviation & Climate Change

Worldwide, flying stands for about 60% of all international arrivals, and as the total number of international arrivals are predicted to increase the number of tourists travelling by flight is likewise expected to grow (UNWTO & ITF, 2019). The total CO_2 emissions from commercial domestic and international aviation in 2018 was 918 Mt CO_2 which is about 2.4% of total global CO_2 emissions. 60% of these total CO_2 emissions from aviation come international aviation, the rest from domestic air travel (Graver et al., 2019). Air travel further contributes to global warming in two ways: through direct emissions of CO_2 and through non-CO_2 effects, in which the non-CO_2 effects are more uncertain and will be further explained in this section. The total contribution from aviation on global warming could thus be double than usually estimated due to the non-CO_2 effects (Azar & Johansson, 2012).

2.2.1 Air Travel Emissions

Aviation causes GHG emissions because of the combustion engines, a process where jet fuel is burned to transform the potential energy to kinetic energy used to fly. This process creates CO_2, but it also creates other substances which when released in the upper atmosphere induces Radiative Forcing (RF). RF is essentially the radiation which stays on Earth and does not escape back into space, and is measured in W/m^2 at the top of the atmosphere. It is often used to describe the forcing on the energy budget since 1750, in which aerosols and trace gases affect with a negative or positive RF. The emissions that affect the RF either negatively (-RF) or positively (+RF) from according to Lee et al. (2009) are:

– CO_2 (+RF)
– NO_x (+RF) which is the sum of; tropospheric O_3 (+RF), longer-term reduction in CH_4 (-RF) and longer term reduction in O_3 (-RF)
– H_2O (+RF)
– sulphate particles (-RF)
– soot particles (+RF)

Aviation also causes formation of linear contrails (+RF) and induced contrail cirrus clouds/aviation-induced cloudiness (AIC)(Radiative +RF). All these factors affect the upper atmosphere and is together an addition to the human-induced climate change (Lee et al., 2009).

The non-CO_2 effects are from all other substances than CO_2 mentioned above, including the formation of linear contrails and AIC, which together are uncertain but with heating net effects (Azar & Johansson, 2012). The contribution can be explained by its addition to the RF, but it can also be explained by the Effective Radiative Forcing (ERF), which also includes indirect effects that affect the radiative budget. The latest IPCC report estimates the ERF from contrails and AIC in 2010 to be around +0.05 (+0.02 to +0.15) $Wm^{\breve{}2}$ (Boucher et al., 2013). This non-CO_2 effect from aviation induced by contrails and AIC can be compared to the total contribution to ERF in 2011, estimated to be around +2.3 (+1.1 to +3.3) $Wm^{\breve{}2}$ (Myhre et al., 2013), thus corresponding to about 2-5% of the global contribution to climate change. This is without the inclusion of the CO_2 emissions from aviation, only the non-CO_2 effect.

To make the non-CO_2 effects easier applicable to calculations of CO_2 emissions from aviation it can be translated into an Emission Weighting Factor (EWF) which is the ratio of non-CO_2 effects over the CO_2 effects. The EWF can then be multiplied with the CO_2 emissions to gain an estimate of the real global warming effects of flying, the total climate impact (Grassl & Brockhagen, 2007; Azar & Johansson, 2012). EWF is calculated through the Global Warming Potential (GWP), which is different depending on the time horizon. A longer time horizon gives a smaller EWF and vice versa. EWF can also be put into different intervals due to the large uncertainties, the biggest uncertainty is the effect from AIC (Boucher et al., 2013; Azar & Johansson, 2012). When these uncertain non-CO_2 effects are included, aviation's contribution to climate change can almost double or triple.

2.2.2 Emission Allocation Options

GHG emission from domestic aviation can naturally be allocated to a specific country, since all emissions are released within the country's territorial system boundaries. However, for international aviation the method is not as straight-forward, and there are thus several different ways that the CO_2 emissions from international aviation can be allocated between different countries. These different options can be divided into two main groups, either they have a territorial or consumption system boundary. In table 2.1 the different options are presented.

Nr	Allocation	Sweden's share (Example)
1	No allocation	None
	Territorial System Boundary	
2	Depend on global share from aviation emission proportional to national emissions from all sectors	1.4% $\cdot CO_{2Sweden,2018}$[kg] added to national budget
3	Depend on where bunker fuel is sold	All fuel bought in Sweden
4	Allocation to nationality of transport company/registered vessels/operator	All Swedish registered companies total emissions i.e. SAS, BRA
5	Allocation depending on departure/destination of aircraft, or shared	All emissions within Sweden from departing/landing (or split) airplanes
6	All emissions in the national airspace	All emissions within Swedish borders, even if flying through
	Consumption System Boundary	
7	Depending on departure/destination of passenger/cargo, or shared	All outgoing OR ingoing passengers/cargo to Sweden emission share
8	Depending on country of origin of passenger/cargo	All emission from Swedish exports/residents' trips abroad
9	To country of residency of final consumer (consumption-based)	Leisure trips by Swedes + consumption in Sweden (cargo etc, also business trips where product is consumed/used in Sweden)

Table 2.1: Table of allocation options of international aviation emissions, based on a 1.4% share from international aviation from total man-made CO_2 (Graver et al., 2019). Allocation nr 1-8 based on (UNFCCC, 1996) and nr 9 added from (Larsson et al., 2018).

The method currently used to report to UNFCCC is option 3 in table 2.1, that is the amount of fuel tanked in Sweden (Environmental Protection Agency, 2019c). However, those allocated CO_2 emissions are not included in the national total that are officially reported to be reduced to the UNFCCC. These GHG emissions are instead regulated on an international level through the UN organisation ICAO. In 1999 the special IPCC report "Aviation and the Global Atmosphere" mentioned that only options 1 (no allocation), 3 (bunker fuel sold), 4 (nationality of transport company), 5 (departure/destination of aircraft), and 7 (departure/destination of passenger/cargo) are to be pursued as adequate (IPCC, 1999).

2.2.3 Alternative Fuels

A proposed way to deal with the CO_2 emissions from air travel is through sustainable aviation fuels (SAFs), brought forward from ICAO (2019a) as an important part to reduce future emissions. Alternative jet fuels (AJFs) is considered SAF only if it meets certain sustainability criteria. However, no such definition is agreed upon internationally, only on EU level in the Renewable Energy Directive (RED) (European Environmental

Agency, European Union Aviation Safety Agency, & Eurocontrol, 2019). ICAO did however provide some guidelines in 2019 for SAF, which they request member states to follow. They state that a SAF has to protect biodiversity and ecosystem which are important to humans according to national and international regulations, achieve net GHG emission reduction in its life cycle, contribute to social and economical development and avoid competition with food and water (ICAO, 2019c).

There are a lot of different options and many different processes to produce AJF, but not all are sustainable or even reduces CO_2 in a life-cycle cradle-to-grave perspective where GHG emissions from cultivation, harvesting, transporting and the conversion-process are included (Takriti, Pavlenko, & Searle, 2017). Takriti et al. (2017) also mention that if including direct or indirect land usage change (LUC or ILUC) the uncertainty is even higher, which can make especially oil-based feedstock such as palm-oil even more carbon intensive than conventional jet fuels. A way to create more CO_2 emission reductions in bio-jet fuel could be to use carbon capture and storage (CCS) in the conversion process from biomass, modelled by Wise, Muratori, and Kyle (2017). In their model the use of CCS even gave net negative CO_2 emissions for each unit of bio-jet fuel produced. However, CCS is a technology not yet commercially available mainly restricted by cost, but will be important in overall future GHG emission reduction pathways to reach the 2°C target (Bui et al., 2018).

To produce bio-fuels from lignocellulosic feedstock and waste (grass, wood, energy crops) are a sustainable option, according to Takriti et al. (2017). However, it cannot be produced in enough quantity to fill the needs for 2050. The availability of these stocks also competes with other sectors, both road and non-transport. The maximum amount of available jet fuel of this option is estimated by Takriti et al. (2017) to be around 4 EJ in 2050, while the demand is estimated to be 24-37 EJ. Therefore, it can only fill the need of about 11-17% of the total demand of jet fuel in 2050 in an optimistic scenario for its availability. The cost is also 2-10 times higher than for conventional jet fuel, so commercialisation face problems too, as aviation has a higher price sensitivity than road transport and might therefore not be able to compete (Takriti et al., 2017). On the other hand, Wise et al. (2017) modelled a scenario where the global price for carbon was increased which induced a 50% overall CO_2 emission reduction in 2050 from 2005 levels. Without bio-jet fuels, they concluded that this scenario would only reduce CO_2 emissions from the aviation sector with about 10% compared to a scenario without the carbon price increase, while the energy sectors achieved bigger reductions. The carbon intensity of aviation stayed at a high level in the model, and only a demand drop induced a change in the level of CO_2 emissions. In their scenario with bio-jet fuels and no carbon tax the CO_2 emission mitigation in 2050 was also bigger than without bio-jet fuels and a carbon tax. At such, bio-jet fuel is vital for future CO_2 emissions reduction in the aviation sector, with or without a price on carbon.

To conclude, bio-jet fuels will be important in the long-term future to reduce CO_2 emissions from aviation. But bio-jet fuels also hold a lot of controversy and can in itself not be the only viable short-term solution for the GHG emissions from aviation if the growing demand continues (Takriti et al., 2017). Furthermore, bio-jet fuel does not help against the non-CO_2 effects at high altitude aviation (Stratton, Wolfe, & Hileman, 2011). The climate impact from using bio-jet fuel instead of fossil jet fuel can thus be exacerbated in calculations which excludes the non-CO_2 effect. Nonetheless, in the long-term, bio-jet fuels will be important in de-carbonizing the aviation sector, which also could be especially aided by CCS (Wise et al., 2017). European Environmental Agency et al. (2019) mention that in the near future SAF is likely to be 1% of EU aviation fuel consumption, but policy actions at EU and global level is likely to increase the uptake in the future.

2.2.4 Electrification and Hydrogen

There are also alternative technological and fuel options often discussed to reduce GHG emissions from aviation, namely electrification and hydrogen. Electrification is however currently limited by the energy to weight ratio of batteries and electric equipment. According to Schäfer et al. (2019) electric aviation with future advanced battery technology only has the potential to travel about 1100 kilometre, which is not enough for international trips. To double that distance (2200 kilometres) they write that extensive technological improvements are needed, which might be decades away. Thus, full electric flights for commercial use are still far away in the future (Wheeler, 2016). Nevertheless, if utilised to its potential on shorter distances, Schäfer et al. (2019) predict electric aviation could reduce 15% of global commercial jet fuel use and thus be an important part of a sustainable future. More Electric Aviation is another concept, where e.g mechanical systems such as fuel pumping are replaced by electrical systems, making sure the energy from the jet engine is more efficiently used throughout the aircraft. Newer aircraft models incorporate more electric systems than before, and electrically assisted engines will soon be available (Wheeler, 2016). This hybrid step is mentioned by Wheeler (2016) to provide an important efficiency improvement in the aviation industry.

Rondinelli, Sabatini, and Gardi (2014) investigated the challenges and benefits from liquid hydrogen fuel and found that it could be a sustainable possibility, implementable on an aircraft and airport-level, possibly even improving safety of aircraft. However, the main challenge spotted was the production, distribution and storage of such fuels, as well as support from the public and the industry so it could be financially possible. The challenges with the technological implementation seem bigger than the capabilities of current aviation (Rondinelli et al., 2014). Furthermore, a hydrogen driven aircraft still release NO_x and H_20, which contribute to global warming through the non-CO_2 effects (Khandelwal, Karakurt, Sekaran, Sethi, & Singh, 2013). Such issues would also need to be addressed if hydrogen would be utilised and diffused more.

In summary, electric aviation holds the opportunity to be a marginal solution to reduce GHG emissions in the aviation sector while hydrogen-fuel face bigger, systemic issues and still contributes to global warming. Batteries are too heavy for long-haul flights even with advanced improvements (Schäfer et al., 2019) and hydrogen-fuelled aircraft need new, sustainable production, distribution and storage measures which are both expensive and extensive (Rondinelli et al., 2014). More Electric Aviation will improve the efficiency of aircraft, but still use conventional jet fuels and thus have only limited impacts on GHG emission levels (Wheeler, 2016). At such, this technological option does not in itself hold enough potential to completely de-carbonize the aviation sector. Bio-jet fuels have a bigger potential and will be important in the long-term, but are also dependent on sustainable production methods from biomass (Takriti et al., 2017). It also competes with other sectors such as transport bio-fuels and food land-use, which are cheaper to produce right now and in which bio-fuel has a better opportunity cost (Rye, Blakey, & Wilson, 2010). Without a carbon price or other policy measures, bio-jet fuel diffusion will be limited and its full potential not realised (Wise et al., 2017).

2.3 Policy Instruments for Aviation's Climate Impact

Aviation is difficult to regulate by nature, as it moves between borders and in international airspace. Domestic GHG emissions are allocated to the national carbon budget, and thereby put under national regulations and policies. However, as the GHG emissions from the international aviation are not included in any country's national GHG emissions' budget (see section 2.2.2), the reduction target has been hard to capture. Also, if some countries would impose regulations within its borders there are always a risk of carbon leakage. Some international policies exist both from i.e ICAO and EU, but these together were recently reviewed by Larsson, Elofsson, Sterner, and Åkerman (2019) and deemed not to be enough to reduce GHG emissions to reach the 1.5°C target set by the Paris Agreement. They argued that national policies should complement the international policies to make sure the GHG emission reductions are sufficient to meet the target, at least to be effective in the short term while international policies can evolve. The International Coalition of Sustainable Aviation (ICSA) likewise argues that more measures are needed, and writes in a proposal to ICAO that "This additional mitigation should not only be taken at an international level through ICAO, but also by national and subnational governments." (ICSA, 2019). The existing policies will be explained below, together with other policy options which could be used in the future to reduce aviation's climate impact.

2.3.1 International and EU Policies

International policies are the most effective instruments, as it make sure all companies fall under the same rule and thus carbon leakage is not a risk. However, they are difficult to implement as many different parties need to agree. There is also no decided allocation on national level of the international aviation, as the GHG emissions are not within any country's boundaries, instead the international organ ICAO hold the responsibility for international aviation regulation. They have the main role in reducing CO_2 emissions from international aviation, and develop international standards and recommended practices for air travel (IPCC, 1999). According to Larsson et al. (2019), the most efficient way to reduce GHG emissions would be a global carbon tax on jet-fuel. They argue that it is a feasible option, however it is not a possibility, as some member states in ICAO oppose such a tax. Instead, ICAO is planning to reduce the CO_2 emissions from aviation by a basket of measures, which includes Sustainable Aviation Fuels (SAFs), technology standards, operational improvements and a new market-based instrument: the Carbon Offsetting Reduction Scheme for International Aviation (CORSIA) (ICAO, 2019a). This basket of measures are implemented to meet the aspirational goals of 2% annual fuel efficiency improvement until 2050 and a carbon-neutral growth from 2020.

ICAO's new, market-based policy instrument for international aviation is as mentioned called CORSIA (ICAO, 2019a). The scheme is voluntarily from 2021-2027 in two phases, after that it will be mandatory for all international flights from and to member states in ICAO, with some exceptions for i.e small island developing states. It is designed to offset all additional CO_2 emissions caused by aviation after 2020, by buying "emissions units" that are compensated with CO_2 emission reductions in other sectors. The scheme also assumes efficiency improvements in aircraft achieved through technology standard requirements and diffusion of SAFs (ICAO, 2019a).

The European Union has the EU Emission Trading Scheme (EU ETS), a cap-and-trade system to reduce EU's total CO_2 emissions with 20% by 2020 and 40% by 2030 (European Environmental Agency et al., 2019), aiming for a 90% reduction by 2050 according to the new European Green Deal (European Commission, 2019). EU ETS provides a set number of EU allowances (EUA), which correspond to the right to emit 1 tonne of CO_2, to all sectors who are part of the scheme. Some of the EUA are allocated for free and some auctioned (purchasable from EU), and the EUA are tradable. Since 2013 air travel within the European Economic Area (EEA), which include EU and other states in Europe with economic cooperation, have been part of EU ETS. It was planned to include all flight from, to and within EEA but the inclusion of non-EEA parts was pushed forward to 2023 because of the development of CORSIA. The cap for aviation was 2013-2020 set to 95% of 2004-2006 average which is about 37.5 Mt CO_2. The total CO_2 emissions from aviation have, however, been increasing throughout these years. In the next phase of the EU ETS (2021-2030) the cap for EU aviation allowances will be reduced at a rate or 2.2% per year (European Environmental Agency et al., 2019).

The difference between EU ETS and CORSIA is that EU ETS is a cap-and-trade system while CORSIA is an offset scheme (European Environmental Agency et al., 2019). The cap-and-trade system ensures CO_2 reductions on a system level, by all sectors covered by EU ETS. CORSIA is only offsetting CO_2 emissions by compensation in emission units that are certified, which ensure that one tonne of CO_2 that would have been emitted without CORSIA is avoided. CORSIA's emission units will have to comply with an Emission Unit Criteria, decided on ICAO level. The two systems for reduction are not compatible in some ways, for instance EU allowances are not accepted as an emission unit under CORSIA and CORSIA's emission units will not be accepted under EU ETS from 2021 (European Environmental Agency et al., 2019). This means that if no further agreements are made, airlines in EEA countries will have to both offset their increased emission from 2021 through CORSIA emission units *and* pay for EU allowances that are over the set cap for aviation under the EU ETS.

2.3.2 National Policies

There exist multiple policy instruments to deal with aviation's climate change issues on a national level. For instance, countries can put a tax on jet fuel, have distance-based air passenger tax or quota obligation for bio-fuels (Larsson et al., 2019). Larsson et al. (2019) also mentions the examples: fostering technological innovation, as well as measures such as a "frequent-flyer"-tax in which the tax is increased for each flight, and tradable personal carbon allowances. Another measures could be a bio-fuel tax relief, where flight operators get a relief depending on the share of bio-fuel they use compared to conventional jet fuel (Åkerman, Larsson, & Elofsson, 2016). The option of bio-fuel tax relief is only effective if another direct tax is attributed to the international flights, for example a passenger tax. Åkerman et al. (2016) argues a quota obligation for bio-fuels is more certain, as the bio-fuel tax relief would be optional and therefore might not be used which would lead to difficulties in meeting set reduction goals. Further they mention that a climate declaration for aviation is also a possibility, where the amount of CO_2 emissions is clearly declared and consumers can at such choose less CO_2 intensive options. The climate declaration option however suffers from the same uncertainty as the bio-fuel tax relief, since it does not imply any emission reductions unless consumers choose less carbon-intensive options. However, the climate declaration would provide consumers with the information they need to make a more climate-friendly decision (Åkerman et al., 2016).

The best policy option for bio-jet fuels in Sweden was according to a commission of inquiry by the Swedish government a reduction obligation for jet fuel suppliers (SOU 2019:11, 2019). The reduction obligation enforces less CO_2 per unit of fuel, thus blending bio-jet fuel with the fossil jet fuel. The inquiry writes that the bio-jet fuels emissions should follow the Renewable Energy Directive (RED) which EU uses to define sustainable aviation fuels, where a life-cycle perspective is taken on the fuel's GHG emissions. The strength with this policy instrument is according to the inquiry that it favours low-carbon bio-jet fuels, since a smaller blend is needed to reach the reduction obligation with those fuels. A bio-fuel quota obligation does not have that strength, since high-carbon bio-jet fuels might be cheaper than low-carbon jet-fuels, thus favourable if a specific blend with bio-fuel is required. To enforce that the reduction obligation is followed the inquiry suggests the fuel suppliers are to be charged with a fee if inadequate blending is noticed, significantly larger than the cost of blending in bio-jet fuel.

Another more unusual instrument to reduce the impacts of aviation especially from tourism is through destination-based carbon management. It is done through changing the market composition, and strategic market development (Gössling, Scott, & Hall, 2015). For example, Gössling et al. (2015) explains that this could be done by marketing destinations closer to where a potential tourist is living, so that tourists are coming either with shorter aviation trips or by alternative modes of transport. He also describes that it could be done through simply not marketing a destination in countries far away. Such an approach does not imply the positive effects of tourism is lost, but rather replaced by other market segments, enabling less carbon-intensive growth. The climate benefit of closer destinations from Swedish residents have recently been quantified by Kamb et al. (2020). They concluded that changing to closer destinations when the purpose was sun and bathing had a potential to give a 7-14% cut in CO_2 emissions from total CO_2 emissions from Swedish resident's air travel. If choosing other means of transport such as train or car, the potential was about 30% CO_2 emission reduction (Kamb et al., 2020).

2.3.3 Climate Policies for Carbon Lock-in

When discussing policies to reduce climate change impact, carbon lock-in is a term that describes the current complex system that is locked-into fossil fuel dependency (Unruh, 2002). The co-evolution of technological, social, organisational and institutional factors creates a techno-institutional complex (TIC) with a carbon lock-in, which is difficult to escape. The carbon lock-in creates self-reinforcing barriers that inhibit policy action against the system, and environmental policy makers must thus often mitigate the environmental degradation while also minimising social disruption. Unruh (2002) mention three policy steps which are used to escape a lock-in: 1) End of Pipe (EOP) solution, 2) Continuity 3) Discontinuity. Generally, many climate policies are at the first step, where the system continues as before but mitigation goals are set for the GHG emissions. Some are also on the second step of continuity, where the system stays the same but other incremental innovations are used. The third step is where radical innovations are used, and is a disruption of the whole system.

The third level, a discontinuity policy option needs exogenous forces to be plausible, such as exogenous technological change or institutional change (Unruh, 2002). The technological change is often done through niche markets which can bubble up from below and then induce system innovation (Geels, 2005). However, such a policy approach is insufficient if environmental degradation has a faster pace than technological innovation (Unruh, 2002). Discontinuity can also be realised through institutional change, where society demands change through environmental movements or that the environmental degradation becomes apparent as was the case with the ozone hole in the Arctic. Such a disruption or discontinuity option is more complex and cannot be implemented internally, but are pushed for by exogenous forces (Unruh, 2002).

2.4 Swedish Tourism-related Strategies and Goals

The tourism sector in Sweden is growing, between 2000-2018 the consumption from international tourists in Sweden grew with 255% (Swedish Agency for Economic and Regional Growth, 2019). This is the fastest growing part of tourism expenditures, and the share has risen to be 43% of all the tourism expenditures in Sweden in 2018, in 2000 the share was 27%. In 2018 the turn-over for Swedish tourism was 337 million SEK. Furthermore, Swedish tourism directly contributes to about 2.6% of Sweden's GDP. Sweden has seen an increase in absolute numbers of tourists as a part of the tourism sectors growth, but is not close to experiencing overtourism at the time (SOU 2017:95, 2017).

Næss-Schmidt et al. (2019) recently looked upon the role of flying in the Swedish tourism industry, and found that it plays a big role, especially for international tourism. About 70% of all international trips to and from Sweden could be ascribed to flights and the biggest increase was from non-Swedish leisure travellers which have increased 380% between 2000-2018. It also revealed that from all the passengers in Swedish airports about 71% is leisure travellers, while 29% travelled for business purposes in 2018. Furthermore, according to a commission of inquiry set up by the Government, there is a clear link between the number of direct flight lines and the number of international visitors in Sweden (SOU 2017:95, 2017). The inquiry also brought forward that it is not easy to replace aviation with any other mode of transport. Inbound tourism and aviation's role is thus important for Sweden. There are multiple existing strategies, goals and policies in Sweden that are related to and affect the tourism industry and aviation, which will be presented in this section.

2.4.1 Climate Goals

To contribute to the Paris Agreement, Sweden is aiming to reach net-zero GHG emissions in 2045, with a 63% reduction target from 1990 emissions levels in 2030 (Environmental Protection Agency, 2019a). Net-zero GHG emissions does not mean no emissions at all, but rather that what can be caught in the natural eco-cycle should not be surpassed. The real reduction goal from man-made emissions in 2045 is 85% from 1990 levels (Ministry of the Environment and Energy, 2018). For domestic transport, the goal is 70% reduction from 2010 levels in 2030, not including domestic aviation which are part of the EU ETS. The goals overall does not include the CO_2 emissions already covered by the EU ETS, which have reductions targets on their own. Nevertheless, Sweden strives to be a pioneer country in the efforts to combat climate change (Swedish Department of Finance, 2019).

The goals are a part of the Swedish climate policy framework which was taken into action in 2018, consisting of the climate goals, the Swedish climate policy council and the climate act (Ministry of the Environment and Energy, 2018). The climate act entails that every year in its Budget Bill the government must present a climate report, and in addition each government mandate (every fourth year) must put forward a climate policy action plan on how they are supposed to reach the goals for 2030 and 2045. The climate policy council independently deems if the climate policy action plan and climate efforts are sufficient, and thus if the current climate policies are enough to reach the climate goals (Environmental Protection Agency, 2019a). The latest climate policy action plan was released in December 2019 and the response from the climate policy council came in early March 2020. They concluded that the goals would not be reached with the current actions and that more policies and actions are needed to get back to the right path (Swedish Climate Policy Council, 2020).

2.4.2 Export Strategy

There exist two relevant national export strategies in Sweden, one from 2015 and one from 2019. The Swedish export strategy from 2015 covers in total 22 areas, in which one is directly related to tourism (Government Offices of Sweden, 2015). It states that there should be a specific focus on increasing the amount of visitors to Sweden to make sure to capture the growth potential in the tourism sector. Visit Sweden which is a governmental-owned DMO, got the directives to conduct two measures to achieve this growth. One was to strengthen the marketing of Sweden as a destination for tourism. The second measure was to start making specific campaigns and increase the presence in growing markets such as China and India, as well as increasing the Swedish profile for eco- and nature tourism.

A third measure taken in the 2015 export strategy was to increase the amount of export-ready destinations in Sweden. In 2016 the Swedish government gave this task to the Swedish Agency for Economic and Regional Growth, who already had a project in the area ongoing since 2012, which was continued within the new project (Swedish Agency for Economic and Regional Growth, 2020a). The purpose of both these projects was to increase the attraction of Sweden as a tourism destination internationally, and to have a long-term growth in the tourism industry.

In the more recent export strategy from 2019, it is stated that these three measures from 2015 had given results, as could be seen in the increased amount of tourists that came to Sweden during 2015-2019 (Government Offices of Sweden, 2019). It did only appraise a continual of the growth strategy and provided no further directives. The export strategy from 2019 did however announce that a new strategy for a sustainable and growing tourism industry for 2020-2030 is currently under construction, which will act as a platform for efforts to capture the potential in the industry going forward.

2.4.3 Swedish Commission of Inquiry in Tourism

There is currently no national strategy for how Sweden should work with tourism on a national level. However, in October 2016 the government set up a commission of inquiry of how a common political direction for the Swedish tourism sector could look like (Dir. 2016:83, 2016). The purpose was to give the government a foundation on how to strengthen the tourism sector as an export commodity as well as an employer in the whole nation. The commissions report was released in December 2017. One of their main suggestions was that the government should develop a national strategy for sustainable tourism and propose how such politics should be conducted until 2030 (SOU 2017:95, 2017). In July 2019 the Swedish government took a decision to initiate the work to formulate such a strategy in line with the commission's suggestion (Ministry of Enterprise, Energy and Communications, 2019). However, the commission's report has not been adopted as a whole by the government, and is still under review at the Ministry of Enterprise, Energy and Communications.

The commission also proposed that the government should set up political goals for a sustainable and growing tourism sector, in which it is important to highlight a balance between the three pillars of sustainability: environmental, social and economical aspects (SOU 2017:95, 2017). The significant impact of the transport system in the tourism sector was also discussed in the report. In this discussion the environmental impacts from aviation and the importance of making the aviation sector sustainable as soon as possible was brought forward. Bio-fuels were suggested as one alternative in this, but also market prioritisation. This entails a strategy that focuses on markets closer to Sweden which is less dependent on air travel. However, this option was only mentioned briefly.

2.4.4 Aviation Strategy & Climate Road-map

The Swedish government released a new aviation strategy for Sweden in 2017 (Ministry of Enterprise, Energy and Communications, 2017). The strategy highlights that aviation is important for the Swedish transport system as well as for Sweden as a country. Aviation contributes directly to the Swedish economy by providing job opportunities but also indirectly by enabling quick transports over long distances which is important for tourism and trade. In the strategy it is also mentioned that the state has a goal for air travel to be accessible for everyone, and that they publicly fund certain flight paths not profitable in themselves. The state is also responsible for a base supply of air travel through the state-owned company Swedavia. The aviation sector has been steadily growing the last couple of years, which has increased its contribution to global warming. The aviation strategy from Ministry of Enterprise, Energy and Communications (2017), therefore aims to contribute to making sure that Sweden has a sustainable aviation sector with a decreasing environmental and climate impact, as well as reasonable and fair terms of competition in the sector.

One focus area that is brought up in the report is "Accessibility in Sweden and internationally" (Ministry of Enterprise, Energy and Communications, 2017). In this area, one effort is that state owned tourism and investment promotion actors should support the work Swedavia is conducting in attracting more direct lines, which is based on and mentioned in the export strategy. It is stated that the number of direct lines to Sweden has significant importance for the tourism industry, as well as for the reductions in CO_2 emissions. Another area of focus in the report is "The environmental and climate impact from aviation should be decreased". It is highlighted that the aviation sector must contribute to the goal of Sweden being the first fossil-free country, as well as to the national environmental targets (Ministry of Enterprise, Energy and Communications, 2017). Furthermore, that Sweden should also actuate the work towards effective demands and management control principles in the EU and in ICAO to decrease the environmental impacts caused by air travel.

In 2018 Swedish Air Transport Society presented a road-map to the Swedish Government to reach the Swedish national climate goals, providing a commitment for the Swedish aviation industry to become fossil-free by 2045, and that domestic aviation should be driven by 100% bio-fuels by 2030 (Swedish Air Transport Society, 2018). The road-map constitutes what is needed in policies for the goals to become a possibility, in this bio-jet fuel is brought forward. In result, the Swedish Government Offices conducted a commission of inquiry in 2019 on the policy instruments to enhance bio-fuel for aviation (SOU 2019:11, 2019). In Sweden, airlines such as SAS and BRA already give the possibility to pay for using partly bio-fuels in a booked trip, and also offers climate compensations (Næss-Schmidt et al., 2019). But, such effects are only marginal; more policies are needed to reduce aviation GHG emissions, according to the bio-fuel investigation. The investigation further explains that EU ETS covers 70% of all fuel tanked in Swedish airport, the rest of the flights go outside EEA. The commission of inquiry for bio-fuels propose a reduction obligation for jet-fuel, which would reach about 27% bio-jet fuel blend in 2030. The proposed goal was fossil-free aviation by 2045, both for national and international aviation in Sweden, by utilising low life-cycle emission bio-jet fuel.

2.4.5 Swedish Aviation Tax

In 2018 a Swedish tax on air travel came into effect (SFS 2017:1200, 2017). The process of designing a tax on aviation started in 2015 as it was deemed necessary to meet the CO_2 emission reduction goals. The tax is meant to internalise the cost of the environmental impact that air travel causes (Government Offices of Sweden, 2017). The tax also aims at encouraging consumers to make more environmentally conscious decisions when they choose their mode of transport, which also would decrease the environmental impacts from the aviation sector.

The tax entails that all commercial air travels from an airport in Sweden which is approved to carry more than ten passengers are liable for taxation for its passengers (SFS 2017:1200, 2017). The tax does not include passengers that come to Sweden and continues their travel with the same or a different aeroplane. The tax is distance-based, hence there are three different tax levels and each one is fixed based on the end destination of a passenger. Which country that have which tax level is specified in the law. The tax levels are set at a level that is coherent with other member states in the EU and with considerations that airlines already have to buy emissions allowances as a part of the EU ETS (Government Offices of Sweden, 2017).

Whether the tax has the intended effect on the environmental impact caused by aviation is not evident. An investigation after half a year with the Swedish flight tax showed that compared to the Swedish Transport Agency forecast there was a decrease in passenger numbers in shorter distances, taxed with the smallest tax (Ekeström & Lokrantz, 2019). However, the longer trips on the second and third tax level was higher than the forecast with 3% and 14% respectively. The total decrease in passengers was more than expected, but other effects such as the closing of an airline in 2018 or natural fluctuations in air travel might have had a part in this. The investigation showed that the tax was at least partly responsible for the decrease in passenger numbers, and that it was the first time such a decrease had been visible.

3

Method

The aim of this report is to quantify the climate impact from non-resident travellers to Sweden and constructing future scenarios until 2030. To compile the CO_2eq emissions a quantitative method with multiple formulas was used, and data was retrieved from various data sources. All assumptions made in regards of these calculations are summarized in Appendix II. In the second part of the report multiple future scenarios were created, and an analysis of the climate impact development for each of them was done. The detailed methodology used will be presented in this section.

The GHG emissions from these calculations did not fit into any of the allocation options found in section 2.2.2. Therefore, a new approach was necessary and allocation options that divide the GHG emissions depending on which kind of trip that is in focus were developed. According to the IRTS[1], a trip can either be inbound, outbound or domestic (IRTS, 2008). The allocation option developed specifically for this study was thus that the GHG emissions from inbound international aviation trips by travellers not living in Sweden (non-residents), should be allocated to Sweden. This allocation option has a consumption-based system boundary and is an origin to final destination approach. It includes all non-resident travellers who are coming to Sweden by flight.

3.1 Aviation Climate Impact Calculations

The calculations for finding the amount of CO_2eq emissions from aviation caused by inbound tourism in Sweden was conducted for the years 2014-2018. This was done with a method that follows a standard methodology used for GHG emissions from the transport sector, $G = A \cdot S_i \cdot I_i \cdot F_{i,j}$ in which G is the GHG emissions, A is the total travel activity, S is a vector of the share for each transport mode in I, I is the energy transport intensity for each share i and F is the sum of all different fuels j used for the transport mode i (Schipper & Fulton, 2003). The transport mode is i, which in this report is set only to aviation. At such, A is the total number of passenger-kilometres (p-km) by aviation from the inbound non-residents, S=1 as aviation is 100% of the share, and I and F together results in the CO_2 per p-km. These three components were used to conduct the calculations, but renamed for clarity: Number of inbound non-resident round trips to Sweden $T_{inbound,non-residents}$ [Trips], average distance travelled per inbound round trip d_{avg} $[\frac{km}{trip}]$ and CO_2 per p-km

[1]International Recommendations for Tourism Statistics

E_{p-km} $[\frac{kg\,CO_2}{km}]$. Multiplying these parts gave the total amount of GHG emissions E_{total} [kg CO_2eq] , seen in formula 3.1.

$$E_{total}[kg\,CO_2eq] = T_{inbound,non-residents} \cdot d_{\text{avg}} \cdot E_{p-km} \tag{3.1}$$

This method can also be derived from the Kaya identity, commonly used to calculate CO_2 emissions depending on the economy but most often for a whole country or the world (Andrew et al., 2017). The Kaya identity is visible in formula 3.2.

$$Total\,CO_2\,emissions = Population \cdot \frac{GDP}{Population} \cdot \frac{Energy}{GDP} \cdot \frac{CO_2}{Energy} \tag{3.2}$$

In this report the formula is specified for aviation, whereas the Population is the number of passengers, the Energy/GDP $\cdot$ CO_2/Energy is CO_2 per p-km and GDP/Population is the average distance. Kamb and Larsson (2019) also used the same formula 3.1 to calculate the outbound trips from Sweden, with a method developed by Larsson et al. (2018). It is also the approach used by UNWTO and ITF (2019) in their latest calculations of CO_2 emissions from transport caused by tourism.

In the following sections each component will be presented in detail.

3.1.1 Number of Trips

The number of arriving and departing passengers at Swedish airports with scheduled and non-scheduled international traffic per airport $P_{international}$, was collected from the Swedish government agency Transport Analysis (n.d.). Each passenger represents a one-way trip, and to get the number of round trips the amount is divided in half. The amount of inbound trips by non-residents ($T_{inbound,non-residents}$ [Trips]) was calculated by multiplying the halved number of international passengers $P_{international}$ with the percentage of non-residents $p_{non-residents}$ [%] at each Swedish airport, see formula 3.3. The percentage data was collected from the report by Kamb and Larsson (2019) who had received the numbers from Swedavia directly. The calculation seen in formula 3.3 was done for each airport, and then summarised to get the total amount of round trips.

$$T_{inbound,non-residents} = \frac{P_{international}}{2} \cdot p_{non-residents} \tag{3.3}$$

It is also notable that when calculating the CO_2eq from Swedish passengers travelling abroad, Kamb and Larsson (2019) included Swedish passengers travelling abroad from Kastrup and Gardermoen. They were included as it is common for people who live close to the boarder to travel from these airports. However, this was not included when the inbound trips were calculated. It is assumed that the majority of people travelling to Sweden fly to an airport in Sweden.

3.1.2 Average Distance per Trip

To calculate the average distance travelled to get to Sweden per trip by a non-resident visitor, data on where the tourist travelled from was needed. The data used was retrieved from UNWTO (2019b), who gathers tourism statistics of arrival tourists by country of residence in accommodation establishments. This data was reported to the UNWTO by SCB/Swedish Agency for Economic and Regional Growth. The data introduces uncertainty to the model as it does not include those living at relatives or at Airbnb or similar, only data from commercial accommodation establishments. How large the share of the trips that are left out will be calculated and presented in the results in section 4.1.

The next factor needed was the coordinates for the departure and arrival destination. As the data was not specific enough to show from/to which airport the tourist had travelled, the geographical middle point of the country was used as the coordinates. This does present a source of error, specifically for some large countries such as China and the US. The coordinates for each country were found at `https://www.cia.gov/index.html`.

The average distance between Sweden and the departure country was calculated using the Great Circle Distance (GCD), the standard used by ICAO to report p-km (ICAO, 2009). The formula for finding the distance between (lat1, lon1) and (lat2, lon2) are shown in formula 3.4, where R=6371,01 km, the mean radius of Earth.

$$GCD = R \arccos[\sin(lat1)\sin(lat2) + \cos(lat1)\cos(lat2)\cos(lon1 - lon2)] \tag{3.4}$$

The data of the tourists country of residence from UNWTO (2019b) includes passengers arriving to Sweden with all modes of transport and it was therefore multiplied with the percentage of arrivals that can be derived from air travel. The numbers used can be found in table 3.1. All passengers that come from outside of Europe, or European countries not mentioned in the table, were assumed to have arrived by flight.

Country / Countries	% of guest nights due to air travel
Norway	10 %
Denmark	30 %
Germany	50 %
Netherlands	70 %
United Kingdom, Spain, Italy, Switzerland, Austria, Czech Republic, Poland, Lithuania, Finland, France	90 %

Table 3.1: The table presents the percentage of guest nights at commercial accommodation establishments that is derived from air travel, data adapted from Næss-Schmidt et al. (2019)

To get the average distance the data was weighted by the number of inbound tourists from that specific country. This was achieved by multiplying the percentage of inbound tourists from that specific country with the distance to Sweden, and all these were then summarised to get the average distance. If i is the current country, and there are n countries in total, the percentage becomes p_i = aviation tourists from country i / total inbound aviation tourists. The average distance of inbound tourist d_{avg} [km] was then calculated according to formula 3.5.

$$d_{avg} = \sum_{i=1}^{n} p_i \cdot d_i \tag{3.5}$$

3.1.3 Average CO_2eq per p-km

In the first step of the calculations, the total CO_2 emissions from aviation fuels were calculated. There are two main fuels used in aviation: jet kerosene (*jetkero*) or aviation gasoline (*avgas*). The calculation was done by using data of final consumption $m_{fuel}[kg\,fuel]$ available from IEA (n.d.) and specific kg CO_2 per kg fuel $e_{fuel}[\frac{kg\,CO_2}{kg\,fuel}]$ from IPCC (2006), including both domestic and international consumption. If data was unavailable, trends from existing data was used. The total consumption and kg CO_2 per fuel were multiplied to get the total CO_2 emissions $E_{fuel}[kg\,CO_2]$, see formula 3.6 and 3.7.

$$E_{jetkero}[kg\,CO_2] = m_{jetkero}[kg\,fuel] \cdot e_{jetkero}[kg\,CO_2/kg\,fuel] \tag{3.6}$$

$$E_{avgas}[kg\,CO_2] = m_{avgas}[kg\,fuel] \cdot e_{avgas}[kg\,CO_2/kg\,fuel] \tag{3.7}$$

The next step was to retrieve the CO_2 per p-km. The total amount of kilometres travelled by air globally (total p-km D_{tot} [km]) was needed in the process and it was retrieved from ICAO (2019b), including both domestic and international p-km. The total global p-km also carries freight. Therefore, for a correct CO_2 per p-km, the share of weight that should be allocated to people $p_{m,pass}[\%]$ was needed. This data was retrieved from ICAO (2019b). Notably Kamb and Larsson (2019) also included the share of the fuel used by the military in their method, however this was not included in this report since the IEA statistics allocates military use of fuel under another product than jet kerosene. Formula 3.8 thus gives the kg CO_2 per p-km E_{p-km} $[\frac{kg\,CO_2}{km}]$.

$$E_{p-km}[\frac{kg\,CO_2}{km}] = \frac{(E_{jetkero} + E_{avgas}) \cdot p_{m,pass}[\%]}{D_{tot}[km]} \tag{3.8}$$

A more detailed presentation of the variables and where they were obtained from can be seen in table 3.2.

Variable	Explanation and Unit	Source
E_{p-km}	CO_2 Emission per p-km [kg CO_2/km]	To be calculated
$m_{jetkero}$	Final consumption jet kerosene per year [kg fuel / year]	IEA statistics (IEA, n.d.) 2014-2017, trend 2018
m_{avgas}	Final consumption aviation gasoline per year [kg fuel / year]	Data sheet (Larsson et al., 2018) 2014-2015, trend 2016-2018
$e_{jetkero}$	Specific CO_2 emission per kg kerosene [kg CO_2 / kg fuel]	IPCC guidelines (IPCC, 2006)
e_{avgas}	Specific CO_2 emission per kg aviation gasoline [kg CO_2 / kg fuel]	IPCC guidelines (IPCC, 2006)
$p_{m,pass}$	Percentage of weight from passengers [%]	ICAO annual report (ICAO, 2019b)
D_{tot}	Total p-km world wide [p-km]	ICAO annual report (ICAO, 2019b)

Table 3.2: Table of variables used to derive the CO_2 emissions per p-km and their sources.

Swedish Adjustment

In one direction of the round trip the flight leaves from Sweden, and the specific CO_2 per p-km in Sweden differs from the global average one. Furthermore, international aviation often have a lower CO_2 per p-km due to the more efficient flying in long-hauls. An adjustment for these effects was thus needed, with the country-specific data for international Swedish CO_2 per p-km. A similar method as the one used above was used to calculate the specific Swedish CO_2 emission data from aircraft leaving Sweden, which was also the approach used by (Kamb & Larsson, 2019). This was calculated according to formula 3.9. The data of the total international aviation CO_2 emissions from fuel sold in Sweden $E_{swed}[kg\ CO_2]$ was collected from the Environmental Protection Agency (2019c). This variable was multiplied with the percentage that is allocated to passengers rather than freight $p_{passengers,2017}$ [%], which was only calculated for 2017 and then used as a baseline for all years. These two variables were further divided by the total p-km from international flights $D_{swe}[km]$ with data from the National Transport Agency, but with a trend for 2018 since data was unavailable. The available data on total international p-km from the Transport Analysis were limited to include only the p-km within Swedish air space (Transport Analysis, 2020a).

$$E_{p-km,swe}[kg\ CO_2/km] = \frac{E_{swe}[kg\ CO_2] \cdot p_{passengers,2017}[\%]}{D_{swe}[km]} \tag{3.9}$$

The percentage difference between the global CO_2 per p-km and the Swedish CO_2 per p-km $p_{glob-swe} = \frac{E_{p-km}-E_{p-km,swe}}{E_{p-km}}$ were calculated for the years 2000-2018. Then, the average difference percentage for those years ($p_{avg,glob-swe}$) was accounted for, and the CO_2 emissions per p-km adjusted accordingly for each year, see formula 3.10

$$E_{p-km,adjusted} = E_{p-km} \cdot (1 - p_{avg,glob-swe}) \tag{3.10}$$

Non-CO_2 effects of aviation

Aviation contributes to global warming through CO_2 emissions but also with non-CO_2 effects, these are commonly not included when the climate impact from aviation are presented (see section 2.2.1). Furthermore, exactly how much they contribute are still highly uncertain. In the latest IPCC report these effects were included(Boucher et al., 2013), and therefore they will be included here . It is still debated which EWF[2] should be used when adding the non-CO_2 effect to the CO_2 effects. The intervals that have been used in different reports can be seen in table 3.3 with GWP[3] for 100 years, and including AIC.

Author	EWF Low	EWF "best estimate"	EWF High
Azar and Johansson (2012)	1.3	1.7	2.9
Grassl and Brockhagen (2007)	1.2	1.6 (mean value)	2.7
Lee et al. (2010)	1.9	-	2.0

Table 3.3: Table of EWF estimates

To get a comparable result with Kamb and Larsson (2019), the lowest estimate from (Lee et al., 2010) with an EWF of 1.9 was used. Thus the total CO_2 emissions E_{total,CO_2} [kg CO_2] was multiplied with 1.9 to get the total CO_2-equivalent emissions E_{total} [kg CO_2eq], see formula 3.11.

$$E_{total}[kg\ CO_2eq] = 1.9 \cdot E_{total,CO_2}[kg\ CO_2] \tag{3.11}$$

3.2 Scenario Planning Process

A useful approach for estimating future demand is using expert and official forecasts, but in 2020 the effects from the COVID-19 pandemic made all prior future predictions significantly invalid. Instead, scenario planning for 2019-2030 was conducted, to include the uncertainties in the future projections of climate impact from inbound aviation. Scenario planning is a useful method to consider changes and extremes not often thought about, and captures more possibilities and threats than a conventional forecast (Schoemaker, 1995). This method aided a better understanding of how national strategies and policies are affected by the COVID-19 pandemic and included the uncertainties of the future. International estimates from i.e UNWTO (UNWTO & ITF, 2019), as well as national passenger forecast from the Swedish Transport Administration (Almkvist & Holmér, 2016), both deemed sufficient estimates prior the COVID-19 pandemic were instead plotted as benchmarks.

The scenarios were developed in a five-step process, which is an adapted version of the method explained by Ogilvy and Schwartz (2004) combined with elements from the

[2]Emission Weighting Factor, multiplied to CO_2 emissions to get the CO_2eq from both CO_2 and non-CO_2 effects

[3]Global Warming Potential, used to translate non-CO_2 green house gases to CO_2eq and give the total global warming from all gases

method from Schoemaker (1995). The five-step process can be seen in figure 3.1 and each step will be further explained below. In the figure the process looks linear, but it was an iterative process. The scenarios were developed by the authors of this report, with consultancy from multiple news articles and early predictions made by organisations about the impacts of the COVID-19 pandemic in general as well as on the aviation and tourism industry. No long-term scenario analysis by expert organisation could be found, only short-term such as the economic impact analysis by ICAO (2020a), which was used as an expert baseline for 2020. When no adequate predictions were found, reasonable assumptions were made based on the logic for each scenario. In this uncertain situation, this was often the case. Detailed information about the use of estimates by experts and the systemic view of the impacts will be presented in the results in section 4.2.

Step 1	*Step 2*	*Step 3*	*Step 4*	*Step 5*
Time-frame, System boundary, Variables subject to change	Identify all main factors, Key trends, Socio-technical system	Identify two most uncertain & main driving factors, Form 2x2 matrix with those factors, One scenario per quadrant	Include all main factors from step 2 to step 3 system, Form narratives, Give name to capture essence	Approximate impact on each variable for all scenarios within the time-frame and system boundary, Plot results

Figure 3.1: Methodical five step process to develop future scenarios, adapted from Ogilvy and Schwartz (2004) and Schoemaker (1995)

In the first step, the focal issues that the scenarios will address was determined, as well as the time-frame. The scenarios focus on the development between the years 2019-2030, with the potential impacts from the COVID-19 pandemic on inbound tourism as a main question. Emphasis was put on how these scenarios would impact the main variables that affect the climate impact from aviation caused by inbound non-resident trips to Sweden: average length of a trip to Sweden, number of international trips to Sweden (consisting of both Swedish-residents and international passengers on Swedish airports) and the average CO_2 emissions per p-km.

The second step in the process was brainstorming all principle factors that could influence the development, with a focus on identifying driving forces and key trends in the external environment. The brainstorming was conduced with a system perspective, to include the whole socio-technical system, looking at micro, meso and macro level in a multi-level perspective (MLP) (Geels, 2005). The MLP is described in these three levels, in which meso-level is the current socio-technical regime, forming the rule-set present within the system. The macro-level is the socio-technical landscape which is the wider external environment, and this cannot be influenced by actors directly. The micro-level are niches, developing from a small scale with the possibility to disrupt the whole system. This way of mapping the system is useful since the COVID-19 crisis has opened up the current socio-technical regime and landscape certainties for changes, with possible lingering effects. A socio-technical system is 'locked-in' in multiple aspects (Geels, 2005) and our fossil-fuel dependent society is referred to as being 'carbon locked-in' (Unruh, 2002). A lock-in can possibly change through interlinked exogenous forces. To understand how the future might develop after a force such as a global pandemic, the processes of transitions is important to understand, to be able to understand future developments and create relevant scenarios. As proposed by Ogilvy and Schwartz (2004), the factors found in this step were divided into five main categories; social, technological, economic, environmental and political factors.

In the third step, the factors were further aggregated into which ones that deemed to be pre-determined elements compared to those more uncertain. The ones that were seen as pre-determined are likely to be included in all scenarios and not vary significantly (Ogilvy & Schwartz, 2004). The uncertain variables were looked at more closely, and their degree of uncertainty and importance were determined. The aim of this step was to find two factors that are the main drivers of future development within the scenarios. These two factors formed a 2x2 scenario matrix which made sure that the scenarios are built on different logic in a deductive, non-random way (Ogilvy & Schwartz, 2004).

The fourth step was expanding and developing each scenario by including the factors in step two. This made sure the logical developments in each scenario was explained explicitly. System thinking was also used here to deepen the scenario and create a logic for the underlying patterns of events. Narratives were built based on each scenario to create a start, middle and an ending, providing an effective way to communicate the scenarios. The narratives at such explain the assumptions made for each scenario and how the future develops in that particular logic. A fitting name was also given to each of the scenarios to capture the essence of each one of the narratives, and to make them easily communicated. Making the narratives and names compelling is an important part of scenario creation according to Schoemaker (1995).

In the fifth and last step, the impacts on the three variables; the average length of a trip to/from Sweden, number of inbound trips to Sweden (consisting of both Swedish and international passengers on airports) as well as the average amount of CO_2eq emissions per passenger were approximated and plotted into graphs. Since they were only approximated, detailed calculations were not done, and some simplifications were made to calculate the variables. The calculations of each variable followed the logic of the ASIF method used to calculate the CO_2 emissions between the years 2014 and 2018, which can be seen in section 3.1. However, in these calculations less details for each factor were used. The aim was to look at future trends based on some of the prior results and the scenario narratives rather than giving a precise forecast, thus the simplifications were justified. The main difference in the calculations for the scenarios and the historic results were:

- CO_2 per p-km was not plotted in detail, for example, the total fuel consumption was not looked at in more detail. Trends were only drawn from the CO_2 per p-km from the historic results.

- The Swedish adjustment of the CO_2 per p-km explained in section 3.1.3 were simplified. The historic average adjustment from 2000-2018 were used for all future years (2019-2030).

- Average distance was only based on previous results and approximated trends depending on the scenario, no detailed interpolation of inbound tourism data was done.

- Passengers were not calculated in detail on *each* Swedish airport but calculated as a *total* on all airports.

- The calculations were simplified as the *average* percentage of Swedish residents and of international passengers were used instead of the percentage on *each* airport.

The exact approximation made for each variable in all scenarios will be listed in the result.

The approximations were then put into relation to each other and plotted for all scenarios, to give a final results for inbound aviation climate impact 2020-2030. A final comparison was also added for outbound trips, in which the variables were given the same approximation on the variables but with the outbound results from Kamb and Larsson (2019) as a baseline. This is showed to ensure that no carbon leakage was present in the result from just a shifting demand to outbound rather than inbound trips.

4

Results and Analysis

The results are divided into two parts, first presenting historic aviation climate impact together with the main variables, then followed by the scenarios. Four future scenarios were created in this report and are outlined and thoroughly explained in the latter part of this chapter. The development process of the climate impact, as well as main variables, are also presented for each scenario.

4.1 Historic Aviation Climate Impact

In this section, the results from each main variable are presented, followed by the total climate impact from inbound non-resident air travel. The results are presented in comparison with the outbound trips done by Swedish residents, calculated for 1990-2017 by Kamb and Larsson (2019) with the same method this report uses. The investigation by Kamb and Larsson ended at 2017 and therefore the variables from outbound trips in 2018 was also calculated. The data that was accessible for 2018 was thus also used for outbound travel, retrieved at the same sources as Kamb and Larsson. If the data was inaccessible a linear trend from the available data was used instead.

4.1.1 Resulting Number of Trips

In figure 4.1 the number of round trips to Sweden is visible between 2000 to 2018. The longer time interval for round trips is provided to give a longer perspective on the historic growth trend. There was a stable increase for both inbound and outbound trips from and to Sweden during this time. The temporary decreases that are visible matches with global historic drops in passenger numbers, mainly due to the 9/11 terrorist attack in 2001 and the global financial crisis in 2008. Both of these events have a well-documented impact on the global air travel according to IATA (Oxley, 2017).

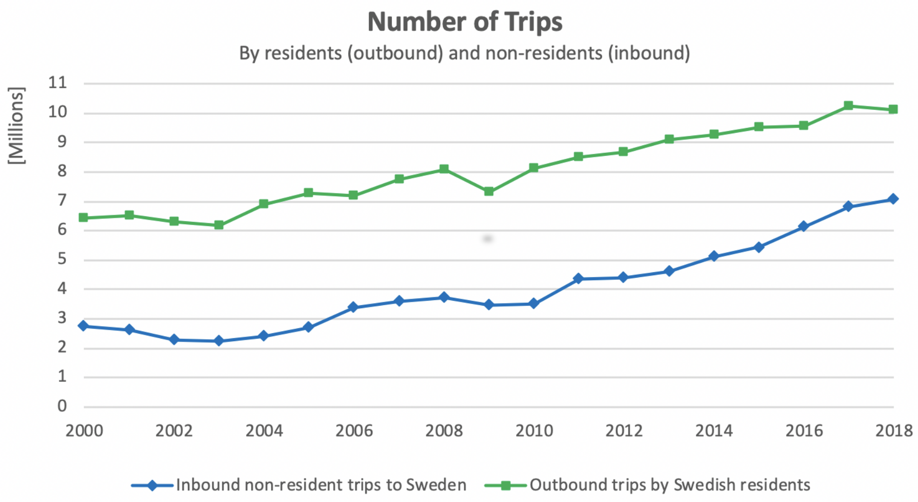

Figure 4.1: Number of international round trips by non-residents and Swedish residents (data based on Kamb and Larsson (2019) and from Transport Analysis (2020a))

The number of inbound round trips by non-residents increased overall with 156% between 2000 and 2018, with an average annual increase of 5.4%. The overall increase of outbound round trips during the same years was 57% which equals to an average annual increase of 2.5%. This means that the inbound trips by non-residents grew with a yearly rate more than double as high as the outbound trips increased. This trend is also visible between 2014-2018 which is the years investigated in this report. The growth between 2014 and 2018 for inbound trips is 39% and 9.1% for outbound trips, with an average annual increase with 8.5% and 2.2% respectively. This means that the yearly growth of inbound trips is almost the same rate as the total growth for outbound trips 2014-2018. The background for the increase is two-fold, the total number of non-resident passengers in Swedish airports since 2000 has increased and the share of non-residents on the airports passengers has simultaneously increased.

The inbound trips increased the last 10 years 2009-2018 with a growth rate at 8.3% per year, which can be compared to the annual growth rate of total international arrivals which the last 10 years has been about 5% (UNWTO, 2020). The number of inbound trips to Sweden is thus growing faster than the number of international arrivals world-wide.

4.1.2 Resulting Average Distance

The distance for both inbound and outbound trips is shown in figure 4.2. The average distance for inbound and outbound trips have both been stable between 2014 and 2018, as well as on the same level. It has stayed around 5 300 km during the time period presented (2014-2018). This suggests that Swedish residents on average fly the same distance to their destinations as non-resident travellers travel to get to Sweden. This seems reasonable as air travel connections to Sweden enables travelling to Sweden conveniently from those areas, and reversely enables trips by Swedish residents to those areas. If the flight path includes several transfers or is otherwise inconvenient, the willingness to travel to that destination is reasonably less tempting than for a convenient, direct flight path. This logic works in both directions, thus both for inbound and outbound travel.

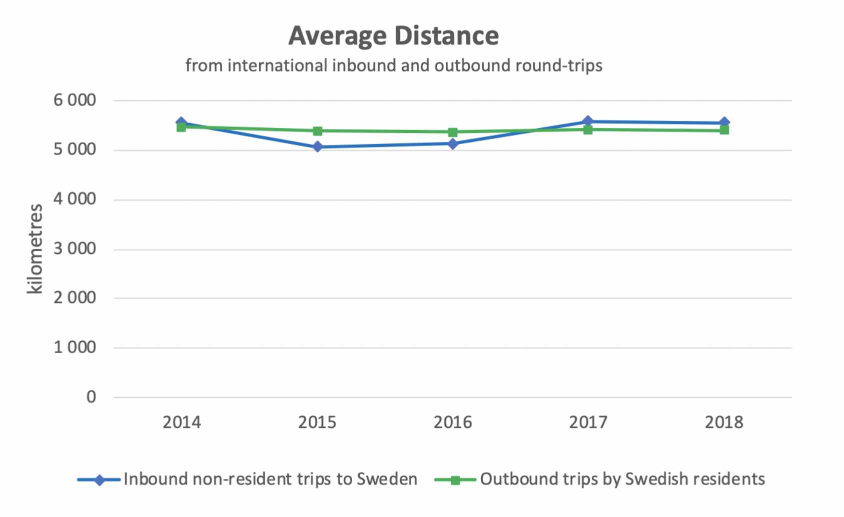

Figure 4.2: Calculated average round trip distance from non-residents in kilometers, compared to outbound trips from Swedish residents with data based on Kamb and Larsson (2019)

The graph shows the average distance for a round trip to a destination, and to give the number a context, a one-way trip to Greece is about 5 200 km and a trip to South Africa is about 20 300 km.

4.1.3 Resulting Average CO_2eq per p-km

The average CO_2 per p-km and CO_2eq per p-km from 2000-2018 is visible in figure 4.3, which is the same for both inbound and outbound trips. The yearly average efficiency improvement in CO_2 per p-km was 2.8% between 2000-2018 and 1.7% per year 2014-2018 according to the results. The efficiency improvements have thus been declining in later years. The overall improvement was a reduction of 40% 2000-2018 and 6.8% 2014-2018.

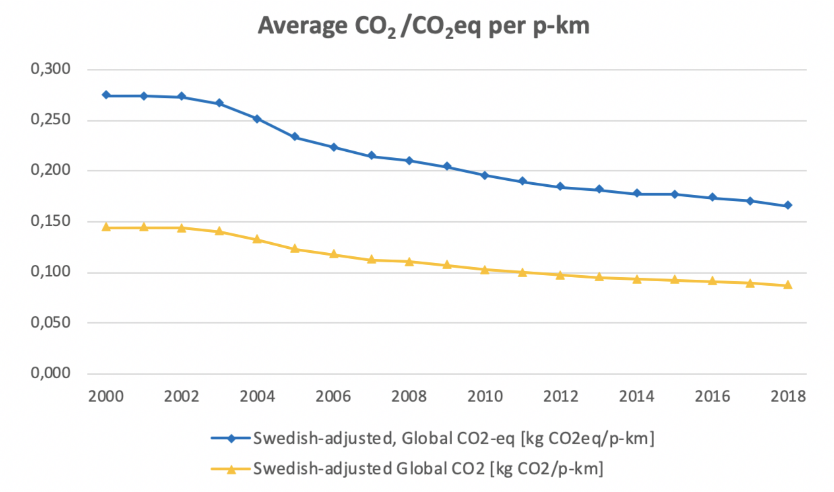

Figure 4.3: Calculated adjusted global CO_2 per p-km

The results for CO_2 per p-km in figure 4.3 (bottom line, yellow) includes the Swedish adjustment of the kg CO_2 per p-km. The mean percentage of the difference between Swedish kg CO_2 per p-km and global CO_2 per p-km between 2000-2018 was about 14%, which was deducted from the global CO_2 per p-km. The resulted Swedish-adjusted global CO_2 per p-km is visible in the figure. The result is thus a bit lower than the global CO_2 per p-km. The non-CO_2 effect was added to the CO_2 per p-km by an EWF of 1.9, resulting in the upper line (blue) in figure 4.3. In the final calculation of total climate impact from aviation the CO_2eq per p-km will be used, to get the total climate impact and not only CO_2 emissions.

To verify the results they can be compared with global CO_2 per p-km estimates from UNWTO. UNWTO and UNEP measured the kg CO_2 per p-km in 2005 to be 0.129, and in the results for 2005 it was 0.144 kg CO_2 per p-km without the Swedish adjustment. Similarly, for 2016 UNWTO and ITF computed the CO_2 emissions to 0.1042 kg CO_2 per p-km, which is close to the 0.107 kg CO_2 per p-km calculated in this report. This means the results in this report is 12% bigger in 2005 and 3% larger in 2016 compared to UNWTO estimates. Since the 2014-2018 data is the one utilised in the final results a 3% variance is deemed acceptable.

4.1.4 Total Climate Impact

The total climate impact from inbound non-resident travellers to Sweden can be seen in figure 4.4. Between 2014-2018 the total climate impact from inbound non-residents went from 5.1 Mt CO_2-eq in 2014 to 6.5 Mt CO_2-eq in 2018, an increase of 29%. Yearly the increase was about 6.7%. The climate impact for outbound trips have stayed more stable and have reached almost the same level in 2018 as it was in 2014 with a 2.6% growth or an average at 0.5% per year. This difference in growth rates between inbound and outbound climate impact is considerable, the inbound climate impact has increased ten times more than the impact from outbound trips.

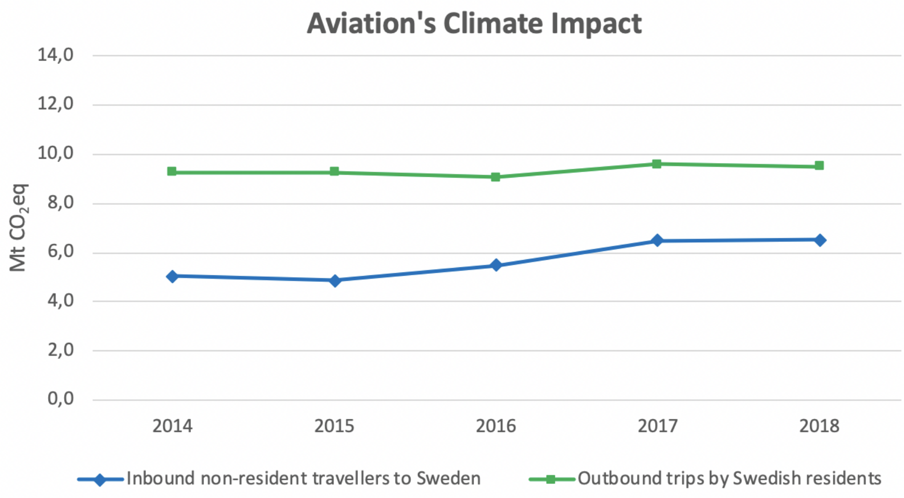

Figure 4.4: Calculated total climate impact in Mt CO_2eq from inbound trips by non-residents, compared with outbound international trips by Swedish residents (data based on Kamb and Larsson (2019))

The main source of the growth of the inbound non-resident tourism is the growing number of inbound passengers, since the average distance has only been growing marginally, see figure 4.1 and 4.2. If the trend would continue further the climate impact from outbound travel would surpass the impact from inbound travel in the near future.

4.1.5 Data Uncertainty

The main data uncertainty in these calculations is the UNWTO data used to calculate the average distance, based on arrivals at accommodation establishments. The average distance for inbound round-trips was calculated from the number of arrivals of non-resident tourists to accommodation establishments by country of residents, which is reported to the UNWTO. However, when collecting these numbers the Swedish agency for Economic and regional growth has a list of 41 countries that are displayed in the statistics as resident countries and all other countries are marked as "not specified" (Swedish Agency for Economic and Regional Growth, 2020c). Almost all countries in Europe are on the list, as well as most other well-populated countries that are large inbound tourism markets for Sweden. However, the number of tourists where the origin is reported as "not specified" have increased, from 16% of the total arrivals in 2014 to 24% of the total arrivals in 2018. This is a large increase, and as most countries in Europe is already on the list of the 41 countries it suggests that these tourists come from countries further away. If this is the case, the average distance travelled to Sweden would have increased more between 2014 to 2018 than what is displayed in the results. Some of the countries was also unspecified only to a region, and not possible to include either. Therefore, the distance that has been calculated only covers about 81% of all the reported arrivals in 2014 and 76% in 2018. This suggests an uncertainty in the data, but it is deemed sufficient as it represents a majority of the origins. Of the countries or more specific regions included in the data set, close to 100% of the data is used in the calculations.

Another weakness in the average distance is that it does not include tourists and visitors that stay at their friends and relatives or in Airbnb. According to Svenska Dagbladet, a Swedish newspaper, Airbnb had 490 000 guests in 2017 and 650 000 guests in 2018 (Amorelli, 2019). Airbnb also states that one in four guests at Airbnb accommodations in Sweden, are Swedish residents (Airbnb, 2019). This entails that in 2017 there were 367 500 non-resident guests and in 2018 there were 487 500. This equals to 6.8% respectively 8.3% of the total number of arrivals that were counted with to get the average distance. Thus, those trips would not have had a significant impact on the average distance, and it is acceptable that they are not included. The distance that people travel when they stay at their relatives or friends is not included either, as information regarding these travellers were not possible to retrieve. Furthermore, the statistics on arrivals at establishments double-count a tourist if this person stays in two different hotels during the trip, since it is reported from each establishment as a new arrival. At such, there is a risk of double-counting, especially risky for tourists travelling from afar, who are more likely to stay longer and visit several cities during their stay. However, altogether the trustworthiness of the scope of the data used to get the average distance is sufficient for the aim of this report.

The average distance could also be skew due to the usage of GCD between the geographical mid-point in the tourists resident country and Sweden, and not specific airports. Limited by the data availability such more detailed calculations was inhibited. Furthermore, this entailed that transfers were excluded. UNWTO and ITF (2019) draws an example between South America and Europe, which on average is 10 000 km. With a transfer in North America that distance is 50% more, 15 000 km. Therefore, the method could underestimate the CO_2eq emissions due to an underestimation of the average distance. The global international air travel distance including transfers, was by UNWTO and ITF (2019) estimated at 4 104 km in 2016 from trajectory data, which is higher than the calculated average distance both from Kamb and Larsson (2019) and in section 4.1.2 (2 565 km and 2 683 km respectively). The average of inbound trips to Europe was however smaller, at 3 332 km in 2016 (UNWTO & ITF, 2019). The total climate impact results for both inbound and outbound trips are thus possibly underestimated.

One overall issue connected to the data was to ensure that all data points related to the same group of people conducting a trip; travellers, visitors, tourists, other travellers etc. The calculated average distance covers tourists in Sweden that stay in accommodations, and the passenger statistic include everyone that travels to Sweden, the broader scope of travellers. These groups overlap but are not entirely the same. This is something that most likely does not affect the end results to a large extent, and it is the reason the calculation's focus has been put on all travellers and not tourists directly.

4.2 Future Scenarios to 2030

This section will first present the results from each step in the process of building the scenarios, following the adapted process based on Ogilvy and Schwartz (2004) and Schoemaker (1995), explained in the method (see section 3.2). After this, each scenario will be presented as a narrative that incorporates how they will affect the variables, followed by the plotted results and the resulting climate impact scenarios until 2030.

4.2.1 Development of Scenarios

In the first step, the focus and timeline for the scenarios were determined. In late 2019 the COVID-19 first appeared in China due to a novel coronavirus, and it spread in Europe and Sweden early 2020. Therefore, the major effects COVID-19 had in Europe become visible first in 2020, and as preliminary data for 2019 was accessible these were used. The scenarios will thus mainly focus on the years 2020-2030, and how the COVID-19 pandemic impacts the future inbound trips and tourism to Sweden.

The second step was to identify major factors and trends that could impact the future. This step required systems thinking, for example taking the carbon lock-in of the system into account. The carbon lock-in is a concept coined by Unruh (2002) which shows that the current system is lined with path dependencies. The factors were identified through reading available scientific articles, economic impact assessments from i.e IATA and ICAO, and following different newspapers to further try to understand the common social worries and the general public discussion. The results of this process and a system view on tourism and impacts of COVID-19 are presented below, including all aspects of a socio-technical system, including niches, regime and landscape level in an MLP (Geels, 2005). The main factors are also summarised in table 4.1 where they are divided into the five categories; social, technological, economic, environmental and political impacts.

Current System, COVID-19 Impact

The global trends in tourism have been increasing international passenger numbers as well as an increased average distance, trends that were expected to continue (UNWTO & ITF, 2019). This growth in tourism is due to many factors, but one main reason is the increased wealth globally leading to higher disposable incomes and increased leisure time. The liberalisation of aviation with Open Skies agreements such as the single market for aviation in Europe from 1990 (European Commision, 2020), as well as the fact that air travel has become 60% cheaper the last 20 years (IATA, 2018), have further resulted in aviation being more commercially available worldwide. In prior crises such as the SARS, MERS and Financial Crisis 2008, tourism and travel have been a resilient sector. Passenger numbers have fast jumped back in a V-shape growth in a short period of time (B. Pearce, 2020a). However, as B. Pearce (2020a) explain the MERS and SARS crises were never followed by a global economic depression, which is likely in the COVID-19 pandemic.

There are several smaller trends or niches in tourism that has been growing stronger with the environmental movement, such as staycations, eco-tourism, community-based tourism, slow tourism and responsible tourism (Thorson et al., 2019; Responsible Travel, n.d.; The International Ecotourism Society, n.d.). All these niches started as movements against the negative impacts that tourism can have on the planet and society. In aviation instead "flygskam" (direct translation flight shame) is another environmental movement, to stop flying to save the climate (Hook, 2019). How these niches and new behaviours will develop after the crisis is not clear, it is likely that whether sustainability is in focus or not in the recovery measures will be a large influence in which direction the development evolves. Regardless, how travel behaviour changes with the crisis will inherently impact the tourism industry. Another factor that is deemed likely to influence future travel behaviour is the perception of security and risk of travelling. Many tourists got stuck in countries far away when the pandemic hit (Bouvin, Lindholm, & Eriksson, 2020), and this may make them hesitant towards travelling far away again. The impact this factor has can increase or decrease depending on how long the COVID-19 pandemic will go on and what kind of measures that are taken to ensure safety for tourists. EU wants to restart tourism and open borders, and thus released a tourism and travel package in May, with a plan to gradually open up tourism within Europe from the 15th of June 2020 in a safe way (European Commission, 2020b). However, if this will play out as planned is not yet certain, as much can happen before then.

The measures taken to reduce the spread of the COVID-19 virus has resulted in closed borders and lock-downs of cities all over the world (UNWTO, 2020a). When the virus spread and its severity became apparent, nations worldwide took nationalistic decisions to combat the virus, thinking firstly about themselves, some ignoring the directives from UN intergovernmental organisations such as the World Health Organisation (Buranyi, 2020). If this tendency will continue, it will impact which kind of measures that will be taken in the future, and how the situation develops. The globalised world and travelling is also one of the key reasons why the pandemic could spread worldwide so fast (Gössling, Scott, & Hall, 2020), which makes it a factor that can strengthen nationalistic measures. If a nationalistic political direction is continued, closed borders and restrictive travel agreements might be a reality. This would have a direct effect on tourism, as it would be difficult or impossible to travel to these countries. These kinds of measures, that are a reality today and have only been in place for a few months, have already had a huge impact on the tourism and travel sector. For how long these kinds of measures will be deemed necessary will also depend on possible treatments for COVID-19, as well as the timeline for the development of antibody tests, immunity tests and a vaccine.

The economic impacts of the COVID-19 pandemic are also deemed to be massive. The global economy is expected to decrease sharply with 3% this year which is a significantly larger decrease than during the 2008-2009 financial crisis (International Monetary Fund, 2020). In Sweden, the GDP has been projected to decrease 4.2% in 2020, with a worst-case scenario of a 10% decline (Swedish Ministry of Finance, 2020), nevertheless resulting in a recession. However, there is also a risk that the crisis will have long-term effects, even resulting in an economic depression. Already now unemployment has increased substantially in many parts of the world, and the unemployment in Sweden is projected to become 9-13.5% (Swedish Ministry of Finance, 2020). Sweden, as well as other countries, have launched multiple economic emergency packages to avoid the substantial impacts on the economy (B. Pearce, 2020a). Closing down whole countries has had a large impact on not only the movement between the countries but also the global trade.

The aviation and tourism sector have so far been largely affected by this crisis, and at the moment tourism can be seen as non-existent due to closed borders and stay-at-home directives. Furthermore, airlines have struggled the last couple of years which have left them with liquidity issues, resulting in that a typical airline only has funds to last about two months (B. Pearce, 2020a). This entails that there is a risk of airlines going out of business if they are not saved by national rescue packages. Furthermore, many businesses in the tourism sector are small businesses which neither have large funds to back them up in a crisis, which means they are also at risk of bankruptcy (Gössling et al., 2020). On the other hand, small businesses have the ability to be innovative and adapt, which is highlighted by the UNWTO when they launched the competition "Healing Solutions for Tourism Challenge" (UNWTO, n.d.) where they encouraged anyone to send in disruptive ideas to combat the effects COVID-19 has on tourism. However, how long the crisis and closed borders last will have a large impact on the progress in the liquidity issues in the tourism sector, since many companies are directly missing their revenue stream. It will have a major influence on how fast the sectors can recover, if all the business go bankrupt before nations open up again from lock-down measures and social distancing. This would also entail there a longer start-up period than if society is opened up sooner.

How the environmental impacts from the tourism and aviation sector develop is impacted by tourism behaviour and norms, but also by technological improvements. Such as, technological developments that enhances the fuel efficiency in aeroplanes together with operational improvements. However, this is limited to about 1.37% per year in the coming years until 2050 according to ICAO (2019a), UNWTO and ITF (2019) estimates 1.9% per year 2016-2030. If passenger numbers grow faster than that, total CO_2 emissions would still increase. The COVID-19 impacts could also mean that fewer choose to fly, leading to operational disadvantage as load factors is lessened, and thus more CO_2 per p-km. The rules in the EU travel package also highlight that aeroplanes should have social distancing, which would entail that lower load factors are to be expected (European Commission, 2020a). However, improvements and more use of bio-jet fuels as well as more electric aircraft might have the possibility to decrease the CO_2 emissions until 2030 regardless how the passenger numbers and load factors develop. How fast these kinds of developments happen could be dependent on which focus that is put on sustainability after and during the crisis. That is if sustainability measures will be paused to enable faster catch-up growth or whether sustainability measures will be enforced even stronger. The Paris Agreement is in effect, and has been ratified, but it is uncertain if it will be enforced when a global recession is imminent. The recovery path could impact travel behaviour but also the pressure put on actors to develop sustainable ways of travelling, steering environmental laws and climate goals in that direction. The urge to get back to business-as-usual is strong as it is also a path-dependency, and especially now that oil is extremely cheap (Oilprice.com, n.d.). But, there are voices that are talking about a green recovery and that governments should not bail out fossil heavy industries without including environmental conditions (Harrabin, 2020). All factors are summarised in table 4.1.

Category	Factors
Social	Tourism norms (weekend trips, global travel, social status etc), Perception of security/risk of travel, Lockdown and social isolation effects, Community perception, Media coverage
Technological	Fuel efficiency development in aircraft, Bio-fuels, Electric aircraft. COVID-19: Vaccine, Tracking, Antibodies test, Immunity test, Research discoveries
Economic	How long the crisis lasts, Recession/depression following, Economical emergency packages, Liquidity for airlines/tourism industry, Global trade
Environmental	Environmental laws and goals (Paris Agreement), Sustainability a recovery focus or not, Carbon lock-in
Political	Nationalism or Globalisation (cooperation), Path dependencies, Governments reaction to pandemic, Tourism prior resilience to crisis

Table 4.1: Main factors that influence the development of tourism after the COVID-19 pandemic, divided into five categories as proposed in the methodology by Ogilvy and Schwartz (2004).

Narrowing Down

Out of the factors in table 4.1 only two were chosen, in line with the third step in the scenario process which was to select the two most uncertain factors that are the main drivers for the development in all scenarios. The two chosen are "How long the pandemic lasts" and "Globalisation vs. Nationalism". The first factor was chosen due to that it repeatedly became an important contributor that made each factor in table 4.1 alter direction. Therefore, if the timeline for when the pandemic is over changed, the future seemed to change accordingly, and almost no factor listed would be the same. How long the pandemic lasts shows how fast the economy recovers from the crisis, and how long-lasting the consequences will be. It is a factor deciding when the overall society will come back to a new normal, when the market is less volatile and when uncertainty is back to normal levels. This factor is important especially for travel and tourism since both these are time-dependent; a trip can be postponed but then it is not the same trip. The revenue-streams for hotels and air travel are temporal in nature, and once lost they cannot be recovered, since the time period is lost. Hence, for how long the pandemic and the measures taken to combat it continues, is vital for the travel and tourism industry.

The second factor was chosen as it shows whether globalisation will continue in the pace it did before the pandemic, or if it will change direction with more closed borders and less global cooperation. Furthermore, this variable also alters the direction of most of the variables in table 4.1, but it is not necessarily dependent on how long the pandemic will last. There has been a stable move towards international cooperation and globalisation for a long time, but as the COVID-19 pandemic hit many nationalistic decisions were made by countries worldwide. This is of major importance for the tourism industry, as of now 100% of all countries have some kind of travel restrictions (UNWTO, 2020a), and without them being lifted the possibility for international travel is lost. Since the spread of the virus is in different stages around different countries it is also uncertain when it can be considered safe to travel again. Domestic markets are expected to recover first, and the EU is trying to restart local travelling this summer (European Commission, 2020a). Whether globalisation and international cooperation continues is thus a factor that will have a large impact on the development in the tourism sector, as open borders are a prerequisite for international travel.

These two factors create the scenario matrix shown in figure 4.5, where each quadrant represents one of four scenarios. These are: Resurrection, Tourism Depression, Staycation and Tourism Redefined.

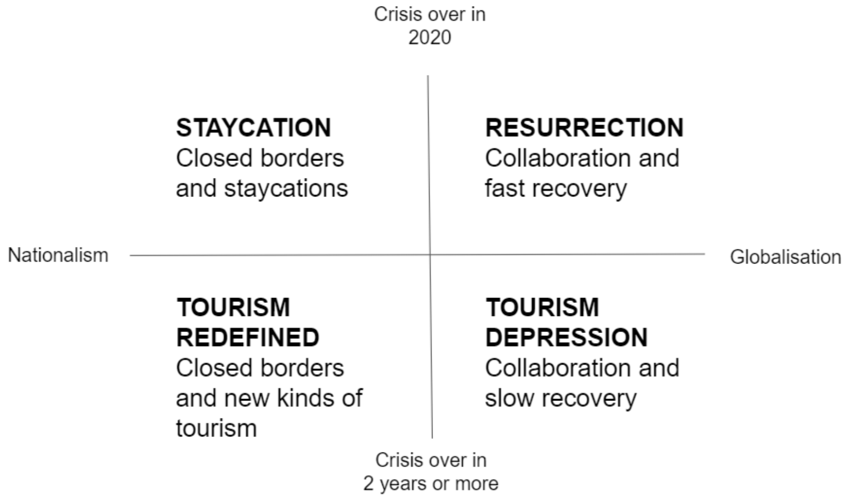

Figure 4.5: Four different future scenarios for the years 2020-2030

4.2.2 Narratives & Approximation

In the fourth step the scenarios were deepened and a narrative around them created. These were then outlined to give an overview of the effects each scenario have on the variables; the average length of a trip to Sweden, number of inbound trips (international passengers and share of Swedish combined) and CO_2 per p-km which all together gave the total climate impact from inbound trips.

The fifth step were also incorporated, whereas approximations for each variable are presented together with the narratives. From the narratives each variable can be approximated from 2020-2030, seen in tables 4.3-4.6. The numbers are only approximation to give a trend, following each narrative's assumptions. When it was possible the approximations are supported by published preliminary estimates from some organisations. The early estimates for number of passengers together with updated estimates can be seen in table 4.2. All organisations highlight the uncertainty of the situation, and that new adaptions are being made as the situation progress. These estimates were used as baselines for the passenger approximations. The latest impact reports are also deemed to be the lowest that the drop in international passengers at Swedish airports can go, thus enhancing the certainty of the passenger estimates for the year 2020. Planes still went as scheduled in January-February, thus a decline lower than 80% in 2020 is deemed impossible for international aviation to and from Sweden. The other variables have not yet been further analysed by experts, and will thus be approximated by the authors following the narrative logic and utilising trends from the historic results in section 4.1. The specific numbers in table 4.3-4.6 are only approximations to highlight trends and should not solely be analysed in detail.

Authority	February-14 March	15 March-15 April	16 April- 8 May
UNWTO	1-3% loss of international tourist arrivals (UNWTO, 2020b)	20-30% loss of international tourist arrivals (UNWTO, 2020c)	58-78% loss of international tourist arrivals (UNWTO, 2020d)
IATA*	Sweden: -7% best case scenario, -24% worst case scenario (IATA, 2020)	-38% RPK** global, -46% RPK Europe (B. Pearce, 2020a)	-48% RPK global, -55% RPK Europe (B. Pearce, 2020b)
ICAO	*Only regional/country specific estimates*	37-47% reduction in seats offered (ICAO, 2020b)	44-80% drop in international passengers or 39-72% drop in seats offered (ICAO, 2020a)

Table 4.2: Estimations of loss in international passenger numbers for 2020 by official authorities, by publication month.
**IATA estimates include domestic aviation as well.*
**Revenue Passenger Kilometres.*

Scenario 1 - Resurrection

The first scenario is named resurrection as it is a scenario where international tourism is re-born after the crisis. The pandemic is over in 2020, and a vaccine is developed and distributed within a year. This entails that the economy can recover quickly, helped by the extensive emergency packages Sweden as well as EU have set up. This will enable a back to business-as-usual approach to the crisis and the growth is larger in the aftermath, catching up to the levels that were expected before the crisis. A major economic depression is therefore avoided and the development continues as was expected before the crisis.

The resurrection is also true for the tourism industry, as people want to travel as soon as possible, and even more than normal to make up for the missed trips during 2020. Tourism is a resilient sector which has survived crises before, as it does in this scenario. Therefore, the number of passengers on airports has a major dip in 2020 as aeroplanes are stranded for a period of time. However, since the crisis is over quickly planes start going again when demand quickly jumps back, following a V-shape curve 2020-2023 followed by a steady growth. The percentage of Swedish residents at Swedish airports follows the declining trend from before the crisis, as more non-resident travellers continue to come to Sweden in a faster pace than Swedish residents go on more international trips. The global CO_2 per p-km goes down as before, as improvements can continue, and planes are filled even more in the aftermath of the crisis. The average distance follows the trend between 2015-2018, with only a minor dip in 2020 since only shorter trips were available for a period of time.

International passengers	Average distance inbound trips	CO_2 per p-km	Share of Swedish residents
• -60% in 2020* • +50% 2021 • +30% 2022 • +10% 2023 • +3.5% per year 2024-2030 (according to trend 2015-2019)	• -20% 2020 • +10% 2021 • +3.2% per year 2021-2030 (according to trend 2015-2018)	-1.74% per year (follow trend 2014-2018)	Follow trend from existing historic data

Table 4.3: Approximation for each variable in the Resurrection scenario, based on the assumptions in the narratives.
**2020 passenger numbers based on UNWTO and ICAO 60-80% passenger drop estimate, see table 4.2*

Scenario 2 - Tourism Depression

Tourism depression is the scenario where the pandemic continues to spread for a long time, and the lock-down of citizens and the economy continues. Globalisation is still sought, there is still a will to travel, but it is not possible for a number of years in the deep crisis. There is a major economic depression that follows the COVID-19 pandemic which slows down the economic activity for the whole decade, however recovering a bit by 2024 and onward as the world learns to live with the COVID-19 and the risks of other pandemics. Travelling abroad is limited until 2022 at the earliest, and during 2020-2021 even travelling within the country is restricted. This entails that the number of aviation passengers drops substantially in 2020 and only starts to recover in 2024, following a U-shape curve. Small increases in 2021-2022 is also apparent when travel agreements are made between countries that make sure travel between them is safe, and that there is no risk that the pandemic will blossom up again.

The CO_2 per p-km first increases, when only essential trips are made where aeroplanes are not always fully loaded, but then goes back quickly. Some airlines go bankrupt before the rebound in 2024, and only profitable flight connections exist in a smaller number of airlines, still ensuring that long-distance trips are possible when the price is right. The big boom comes in 2025 when investments become available again and stranded planes can take to the sky once more. The average distance also decreases for a couple of years since trips to close locations is the norm at start, but it will increase as the perceived and real safety of travelling is increasing and with the big economic boom. The trend toward less Swedish residents on airports continues but at a slower pace, as tourism in general has become less common internationally as well. After a few years, in about 2024, the economy starts recovering slowly as the COVID-19 depression starts to come to an end. Also, the Tourism Depression ends as the tourism habits present today slowly becomes the norm again, substantial growth following in 2025-2026 but then more slowly for the rest of the decade.

International passengers	Average distance inbound trips	CO_2 per p-km	Share of Swedish residents
• -80% 2020* • +15% 2021 • +5% per year 2022-2023 • +15% 2024 • +30% 2025 • +40% 2026 • +20% 2027 • +5% per year 2028-2030	• -30% 2020 • -5% 2021 • +4% per year 2022-2024 • +25% 2025 • +2% per year 2026-2030	• +2% 2020 • +1% 2021 • +0% 2022 • -2.5% per year 2023-2025 • -1.74% per year 2026-2030 (follow trend 2014-2018)	Declines 1% per year 2020-2024 and 2% per year 2025-2030

Table 4.4: Tourism Depression scenario approximation for each variable, based on the assumptions explained in the narrative.
**2020 passenger numbers based on UNWTO and ICAO 60-80% passenger drop estimate, see table 4.2*

Scenario 3 - Staycation

The third scenario, Staycation, entails a scenario where the COVID-19 pandemic is over in the end of 2020. However, borders remain closed and countries turn inward into the community spirit, fuelled by the unity created during the crisis and fear for another pandemic. The Swedish economy recovers slowly with the help of extensive national emergency packages. To benefit local businesses and travel domestically becomes the new norm. During the crisis people tried this other way of travelling and formed new habits because of it, resulting in lasting effects. Also, the environmental movement takes advantage of this momentum and further promotes the development of travelling closer to home.

Some still travel abroad, by air, but they do not go as far as before. The fear of becoming stranded in a country far away where there is no sufficient healthcare if a new pandemic hits makes people travel closer to their home. How the globalised world made the virus spread to such extent has made some world leaders question the phenomena of globalisation altogether. Many turn inwards and start securing the national security and growth, prioritising it over global interests. This results in a drop in international passengers in 2020 which jumps backs a bit in 2021 because of some business trips being reinstated, but then decline as international leisure travellers decrease. The average distance of air travel is reduced as trips are mostly made to locations within Europe, where the community sense somewhat continues. The CO_2 per p-km goes up for some years as more demand is expected than is realised, but then starts to drop again as only air travel that is profitable remain, leading to higher load factors once more. As short distance trips become the new norm, the possibility to exchange travel mode also grows, which is another factor that decreases the passenger numbers on flights. More people choose to travel by car as it is seen as safer and more flexible than air travel if a new crisis would happen.

International passengers	Average distance inbound trips	CO_2 per p-km	Share of Swedish residents
• -60% 2020* • +20% 2021 • +10% 2022 • -2% per year 2023-2030	• -50% 2020 • +10% 2021 • +2% per year 2022-2030	• +2% per year 2020-2021 • +1% per year 2022-2023 • -0.5% per year 2024-2030	Goes to 50% 2020 then declines 2% per year

Table 4.5: Staycation scenario approximation for each variable, based on the assumptions explained in the narrative
**2020 passenger numbers based on UNWTO and ICAO 60-80% passenger drop estimate, see table 4.2*

Scenario 4 - Tourism Redefined

Tourism Redefined is a scenario where the COVID-19 pandemic is not contained for many years, and an economic depression follows. Nationalism grows as it becomes important to benefit local businesses and Swedish jobs, and the fear of the outside world is enhanced. With the major depression many people cannot travel and need to save money even longer before it is possible to go on a trip. Furthermore, people are afraid of a new pandemic which makes them not want to travel far away, even if they could. Therefore, tourism as we know it today never recovers.

This entails that air travel passengers decline even after the virus is contained. This is the case both for Swedish residents and international passengers, and the share of Swedish residents at Swedish airports is stable for all years. Growth to rebuild the society is focused on other areas than tourism, since just a few tourists come to Sweden and Swedish residents do not travel abroad. CO_2 per p-km rises quite similarly to the Staycation scenario, but then more rapidly decreases again as aviation's demand is so lessened and many airlines go out of business. Average distance rapidly declines and then stays at the same level, since only necessary trips remain throughout the years. Furthermore, tourism and travelling takes on a new meaning, during the crisis people got used to fulfil the same needs that they used to fulfil with travelling, in other ways. Therefore, the concept of tourism will be reformed completely.

International passengers	Average distance inbound trips	CO_2 per p-km	Share of Swedish residents
• -80% 2020* • +10% 2021 • -5% 2022 • -3% per year 2023-2030	• -50% 2020 • 0% 2021-2030	• +2% per year 2020-2021 • +1% per year 2022-2023 • -1% per year 2024-2030	Goes to 50% 2020 and stays there.

Table 4.6: Tourism Redefined scenario approximation for each variable, based on the assumptions in the narrative
**2020 passenger numbers based on UNWTO and ICAO 60-80% passenger drop estimate, see table 4.2*

4.2.3 Plotted Scenarios

The approximation for each variable in tables 4.3-4.6 gives the results which are plotted in this section. Each variable is also presented together with forecasts made prior to the COVID-19 crisis, to give a comparison to what was predicted from relevant authorities such as UNWTO and the Swedish Transport Administration.

International Passengers at Swedish Airports

In figure 4.6 the international passengers at Swedish airports have been mapped out for the different scenarios. All scenarios start from 2020, since data from 2019 was available through Swedish Transport Agency (2020). The following approximated trends exist for each scenario, listed in tables 4.3-4.6:

– Resurrection scenario: Drops 60% as per the May predicament by UNWTO (2020d), recovers with 50% growth in 2021, 30% 2022, and 10% 2023, then grows 3.5% until 2030

– Tourism Depression scenario: Falls 80% 2020 as UNWTO (2020d) worst case and ICAO (2020a) worst case scenarios, jumps back a bit in 2021 with 15% growth, then only grows 5% per year 2021-2023, starts really growing at 15% 2024 followed by increase by 30% 2025, 40% 2026, easing down 2027 at 0% and then 5% per year until 2030

– Staycation scenario: Declines 60% 2020 as the Resurrection scenario, recovers 20% 2021 and 10% in 2022, followed by a decline at 2% per year until 2030

– Tourism Redefined scenario: Drops 80% 2020 just as the Tourism Depression scenario, recovers just a bit with 10% 2021 but declines 5% 2022, then declines at 3% per year 2023-2030

According to figure 4.6 the number of passengers will not recover to expected levels before the crisis in three out of four scenarios. The drop in 2020 is severe in all cases, ranging between a 60-80% drop the whole year. A 60% drop means that international passenger numbers at Swedish airports corresponds to 1996 level, and an 80% drop corresponds to international passenger numbers not seen since long before 1990. Only in the Resurrection scenario the growth is almost in line with what was expected before the COVID-19 pandemic, with passengers number back on 2019 levels in 2026. The Tourism Depression scenario clearly has an increase in 2025 that is due to the depression finally turning around, whereas it surpasses the number of international passenger in 2010 in 2029. It also catches up and surpasses the Staycation scenario with the growth spurt.

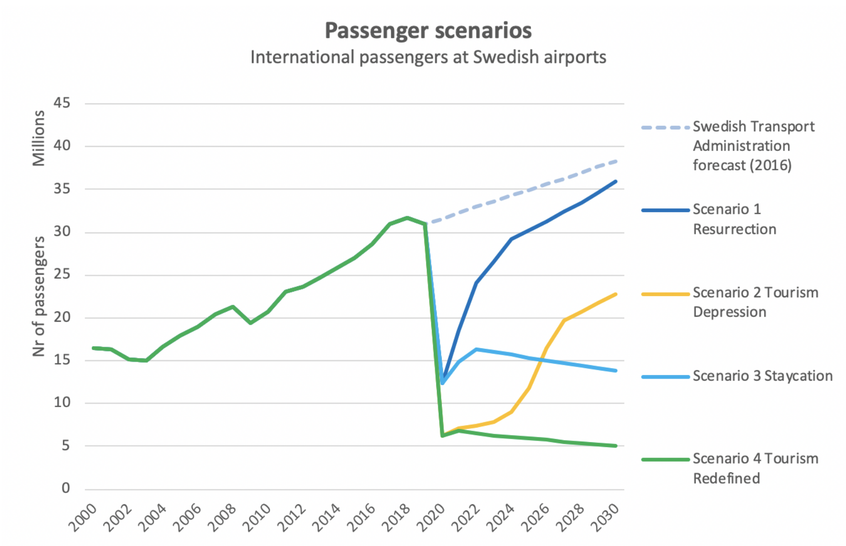

Figure 4.6: Scenario for total international passengers at Swedish airports (both Swedish residents and non-residents) compared with pre-Coronavirus forecasts from Swedish Transport Administration and Swedavia (Almkvist & Holmér, 2016; Thelin, 2019)

Share of Swedish passengers

The following approximated trends exist for each scenario, listed in tables 4.3-4.6

- Resurrection scenario: Follow linear trend of average from years where data is available from (Kamb & Larsson, 2019)
- Tourism Depression scenario: Declines 1% per year 2020-2024, and 2% per year 2025-2030
- Staycation scenario: Goes to 50% Swedes in 2020, declines 1% per year 2021-2030
- Tourism Redefined scenario: Is stable at 50% 2020-2030

The Swedish share of international passengers at Swedish airports in the three scenarios can be seen in figure 4.7. The share is diminishing in all scenarios, somewhat following the trend since 2010. The share of Swedish residents of all international passengers at airports is an average from all airports, a simplification made compared to the historic results which used the share for each airport.

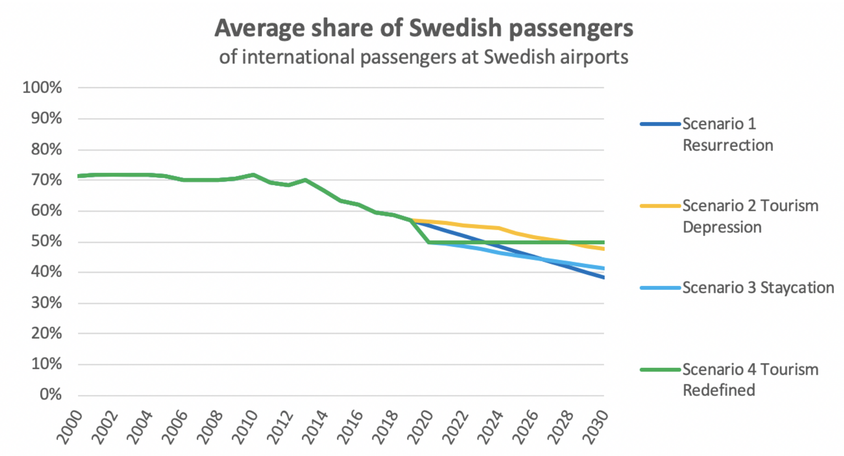

Figure 4.7: Average share of Swedish passengers of all international passengers at Swedish airports for each scenario

CO_2-equivalent per p-km

The CO_2-equivalent per p-km scenarios are presented in figure 4.8. The following approximated trends exist for each scenario, listed in tables 4.3-4.6

– Resurrection scenario: Declines 1.74% per year 2020-2030 according to trend in historic data 2014-2018 (see results section 4.1.3)

– Tourism Depression scenario: Increases 2% 2020 and 1% 2021, then stays level 2022, followed by a steady decline of 2.5% per year 2023-2025 then declines 1.74% per year following historic trend 2014-2018

– Staycation scenario: Grows 2% per year 2020-2021 and 1% per year 2022-2023, then declines slowly at 1% per year

– Tourism Redefined scenario: Grows 2% per year 2020-2021 and 1% per year 2022-2023, then declines slowly at 0.5% per year

The increase that can be seen in the Staycation, Tourism Depression and Tourism Redefined scenarios is due to the assumption that the load factor (amount of passengers filling the plane) is lessened due to the recession and general decreased demand to fly, while the planes are designed to carry more passengers. However, the share allocated to passengers and not goods is estimated to be the average of 2009-2018, that is 83.7%, in all scenarios.

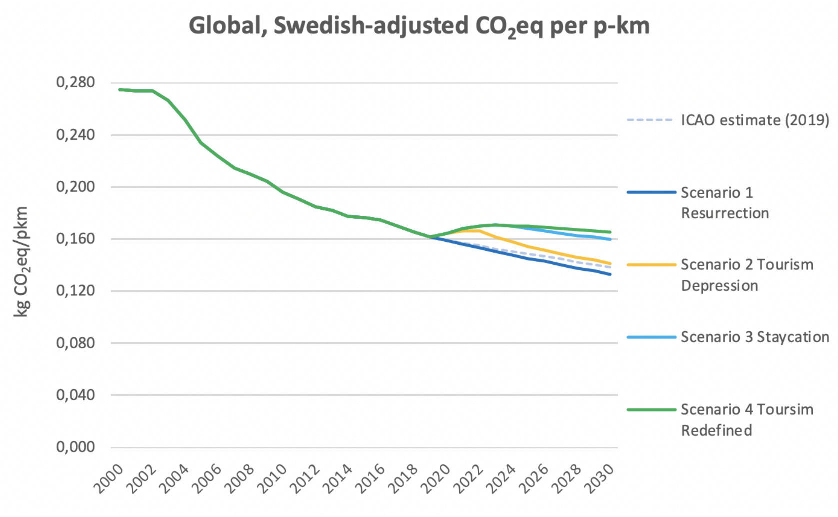

Figure 4.8: CO_2 per p-km scenarios compared with the efficiency estimates from ICAO (2019a) at 1.37% per year

Average Distance

In figure 4.9 the average distance for inbound round trips is shown. The following approximated trends exist for each scenario, listed in tables 4.3-4.6

– Resurrection scenario: Drops 20% 2020, recovers with 10% growth in 2021, then grows 3.2% until 2030

– Tourism Depression scenario: Drops 30% 2020 and 5% 2021, then increases slowly at 4% per year 2022-2024 followed by a 25% recovery in 2025, then 2% per year 2026-2030

– Staycation scenario: Declines 50% in 2020 and somewhat recovers 10% in 2021, then grows at 2% 2022-2030.

– Tourism Redefined scenario: Drops 50% 2020 then stays at the same average distance until 2030

The UNWTO and ITF (2019) forecast for travel distances by air is also displayed in the figure, with an annual growth rate inbound to Europe at about 163 km per year. This is the forecast before the COVID-19 pandemic and Resurrection or Tourism Depression scenarios would be the ones most likely to go in that direction. However, this UNWTO data is based on trajectories including transfers, as is not the method used for the average distance calculation done in this report (see section 3.1.2). Therefore, the distances in this forecast is naturally significantly higher than the scenarios. However, the growth rate is possible and relevant to compare with.

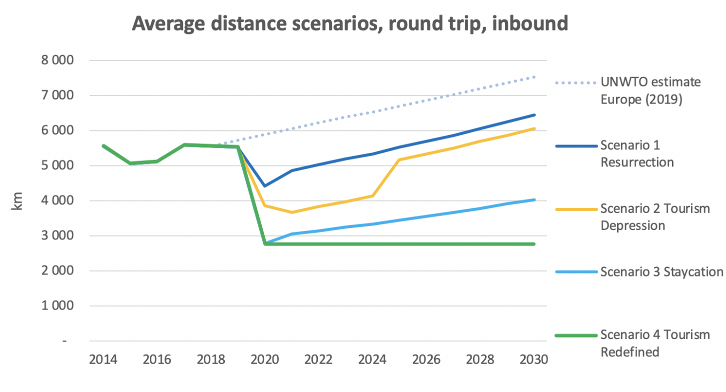

Figure 4.9: Average inbound distance for round-trips in each scenario

Total Climate Impact, All Scenarios

Combining the number of international passengers at Swedish airports and the share of non-residents at airports, with the CO_2eq per p-km and average distance, gives the results of total CO_2eq emissions for inbound non-residents trips for each scenario, seen in figure 4.10. Since the method for the share of passengers were simplified, the results for 2014-2018 was somewhat distorted, and the more detailed results was thus 9-16% higher than the corresponding numbers in figure 4.4. What can be read from the scenarios is that there is an increase in climate impact in the Resurrection scenario with 60% from 2019, in the Tourism Depression scenario the impact decreases with 19% while in the Staycation scenario and the Tourism Redefined scenario the climate impact decrease substantially with 63% and 92% respectively.

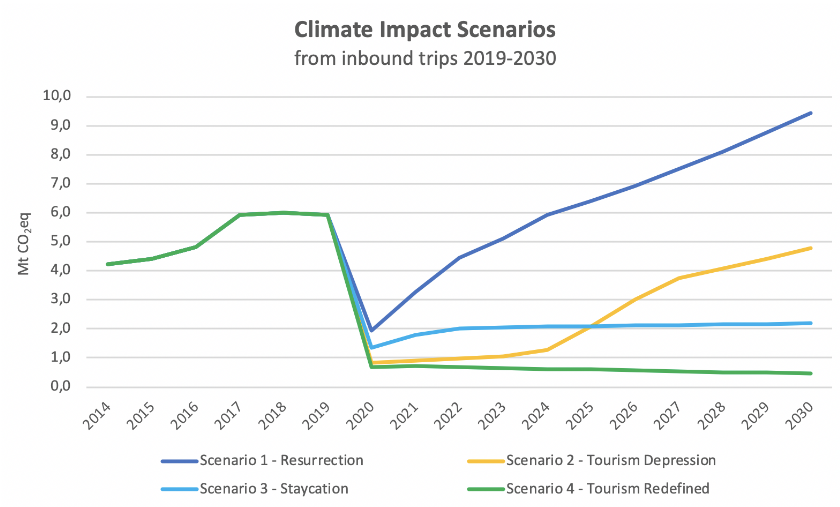

Figure 4.10: Four scenarios for the total inbound climate impact 2020-2030

Expanded Scope, Inbound and Outbound Climate Impact

For a holistic perspective the scope can be expanded to include outbound climate impact. The outbound scenarios used the same approximations as the inbound (passengers at

Swedish airport, share of Swedish residents on airport, CO_2 per p-km), with the average distance being the only difference. The average distance for outbound trips have the exact same approximations (in percentage) as the inbound, but adjusted with outbound distance data from Kamb and Larsson (2019), with the resulting graph visible in figure 4.11.

The outbound average distance approximations which the graph was drawn from are:

- Resurrection scenario: Drops 20% 2020, increases 10% 2021, then from 2022 and onward it follows the linear trend from 2013-2017 as if no drop had happened
- Tourism Depression scenario: -30% 2020, -5% 2021, +4% per year 2022-2024, +25% 2025 and then +1% 2026-2030
- Staycation scenario: Declines 50% 2020, then up 10% 2021, followed by 2% increase per year 2022-2030
- Tourism Redefined scenario: Drops 50% 2020 then neither grows or declines 2021-2030

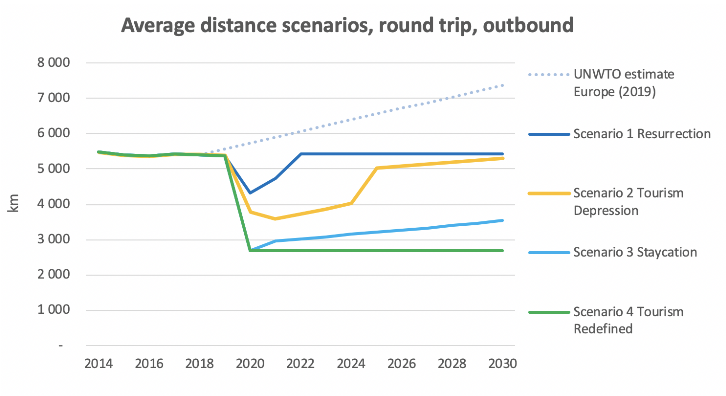

Figure 4.11: Outbound distance in each scenario

The expanded scope is seen in figure 4.12, which gives an overview of the total future climate impact scenarios from both inbound and outbound trips to and from Sweden. This highlights the overall increase in climate impact in each scenario from all international travel to Swedish airports, to give a holistic perspective. The magnitude is naturally bigger than when looking at only the inbound climate impact scenarios. It can also be noted that for all scenarios the inbound allocated climate impact is larger than the outbound climate impact in 2030. The bigger share is mainly due to the larger share of non-residents of all international passengers at Swedish airports. Note that the CO_2eq emissions are in the same positions as in figure 4.5 to give a comparable image.

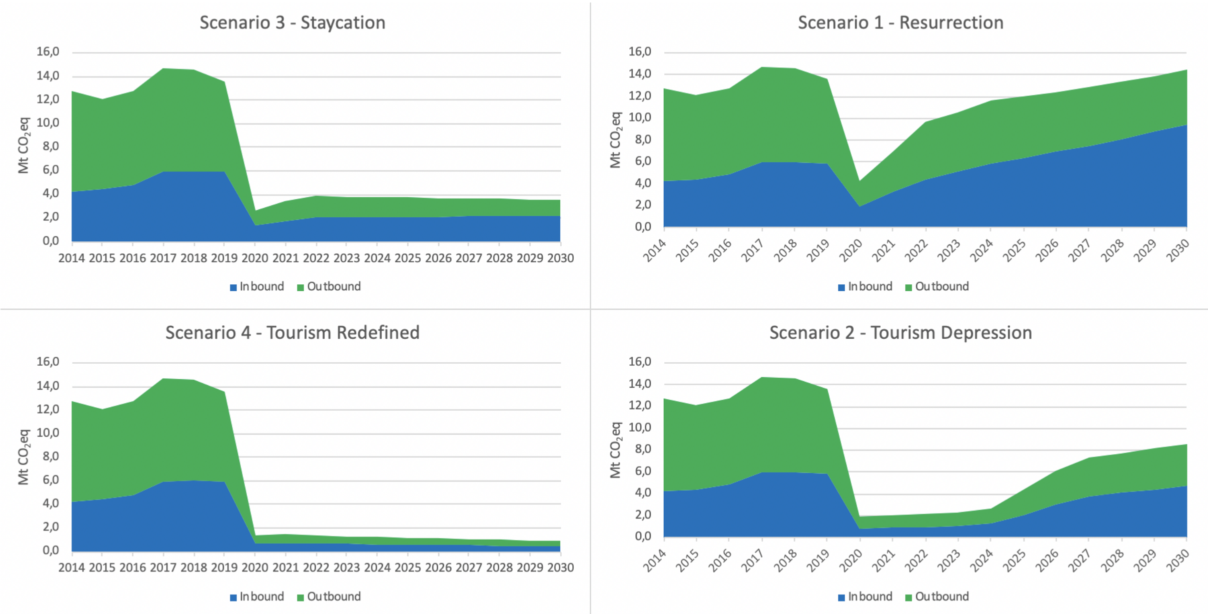

Figure 4.12: Four scenarios for the total inbound and outbound climate impact 2020-2030, where share of emissions become apparent

To put the total inbound and outbound future climate impact in perspective it can be compared to the Swedish climate goal and the carbon budget the goals entail in 2030 for domestic transport in Sweden. The goal for domestic transport for all transport modes excluding domestic aviation is to reach a 70% decrease in CO_2eq emissions in 2030 from 2010 levels (Ministry of the Environment and Energy, 2018), as mentioned in section 2.4.1. Using available Swedish official GHG emission data from Environmental Protection Agency (2019b), the total carbon budget for domestic transport can be calculated. The calculation is simply multiplying 0.3 with domestic GHG emissions in 2010. The result is that the maximum carbon budget for domestic transport in 2030 is 6.1 Mt CO_2eq. The Resurrection scenario climate impact in 2030 for inbound and outbound trips reaches about 14.5 Mt CO_2eq. This means that the international air travel climate impact with the inbound and outbound allocation could be more than double the climate impact from domestic transportation in Sweden by 2030 in a Resurrection scenario. Even the climate impact solely from inbound non-resident trips are larger than the domestic transport carbon budget in 2030 in the Resurrection scenario. The inbound trips' climate impact equals 9.5 Mt CO_2eq and are thus 50% bigger than the carbon budget for domestic transport in Sweden. For the Staycation scenario, the climate impact in 2030 is 3.5 Mt CO_2eq, which is about half of the domestic transport carbon budget in 2030. Notably, the calculated climate impact does not include domestic air travel, only international air travel. Putting the GHG emissions in relation to the future domestic transport carbon budget shows that without limitations or policies for the climate impact from Swedish inbound/outbound international air travel it will be considerable.

Since international air travel is also affected by the EU ETS and CORSIA system these should also be regarded when analysing this result. These systems would make sure the increased CO_2 emissions would lead to a decrease or abatement of CO_2 emissions in other sectors or places, but those are not plotted in the graph or quantified further in this report. Also, whether the effect from these measures will be enough is debatable. CORSIA will only offset CO_2 emissions above 2020 levels (which will be adjusted for 2019 levels or otherwise changed (European Regions Airline Association, n.d.)) which would only in the Resurrection scenario actually induce offsets, but only after 2028 when the combined outbound and inbound climate impact reach 2018 levels. EU ETS is stricter, having the goal of 2.2% smaller cap each year 2021-2030 (European Environmental Agency et al., 2019). However, until 2023 EU ETS only covers about 70% of all fuel sold in Sweden, since many flight goes outside EEA (SOU 2019:11, 2019). Whether these 30% will be covered by EU ETS after 2023 is unclear, and with CORSIA in its recent form being insufficient, especially after the drop in GHG emissions 2020, there will be a gap. Larsson et al. (2019) looked at the residence-based (outbound) CO_2 emissions, and calculated with forecasts that CO_2 emissions with EU ETS and CORSIA together only meant a 0.8% yearly reduction of CO_2 emissions while at least -2% per year is needed. If non-CO_2 effects were included the climate impact would even increase each year, according to Larsson et al.. The results from Larsson et al.'s study is mainly applicable to the Resurrection scenario, where outbound trips have the same emission level as the forecast by 2030 in Larsson et al. (2019). In the other scenarios exactly how the policies will respond is unclear, and whether EU ETS will include international aviation outside EEA in 2023 will also matter.

5

Discussion

A discussion regarding the results and methodological choices made in this report are presented in this section. The implications of the results on policy options, the tourism definition, future climate impact reductions and Swedish national tourism strategy is also discussed. Lastly, a discussion of how the COVID-19 pandemic might impact the tourism and aviation sector in the future is also presented.

5.1 Main Findings

The climate impact from inbound travellers was calculated in this report to answer the first part of the first research question, "What is the climate impact from aviation due to inbound non-resident travellers to Sweden 2014-2018 and in different scenarios until 2030?". The most interesting finding in these results is that the climate impact from inbound travellers has increased significantly with 29% between 2014-2018, and the growth outpaces the impact from international trips made by Swedish residents, which had a 2.6% increase between 2014-2018. This is an important finding not previously explored.

The difference discovered between inbound and outbound travellers enhances the importance of the findings. As the climate impact from inbound trips has increased by a higher rate than outbound trips, to achieve an absolute decrease in climate impact both kinds of trips need to be considered. Currently, this is not the case in Sweden as the focus has mostly been on Swedish residents' travel habits in the medial debate. Today, the Swedish resident's aviation climate impact calculated by Kamb and Larsson (2019) can even be found on the official CO_2 emissions from aviation web page on the Swedish Environmental Protection Agency website (Environmental Protection Agency, 2019c). However, while the interest in this climate impact have increased, the inbound trips and climate impact by non-residents have not received the same attention, even if they have increased at a higher rate. To only focus on residents' climate impact can be reasonable if all nations utilised that allocation approach. In a consumption-based allocation method with a resident-approach such as Kamb and Larsson (2019) used, the CO_2 emissions from a country's residents aviation trips falls under the resident country's responsibility. The country has the possibility to exert some control over these emissions and can implement policy instruments that affect them. Therefore, it is reasonable to assume that the CO_2 emissions from inbound tourists to Sweden is accounted for by the resident country of that tourist, and therefore should not be considered by Sweden. Hence, a focus on limiting only the residents air travel is justified with this allocation. However, the authors argue that this rhetoric falls short-handed. As Sweden is working proactively towards meeting climate targets in the Paris agreement and to stop global warming before it increases the global temperature with more than 1.5°C, this report suggests a wider scope of responsibility. Furthermore, the expanded responsibility might not be needed if every country took responsibility for their country's residents aviation CO_2 emissions, but such is not the case today. Moreover, Sweden is actively trying to increase the inbound tourism by aviation as outlined in section 2.4, which means the expanded allocation for inbound trips is a useful measure to decide whether the inbound tourism is on a sustainable trajectory.

Four scenarios were also presented in the results and used to show possible futures for inbound air travel and its climate impact until 2030, thus answering the second part of the first research question. The scenarios provided a wide range of the magnitude of future climate impact, which is reasonable as the future is uncertain. The four scenarios are supposed to be used to show extremes in scenarios going forward, to quantify the uncertainties of the situation. It is not possible or the aim to say which one is more likely to happen than another, neither to look at specific data points in the scenarios. It is important to note that any new crisis can alter the recovery paths, and new technological breakthroughs or regulations can also change the CO_2 emissions course. If it becomes apparent that the CO_2 emissions start to rise again as in the Resurrection scenario, there is a possibility for nations and international coalitions to act early and ensure that the climate impact from aviation stay on lower levels. However, as previously discussed in the results, these measures must be stronger than the current policies implemented. The combined efforts from EU ETS and CORSIA pathway is not enough to meet the Paris agreement target in a Resurrection scenario, as supported by Larsson et al. (2019).

5.1.1 Climate Impact Reduction Options

There are three ways to directly decrease the climate impact from aviation. To decrease the distance travelled, the number of passengers or the CO_2eq per p-km. The CO_2eq per p-km can be reduced mainly in two ways: to improve the fuel efficiency of aircraft or to switch the fuel used. Looking at the Swedish aviation strategy and export strategy, explained in section 2.4.2 and 2.4.4, there is no focus on limiting inbound travellers or distance travelled. However, a goal to reduce CO_2 emissions from aviation is brought forward in the aviation strategy, and there is also a mission to attract more direct flight lines to Sweden. In the strategy it is also argued that direct lines to Sweden reduce CO_2 emissions since it enables a shorter flight path. However, more direct lines have a correlation to bigger number international visitors, as brought forward by Halpern (2008) and in the Swedish inquiry SOU 2017:95. Hence, there is a focus on limiting the CO_2 emissions, while still increasing the amount of air travel. This would only be possible if the CO_2 per p-km can also be reduced, but historically the efficiency increases have never been enough to outpace distance or passenger growth. As mentioned in section 4.2.1 the efficiency improvements are not set to become larger, so it is likely that they will not outpace growth in the future either.

Another way to reduce the CO_2eq per p-km is to make sustainable bio-jet fuel commercially available, which could decrease total GHG emissions. Different bio-jet fuel options exist and they are presented in section 2.2.3. Bio-jet fuels are right now limited by the supply of bio-mass and it is also competing with other sectors that want to use this supply, such as road transport. However, the aviation sector is more costly to de-carbonise in other ways than with bio-jet fuel. Thus, it could be argued that resources would be better directed towards aviation bio-jet fuels rather than to road bio-fuels. Electrification is a commercially available option in road transport, while it is still challenging in aircraft. A joint effort to direct the bio-mass resources to aviation rather than road transport would then be needed. On the other hand, road transport is a bigger part of total man-made CO_2 emissions and the environmental footprint to convert biomass into bio-fuels for road transport is smaller than to convert biomass into bio-jet fuel. Thus, the biomass opportunity costs are lower for road transport than for aviation (Rye et al., 2010). Also, domestic road transport holds tight targets in Sweden, and might be dependent on bio-fuels to be able to reduce their GHG emissions by 70% from 2010 GHG emission levels (Ministry of the Environment and Energy, 2018). Either way, a joint approach for bio-fuels in domestic and international transport including aviation is necessary, if bio-jet fuel's full potential is to be realised. Aviation is also important for Swedish society, as Sweden is a sparsely populated country with long distances which is pinpointed in the aviation strategy Ministry of Enterprise, Energy and Communications (2017). Næss-Schmidt et al. (2019) further highlights the importance of aviation for inbound tourism, as air travel is the most common transportation mode for international trips to and from Sweden. It is also difficult to replace with other modes of transport as both e.g road and rail needs good infrastructure to function properly. Hence, resources reasonably ought to be directed to make sure bio-jet fuel become commercially available. If bio-jet fuels are not enforced by policies, there is probably no drastic further development of the CO_2eq per p-km, and then either the number of passengers or the average distance needs to be decreased to reach a future CO_2eq emission reduction.

To reduce the climate impact from aviation Sweden have a distance-based passenger tax explained in section 2.4.5. A consequence of this tax is that shorter trips are favoured over longer ones, as short-distance trips in general entail less CO_2 emissions. This suggest a focus from the Swedish government to lower CO_2 emissions by reducing the distance travelled, which effect the inbound and outbound trips the same way. However, when the tax was reviewed after being in affect half a year, it was clear that it had had a reverse effect where the number of short trips had declined while the longer ones had increased more than expected. There are also plans from the Swedish government to include a climate declaration on all kinds of long-distance trips (longer than 150 km) in the marketing of them, so that the consumer can make a more informed decision and be able to easily choose a better option for the environment (Transport Analysis, 2020b). This would also provide incentives to short-distance trips, or trips with another mode of transport to enable CO_2 emission reductions. This measure is only aimed at the Swedish market, the outbound travel, not the inbound travel. Nevertheless, the aviation tax and climate declaration show a focus on incentives for shorter trips by the government. However, when looking at inbound trips, the government through Visit Sweden market Sweden as a tourism destination towards markets far away (Government Offices of Sweden, 2015). No contrasting view regarding the distance they travel to Sweden and the GHG emissions the long-haul flights cause have been found, with the only exception when briefly mentioned in the commission of inquiry in tourism (SOU 2017:95, 2017), further explained in section 2.4.3. Hence, there are measures indirectly trying to limit the distance travelled by Swedish residents, while inbound tourists are encouraged to travel to Sweden from long distances. This presents a gap in the logic used between inbound and outbound travellers.

Another way of reducing the total climate impact is to decrease the amount of trips. The government is working towards attracting more flight lines to Sweden to increase the number of visitors, as the tourism industry is important for the Swedish economy (Ministry of Enterprise, Energy and Communications, 2017). However, an important note is that it is not the tourism in itself that is investigated in this report, only the mode of transport used to get to the tourist destination. Therefore, it is suggested that tourism in itself does not need to decrease, only the share of tourists that get to Sweden by air. If inbound tourists to a higher degree came from markets closer to Sweden, instead of from markets far away, this would suggest shorter air travel to get to Sweden, or enable a change in transport mode. This would make sure that the positive aspects of tourism could be maintained, while decreasing the negative impacts from aviation. One way to reach this could be to stop marketing Sweden as a destination in markets far away, this suggestion will be further discussed in section 5.3.

5.2 Method Limitations

The main method used in this report to calculate the climate impact uses the basic components that causes aviation's climate impact: the numbers of trips, average distance and CO_2eq per p-km. It is a method accepted widely as a way to calculate the climate impact from economic activity. Therefore, the main uncertainty in this report is in the data. There is a lack of well-documented data of inbound travellers, which was an issue when conducting this thesis. The specific uncertainties for the data was brought up and analysed in the result section, more specifically in section 4.1.5 and also summarised in Appendix II. However, altogether it is deemed that the reliability of the data was sufficient for the purpose of this report.

The lack of data on inbound tourism in Sweden was discovered in the process of making this report. The latest review of inbound visitors to Sweden was made in 2014 by IBIS, done by the Swedish Agency for Economic and Regional Growth in (2014). However, it became clear that this study withhold flaws, as the method for doing the choices of participants is not fully disclosed, which was communicated to the authors of this report in personal communication with a person at Economic and Regional Growth. Another similar study of the inbound visitors in Sweden was initiated in March 2019 (Swedish Agency for Economic and Regional Growth, 2020b), still being conducted in the spring of 2020 when this report was written. The new investigation was conducted with a significantly different method than the one from 2014, making it more reliable, also disclosed in personal communication. This presents the fact that it is not reasonable to compare the data from 2020 with the data from the 2014 study. Furthermore, the study still collected data of inbound visitors in the first phase of the COVID-19 pandemic, which only escalated and had a large impact on who could travel to Sweden. The data used in this report, from UNWTO's database, is therefore the best estimates that could be found on the origins for travellers to Sweden.

There are some limitations to the method in regards of allocating CO_2 emissions from inbound trips by non-residents to the destination country. It is also a new allocation method, not before presented in literature. Thus, whether this is a useful allocation can be discussed. Larsson et al. (2018) bench-marked the allocation options presented in table 2.1 with the following five criteria: sensitivity, additivity, non-leakage, validity and reliability. Their verdict was that the resident-approach (option 7) fulfilled all criteria. This report's addition, inbound trips by non-residents, does not fulfil all these criteria. For example, it is not additive between countries without modification. There is a risk that round-trips get double-counted, if a tourist for example travels with aviation from China to Norway, then to Sweden, then to Finland and then back. If all countries used the method in this report, such a tourist would be accounted for in all countries, and more CO_2 emissions would be accounted for than what is actually released. This means that if the method would be used for more than one country, the results would not be *additive*, that is they could not be added together to form a total of all inbound GHG emissions. A solution to that problem could be to calculate the climate impact from all transports in the round-trip and allocate it to all destinations evenly, or allocate the GHG emissions to the "main destination" country where the tourist stays the most nights. Such round trips could result in less GHG emissions as the traveller visits multiple destinations in one trip instead of visiting them in multiple trips, entailing less GHG emissions since three aviation round-trips results in more GHG emissions than one single round-trip where multiple countries are travelled in-between by i.e rail. This could be an interesting research topic to look more into. Doing this kind of calculations further present a need for more specific data of a tourists' trips than what is accessible for Sweden today. It presents a need to know where and how travellers travel between and to places, to be able to allocate the climate impact accordingly.

5.3 Implications of Results

This section will concern the second research question in this thesis, which is: "What are the implications of these results on Swedish climate impact reduction policies and national tourism strategies?". It will put the results in a context of ongoing discussions and theory, connecting it to published research and strategic documents in the area.

5.3.1 Policy Implications

According to Larsson et al. (2019), a global tax on aviation fuel would be the best option to reduce CO_2 emissions from aviation, but it is difficult to implement. ICAO's measures together with the EU ETS are cost-effective and international, but not enough to meet the targets set by the Paris agreement as analysed in section 4.2.3 under the expanded scope. The Swedish climate goals and action plan does not include the CO_2 emissions from international aviation either, as these are supposed to be covered by the EU ETS (Swedish Climate Policy Council, 2020). However, at least until 2023, the EU ETS only covers about 70% of international aviation fuel sold in Sweden (SOU 2019:11, 2019). This entail that some CO_2 emissions will not be accounted for in Sweden until the start of

CORSIA in 2021, which only includes an offset of the increase from 2020. Further policy measures for inbound aviation can thus be argued for, especially if Sweden wants to be the proactive climate combating country it aims to be. Which the best policy measures are, are not straight-forward, as the benefits of tourism wants to be kept. Some options exist which allows for a balanced solution: destination-based carbon management or bio-jet fuel.

From the historic results of climate impact from inbound air travel to Sweden it is apparent that it is growing at a fast pace. However, most efforts previously debated, such as a climate declaration proposed by Åkerman et al. (2016) which has been investigated further by Transport Analysis (2020b), only targets the Swedish residents and their trips. To target the inbound travel other tactics are needed, such as destination-based carbon management. Changing the market composition and only marketing to closer countries can result in the average distance declining for aviation or that other travel modes are used. Thus, it reduces the climate impact from the tourism sector while still upholding the tourism numbers and economic growth. However, many markets close to Sweden are mature and the growing markets such as China and India with over 1 billion inhabitants each are located far away. In these countries there is a growing middle-class which has resulted in the surge of tourism from these regions, while Nordic/Europe markets does not inhibit the same growth possibility and have smaller populations.

The problem with many policy options as the climate declaration, destination-based carbon management and subsidy options is that the responsibility is put into the hands of consumers or companies, without reassuring tangible results. This means they indirectly have a possibility to affect the CO_2 emissions, but it does not provide a fixed CO_2 emissions reduction. For example, when discussing not to market Sweden as a destination in countries far away it would be useful to first quantify the effect that marketing might have, and thus if the de-marketing could have any effects. On the other hand, even if the results from such a study proved that the marketing had no effect on the number of inbound tourists to Sweden, stop marketing would still be favourable. If the resources spend at marketing gave no benefits, not even more inbound tourism, they would be better spent elsewhere. The resources could instead be focused on designing better options to reduce CO_2 emissions and carbon-intensive tourism growth, for example invested in marketing closer to Sweden. Therefore, as part of a bigger package for reducing the climate impact from inbound tourism, de-marketing in far-away markets is a vital part. Similar is also the argument from Åkerman et al. (2016) for Swedish residents policies, who mentions the climate declaration on its own is not enough, but combined with other instruments gives a coherent strategy to reduce CO_2 emissions.

Bio-jet fuel is an option that also keeps the benefits from aviation while still ensuring reduced climate impact. As sustainable bio-jet fuel is expensive policies are needed, where the bio-jet fuel inquiry suggest bio-jet fuel obligations for airlines (SOU 2019:11, 2019). This option is also supported by the aviation industry in Sweden as it is part of their road-map to de-carbonize air travel, see section 2.4.4. The results from such policy is higher prices for aviation ticket since bio-jet fuel is more expensive than conventional jet fuel, which will also reduce some amount of passengers where the price sensitivity is high. In section 2.2.3 alternative technologies and fuels were also discussed, where CCS could also help with making more low-carbon bio-jet fuels available. CCS is expensive and need investments, and if aviation would make sure that it could be commercialised aviation's carbon-intensive effects could be lowered or more acceptable. However, bio-jet fuels does not stop the high-altitude non-CO_2 effects from aviation, leaving a climate impact gap that needs to be addressed with other means.

The scenarios presented an interesting observation regarding the Swedish climate goals for domestic transport. The Resurrection scenario would be double as much as the total GHG emissions from domestic transport in 2030 and the Staycation about 50% of 2030 domestic transport GHG emission levels (see section 4.2.3 and figure 4.12). If these CO_2 emissions would be included in the target they would fill the whole carbon budget for domestic transport in 2030, implying a significant climate impact from the combined outbound and inbound air travel. However, if the bio-jet fuel plans proposed in the inquiry SOU 2019:11 (2019) would become reality, such a drastic contribution could be avoided. With less aviation from the start, the bio-jet fuel plans could also become more applicable, as the resource for bio-mass to produce sustainable bio-fuel is limited.

When discussing policy options, the current carbon lock-in in the socio-technical system should also be addressed. It limits the possibilities for policy makers to create climate policies (see section 2.3.3). The EU ETS and CORSIA are only end of pipe (EOP) policies, as they limit CO_2 emissions by setting targets. The bio-fuels quotas or obligation policy options can be seen more on the second level, incremental innovation. The third level, a discontinuity policy option, needs exogenous forces such as technological innovations or institutional change. Aviation today lacks niche markets with a momentum for a technological breakthrough, as possibilities such as electric aviation or hydrogen-fuelled aircraft are decades away from becoming commercially available (see section 2.2.3). The climate change issue needs faster responses than waiting for such options to become cost-competitive. Institutional change has a better prospect of enabling radical policies, where the Fridays for Future movement and Climate strikes (Fridays for Future, n.d.) could be the start for such change. This is also seen through acts such as Greta Thunberg coining the "flygskam" expression (Fridays for Future, n.d.; Hook, 2019). Furthermore, extreme weather events have been increasing in the last decades (Wuebbles et al., 2014). This together with the warmest global temperature records in 2016 and 2019 (NASA, 2020) could be the "external shock" which Unruh (2002) means can create radical change and discontinuity. New climate policies such as the Swedish climate act or the European Green Deal would probably not be possible without such movements, making it more plausible that a system shift is impending where more radical policy options are acceptable.

5.3.2 Implications on National Strategy for Tourism

Climate change impact from tourism and aviation has been the main focus in this report. However, tourism also cause other negative effects in a social, economic and environmental perspective. When the negative effects become lager than the positive impacts it is referred to as overtourism. Overtourism is not a problem in Sweden at the moment according to Dir. 2016:83 (2016) but it was marked as a possible future threat as some spots in Sweden have received a large increase in number of tourists the last couple of years. As visible in the results in this report, the inbound tourism has increased significantly in the last couple of years. This entails that the risk of overtourism is further enhanced. Therefore, if Sweden wants to work proactively with sustainable tourism there is a need to consider this phenomenon now and make up a road map for how to manage an increased magnitude of visitors.

Séraphin et al. (2019) have shown that a branding focus on only increasing visitor numbers has been a reason for overtourism in other destinations. Furthermore, Becken (2005) brings up the risk of relying on landmarks when attracting tourism, as a large focus on landmarks promotes shorter visits and only travels between them. These two management directions have been visible in places where overtourism has become reality, and it is also the focus found in the current Swedish Export Strategy (Government Offices of Sweden, 2015). When developing the new sustainable tourism strategy, it is here again brought forward that a wider scope is needed to be considered. Both the positive and negative effects of inbound tourism need to be taken into account when forming these policies.

Tourism brings many positive effects to a country, not only economical ones. All of these needs to be kept to as large extent as possible. Marketing to closer markets was brought up as a possible policy instrument to reduce the environmental impacts of tourism. This instrument does not necessarily entail a decrease in the amount of visitors that go to Sweden, but only change *who* comes. This might be favourable in a tourism development perspective and keeps the growth of the sector while decreasing the GHG emissions. Furthermore, this kind of strategy does not entail discouraging anyone from far-away markets to come to Sweden, it just does not actively try to pull them here. This logic could also be aimed at Swedish resident, promoting staying in Sweden when travelling while not actively discouraging longer trips either. This combined with the proposed climate declaration could give reasonable options for Swedish residents as well, as the national strategy for tourism should include domestic tourism. Having a strategy to market closer to the destination thus enable a more sustainable inbound and domestic tourism growth. It takes a more holistic approach on whom should be responsible for CO_2 emission reductions than only the climate declaration, putting it not only on Swedish residents but on all travellers.

5.3.3 Tourism Definition and Business Visitors

In this report, both business and leisure travellers have been included in the calculations of the climate impact. However, whether it is reasonable to treat these two groups of travellers the same way can be questioned. In the definition of a tourist, business overnight visitors counts as tourists and in 2018 67% of non-residents on Swedish airports were leisure travellers according to Næss-Schmidt et al. (2019), in which the share of non-resident business travellers had also been declining. The trend of an increasing share of leisure travellers over business travellers in Sweden is also visible both in the accommodation and consumption statistics between 2010 and 2018, according to Swedish Agency for Economic and Regional Growth (2019). This means that the majority of inbound travellers to Sweden today are leisure travellers, and it is the major growing part. Therefore, when looking at possible CO_2 emission reduction measures it is important to consider the differences between the two groups.

Leisure travellers are more price-sensitive than business travellers (SIKA, 2006). This means that business travellers are less price-sensitive and it is more likely that they would continue to fly even if the cost of air travel would include the negative environmental externalises that aviation entails. Therefore, business travellers are not as impacted as leisure travellers by economic measures such as the aviation tax. A suggestion brought forward in this report is to stop market Sweden as a tourist destination in markets far away. This measure would likely impact the business and leisure travellers in different ways as well. As a business trip is a business decision, and not an individual's personal choice, this could entail that leisure travellers would be more affected by such a measure. That there are other Swedish actors trying to attract international business to Sweden, such as the government-owned organisation Business Sweden (Business Sweden, 2020), further reinforce this assumption. This suggests that if Sweden was not marketed in markets as a tourist destination, leisure travellers would to a higher degree be impacted than business travellers.

This focus can be justified with an expanded view on sustainability. Looking at it from a social and environmental perspective the absolute number of trips should be limited, to decrease the risks of overtourism and to limit the climate impact. The leisure travellers are more in numbers as well as the major growing part, and therefore the measure has the possibility to accomplish a higher absolute reduction than if focusing on business trips. Incorporating an economical sustainability dimension into the reasoning suggest that if any trips are to be decreased the tourist group with the least contribution to the economy should be decreased first. To make sure to have a cost-efficient approach to these CO_2 emissions, reducing the less costly CO_2 emissions first. In 2018 leisure travellers were responsible for 72% of the total tourism consumption in Sweden and business travellers only 28% (Swedish Agency for Economic and Regional Growth, 2019). However, remembering that the leisure travellers are around 67% of the two groups. Furthermore, business travellers could contribute indirectly to the economy by enabling Swedish companies to expand and collaborate globally. This indirect contribution to the economy would be difficult to quantify and a comparison between the two groups are therefore difficult.

On the other hand, business trips could to some extent be exchanged with video calls, and therefore the same economic value added to the economy could be reached without the environmental consequences. This has become apparent in the COVID-19 crisis as video conferencing has become increasingly popular (Neate, 2020). The stay-at-home directives visible in many countries have forced a fast adjustment to working from home and digital meetings. If this development will continue after the crisis is not clear, but it has shown the potential and might enable a permanent reorganisation towards less business travel. This argument could either push for that business trips should be in focus as they can be replaced, and still the same value-added reached, or it shows that a specific focus on them is not needed, as they will decrease naturally when companies realise they are not needed. Furthermore, as business travellers are less price-sensitive than leisure travellers, designing measures that specifically target them and not leisure travellers seems difficult. Therefore, weighing in all factors, it is deemed justified that the measure of stopping marketing Sweden in markets far away, is affecting the leisure travellers at a higher degree than business travellers.

5.4 COVID-19 Impacts

The COVID-19 pandemic has had unprecedented impacts on the tourism sector so far, and the continued development is uncertain. UNWTO released a first prediction in February 2020, which predicted a decline in global tourist arrival of 20-30% in 2020 (UNWTO, 2020c), updated in early May to a 60-80% decline (UNWTO, 2020d). ICAO released estimates of the impacts in scenarios which ranged between a decline of 44-80% in passenger numbers (ICAO, 2020a). The pandemic started to spread when this report was written, and its effects had to be incorporated into the scenarios to give a more reasonable view of the future. Estimates on the effects from the pandemic were made by different organisations continuously and therefore the estimates used in this report needed to be updated regularly as well.

Pandemics have happened before, but since World War II there has never been one which affect society in this magnitude. Whether travelling and destinations norms will ever go back to how it was before the crisis can be questioned, and it is currently debated in major news outlets and by scientists. Other topics discussed are whether people might choose different locations based on the experiences of the crisis. The risk of getting stranded at a remote location might scare people, and affect decisions such as where to travel, favouring closer and more local destinations. The EU package for tourism and travel also hold recommendations for local tourism (European Commission, 2020a). Hence, closer markets are more resilient in a crisis, further strengthening the strategy of aiming for a tourism market composition where tourists live closer to the destinations. Destinations might also be affected by their availability of good health care, and people might choose not to go to places depending on such factors, which was not as important prior to the crisis. For some Small Island Developing States (SIDS) with a weak health care system, whose economy is dependent on tourism, the pandemic could prove fatal especially if the lingering effects would affect the number of arrivals to their destinations. Some SIDS depend on as much as a third of their GDP on tourism (UNWTO, 2014). This shows how major the tourism sector is, and the inherent risk when building an economy dependent on it.

The scenarios showed that the development of tourism might be different from what was estimated prior to the pandemic. An important result is that the Staycation or Tourism Redefinition scenarios have less climate impact than the historic climate impact and is therefore preferable in a climate perspective. The scenarios do not necessarily have to be negative in other perspectives either. They only steer the tourism to other markets and enable spending on other leisure activities instead of tourism. Today Sweden export more tourism expenditures than international tourists spend here (Swedish Agency for Economic and Regional Growth, 2019). Therefore, in a Staycation scenario where the money is kept within the borders this does not automatically mean that growth would cease. A possibility is that the same amount of money is spent on leisure, and instead circulates within the Swedish economy. However, when looking from a trade or global cooperation perspective, this scenario could be negative. If borders remain closed inhibiting travelling, sharing of cultures and global trade, these positive effects from globalisation could be lost. In such case many countries will suffer, including Sweden since we are dependent on other's resources and are accustomed to a life-style of eating crops not grown in Sweden or utilising metals not found within our border. Whether such a future is even possible is questionable, as the economy is globalised and companies' supply chains are currently spread all over the world. But, future supply-chains might be designed in a different way, as the inherent risks of having global trade has become apparent in this crisis. Nevertheless, such a change will take time.

5.4.1 Momentum for Change

Positive effects caused by COVID-19 which are sometimes brought forward is the clear skies in India where in some places the Himalayas are visible for the first time in 30 years due to the lock-downs (Rai, 2020). In Venice, see-through water with wild-life returning was also reported, a location which prior the crisis was suffering from overtourism (Brunton, 2020). However, it must be noted that such development is not in the current way sustainable. The cost of these blue skies in social and economical measures are severe, for example in the US the unemployment has skyrocketed (U.S. Department of Labor, 2020). However, what it can provide is a vision of how the world could look without an extensive climate impact and with sustainable development. Therefore, the COVID-19 crisis has the potential to become a momentum for change.

When discussing the carbon lock-in, Unruh (2002) pinpoints that an exogenous force might induce radical change or discontinuity in the current system. An interesting question is whether COVID-19 could be such an exogenous force, creating a momentum for change. COVID-19 could be the accelerator towards sustainable tourism by creating a social disruption, a possibility media and Gössling et al. (2020) brings forth. This is also visible in the Staycation and Tourism Redefined scenarios, where the system changes completely into a new path. However, the path dependency is strong, and others argue we should be careful what we wish for as the rebound effect might prove substantial (Hall, Scott, & Gössling, 2020). Whether the COVID-19 pandemic will break us away from the carbon lock-in is difficult to assess. It may be that in low-carbon aviation scenarios such as Staycation and Tourism Redefined, the climate impact only move from international air travel to travel by car or domestic air travel, which increase the impact from those sectors instead. No scenario deduce that carbon leakage to other sectors is inevitable. Furthermore, if only a national approach is taken, global sustainability might be hard to achieve, as the SDGs focus on inclusiveness of all the world's population, not all nations for themselves. If national growth is regarded as more important than global sustainability, this might entail a lock-in into another path and not necessarily a better one.

To escape the carbon lock-in policy makers could make sure to grasp this opportunity and only give funding to greener companies, as is the recommendation from Gössling et al. (2020). This is a possibility, but the question is if the forces for sustainability are strong enough or if the policy makers are still too bound to the current carbon locked-in system. IEA predicts a 8% drop in global CO_2 emissions in 2020 due to COVID-19, which takes them back to 2010 emission levels. However, they also highlight that the rebound will probably be larger than the decline as in previous crisis unless recovery investments are placed on cleaner and more resilient energy infrastructure (IEA, 2020). Some recovery efforts have been given under greener promises, for example Air France was bailed out only with the promise to reduce CO_2 emissions by introducing alternative fuels and phase out air travel that competes with available train travel shorter than 2.5 hours (Watts, 2020). This shows that COVID-19 might become an accelerator for change. On the other hand, with higher unemployment and other urgent matters perceived as more important to be dealt with, the chances for a green disruption is uncertain.

5.5 Future Research

This report has opened a lot of questions that are left to address. The need for reliable data on inbound tourists is brought forward, which is important to have to be able to take the right strategic choices in the future. Furthermore, to investigate how large share of inbound tourists that go to Sweden specifically due to Visit Sweden's marketing. This would further give a view on the importance those undertakings have to the tourism sector in Sweden, and the difference it would be to steer those marketing efforts towards other markets. An interesting further research could also be to look into different allocation methods, and discuss how the responsibility of this climate impact could be shared between countries. If it is possible to expand the scope when counting CO_2 emissions, and if there is a point in calculating them even if they do not add up in the national GHG emission inventory.

Future research could also be directed post-corona, to see which scenario (if any) will become the dominant one. It will be interesting to see if the tourism industry's resilience stands intact, or if in fact tourism will be redefined. When the crisis is over many interesting impact assessments are needed as well, especially on the effect of the COVID-19 pandemic has on both globalisation, tourism but also climate change.

6

Conclusion

This report has shown that between 2014 and 2018 aviation's climate impact from inbound travellers has increased ten times more than the impact from outbound trips by Swedish residents. Reviewing Swedish goals and strategies regarding climate, tourism and aviation, it becomes clear that when limiting CO_2 emissions from the aviation sector to meet climate goals, inbound travellers are not in focus. Furthermore, that Sweden actively tries to attract visitors from markets far-away brings forward a new perspective of expanded responsibility. The Swedish strategy to grow its tourism sector catches the positive effects these trips bring, while the negative externalities are overlooked. This should not be the case in a nation that aims to be in the forefront with its work against climate change, especially when considering that the climate impact from inbound non-resident air travel has increased considerately. A conclusion is thus that more measures should be taken by the Swedish government to address this growing climate impact, in an expanded responsibility approach.

For Sweden to have a sustainable tourism sector, an efficient option is to market Sweden as a tourist destination in markets closer to the destination and stop marketing in countries far away. Having closer tourism markets entail shorter aviation trips, or that other means of transports than aviation are available, thus less CO_2 emissions. This change in the national tourism marketing strategy would make sure to include an environmental and climate dimension, while still enabling sustainable economic growth. For tangible GHG emission reduction results more aggressive policies are also needed, for example policies for bio-jet fuel diffusion. Future measures should be directed both to residents outbound travel but also to non-residents inbound travel, for a holistic approach.

The COVID-19 pandemic has heavily impacted the tourism and travel industry, and future development is uncertain. The four scenarios created in this report showed how many factors that can influence the magnitude of aviation's future climate impact. How the future develops will impact which climate impact reduction alternatives that are needed. The tourism recovery is expected to be faster in domestic and neighbouring countries than globally. Thus, the measure of marketing closer to Sweden is still beneficial, as it ensures a more resilient crisis position. The likeliness for a carbon-intensive trajectory is still deemed as high, but recovery policies and measures can be strategically directed to less CO_2 emissions-intensive travel alternatives. This momentum can thus be used to create a more resilient and low-carbon future for the tourism sector in Sweden.

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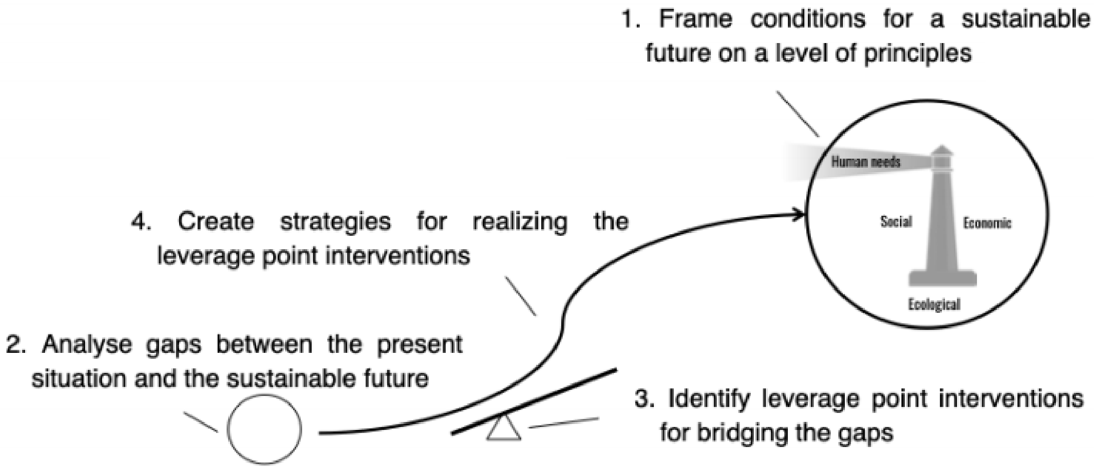
Appendix

Appendix I - Challenge Lab context

Sustainability challenges are often deeply entrenched or locked-in within the current system, therefore a new way of thinking is needed, where we must learn continuously while navigating through the uncertainty (Holmberg & Robert, 2000; Stewart, 1993; Senge, 1990). Challenge Lab is about finding the solutions to these complex societal challenges which are inhibiting a sustainable future. It is done through a multi-disciplinary approach, where the participants come from different backgrounds and start off by co-creating the basis of the thesis. At such, Challenge Lab can challenge the status quo and plant "seeds of change", to enable system innovation (Geels, 2005).

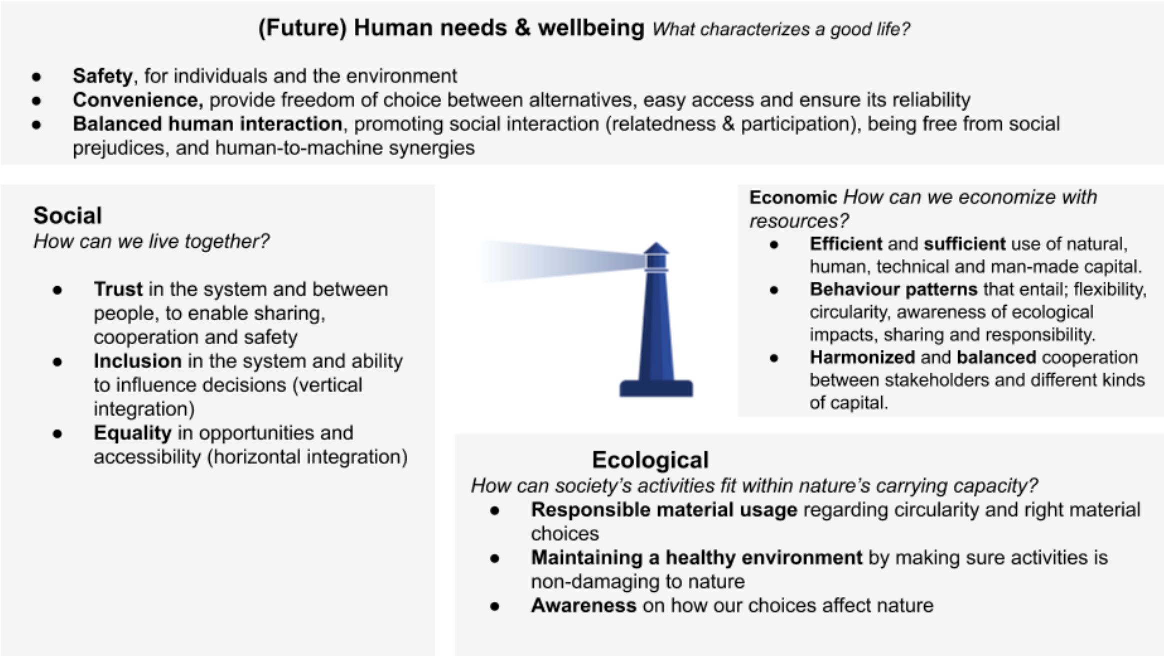
In 2020, the theme for the Challenge Lab was mobility, narrowed down into three subthemes: transportation due to tourism, personal mobility and transportation of goods. The method used in Challenge Lab is "backcasting" (see figure ??), a system's mapping approach linking current system to a desirable future, designed to bridge a sustainable transition and foster collective approaches (Holmberg & Larsson, 2018). The process lasted for four weeks and led to forming the research questions for the thesis.



Backcasting approach, adapted from Holmberg and Larsson (2018)

Backcasting - Step 1

Step 1 in the backcasting process entails creating a vision for a desirable future. Specifically, at Challenge Lab, guiding principles were created to decide in which direction the society *should* go according to personal and collective values (Holmberg & Robrt, 2000). It was done with a base in Holmberg and Larsson's (2018) sustainability lighthouse, a conceptual framework to support and inspire conversations about sustainability transitions. The principles created in Challenge Lab can be found in figure ??. Creating a vision of how the society should look like enables intrinsic motivation for the individuals, and motivation creates action (Stewart, 1993; Ryan & Deci, 2000). It also enables thinking beyond the current system by creating a shared mental model that enables collaboration and fruitful discussions (Holmberg & Larsson, 2018).



Principles created in phase I during Challenge lab

Backcasting - Step 2

Step 2 in the backcasting process is looking at the current system, to create a creative tension between the current state and the desired state or vision (Senge, 1990). At Challenge Lab the system was mapped according to the multi-level perspective (MLP), with niches, current socio-technical regime and landscape trends (Geels, 2005). Three dialogues were conducted to help map the system, one for each sub-theme. Including stakeholders is a vital part of Challenge Lab, to ensure the system mapping is realistic and understanding the underlying system dynamics.

In this phase tourism was the sub-theme decided to be in focus by a group of the Challenge Lab-participants. The result from the system's mapping and dialogues showed that there was no clear vision and strategies for sustainable tourism. Tourism is growing worldwide and many want the economical benefits from it, but the ecological and social factors were not highlighted. It is sought and discussed as desirable, but the definition of sustainable tourism is not coherent. One factor discussed often was air travel, which according to recent reports is quite potent in releasing a large amount of CO2-equivalents per p-km and a challenge for sustainability (brought forward orally in the dialogues). This realisation have resulted in multiple plans to reduce the emission from flying, in cities such as Gothenburg and in nationally in Sweden (City of Gothenburg, 2014; Ministry of Enterprise, Energy and Communications, 2017).

Backcasting - Step 3

After the system is more apparent, step 3 can begin, which is forming leverage points to find the root of the problem, and finding intervention points where a small change can make a big difference. Step 4 is then about developing strategies for addressing those leverage points (Holmberg & Larsson, 2018). At Challenge lab, only steps 1-3 were followed to find the research question relevant to make a change in the system. After finishing the discussions about aviation with the actors, and the system's dynamics mapping, an interesting gap was found; air travel from the Swedish residents are to be reduced, yet the tourism strategies for Sweden are targeting markets far away such as China, India and USA. This gap is the basis that formed the research questions and purpose for this report, grounded in the concept of sustainable tourism, emissions caused by flying and marketing strategies in foreign countries.

The formula is presented below but based on the method from Larsson et al. (2018), where only adjustments have been done where the data had newer updates and to fill in data for 2018.

Appendix II - Assumptions

Variable	Assumption	Source/Comment
Scope of calculations	The calculations was conducted between the years 2014-2018.	The available data was constricted within this interval.
Total emissions	Distance is calculated on accommodation data which entail that data on passengers and distance do not entirely overlaps	More direct data unavailable, sufficient reliability
Average distance	The percentage of tourists at commercial residents that can be attributed to aviation, see table 3.1 in the method. Furthermore, the same numbers were assumed for all years.	Assumptions based on Næss-Schmidt et al. (2019)
Average distance	Travellers to Sweden only fly to airports in Sweden and not to a neighbouring country.	Assumption since data of purpose for trip not available
Average distance	Tourists staying at AirBnb or with relatives are not included in the average distance calculations, only those staying at commercial accommodation establishments are. Therefore, 6.8-8.3% of total international arrivals are not accounted for in the average distance.	490 000 guests in 2017 and 650 000 guests in 2018, data from Amorelli (2019). One in four guest at Airbnb accommodation in Sweden is Swedish residents, data from Airbnb (2019). Those trips would not have a significant impact on the average distance, acceptable to exclude.
Average distance	Only tourists from 41 countries were accounted for in average distance calculations, might skew result	Data from UNWTO (2019b) was limited to report 41 countries. Reliability deemed sufficient as about 80% of the reported data was used in the calculations
Average distance	Distance is calculated between the geographical middle point of Sweden and the tourist's country of resident, and not airport to airport.	Detailed data of exact airport the traveller flew from was unavailable.
Average distance	The average distance between Sweden and the departure country are calculated with the Great Circle Distance (GCD)	Standard used by ICAO to report p-km (ICAO, 2009). Formula uses calculates the distance in a simplified manner as it looks on Earth as a perfect sphere, small source of error.
Average distance	A traveller is assumed to stay in one accommodation in one trip	There is a risk that one tourist is counted more than once if this is not the case.

Average distance	Travellers staying at family and friends not included in average distance, only commercial establishments	Data unavailable, and these travellers not affected by inbound tourism marketing
Number of trips	Percentage of Swedish residents at Swedish airports linear trend assumed for 2018	Data from Kamb and Larsson (2019) was used who had received the data directly from Swedavia, no update for 2018
CO_2eq per p-km	Non-CO2 effects are included in the calculations with and EWF of 1.9, making the CO_2eq per pkm larger than when only looking at CO_2 emissions.	Based on Lee et al. (2010), used by Kamb and Larsson (2019) too. Not included in estimates from e.g. UNWTO and ITF (2019)

Table of main assumptions made and their impact on the results