THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Climate Policy for Aviation

Analyses of measures at multiple levels

ANNA ELOFSSON

Division Physical Resource Theory
Department of Space, Earth and Environment

CHALMERS UNIVERSITY OF TECHNOLOGY

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ANNA ELOFSSON

Department of Space, Earth and Environment
Division of Physical Resource Theory
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Author email: anna.elofsson@chalmers.se

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Abstract

The aviation sector is affected by local, national, multinational (EU) and/or global climate policies targeting domestic, intra-European and intercontinental flights in different and partly overlapping ways. The aim of this thesis is to strengthen further knowledge on climate policy for aviation at multiple governance levels and by doing so contribute to a more informed policy process. This work is done by analysing climate policy, by both qualitative document analysis and energy-economic modelling, concerning aviation.

Our results show that actions to reduce aviation emissions are taken at all geographical levels of governance. On the local level, a surprisingly large share, more than a quarter, of the cities studied are taking policy initiatives to reduce aviation. Moreover, we have recognized that cities tend to choose the system boundary (consumption or territorial perspective) that results in the lowest reported emissions. The major perceived conflict of interest at the local level is economic growth vs reduced air travel. With limited authority within the local setting, such as in the case of aviation emissions, governing by 'agenda setting' can be an important channel for cities to express their concerns and support change at higher levels.

On the national level, some countries have policies such as passenger taxes, biofuel blending mandates (from 2020 in Norway) and carbon taxes on jet fuel. National policies in a country within the European Economic Area (EEA) will overlap fully with CORSIA and/or the EU ETS, which adds challenges regarding additionality of the emissions said to be reduced due by the different policies. Further, there is a potential for national policies to be spread and thereby achieve cumulative emissions reduction.

Keywords: aviation, climate policy instruments, local governance, biofuels

List of appended papers

I **Local governance of greenhouse gas emissions from air travel**
Journal of environmental policy and planning (2018)
Elofsson, A., Smedby, N., Larsson J. & Nässén J.

AE, NS, JL & JN developed the idea. NS and AE developed the method. NS contributed with theoretical background of modes of governing. AE collected the data, conducted the analysis and wrote the paper with contributions from NS, JL and JN. AE conducted the review by support from JN.

II **International and national climate policies for aviation: a review**
Journal of Climate Policy (2019)
Larsson, J., **Elofsson**, A., Sterner, T. & Åkerman, J.

JL, AE and JÅ developed the idea. AE contributed with background research. JL conducted the analysis and wrote the paper with contributions from AE, TS and JÅ. JL conduced the review by support from other authors.

III **Policy Analysis of a biofuel mandate for aviation**
Manuscripts to be submitted (2020) to Environmental Research Letters
Elofsson, A., Johansson D, & Larsson J.

AE initiated the work and together with DJ and JL developed the idea. AE collected the data. AE built first draft model, which was refined by DJ & AE. AE conducted the analysis supported by DJ and wrote the paper with contributions from DJ.

Related publications not included in this thesis

IV **Biojet för flyget**

SOU 2019:11 (2019)
Swedish governmental commission of inquiry
Elofsson & Kannesten constituted the secretariat of this inquiry.

V **Svenska handlingsalternativ för att minska flygets klimatpåverkan**

Report published at KTH and Chalmers (2016)
Åkerman, Larsson, **Elofsson**

VI **Plug-in hybrid electric vehicles as regulating power providers**

Energy Policy (2010)
Andersson, **Elofsson**, Galus, Göransson, Karlsson, Johnsson, Andersson

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1 Introduction

Limiting global warming to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, as the Paris agreement stipulates, will require net zero carbon emissions by around 2050 (IPCC, 2018). Aviation today accounts for around 2.4 per cent of global CO_2 emissions from the use of fossil fuel (Brandon Graver; Kevin Zhang, 2019). For the coming decades, International Civil Aviation Organization (ICAO) forecasts a yearly passenger kilometre increase of around 4.1-4.3 per cent (ICAO, 2018). ICAO has also set a goal for a yearly fuel efficiency improvement of 2 per cent (ICAO, 2010). Even if the efficiency improvement target is reached, CO_2 emissions from aviation are expected to increase due to the passenger kilometre increase. Net zero carbon emission by 2050 would require either a radical change in the development of aviation emissions, by new technology or changed travel volumes, or negative emission in other sectors compensating for this increase.

The development towards net zero emissions provides motivation for a number of climate policies in different sectors, initiated by multiple actors. Aviation is an interesting example of an international mobile source of emissions with global and local implications. For aviation, the local co-benefits in the form of decreased air pollution and noise appear more limited than for many other environmental policy areas, and the local risks associated with these policy measures, in the form of fewer direct flights for example, which could impact local businesses negatively, loom larger. Policies targeting aviation emissions are therefore particularly interesting in relation to the 'matching principle' and correlated political feasibility and conflicts of interest (Adler, 2005; Butler and Macey, 1996). Furthermore, due to the international character of aviation emissions, one challenge for the institutional structures at different levels of governance is to find a combination of appropriate geographical authority and policy (Button, 2019).

The aim of this thesis is to strengthen knowledge on climate policy for aviation at multiple governance levels and by doing so contribute to a more informed policy process. This work is done by analysing climate policy concerning aviation at local, national, multinational and global levels. The research questions are the following:

i. Are there policy actions at the local level to reduce greenhouse gas emissions from aviation? How are greenhouse gas emission from aviation treated in local emissions inventories? What policy initiatives have been taken within this domain and what are, from the cities' perspectives, the conflicts of interest related to this domain?

ii. What is the expected effect of current and planned international policies (the EU ETS and CORSIA) regarding reductions in carbon emissions from aviation up to 2030? Are there legally feasible policy instruments that can be decided nationally which would result in additional emissions reduction from both domestic and international air travel?

iii. What is the climate impact and change in passenger volume due to the biofuel blending mandate suggested in Sweden? How will the biofuel blending mandate interact with other aviation climate policies at the national and international level? What will the impact be on the accounting of emissions towards national and international climate targets?

This work focuses on climate impacts and does not analyse other sustainability effects of the aviation policies in question.

2 Theoretical Background

In this chapter I present a theoretical background for this thesis work on the analysis and assessment of climate policies for aviation. First I will describe some crucial concepts for this work; such as governance, policy, the matching principle, collective action problems, polycentric approach and political feasibility. Thereafter I will give a background to this specific policy field, namely climate policies for aviation.

Governance and policy

One common use of the term governance is to describe an act of governing where the traditional state is less dominant than before, and more actors, such as civil society, networks, partnerships, private and community activities, are involved in the solving of collective problems (Smedby, 2016). Even with this view of governance, the state can play a central role in the governing processes (Hildingsson, 2014; Jordan et al., 2015). How central the role of the state is varies between geographical settings and policy areas. Governing of cities, nations, unions of many nations (e.g. EU) and the globe can be seen as different levels of governing. These levels will interact with each other and cannot be studied as isolated objects. Figure 1 gives a schematic outline of the levels of governance and the interactions between them, which are studied in this thesis.

Figure 1: Levels of governance

Matching principle and collective actions

A basic principle of environmental policy is to match the policy instrument with the scale of the environmental problem at play. In environmental law, this is known as the matching principle (Adler, 2005; Butler and Macey, 1996). It is based on an understanding of environmental problems as externalities or problems of collective action (Brennan, 2009; Young, 2002). From this perspective, local and national policies addressing the global challenge of climate change, such as measures to limit air travel, are paradoxical. Firstly, such policies would usually not be likely to gain political support, since the costs of introducing such policies would be incurred at the local level

while the benefits would be shared globally (Hardin, 1968; Olson, 1965). Secondly, even if local climate policy measures were to be implemented anyway, there may be problems in terms of their effectiveness and efficiency due to leakage, i.e. the direct or indirect relocation of polluting activities to outside the area subject to such an environmental policy (Ostrom, 2010; Wiener, 2007).

Despite the reasons for non-action as mentioned above, we are witnessing a strong level of commitment and actions to address climate change at the diverse scales of governance (Bulkeley, 2010; Castán Broto and Bulkeley, 2013; Hoffmann, 2011; Jordan, et al., 2015; Ostrom, 2010). This has partly been explained by the increasingly complex nature of environmental challenges, and the fact that many climate policies come with local co-benefits, such as decreased local air pollution. Ostrom (2010) goes further and argues that the conventional theory of collective actions lacks empirical support.

While the governing as outlined above are engaged in ways to promote certain developments, Zvolska et al. (2017) highlight the possibilities for governments to act both as promoters and inhibitors through their actions. This aspect is visible when looking at goal conflicts between different policy areas (Lougheed, Metuzals, & Hird, 2017). One example where an actor, e.g. a city, can act both as promoter and inhibitor, is by initiating actions aimed at impacting the volume of air traffic. Governance actors face conflicting interests and might initiate countervailing activities, both indirectly promoting an increase of aviation emissions and supporting other activities that inhibit such emissions.

Polycentric approach

Ostrom (2010) raises the importance of not only focusing on global actions for solving a global collective-action problem such as climate change. While world leaders discuss and take steps towards (and sometimes away from) a global treaty, many activities can be undertaken by multiple units at diverse scales to make a cumulative difference – a so called polycentric approach (Ostrom, 2010). For such an important issue as the global climate, it could also be argued that it is appropriate to have a plan B. If Plan A is to have a global treaty, plan B could be to solve the climate challenge with local and regional efforts as back up if Plan A does not work or is delayed (Ostrom, 2010). A related idea often highlighted by policy researchers is to avoid that the perfect becomes the enemy of the good. In other words; if the theoretical, most cost-efficient, policy option is unavailable due to for example political feasability reasons, then the second best should be used. This idea stresses that policy makers must think beyond merely cost-efficiency. Political feasibility and public support are two main hurdles. Inability to use the theoretical best option should not be seen a reason for inaction (Azar, 2009).

Furthermore, global or international policies seldom come out of nothing. One advantage of a polycentric approach is experimentation and learning from experience with diverse polices. This gained collective learning can influence other levels of governance. Further, one can argue that the largest impact a small country such as Sweden can have on the reduction of global greenhouse gas emissions is by inspiring others and showing what is possible and transforming to a fossil-free welfare state.

There are though also risks with the polycentric approach. With many projects and activities operating at multiple scales without effective support of a global treaty there is potential overlapping and leaking, and thereby lowering the political support (Betsill, 2001; Ostrom 2010). Other risks are inconsistent policies, inadequate certification, gaming the system and free riding (Ostrom, 2010).

Modes of governing at the local level

One typology where policy instruments are categorized into different modes of governing at the local level has been developed by Bulkeley and Kern (2006). We apply this topology in paper I when studying actions taken at the local level to reduce aviation emissions. The original typology distinguishes between four different capacities employed in local governance:

> *1. Self-governing* refers to instruments based on the capacity to manage the city's own organisation. It includes aspects such as travel policies for municipal employees or the renovation of the municipal building stock to increase energy efficiency.
>
> *2. Governing by provision* refers to initiatives based on the local government's role as a provider of goods and services, and may include for example the provision of low-carbon district heating or the provision of public transport.
>
> 3. When *governing by authority*, local governments rely on their capacity to introduce sanctions if a certain mandate is not followed. This may refer to local regulations, such as those related to road traffic. Also, the municipality's responsibility for spatial planning usually includes some element of governing by authority through legally binding spatial plans.
>
> 4. In contrast, *governing by enabling* refers to the local government's capacity to persuade and encourage through the use of *positive* incentives such as subsidies or through information campaigns.

Different modes of governing are not mutually exclusive and are often employed in combination (Bulkeley, Watson, Hudson, & Weaver, 2005). While *self-governing* entails the least challenges in terms of the capacity to act, the impact that can be achieved through this mode of governing is limited. In the case of *governing by authority*, the local

government's capacity to influence is usually rather limited. Therefore, many municipalities tend to focus on initiatives which can be categorised as *governing by enabling* when seeking to influence outcomes beyond their own organisations. However, *governing by enabling* comes with its own challenges in terms of effectiveness, efficiency and cost.

Some previous suggestions have been made to extend the typology to include an additional mode of governing. Bulkeley et al. (2009) identified a mode as *governing by partnership* in which state and non-state actors work together. This is conceptualised as an extension of *governing by enabling*, in which the state acts on more equal terms with non-state actors. Similarly Holm, Stauning, & Søndergaard (2012) argued that *governing by enabling* could be taken one step further by emphasising the role of local governments as 'strategic actors in shaping local sociotechnical networks, including the shaping of shared visions and goals for such networks'. In addition to policy implementation, the modes of governing may also address outputs in terms of policy formation (Khan, 2013). Policy formation is particularly important in relation to partnership and vision building. Building on the work done by Bulkeley, et al. (2009), Holm, et al. (2012) and Khan (2013), we add (in Paper I) the following fifth mode of governing:

> *5. Governing by agenda setting*. The local government's capacity to act through various types of partnerships and other fora in order to build visions and influence policy and industry agendas *beyond* the local setting in a direction that supports the overarching goals set by local actors.

With their authority limited to the local setting, such as in the case of aviation emissions, governing by agenda setting can be an important channel for cities to express their concerns and support change at a higher level.

Climate policy for aviation

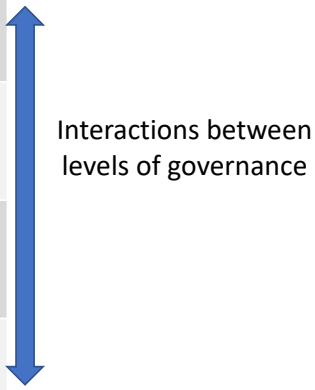
The aviation sector is affected by a local, national, multinational (EU) and/or global climate policies targeting domestic, intra-European (EEA) and intercontinental flights in different and partly overlapping ways. These are summarised in table 1 below. In 2016, ICAO made the decision to implement a Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) with the aim of achieving "carbon neutral growth" from 2020 (ICAO, 2016a). The agreement under this scheme stipulates that airlines are obliged to offset their increase in emissions after 2020 by purchasing credits from emissions mitigation projects outside the aviation sector. Between 2020 and 2027

the system is voluntary, but after that it becomes mandatory for most countries[1] (IATA, 2019). When looking at both domestic and international flights, and at total emissions, not just the increase, it has been estimated that 12% of aviation emissions will be offset due to CORSIA in 2030 (Scheelhaase et al., 2018). There are still large uncertainties regarding which types of offset credits that will be eligible for CORSIA and what the price of them will be.

Further, CO_2 emissions from flights having both the origin and the destination within the European Economic Area (EEA) are included in the EU Emissions Trading Scheme (EU ETS) (European Commission, 2014). In addition, many countries (e.g. Germany, Sweden, France, Norway, Austria, UK, South Africa) are applying a passenger taxes on both domestic and international flights (Faber and Huigen 2018). Norway will introduce a biofuel quota (starting in 2020) and Sweden has a proposal on a biofuel blending mandate with a specified reduction obligation (SOU, 2019:11).

Table 1. Climate policy for aviation at different levels of governance

Geographical level of governance	Actors	Policy
Global	ICAO	CORSIA
Multinational	EU	EU ETS
National	States	Air passenger tax Tax on jet fuel Biofuel blending mandate
Local	Cities	e.g. information campaigns & travel policies



In addition to CO_2 emissions, there are also so called non-CO_2 effects from aviation, principally emissions of nitrogen oxides, contrails, and aviation-induced cirrus clouds. The flight needs to be at a certain altitude for these non-CO_2 effects to significantly contribute to the warming, short distance flights spend in relative terms a small fraction of the trip on such altitudes (Azar and Johansson, 2011). There is uncertainty about exactly how large these non-CO_2-effects are. Österström (2016) present the non-CO_2

[1] Exemptions are: Least Developed Countries, Small Island, Developing States, Landlocked Developing Countries and States that account for less than 0.5% of total Revenue Tonne Kilometers from international aviation in 2018 (IATA, 2019).

effects to add 30% for domestic flight, 70% for flight within EU and 90% for intercontinental flights on top of combustion emissions. It is likely that there is potential to modify fuels in order to reduce non-CO_2 climate effects (Moore et al., 2017). This can apply to both biofuels and fossil fuels. None of the above-mentioned policy instruments specifically target non-CO_2 effects in their policy design, but since policy instruments such as CORSIA, the EU ETS and biofuel blending mandate all have a price increase effect they could result in a decreased relative travel volume, which in turn reduces not only fuel demand but also non-CO_2 effects. It is also noteworthy that some measures to reduce non-CO_2 effects, e.g. flying at a lower altitude, may imply increasing CO_2 emissions by increasing fuel consumption. The flight with the lowest climate impact is therefore not necessarily the one with lowest fuel consumption.

3 Methodology

The following text will present the methods used in paper I, II and III and I will reflect upon the reasoning behind the choice of method, potential alternative methods, advantages & shortcomings. But firstly, I will give some general reflections on the research process for this thesis.

Multiple methods & inter-disciplinary collaborations

The primary focus of this thesis is to address a number of policy-relevant research questions rather than methodological development. Consequently, I do not focus on one method for all three papers, instead I have adapted the choice of method to each research question respectively. This approach has given me the opportunity to explore different methods, but of course also the disadvantage of not deepening my knowledge on one specific method.

I have been working with researchers from different universities and from different research fields. In the first paper, I had the opportunity to work closely to Dr Nora Smedby, a *political scientist* in the field of local governance and sustainability at IIIEE (University of Lund). In this work also my supervisors, *consumption researcher* Associate Professor Jonas Nässén and *sociologist* Associate Professor Jörgen Larsson were involved. In the second paper I worked with *transport researcher* Dr Jonas Åkerman at KTH and Jörgen Larsson at Chalmers. Also *environmental economist* Professor Thomas Sterner was involved as a co-author. In the third paper, *climate modeller* Associate Professor Daniel Johansson at Chalmers, was my main colleague with whom I developed the model. I have very much appreciated the opportunity to work and thereby learn from a broad spectrum of researchers from diverse academic settings and backgrounds, who have different motivations and use a variety of methods. Before starting my doctoral studies I also wrote a paper as an employee of ETH Power system Lab in Zürich. This paper was done in collaboration between ETH (Professor Göran Andersson and Dr Mathias Gallus) and Chalmers (Professor Filip Johnsson, Associate Professor Sten Karlsson, Dr Lisa Göransson, Sara-Linnea Östervall). In my future research I will strive to continue with inter-disciplinary collaborations.

Paper I: Qualitative document analysis

Paper I aims to examine how cities address aviation emissions in their Sustainable Energy Action Plans (SEAP), which is an umbrella term for official documents that describe a city's measurements of emissions as well as plans and activities to reduce them. Two networks of cities, the Compact of Mayors and the Covenant of Mayors, provide databases of SEAPs uploaded by the cities in these networks. These databases

have been used as the main sources of SEAPs. Emissions inventories were sorted according to the schematic outline in Wood, Bows, & Anderson (2010), which distinguishes between consumption and territorial perspective on emissions. Policy interventions were characterised and analysed according to the typology of the five modes of governing (Castán Broto and Bulkeley, 2013). In total, 231 SEAPs were included in the analysis.

This work came from a discussion with Dr Nora Smedby at IIIEE (Lund University) about local governance and its role in reducing aviation emissions. A merging of her knowledge on local governance and my focus on aviation emissions and climate policies started the formulation of some research questions and methods. The original idea was to answer the research question with a case study of five cities and a document analysis of SEAPs. I started with Gothenburg as one case, performing interviews with persons employed by city-owned destination management company, the regional destination authority and the environmental department of the municipality. I also analysed documents from these organisations to find activities promoting or inhibiting (see Theory section for this concept) aviation emissions. The work with the first preliminary results were presented to researchers at Gothenburg University (Dr Erik Lundberg and John Armbrecht) and at IIIEE at Lund University (Dr Oksana Mont). The common feedback I received was that the scope was too broad to be thoroughly covered in only one paper and should be split in two. Their arguments convinced me and my supervisors and I didn't move forward with further case studies as planned, but instead continued with a method of only using the SEAPs uploaded to the databases. To do the case study of three cities and their activities concerning aviation emissions would be a possible separate paper. A case study would, in addition to the already completed study, better grasp the city's reasoning behind the activities, and also find out which proposed activities were not yet accomplished.

System boundaries and limitations

My search was limited to English, German - and 'Scandinavian'[2]-speaking OECD countries, which comprised around 400 cities in the databases[3] mentioned above, of which more than 200 had uploaded SEAP documents. Supplementary searches for SEAPs were carried out on the websites of cities in countries with a low number of SEAPs in the databases. By adding language competences, especially French and Spanish, it would be possible to increase the geographical scope of SEAPs.

The cities studied are probably the more ambitious ones in the domain of documentation of sustainability efforts, since they have completed the work of a SEAP

[2] Sweden, Norway, Denmark and Iceland

[3] Total number of cities registered in the Covenant of Mayors (1000) and the Compact of Mayors (500).

and also upload it to the networks database. Moreover, what one can expect to find in a SEAP is a city's activities to reduce aviation emissions. Countervailing activities, such as actively lobbying for more flight connections in order to stimulate growth and employment, are not found in the SEAPs, but in other documents, such as the cities' growth and destination strategies. So with the method chosen, I just saw the "green" side of the story.

Potential other methods & modified research questions

To be able to do a more comprehensive analysis of governance of aviation emissions (both increasing and decreasing these emissions), one potential research project could be to use the same method, but instead search in growth strategies as well as destination strategies from the same cities. With those two studies at hand, it would be possible to analyse contradicting actions taken by cities that effect the emissions from aviation, instead of just actions taken to reduce emission from aviation (as I did). We studied some criticism of these SEAPs and countervailing activities and found that cities often have different and inconsistent goals and strategy plans, and that activities to increase air travel (implying an increase in aviation emissions) exist in cities which have also introduced interventions to reduce aviation emissions. Since the interventions found in the SEAPs were mostly of the kind that have limited expected impacts, it is possible that cancelling pro-aviation activities, such as subsidies to local airports, might be the most effective local intervention to reduce aviation emissions. Here, the city has full authority, but also faces conflicts of interests with other local goals.

Another potential project would be to do the planned case study of five cities in order to analyse the activities of local governance in this domain. It would probably also be a better way to grasp the "passivities" (actions that have not been taken) and see more nuances of countervailing activities and conflicts of interest.

Paper II: Analysis of policy papers and journal publications

Paper II, was the first paper I worked with starting my doctoral studies. My supervisor Jörgen Larsson is the main author and Jonas Åkerman and Thomas Sterner are co-authors alongside myself. The method of this paper is mainly an analysis of policy papers from relevant organizations (EU, ICAO) as well as a literature review of academic journal publications. As a new doctoral student this gave me an opportunity to grasp the field of climate policies for aviation and discuss the literature with my senior colleges. The selection of documents to be analyzed was based on the senior authors previous knowledge in the field.

Paper III: Development of an energy-economic model

In paper III one aim is to quantify the effect on passenger volumes and climate impact of a suggested Swedish biofuel blending mandate for 2030. In order to do so we (Daniel Johansson and myself) developed an energy-economic model based on ASIF-reasoning (Schipper, 2003). The fundamental logic in the model is seen below. The total emissions for each trip category (i) are dependent on ticket price (P), blending rate (b) and time (t). Multiplying the Activity (A), which is defines as number of trips, with energy intensity (e), defines as energy per trip, with CO_2e intensity depending on biofuel blending rate (b) gives the total emissions. We have differentiate between six categories of trips; domestic-coach, EEA-coach, intercontinental-coach, domestic-business, EEA-business, intercontinental-business.

$$E_i(P_i, t, b) = A_i(P_i, t) \cdot e_i(t) \cdot c\big(b(t)\big)$$

E_i = Emissions (kg CO_2)
P_i = Ticket price (Euro)
A_i = Activity (number of trips)
e_i = energy intensity (MJ/trip)
c = CO_2 intensity (kg CO_2/MJ)
t = time
b = blending rate (based on reduction levels on LCA[4] emissions)
i = type of trip

The "ASIF" reasoning is intuitive and simple to grasp, which also makes the model transparent and not "covered" by a structure that is more complicated than necessary. The risk with detailed quantified results is that they give a sense of false accuracy. Numerous assumptions are always needed even if it is a model of a present situation. If, as in our case, it is a simulation into the future, the assumptions will be more uncertain than simulations of the present. In the work with this paper I have been mainly responsible for doing the research considering all input values. A paper should always be reproduceable, and the methodology should be clear and understandable for the reader. This is an important issue for me, because I do not want to become associated with a personal opinion which biases my results due to assumptions made and methods chosen in my research. I want to stay as objective and transparent as possible, also acknowledging that I have both conscious and unconscious biases. Lastly, in this paper we only look at one aspect of sustainability, namely climate impact, and do not include aspects such as preservation of biodiversity.

[4] LCA = Life Cycle Analysis

4 Summary of Appended Papers

Paper I: Local governance of greenhouse gas emissions from air travel
This study aims to examine how local government (cities), addresses aviation emissions in their Sustainable Energy Action Plans (SEAP). To fulfil this aim, over 200 SEAPs were analysed focusing on three issues: (1) Treatment of aviation emissions in local emissions inventories; (2) Policy initiatives within this domain; and (3) The cities' perceptions of the conflicts of interests. Results showed that more than half of the cities acknowledge the challenge of aviation emissions, around one third include aviation emissions in their emissions inventories, and more than one quarter have initiated policy interventions. To categorise these interventions, we have added a mode 'governing by agenda setting' to an existing analytical framework, 'Modes of governing'. With their authority limited to the local setting, this mode of governing is a common channel for cities to push changes at higher levels. By raising awareness within the local setting (through their own organisation, local business, residents) and placing the challenge on the agenda at higher levels, acceptance for and the likelihood of more efficient policies could rise. It is difficult, however, to monitor how such activities are received and their actual outcome.

The initiatives chosen mainly rely on *self-governing* or *governing by enabling*. Governing by provision, which has been identified by previous studies as the most important area for local climate action, turned out to have limited relevance for aviation emissions reduction. The initiatives were divided into the following three reduction strategies: (A) reducing air traffic volume; (B) improving eco-efficiency of aviation; and (C) reducing ground level aviation emissions. The reduction strategies chosen for most of the interventions found in *self-governing* and *governing by enabling* were to reduce air traffic volumes followed by actions to decrease ground-level aviation emissions.

Paper II: International and national climate policies for aviation: a review
The aim of this paper is to provide an comprehensive analysis of international and national climate policies for aviation. The analysis is based on policy papers from the relevant organisations (mainly the EU and ICAO), on literature review of academic journal publications as well as a quantitate analyses of the emission reductions. In 2016, the ICAO decided to implement a Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and in 2017 the EU decided on faster emission reductions in its Emissions Trading System (EU ETS), which since 2012 includes the aviation sector. The effects of these policies on the expected development of air travel emissions from 2017 to 2030 have been analysed. For the sample country Sweden, the analysis shows that when emissions reductions in other sectors are attributed to the

aviation sector as a result of the EU ETS and CORSIA, carbon emissions are expected to reduce by 0.8% per year. Our analysis of potential national aviation policy instruments shows that there are legally feasible options that could mitigate emissions in addition to the EU ETS and CORSIA. Distance-based air passenger taxes are common among EU Member States and through increased ticket prices these taxes can reduce demand for air travel and thus reduce emissions. Tax on jet fuel is an option for domestic aviation and for international aviation if bilateral agreements are concluded. A biofuel blending mandate is a third option.

Paper III: Policy analysis of biofuel blending mandate for aviation

Sweden is planning a biofuel blending mandate, heading towards a 27% decrease in the fuel's CO_2 emission intensity by 2030. In this paper, we analyse this policy from two perspectives: (1) its impact on emissions from flights fuelled in Sweden; and (2) the interaction between the national biofuel blending mandate and existing and planned aviation climate policies at the national, EU and global levels.

In a reference scenario without the biofuel blending mandate, CO_2 emissions from flights fuelled in Sweden are estimated to increase by about 6 per cent by 2030 compared with the 2017 emissions level. With the biofuel blending mandate, CO_2 emissions would instead decrease by about 24 per cent during the same time period. The reduction in CO_2 emissions would originate from two separate effects: (a) the reduction in CO_2 intensity by mixing biofuels into jet fuel; and (b) by a reduction in the demand for air travel due to the increase in costs. The effect of the reduction in CO_2 intensity is roughly 20 times more important than the demand effect.

The biofuel mandate will, if implemented as suggested, reduce the demand for the EU ETS permits by around 780,000 tonnes of CO_2 by 2030, which corresponds to 69 per cent of the total end-of-pipe CO_2 emissions reduction due to the biofuel blending mandate. If this leads to an actual emissions reduction or not will depend on the degree to which this will result in cancellations of permits within the market stability reserve. Around 86 per cent of the total combustion emissions reduction due to the biofuel blending mandate is estimated to fall under CORSIA by 2030, and will thereby reduce the offset credits that need to be purchased within the CORSIA scheme. Fifty-five per cent of the estimated emissions reduction will be included in both the EU ETS and CORSIA if intra-EEA flights are covered by both schemes.

5 Results & Discussion

The aim of this thesis is to strengthen knowledge on climate policy for aviation at multiple governance levels and by doing so contribute to a more informed policy process. For this we need to map policy instruments at different levels of governance and better understand their interaction. The theory of collective action predicts that for a global collective problem such as climate change, only global solutions is the appropriate (Ostrom, 2010). By studying existing and planned policies at different geographical levels of governance, we can show that in reality there are policy initiatives at several levels. Table 2 summaries the geographical level of governance (see figure 1 and table 1 in theory section), actors, policy instruments and interactions studied by the three papers appended in this thesis.

Table 2. Climate policy for aviation: Geographical level of governance, actors, policies i and interactions studied by the three papers appended in this thesis.

Geographical level of governance	Actors	Policy	Interactions between levels of governance		
Global	ICAO	CORSIA	Paper I: Identification and analysis of "agenda setting", e.g. cities aiming for influencing policy making at national and international level.	Paper II: Analysis of overlap and emissions reduction contribution of international and national policies.	Paper III: Quantification of emissions reduction of a national biofuel blending mandate overlapping with EU ETS and CORSIA.
Multinational	EU	EU ETS			
National	States	Air passenger tax Tax on jet fuel Biofuel blending mandate			
Local	Cities	Self-governing Governing by enabling Governing by provision Agenda setting			

In this chapter I will present results acquired from this thesis considering aspects of:

1. System boundaries
2. Actions taken
3. Conflicts of Interest
4. Agenda Setting
5. Interaction of policies

1. Choice of system boundaries for 'no-man´s land-emissions'

In Paper I we show that, over half of the cities analysed acknowledge aviation as a climate issue in their Sustainable Action Plans. Limited authority combined with this recognition of a responsibility puts cities in a situation that is difficult to manage in a consistent way. One third of the cities examined include aviation in their emissions inventories in one way or another. However, system boundaries and allocation methods varied considerably between cities. Wood, et al. (2010) argued that the inclusion of aviation in emissions inventories is important as a basis for setting goals and choosing actions, and by providing credible comparable data this serves as a tool pushing policy makers to measure and introduce policies. Our results, however, show that excluding aviation in emissions inventories does not necessarily imply that no policy actions are taken. Indeed, some cities stated that they did not include emissions data in their inventories, but still intended to act for a reduction of this source of emissions. At the same time, this raises questions as to how such measures would be evaluated and regarding accountability.

Inclusion of aviation emission can be made independently of choice of system boundary (see table 3). The territorial system boundary is often referred to by cities as Scope 1 and the consumption system boundary as Scope 3[5] (Chavez and Ramaswami, 2014). The choice of a consumption or a territorial system boundaries for different actors at local, national, multinational level, results in a difference in the prominence of aviation emissions. For example, on the local level; a city with an airport hub within its territory is more likely to allocate more emissions based on a territorial system boundary rather than a consumption system boundary that includes only its own residents' air travel. A city without an airport within its territory, is more likely to allocate more emissions based on a consumption system boundary. Therefore, each actors' choice of system boundary is important to note, as is the reasoning behind their choice. The complexities of proper accounting due to "emissions serving a region", which is also the case for port cities (e.g. Rotterdam), is emphasized in the Greenhouse gas protocol (GPC) (Fenton, 2017).

[5] Scope 2 is emissions from the consumption of purchased energy.

Table 3. System boundaries on GHG emissions from air travel in local emissions inventories. Each system boundary is shown with identified alternative implementations and examples of such cities.

System boundary	Example cities
Territorial	
Take-off and landing	Stockholm (SE), Hagfors (SE), Västerås (SE), Berlin (DE), Lidköping (SE)
Tanked fuel at local airport	Munich (DE)
Ground operations at local airport	
Consumption	
Resident as consumer	Gothenburg (SE), Aspen (US)
Tourist as consumer	Aspen (US), Haninge (SE), Gothenburg (SE), Reykjavik (IS)
Own organisation as consumer	
Exclusion of GHG emissions from air travel	Dublin (IE), Wolfurt (AT) Bregenz (AT), Tyresö (SE), San Francisco (US), Philadelphia (US), Gislaved (SE), Knowsly, GB

We have recognised that cities tend to choose the system boundary giving the lowest reported emissions. In contrast, the biofuel blending mandate applies a system boundary of all fuel tanked within Swedish territory. This will result in only 14 per cent of the expected emissions reduction from the biofuel blending mandate, which will fall under Sweden's Nationally Determined Reduction (see figure 3). This in comparison 100 per cent would contribute to Sweden's Nationally Determined Reduction if the policy only would be applied for domestic flights.

The additionality of a biofuel blending mandate is also ambiguous for the system boundary of all fuel tanked, since the majority of affected fuel also is covered by CORISA and/or the EU ETS. To "guarantee" 100 per cent "real" reduction, one option would be to introduce a blending mandate exclusively on domestic fuel. Thereby the nation would receive the credit for this in the National Determined emission reduction.

2. Actions are taken at global, multinational, national and local level

According to the conventional collection-action theory global aviation emissions will not be significantly reduced unless an external authority determines appropriate actions to be taken, monitors behavior, and imposes sanctions (see Theory section). In the case of aviation emissions, this external authority can be ICAO and one global action can be CORSIA. In Paper II we highlight that it is unprecedented for almost all the world's nations to have agreed to implement a global policy instrument that will entail out-of-pocket expenses for companies. On the other hand, CORSIA has a major shortcoming since it will not achieve absolute emissions reductions. In Paper II we also map actions

taken at the national level, such as air passenger tax, biofuel blending mandate and carbon tax on fuel.

Given the cross-border nature of aviation emission and the strong emphasis on international solutions (Wood, et al., 2010), our results in paper I shows that a surprisingly large share, more than a quarter, of the cities are taking policy initiatives to reduce aviation (Figure 2). Most interventions found were within the modes self-governing and governing by enabling. Reducing air traffic volume is the reduction strategy applied most frequently in these interventions. The modes of governing applied are consistent with the previous results for perceived authority. Cities stated high levels of control of emissions resulting from their own internal activities (self-governing) and their capacity to use information to reduce air travel by their residents, tourists and local businesses (governing by enabling). On the other hand, not a single intervention could be categorised as governing by authority, and only a few interventions were found that focused on improvements in the eco-efficiency of aviation, which some cities state has low potential for influence by a local actor. For interventions focused on reducing ground level greenhouse gas emissions at airports and in airport transfers, a few examples were found in every mode of governing.

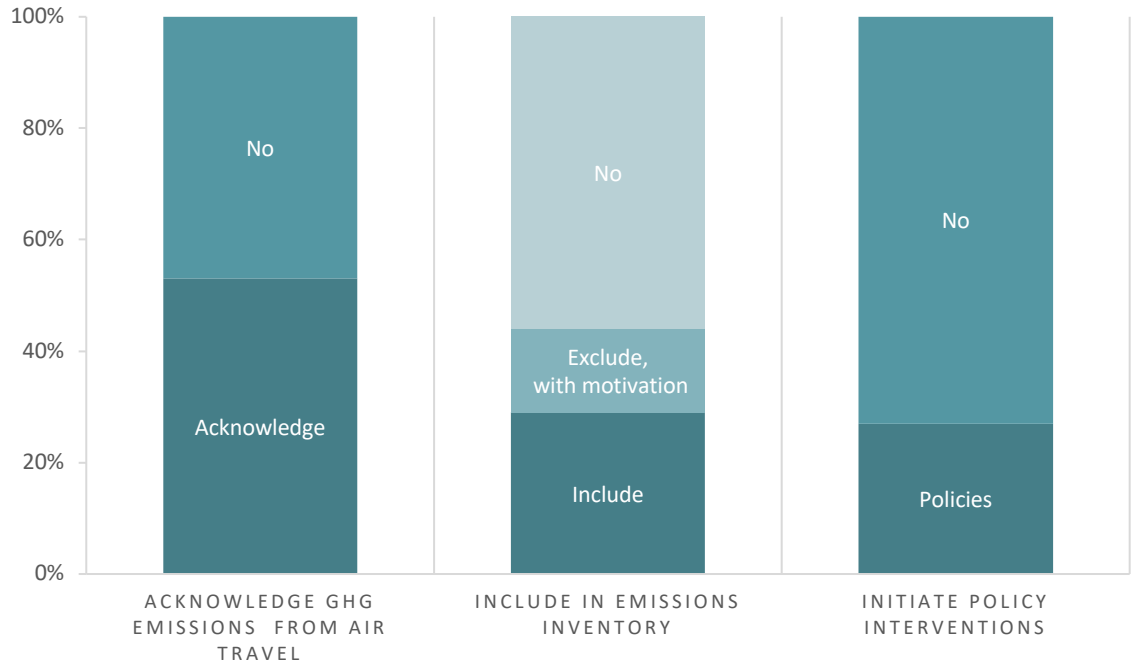


Figure 2. Summary of how sustainability focused cities address greenhouse gas emissions from air travel in their Sustainable Energy Actions Plans.

3. Conflicts of interest

In Paper I we analyse the perceived conflicts of interest coupled with interventions to reduce aviation emissions. With the reduction strategy of reducing air traffic volume, some cities state that this can be in conflict with other goals. A major concern is accessibility, which is perceived as crucial in order to be an attractive region for business, academia, tourism, and as a city to live in. All these aspects are coupled with employment and economic growth. The airport itself is mentioned as an important employer. Some cities also own the local airport, which means financial gains from an increase in air travel. Manchester highlights the difficulty of enforcing a reduction in aviation emissions at the local level and the need for agenda setting to develop national and global solutions:

> *'There is a real and immediate challenge in the potential conflict between aviation growth and tackling climate change. Until an appropriate UK, European and international framework is in place which can reconcile aviation growth and climate change strategies, it would not be sensible for Manchester to take action which simply damaged the economy of the city region and transferred aviation growth elsewhere. However, we need to develop and communicate a clear policy stance on this issue and engage at national level to ensure this potential conflict is rapidly and transparently reconciled'*
>
> (Manchester city council, 2008, p.10.)

Cities with ambitious climate targets can also have parallel activities that lead to increased air travel, which shows the different interests of the city (see Theory section "inhibitor" and "prohibitor"). The examples listed below are categorised by mode of governing (No example of *governing by provision* was found):

- *Self-governing*: Financial support to local airport to cover economic losses
- *Governing by authority*: Allow/encourage expansion of airport
- *Governing by enabling*: Target far away tourists in destination marketing
- *Governing by agenda setting*: Lobbying for more flight connections hindering national policies to reduce aviation emissions by commenting negatively on any such proposals circulated for comment.

4. Agenda setting as action when authority is perceived as limited

In Paper I we found that many cities try to influence policy and industry agendas beyond the local setting. We have categorised these activities as governing by agenda setting, a fifth mode of governing in addition to the framework by (Bulkeley and Kern, 2006). The fact that many highlight such activities in their SEAPs is likely a result of the limited authority that cities have in the aviation domain. By raising awareness within the local setting (through their own organisation, local business, residents) and placing

the challenge on the agenda at higher levels, acceptance for and the likelihood of more efficient policies could rise. It is, however, important to recognize that even if cities' targets and plans are ambitious on paper, cities are typically not accountable to higher level authorities at the national level. If cities would have been obliged to take on shares of the Intended Nationally Determined Contributions to the UNFCCC, then the stakes would have been much higher.

Also the national policies studied in Paper II & III have a potential agenda-setting role, as a national policy instrument can be upscaled to include more countries. One example is the Norwegian biofuel blending mandate which Sweden may also introduce. These Scandinavian countries could export the biofuel blending mandate to more nations and push for international biojet fuel policies.

5. Interaction of policies: A national policy in relation to the EU ETS and CORSIA

Figure 3 presents the results from Paper III considering the amount of combustion emissions reduction due to the biofuel blending mandate and distinguishes these for flights covered by the EU ETS and CORSIA. The biofuel blending mandate will reduce the demand for EU ETS credits by around 780 000 tonnes of CO_2 by 2030, which corresponds to 69 percent of the total emission reduction due to the biofuel blending mandate. Whether this leads to an actual emissions reduction or not depends on to what degree this will result in cancellations of credits within the market stability reserve. Around 970 000 tonnes, 86 percent of the total emissions reduction due to the biofuel blending mandate is estimated to fall under CORSIA by 2030, and will thereby reduce the demand on credit purchased due to the CORSIA scheme. Of the emissions reduction, 55 percent might be included in both the EU ETS and CORSIA. However, it is still not clear, if intra-EEA flights will be covered by both schemes. Even though the total emissions reduction from fuel tanked in Sweden due to this national climate policy instrument (biofuel blending mandate) is around 1.1 millions of CO_2 in 2030, only 14 per cent, 156 000 tones, can be reported as "Swedish emissions reduction". The reduction of non- CO_2 effects will not be reported to any climate political target.

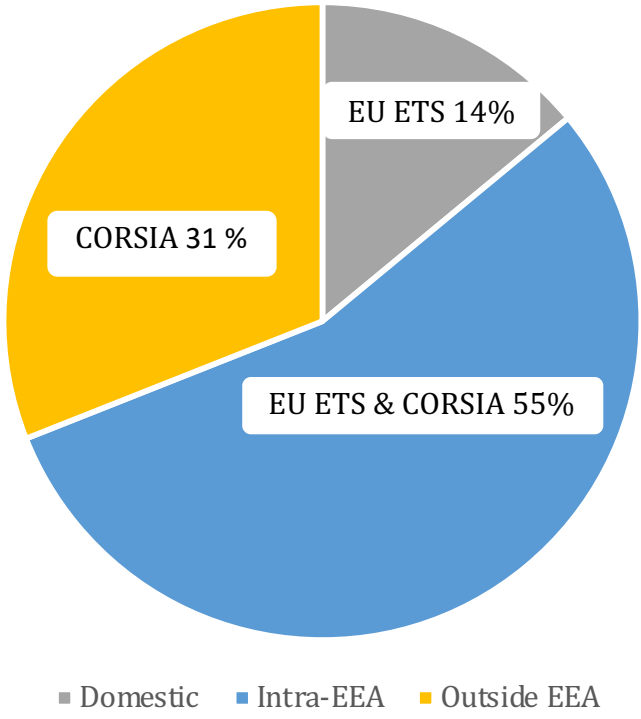


Figure 3. Reduced emissions (ton CO_2e) from jet fuel tanked at Swedish airports due to the biofuel mandate in 2030 and how this will affect the reported emissions for different reporting systems. Total combustion emission reduction is 1 128 000 tonnes of CO_2. 69 percent (Domestic and Intra EEA) will fall under the EU ETS. 86 per cent will fall under CORSIA (all international). 55 per cent will fall under the EU ETS and CORSIA.

For a long time there has been a discussion about the additionality of national climate policies on sectors already covered by the EU ETS. If the cap is fixed further interventions to reduce emissions in one place could cause emissions to increase in other sectors and/or in other member states. With this reasoning there will be no climate benefits from national interventions targeting emissions included in the trading sector. However, it can be argued that emissions do not automatically move to other sectors or member states. The accumulated surplus of permits could demonstrate this, since the surplus could mean that the permits have not been used at all (Konjunkturinstitutet, 2018). In 2023, permits held in the market stability reserve above the number of permits auctioned the previous year will be cancelled. This cancellation mechanism of the EU ETS implies that emission reductions in the trading sector will have a larger climate benefit than before. In addition, a reduced demand for ETS permits could also have a long-term effect on the cap, by reducing it (Carlén et al., 2019).

If the primary goal of introducing a biofuel mandate is to reach a guaranteed reduction of emissions through the use of biofuels, it is an option to relocate the planned use of biofuel for aviation to the road sector, which is excluded from the EU ETS. But if one

goal is to push for a specific technology shift within the aviation sector, a specific technology policy is needed. A specific technology policy is not the most cost-efficient way of emissions reduction in the short term perspective, but can be needed to realize cost reduction in the long term and thereby make a shift in technology possible (Azar and Sandén, 2011). In this perspective the biofuel blending mandate can be seen as a complementing policy instrument in comparison with the EU ETS and CORSIA, which both are in the policy category of setting a price of the emissions and do not complement each other. Another argument in favour of the biofuel blending mandate is the relatively strong public support for this policy instrument in Sweden (Larsson, Matti, & Nässén, 2019).

One major discussion concerning the proposed reduction scheme CORSIA, is whether it will result in real reductions, in other words if the certifications are adequate. The basis of the Paris Agreement is that nations make commitments through what are termed nationally determined contributions (NDCs). The CORSIA document stipulates that 'double counting' must be avoided (ICAO, 2016b), e.g. that the emissions credits from a wind farm in India cannot be sold to an airline and also counted as a contribution from India. However, it might be tempting for countries to sell credits to airlines instead of using emissions reductions to achieve their own NDC since the former provides additional income. On the other hand, the increased demand for carbon credits in developing countries caused by CORSIA may contribute to continued interest in the climate issue in those countries until more effective global measures can be implemented.

6 Key Contributions & Future Research

The key contributions from this thesis are summarised below. This contribution to knowledge on aviation climate policy at different geographical levels provides can make the policy process more informed.

1. **System boundaries:** At local level both consumption perspective and territorial perspective is used. We have recognised that cities tend to choose the system boundary giving the lowest emissions.

2. **Actions taken:** Actions to reduce aviation emissions are taken at all geographical levels of governance. A surprisingly large share, more than a quarter, of the cities studied are taking policy initiatives to reduce aviation. National policies such as passenger tax, biofuel blending mandate and carbon tax of jet fuel are in place at national levels.

3. **Conflicts of interest & countervailing activities:** The major perceived conflict of interest at local level is economic growth vs reduced air travel.

4. **Agenda setting:** Building on the work done by Bulkeley, et al. (2009), Holm, et al. (2012) and Khan (2013), we add a fifth mode of governing: Governing by agenda setting. With their authority limited to the local setting, such as in the case of aviation emissions, governing by agenda setting can be an important channel for cities to express their concerns and support change at a higher level. There is also a potential of national policies to upscale to multilateral polices and thereby achieve cumulative emission reduction.

5. **Interaction of policies:** National policy such as a biofuel blending mandate in a EEA country will overlap fully with CORSIA and/or the EU ETS, which adds challenges regarding additionality of the emissions said to be reduced due to respectively policy.

In the continuation of my doctoral studies I will research the option of night trains as an alternative travel mode to aviation. I plan to use the theory of 'Strategic Niche Management' to understand why European night trains have failed during a time with increased concerns about global warming and more intense European integration. What are the critical factors? What would be needed to make night trains mainstream again? Expert interviews will be used as one part of a qualitative method.

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