UITP ADVANCING PUBLIC TRANSPORT

ASSURED

PROJECT BRIEF

ASSURED

A REAL DRIVER FOR THE ELECTRIFICATION OF URBAN BUS FLEETS

DECEMBER | 2022

INTRODUCTION

In order for cities to meet their transport emissions reduction targets, many around the world are deploying electric buses, with mass production reducing both unit costs and the associated technological risks. Today, electric vehicles offer reliable technology, a stable operating environment, a practical daily range and ready access to a variety of proven charging systems, either at the depots or on the street.

Against this background, the ASSURED project has been fundamental in advancing the electrification of urban commercial fleets and their integration with high-power, fast-charging infrastructure. To achieve this, the project has developed and tested high-power solutions for full-size, urban, heavy-duty applications, with the goal for each being to be able to successfully charge various types of vehicles. This would enable operators to 'mix-and-match' the different brands of vehicles and chargers they deploy.

Under the coordination of VUB - and strongly supported by UITP as the demonstration activities leader - the ASSURED project gathered the most relevant players along the entire value chain of electric mobility. The objective was to collectively address the standardisation and interoperability challenges posed, and to develop solutions that enable the full electrification or urban commercial fleets. ASSURED provides an outstanding example of how cooperation can make a difference and can provide productive results capable of advancing the sector.

DURATION

October 2017 – March 2022 (54 months)

BUDGET

€ 18.65 million EU funded
(total budget € 23.64 million)

OVERVIEW OF THE SOLUTIONS DEVELOPED AND TESTED BY ASSURED

With a strong focus on electric buses, the project has developed and delivered key innovations allowing fleet operations to be optimised. These include the interoperability and standardisation of e-bus charging through high-power fast charging solutions and introducing intelligent tools for smart charging and energy storage systems.

To do this, electric buses, trucks, and vans were tested for a range of charging solutions, including different types of pantographs, plug-in approaches and wireless charging. Another element that ASSURED investigated was the stability of the energy supply, essential for future use when an increased number of vehicles will rely on the charging infrastructure.

Figure 1. The ASSURED solutions

To build upon the ASSURED legacy, a set of recommendations have been created for bus operators, authorities and municipalities on how to face the challenges of upscaling electric bus fleets. These can be found in the 'Guidelines on fleet upscale with electric buses' [1].

ASSURED INTEROPERABILITY REFERENCE

The standardisation and interoperability of e-bus charging are essential for achieving the full electrification of fleets and for enabling large fleet upscaling. In addition to standardisation, conformance and interoperability testing are needed to ensure full interoperability, particularly for multi-brand fleets.

The ASSURED journey towards full interoperability began in 2017, when the project took over the work achieved by the ZeEUS project. The focus was testing and demonstrating the interoperability of the fast-charging solutions for the heavy-duty vehicle segment. Since the official standards had not yet been finalised or lacked definitions for some of the parts required for successful interoperability, ASSURED agreed to draft a reference document to cover the existing gaps and thus be able to test interoperability as defined in the project. The

Figure 2. Development of European electric bus standardisation

first version of this document, titled 'ASSURED 1.0 Interoperability Reference', was published in June 2019. A further update, including the learnings gathered during the ASSURED demos was released in December 2021 as ASSURED 1.1 Interoperability Reference[2]'.

To continue with this work, the ASSURED partners have agreed to further develop and update the current open points in version 1.1. They plan to follow this up with recommendations for future research. A dedicated working group, led by UITP, is envisaged for continuing this task.

WHAT IS INTEROPERABILITY AND WHY DOES IT MATTER?

In ASSURED, charging interoperability refers to the ability of electric vehicles to work with different charging infrastructure seamlessly, irrespective of brand and without any limitations or technical restrictions. However, full interoperability is achieved not only through robust standardisation; it also requires conformance and interoperability testing to ensure that the standards are properly understood and correctly followed by vehicle and charger suppliers.

The standardisation of electric bus charging solutions covers numerous aspects, such as the mechanical implementation, parking tolerances, electrical interfaces, electrical and functional safety and communication requirements. Agreed standards stimulate innovation, boost confidence and create suitable market conditions for further technological advances while reducing deployment barriers and encouraging competition.

A standards-based and interoperable charging system that includes both technical capabilities and contractual rights provides an invaluable basis for wider market penetration and enables the flexibility and optimisation of bus operations, as well as higher rest value of the equipment. Furthermore, by not binding the product choice to a single solution or supplier, this approach contributes to reducing the cost of charging infrastructure by ensuring functionality, compatibility and interoperability.

Interoperability testing at controlled conditions at IDIADA

INTEROPERABILITY TESTING IN ASSURED

One of the key goals of ASSURED was to ensure the interoperability of the charging infrastructure by performing conformance and interoperability testing for partners' vehicles and chargers.

The ASSURED 1.0 Interoperability Reference was used to test vehicles and chargers with infrastructure-mounted and roof-mounted pantograph technologies. This was first undertaken in a controlled laboratory environment at IDIADA facilities, and subsequently at demo cities in Barcelona and Osnabruck. The results demonstrated that full interoperability had been achieved in the project.

> *The ASSURED demos in Barcelona, Jaworzno and Osnabrück, as well as external data from Trondheim, showed that the super-fast charging infrastructure for opportunity charging completely mitigated the stress on service added by electric fleets.*

This means that no additional vehicles - compared to diesel operations - were required for a given line and that the propulsion type had low or no impact on service scheduling, achieving the same passenger capacity.

INNOVATIVE ENERGY STORAGE SYSTEMS AND CHARGING MANAGEMENT STRATEGIES

As electric fleets progressively grow, so does the demand for electric power. Here, defining a suitable energy management strategy is a key element for ensuring a sustainable future for e-fleet upscaling. With so-called 'smart charging' (V1G) it is possible to control the time and magnitude of charging power from the electricity grid to the vehicles.

Uncoordinated charging is where e-buses connect to be charged with the maximum allowed power by the connector until fully charged (100% state of charge) without taking account of the number of e-buses simultaneously connected to the chargers and their impact on the grid infrastructure. In the event that a large number of e-buses connect for charging simultaneously, there would be a significant impact on the grid in terms of the voltages on the bus bars, distribution system operator transformer load profile and line rating. In addition, uncoordinated charging has an impact on the operational cost of the e-buses, as the energy price in peak hours is higher than that during off-peak hours, according to the DSO grid load profile.

Indeed, the aim of smart charging is to resolve the above scenario by using smart software rather than costly investments in infrastructure expansions. Furthermore, smart charging has numerous applications, such as flattening the load profile (peak shaving), congestion management or allowing charging from renewable energy sources such as photovoltaic solar or wind.

Of course, the added value of smart charging increases with the number of electric buses in the fleet - as does energy demand, particularly in terms of energy cost and grid impact reduction. Under these circumstances, smart charging allows a controlled transfer of energy to the buses, adjusting the power or timings to minimise the burden on the grid. By bundling sufficient electric buses, a substantial controllable power asset will arise that will make the grid more stable/reliable and deliver economies for PTOs, energy companies and countries.

The IDIADA eBus Charging Lab

This practice offers both direct and indirect benefits to the distribution system operator in reducing costs, line and transformer loss reduction and voltage support. From the electric vehicle owners' perspective, it could increase revenue by – among others - providing ancillary services to the grid, optimising consumption and minimising electricity bills.

Overall, smart charging is a crucial tool for enabling the more efficient use of the grid and a higher penetration of renewable energy sources. The next step in this area will be the implementation of V2G systems that allow the energy in the batteries of the vehicles to be fed back to the grid.

Energy storage systems can be also used to provide extra required capacity (kW) to the charging infrastructure. Therefore, in-depot batteries can avoid any sudden rise of peak load demand of the customer's installation and thus the requirement for a larger network connection capacity/ contracted power (at a higher cost).

SMART TOOLS FLEET-LEVEL OPTIMISATION

Today, the operation of electric bus systems cannot be separated from the use of smart tools at all levels. It covers the intelligent planning of the electric bus system to the supervision of vehicles' on-route performance and the charging activity, both at the opportunity charging locations and at the depots.

Data is gathered via a vast array of sensors, capturing relevant data including passenger load, internal and external temperature, remaining range, state of charge of the batteries and the power recuperated. The intelligent exploitation of this data leads to a continuous improvement in operations. Indeed, the smart use of telemetry becomes increasingly vital as electric bus fleets grow.

For the charging infrastructure, it is also possible to monitor and manage it to ensure it delivers a high-quality service while reducing operational costs, minimising the impact on the power grid and improving the battery state of health.

Current technology allows energy to be recuperated through the braking system, which helps increase the range of electric vehicles. Of course, this is heavily dependent on enhancing drivers' eco-driving capabilities. The recuperated/consumed energy ratio ranged between 15 -40% (demo site Jaworzno).

VUB has developed a simulation tool to plan for the electric fleet upscaling. Using this, end users can gain a better understanding of the role played by key features such as battery size, required charging time or the optimal charging power according to their specific boundary constraints. Beyond single-bus or single-line operations, the new simulation platform also makes it simple to design vehicle fleets for multiple routes in any given city. The route can be designed with the actual operational and charging scenarios, including seasonal, elevation, velocity, passenger and charging profile parameters to evaluate the impact on the daily grid and the TCO. Furthermore, buses using batteries based on different chemistries can be easily selected.

ASSURED also investigated a strategy for the smart use of energy. Deploying the three eco-features stated below contributed to the goal of reducing the energy consumption of the system. In turn, energy savings reduce TCO and the impact on the grid.

The three features are eco-driving, eco-comfort and eco-charging. In eco-driving, the reduction in traction energy is assessed for an eco-friendly profile using optimal energy recovery techniques. In eco-comfort, the reduction in auxiliary energy consumption is balanced against the discomfort level in the bus cabin. In eco-charging, heat generation from high C-rate charging is minimised. The impact of various factors on the efficiency of the eco-features, including the climate / season and average driving speed, was also analysed.

The eco-features strategy considers battery aging and the impact of superfast charging systems on the grid. It extends the range of electric vehicles by using state-of-the-art energy reduction techniques. Combined, the eco-drive and eco-comfort features were effective in reducing the vehicle's energy usage by a minimum of 25 up to 45%. In addition, eco-charging was able to reduce the average load on the grid by more than 10% when incorporated into a fleet-wide charging strategy. In the simulation framework, the eco-features can be activated through the simple setting of the appropriate flags, making it easy for the bus operator to evaluate the reduction in energy demand for a given use-case scenario in cities. Using the eco-features, it is possible for a user to forecast the decrease in the TCO through the savings generated from lower electricity consumption costs, smaller battery sizes and the reduction in the required charging infrastructure.

TESTING PROJECT SOLUTIONS ACROSS EUROPE

To enable the interoperability and standardisation of electric vehicles and chargers, ASSURED has developed and tested solutions for public transport electric buses, trucks and delivery vans.

Up to seven use cases described the baseline vehicles adapted and modified in order to comply with the technical requirements of the ASSURED solutions and to fulfil the needs of the end users at the demonstration cities. Before entering the demo operation, the vehicles were verified at control sites and test tracks to ensure the adaptations would fulfil the operational requirements.

After being tested under controlled conditions, the above-mentioned ASSURED solutions were demonstrated in five European cities: Gothenburg (Sweden), Barcelona (Spain), Osnabrück (Germany), Eindhoven (the Netherlands) and Jaworzno (Poland). In each, the vehicles and chargers were integrated into the public transport network and tested in real operations. The table below provides the key outcomes of each of the city demos.

Table 1. Overview of ASSURED city demos

CITY	DESCRIPTION	KEY OUTCOMES & LESSONS LEARNED
GOTHENBURG Testing interoperability of e-bus, e-truck and e-car charging	Between 2018 and 2020, Volvo displayed different vehicles (bus, truck and van) using the same infrastructure and charging technology by partner ABB, aiming to enhance the TCO.	• In Gothenburg the two articulated buses operated for approximately two years on Line 16, with 60,000 km per bus per year (average in Gothenburg city traffic). • Multi-brand usage enables lower TCO, scale of economy, lower development cost, plus the future use of components will be lower. • Charging on route requires pantograph charging, which type depends much on the city and regional preference.
OSNABRÜCK Testing interoperability of buses and chargers	In Spring 2021, this demo tested interoperability in real operation with four electric bus types and two different infrastructure-mounted pantograph chargers from ABB and Heliox.	• Daily operations of the buses during 60 days and more than 4,000 electric km driven. • Focus should be on interoperability and interpretation of the norms by the different bus OEMs and charger suppliers. • Satisfied customers that got familiar with new buses and technologies.
EINDHOVEN From E-Mobility to I-Mobility: Testing smart tools for fleet level optimisation and innovative storage system and charging management strategies	Between 2016 and 2022, demo leader VDL Bus & Coach introduced more than 60 vehicles to the existing fleet of 43 articulated electric buses. The aim was to demonstrate that future operation of e-buses and charging can be scaled up in a smart and cost-effective way.	• The 43 articulated electric VDL Citea buses (2016) have covered about 400,000 km each. • The running fleet of electric buses will be expanded with 60 to 65 electric 12m buses, replacing existing 12m Euro 5 EEV diesel buses (2008). • Chargers are becoming more intelligent and are able to be fully integrated into the digital infrastructure of fleet management and energy management.
BARCELONA Showcasing interoperability bus-charger with roof-mounted pantograph tech	Led by TMB, the goal was to showcase interoperability of buses and chargers with roof mounted pantograph technology. With this purpose, two buses and three chargers (ABB, Heliox, Jema) were tested in real operation and fully integrated into the fleet.	• The demo proved validity of the ASSURED 1.0 Interoperability Reference, which enabled full interoperability between buses and chargers independently of brand in real operating conditions. • Benefits of interoperable charging for TMB are manifold: 1) Possible to choose best option without vendor lock-ins 2) Possibility to share the opportunity chargers on route with other vehicles 3) Simplified maintenance. • In future tenders TMB will include the requirement of a certification by a third party that validates compliance with the ASSURED 1.1 Interoperability Reference.
JAWORZNO Displaying smart charging management and improved efficiency	Bus operator PKM tested 23 electric buses of three different sizes (8.9m, 12m, and 18m) in terms of optimised charging strategies. The goal of the demo was to optimise the vehicle operation process, including the power consumption, and provide an improved version of the baseline vehicle.	• Optimised charging strategies: less daily charging, resulting in increased life of traction batteries. Replacements were less frequent and the e-bus charging grid was redesigned to increase the amount of charging at night, resulting in a reduction of electricity consumption costs. • Overall, the demo resulted in operational cost reduction compared to the baseline vehicle. • The conducted research allowed PKM to increase the efficiency of e-bus transport by increasing the reliability, reducing the number of recharging and scheduling charging at night-time.

All the key takeaways of the use cases and demonstrations performed in ASSURED can be found in the ASSURED use cases and city demos brochure[3].

THE WAY FORWARD

The ASSURED pre-normative technology roadmap provides an overview of the most popular charging technologies both today and for the near future. A series of interviews with experts were conducted to collect the views of industry and end users (cities, operators).

In terms of technology development, the roadmap forecasts articulated buses to reach battery capacities of 400 to 500 kWh, while for solo buses battery capacity is expected to go beyond 700 kWh in 2022 and 1 MW charging capacity. This aligns with the charging approaches foreseen for the three main bus service types, stating that BRT and trunk lines would ideally rely on opportunity charging, while feeder lines are expected to rely on overnight depot charging beyond 2024.

The scaling up phase for e-buses should also cover the most demanding routes. Therefore, the biggest benefits in reducing GHG emissions and improving air quality are likely to derive from converting the longest, fastest and busiest routes into electric lines. High-power opportunity charging systems for battery electric buses at head and end stops as well as major stops, can be tested in BRT systems operations.

ASSURED has helped advance this vision through the development and demonstration of high-power, (ultra-)fast charging solutions. As mentioned above, electric BRT lines will ideally rely on opportunity charging. A more-detailed overview of how ASSURED innovations are ready to be transferred into BRT systems can be found in the ASSURED Innovation in e-Bus Rapid Transit[4].

Given this, the combination of battery bus technology, supported by interoperable, high-power fast charging (as developed in ASSURED), with automation and connectivity constitutes the next step for e-BRT innovation. It has been identified as one of the priority topics of the Horizon Europe research (2ZERO SRIA).

Building on the ASSURED legacy, as of January 2023 UITP will coordinate the EC-funded project EBRT2030. This will support sustainable urban transport by reducing operational costs, TCO, greenhouse emissions and traffic congestion through technical solutions, business models, operational scenarios and impact assessment processes. This will be achieved through deploying innovative, integrated, efficient, end-user-centric, economically viable and flexible solutions, demonstrated via real-life cases in Europe and beyond.

CONCLUSION

For the bus sector, the electrification of fleets can bring many benefits and opportunities to cities and operators. First, it can revamp the image of the urban bus, thus improving the attractiveness of the service and the city; second, it can increase the quality of bus service by providing innovative, more comfortable and environmentally friendly transport; last, it can win back passengers' trust, particularly in the post-pandemic period. This is currently one of the most pressing issues for bus operators: reconciling the challenge of fleet renewal and energy transition with the need for improved ridership values and revenues.

Only five years ago the focus for the bus sector was set on how to optimise e-bus fleet management and operation. Now, thanks to projects such as ASSURED, operators can benefit from standardised interoperable high-power fast charging, thus facilitating solutions for opportunity charging that increase the flexibility of operations. This, in addition to smart-charging strategies and innovative energy storage solutions, has significantly contributed to reducing both the total cost of ownership and operational costs. This in turn is increasing the competitiveness of the technology, user acceptance and facilitating mass adoption and fleet upscale.

Testing roof mounted pantograph tech in Barcelona

THANK YOU TO THE PROJECT PARTNERS

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- Jema
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- Scholt Energy Services
- Schunk
- Siemens
- Solaris Bus & Coach
- Stadtwerke Osnabruck
- TMB Barcelona
- TNO
- Tofaş
- UITP
- VDL Bus & Coach
- Virtual Vehicle
- Volvo Buses
- VTT

LINKS TO FURTHER INFORMATION ABOUT ASSURED

Final event recording

Highlight the essence of e-bus interoperability video

ASSURED project video

SOURCES

1 https://assured-project.eu/storage/files/assured-guidelines-on-fleet-upscale-with-electric-buses.pdf

2 https://assured-project.eu/storage/files/d44-assured-11-interoperability-reference-pdf.pdf

3 https://assured-project.eu/storage/files/d114-d115-final-use-case-demo-brochure_1.pdf

4 https://assured-project.eu/storage/files/assured-innovation-for-bus-rapid-transit-public-version.pdf.

https://cms.uitp.org/wp/wp-content/uploads/2022/05/ASSURED-Clean-Bus-report_final2.pdf

This is an official Project Brief of UITP, the International Association of Public Transport. UITP has more than 1,900 member companies in 100 countries throughout the world and represents the interests of key players in this sector. Its membership includes transport authorities, operators, both private and public, in all modes of collective passenger transport, and the industry. UITP addresses the economic, technical, organisation and management aspects of passenger transport, as well as the development of policy for mobility and public transport worldwide.

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