Aircraft APU Emissions at Zurich Airport

Content

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1 Introduction

1.1 Airport Emissions

Handling in total is usually the second largest contributor to local air pollution at an airport (figure 1-1). It includes emissions from the non moving aircraft (e.g. Auxiliary Power Units, APU), all Ground Support Equipment (GSE, including GPU) for handling aircraft, but also vehicles circulating on airside premises (e.g. sweeper trucks, crew busses, catering trucks, cargo tractors, etc).

Table 1-1: Emissions (based on LASPORT Methodology[1]) for 2003

Source Group	Emission Source	Emissions		
		CO (t/a)	HC (t/a)	NOx (t/a)
Air Traffic	Aircraft (incl. Helicopters)	1,204.89	146.64	1,114.14
Handling	Aircraft Main Engine Ignition	-	54.24	-
	Aircraft APU	27.54	2.47	23.36
	GPU	13.69	3.56	25.18
	GSE	13.97	3.00	14.61
	Roadways (airside)	59.57	17.35	63.16
	Refuelling (Aircraft, Vehicles)	-	12.75	-
	Aircraft De-icing	-	-	-
Infrastructure	Boiler House, Power Generation Plant, Aircraft maintenance, Airport Maintenance, Construction, Engine Test Runs.	12.01	77.79	69.32
Landside Traffic	Roadways (landside access and parking)	124.43	11.83	45.92
Total		**1,456.10**	**329.63**	**1,355.79**

Within the handling emissions, APU-emissions can contribute significantly to the overall airport emissions as well as to the local pollution concentrations. In 2003, APU contributed with 18.5% to the NOx handling emissions.

1.2 Study Scope

The scope of this study is to present a methodology and emission factors for the emissions calculation of Auxiliary Power Units (APU). Base year is 2003 for Zurich Airport with a total of 269,392 movements, 17.0 millions passengers and 411,500 tons of cargo/airmail.

The methodology discussed is limited to APU i.e. any other ground handling equipment is not considered. There are quite some data on APU available today and the emission calculation generally follows the methodology similar as applied for aircraft main engines: $Time_{Mode} \times Fuel\ Flow_{Mode} \times Emission\ Index_{Mode}$.

[1] The current methodology used for the emission inventory published in the airport's annual environmental reports is still based on a simpler approach with less refined assumptions. The methodology described in this study will be introduced sometime in the future after consultations with local and/or national authorities.

2 Auxiliary Power Unit

2.1 Technical Issues

Auxiliary Power Units are gas turbines mounted usually in the aft part of aircraft. Fuels used are Jet A, Jet A1, Jet B or JP-4. The purpose of an APU is to:

- provide electrical energy (115V, 400 Hz) for aircraft systems during ground time;
- provide air to the environmental control system (air-conditioning) during ground time;
- provide air (bleed air) for main engine start;
- serve as electric and hydraulic back-up system in flight;

APU are available for large, medium, small jet aircraft, regional or commuter jet aircraft, corporate or business jets and turboprops (cf. annex).

Emissions of APU are similar to those of aircraft main engines. The following pollutants are of interest for emission inventory and dispersion calculation purposes:

- NOx Nitrogen Oxides
- HC Hydrocarbons
- CO Carbon Monoxide
- PM Particulate Matter
- CO_2 Carbon Dioxide

For dispersion calculations, the exhaust plume needs to be modelled, too. This requires additional data for exhaust nozzle diameter, exhaust gas temperature and exhaust gas velocity. Some limited information is available, e.g.

- Allied Signal 331-500: Exhaust nozzle diameter: 38.11 cm (Utzig, 2004);
- APS 500R APU: Max Continuous rated EGT: 704°C (Hamilton, 2004)
- TSCP700-4E: Continuous EGT: 585°C (JAA, 1998).
- Honeywell 36-150CX: Max. Continuous EGT: 665°C; Idle EGT: 300°C (HTG, 2004)

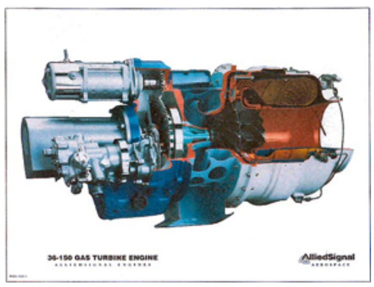
Hamilton Sundstrand APS 3200 APU for A320 family	Hamilton Sundstrand APS 500R APU for ERJ 135/140/145	Honeywell 36-150CX APU for Do328
		

Figure 2-1: Auxiliary Power Units for commercial aircraft

2.2 APU Modes of Operation

APU are operated in different modes, according to the desired operation (e.g. generating electricity). There are currently a number of different terms used to describe particular APU operations (ICCAIA, 1999):

Table 2-1: APU Terms and Explanations

Term	Explanation
No Load	same as Idle – no shaft or bleed load extracted – may be at 100% engine speed or reduced speed depending on the particular APU model.
Combined Load	combination of shaft (electric) and bleed loads – bleed air could be for main engine starting (MES) or the environmental control system (ECS) – bleed air extraction could have been set to a specified corrected flow (ppm) or to a specified APU exhaust gas temperature (EGT).
Max Combined Load	combination of shaft and bleed loads, but engine is at the maximum EGT limit – test usually run by setting the shaft load to the maximum level, then extracting bleed air until the EGT limit is reached – load condition may be higher than an actual aircraft load condition.
Bleed Load	bleed air extraction only, no shaft (electric) load – usually a part power condition – may not be representative of an actual aircraft operating condition.
Max Bleed Load	bleed air extraction only, no shaft (electric) load – test usually run by extracting bleed air until the APU EGT limit is reached – load condition may be higher than an actual aircraft load condition – not an actual aircraft operating condition.
Max Shaft Load	shaft (electric) load only, no bleed air extraction – a part power condition – shaft load could be representative of an aircraft load condition, or set to the APU gearbox load limit.
ECS	environmental control system – bleed air supplied to the aircraft air conditioning packs – the bleed load condition is set for typical aircraft gate operation (depending on the aircraft type and size) - normally includes some shaft (electric) load.
Max ECS	maximum environmental control system – bleed air supplied to the aircraft air conditioning packs – the bleed load is set for the maximum aircraft load condition – normally includes some shaft (electric) load.
Max IGV	indicates the APU load compressor inlet guide vanes (IGVs) were set to the maximum, full open condition – usually this would be designated either a Max ECS or a MES condition – may or may not include shaft (electric) load.
MES	main engine start – bleed air supplied to the main engine air turbine starter – bleed load usually set to a specified corrected flow condition representative of typical aircraft operation – normally includes some shaft (electric) load.
MES+180KW	main engine start plus 180KW of electric load – same as MES, but the actual shaft (electric) load is specified for a particular aircraft.

3 Aircraft and Airport Operational Issues related to APU

The interdependencies of aircraft APU operations are characterised in figure 3-1.

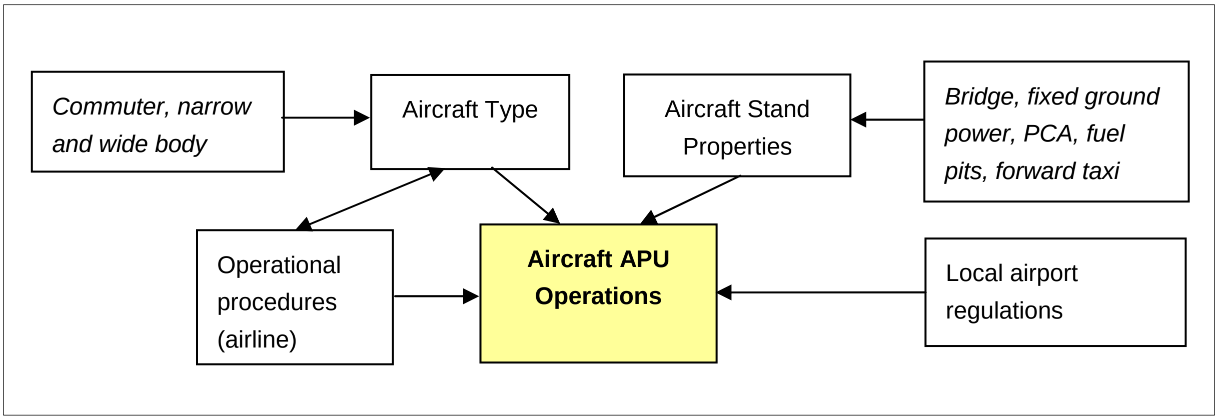


Figure 3-1: Characterisation of APU use.

It has to be recognised that the operation of an APU is determined by the aircraft and the aircraft stand as well as applicable operational procedures at the airport (e.g. restrictions).

3.1 Aircraft Type

The size of the aircraft often determines the stand allocation and the handling procedures. At Zurich Airport, all aircraft have been categorized into 8 groups. This grouping is used to attribute properties used to create and calculate emission inventories in a generalized manner.

Table 3-1: Aircraft Group Characterisation

Aircraft Group	Characterisation
Large Jet Aircraft (B-777, B-747, A340, MD11) Medium Jet Aircraft (A330, B767)	• Handling at pier or remote stands • APU available
Small Jet Aircraft (B-757, B-737, A319-A321)	• Handling at pier or remote stand • APU available
Regional Jet Aircraft (RJ-85, EMB-145, CL65)	• Handling mostly at remote stands • APU available
Turboprop Aircraft (S20, DH8, AT42/72, D328)	• Handling at remote stands • Sometimes no APU available
Business Jets (Citations, Falcon, LearJet, Global)	• Handling at remote stands • APU available
General Aviation Propeller Aircraft (Piper, Cessna)	• No APU available
Helicopter	• No APU available

It is possible to attribute an average (or standard) APU type to each group of aircraft if it is equipped with one. At Zurich Airport, proper aircraft – APU attributions have been made and entered into the system table data base (cf annex).

3.2 Aircraft Stand

At airports, two types of aircraft stands can be found:

- pier stands where a passenger loading bridge connects the aircraft to the building and
- remote stands where an aircraft is parked free of direct building connections (for passenger and/or cargo operations).

The stands themselves can show considerable differences in terms of place and technical equipment which can influence emissions from APU.

Table 3-2: Properties of Aircraft Stands

Properties	APU Consequences	Remarks
No electrical or pneumatical equipment	• APU required for ground power, air-conditioning and main engine start	Common on remote stands
Stand equipped with fixed or semi-mobile 400 Hz	• Doesn't require GPU; • APU still required for heating/cooling and for main engine start-up	Common on stands with loading bridge
Additionally equipped with PCA (stationary or through ACU)	• Doesn't require GPU; • APU required for main engine start-up only;	Stationary equipment only together with 400 Hz

3.3 Zurich Airport APU Regulations

Based on articles 36 and 51 of the Operating License for Zurich Airport (of 1.6.2001), the use of auxiliary power units (APU) is subject to certain restrictions. These are laid down in the AIP LSZH, section AD 2:

AIP SWITZERLAND[2]
LSZH AD 2

2.21.2.5 Auxiliary Power Units (APU)
Docking Stands
Primarily, the stationary airport pneumatic and electrical service units shall be used. Alternatively, mobile units shall be used.

Other stands
For pneumatic and power supply of aircraft not parked at docking stands, mobile units shall be used.

APU shall only be started:

- To start engine, but earliest 5 minutes before off-block time.
- If maintenance work on the aircraft makes it unavoidable; in that case the service period shall be kept as short as possible.
- If the stationary or mobile units are not available or unserviceable for specific aircraft types. In that case the APU shall be started at earliest 60 minutes before off-block time and kept in operation not more than 20 minutes after the on-block time.

In particular cases, the Airport Manager of the Airport Authority may permit longer service periods.

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[2] 31 OCT 2003 and AIRAC 15 APR 2004

3.4 Airline Regulations

Some airlines establish additional and company based procedures for the usage of APU. These procedures can be dependent on aircraft type, actual take-off weight and characterisation of the airport (altitude, runway length, etc).

One airline operating in and out of Zurich has established the following procedures (properly reflecting the airport's regulations):

4. USE OF APU

- Use of APU restricted.
  Use APU for ENG – start MAX 5 MIN before block off.
  If GPU U/S: Start APU MAX 60 MIN before block off.
  APU OPS MAX 20 MIN after block on.
  For A320 taxi-in without APU approved.
- ACFT on hard stands: switch off APU when GND Power Unit (GPU) connected.
- Terminal A/B: Preconditioned air and electrical power avbl.
- Energy saving:
  The crew shall decide, depending on WX COND or technical requirements, whether air conditioning is required or not.
  Generally, the air conditioning system should be switched off with AOT of APRX 10°C to 25°C. The air conditioning system should also be switched off after PSGR have disembarked or before leaving the ACFT.

4 Emission Calculation Methodology

4.1 APU Modes

For emission inventory purposes and subsequent concentration modelling, Zurich airport has created an APU-cycle that reflect APU operations in a simplified manner and that is used to build the model for the emission calculation.

This APU cycle consists of 4 modes of operation (table 4-1). By reducing the actual more detailed operations into just 4 modes enables the use of more standard calculation procedures (similar to the aircraft LTO cycle).

Table 4-1: APU-Operations and Alternatives

APU-Mode	Operations
Idle	Idle operation
400 Hz	Provides electricity when aircraft is on ground and in operations (e.g. pre-flight)
PCA	Provides pre-conditioned air (cooling or heating) if needed for pre-flight (boarding) or post-flight (disembarking) activities;
Bleed air	Provides necessary bleed air MES (main engine start);

Since a number of terms for APU operations are being used by the different manufacturers, they have been assigned to the suggested APU-modes (table 4-2).

Table 4-2: Zurich Airport Authority APU Terminology (ICCAIA, 1999)

Terminology	Idle (no load)	Electricity (400Hz only)	PCA (air & 400 Hz)	Bleed Air (engine start)
No Load	X			
Combined Load			X	X
Max Combined Load			X	X
Bleed Load			X	
Max Bleed Load			X	X
Max Shaft Load		X		
ECS			X	
Max ECS			X	
Max IGV			X	X
MES				X
MES+180KW				X

4.2 Operational Characterisation

Operational procedures may vary from airport to airport. Aircraft in Zurich are handled on remote stands or on pier stands. On most remote stands, GPU are available for delivering electricity to the aircraft (operated by the handling agents). There are only few air climate units (ACU) available. On all pier stands (piers A and E), fixed ground power systems for electricity and pro-conditioned air is available and is delivered to the aircraft by the handling agents immediately after on-block.

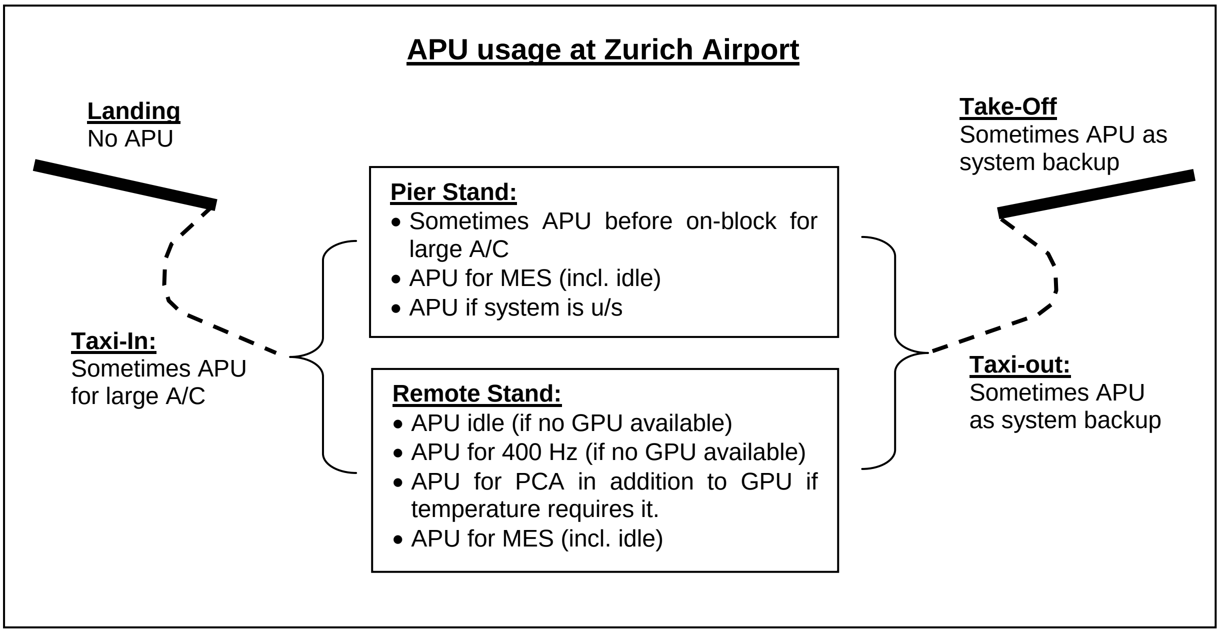

Figure 4-1: Operational characteristics of APU usage

The turn around times of all aircraft equipped with an APU are thus covered either by APU, GPU or fixed energy systems (FES). The model built for the emission inventory for Zurich airport makes use of the available operational data like aircraft turn-around times, total GPU operating times and the availability of the fixed energy system (FES). This returns APU running times for both pier stands (figure 4-2) and remote stands (figure 4-3), also reflecting the airport's requirements.

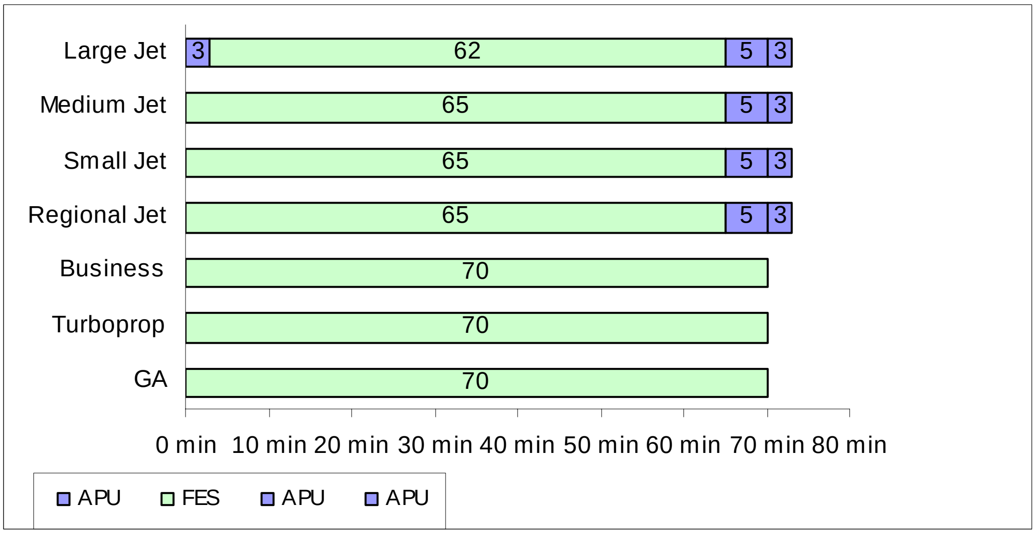

Figure 4-2: Model for Pier Stands, 2003 (FES times for Business, Turboprops and GA are dummy values, as these aircraft categories are not parked at pier stands)

The 3 minute period for large jets upon arrival is assumed for the time delay occurring when connecting the aircraft to the fixed ground power system (step ladder needed). The 3 minutes at the end of each cycle is bleed air, while for every cycle, a 1 minute idle time is assumed. The 5 minute period for jet aircraft is an average time for aircraft refusing to use fixed power or when the system is out of service.

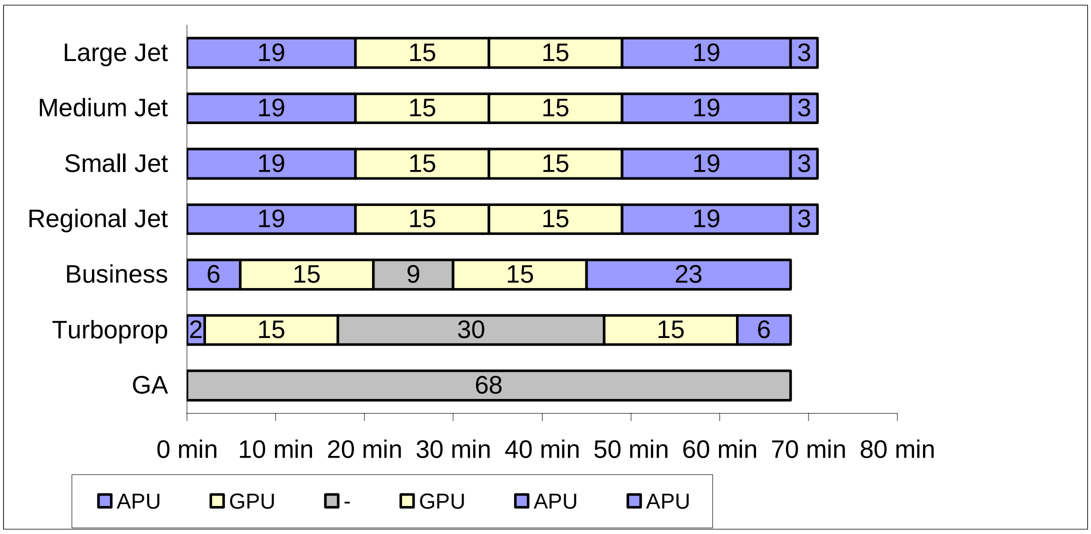

Figure 4-3: Model for Remote Stands (2003)

On remote stands, no fixed energy support is available; in this case the APU times have been derived from the difference between the average turn-around time of the aircraft and the average GPU operating time per cycle.

The APU/GPU/FES times can vary annually, depending on the turnaround times of aircraft, the total GPU running time and the technical availability of the fixed energy system.

4.3 Fuel Flow and Emissions Factors

The fuel flow data and emission factors are available from the airport's APU engine data base. This database has been setup starting in 1994 with support of APU manufacturers. Information is generally available for fuel flow, HC, CO and NOx emission indices for different operating modes.

The average emission factors used have been derived by:

1. Determining the most frequent APU type used for all aircraft types in the same group; more than 2/3 of the aircraft in a group could be described with one APU type except for small jets, where 3 APU types where chosen that account for 83% of the movements and applying this "mostly used" APU to all aircraft movements of the respective group.
2. Calculating an unweighted average fuel flow or emission factor by using the original emission factors from the manufacturers for all four modes (i.e. idle, 400Hz, PCA, bleed air). These emission factors (table 4-3) are used with the times as specified in figures 4-2 and 4-3.

Table 4-3: APU and Emission factors Zurich Airport 2003

Aircraft Group	APU	Represen-tation	Fuel (kg/h)	CO (g/kg)	HC (g/kg)	NOx (g/kg)
Large Jets	GTCP660-4	68%	435.90	8.44	0.25	5.39
Medium Jets	GTCP331-350	67%	192.25	2.74	0.31	9.80
Small Jets	GTCP36-150[R]	*28%*	*51.95*	*6.12*	*0.84*	*5.59*
	GTCP36-300	*35%*	*105.15*	*2.04*	*0.18*	*10.18*
	GTCP85-129	*20%*	*86.00*	*17.86*	*1.13*	*4.63*
	Average	(83%)	81.03	8.67	0.71	6.80
Regional Jets	GTCP36-150[R]	85%	51.95	6.12	0.84	5.59
Business Jets	GTCP36-150[RR]	100%	63.50	7.51	0.86	5.55
Turboprop	GTCP36-150[RR]	100%	63.50	7.51	0.86	5.55

4.4 APU Emission Calculation and Results

Emissions of APU are then calculated using the standard approach:

Number of Operations $\times$ $Time_{Mode}$ [min.] $\times$ Fuel $Flow_{Mode}$ [kg/h] $\times$ Emission $Index_{Mode}$ [g/kg].

Table 4-4: APU emissions at Zurich Airport in 2003

Emissions in t/a	CO	HC	NOx
Aircraft APU	27.54	2.47	23.36

Improvements of the results can be made by:

- implementing weighted averages for the emission factors according to a generic model for the times in the various operating mode;
- introducing more APU types per aircraft group (to cover 95-100% of the moevements with their proper APU) and calculate weighted average fuel flow and emission data.
- introducing emission factors for particulate matter.

5 Mitigation Possibilities

Auxiliary power units are an important source of emissions at an airport. There may be initiatives to reduce emissions of this source. This can either be through reduction at source (more efficient APU, less emissions), operational restrictions (reduction of operating hours) or alternative systems (replacement of APU operations by other means).

Table 5-1: APU-Operations and Alternatives

APU-Mode	Operations	Alternatives
Idle	Idle operation	--
400 Hz	Provides electricity when aircraft is on ground and in operations (e.g. pre-flight)	Mobile (electric or diesel) GPU or stationary system
PCA	Provides pre-conditioned air (cooling or heating) if needed for pre-flight (boarding) or post-flight (disembarking) activities;	Mobile (electric or diesel) GPU, ACU (air climate unit) or stationary system; Electric half-mobile ACU for open stands are possible;
Bleed air	Provides necessary bleed air for main engine start; 3 minutes ops time is sufficient.	ASU (air starter unit);

At Zurich airport, a combination of measures is in place to reduce emissions from APU:

- APU restrictions (cf. chapter 3.3)
- Alternative Systems

All pier stands are equipped with fixed ground power (115V, 400 Hz) and pre-conditioned air (figure 5-1). Energy for these systems is taken from the central power plant at the airport. The availability of the system is >95% of all times.

Figure 5-1: Fixed ground power systems

On open stands, the handling agents operate a total of 43 ground power units (GPU, figure 5-2). Aircraft are hooked up by default. The disadvantage of this system is that only electrical power can be supplied. Depending on the outside ambient temperature, the APU must be operated to provide preconditioned air.

Figure 5-3: GPU for electrical power

The benefits of the fixed ground power systems are convincing: In 2001, a total of 118,000 cycles of aircraft equipped with APU has been recorded (of a total of 309,000 aircraft movements and 21 million passengers).

The use of the fixed energy system has saved 12,170 t of fuel amounting to 38,500 t of CO_2 and 75 t of NOx. The NOx reduced equals 4.3% of all airport induces NOx-emissions and 60% of all APU induced NOx-emissions.

6 Gaps

Despite that some information on APU is available, there has a number of gaps been identified that need closer attention:

- Definitions: there is currently a variety of terms being used to describe the operating mode of an APU. Harmonisation is needed to achieve a single set of terms that is valid to describe APU operations;
- Operating cycle: although the operating time of an APU in the mode electrical power and/or air to the ECS varies, some generally applicable assumptions should be agreed as to necessary idle time or bleed air time for MES. In addition, there are uncertainties on how airlines actually use the APU in operations, i.e. during taxi-in or taxi-out.
- Emission factors: the current emission factors might need to be crosschecked and it is necessary to derive emission factors for particular matter.
- Turbine characteristics: In order to properly model the dispersion of the APU exhaust plume, information should be derived relating to exhaust nozzle diameter, exhaust gas temperature, the heat flux and exhaust gas velocity.

7 Annex

7.1 Abbreviations

ACU	Air Climate Unit
APU	Auxiliary Power Unit
ASU	Air Starter Unit
ECS	Environmental Control System
EGT	Exhaust Gas Temperature
FES	Fixed Energy System
GPU	Ground Power Unit
GSE	Ground Support Equipment
hp	Horsepower
Hz	Hertz
IGV	Inlet Guide Valves
kW	Kilowatt
LTO	Landing and Take-off Cycle
MES	Main Engine Start
PCA	Pre-conditioned Air
V	Volts

7.2 References

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7.3 Aircraft-APU Combinations

Honeywell:

(Source: Honeywell, June 2002)

Aircraft	APU	Aircraft	APU	Aircraft	APU
A300-600	GTCP331-200ER (143 HP)	B777-300	GTCP331-500 (143 HP)	DHC-7	GTCP 36 (80HP)
A300-600C	GTCP 660 (300 HP)	BAC-111-100	GTCP85-129 (200 HP)	DHC-8	GTCP 36 (80HP)
A300-600F	GTCP 660 (300 HP)	BAC-111-200	GTCP 36 (80HP)	DHC-8-100	GTCP 36 (80HP)
A300-600R	GTCP 660 (300 HP)	BAC-111-300	GTCP 36 (80HP)	DHC-8-200	GTCP 36 (80HP)
A300B	TSCP700-4B (142 HP)	BAC-111-400	GTCP 36 (80HP)	DHC-8-300	GTCP 36 (80HP)
A300-B2-100	TSCP700-4B (142 HP)	BAC-111-400F	GTCP 36 (80HP)	DHC-8-400	GTCP 36 (80HP)
A300-B2-200	TSCP700-4B (142 HP)	Bae ATP	GTCP 85 (200 HP)	DIAMOND 300	GTCP 36 (80HP)
A300-B4	TSCP700-4B (142 HP)	BAE146	GTCP 36 (80HP)	DO 328	GTCP 36-150[]
A300-B4-100	TSCP700-4B (142 HP)	BAE146-100	GTCP 36-100	EMB-110KQ1	GTCP 36 (80HP)
A300-B4-200	TSCP700-4B (142 HP)	BAE146-200	GTCP 36-100	EMB-120	GTCP 36-150[]
A300-B4-605R	GTCP 660 (300 HP)	BAE146-300	GTCP 36-150[]	EMB-145	GTCP 36 (80HP)
A300-B4-622R	GTCP 660 (300 HP)	BAE146-RJ	GTCP 36 (80HP)	EMBRAER	GTCP 36-150[]
A300-C4-200	GTCP 660 (300 HP)	BEECHJET 400	GTCP 36 (80HP)	F-27 SERIES	GTCP30-54
A300-F4-200	GTCP 660 (300 HP)	BEECHJET 400A	GTCP 36 (80HP)	F-28-1000	GTCP 36-4A
A310	GTCP331-200ER (143 HP)	BH-C99	GTCP 36 (80HP)	F-28-1000C	GTCP 36 (80HP)
A310-200	GTCP 85 (200 HP)	Bombardier Global Exp	GTCP 85 (200 HP)	F-28-2000	GTCP 36 (80HP)
A310-200C	GTCP 85 (200 HP)	Canadair Reg-100	GTCP 36-150[RR]	F-28-3000	GTCP 36 (80HP)
A310-200F	GTCP 85 (200 HP)	Canadair Reg-700	GTCP 85 (200 HP)	F-28-3000C	GTCP 36 (80HP)
A310-300	GTCP 85 (200 HP)	Caravelle-10	GTCP 660 (300 HP)	F-28-4000	GTCP 36 (80HP)
A310-304	GTCP 85 (200 HP)	Caravelle-12	GTCP 660 (300 HP)	F-28-4000/600	GTCP 36 (80HP)
A319	GTCP 36-300 (80HP)	CITATION I	GTCP 36 (80HP)	F-70-100	GTCP 85 (200 HP)
A320	GTCP 36-300 (80HP)	CITATION I SP	GTCP 36 (80HP)	Falcon 100	GTCP 36 (80HP)
A320-100	GTCP 36-300 (80HP)	CITATION II	GTCP 36 (80HP)	Falcon 50	GTCP 36 (80HP)
A320-200	GTCP 36-300 (80HP)	CITATION II SP	GTCP 36 (80HP)	FH-227	GTCP 36 (80HP)
A320-211	GTCP 36-300 (80HP)	CITATION SII	GTCP 36 (80HP)	FOKKER 100	GTCP 36-150[RR]
A321	GTCP 36-300 (80HP)	Citation Ultra	GTCP 36 (80HP)	FOKKER 100-100	GTCP 36-150[RR]
A321-100	GTCP 36 (80HP)	CITATION V	GTCP 36 (80HP)	FOKKER 70	GTCP 85 (200 HP)
A330	GTCP 331-350	Citation VII	GTCP 36 (80HP)	Fokker50	GTCP 36 (80HP)
A330-300	GTCP 85 (200 HP)	CITATION X	GTCP 36 (80HP)	Fokker50 HI Perf	GTCP 36 (80HP)
A330B	GTCP 85 (200 HP)	CL600	GTCP 85 (200 HP)	Fokker60 Utility	GTCP 36 (80HP)
A340-200	GTCP 331-350	CL600S	GTCP 85 (200 HP)	Gulfstream I	GTCP 85 (200 HP)
A340-300	GTCP 331-350	CL601-3A	GTCP 85 (200 HP)	Gulfstream II	GTCP 36 (80HP)
ATR42	GTCP 36-150[]	CL601-3R	GTCP 85 (200 HP)	Gulfstream III	GTCP 36 (80HP)
ATR42-400	GTCP 36 (80HP)	CN-235-200	GTCP 660 (300 HP)	Gulfstream IV	GTCP 36 (80HP)
ATR42-500	GTCP 36 (80HP)	CONCORDE-101	GTCP 85 (200 HP)	Gulfstream V	GTCP 36 (80HP)
ATR72-200	GTCP 36 (80HP)	CONCORDE-102	GTCP 85 (200 HP)	HS 748 2A SERIES	GTCP 36 (80HP)
ATR72-210	GTCP 36 (80HP)	Convair Liner	GTCP 85 (200 HP)	HS 748 2B SERIES	GTCP 36 (80HP)
AVRO-RJ100	GTCP 85 (200 HP)	DASH-7	GTCP 36 (80HP)	Il-62	GTCP 660 (300 HP)
AVRO-RJ115	GTCP 85 (200 HP)	DC10-10	TSCP700-4B (142 HP)	Il-76	GTCP 660 (300 HP)

Aircraft	APU	Aircraft	APU	Aircraft	APU
AVRO-RJ70	GTCP 85 (200 HP)	DC10-10C	TSCP700-4B (142 HP)	Il-86	GTCP 660 (300 HP)
AVRO-RJ85	GTCP 85 (200 HP)	DC10-10F	TSCP700-4B (142 HP)	Il-96-300	GTCP 660 (300 HP)
B. 99A	GTCP 36 (80HP)	DC10-15	TSCP700-4B (142 HP)	Il-96M	GTCP 660 (300 HP)
B707-100	GTCP 85 (200 HP)	DC10-30	TSCP700-4B (142 HP)	L-100 HERCULES	GTCP 85 (200 HP)
B707-120	GTCP 85 (200 HP)	DC10-30C	TSCP700-4B (142 HP)	L-100-30	GTCP 85 (200 HP)
B707-300	GTCP 85 (200 HP)	DC10-30CF Series	TSCP700-4B (142 HP)	L-1011-1	ST-6
B707-300C	GTCP 85 (200 HP)	DC10-30ER	TSCP700-4B (142 HP)	L-1011-100	GTCP 660 (300 HP)
B707-E	GTCP 85 (200 HP)	DC10-30F	TSCP700-4B (142 HP)	L-1011-150	GTCP 660 (300 HP)
B717-200	GTCP 85 (200 HP)	DC10-40	TSCP700-4B (142 HP)	L-1011-1F	GTCP 660 (300 HP)
B720-00B	GTCP 85 (200 HP)	DC8	GTCP 85 (200 HP)	L-1011-200	GTCP 660 (300 HP)
B727-100	GTCP85-129 (200 HP)	DC8-50F	GTCP85-129 (200 HP)	L-1011-250	GTCP 660 (300 HP)
B727-100C	GTCP85-129 (200 HP)	DC8-51	GTCP 85 (200 HP)	L-1011-40	GTCP 660 (300 HP)
B727-100F	GTCP 85 (200 HP)	DC8-51F	GTCP 85 (200 HP)	L-1011-50	GTCP 660 (300 HP)
B727-100RE	GTCP 85 (200 HP)	DC8-52	GTCP 85 (200 HP)	L-1011-500	GTCP 660 (300 HP)
B727-100RF	GTCP 85 (200 HP)	DC8-52F	GTCP 85 (200 HP)	L-1011-500 TR	GTCP 660 (300 HP)
B727-200	GTCP85-129 (200 HP)	DC8-53	GTCP 85 (200 HP)	L-188 A/C	GTCP 36 (80HP)
B727-200F	GTCP 85 (200 HP)	DC8-53F	GTCP 85 (200 HP)	MD-11	TSCP700-4B (142 HP)
B727-200RE	GTCP 85 (200 HP)	DC8-54F	GTCP 85 (200 HP)	MD-11-11	GTCP 660 (300 HP)
B727-200RF	GTCP 85 (200 HP)	DC8-55	GTCP 85 (200 HP)	MD-11-11C	GTCP 660 (300 HP)
B737-100	GTCP85-129 (200 HP)	DC8-55C	GTCP 85 (200 HP)	MD-11-11F	GTCP 660 (300 HP)
B737-200	GTCP85-129 (200 HP)	DC8-55F	GTCP 85 (200 HP)	MD-80	GTCP85-129 (200 HP)
B737-200C	GTCP 85 (200 HP)	DC8-60	GTCP 85 (200 HP)	MD-80-81	GTCP85-129 (200 HP)
B737-200F	GTCP 85 (200 HP)	DC8-61	GTCP85-129 (200 HP)	MD-80-82	GTCP85-129 (200 HP)
B737-300	GTCP85-129 (200 HP)	DC8-61F	GTCP 85 (200 HP)	MD-80-83	GTCP85-129 (200 HP)
B737-300F	GTCP 85 (200 HP)	DC8-62	GTCP85-129 (200 HP)	MD-80-87	GTCP85-129 (200 HP)
B737-400	GTCP85-129 (200 HP)	DC8-62C	GTCP 85 (200 HP)	MD-80-88	GTCP85-129 (200 HP)
B737-500	GTCP85-129 (200 HP)	DC8-62F	GTCP 85 (200 HP)	MD-90-10	131-9
B737-600	131-9	DC8-63	GTCP85-129 (200 HP)	MD-90-30	GTCP 85 (200 HP)
B737-700	131-9	DC8-63C	GTCP 85 (200 HP)	MD-90-40	GTCP 85 (200 HP)
B737-800	131-9	DC8-63F	GTCP 85 (200 HP)	MD-95	GTCP 85 (200 HP)
B737-900	GTCP 85 (200 HP)	DC8-70	GTCP85-129 (200 HP)	Mercure-100	GTCP 85 (200 HP)
B747-100	GTCP 660 (300 HP)	DC8-71	GTCP85-129 (200 HP)	N262	GTCP 36 (80HP)
B747-100B	GTCP 660 (300 HP)	DC8-71F	GTCP 85 (200 HP)	REG'L JET 200	GTCP 85 (200 HP)
B747-100F	GTCP 660 (300 HP)	DC8-72	GTCP85-129 (200 HP)	REG'L JET 200 ER	GTCP 85 (200 HP)
B747-100SR	GTCP 660 (300 HP)	DC8-72C	GTCP 85 (200 HP)	REG'L JET 200 LR	GTCP 85 (200 HP)
B747-200	GTCP 660 (300 HP)	DC8-73C	GTCP85-129 (200 HP)	SA-227 AC Metro3	GTCP 36 (80HP)
B747-200C	GTCP 660 (300 HP)	DC8-73F	GTCP85-129 (200 HP)	SA-227 AT Exped	GTCP 36 (80HP)
B747-200F	GTCP 660 (300 HP)	DC9-10	GTCP85-129 (200 HP)	SA-227 AT Metro3	GTCP 36 (80HP)
B747-300	GTCP 660 (300 HP)	DC9-10C	GTCP 85 (200 HP)	SD330 Sherpa	GTCP 36 (80HP)
B747-400	PW910A	DC9-10F	GTCP 85 (200 HP)	SF-340-A	GTCP 36 (80HP)
B747-400F	PW910A	DC9-15F	GTCP 85 (200 HP)	SF-340-B PLUS	GTCP 36 (80HP)
B747-SP	GTCP 660 (300 HP)	DC9-20	GTCP 85 (200 HP)	SHORT 360	GTCP 36 (80HP)
B757-200	GTCP331-200ER (143 HP)	DC9-30	GTCP85-129 (200 HP)	Swearingen Merlin	GTCP 36 (80HP)
B757-200F	GTCP 85 (200 HP)	DC9-30C	GTCP 85 (200 HP)	Swearingen Metro 2	GTCP 36 (80HP)
B767-200	GTCP331-200ER (143 HP)	DC9-30F	GTCP 85 (200 HP)	Tu-134	GTCP 85 (200 HP)
B767-200ER	GTCP 660 (300 HP)	DC9-40	GTCP85-129 (200 HP)	Tu-154	GTCP 85 (200 HP)

Aircraft	APU	Aircraft	APU	Aircraft	APU
B767-300	GTCP331-200ER (143 HP)	DC9-40F	GTCP 85 (200 HP)	Tu-204	GTCP 85 (200 HP)
B767-300ER	GTCP 660 (300 HP)	DC9-50	GTCP85-129 (200 HP)	VFW 614	GTCP 36 (80HP)
B767-300F	GTCP 660 (300 HP)	DC9-80	GTCP 85 (200 HP)	Vickers 953 Vanguard	GTCP 85 (200 HP)
B777-200	GTCP331-500 (143 HP)	DHC-6	GTCP 36 (80HP)	YAK-42	GTCP 85 (200 HP)
B777-200 IGW	GTCP331-500 (143 HP)	DHC-6/300	GTCP 36 (80HP)	YS-11	GTCP 36 (80HP)

Hamilton Sundstrand:

(Source: http://www.hs-powersystems.com/2190600_web.pdf)

Commercial Applications

	Model Name/Number	Maximum Bleed Air/ Shaft Output (PPM/HP)	Size (in) LxWxH	Dry Weight (lbs)	Application Summary
Business Jets	Gemini/T-62T-20G10C3/4	0/28	24.4x13x13.7	70	Learjet 55B/60, Raytheon King Air
	APS 500/T-62T-39	37/40	29.8x20.9x21.2	94	Falcon 20, Jetstar, HS-125, Sabreliner 60
	APS 500/T-62T-40C2	76/80	30.1x15.6x21.9	96	Gulfstream GII, Jetstar
	APS 500/T-62T-40C3	76/80	26.5x16x17.5	87	Falcon 200
	APS 500/T-62T-40C3A/A1	76/60	24.4x13x13.7	87	Falcon 50, Cessna Citation VI, VII
	APS 500/T-62T-40C7A	76/50	31.6x16.2x20.1	96	Cessna Citation III
	APS 500/T-62T-40C7B/D	72/50	31.8x10x23.5	105	deHavilland Dash 8-100/200/300 Series
	APS 500/T-62T-40C7E1	45/95	29x19x18.9	116	EMBRAER 120
	APS 500/T-62T-40C7E2	70/90	29x19x18.9	111	Falcon 20
	APS 500/T-62T-40C8D/D1	36/40	31.4x18.5x18	96	Raytheon Hawker 125-800/1000
	APS 500/T-62T-40C9	44/40	26x19x18	102	Business Jet Applications
Regional Jets	APS 500/T-62T-40C11	61/25	27x22x21	115	EMBRAER ERJ 135/140/145
	APS 500R/T-62T-40C14	77/25	27x22x21	120	EMBRAER ERJ 135/140/145
	APS 1000/T-62T-46C1	97/150	33.6x20.5x20.6	175	Fokker 50
	APS 1000/T-62T-46C3	97/100	36.4x27x22.3	190	BAE RJ/146, AVRO RJ
	APS 1000/T-62T-46C3A	97/100	36.4x27x22.3	190	BAE AVRO RJX
	APS 1000/T-62T-46C7	83/90	39.2x23x26	160	Saab 2000
	APS 1000/T-62T-46C12	84/25	30x24.5x22	135	deHavilland Dash 8 Q400
Large Transports	APS 2000/T-62T-47C1	175/95	42.1x20.9x21.9	282	Boeing 737
	APS 2100	175/95	46.4x27x25.6	410	Boeing 717
	APS 2300	127/62	36x20x22	260	EMBRAER ERJ 170/190
	APS 3200	200/170	26.9x15.4x18.4	308	A318/319/320/321