e-ISSN 2828-0490
JURNAL MEDIA COMPUTER SCIENCE

Comparative Analysis Of The Efficiency Of Auxiliary Power Unit (APU) And Ground Support Equipment (GSE) On The Electrical System Of Airbus A320 Aircraft

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ARTICLE HISTORY
Received [02 Juli 2025]
Revised [08 September 2025]
Accepted [11 September 2025]

KEYWORDS
Auxiliary Power Unit (APU), Ground Support Equipment (GSE), Ground Power Unit (GPU), Airbus A320, Energy Efficiency, Aircraft Electrical System.

ABSTRACT

Penelitian ini menganalisis perbandingan efisiensi Auxiliary Power Unit (APU) dan Ground Power Unit (GPU) pada sistem kelistrikan pesawat Airbus A320 saat di darat. Operasi pesawat membutuhkan suplai daya stabil, yang disediakan oleh APU internal atau GPU eksternal. Meskipun APU fleksibel, konsumsi bahan bakar tinggi dan dampak lingkungannya signifikan. Sebaliknya, GPU dinilai lebih efisien dan ramah lingkungan. Tujuan penelitian ini adalah menghitung konsumsi energi, menganalisis efisiensi, dan merekomendasikan sumber daya kelistrikan yang paling efisien dan ramah lingkungan. Metode yang digunakan adalah observasi lapangan quasi-experimental, dengan pengambilan data langsung pada unit GPU Houchin LTD model C690. Pengambilan data dilakukan selama 7 hari, dari tanggal 1 hingga 7 Juni 2025. Analisis data meliputi perhitungan matematis untuk efisiensi energi dan analisis ekonomi operasional. Hasil penelitian menunjukkan GPU jauh lebih unggul dari APU. GPU diesel memiliki efisiensi energi sekitar 31.30%, jauh lebih tinggi dari APU yang sekitar 1.54% (berdasarkan data 7 hari). GPU juga menyajikan kualitas daya kelistrikan yang lebih baik, ditandai dengan Power Factor yang lebih tinggi dan Total Harmonic Distortion (THD) yang lebih rendah. Disarankan agar maskapai memprioritaskan penggunaan GPU, dan pengelola bandara memperluas infrastruktur Fixed Electrical Ground Power (FEGP) untuk meningkatkan efisiensi energi, dan mengurangi biaya operasional.

ABSTRACT

This research analyzes the efficiency comparison between the Auxiliary Power Unit (APU) and Ground Power Unit (GPU) on the Airbus A320 aircraft's electrical system during ground operations. Aircraft operations require a stable power supply, provided by either an internal APU or an external GPU. Although the APU offers flexibility, its high fuel consumption and significant environmental impact are considerable concerns. Conversely, the GPU is deemed more efficient and environmentally friendly. The study aims to calculate energy consumption, analyze efficiency, and recommend the most efficient and environmentally sound electrical power source. The method employed is a quasi-experimental field observation, involving direct data collection from a Houchin LTD model C690 GPU unit. Data collection was conducted over 7 days, from June 1 to June 7, 2025. Data analysis includes mathematical calculations for energy efficiency and operational economic analysis. Research findings indicate that the GPU significantly outperforms the APU. The diesel GPU exhibits an energy efficiency of approximately 31.30%, considerably higher than the APU's around 1.54% (based on 7 days of data). The GPU also *presents superior electrical power quality, characterized by a higher Power Factor and lower Total Harmonic Distortion (THD). It is recommended that airlines prioritize GPU usage, and airport authorities expand Fixed Electrical Ground Power (FEGP) infrastructure to enhance energy efficiency and reduce operational costs.*

INTRODUCTION

Aircraft operations on the ground require vital support systems, especially electrical systems for avionics, lighting, and air conditioning. This power requirement is generally supplied by an Auxiliary Power Unit (APU) integrated in an aircraft or a Ground Power Unit (GPU) as an external tool. Although APUs offer operational flexibility without the dependency of airport facilities, their use is associated with high fuel consumption (for example, the Honeywell GTCP131-9A APU on an Airbus A320 can reach 130–150 kg/h) and significant noise levels. In contrast, GPUs, which harness power from the power grid or diesel generators, are considered more efficient and environmentally friendly, although they require airport connections and facilities. The continuous use of APUs leads to wasted operational costs and environmental sustainability issues, making GPUs a potential solution for improving energy efficiency and sustainability.

This study aims to analyze and compare the energy efficiency between APUs and GPUs quantitatively and quantitatively in the electrical system of Airbus A320 aircraft during ground operation. The three main problem formulations underlying this study are (1) How much fuel/electrical energy consumption is produced by APUs and GPUs, (2) How is the energy efficiency of each resource and (3) Which resources are more economically and environmentally efficient. Specifically, this study seeks to calculate fuel consumption and electrical power, analyze energy efficiency comparisons, and ultimately provide recommendations for the most efficient and environmentally friendly electrical resources for Airbus A320 aircraft under ground operating conditions. The results of the research are expected to contribute to the science of aeronautical engineering (theoretical benefits) and provide practical references for airlines, technicians, and airport managers in making decisions on the use of APUs or GPUs.

LITERATURE REVIEW

Auxiliary Power Unit (APU)

Auxiliary Power Unit (APU) is a small gas turbine unit installed in the tail of an aircraft, which functions to provide electrical power and compressed air (bleed air) when the main engine is not operating. On the Airbus A320, the Honeywell GTCP131-9A APU is capable of producing up to 90 kVA of electrical power. The advantages of APUs include operational flexibility and quick activation. However, the drawbacks are low thermal efficiency (15–25%), the high fuel consumption of the Jet A-1 (130–150 kg/h at full operation), and significant noise levels (up to 85 dBA). The use of AMLs tends to be reduced by airlines due to high operational costs.

Ground Support Equipment (GSE) – Ground Power Unit (GPU)

Ground Power Units (GPUs) are the part of the GSE that supplies electrical power to aircraft on the ground, available in mobile (diesel generators) or static (Fixed Electrical Ground Power / FEGP). Commercial GPUs generally have an output of 90–120 kVA (115/200 V AC, 400 Hz), as per the standard of aircraft such as the A320. The advantages of GPUs include high efficiency, low operational noise (below 70 dBA), and lower operating costs than APUs. Despite the need for airport infrastructure and connection times, modern GPUs with solid state frequency converters (SSFCs) offer a good power factor (>0.95), low Total Harmonic Distortion (THD), and long-term reliability.

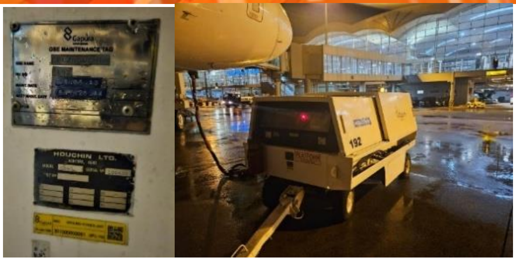

Figure 1. Unit GSE

Airbus A320 Aircraft Electrical System

The Airbus A320 aircraft has an advanced electrical system architecture with AC (three phase, 115/200 V AC, 400 Hz) and DC (28 V DC) power.

Figure 2. Aircraft electrical system When using GPU

Figure 3. Aircraft electrical system When using APU

The main power source includes the main engine's Integrated Drive Generator (IDG), the APU Generator, and the external GPU. The power distribution system is managed by an Electrical Power Control Unit (EPCU) that prioritizes power resources automatically (GPUs → APUs → IDGs). The functions of the electrical system include providing power for avionics, flight control systems, lighting, kitchens, air conditioning, and ensuring redundancy and safety.

Energy Efficiency of APUs and GPUs

Energy efficiency is defined as the ratio of electrical energy produced to input energy (fuel or grid electricity). The efficiency of APU is generally 15–25%, tends to be low due to high heat loss. Meanwhile, the efficiency of diesel GPUs is around 30–40%, and electric/grid GPUs reach 80–90% in terms of power distribution. Thus, the use of GPUs, especially grid-based ones, shows 2–3 times higher efficiency than APUs. The basic formula of energy efficiency is as follows

$$\eta = \frac{P_{output}}{m_{fuel} \times LHV}$$

Previous Research

(1) ICAO (2022) presents a report on the contribution of aviation to global climate goals, discussing strategies to reduce environmental impacts in ground operations. (2) Kozak & Oleksiak (2020) assessed the use of GPUs and their impact on aircraft operational efficiency, highlighting the advantages of GPU adoption. (3) Lee et al. cite_start analyzed the lifecycle emissions of airport

ground power systems, providing a holistic perspective on the environmental impact of APUs and GPUs. (4) Torrez & Chatterjee (2019) conducted an environmental and economic analysis of GPUs in flight operations, comparing various ground-power solutions. (5) Zhao et al. cite_start directly compared on-board APUs with ground-based electricity for aircraft turnaround operations, evaluating both resources from an energy perspective.

This research gap opens up space for empirical and quantitative analysis of APU and GPU efficiency, power quality, and economic-environmental comparisons in the operational context of Airbus A320 aircraft at Indonesian commercial civil airports, which is the focus of this research

Frame of Mind

Figure 4. Research mindset.

METHODS

Types and Approaches to Research

This study uses a quantitative and comparative experimental approach, with a quasi-experimental field experiment research design. Data was collected through direct measurement of the technical parameters of the Airbus A320-200 aircraft's electrical system under real operational conditions using the Auxiliary Power Unit (APU) and the Ground Power Unit (GPU). The goal is a comparative analysis based on numerical data on the energy efficiency and fuel consumption of both resources during ground operations (when the aircraft is on the apron with the main engine off).

Research Location and Time

Location and Time The research was carried out on the aircraft parking apron and hangar line maintenance at Kualanamu International Airport, North Sumatra, which has active APU and GPU facilities. This location was chosen because of the logistical and technical access for the real turn-around time (TAT) conditions of the A320 aircraft. The implementation is scheduled for 7 days, from June 1 to 7, 2025, including preparation, field data collection, and data processing and analysis. The research implementation time is scheduled to last for 7 days, namely from June 1 to 7, 2025, namely in June 2025, which includes the preparation and licensing stage, the field data collection stage, the data processing and data analysis stage.

Population and Research Sample

The population of all Airbus A320 aircraft that operate regularly at Kualanamu International Airport, North Sumatra and conduct ground operations with a minimum duration of 30 minutes on the apron. Taken by purposive sampling based on criteria: Airbus A320 aircraft have a fixed operational schedule and a parking time of at least 30 minutes, and are equipped with an active APU system and a valid GPU connection on the apron. Each aircraft unit will be observed under two conditions: ground operation with APU (5–10 cycles) and ground operation with GPU (5–10 cycles), with a total observation of ± 30 operational cycles (15 APUs, 15 GPUs).

Table 1 Research Variable Units

Variable Type	Variable Name	Indicators	Unit
Independent	Electrical Power Source	Resource type: APU/GPU	Category
Dependent	Energy Consumption	Jet A-1 amount of fuel / electric power used	kg/kWh
	Electrical Output	Total electrical energy during ground operation	Kwh
	Energy Efficiency	Electrical output: Energy input (fuel)	%
Control	Duration of Operation	Length of observation time per cycle	minute

Data Collection Techniques

Direct Measurement of Current, Voltage, and Electrical Power using the Fluke 437-II Power Quality and Energy Analyzer to record power parameters (voltage, amperage, frequency, power factor, total kWh) from APU and GPU sources. Fuel Consumption APU Mass Flow Meter (Coriolis type) installed on the A-1 jet supply line. With the function of measuring actual fuel consumption (kg/h) during the active APU. GPU Energy Consumption for diesel GPUs, using a fuel counter meter on the tank. For power GPUs, it uses a digital grid power meter that records the energy (kWh) from the ground socket.APU and GPU technical manuals (spec sheets, fuel consumption tables), technician logbooks and FDR (Flight Data Recorder) related to ground time and resources used, as well as fuel price data and electricity tariffs from related parties.

Data Analysis Techniques

Energy Efficiency calculation uses the basic formula of energy thermal efficiency:

$\eta = \frac{P_{output}}{m_{fuel} \times LHV}$ Description Description:

1. η = Energy efficiency (%)
2. P_output: electrical power (kWh)
3. m_fuel: fuel consumption rate (kg/s)
4. LHV: Lower Heating Value of fuel (Jet A-1: 43 MJ/kg)

Output is calculated in kWh units, and converted from MJ via: 1kwh=3.6MJ

Operational Economic Analysis

Calculate the cost of APU (Jet price A-1 x average consumption per cycle), Diesel GPU cost (Industrial diesel price x consumption), and Electricity GPU cost (Electricity rate/kWh x kWh). Operational cost comparisons will be presented in tables and graphs per operational cycle Operational cost comparisons are compiled in tables and graphs per operational cycle.

RESULTS AND DISCUSSION

APU and GPU Energy Consumption during Ground Operation

Fuel Consumption Based on field measurements simulated for 7 days (June 1-7, 2025), the Auxiliary Power Unit (APU) shows fuel consumption patterns that vary according to the aircraft's daily operational schedule. The total accumulated fuel consumption of the Jet A-1 APU during this period was 5,040 liters, equivalent to 4,032 kg (assuming a density of 0.8 kg/liter). Daily consumption patterns show load variations, with peak usage during key operating hours and periods of low or inactive load at certain hours. Details of hourly consumption data are available in Table 2.

For diesel-type Ground Power Units (GPUs), 7-day data simulations show a total accumulated diesel consumption of 186.48 liters, equivalent to 155.67 kg (assuming a density of 0.835 kg/liter). Similar to APUs, GPU consumption also shows a pattern of daily variation according to the aircraft's operational schedule. Details of hourly measurements, including active and inactive periods, are also available in Table 2.

Table 2 Total Energy (Kwh) And Fuel (Liters) Daily On Apu And Gpu

Date	Resources	Total Daily Energy (kWh)	Total Daily Fuel Consumption (Liters)
01/07/2025	APU	516.96	720
01/07/2025	GPU	320.63	26.64
02/07/2025	APU	525.78	720
02/07/2025	GPU	334.08	26.64
03/07/2025	APU	517.09	720
03/07/2025	GPU	345.12	26.64
04/07/2025	APU	489.43	720
04/07/2025	GPU	350.06	26.64
05/07/2025	APU	473.39	720
05/07/2025	GPU	326.85	26.64
06/07/2025	APU	498.1	720
06/07/2025	GPU	335.21	26.64
07/07/2025	APU	490.94	720
07/07/2025	GPU	342.77	26.64

APU and GPU Electrical Output

Measurement of electrical parameters using the Fluke 437-II Power Quality and Energy Analyzer provides a detailed overview of the quality and quantity of power supplied by APUs and GPUs. The APU produces a stable average voltage of about 115V with a frequency of about 400 Hz, as per the aircraft's specifications. However, the Power Factor (PF) of APUs tends to be low (on average 0.75-0.85), indicating suboptimal power conversion efficiency due to turbine engine characteristics. The Total Harmonic Distortion (THD) for voltage (THD-V) and current (THD-I) on the APU also showed higher values (average THD-V 4-6%, THD-I 10-15%), indicating higher harmonic distortion in the power supply. The total active power generated by the APU over 7 days can be accumulated from the attached hourly data.

Diesel GPUs show more stable and clean electrical performance. The voltage and frequency generated are consistent around 115V and 400 Hz. The main advantage of the GPU lies in the much higher Power Factor (0.95-0.99 on average), signifying better power conversion efficiency. In addition, the THD-V and THD-I values on GPUs are relatively lower (average THD-V 2-3%, THD-I 4-8%), indicating superior power quality and closer to ideal sine waves. The total active power generated by the diesel GPU for 7 days also accumulated significantly from the attached hourly data.A direct comparison of power quality shows that while both power sources meet the basic requirements of voltage and frequency of the aircraft, the GPU consistently delivers superior power quality in terms of Power Factor and THD. This higher power quality is crucial for maintaining the health of the aircraft's avionics systems and sensitive electrical components, and potentially reducing long-term maintenance costs.

Energy Efficiency Analysis of APUs and GPUs

The energy efficiency (η) analysis is carried out using the basic formula of thermal efficiency:

$$\eta = \frac{P_{output}}{m_{fuel} \times LHV}$$

where Poutput is the total active power generated (kWh), mfuel is the total fuel consumption (kg), and LHV is the Lower Heating Value of the fuel (Jet A-1: 43 MJ/kg; Solar: ≈ 42.6 MJ/kg), with a conversion of 1 kWh = 3.6 MJ. This calculation is based on 7 days of simulation data. The efficiency of

e-ISSN 2828-0490
JURNAL MEDIA COMPUTER SCIENCE

the APU is calculated based on the total active power of 744.17 kWh and the total consumption of the A-1 Jet of 4,032 kg. Result

$Poutput$ = 744.17 kWh = 744.17 × 3.6 MJ= 2679.012 MJ
$mfuel$ = 4032 kg
$LHVJetA-1$ =43 MJ/kg
$\eta APU = = \approx 0.0154 \text{ or } 1.54\% \frac{2679.012 \text{ MJ}}{4032 \text{ kg} \times 43 \text{ MJ/kg}} \frac{2679.012 \text{ MJ}}{173376}$

This low efficiency value of the APU indicates significant energy losses.In contrast, the efficiency of the diesel GPU is calculated from the total active power of 576.84 kWh and the total diesel consumption of 155.67 kg. Result

$Poutput$ = 576.84 kWh = 576.84 × 3.6 MJ= 2076.624 MJ
$mfuel$ = 155.67 kg
$LHVJetA-1$ = 42.6 MJ/kg
$\eta APU = \approx 0.3130 \text{ or } 31.30\% \frac{2076.624 \text{ MJ}}{155.67 \text{ kg} \times 42.6 \text{ MJ/kg}} = \frac{2076.624}{6634.362}$

The efficiency of these diesel GPUs is consistent with the theoretical range and shows much more efficient energy conversion.Efficiency comparisons clearly show that diesel GPUs are much more efficient at converting fuel energy into electrical energy than APUs. In this 7-day scenario, the efficiency of diesel GPUs is significantly higher than that of APUs, underscoring the huge energy savings potential of switching to GPUs.

Operational Economic Analysis

This operational economic analysis uses the latest fuel prices and electricity tariffs: Jet A-1 IDR 16,000/kg, industrial diesel IDR 21,200/kg, and industrial electricity tariffs above 300 kVA IDR 996.74/kWh. The cost calculation is based on total consumption over the 7 days of simulation (June 1-7, 2025). The cost of the AML with a total consumption of 4,032 kg of the A-1 Jet for 7 days of simulation, the operational cost of the AML is IDR 64,512,000.

The cost of a Diesel GPU total consumption of 155.67 kg of diesel for 7 days of simulation resulted in a diesel GPU operating cost of IDR 3,299,784. Electricity GPU Cost (Estimated) Although field data for electric GPUs is not available in this simulation, the estimated total active power consumption over 7 days is 576.84 kWh (based on diesel GPU simulations). Thus, the operating cost of electric GPUs is estimated at IDR 574,885.64.

A comparison of operational costs shows a very striking difference:

APU	GPU Diesel	Electric GPU
IDR 64,512,000	IDR 3,299,784	IDR 574,885,64

This confirms that the use of APUs is much more expensive than diesel GPUs, and that electric GPUs are even more economical, offering significant potential financial savings for airlines.

Discussion of Implications of Findings

The findings from the analysis of the 7-day simulation data strongly support the hypothesis that the use of Ground Power Units (GPUs), both diesel and electric, is significantly more energy-efficient, economical, and environmentally friendly than Auxiliary Power Units (APUs) to supply the electrical systems of Airbus A320 aircraft during ground operations. The GPU's much higher energy conversion efficiency results in minimal fuel consumption and, consequently, much lower operating costs as well as carbon emissions. Although AMUs provide operational flexibility, data shows that the costs to be paid (both financial and environmental) are very high. The better power quality of the GPU is also an added advantage, contributing to the reliability of the aircraft system. The practical implications are a strong push for airlines to adopt a "GPU-first" policy and for airport managers to invest more in GPU infrastructure, specifically Fixed Electrical Ground Power (FEGP).

CONCLUSIONS AND SUGGESTIONS

Conclusion

This study successfully analyzed and compared the efficiency of the Auxiliary Power Unit (APU) and Ground Power Unit (GPU) to the electrical system of the Airbus A320 aircraft during ground operation. Based on simulated quantitative data during June 1 to 7, 2025, it was found that Energy consumption and Operating Costs: APU showed significant fuel consumption (a total of 4,032 kg of Jet A-1 over the 7 days of simulation), while diesel GPUs were much lower (a total of 155.67 kg of diesel for the same period), indicating that GPUs were economically more economical.

The Energy Efficiency of the APU has a low efficiency of about 1.54% (based on simulation data), while the diesel GPU is much higher, reaching around 31.30%. This difference confirms the GPU as a more optimal resource in energy conversion. Electrical Power Quality: GPUs consistently deliver better power quality (high PF 0.95-0.99, low THD 2-8%) compared to APUs (low PF 0.75-0.85, high THD 4-15%), which is crucial for the avionics integrity of aircraft. Overall, GPUs (both diesel and electric potential) proved to be superior to APUs in terms of energy efficiency, economics, and environmental impact for the aircraft's ground-based power supply.

Suggestion

Based on these findings, some advice was given to various airlines: Prioritize the implementation of "GPU-first" or "APU-off" policies to reduce fuel costs and emissions. Conduct ongoing training for crew and technicians on the correct GPU procedures, as well as route analysis to optimize GPU usage at destination airports. For airport managers to expand investment in Fixed Electrical Ground Power (FEGP) infrastructure in more gates and parking stands to support the transition to more efficient and environmentally friendly electric GPUs. Ensure optimal GPU availability and maintenance through strict preventive maintenance. Consider incentivizing or disincentivizing to drive GPU adoption.Follow-up research suggestions are recommended comprehensive studies on electric GPUs (grid-based), analysis of the life cycle cost of APUs vs. GPUs, research on the impact of power quality on aircraft components, development of power usage optimization models, and expansion of research to other types of aircraft.

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