



D3.2: Ramp operations 100% electrical

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List of Abbreviations

AF	Air France
ADP	Groupe ADP
CDG	Paris-Charles de Gaulle airport
GPU	Ground Power Unit
GSE	Ground Support Equipment
PAX	Passenger



1 Executive summary

This project addresses the decarbonisation of Ground Support Equipment (GSE) operations at Paris-Charles de Gaulle airport through the electrification of existing diesel-powered units.

Rather than relying solely on fleet renewal, the project demonstrates the feasibility, relevance and scalability of retrofitting existing equipment. This approach contributes to reduce direct CO₂ emissions, limits lifecycle emissions linked to manufacturing and supports circular economy principles.

This project specifically aimed to improve the sustainability of Air France (AF) Ground Support Equipment (GSE) at Paris-Charles de Gaulle airport (Paris-CDG) by converting them from carbon-based energy to electric power.

The main objectives were to reduce both direct CO₂ emissions from operations and indirect emissions related to equipment manufacturing and maintenance operations. The project illustrates how existing airport equipment can be modernised through retrofit solutions, contributing to a low-carbon airport ecosystem.

2 Project Analysis

The task was structured into three main phases: analysis, design, and retrofit deployment on the Air France GSE fleet, following the planning below:



Figure 1: Task planning

✓ Assessment of the GSE fleet and electrification potential

A preliminary assessment showed that part of the GSE fleet was already electrified, such as baggage tractors and forklifts. Other equipment with high energy demand—such as Ground Power Units (GPU) and Aircraft Air Conditioning Units - can be progressively replaced either by fixed airport infrastructure or by electric alternatives, depending on power availability at aircraft stands.



However, certain categories of equipment were identified as unsuitable for retrofit.

Aircraft tractors:

- Require very high-power levels to tow long-range aircraft (e.g. the B777-300 or A350 over distances exceeding). 10km per trip several times a day.
- The design, especially for towbar less systems, makes electrification through retrofit technically complex.
- Certification constraints are also significant, as the engine is an integral part of the control system and aircraft compatibility. On these vehicles, the engine is not just a power source, but also a key element of the system. It adapts power and tractor response to the aircraft type according to the specifications of each manufacturer.

The analysis concluded that retrofitting such equipment would be extremely challenging, both technically and from a certification perspective. From a technical perspective, integrating batteries capable of delivering the required power would be difficult. From a certification standpoint, the propulsion system is a critical component that directly influences vehicle behaviour and must comply with aircraft manufacturer specifications.

Consequently, retrofitting would require a complete redesign of the vehicle, which could only be achieved with manufacturer involvement. Economically, this approach would not be competitive compared to acquiring new electric tractors.

A similar conclusion was reached for scissor cargo loaders for which retrofitting would not provide a cost-effective solution compared to replacement by anew equipment.

✓ **Selection of suitable equipment for retrofitting**

During the analysis phase, passenger boarding stairs were identified as the most suitable candidates for electrification, considering both technical feasibility and operational relevance.

These units are currently powered by diesel engines, with an average fleet age of approximately 20 years, corresponding to the typical lifecycle of their powertrain. Three options were therefore considered: full replacement, diesel engine renewal, or electrical retrofit.

Since the mechanical structure and other components of the GSE remain in good condition, electrification emerged as the most relevant option.

Additionally, Operational usage of passenger boarding stairs—which involves short movements and extended periods of idling—further supports this choice. Electric systems are particularly efficient in such conditions as these vehicles only consume energy when in motion, maximizing energy efficiency.



From a design perspective, the architecture of the vehicle with on one side traction for displacement and hydraulic for the different functions can be easily split in one electrical motor for motion and one electrical pump for hydraulics.

In addition, the power requirements are compliant with standard battery technologies already used in other electric GSE applications.

In conclusion, the electrical retrofit option was selected as the most environmentally and economically relevant.



Figure 2: Passenger stairs for remote aircraft parking stand

3 Technical Aspects and Design

Following the selection of passenger boarding stairs as the most suitable equipment for retrofit, the project focused in 2022 on defining the retrofit solution in collaboration with industrial partners

An in-depth review of operational needs and technical constraints was performed, leading to:

- Definition of technical specifications
- Selection of key components
- the establishment of an appropriate architecture to build up the modification.

✓ Initial configuration



Figure 3: Engine before the retrofit

This process involved precise measurements, detailed definition of component integration, a comprehensive review of applicable regulations. Particular attention was paid to achieving an optimal balance between performance, eco-design principles, and cost-efficiency.

As a result, the final design successfully integrates all technical, regulatory and environmental requirements.

✓ **Electrical architecture design**

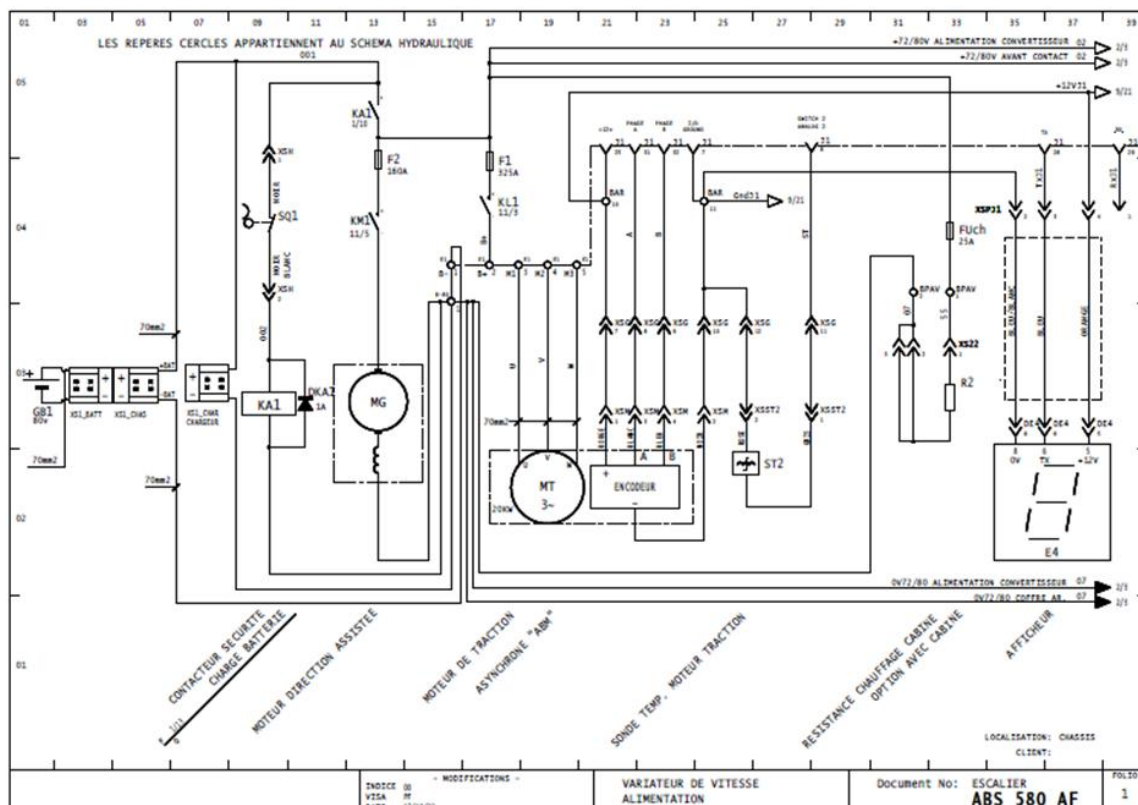
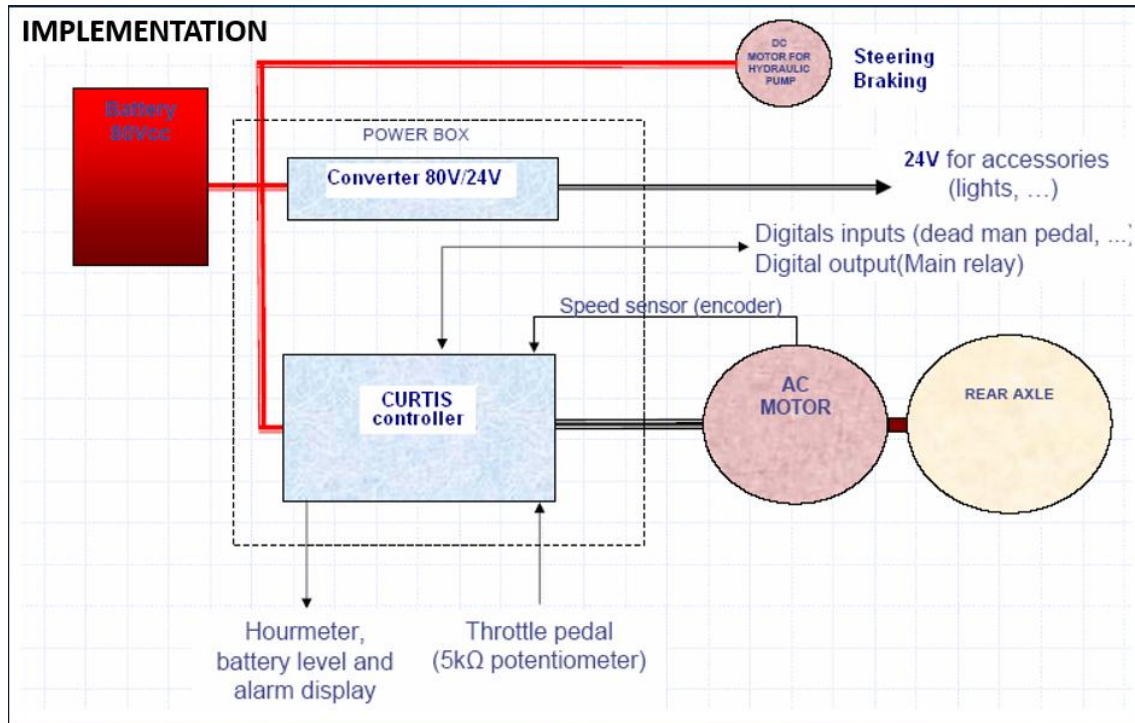


Figure 4: Electric scheme conception:



Particular attention was given to ensuring that modifications remain easy to implement and compatible with maintenance practices. The selected components were chosen based on availability, reliability, and compatibility with existing maintenance practices, allowing mechanics to operate and service the equipment without significant additional complexity.

This analysis has also included the identification and selection of appropriate suppliers for all major components.

Technically all the old components linked to diesel engine were removed. These were replaced by a new electric engine and associated battery to power the vehicle and ensure both traction and energy for onboard functions.

Mechanical integration

Example of part conception with a new engine mount to fit the electrical engine in place of diesel engine.

Here under engine mount 3D conception:

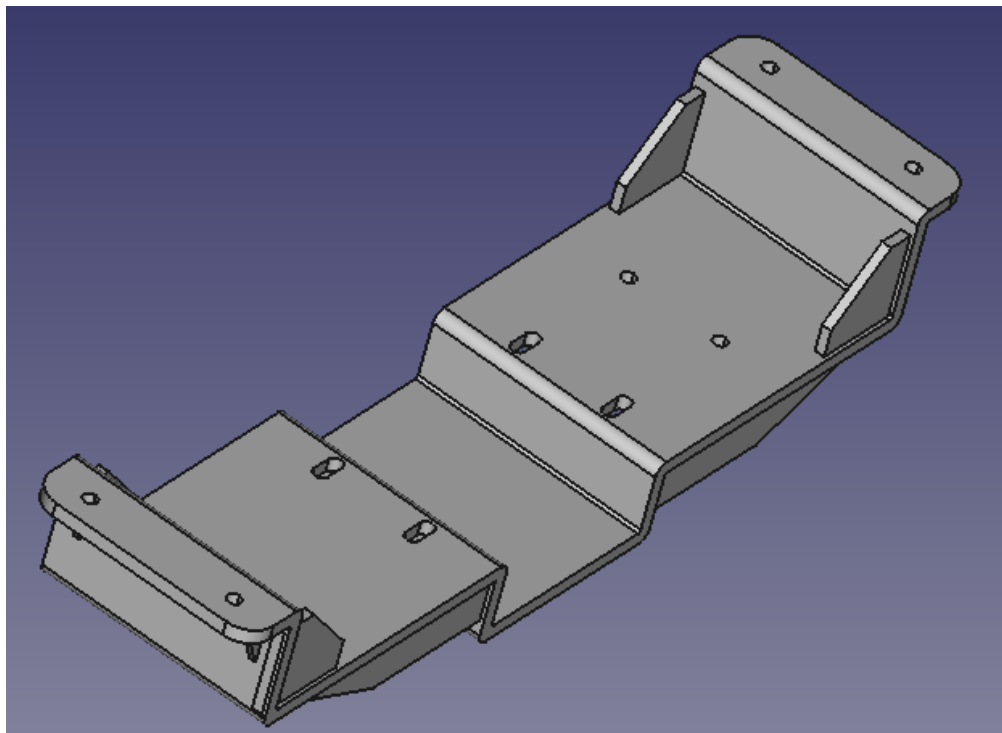


Figure 5: Engine mount 3D conception

The integration of the electric motor required the design of new mechanical interfaces, including adapted engine mounts to ensure compatibility with the existing structure.



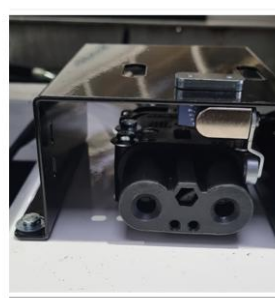
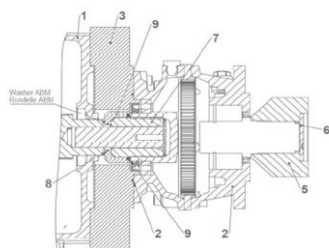
Additional modifications were implemented to accommodate electrical components, wiring, and control systems, while maintaining the overall integrity and functionality of the equipment.

✓ **Final configuration**

Other modifications:

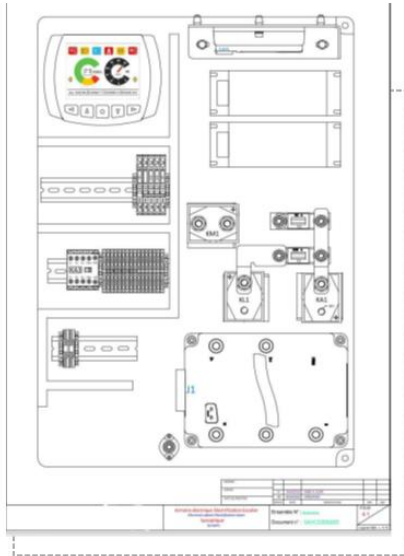
IMPLEMENTATION

- Dashboard
- Dead man's pedal
- Gearbox and driveshaft
- Charge inlet





ELECTRICAL CABINET



RESULT

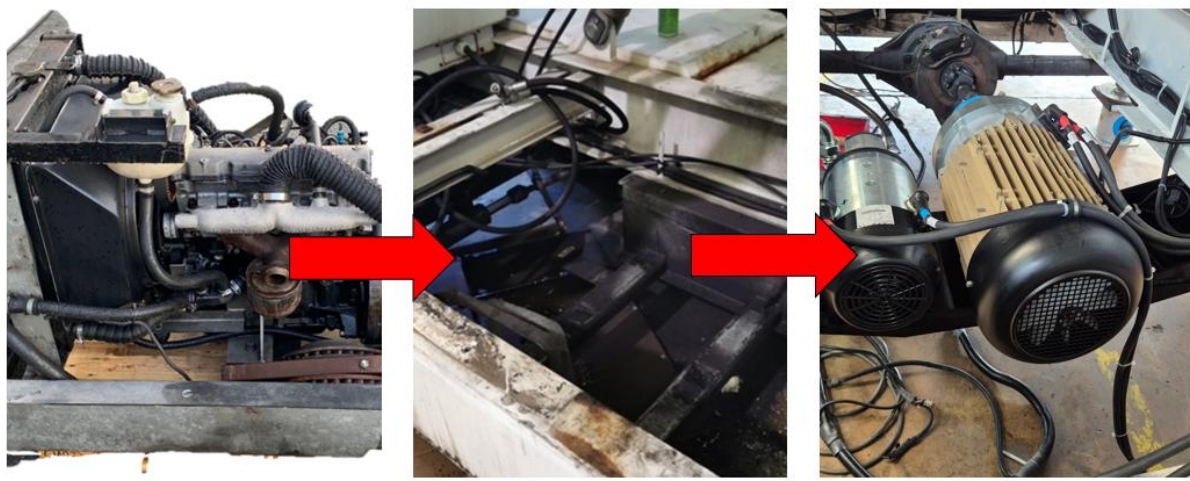


Figure 6 : Implementation – Electrical cabinet - Result

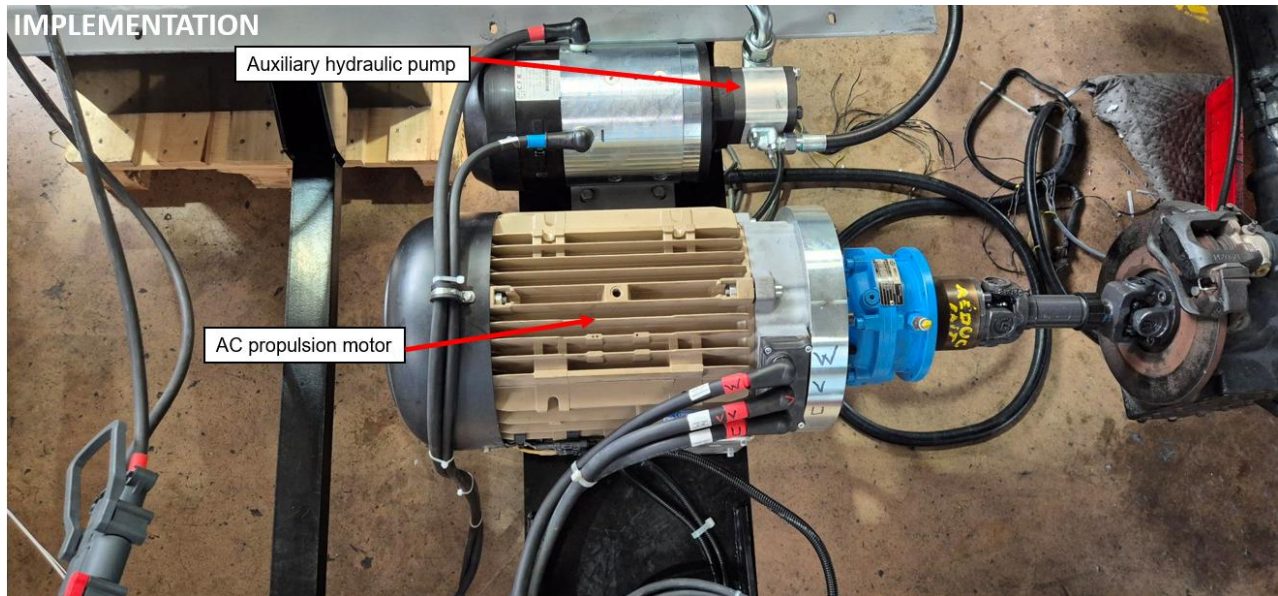


Figure 7 Engine after the retrofit

✓ Environmental and circular design approach

The retrofit solution was developed with a strong focus on environmental performance and circular economy principles.

Key considerations included:

- Minimizing environmental footprint by reuse of existing structural and mechanical components.
- Redesigning with electric power to replace the diesel engine to eliminate direct emissions.
- Extending the operational lifespan of the equipment, including both technical upgrades and aesthetic refurbishment.
- Integrating circular practices through the reuse and recycling of components where possible. These were checked and refurbished to ensure efficiency before reuse.

4 Battery recycling

For the energy storage system, Air France selected lead technology.

This type of batteries has the advantage to fulfil the condition needed to power equipment as passenger stairs with sufficient autonomy.

It is a well-known technology widely used across industrial applications, which facilitates implementation, operation, and maintenance.



Compared to lithium-based alternatives, that are more complex, lead battery recycling industry is mature and well-structured in Europe enabling safe end-of-life treatment with a high rate of material valorisation recycled in new batteries.

As for overall retrofit strategy, the objective was to maximise efficiency while minimising environmental impact. AF already operates other GSE equipped with lead-acid batteries, which are typically sent for recycling after their service life (generally ranging from 7 to 10 years).

However, batteries are composed of several singles elements. At the end of its operational life, some cells may become inoperative (e.g. due to reduced capacity or short circuit) while others remain fully functional and can be reused. Similarly, structural elements such as battery casings can be often reconducted for a second life.

Based on this observation, a second-life approach has been used for batteries supply. This consists of selecting functional elements from reformed AF batteries. Second-life batteries recovered from other scrapped AF GSE are therefore checked, tested, refurbished and rebuilt into new packs suitable for use in passenger stairs.

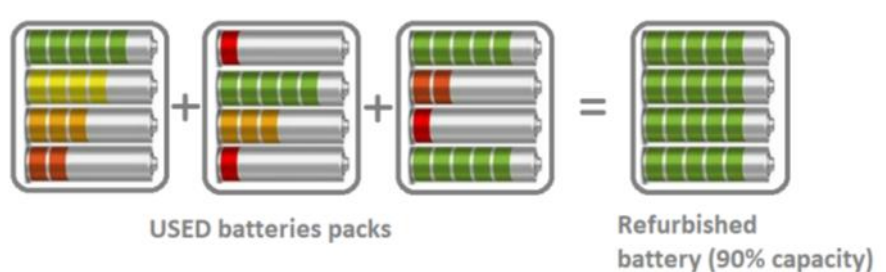


Figure 8 Example of battery elements selection:

This approach contributes to a circular economy model by extending the useful life of battery components, reducing waste generation, and limiting the environmental impact associated with battery manufacturing and disposal.

5 Deviation and corrective actions

No major deviations from the original plan are to be reported as the project successfully achieved its main objectives.



However, during the implementation period, AF encountered two primary challenges that led to slight delays compared to the original expected cadence for the retrofit.

The first challenge was related to temporary shortages in component availability following the COVID-19 period. During this time, some components became difficult to source or were subject to significantly extended delivery times, impacting the overall retrofit timeline.

The second challenge is linked to the availability of sufficient electrical power on the airport ramp to charge the batteries. Since the infrastructure at Paris-CDG airport terminals was not originally designed to accommodate for a large number of electric GSE, the deployment of retrofitted units required additional coordination with ADP to adapt the existing electrical network. This included the development and implementation of an action plan to ensure adequate power supply across operational areas, particularly at aircraft parking stands where passenger boarding stairs are deployed.

To address these challenges, AF worked closely with both components suppliers and ADP to identify and implement appropriate solutions.

As a result, while the overall project timeline experienced minor delays, the necessary corrective actions ensured the successful continuation and completion of the retrofit programme.

6 Main results

6.1 Environmental impact

The retrofit programme significantly contributes to reducing the environmental footprint of Ground Support Equipment operations.

By extending the operational lifespan of the equipment by an estimated 10 to 15 years, the need for replacement is avoided. According to the original manufacturer TLD, the production of a new unit generates approximately 14 tonnes of CO₂ emissions. For a fleet of 60 units, this represents a total of around 840 tonnes of CO₂ emissions avoided.

In addition, each retrofitted unit enables savings of approximately 200 litres of diesel per year. Across the fleet, this corresponds to an annual reduction of approximately 31 tonnes of direct CO₂ emissions. The transition to electric power also contributes to the reduction of other pollutants associated with combustion engines, such as combustion particulates. Furthermore, it reduces the waste related to maintenance operation such as oil changes and filter replacements thereby reducing environmental impact throughout the operational lifecycle.



6.2 Other considerations

Beyond environmental benefits, the retrofit programme also improves operational and working conditions.

Electrified units are more user-friendly experience including significant direct noise reduction, elimination of engine vibrations for the driver and the absence of exhaust fumes and odours induced by thermal combustion. These improvements contribute directly to better working conditions for ground handling personnel.

From an energy perspective, electric systems enable more efficient power usage, as energy consumption is aligned with actual operational needs. Unlike thermal engines, which may consume fuel during idle phases, electric systems avoid unnecessary energy losses, resulting in improved overall efficiency.

7 Key Figures

The current fleet has an average age of approximately 21 years. Through the retrofit programme, the operational lifespan of the equipment is extended by an additional estimated 10 to 15 years.

Each retrofitted unit saves around 200 litres of diesel per year. For a fleet of 60 passenger boarding stairs, this represents an annual reduction of approximately 31 tons of direct CO₂ emissions.

The retrofit process requires around 150 mechanic man-hours per unit, reflecting the level of technical intervention needed to convert existing diesel-powered equipment into fully electric units.

8 Industrialization

As part of this project, an initial first prototype was developed and retrofitted by Air France maintenance teams during the early design phase. This first implementation made it possible to validate the proof of concept, assess the operational performance of the retrofitted unit, and confirm the technical choices regarding technology, component selection and battery capacity.

Based on the results from this prototype, several minor adjustments were introduced, particularly regarding the integration of components. Improvements contributed to simplifying the retrofit process, enhancing system efficiency, and reducing the overall time required for each conversion.

All retrofit work is carried out internally by AF mechanics at the GSE maintenance facility located at Paris-CDG airport. The process begins with the partial disassembly of the original unit, including the removal of the original diesel engine and associated components that are no longer required. At this



stage, the chassis is thoroughly inspected to ensure structural integrity and any necessary repairs are performed. Reusable components are also carefully checked and validated prior to reinstallation.

The unit then undergoes the required mechanical and electrical modifications to integrate the new electric components and battery. Following the retrofit, each converted unit is thoroughly tested to verify performance, safety, and compliance with operational requirements before being released into service.

9 Conclusion and outlook

This project has demonstrated the technical feasibility and environmental relevance of retrofitting GSE with electric powertrains. The results confirm that such an approach is both effective in reducing emissions and viable from an operational perspective.

The retrofitted units are now fully operational and deployed at Paris-CDG airport. To date, 34 units are in service while the remaining units are scheduled for retrofitting to achieve a fully electrified fleet of passenger boarding stairs.

The analysis conducted during the project also highlights the potential for replicating this approach across other types of equipment with similar design characteristics. As a result, AF has already initiated similar retrofit projects, notably for belt loaders.

More broadly, the solutions developed within this project can be transferred to other airport environments, regardless of the original equipment manufacturer or engine configuration. This demonstrates the scalability and adaptability of the retrofit concept in supporting the transition towards low-carbon airport operations.