# Aircraft Emission Charges Zurich Airport

# Contents

# 1. Regional Air Quality in 1990

**Moderate Air Quality in the Airport Region**
In the late eighties, calculations and measuring campaigns showed high values for nitrous dioxide ($NO_2$), ozone ($O_3$) and $PM_{10}$ in the region North of Zurich, where the airport is located. They were exceeding national limits. Nitrous oxides are the major problem, as a pollutant itself and as a precursor for ozone formation. Values ranged from 20–25 $\mu g/m^3$ ($NO_2$ annual mean) in rural areas off the airport to more than 50 $\mu g/m^3$ at the airport and along major traffic routes in the closer region (figure 1). At that time, the airport contributed up to 30 % to the $NO_2$-pollution. This percentage was rapidly decreasing with growing distance to the airport.

**Air Traffic Dominates Airport Emissions**
Detailed emission calculation show that within the closer airport perimeter, air traffic contributes up to 80 % to the $NO_x$ emissions, thus being the largest single source even though this nis not a metric to describe the actual impacts. Over the past, the specific emissions per traffic unit (1 passenger or 100 kg cargo) have decreased due to the development in engine technology. This effect has been overcompensated and the absolute emissions tned to rise again as the traffic volume increases again.

# 2. Legal Framework for Emission Charges

**Stringent Clean Air Legislation**

According to the national clean air concept laid down by the federal parliament, emissions of air pollution substances are to be reduced to the levels of 1960. One of the tools is the Clean Air Ordinance of 1986, which sets certain emission limits and pollution standards and describes the procedures to be taken when they are exceeded. The cantons are then under obligation to set up a "clean air action plan". Having exceeded air pollution levels, the Canton of Zurich did so in setting up its program in April 1990, with revisions in 1996 and 2009, confirming that all emission sources have to contribute their share to achieve overall reductions. With the revision of the Clean Air Ordinance in 1998, a limit for particulates ($PM_{10}$) was introduced.

| Pollutant | (selection) | Limit in µg/m³ |
|---|---|---|
| $NO_2$ | (annual mean) | 30 |
| | (24h-mean) | 80 |
| $SO_2$ | (annual mean) | 30 |
| | (24h-mean) | 100 |
| $O_3$ | (98 %- ½h-mean) | 100 |
| $PM_{10}$ | (annual mean) | 20 |
| | (24h-mean) | 50 |

**Tab. 1: Air Quality Standards (according to Clean Air Ordinance, 1998).**

**Comprehensive Mitigation Planning**

Zurich airport supported the canton's obligation for mitigation planning by submitting the airport's clean air program in 1992. The airport proposed a number of technical and operational measures to reduce emissions in the areas of air traffic, handling activities, infrastructure and landside traffic. Studies have been made for a model of tradable emission certificates and market based financial incentives instead of just setting operational limits to air traffic. In June 1993, Zurich airport finally submitted a proposal to the federal authorities, asking for the legal basis to introduce emission based landing charges.

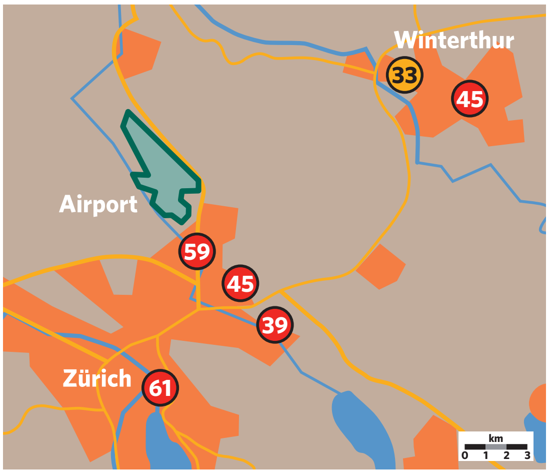


**Fig. 1: $NO_2$ pollution Airport region 1988 (µg/m³).**

**Federal Aviation Law Requires Emission Charges**

The revised aviation law became effective on 1 January, 1995. The major change concerning environmental protection was article 39, stating that "when levying landing charges, airports have to take into account differing noise and gaseous emissions of aircraft". Noise related landing charges in Switzerland have been in use since 1980, whereas emission charges had been unknown until then. According to the revised law, it is within the competence of the airport operator to define the charge, although the regular procedure involves consultations with other airports, airlines and federal authorities.

# 3. Emission Charges Model 1997

### Emission Charge Sets Incentives

The 1997 model was developed by the Federal Office for Civil Aviation (FOCA) in co-operation with the Federal Office for Environmental, Zurich and Geneva Airport Authorities and an airline. It aims at setting incentives to accelerate introduction and to foster the use of the best available engine technology. The main guidelines, passed on to all Swiss airports in 1996, were to relate charges to aircraft engine emissions, to secure operational freedom of aircraft operators and to keep the revenue of the charges bound for aviation emission reduction programs.

### Local Solution for a Local Problem

Exceedance of air quality standards for $NO_2$, ozone and particulate matter around airports is a local problem. This called for a local solution which does not compromise global problems and initiatives. It is therefore sufficient to consider the pollutants nitrous oxides (NOx) and hydrocarbons (HC). These two substances are the main contributors to combustion-related local air pollution, precursors of ozone, and they are explicitly designated for reduction in the Federal Clean Air Concept. $CO_2$ and other greenhouse species of global relevance have been excluded in the local considerations.

Engine manufacturers have achieved significant improvements in fuel efficiency over the last decades. The developments of combustion systems have also brought a decrease in HC emission indices but a relative increase in NOx. The new technologies that went into service have shown a reduction of both pollutants. Decreasing emission indices and better fuel efficiency lead to an overall improvement in emission performance which should be further promoted.

Given the local characteristics, the standardised LTO-cycle (landing and take-off movements below 3000 ft) was the basis for determining the emissions. Data had been taken from the ICAO document 9646-AN/943 (1995) with its addendum (Engine Exhaust Emission Data Bank) for all turbofan engines with more than 26.7 kN thrust and from manufacturers for other engine types (using the measured data).

### Engine Technology is Ranked

Based on all the above considerations, a so-called engine emission factor (EEF) had been defined as the sum of NOx and HC emissions in the certification LTO-cycle divided by the installed thrust or horsepower. All engines have been ranked into one of five classes according to their EEF. Because the same aircraft model can be equipped with different engines with quite different emission characteristics, the engine is being considered for the emission charge, not the aircraft.

As the emission charge had been planned to be revenue neutral and not to increase the airport's revenues, the weight based landing fee for aircraft had been reduced by a flat 5% for all aircraft. The emission charge, intended to compensate for this reduction then levies a percentage of the landing fee according to the engine technology class (figure 2). Aircraft with engines already ranking in class five are thus subject to a bonus.

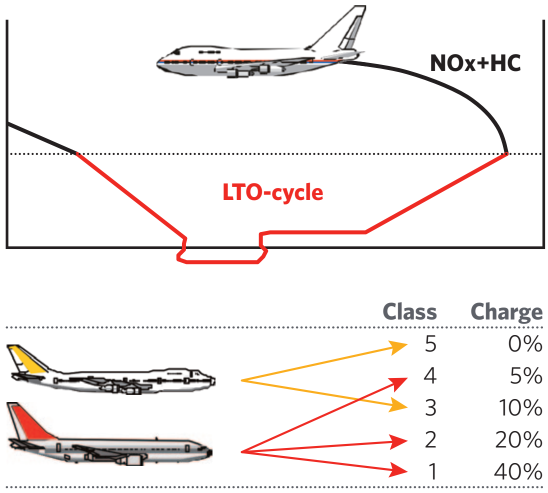


**Fig. 2: Engine Emission Charge Model.**

### Legal Compliance Confirmed

On September 1st, 1997, the cantonal government introduced the emission charge after a formal consultation procedure with airline operators and international parties in aviation. Zurich airport thus became the first airport worldwide to introduce market-based incentives in order to address air quality problems caused by air traffic.

In 1999, the Swiss Federal Court confirmed legal compliance with Swiss legislation and international recommendations and agreements after a suit had been filed against the introduction of this charge. Soon after the introduction in Zurich, a similar charge has been introduced at a number of Swedish airports in 1998, also using NOx and HC as a basis and ranking the engine technology in classes. Geneva airport followed with the Swiss model later in 1998, Bern airport in 2001 and Basel airport in 2003.

# 4. Positive Results Achieved

**Emission Reductions Observed**
While emission charges are just one of several factors driving decisions on fleet acquisition or operations, some positive effects can be observed that indicate the effectiveness of the system. As the local home carrier was about to change its short-haul fleet at that time, it opted for a newly designed low NOx-technology engine (double annular combustor). This decision led to annually avoided NOx-emissions of approximately 140 t NOx while granting a 5% bonus on the landing charges.

Evidence has been given from an airline with daily long-haul operations to Zurich. Due to the introduction of the charge the operator decided to change the aircraft type (B747-200) operating to Zurich by at least one year sooner than anticipated. The change in emission charges was from a 20% to a 5% charge, while the environmental benefit was 4.0 t NOx/a and 3.9 t HC/a.

The fixed ground power available at all pier stands and being used as required by the airport operator has led to savings of 90 t NOx and 30,000 t of kerosene in 2009.

**Improved Technology Development**
The analysis of the movements in emission classes shows the rapid technology change between the announcement and the introduction of the charge due to a major fleet change of the home carrier. At the time of announcing the charge, approximately 55% of all movements were in the emission classes 4 and 5. By 2009, more than 85 of all movements are in classes 4 and 5 technology. Movements of the worst classes 1 and 2 have decreased from 8% down to a 1.3% (figure 4).

**Revenues Bound for Air Quality Measures**
The total revenues of emission charges range between 2 and 3.2 million EUR annually. Initially constituting about 5% of the landing charges, it has now decreased to an average of 3.7%. These revenues are used for air quality projects at the airport. Some measures have been required by the authorities in the course of the construction permits of the 5th airport expansion programme (1999).

**Emission Classes**

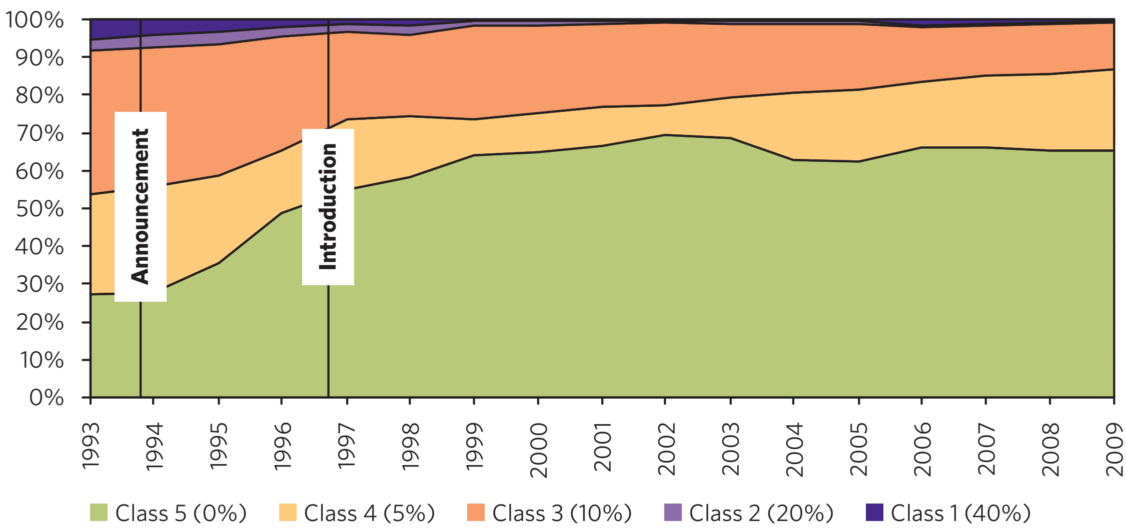


**Fig. 4: Development of Engine Technology.**

A few examples may illustrate this:

- Required air quality monitoring network airport and region (figure 5)
- Required emission inventory calculation and dispersion modelling
- Required fixed ground power for aircraft at piers (3.0 mio CHF/a) (figure 6)
- Contribution to CNG fuel station for handling equipment and airside traffic
- Contribution to aircraft ground movement systems to enhance taxiing (taxiway bypass)
- Air quality management, research and development

**Fig. 5: Air quality measurements.**

**Fig. 6: Fixed Ground Power at Piers.**

### Wide Recognition Gained

Not only airline operators have responded to the implementation of emission charges. Engine manufacturers had been revisiting their efforts for low NOx technologies as well. It has been recognised that the most likely constraints for the growth and development of civil aviation to meet society's needs for mobility will emerge at airports – places where environmental impacts are concentrated and local legislation applies.

Authorities at all levels acknowledged the efforts of the airport operator to define ways for sustainable development of civil aviation. This enabled Zurich airport to obtain the permit its 5$^{th}$ expansion programme and thus the license to grow.

### Ambient Air Quality Improved

Over time and due to a number of technological advancements from the various emissions sources and implemented measures, the ambient air quality has improved. However, there are still non-compliances observed for NOx, ozone and PM10. This requires the airport to continue with the programmes.

# 5. International Developments

**European Approach for Harmonisation**

Upon introduction of the emission charge in Switzerland and Sweden, the national authorities promised a review to be conducted after some years. In 2000, both authorities and some stakeholders presented their experience at the Geneva meeting. Industry representatives expressed their wish for a harmonisation of the different models. Further discussions among the European Commission with their transportation policies and the European Civil Aviation Organisation (ECAC) lead to the initiative of ANCAT to investigate in the issue of emission charges in November 2000.

The Emission Related Landing Charges Investigation Group (ERLIG) was represented by member states and industry representatives from manufacturers, airlines, airports, science and NGOs. The group evaluated existing environmental pricing schemes and drafted guidance on how to calculate emissions from aircraft potentially to be used for charging purposes. The formal ECAC recommendation with guidance material was adopted by the Directors General of Civil Aviation in May 2003 and by the ECAC Assembly in July 2003 (Recommendation ECAC/27-4).

**The ECAC Recommendation**

The recommendation aims at providing a common aircraft emission classification scheme in the context of local emission charges. It is not a recommendation for the introduction of emission charging schemes or operational restrictions to aircraft operation. Nitrogen oxides (NOx) are the prime pollutant used for this classification. The absolute amount of NOx within the certification LTO cycle is calculated by using the average measured values for all LTO-modes of the individual engine, multiplied by the number of engines on the individual airframe.


**Fig. 7:** ■ **Local aircraft emission charges in Europe.**

Hydrocarbon (HC) emissions are also accounted for to cater for older engines that tend to have low NOx emission values, but at the same time relatively high HC emissions. This is accomplished by applying a factor relating the actual HC value to the ICAO HC standard to the NOx value (where a HC standard is applicable). This overcomes the need to introduce HC as a separate pollutant whilst avoiding unduly favouring older engine technology. This calculation returns an emission value per aircraft on a continuous scale which is directly used to apply a charging rate per emission unit. The data again is taken from ICAO engine emission data base for engine > 26.7 kN thrust and from a turboprop and piston engine database administered by the Swedish Aeronautical Institute (FOI) and Swiss FOCA.

To ensure non-discrimination, all civil aircraft with a maximum take-off weight (MTOW) over 8,618 kg should be classified using the recommended methodology. The Civil Aviation Authorities of Sweden and Switzerland decided to introduce a simplified method to classify aircraft with non-regulated engines or which are below the take-off mass threshold of 8,618 kg. In those cases, an emission value matrix is being used, giving values depending on type, size and number of engines for aircraft. In doing so, the overall system becomes non-discriminatory and easy to administer for both aircraft operators and small airports.

**ICAO Document 9884**

In 2007, ICAO published its document 9884, the Guidance on Aircraft Emissions Charges Related to Local Air Quality. This guidance further outlines scope, purpose and approach to local emission charges. It hightlights the importance of analysing a full range of potential mitigation options and to conduct careful cost-benefit analysis prior to taking a decision to implement local emission charges.

**Continuous Implementation of Charging Schemes**

In view of concerns about ambient air quality, the introduction of air quality legislation and the need to further develop aviation infrastructure to accommodate the growing need of mobility, states and airports investigate into the introduction of local emission charges. To date, a number of airports in Europe have introduced emission charges, mostly in the basis of ECAC recommendation 27-4 (figure 7).

# 6. Introducing the New Emission Charges Model

The Swiss International Airports Association (SIAA) decided in 2008 to start the process for changing the existing model at the Swiss airports to the new model based on the ECAC recommendation. Again the model change aimed at being revenue neutral for the airport operator. However, changes among the aircraft operators are inevitable, as the classes 4 and 5 (bonus and no charge) disappear and the "polluter-pays-principle" directly applies. As before, the same aircraft can be subject to different emission charges, depending on the actually fitted engine (figure 8).

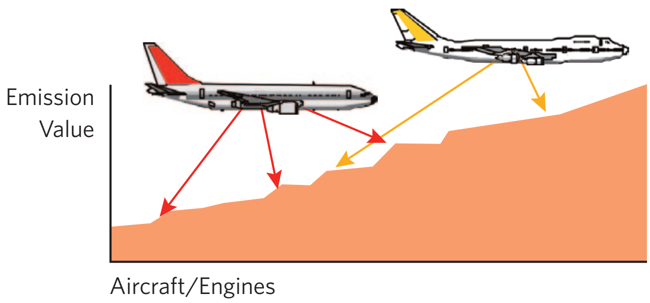


**Fig. 8: ECAC emission charges model.**

In order to assist the airports, the Swiss FOCA issued its directive 33-05-027 in May 2009 on aircraft engine emission charges in Switzerland. With the revision of the Swiss ordinance on infrastructure in aviation, the authorities have obtained the authority to decide on the emission charges model.

After reviewing the individual situations and conducting an analysis on the economic framework, the Swiss airports consulted the aircraft operators on the new emission charges model. Based on the outcome, the airports Zurich, Geneva, Bern and Lugano decided to change the emission charges model.

At Zurich airport, the change became effective on 1st April 2010, almost thirteen years after the introduction of the first model. The applicable rate is CHF 2.50 (1.56 EUR) per emission value. Table 2 gives some emission charges examples for typical aircraft. Revenues will continue to be used for air quality and environmental work as it has been before. This new emission charges model is again a local measure designed to address a local problem, implemented by the airport.

| Aircraft | Engines | Number | Charge (CHF) |
|---|---|---|---|
| A320-200 | CFM56-5B4/2P | 2 | 19.25 |
| A321-200 | V2533-A5 | 2 | 43.23 |
| A330-300 | CF6-80E1A3 | 2 | 96.27 |
| A340-300 | CFM56-5C4 | 4 | 87.00 |
| AVRO RJ85 | LF 507-1F | 4 | 10.86 |
| B737-300 | CFM56-3-B1 | 2 | 17.98 |
| B737-800 | CFM 56-7B26 | 2 | 30.50 |
| B747-400 | PW4056 | 4 | 119.75 |
| B757-231ER | PW2037 | 2 | 40.60 |
| B767-300ER | PW4060 | 2 | 70.49 |
| B-777-200 | TRENT 892B-17 | 2 | 132.00 |
| CRJ-900 | CF34-8C5A1 | 2 | 11.03 |
| DHC-8Q-400 | PW 150 A | 2 | 7.33 |
| EM195 | CF34-10E5 | 2 | 20.80 |
| MD82 | JT8D-219 | 2 | 30.50 |

**Tab. 2: Typical emission charges.**

# Annex

**Swiss Emission Charges Model**

**Aircraft with turbofan, turbojet or turboprop engines with emission data available to the FOCA**
Aircraft, equipped with turbofan, turbojet or turboprop engines that are:
• regulated under the ICAO Annex 16, Volume II, or
• not regulated, but have detailed emission data for the LTO cycle available to the FOCA,
are subject to the emission calculation as specified in ECAC Recommendation 27/4. Specifically, the following emission calculation formula applies:

$$\text{EmissionValue Aircraft} = a * \# \text{Engines} * \sum_{\text{LTO-modes}} (60 * \text{time} * \text{fuelflow} * NOx_{\text{Emissionsfactor}} : 1000)$$

where:
a = 1 if the characteristic certification LTO Hydrocarbon emissions per rated thrust (HC Dp/Foo) is less than or equal to the current ICAO standard of 19.6 g/kN rated thrust or for unregulated engines.
a > 1 if the characteristic certification LTO Hydrocarbon emissions per rated thrust (HC Dp/Foo) is greater than the current ICAO standard.
a = HC Dp/Foo /19.6, with a maximum value for 'a' of 4.0

| LTO-Modes | ICAO Certification LTO Modes |
|---|---|
| **Mode** | **Time (in minutes)** |
| Take-off | 0.7 |
| Climbout | 2.2 |
| Approach | 4.0 |
| Taxi/Idle | 26.0 |
| # Engines: | number of engines fitted to the aircraft |
| Time: | time in mode (s. above) (in minutes) |
| Fuelflow: | fuel flow per mode (in kg/sec) |
| $NOx_{\text{Emissionfactor}}$ | Measured NOx-Emission factor per mode (in g/kg fuel) |

Emission factors and fuel flow for the four modes and the hydrocarbon certification value are taken from the ICAO engine database (regulated engines). Emissions data for unregulated engines are taken from the FOCA and FOI emissions database. The FOCA website provides additional information:
www.bazl.admin.ch ➠ For Specialists ➠ Environment

**Aircraft with piston engines, helicopter and aircraft with engines without emission data available to the FOCA**
Aircraft, equipped with
• piston engines
• rotary wing engines
• any other engine without emission data available to the FOCA
are also subject to an emission charge. Specifically, they are assigned an emission value derived from the following table 1 and depending on the type, performance and number of engines fitted to the aircraft.

| # Eng. | Piston: Turbodiesel Microlight Ecolight | Piston: Conventional | Piston: Conventional | Piston: Conventional | Helicopter | Helicopter | Business-Jets | Business-Jets | Turboprops |
|---|---|---|---|---|---|---|---|---|---|
| | | < 200 hp | 200–400 hp | > 400 hp | < 1000 shp | > 1000 shp | (< 16 kN) | (> 16 but < 26.7 kN) | |
| 1 | 0.1 | 0.2 | 0.4 | 0.5 | 0.2 | 0.7 | 0.5 | 1.0 | 0.8 |
| 2 | 0.2 | 0.4 | 0.8 | 1 | 0.4 | 1.4 | 1.0 | 2.0 | 1.6 |
| 3 | – | 0.6 | 1.2 | 1.5 | – | 2.1 | 1.5 | 3.0 | 2.4 |
| 4 | – | 0.8 | 1.6 | 2 | – | 2.8 | – | – | 3.2 |

**Tab.: FOCA Aircraft Emission Value Matrix.**

**Acronyms and Abbreviation**

| | |
|---|---|
| ANCAT | (ECAC) group of experts on the Abatement of Nuisances Caused by Air Transport |
| CAA | Civil Aviation Authority |
| CAEP | (ICAO) Committee on Aviation and Environmental Protection |
| CHF | Swiss Franc |
| CNG | Compressed Natural Gas |
| Dp/Foo | Dp is the mass of any gaseous pollutant emitted during the reference emissions LTO cycle. Foo is the rated output, which for engine emissions purposes, is the maximum power/thrust available for take-off under normal operating conditions at ISA sea level static conditions without the use of water injection as approved by the certifying authority. |
| ECAC | European Civil Aviation Conference |
| EEF | Engine Emission Factor |
| EMCAL | (ANCAT) Subgroup on Emissions Calculations |
| ERLIG | (ANCAT) Emissions Related Landing Charges Investigation Group |
| EUR | Euro |
| FOCA | Swiss Federal Office for Civil Aviation |
| FOI | Swedish Aeronautical Institute |
| HC | Hydrocarbons |
| hp | Horsepower |
| ICAO | International Civil Aviation Organisation |
| ISA | International Standard Atmosphere |
| kN | Kilo-Newton (thrust) |
| LTO | Landing and Take-Off cycle: one LTO cycle comprising a landing plus a take-off |
| MTOW | Maximum Take-Off Weight (if the term MTOM, Maximum Takeoff Mass is being used, they shall mean the same). |
| NOx | Nitrogen Oxides |
| PM10 | Particulate matter with a diameter < 10 µm |
| Regulated Engines | Turbojet and turbofan engines of rated output > 26.7 kN covered by current ICAO certification standards. |
| SIAA | Swiss International Airports Association |
| $SO_2$ | Sulfur Dioxide |
| Traffic Unit | 1 PAX (= passenger) or 100 kg freight/air mail |

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