# MODEL OF ENVIRONMENT - FRIENDLY AIRCRAFT HANDLING – CASE STUDY: ZAGREB AIRPORT

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## ABSTRACT

In the era of increased awareness surrounding global warming and the importance of renewable energy, airports are affected by the rising costs of fossil fuels, as well as by the demands for the reduction of greenhouse gases emission. This paper reports the effort to determine the benefits of replacing gasoline and diesel-fueled internal combustion engine ground support equipment (ICE GSE) with electric ground support equipment (eGSE). The model of environment-friendly aircraft handling will be based on the examination of cost-effectiveness and reduction of greenhouse gases in the case of replacing fossil-fueled GSE with cleaner, more efficient electric-powered alternatives. In comparison with the current procedures of Ground Handling, the authors choose Zagreb Airport Ltd. as the representative airport for building Case Study and Airbus A319/A320 as the reference aircraft for calculation of greenhouse gases emission during handling process. The calculation method will be based on real time duration of processes performed by each piece of GSE during aircraft handling procedure. The usage of the model will be tested on aircraft handling for two airline business models: network and low cost. This research will show for the first time the relation between environmentally friendly procedures and vehicles, costs and increase in effectiveness during Aircraft Ground Handling.

**Keywords:** electric ground handling equipment, environment, aircraft emission, airport

## 1 INTRODUCTION

The aviation industry has the highest growth rate of all modes of transport and it could have serious implications for the environment in terms of pollution at local and global levels, and also in relation to land use planning, which means building new passenger terminals and runways. It is well known that aviation is a critical part of most economies worldwide, providing for the movement of people and goods throughout the world, enabling economic growth. It is known that aviation has impact in several environmental areas like: noise, air pollution, water, soil, and in this scientific paper the focus will be on air pollution. Air transport's contribution to climate change represents 2% of human-induced $CO_2$ emissions (12% of all transport sources) with airport activities share up to 5% of total aviation emissions. In the European Union, greenhouse gas emissions from aviation increased by 87% between 1990 and 2006 and over the past 40 years fuel efficiency improved by 70%; from 2001 – 2008 by 16%. There are many subjects which influence air pollution in the air traffic segment and they can be divided into several categories defined by the sources:

- aircraft through the burning of fuels such as Jet-A or Avgas
- aircraft ground movements
- ground airport vehicles (airside)
- transport used by passengers and staff to access airports,
- emissions generated by the production of energy used in airport buildings,
- the construction of airport infrastructure

## 2 REACTION OF ALL AVIATION STAKEHOLDERS ON REDUCING AIR POLLUTION

As Croatia will become 28th member of EU on July 1st 2013, it is mandatory to prepare all environmental obligations which will follow EU targets, better known as EU 20-20-20 Targets. It means that there should be a 20% reduction in EU greenhouse gas emissions from the 1990 levels; a rise in the share of EU energy consumption produced from renewable resources to 20%; and a 20% improvement in the EU's energy efficiency. In the following paragraphs there will be shown the best practices worldwide in achieving emission reduction goals divided by each stakeholder:

- **Government and aviation organizations** published lots of documents which precisely covered laws and methods how to reduce emissions. The main documents in this area are: ICAO Annex 16 and ICAO Doc 9889 “Airport Air Quality Manual”, European Commission Documents, National directives and legislation, and Advisory Council for Aeronautics Research in Europe (ACARE) documents.
- **Aircraft manufacturers** – from the point of aircraft manufacture the two strongest manufactures in the market can be used: Airbus and Boeing. In the next few sentences their improvements will be shown: Airbus 380 has the lowest emissions of any large commercial aircraft 75g of CO2 per passenger km; Airbus 350 XWB is 86% below the current CAEP6 carbon monoxide (CO) limit and 35 % below the current mono-nitrogen oxide (NOx) limit. Boeing on the other side with a new Boeing 787 Dreamliner has a 20% reduction in fuel and CO2 emissions and 28% below 2008 industry limits for NOx (in comparison to Boeing 767); Boeing 737 MAX has a 13% reduction in fuel and Carbon dioxide and 50% below CEAP/6 limits for NOX (in comparison to Next Generation 737).
- ***Airlines reaction*** - using available GPU instead of APU results in fuel savings and less emissions– this saves about 19 million liters of jet fuel and eliminates more than 45 million kg of $CO_2$ emissions annually; engine wash: keeping aircraft engine components cleaner - engines operate more efficiently and save more than 27 million liters of jet fuel per year, as well as 68 million kg of $CO_2$; Single-Engine Taxi - using only one engine during taxi, when safe and operationally feasible it saves nearly 11 million liters of jet fuel and about 27 million kg of $CO_2$ emissions annually; replacing 19,000 catering carts with newer models made of lighter materials saves nearly 7,5 million liters of jet fuel annually. Also, a few years ago the airlines have started testing the usage of alternative fuel, and the first commercial flight using biokerosene was on October 6th 2011 with Boeing 757-200 operated by Thomson Airways, which carried 232 passengers from Birmingham Airport, UK to Arrecife, using a sustainable biofuels blend in one engine.
- ***Reaction of airports*** – airports have started to implement energy-efficient architecture, investing in energy-efficient technology and optimizing energy which they currently use; using Fixed Ground Power - aircraft parking positions with air bridges equipped with fixed GPU’s result saving more $CO_2$ (aircraft APU can be switched off); alternative power sources – the airports across Europe invest in renewable energy facilities such as biomass, geo-thermal power, solar power and even wind turbines; Ground Handling Vehicles - GH companies convert their vehicle fleets to electric, hybrid, hydrogen or LPG technology (e.g. High-speed Tow Tractors: transport aircraft between terminals and maintenance hangars, saving more than 15 million liters of jet fuel and reducing $CO_2$ emissions by 40 million kg annually); Airport Public Access - States/Counties/Cities/Airports invest in better public transport links to an airport (the encouraged use of bus, train or metro). The airports

have started to compete in reducing emissions through Airport Carbon Accreditation Program which was launched in 2009. This program has four levels (mapping, reduction, optimization, neutrality) and 64 airports in Europe are accredited in this program.

- ***Reaction of Air Traffic Control*** – the implementation of CDM (Collaborative decision making) and CEM (Collaborative Environmental Management), in addition with CDA (Continuous Descent Arrival) and CCO (Continuous Climb Operation) at airports, results in the decrease of congestion during landings and takeoffs, on runways and taxiways, which results in the reduction of fuel, emissions and noise. Airports Council International Europe is working together with Eurocontol on the implementation of CDM on 40 airports which will have a benefit in estimated result savings over 475.000 tones of $CO_2$.

## 3 ROLE OF AIRPORT GROUND HANDLING IN REDUCING EMISSIONS AND FUEL SAVINGS

Each airport in line with its traffic increscent has a significant amount of activities during aircraft handling on the apron. Around the aircraft there are many vehicles and equipment which are specialized for some handling servicing activities, and also those vehicles and equipment were mostly powered by diesel or petrol fuel. From the point of view of the airport it is very important to follow and analyze the emissions from handling vehicles on a monthly or yearly basis, and also to work actively on the implementation of environmentally friendly equipment because it is already a major question of the airport future sustainable development. For that reason many airports are strategically focusing on the change of their apron ground handling equipment from gasoline or diesel to electric powered. In table 1 it is shown which equipment is currently used for aircraft handling, and in addition to that it shows the possibilities to change the existing conventional powered equipment with electric powered alternative.

**Table 1 Insight into the ground handling equipment and its power sources**

| Ground Support Equipment | | | Power | |
|---|---|---|---|---|
| Acronym | Description of equipment | Purpose of use | Diesel/Gasoline | Electric |
| AC | Air conditioning unit | Aircraft | ✓ | × |
| AS | Air starting unit | Aircraft | ✓ | × |
| BULK | Bulk train | Baggage / cargo | ✓ | ✓ |
| CAT | Catering truck | Passengers | ✓ | ✓ |
| CB | Conveyor belt | Baggage / cargo | ✓ | ✓ |
| CLEAN | Cleaning truck | Passengers | ✓ | ✓ |
| FUEL | Fuel hydrant dispenser or tanker | Aircraft | ✓ | × |
| GPU | Ground power unit | Aircraft | ✓ | × |
| LD | CL lower deck cargo loader | Baggage / cargo | ✓ | ✓ |
| LV | Lavatory vehicle | Passengers | ✓ | ✓ |
| BUS | Bus for transfer passengers to aircraft | Passengers | ✓ | ✓ |
| PS | Passenger stairs | Passengers | ✓ | ✓ |
| TOW | Tow tractor | Aircraft | ✓ | ✓ |
| ULD | ULD train | Baggage / cargo | ✓ | ✓ |
| WV | Potable water vehicle | Passengers | ✓ | ✓ |

*Source: Authors research based on official Ground Handling Equipment Websites*

For the better understanding of the equipment around aircraft for ground handling purpose, Figure 1 shows the position of all the equipment which can be used for handling

Airbus A319/A320 aircraft. Each acronym marked on equipment on Figure 1 is described in Table 1.

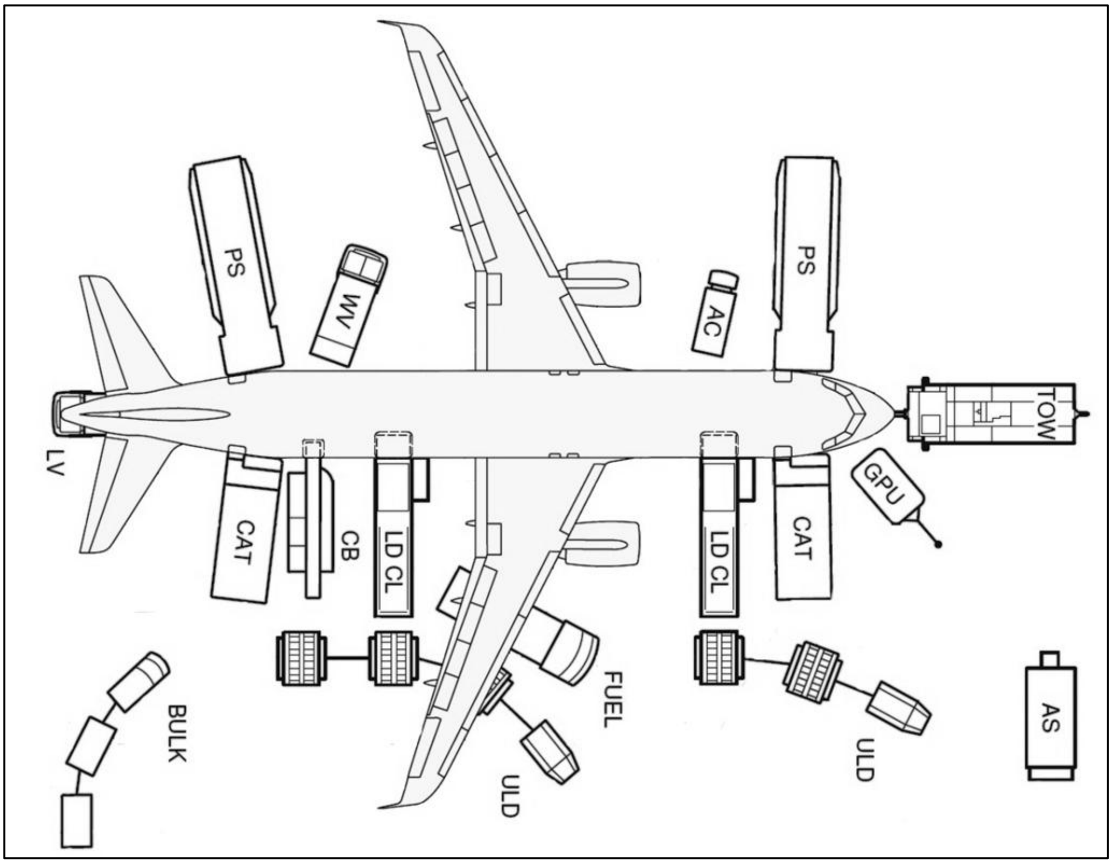


**Figure 1 Standard position of Ground handling equipment for Airbus A319/A320**
*Source: Airbus aircraft characteristics airport and maintenance planning – manual*

## 4 ENVIRONMENTAL AND FINANCIAL COMPARISON BETWEEN DIESEL/GASOLINE VS. ELECTRICAL GROUND HANDLING EQUIPMENT AT ZAGREB AIRPORT

For making the precise calculation and benchmark between diesel/gas and electrical equipment, it is necessary to measure time of activity for each equipment around aircraft, and as this scientific paper will also make a calculation for two different airline business models, such as traditional network carrier and low cost model, Figure 2 shows the difference in aircraft handling time divided by equipment. Table 2 shows the list of ground support equipment at Zagreb Airport considered in the Model of environmentally friendly aircraft handling. Fuel consumptions, as well as technical specifications concerning gasoline and diesel-fueled internal combustion engine ground support equipment (ICE GSE) were provided by Zagreb Airport. Technical specifications and information concerning electric ground support equipment (eGSE), selected to replace fossil-fueled GSE, were provided by eGSE manufacturers. eGSE is chosen to have the same capacities as ICE GSE, except in the case of replacing buses used to transfer passengers to the airport. COBUS 2500e, chosen to replace COBUS 3000, has a passenger capacity half the size of COBUS 3000. When calculating economical and environmental benefits due to fuel replacement, COBUS 2500e is considered to cover double distance of COBUS 3000 to transfer as many passengers as COBUS 3000.

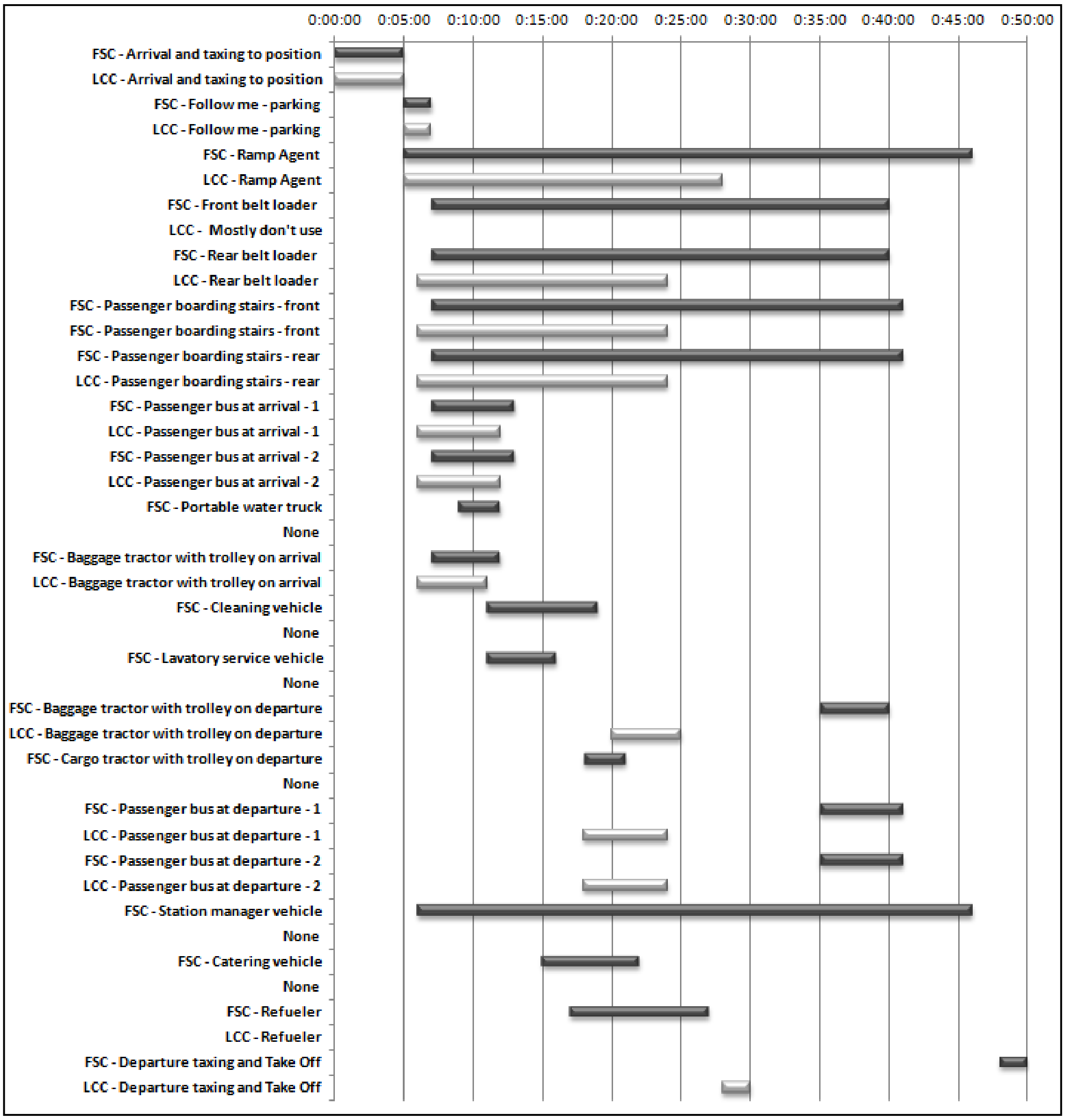


**Figure 2 Comparison between aircraft handling time for Network (*FSC*) and Low cost (*LCC*) business model**

*Source: Average data measured by several handling operations at Zagreb Airport*

From Figure 2 it can be easily seen that due to economic reasons and business strategy of Low cost airlines in comparison with Network carriers (FSC – Full Service Carriers), low cost airlines have aircraft block time of 25-30 minutes while Network Carriers have 45 minutes. That short block time on low cost strategy is mainly because their business is based on higher aircraft utilization, using very basic equipment (stewardess clean the aircraft by themselves, refueling is usually made at a low cost base airport, the loading area is in advance determined due to weight and balance reasons). As low cost airlines do not use all the equipment that Network Carriers do, and by analyzing the list of available electric powered equipment it can be said that the airports on which low cost airlines do not make refueling it is possible to create green apron with only electrical powered equipment and zero emissions.

**Table 2 List of GSE considered in the Model of environmentally friendly aircraft handling**

| GSE Type | ICT GSE | Fuel | Fuel consump. [l/h] | Characteris. | eGSE | Fuel | Battery capac. [kWh] | Motor: contin. power [kW] | Characteristics |
|---|---|---|---|---|---|---|---|---|---|
| Belt Loader | Mulag Diesel Convoyer Belt Orbiter 9D | **Diesel** | 0,94 | Max. height front (mm): 4800 Distributed load (kg/m): 150 Max. individual unit weight (kg): 400 | Mulag Orbiter 9E | **Elect.** | 40 | 12 | Max. height front(mm): 4930 Distributed load (kg/m): 135 Max. individual unit weight (kg): 400 |
| Passen. boarding stairs | Hunert 427-03 D | **Diesel** | 2,51 | Load capacity per step (kg): 150 Platform height: Max: 5800 mm Min: 2450 mm | JBT UES-2 | **Elect.** | 40 | 13 | Load capacity per step (kg): 228 Platform height: Max: 5730 mm Min: 2450 mm |
| Baggage Tractor<br>Cargo Tractor | Mulag Comet V-1 | **Diesel** | 2,63 | Drawbar pull (kN): 20 | Mulag Comet 3E | **Elect.** | 49,6 | 20 | Drawbar pull (kN): 20 |
| Lavatory service vehicle | Schrader (Chassis: Iveco ML75) | **Diesel** | 2,41 | | CLT200E - Electric Lav Truck | **Elect.** | 40 | 30 | |
| Potable water truck | Schrader (Chassis: Iveco ML75) | **Diesel** | 2,05 | | CWT300E - Electric Water Truck | **Elect.** | 40 | 30 | |
| | | | Fuel consump. l/km] | | | | | | |
| Cleaning vehicle | VW Transpor. | **Gasol.** | 0,2627 | Payload capacity : 900 kg | Mercedes Vito E-Cell | **Elect.** | 36 | 60 | Payload capacity : 900 kg |
| Catering vehicle | MAN Catering Truck | **Diesel** | 0,2147 | | Smith Newton – Refrigerated Box | **Elect.** | 84 | 120 | |
| "Follow me" vehicle<br>Ramp Agent<br>Station manager | VW Polo 1.6 TDI | **Diesel** | 0,034 | Max. Speed (km/h): 170 Acceleration 0-100 (sec): 14 Dimensions (cm): 397 x 168,2 x 148,5 | Mitshubishi i MiEV | **Elect.** | 16 | 49 | Max. Speed (km/h): 130 Acceleration 0-100 (sec): 15,9 Dimensions (cm): 347,5 x 147,5 x 161,0 |
| Bus | COBUS 3000 | **Diesel** | 0,665 | Passenger capacity : Up to 112 passengers and up to 14 seated | COBUS 2500e | **Elect.** | 150 | 134 | Passenger capacity : Up to 66 passengers and up to 24 seated |

*Source: Authors collected data via direct communication with manufactures and sales agents*

Since GSE used in aircraft handling operations in the network business model differs from GSE used in low cost business model, as well as the durations of participation of each piece of equipment, separate calculations for these two models have been made. When calculating economic benefits and carbon dioxide reduction due to fuel replacement, the data from Table 3 have been used.

**Table 3 Fuel prices and carbon dioxide emissions**

| Fuel | Type | Fuel price [EUR] | Tailpipe carbon dioxide emission [kg] | Carbon dioxide emission from electricity generation[kg] |
|---|---|---|---|---|
| Diesel | INA Eurodizel BS | 1,2832 | 2,6817 | 0 |
| Gasoline | INA Eurosuper 95 BS | 1,3782 | 2,3533 | 0 |
| Electricity | Low (night) tariff | 0,0593 | 0 | 0,305 |

*Source: Official prices from INA http://www.ina.hr/ and HEP http://www.hep.hr/*

### 4.1 Economic benefits of fuel replacement

The economic benefits resulted from fuel replacement have been calculated in the case of one aircraft Airbus A319/A320 handling operation, as well as in the case of several operations performed on a single battery charge for network and low cost business model. When calculating power consumptions of belt loaders, passenger boarding stairs, baggage and cargo tractors, potable water trucks and lavatory service vehicles, eGSE was considered to work with rated power for the whole duration of participation in aircraft handling operation. When calculating power consumptions of cleaning and catering vehicles, buses, station manager, ramp agent and "Follow me" vehicles, the distances covered in handling operation were taken into consideration.

**Table 4 Economic benefits of fuel replacement in one aircraft Airbus A319/A320 handling operation – network business model**

| | | | ICE GSE | | eGSE | | |
|---|---|---|---|---|---|---|---|
| Qty | GSE Type | Duration of participation in one aircraft handling procedure [min] | Fuel consump. [l] | Fuel cost [EUR] | Electrical power consump. [kwh] | Electrical power cost [EUR] | Savings due to fuel replacement [EUR] |
| 2 | Belt loader | 16,50 | 0,517 | 0,663 | 6,600 | 0,391 | **0,272** |
| 2 | Passenger boarding stairs | 10,20 | 0,853 | 1,095 | 4,420 | 0,262 | **0,833** |
| 1 | Baggage tractor | 10,00 | 0,438 | 0,562 | 3,333 | 0,198 | **0,365** |
| 1 | Cargo tractor | 8,00 | 0,351 | 0,450 | 2,667 | 0,158 | **0,292** |
| 1 | Potable water truck | 3,00 | 0,103 | 0,132 | 1,500 | 0,089 | **0,043** |
| 1 | Lavatory service vehicles | 5,00 | 0,201 | 0,258 | 2,500 | 0,148 | **0,109** |
| | | Distance covered in one aircraft handling procedure [km] | | | | | |
| 1 | Station manager | 0,80 | 0,027 | 0,035 | 0,108 | 0,006 | **0,028** |
| 1 | Ramp Agent | 2,20 | 0,075 | 0,096 | 0,297 | 0,018 | **0,078** |
| 1 | "Follow me" vehicle | 1,40 | 0,048 | 0,061 | 0,189 | 0,011 | **0,050** |
| 2 | Bus | 1,40 | 1,064 | 1,365 | 5,600 | 0,332 | **1,033** |
| 1 | Cleaning vehicle | 0,75 | 0,263 | 0,362 | 0,208 | 0,012 | **0,350** |
| 1 | Catering vehicle | 0,50 | 0,215 | 0,275 | 0,261 | 0,015 | **0,260** |

The economic benefits of fuel replacement in one aircraft Airbus A319/A320 handling operation in the case of network business model can be seen in table 4. Saving due to fuel replacement in the case of network business model is 3,71 EUR per aircraft handling operation. Zagreb Airport has approximately sixteen network carrier handling operations with aircraft Airbus A319/A320 daily. Savings due to fuel replacement are 59,36 EUR daily and 21.666,40 EUR annually.

**Table 5 Economic benefits of fuel replacement in aircraft Airbus A319/A320 handling operations performed on a single battery charge – network business model**

| | | eGSE | | | ICE GSE | |
|---|---|---|---|---|---|---|
| Qty | GSE Type | Time operating on a single battery charge [h] | Number of ground handling operations performed on a single battery charge | Electrical power consumption [kWh] | Fuel consump. [l] | Savings due to fuel replacement [EUR] |
| 2 | Belt loader | 3,33 | 12 | 80,00 | 6,27 | **3,30** |
| 2 | Passenger boarding stairs | 3,08 | 18 | 80,00 | 15,45 | **15,08** |
| 1 | Baggage tractor | 2,48 | 15 | 49,60 | 6,52 | **5,43** |
| 1 | Cargo tractor | 2,48 | 19 | 49,60 | 6,52 | **5,43** |
| 1 | Potable water truck | 1,33 | 27 | 40,00 | 2,73 | **1,13** |
| 1 | Lavatory service vehicles | 1,33 | 16 | 40,00 | 3,21 | **1,75** |
| | | Distance covered on a single battery charge [km] | | | | |
| 1 | Station manager | 118,52 | 148 | 16,00 | 4,03 | **4,22** |
| 1 | Ramp Agent | 118,52 | 54 | 16,00 | 4,03 | **4,22** |
| 1 | "Follow me" vehicle | 118,52 | 85 | 16,00 | 4,03 | **4,22** |
| 2 | Bus | 150,00 | 54 | 300,00 | 57,00 | **55,35** |
| 1 | Cleaning vehicle | 130,00 | 173 | 36,00 | 45,53 | **60,61** |
| 1 | Catering vehicle | 160,00 | 322 | 84,00 | 69,12 | **83,72** |

The economic benefits of fuel replacement in aircraft handling operations performed on a single battery charge in the case of network business model can be seen in Table 5. The number of ground handling operations performed on a single battery charge differs for every piece of ground support equipment, as it depends on battery capacity, motor power, duration of participation and distance covered in one aircraft Airbus A319/A320 handling operation.

**Table 6 Economic benefits of fuel replacement in one aircraft handling operation – low cost business model**

| | | | ICE GSE | | eGSE | | |
|---|---|---|---|---|---|---|---|
| Qty. | GSE Type | Duration of participation in one aircraft handling procedure [min] | Fuel consumpt. [l] | Fuel cost [EUR] | Electrical power consumption [kwh] | Electrical power cost [EUR] | Savings due to fuel replacement [EUR] |
| 1 | Belt loader | 16,20 | 0,254 | 0,326 | 3,240 | 0,192 | 0,134 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | Passenger boarding stairs | 5,40 | 0,452 | 0,580 | 2,340 | 0,139 | 0,441 |
| 1 | Baggage tractor | 10,00 | 0,438 | 0,562 | 3,333 | 0,198 | 0,365 |
| | | Distance covered in one aircraft handling procedure [km] | | | | | |
| 1 | Ramp Agent | 2,20 | 0,075 | 0,096 | 0,297 | 0,018 | 0,078 |
| 1 | "Follow me" vehicle | 1,40 | 0,048 | 0,061 | 0,189 | 0,011 | 0,050 |
| 2 | Bus | 1,40 | 1,064 | 1,365 | 5,600 | 0,332 | 1,033 |

*Source: Calculation was made by authors based on manufacture data*

The economic benefits of fuel replacement in one aircraft handling operation in the case of low cost business model can be seen in Table 6. Saving due to fuel replacement in the case of low cost business model is 1,80 EUR per aircraft handling operation. Zagreb Airport has approximately three low cost airlines with aircraft Airbus A319/A320 handling operations daily. Savings due to fuel replacement are 5,40 EUR daily and 1.971 EUR annually.

**Table 7 Economic benefits of fuel replacement in aircraft handling operations performed on a single battery charge – low cost business model**

| | | eGSE | | | ICE GSE | |
|---|---|---|---|---|---|---|
| Qty. | GSE Type | Time operating on a single battery charge charge [h] | Number of ground handling operations performed on a single battery charge | Electrical power consumption [kWh] | Fuel consumpt. [l] | Savings due to fuel replacement [EUR] |
| 1 | Belt loader | 3,33 | 12 | 40,00 | 3,13 | 1,65 |
| 2 | Passenger boarding stairs | 3,08 | 34 | 80,00 | 15,45 | 15,08 |
| 1 | Baggage tractor | 2,48 | 15 | 49,60 | 6,52 | 5,43 |
| | | Distance covered on a single battery charge [km] | | | | |
| 1 | Ramp Agent | 118,52 | 54 | 16,00 | 4,03 | 4,22 |
| 1 | "Follow me" vehicle | 118,52 | 85 | 16,00 | 4,03 | 4,22 |
| 2 | Bus | 150,00 | 54 | 300,00 | 57,00 | 55,35 |

*Source: Calculation was made by authors based on manufacture data*

The economic benefits of fuel replacement in aircraft handling operations performed on a single battery charge in the case of low cost business model can be seen in Table 7. The results indicate that the higher the consumption of fossil fuels is, the greater savings due to replacement there will be. Such results are expected since diesel and gasoline have much higher prices than electricity. The calculated daily savings due to fuel replacement in the case of sixteen network carrier and three low cost carrier aircraft Airbus A319/A320 handling operations are 38,79 EUR. The calculated annual savings rise up to 23.637,40 EUR.

### 4.2 Environmental benefits of fuel replacement

The environmental benefits due to the replacement of fossil fuels with electricity, as well as the economic benefits, have been calculated in the case of network and also in the case of low cost business models. Table 8 shows the reduction of carbon dioxide emission due to fuel replacement in aircraft handling operations performed on a single battery charge in the case of network business model, and Table 9 shows the reduction in the case of low cost business model. The results indicate that not all of the replacements of fossil-fueled ICT GSE with eGSE lead to carbon dioxide emission reduction. Electric vehicles have zero tailpipe emissions, but carbon dioxide emissions are produced in electricity generation. The $CO_2$ emission from fossil fuels consumed for generating one kWh of electricity in Croatia, in both electricity-only and combined heat and power plants, amounts to 305 grams. In areas that use relatively low-polluting energy sources for electricity production, electrical vehicles typically have emissions advantage over similar conventional vehicles running on gasoline or diesel. In areas that are heavily dependent on conventional fossil fuels for electricity generation, electrical vehicles may not demonstrate carbon dioxide emission reduction. The replacement of belt loaders in both business models and the replacement of potable water truck and lavatory service vehicle in network business model do not result in the emission reduction. These vehicles do not have high diesel consumptions; hence generation of electricity used to charge batteries produces greater carbon dioxide emissions than tailpipe emissions from fossil fuel combustion. The replacement of ICE GSE with high fossil fuel consumption shows a significant carbon dioxide emission reduction.

**Table 8 Environmental benefits of fuel replacement – network business model – A319/A320**

| | | | ICE GSE | eGSE | | |
|---|---|---|---|---|---|---|
| Qty | GSE Type | Number of aircraft handling operations performed | Talpipe carbon dioxide emission [kg] | Tailpipe carbon dioxide emission [kg] | Carbon dioxide emission due to electricity generation [kg] | Reduction of carbon dioxide emission due to fuel replacement [kg] |
| 2 | Passenger boarding stairs | 18 | 41,42 | 0,00 | 24,40 | **17,02** |
| 1 | Baggage tractor | 15 | 17,49 | 0,00 | 15,13 | **2,36** |
| 1 | Cargo tractor | 19 | 17,49 | 0,00 | 15,13 | **2,36** |
| 1 | Station manager | 148 | 10,81 | 0,00 | 4,88 | **5,93** |
| 1 | Ramp Agent | 54 | 10,81 | 0,00 | 4,88 | **5,93** |
| 1 | "Follow me" vehicle | 85 | 10,81 | 0,00 | 4,88 | **5,93** |
| 2 | Bus | 54 | 201,13 | 0,00 | 91,50 | **109,63** |
| 1 | Cleaning vehicle | 173 | 107,14 | 0,00 | 10,98 | **96,16** |
| 1 | Catering vehicle | 322 | 185,37 | 0,00 | 25,62 | **159,75** |

*Source: Calculation was made by the authors based on the manufacture data*

The reduction of carbon dioxide emission due to fuel replacement in the case of low cost business model is 3,64 kg per aircraft handling operation. Zagreb Airport has approximately sixteen network aircraft Airbus A319/A320 handling daily. The reduction of carbon dioxide emission due to fuel replacement is 58,24 kg daily and 21.257,60 kg annually.

**Table 9 Environmental benefits of fuel replacement – low cost business model**

| | | | ICE GSE | eGSE | | |
|---|---|---|---|---|---|---|
| Qty. | GSE Type | Number of aircraft handling operations performed | Talpipe carbon dioxide emission [kg] | Tailpipe carbon dioxide emission [kg] | Carbon dioxide emission due to electricity generation [kg] | Reduction of carbon dioxide emission due to fuel replacement[kg] |
| 2 | Passenger boarding stairs | 34 | 41,42 | 0,00 | 24,40 | **17,02** |
| 1 | Baggage tractor | 15 | 17,49 | 0,00 | 15,13 | **2,36** |
| 1 | Ramp Agent | 54 | 10,81 | 0,00 | 4,88 | **5,93** |
| 1 | "Follow me" vehicle | 85 | 10,81 | 0,00 | 4,88 | **5,93** |
| 2 | Bus | 54 | 201,13 | 0,00 | 91,50 | **109,63** |

*Source: Calculation was made by the authors based on the manufacture data*

The reduction of carbon dioxide emission due to fuel replacement in the case of low cost business model is 1,98 kg per aircraft handling operation. Zagreb Airport has approximately three low cost aircraft Airbus A319/A320 handling operations daily. The reduction of carbon dioxide emission to fuel replacement is 5,95 kg daily and 2.170,34 kg annually. The calculated reduction of carbon dioxide emission due to fuel replacement in the case of sixteen network and three low cost aircraft Airbus A319/A320 handling operations is 38,70 kg daily. Calculated annual reduction of carbon dioxide emission is 23.427,94 kg.

## 5. CONCLUSION

The airport sustainability is very dependent on the care about the environment, and in future there will be much more pressure on airport management and aircraft handling agents to fulfill all the requirements that Countries will put in place. The results of economical and environmental benefits analysis due to fuel replacement in the cases of one aircraft handling procedure, as well as several handling procedures performed on a single battery charge, indicate that the higher the consumption of fossil fuels is, the greater savings and carbon dioxide emission reduction due to replacement there will be. In the case of replacing ICE GSE with low fossil fuel consumption with eGSE with a large battery capacity, there is no carbon dioxide emission reduction because the generation of electricity used to charge batteries produces greater carbon dioxide emissions than tailpipe emissions from fossil fuel combustion. This scientific paper showed that airports have space for improvement in environmental way, and there is a possibility in their core business for aircraft handling to be done with very low emissions provided by equipment. By using electric power equipment instead of the current diesel or gasoline, the research has showed that it is possible to create environmentally friendly business surroundings at an airport by creating the “Green Apron” system.

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