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TERM PAPER IN ENERGY ECONOMICS AND POLICY

THE FUTURE AIR TRAVEL : MEETING THE CLIMATE CHALLENGE

AMBITIOUS REDUCTIONS IN CO_2 EMISSIONS WITH LOW CARBON FUELS

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INTRODUCTION: THE STATE OF AIR TRAVEL TODAY AND IN THE FUTURE

The aviation industry has become a significant player in world globalization. According to the Joint Transport Research Center of the OECD and the International Transport Forum, 35% of world trade by value is transported by air. By 2008 it reached 0.7% of the world's GDP (JTRC, 2008). In contrast, in 2009 passenger travel declined by 4.2%, to 880 million. This reduction was due to a combination of the financial crisis affecting business travel and the uncertainty of the H1N1 influenza virus pandemic that influenced the tourist sector.

In 2010, according to the Swiss Federal Statistical Office, over 18% of international departures from Zurich were within Europe (including direct and transfer flights). The industrialized countries of Europe, the Americas and Asia/Pacific are the major origins of touristic air travels. Higher income in emerging countries permits a follow up of these countries revealing rapid growth over the last years. Business and professional trips are at 15%, while 51% (446 million) of arrivals are related to tourism (UNWTO, 2010).

In 2005, emissions caused by the airline industry were estimated at 641 million metric tons CO_2-eq. (total domestic and international world-wide, military and general aviation excluded). The Marine Transportation, which produces, together with aviation, the most greenhouse gas (GHG) emissions in the transportation sector, is slightly higher, at 651 million metric tons CO_2-eq. (IEA 2008; IPCC 2007).

The airline industry is responsible for an estimated 2% of the global manmade CO_2 emissions (IPCC 2007). Since the combustion of airplane engines occurs at high altitudes, the effects on the climate change may be significantly higher. Besides CO_2, other emissions are also produced, such as nitrogen oxides (NO_x), methane (CH_4) and sulfur oxides (SO_x), to name some of them, that have a negative impact on the radiative balance in the atmosphere (Olst, 2001). It is estimated, by Henderson and Wickrama (1999), that the impact on radiative forcing is thus 2.5 times higher than CO_2 emissions alone. According to Lee et al. (2009), radiative forcing refers, to all global emissions accounted for, even 4.9% of all radiative forcing from the total estimated environmental impact caused by humans in 2005, was caused by the aviation industry (aviation-induced cirrus clouds considered). By reducing CO_2 emissions, other GHG will decrease accordingly.

While other industries have reduced their CO_2 emissions, the transportation sector's is still increasing. Hence, the relevance of the aviation industry to climate change is important, not least due to the energetic evolution of this segment of transportation. The estimated higher real income by emerging countries allows them to fly more frequently and longer. This leads to more energy consuming distances for leisure purposes. Furthermore, as globalization is likely to continue, it may lead to a higher frequency of non-business flights. In 2005 alone, the worldwide demand for aviation increased by 5.9% (IPCC, 2007). It is possible that the total CO_2 emissions of aviation (including military and general aviation) may increase by over 15% by 2050 (HeWi, 1999). Based upon the trends, it can be assumed that flight activity will continue to increase, unless measures of environmental policy on a global scale are implemented. This paper provides an overview on the future of aviation in regard to rising pressure on the industry in regard to GHG emissions. A model shows a possible scenario of less flight activity and additional earnings due to a CO_2 emission tax. The model is based on Swiss-wide departures with destinations outside of Europe. Therefore, to destinations that are not reachable by any comparable means other than by air transportation.

The reduction of GHG emissions from the aviation as well as the marine transportation sectors are until today still unregulated. In the Kyoto Protocol, international emissions from transportation are excluded from the national targets. Few countries have domestic policies in place; the vast majority have not. Australia, New Zealand and the European Union have already integrated the industry sector in their GHG emission trade systems[1] (McCo, 2010). Many airlines set up a way to calculate and pay CO_2 taxes on a voluntary basis. This paper shows calculations done for additional payments on a mandatory basis.

Many factors regarding the exact correlation of GHG emissions and global temperature change remain uncertain. The IPCC (2007) report shows that worldwide emissions have to decrease by 80 - 90% by the year 2050 in relation to 1990 levels. As this paper further reports, this can stabilize the climate. The stabilization refers to an avoidance of temperature changes greater than 2°C compared to preindustrial times (IPCC, 2007).

In 2008, a global declaration for action on climate change was signed by the major representatives of the aviation industry. This declaration contains a commitment on a global level that consists of three steps (Fig. 1):

- 1.5 % per year of fuel efficiency until 2020
- From 2020 to 2050 carbon neutral growth
- From 2050 onwards, 50% reduction in net CO_2 emissions over 2005 levels

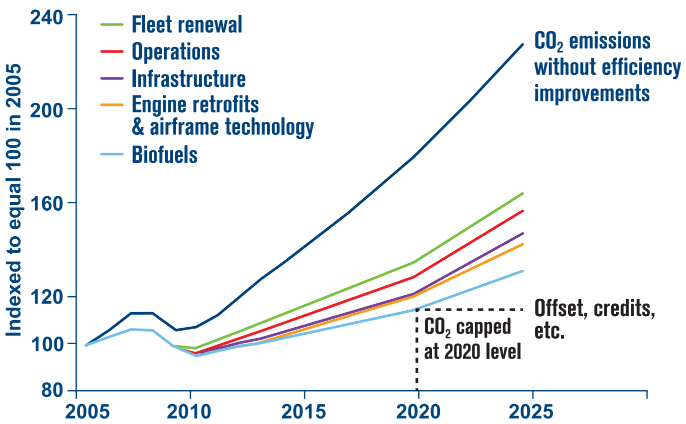


Fig. 1 : Commitment by the airline industry to action on climate change

1 A market-based approach to control pollution by putting economic incentives in place

These targets were presented at last year's Aviation and Environment Summit (ATAG, 2010). The roadmap consists of a four pillar strategy. A major reduction of CO_2 emissions is planned to be achieved by fleet renewal, which the airline industry will implement over time. It is estimated that some 5,500 airplanes will be replaced by 2020, corresponding to a value of US$1.5 trillion (ATAG, 2010). The second pillar refers to aircraft operations and improvements in operational practices by advising airline companies. The third pillar consists of an infrastructure change. This will have a positive impact in optimized air traffic management and thus will cut delay times, increasing overall flight route efficiency. The last pillar is an economic policy measure to increase the rate of carbon neutral growth by the industry (ATAG, 2010).

The aviation industry greatly relies on these "truly ambitious targets", as Paul Steele, Air Transport Action Group CEO, calls them. The last step, in particular, involves considerable government spending amounting to US$7 billion per year (ATAG, 2010). The focus of this paper analyzes to what extent can alternative fuel powers contribute towards reaching the target by 2050 (long-term) or do some specifics of air transportation have to change in order to return to the emission levels of 1990. A basic cost allocation approach, where the quantity of flights reduces due to higher ticket prices as a result of an additional emission tax, is shown in the following chapter. This shows a supplementary and feasible way to reduce CO_2 emissions by the ATAG. Depending on the extent that the tax is implemented, the leisure or business flights can be reduced by regulated higher flight costs. This extends beyond the IPCC report and far further than targets set by the ATAG by being more specific on less air travel via a carbon neutral or even a carbon decreasing approach by price augmentation. The technical optimization of the airplane itself, other than adopting sustainable fuel power measures, is not in the scope of this paper nor the short- to mid-term based infrastructure and operational optimizations.

PRODUCER-RELATED COST ALLOCATION

Methodological Approach

In order to achieve a producer-related cost allocation, a CO_2 emission tax will be implemented, which is based on an addition fee per metric tons of CO_2 discharge caused by each passenger. It is assumed that this additional environmental tax will be charged at departure.

The emission produced by each passenger has to be a calculated, based on various factors. There are several approaches by airlines and air travel related parties to compute the CO_2 rate per passenger. In this paper two different existing models are used. The calculated CO_2 emission is either from the emission calculator provided by the International Civil Aviation Organization (ICAO) or, if no data is provided for certain destinations, alternately by the Scandinavian Airlines (SAS) emission calculator. The data set provided by ICAO is more sophisticated and therefore preferred over the data imparted by SAS.

The model to compute the amount of CO_2 produced per passenger based on ICAO:

$$\boxed{m_{CO2} = \frac{3.157 \cdot (W_{Fu} \cdot \frac{W_P}{W_F})}{N_S \cdot \kappa}} \qquad (1)$$

m_{CO2}	CO_2 per passenger (pax)	[kg/pax]
3.157	Constant, number of tonnes of CO_2 produced by burning a tonne of aviation fuel	
W_{FU}	Weighted average of fuel used (factor). A ratio of number of departs for each equivalent aircraft type, to the total number of departs	
W_P	Weight of loaded passengers (ICAO database)	[kg]
W_F	Weight of loaded freight (ICAO database)	[kg]
N_S	Total number of seats (ICAO database)	
κ	Passenger load factor (ICAO database)	

Tab. 1 : Abbreviations (1)

While both calculations are distance-based, the main difference lies in the data set up detailed by carriers (average fuel consumption by aircraft type) and cabin factors. The Cabin factor is defined as the number of passengers in the aircraft divided by passenger capacity for the aircraft type. The resulting CO_2 emission per passenger is close to the SAS model results (revised by Deloitte & Touche). The difference is mainly due to the fact that the SAS uses an over all capacity utilization average by airline. While ICAO on the other hand, bases its calculations on the actual aircraft type (including the actual exact engine type) used on the accordant route.

To calculate the estimated passenger decrease as a result of higher price due to the supplementary tax, the price elasticity of demand factor is used from the World Tourism Organization. In that report, 21 studies about price elasticities were analyzed and summarized (Gill, 2003). In this paper the median of long-haul international business and leisure as well as short/medium-haul business and leisure price elasticity of demand are applied. As the consumer price for air travel varies considerably, an example route will be used in order to calculate the average route price. The higher the tax (hence the overall price), the fewer the passengers. According to the example return flight for long-haul Zurich - Denver and the medium-haul flight Zurich - Cairo, the tax-related quantity change is used for calculations on other routes. The base data of departing passengers in 2010 is provided by the Swiss Federal Statistical Office.

Assumptions

ASSUMPTION 1: Flights producing more than 400 kilogram of CO_2 per passenger are considered as long-haul flights. Whereas flights with less environmental impact, due to shorter distances, are considered as medium-haul flights. The shorter the travel distance, the more feasible alternative transportation options are, hence higher traveller elasticity. Moreover, it is assumed that price elasticity does not vary other than by flight distance (categorized by medium- and long-haul) or purpose of travel (leisure or business).

ASSUMPTION 2: The purpose of travel is, as stated in the introduction, 15% business and 51% leisure related (UNWTO, 2010). It is assumed that the other 34% are proportionally allocated to either purpose. Thus, the calculation is done with 32% business and 68% leisure related travel.

ASSUMPTION 3: The methodology assumes that if fewer passenger use air travel, then one of the positive outcomes maybe synergy effects of airlines and their alliances and consolidation affects. This may result in an even higher scale effect, which is not considered in the model, neither is the decreased emissions effect by further energy efficiency implementations.

ASSUMPTION 4: All five scenarios assume that emissions are the same, departing from Zurich International Airport or another Swiss airport to a non-European destination.

ASSUMPTION 5: The constants used in the ICAO model (1) are assumed to remain steady regardless further calculations. The passenger load factor κ is considered to be equal before and after. Therefore, a decreasing result flight passengers (based on a negative price elasticity of demand) will not be considered in the model and therefore κ remains constant.

Scenarios

SCENARIO 0: There is no tax implemented. Based on an average price for a long-haul (Zurich - Denver) and a medium-haul flight (Zurich - Cairo) calculations are applied.

SCENARIO 1: In the model, five different CO_2 emission tax scenarios are considered. The first scenario corresponds to a tax of € 5.42 per metric ton CO_2 per passenger. This tax is considered in the SAS model as a carbon neutral way to travel by air. It is also mentioned that the money is used to build a portfolio of wind projects and the tax therefore is relatively low.[2]

SCENARIOS 2-4: These scenarios are priced between the two extremes (scenario 1 and 5) to refine the results.

SCENARIO 5: A carbon reduction of 30% on the example long- and medium-haul flights is calculated. The calculation is based on departures from Zurich to non-European destinations from 2010 out of the equation matrix (2).

2 http://www.carbonneutralcalculator.com/

$$
\begin{aligned}
&Q_{1,B} + Q_{1,L} = Q_1 \\
&Q_{2,B} + Q_{2,L} = Q_2 = Q_1 \cdot 0.7 \\
&P_{eod,B} = \frac{Q_{2,B} - (Q_1 \cdot 0.32) / [(Q_{2,B} + (Q_1 \cdot 0.32)) / 2]}{P_{2,B} - P_{1,B} / [(P_{2,B} + P_{1,B}) / 2]} \\
&P_{eod,L} = \frac{Q_{2,L} - (Q_1 \cdot 0.68) / [(Q_{2,L} + (Q_1 \cdot 0.68)) / 2]}{P_{2,L} - P_{1,L} / [(P_{2,L} + P_{1,L}) / 2]} \\
&P_{2,B} = P_{2,L} \\
&P_{1,B} = P_{1,L}
\end{aligned}
\tag{2}
$$

Where Q stands for the number of departing passengers and P for the price. The equation differs between business and leisure flights. Hence, the percentage of travellers and the price elasticity varies. The tax added price is assumed to be the same for leisure and business purpose.

The Model

The model shows the effect of an additional tax on each departing passenger based on the CO_2 emission they producing individually. The objective is to show the affect on tax revenue compared to revenue loss by the airline industry caused by fewer clients. As a result the CO_2 reduction can be calculated.

The total amount of CO_2 can be calculated as follows (3):

$$
M_{CO2} = \sum_{n=i}^{k} m_{CO2_i} \cdot Q_i \tag{3}
$$

The estimated effect on passenger decrease by the five calculated tax incentives, can be shown based on the price elasticity of demand, which is defined as follows:

$$
\mathrm{P}_{eod} = \frac{(Q_2 - Q_1) / [(Q_2 + Q_1) / 2]}{(P_2 - P_1) / [(P_2 + P_1) / 2]} \tag{4}
$$

The base price is estimated for two example flights, as mentioned earlier. Zurich - Denver is calculated as a one-way flight at a basis of € 475 whereas the average one-way flight Zurich - Cairo is estimated at €265. The estimated average price on a return flight has been divided by two. On behalf of this base price (P_1) other initial prices have been calculated accordingly to their CO_2 emission per passenger calculated earlier. Therefore, the equation (4) can be solved for the departures by passenger after the tax has been added to the price (= Q_2) as shown in equation (5):

$$Q_2 = \frac{-Q_1 \cdot ((P_{eod} + 1) \cdot P_2 - (P_{eod} - 1) \cdot P_1)}{(P_{eod} - 1) \cdot P_2 - (P_{eod} + 1) \cdot P_1} \tag{5}$$

The calculation is based on the price elasticities as shown in table 2 and referred in the methodological approach section. Various travel purposes should be differentiated. The values of business and leisure related travel differ:

Category	*Median*
Long-haul international business	- 0.475
Long-haul international leisure	- 1.650
Short/medium-haul business	- 0.798
Short/medium-haul leisure	- 1.745

Tab. 2 : Price elasticity of demand (Source: Gill, 2003)

Once Q_2 for all departing countries is defined, based on the business/leisure ratio and the long- or medium-haul flight P_{eod}, calculations on CO_2 emission reduction (6), tax revenues (7) and revenue decrease by the airline industry (8) can be calculated as follows:

$$R_{CO2} = \sum_{n=i}^{k} m_{CO2_i} \cdot (Q_{2_i} - Q_{1_i}) \tag{6}$$

$$R_{DA} = \sum_{n=i}^{k} P_{1_i} (Q_{1_i} - Q_{2_i}) \tag{7}$$

$$R_T = \sum_{n=i}^{k} Q_{2_i} \cdot (P_{2_i} - P_{1_i}) \tag{8}$$

Results

Price elasticity of demand

The price elasticity of demand is, as mentioned earlier, highly dependent on the possibility for substitution. Since the model focuses on medium- to long-haul flights, other means of transportation are few, therefore a relatively low price elasticity results. Solving the model modification of price elasticity (5) for departing passengers, the effect on travel behavior as a consequence shown in figure 2.

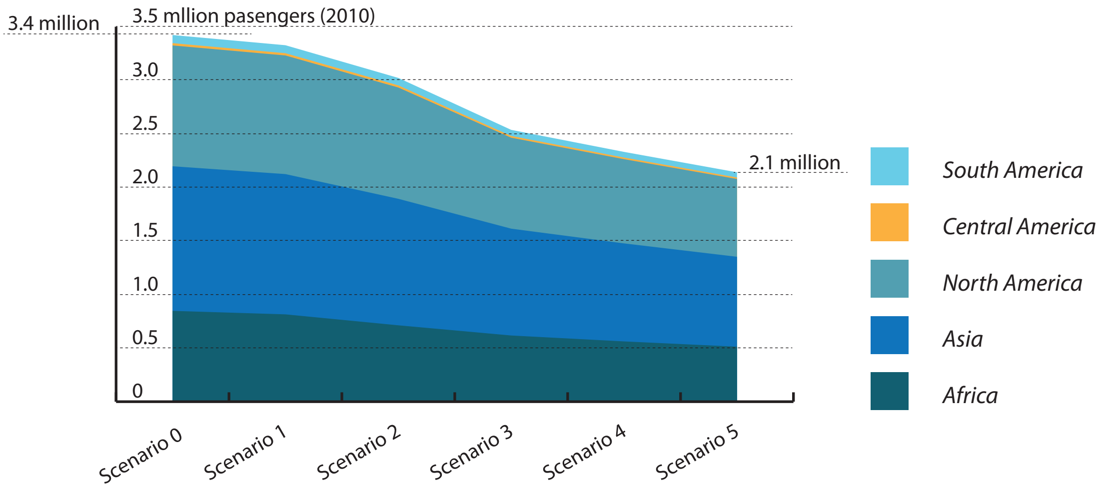


Fig. 2 : Change in passenger quantity due to tax implementation

In scenario five the number of air travellers drops from 3.4 to 2.1 million air travelers when implementing a tax which equals 78% of the base price (total cost sums up to 178%) for a medium-haul flight. Whereas a tax of 75% for a long-haul flight is charged.

Tax revenue versus airline industry losses

Based on this result, the decrease in airline company revenues can be calculated by solving equation (6). On the other hand solving equation (7) results in an increase of CO_2-tax revenues.

Figure 3 shows that the airline loss is significantly higher than the tax revenues, especially when there is a proportionally high tax implemented. The result for the comparison of the revenues generated and the revenue losses results in a overall decrease. Thus a 30% CO_2 reduction from today's departures equals a net loss of €144 million a year.

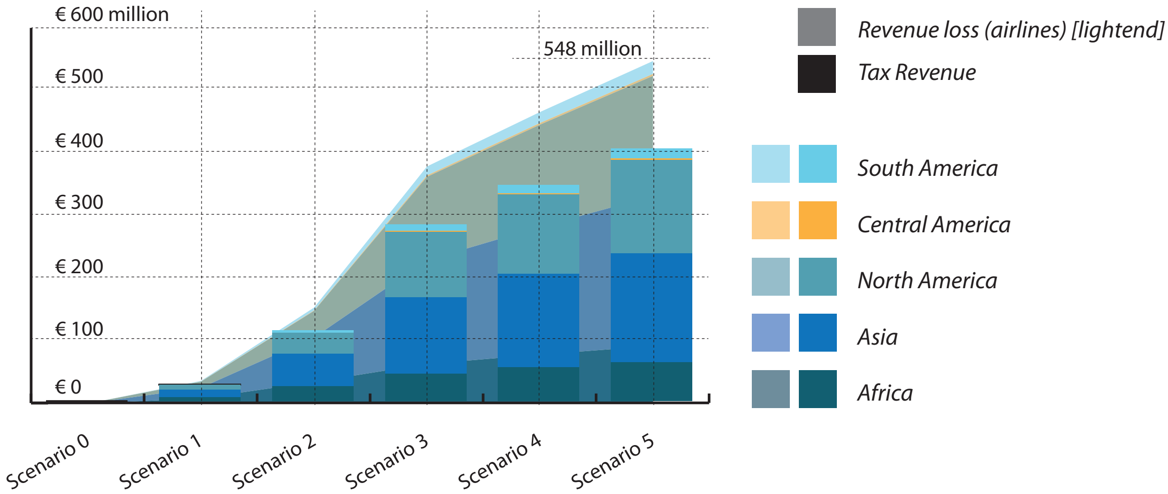


Fig. 3 : Tax revenue versus airline industry losses

Impact on CO_2 emissions

The CO_2 decrease is based on a smaller number of passengers using air travel. Hence the coresponding CO_2 reduction can be seen in figure 4.

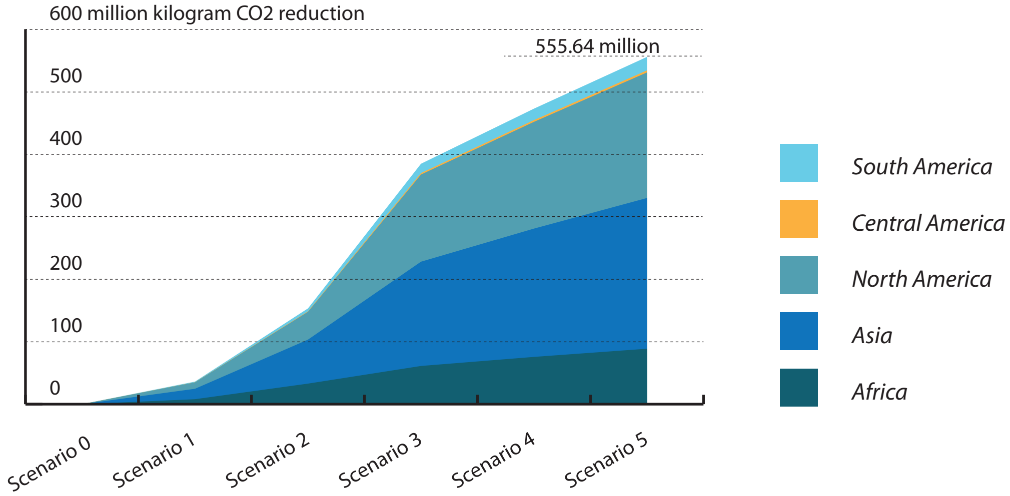
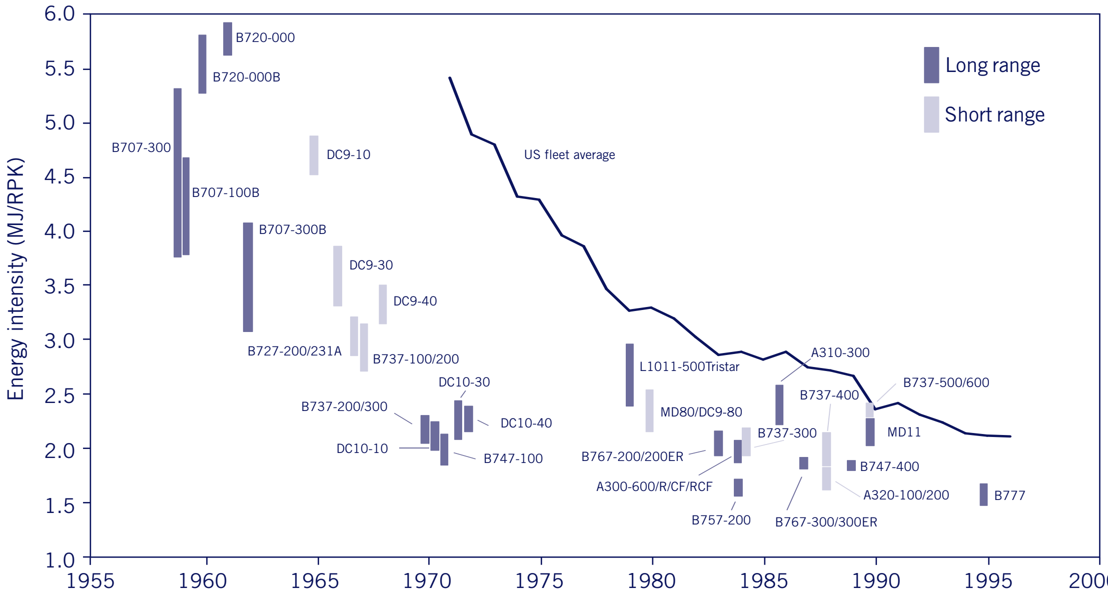


Fig. 4 : CO_2 reduction scenarios

A mitigation of emissions is achieved by a lower demand in air travel or reduced energy consumption. The former can be achieved by a substitute or an over all reduced demand. A reduced demand in general was looked at in the European Unions GHG Emission Trading Scheme and results have shown small changes (Batch, 2008). A substitute for travelling long distances is, when it comes to intercontinental transports and long distance travel in general, not available. High-speed trains are an alternative to airplanes for shorter ranges, but they have not proved to be a comparable substitute for longer distances. To what extent telecommunication capabilities are a replacement for air travel on a global scale is unclear (MoSa, 2002). Less energy consumption can be accomplished by higher fuel prices, as higher prices lead to lower demand. This can substantially be steered by policies and thus speed up further research on other, currently immature power fuels. The more ambitious the targets set by the airline industry are, the more (initial) investment is required. Aircraft efficiency improvements are slowing down

Efficiency improvements have progressed every year since the early age of flying, currently however the improvement rate is slowing down (Figure 5) (IEA, 2008; ORNL,



Notes: 1) The bar for each aircraft reflects varying configurations; the line shows estimated fleet average for the United States across all existing aircraft. 2) RPK = revenue passenger kilometer = number of passengers carried x distance flown (in km).

Source: IEA 2008

Fig. 5 : Evolution of Aircraft Energy Intensity, New Aircraft and U. S. Fleet Average

2008). The International Air Transport Association (IATA) has targeted a 30% higher fuel efficiency in 2025 compared to 2005 (ATAG, 2010). The time an airplane is on duty (its actual lifetime) is between 20 to 30 years (Lee, 2001). If older aircrafts are replaced earlier, as has been the case in the past, then a better fuel efficiency results (as shown in Fig. 5).

So far it can be summarized that fuel efficiency may not be enough to reach the outlined targets by the aviation industry. In order to dramatically improve efficiency by 2050, a radical innovation has to take place. This has been less officially taken into account because it is rather hypothetical, thus drastic changes are less likely since they have to be tested intensively first. Furthermore, investment has to be done in order to reach a competitive market price. To what extent the investment can be shifted to the consumer and what expenditures have to be committed by government has to be further analyzed outside the frame of this paper. The estimated prices and availability of the fuel resources are in the focal point of this term paper.

The target definition in detail

As the aviation industry has a clear road map based on the IPCC (2008) report, the question remains on how the different countries divide the emissions among each other. According to Bristow et al. (2004), it is done on a per capita base among developed countries. Based on the example of the United Kingdom, this will lead to a 60 - 80% emission decrease by 2050 (over all industries). The corresponding acceptable CO_2 concentration would then be 450 ppm or 550ppm, respectively (Bristow, 2004).[3]

Which alternative resources are viable to compete with fuel power

Renewable energies are seen more as an optional strategy rather than a reliable fuel alternative. Biofuel is the most promising alternative to fossil fuel (ATAG, 2010). Grahn (2006) extends the possible renewable energies to solar hydrogen, which has a major role in the future within the transportation sector. Biomass is seen as an energy

3 Bristow, et al. based their analysis on the two CO_2-levels; ppm stands for parts per million and is a measure unit for CO_2 emissions

resource that can compete with today's fossil fuel. Although, this does not take into account that biomass itself is a scarce resource over the mid-term and will thus become more expensive over time.[4] However, in the short-term, biofuel accounts among the solutions that lead to relatively low investments, whereas hydrogen and solar energy need more capital to undergo further research and development.

As an alternative to renewable energy stands technological improvement and development of existing fuel powers, such as carbon capture and storage (CCS), in the hope that this can acceptably reduce the emissions of fossil fuels and biomass. It is all dependent on the price and the question of whether or not the awareness of CO_2 emissions leads to paying higher prices by the market (customer). Nuclear energy is not considered as an option in this paper, as further development has most probably been slowed down due to the three core melts that have occurred within the last thirty years in nuclear reactors, thus generating a bad reputation for nuclear energy in general (Cepe, 2011). It has to be mentioned that direct influences of GHG are taken into account when referring to the air transportation industry, but one must also consider the significant indirect impacts of machineries and vehicles on ground related to the air industry.

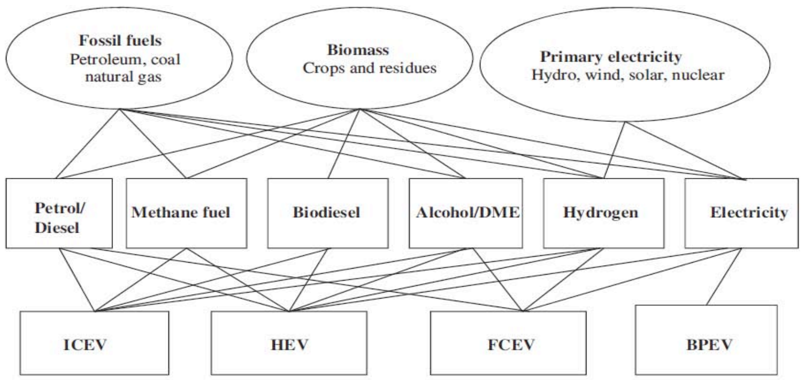
It may be possible that the demand for transportation in general is decreasing, even though the economy keeps growing. The aviation industry will only increase if the consumer is willing to pay more in future for transportation than they do today. Higher fuel prices affect the sector directly as they are the second biggest cost after labor (IPCC, 2007). The rising fossil fuel price is going to increase prices over the short to long run but also increase the energy efficiency for energy consuming vehicles and machineries.

4 See next chapter for further details

TO WHAT EXTENT ARE LOW CARBON FUELS AVAILABLE

An overview of possible energy sources in the overall transport sector is shown in Figure 6. The illustration shows that a combination of primary resources can be an energy option as demonstrated by the car industry.

Both biofuels and hydrogen systems could provide fundamental reductions in emission (>70%), even if fossil fuel is used as energy input (Kahn, 2007). Without any use of fossil fuel, the emission reduces to almost zero while continuing to generate energy. Biomass can be converted to liquid form, while wind (solar or nuclear) is converted to electricity or hydrogen (by electrolysis). After conversion, the storage capability



ICEV = internal combustion engine vehicle, HEV = hybrid electric vehicle, FCEV = fuel cell electric vehicle, BPEV = battery-powered electric vehicle. From Johansson(2003)

Fig. 6 : Possible energy pathways from primary resource to end-use

problem of hydrogen and electricity is confronted. Hydrogen has to be liquid and to be cooled for storage, while electricity cannot yet be stored long term in high quantities in an acceptable light travel weight. This problem can also be observed in the car industry. The future might bring a storage solution or a closed system where storage does not play such a big role as it does today. Also CCS can be executed in terms of addressing the relatively high amount of remaining coal and the advanced technology in coal burning. If CCS represents an environmentally acceptable technology, then it can be used in combination with renewable energy as an energy input source. In this manner, the need for storage can be reduced by generating continuously new energy.

Fossil fuel resources are still large (table 3), although the peak oil recovery is near, if not already reached.[5] Nonetheless, fluctuations in oil price can cut aviation profits significantly if they rise too high. The current price for fossil fuel is at US$143.10/barrel. The average fuel price of 2011 is stated at US$124.5/barrel (IATA, 2011). The forecast for 2020 is at US$100 - US$110/barrel, which is economically practicable to put sustainable pressure on the development of alternative fuel power.

Specific energy source	Estimated available energy resource (EJ)	Rate of use in 2005 (EJ/yr)
Coal (conventional)	>100,000	120
Coal (unconventional)	32,000	0
Peat	Large	0.2
Gas (conventional)	13,500	100
Gas (unconventional)	18,000	Small
Coalbed methane	>8000?	1.5
Tight sands	8000	3.3
Hydrates	>60,000	0
Oil (conventional)	10,000	160
Oil (unconventional)	35,000	3

Tab. 3 : Potential for fossil fuels (Source: Sims et al., 2007)

It has to be kept in mind that an alternative energy resource has to be shared among other markets. The transport sector always has to compete (energy related) with heat and electrical power production. Also, incentives such as tax or subventions by the government on other renewable energy sources have a significant impact on the future energy for the aviation industry. According to the IPCC (2008) report, the potential of biomass is uncertain in the long term. By 2050 the biomass resources are estimated at 125 - 760 EJ/yr. (Barker, 2007). Sims (2007) estimations lie at 250 EJ/yr. The forecasted needs of worldwide primary energy demands in biomass are at 600 - 1350 EJ/yr by 2050 (Sims, 2007). This gives reason to assume that biomass will be a scarce resource in the long-run and has to compete with other sectors (e. g. food production).

Resource	Technical potential (EJ/yr)	Theoretical potential (EJ/yr)
Hydropower	50	150
Biomass energy	>250	2900
Solar energy	>1600	3,900,000
Wind energy	600	6000
Geothermal energy	5000	140,000,000
Ocean energy	–	7400
Total	>7500	>143,000,000

Tab. 4 : Global renewable resource base (Source: Johansson et al., 2004)

5 Referring to Fharsi, M., Spring Semester, Lecture 5 «The End of Oil», Energy Economics and Policy, 2011

Table 4 shows, on the other hand, the high availability of renewable resources, such as solar and wind. The restrictions, which represent the gap between the theoretical and technical potentials shown in table 2, are due to material limitations (Johansson et al., 2004). Future research and development can close this restriction by evolving other materials.

Other aspects that arise by low carbon fuels

Low carbon fuels are more expensive than fossil fuels, especially when total costs are taken into account, such as higher production and distribution costs as well as cost increase due to aircraft redesign for fuel storage. The economy of scale effect can only be estimated at this stage of maturity. Higher oil prices (as a result of, for example, scarcity or tax policies) can result in a reduced transport demand and stimulate technical improvements for higher efficiency. However, subsidies can set incentives to develop new and more efficient solutions.

Grahn (2006) is targeting in his study a CO_2 stabilization at 450 ppm. The biomass price he refers to is at US$10/GJ by 2050 and US$37/GJ by 2090. The price of hydrogen based solutions is more difficult to estimate. For ground vehicles, Johansson (2003) estimates a price for solar-generated hydrogen at US$40 - US$45/GJ. Prices for aircraft may be significantly higher, thus storage and transportation is more difficult than for ground vehicles. While these prices vary considerably, it has to be taken into account that higher efficiency may be achieved over time thus reducing the cost further to the consumer.

FURTHER ASPECTS IN REDUCING CO_2 EMISSIONS

Lawrence (2009) concludes in his scientific article, "it is highly regrettable that no consensus exists on the basic facts about aviation emissions". Lawrence points out that data from government and the European Union, Non-Governmental Organizations and Industry are highly incongruous. The differences are found in non-global applicable numbers, different measurements, and diversified spectrum of applied emission data.

Airlines choice of aircraft

Airlines focus on economical key drivers such as market shares (market penetration), profits, and passengers' preferences when it comes to aircraft decisions (SmHa, 2009a). Passengers focus on short flying time, frequent flights, and their preference lies on flying in a jet rather than a turboprop aircraft (SmHa, 2009b). Which aircraft should be deployed, should rather be a question of operating and passenger costs (with the ecology in consideration). Smirti and Hansen (2009b) show that a price greater than US$4/gallon makes passenger transportation on turboporp airplanes more attractive than jet airplanes in terms of total cost per passenger for short haul flights up to 1000 miles. In comparison, today's fuel price is at US$3.41/gallon (US$143.1/barrel) (IATA, 2011). The degree of capacity utilization per airplane and route efficiency of airlines will eventually demand more transparency. It may be assumed that optimization of efficiency will have a major impact on the reduction of CO_2 emissions among the industry. Alliances, joint ventures, and further route sharing could bring emissions closer to the desired targets within the transportation sector.

Changed mind-set within the society

Predicting uncertain developments can be speculative. It can also be seen as an opportunity to develop a future society that is more aware of pollution and thus alters its attitude towards the need for further transportation needs. As the world economy and population continually grows, the demand for CO_2 neutral transportation has not exhibited the same pace (IPCC, 2007). To cut down GHG emissions more effectively, investments in research and development must continue to advance. In the mean time, society should be aware of corresponding consequences, such as declining air travel prices due to competition and relatively cheap fossil fuels.

CONCLUSION

The results of this paper show that alternatives to fossil fuels are still at an early stage. The initial decrease in GHG emissions is not enough to replace the traditional fossil fueled jet engines. Especially in the long term, a complete substitution will be determined by price. The model's results show that leisure related flights and especially medium-haul trips have higher elasticities. Hence, the shorter the flight, then the higher the price elasticity. The flight purpose has a smaller impact on change in passenger quantity than the flight distance. A substitution to air travel is more existent, on business unrelated and medium-/short-haul flights. Thus, price changes have a higher impact on passenger quantity.

Although biomass shows significant potential to take its place in the air transportation sector, renewable energies such as solar and wind have greater potential in the long-term due to their large availability. The cost of these energies are presently too high to compete with fossil fuels, however with further improvements over time and higher demand, renewable energy can come down to a price that consumers are ready to pay.

The aviation industry is pragmatic to rely on targets that can be measured and foreseen to some extent. Their targets should lie in influential values and their interest in investments, which support future technical developments in the industry.

Governments and air associations, such as IATA and ICAO, on the other hand, should demonstrate more assertive actions in reducing GHG emissions. In order to achieve this, capital can be raised through taxes as price elasticity of demand is rather inelastic in the passenger air travel sector as seen.

Nonetheless, air as well as marine transportation should be considered as reaching peak cheap transportation to long haul destinations. A rethink on the status and outcomes of global warming, and at what cost, has to take place. Appropriate incentives on a worldwide scale, such as a moderate CO_2 emission tax, would raise money for future projects. These projects may decrease GHG emissions drastically over time and therefore may help the industry to significantly strengthen their position in the transportation sector.

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