Integrating Heavy-Duty Vehicles in the electricity system

Highlight of best practices

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SMART ENERGY EUROPE

Introduction

Heavy-duty vehicles (HDVs)[1], represent one quarter of road transport greenhouse gas emissions in the European Union, amounting to around 6% of the total EU emissions. The road transport sector is one of the few sectors where emissions have continued to rise since 1990.

In this context, the EU has set ambitious targets for HDVs: a reduction of CO2 emissions of 45% by 2030, and of 90% by 2040, while mandating all newly registered urban buses to be zero-emission by 2030[2] and in many cases, electric HDVs are the most competitive solution compared to diesel and petrol vehicles. For example, major trucks manufacturers forecast a steep increase with 600 000 electric trucks by 2030, i.e., half of the total new trucks sales.[3]

This surge will inevitably impact the electricity system. Already now, the surge of electrified assets pushes European grids at their limits, resulting in grid congestion as experience in the Netherlands or in Poland, where 60 to 80% of the consumers are denied a connection with the grid.[4] Electric HDVs could reach up to 30% of all electrified road transport, with a peak power demand amounting to 20GW, representing around 5% of the total power peak load.[5] To smoothen this increase and alleviate stress on the system, smart management solutions are needed to efficiently integrate HDVs into the grid. Such solutions already exist thanks to smart and bidirectional charging. HDVs have also the advantage to be more predictable as regards to the routes and driving patterns compared to private cars.

This paper aims to shed light on some inspiring use cases where HDVs become an asset to the grid rather than a burden. Trucks and buses are the main focus of this paper.

[1] HDVs comprise trucks, buses and coaches. They can be defined as freight vehicles of more than 3.5 tonnes (trucks) or passenger transport vehicles of more than 8 seats (buses and coaches). https://ec.europa.eu/commission/presscorner/detail/en/memo_14_366
[2] European Commission, Regulation 2024/1610 strengthening the CO2 emission performance standards for new heavy-duty vehicles and integrating reporting obligations, 2024.
[3] https://www.adlittle.com/en/insights/viewpoints/truck-electrification-profit-booster-or-white-elephant
[4] smartEn, 'Why flexible consumers matter – A contribution to EU elections 2024', 2024.
[5] ENTSO-E, 'Deployment of Heavy-Duty Electric Vehicles and their Impact on the Power System', 2023.

Top 3 benefits of grid-integrated HDVs

1. Decarbonisation

Smart and bidirectional charging would help a better integration of renewables in the electricity system, which would ultimately ensure that the vehicle is charged with decarbonised electricity. For example, a waste truck with a daily or weekly cyclic route in the morning would be charged during the afternoon taking benefit of the peak production of solar energy. In addition, one truck consumes the equivalent of fifty cars, and an average truck battery lies between 250 and 600kWh, five to ten times more than an average car. This leaves huge opportunities for HDVs to integrate large shares of renewables in their batteries, especially in countries where curtailment of renewables is high.

2. Benefits for the grid

As European countries are witnessing growing congestion within their networks, especially at distribution level, flexible HDVs could represent an important lever of mitigation. If considered as flexible storage assets, their batteries could absorb excess generation and store renewable electricity, but also discharge to the grid when needed. The Electricity Market Design (EMD) already provides incentives to use flexibility from decentralised assets, and its swift implementation at national level would create the good conditions for HDVs to participate in electricity markets and provide grid services. Their large batteries and the predictable patterns of their use (compared to LDVs) are ideal for participation in wholesale markets, balancing services or congestion management.

3. Benefits for the fleet manager

The Total Cost of Ownership (TCO) of electric trucks is considerably falling and catching up with diesel options, and is already cheaper in several European countries.[6] Smart and bidirectional options would enhance these financial benefits, and it has for example been estimated that a fleet manager could yield up to €15,000 of savings annually thanks to smart charging strategies for a fleet of ten trucks, representing 10 to 15% of the total energy costs.[7] Bidirectional charging would bring additional benefits in providing grid services and revenue opportunities for the HDV driver or manager which would further reduce the TCO.

[6] RAP & ICCT, 'Electrifying last-mile delivery: A total cost of ownership comparison of battery-electric and diesel trucks In Europe', 2022.
[7] RAP & ICCT, 'Electrifying EU City Logistics: An analysis of energy demand and charging costs', 2020.

Best practices: HDVs as a smart and grid integrated asset

Reducing Total Cost of Ownership with FLEXO Smart Charging: A Hive Power and Iveco Bus Success Story

Problem statement

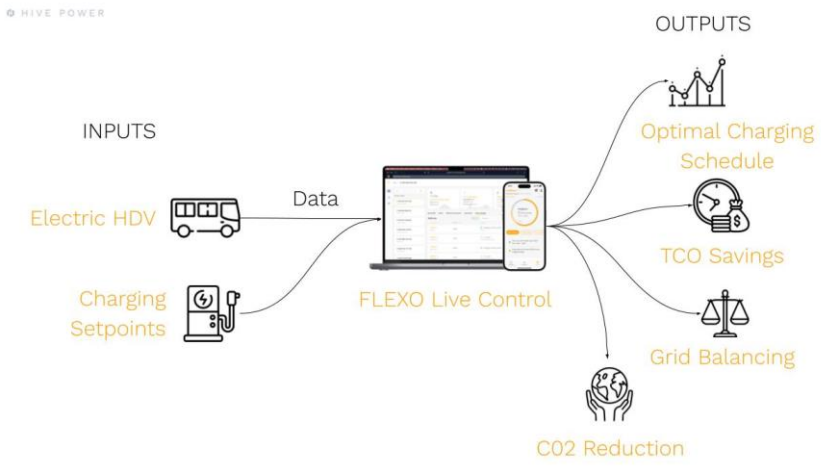
The cost of purchasing new electric HDVs presents a challenge for the electrification of a fleet of ICE HDVs. The aim of this project was to investigate how smart charging can reduce the total cost of ownership (TCO) of an eHDV, to quantify how that can support the business case for fleet electrification.

Approach

The project conducted by Hive Power with Iveco buses consisted of a simulation, in which FLEXO's flexibility orchestration software optimized and provided access to the savings made available through dynamic tariffs, taking account of each HDV's energy needs. This approach can shift demand to times when variable generation is higher and therefore cheaper. Because variable generation tends to be renewable, this means that the approach further reduces the carbon emissions associated with powering the fleet. Leveraging the large batteries of HDVs for demand response and flexibility services also supports a greater integration of renewables in the grid.

The project found that eHDV retailers and leasers needed smart charging compatibility across different charging infrastructures in order to offer integrated smart charging solutions powered by FLEXO. One of the best ways to achieve this is to enable cloud-based systems to modulate eHDV battery charging. This integration would enable reduced charging cost for fleet managers and allow them to offer demand response and other grid balancing services for maximal savings or extra incentives, which reduces costs for users and also enables participation in energy markets.

Charging costs can be significantly reduced through smart charging techniques without compromising the mobility needs of HDV owners, effectively turning the challenges posed by dynamic tariff schemes into revenue opportunities and thereby reducing the TCO.



The FLEXO flow

Hive Power's AI engine, FLEXO, enables EVs to act as virtual power plants, earning back thousands of euros per year and significantly reducing TCO. It optimizes energy usage based on energy market prices, PV energy availability, and opportunities for aggregation and ancillary services to the grid. FLEXO connects EVs to the grid and buildings, unlocking power and data exchange possibilities. Ideal for EV fleet owners, energy companies, and automakers, it guarantees savings and promotes renewable energy integration.

Results and Conclusion

The study illustrated the potential savings achievable with smart charging. Each day, each HDV has different energy needs and can face different dynamic prices, when available. By employing Hive Power's FLEXO smart charging algorithms, annual charging cost savings of 17% to 35% were identified for night charging e-buses using V1G technology alone, and up to 57% with vehicle-to-grid (V2G) enabled buses. Importantly, this solution delivered reduced charging costs without need for any changes in user behaviour.

Many end-users are unaware that smart charging can reduce the TCO of e-buses to such an extent. The conclusion is that such savings have the potential to facilitate the widespread adoption of smart charging for HDVs. Integrating smart charging solutions into the sale packages for fleets could significantly encourage the switch to electric HDVs.

Company

HIVE POWER

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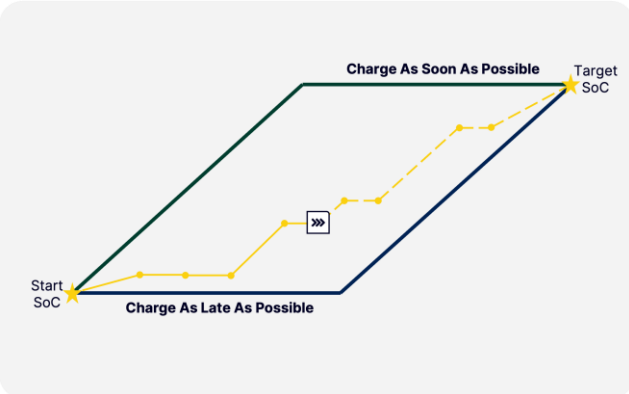
Smart Charging for e-buses: The Mobility House is electrifying Amsterdam's public transport

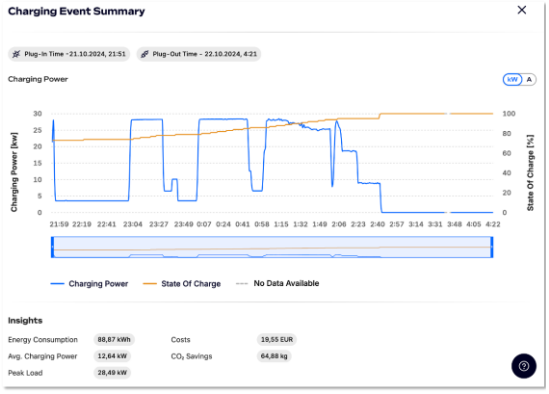
Problem statement

To achieve emission-free travel by 2025, Amsterdam's public transport operator GVB is rapidly electrifying its bus fleets. This shift, however, requires innovative solutions to ensure reliable high-power charging within the constraints of the local grid while charging at the lowest possible cost.

Approach

Recognizing these challenges, GVB partnered with The Mobility House to implement ChargePilot, a hardware and software agnostic local and cloud based charging and energy management system. Deployed at five different bus depots, ChargePilot manages charging for over 150 electric buses, with further expansions to additional depots underway. At each site, a local ChargePilot controller adjusts the charging power based on real-time grid conditions, ensuring fail-safe dynamic load management. Additionally, the system's advanced peak shaving capabilities optimize peak power demands in 15-minute intervals, significantly reducing grid operator fees. Using open standards, ChargePilot integrates with various charger types and fleet management systems which enable the creation of tailored charging plans based on vehicle schedules and energy needs. By thus each bus is charged to the required state of charge at the right time, ready to leave for its route without delays or disruptions.





Results and conclusion

Experience shows that high-power charging of buses requires an advanced charging and energy management system capable of addressing local grid limitations, preventing overloads and optimizing energy use. Taking efficiency a step further, ChargePilot adapts individual charging plans to account for specific vehicle schedules and dynamic electricity prices, essentially enabling V1G. This results in significantly reduced operational and investment costs, with savings amounting to 30-80% for grid connection costs and up to 50% savings for energy cost.

Importantly, these savings do not come at the expense of smooth operations: reliability is key, and ChargePilot's proven performance – demonstrated across more than 2,000 sites globally for various customers makes it a trusted solution for large-scale fleet electrification.

This approach minimizes fleet operator's total cost of ownership while integrating high-power charging efficiently und sustainably. With Vehicle-to-Grid (V2G) technology on the horizon, the next step – bidirectional charging – is within reach, transforming vehicle batteries into grid assets more valuable than ever. A first example can be seen in France where The Mobility House realizes together with Renault Group's R5 and Mobilize 10.000 km of free driving if the customer plugs in around 15 hours/day.

Company

THE MOBILITY HOUSE

Founded in 2009, the technology company The Mobility House is shaping the future of energy and mobility. With activity in over 50 countries worldwide from its locations in Munich, Zurich, Belmont (CA), Paris and Singapore, The Mobility House supports its customers and partners from the introduction of electromobility to the commercialization of flexibility in energy markets. To pursue a zero-emission energy and mobility future, The Mobility House technology unites the automotive and energy sectors. Using intelligent charging and energy solutions, vehicle batteries are integrated into the power grid to promote the expansion of renewable energies, stabilize the grid and make electromobility more affordable.

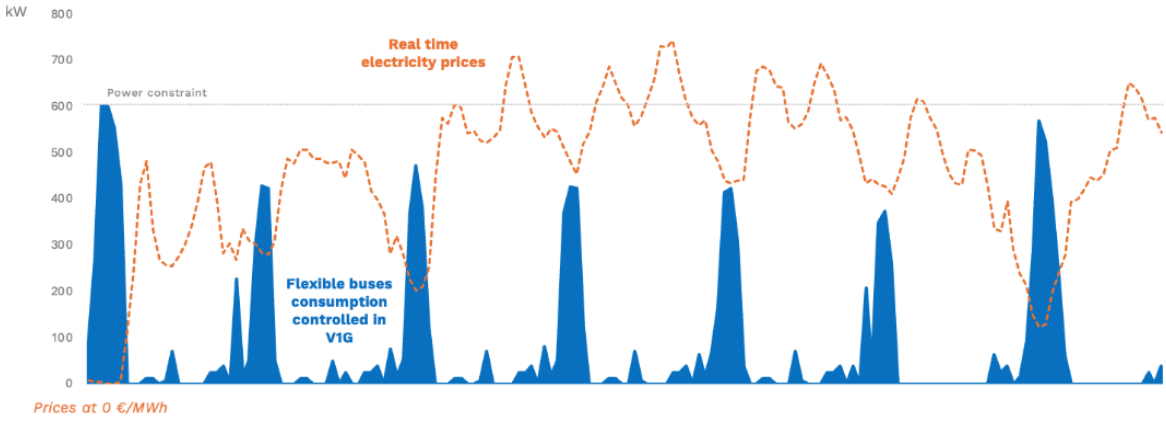
Optimized system integration of renewables and public buses in Paris with smart charging

RATP bus charging at depot (Source : RATP group)

Problem statement

Several hundred electric buses service the daily public transportation needs of Paris, recharging at a central bus terminal during their idle time. Charging a large number of public buses simultaneously or during peak times can increase grid stress and electricity costs. Optimized system integration required a comprehensive charging strategy.

Approach



Simulation of a flexible buses consumption controlled in V1G of a bus depot over one week (Source : DREEV).

Optimization concentrates the load at the best times of real time electricity prices (low prices, negative prices, etc…), respecting mobility needs and power limits. Electric public buses need to be recharged between shifts, but several hundred buses represent a consequential electrical load, but the charging period can become an opportunity rather than a burden to the electric grid by shifting charging to times when load is low (typically when the bus is idle in the depot overnight). The charging strategy was optimized using the Dreev smart charging platform that synchronizes the buses' charging requirements with electricity prices. This approach reduces and manages discrepancies between forecasted and actual power needs and prices.

Results and conclusion

Consequently, electricity costs were reduced noticeably for the client compared to a scenario without smart charging. The system flexibility gained by this managed charging strategy can also facilitate the integration of renewable energy into the generation mix.

The technology is fully mature, but to ensure better replicability of the business model, it could be worthwhile to consider improved flexibility incentives within the grid tariff (peak hours vs off-peak hours), while also ensuring that the grid tariff still covers the cost of the concerned flexible consumers' use of the grid. One example already in use in some European countries is to encourage consumers to subscribe to differentiated levels of power demand, facilitating a more significant increase in demand during off-peak hours. This would encourage flexibility at night, which allows a maximum amount of power to be concentrated for recharging at the best hours, particularly when there is a surplus of renewable generation.

Company

DREEV is an EDF Group Company (joint venture with Nuvve) specializing in V1G and V2G solutions, with the objective to create a virtuous circle between e-mobility and the power system.

SPIRIT-E: Shared Private Charging Infrastructure and Reservation for Bidirectionally Integrated Truck Electrification

Problem statement

The SPIRIT-E research project aims to accelerate the adoption of battery-electric trucks with bidirectional charging capabilities. Its primary goal is to quantify the economic potential of integrated truck operations and bidirectional charge management while assessing their impact on road transportation and energy grids. The final product will be demonstrated in real-world laboratories at logistics sites.

Approach

The SPIRIT-E project tackles the electrification of heavy-duty transport as a key step toward reducing CO2 emissions and achieving climate goals. Electrifying heavy-duty vehicles poses significant challenges, particularly in terms of payload, range, and efficiency. Additionally, the lack of sufficient charging infrastructure, especially for bidirectional charging, slows down electrification.

To address these challenges, the SPIRIT-E project is developing an operating concept for shared private charging infrastructure, utilizing high-power bidirectional charging stations and vehicles. These solutions will be tested in field trials. A near-series bidirectional charging station will be deployed at the pilot site, and intelligent vehicle-to-everything (V2X) functionalities will be developed and integrated into pre-series vehicles. The project also includes the development and testing of a comprehensive communication system for V2X connectivity and the seamless system integration of the vehicles.

Results and conclusion

The resulting benefits for fleet managers include reduced total cost of ownership (TCO) and decarbonization. Utilizing vehicle downtime for bidirectional charging can help lower TCO, while combining self-generated

photovoltaic (PV) power with intelligent charging solutions can further reduce energy costs. Moreover, electrifying heavy-duty vehicle (HDV) fleets contributes to CO2 emission reductions and supports climate goals.

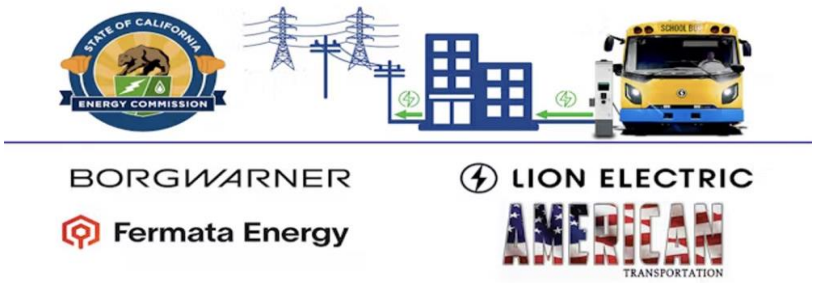
For the power grid, the benefits include simpler grid connections and enhanced grid services. Integrating decentralized consumption and generation units, as well as battery storage, into grid operations can alleviate bottlenecks and improve grid stability. Additionally, bidirectional commercial vehicles, with their high charging and discharging capacity, offer flexibility and economic services that enhance the overall efficiency of the energy system.

The project has significant scalability potential. Expanding the charging infrastructure and integrating additional fleets and locations would broaden its impact. Developing standardized data exchange systems could further streamline integration and promote the use of flexibility options. In the long term, the project could be scaled to a European level, supporting the electrification of the commercial vehicle sector across multiple countries.

Company

The project is funded by the "German Federal Ministry for Economic Affairs and Climate Action", the project authority is the "German Aerospace Center", and worked out by the consortium partners "Consolinno Energy", "FfE", "Fraunhofer IEE", "Hubject", "MAN", "SBRS", "Technical University of Munich", and "TenneT".

V2G for School Bus Fleet Pilot with Fermata Energy



Problem statement

The electrification of school transportation holds great promise for delivering significant grid, economic, and health benefits to local school districts in California. However, few electric school bus projects, and even fewer bidirectional school bus projects, have been deployed, and data on the benefits has yet to be gathered. More deployments with V2G school buses are needed to examine the ability of this technology to provide cost effective solutions to Public Safety Power Shutoffs events, peak reduction, and for the transition to renewable energy.

Approach

The California Energy Commission (CEC) GFO-22-612 project awarded to a partnership of Lion, BorgWarner, American Transportation Systems, and Fermata Energy is a pilot demonstration under real-world conditions, which aims for the mass deployment of Vehicle-to-Everything (V2X) bidirectional charging with electric school buses. Fermata Energy's V2X software platform optimises and manages the charging and discharging of the buses to maximise grid benefits and V2X revenue for the site hosts. The bidirectional charging systems participate in an emergency response program for a minimum of three years, in addition to other V2G rates and programs.

In March 2024, Fermata Energy, BorgWarner, and Lion Electric were awarded $3million in California Energy Commission (CEC) grant funding to bring grid-supporting and cost-saving V2G solutions to the Conejo Valley Unified School District and the Los Angeles County Office of Education, in cooperation with school bus fleet operator American Transportation.

The project aims to support grid reliability and mitigate the impact of Public Safety Power Shutoffs and extreme weather events. This project also demonstrates the health and economic benefits of zero-emission transportation

solutions for communities leveraging V2G technology. In particular, the application of Fermata Energy's grid CO2 optimisation algorithms will be explored to pave the way for participation in carbon credit programs for projects like this in the future.

Twenty-one BorgWarner 125 kW UL 1741-SA listed bidirectionally-enabled CCS1 chargers
will be installed with an expected go-live date in early 2025 and will be paired with at least 20 LIOND all-electric school buses utilised by the two different Los Angeles-area school districts. The chargers will be using Fermata Energy's optimised V2X software platform to maximise benefits while maintaining utility of the high-duty vehicles.

Results and conclusion

The current estimate of the revenue for this project, using 210 kWh electric buses, is up to $3,150 per year per charger for participation in the Emergency Load Reduction Program. This value takes into account the average number of dispatch events during a year (10 events, 36 hours per year of participation) based on historical data, the program incentive price currently at $2/kWh, and an adjusted battery duration to reflect real-world operations.

This 2.5 MW project is one of the largest V2G deployment in the state of California and will operate for 3 years. The learnings from this project will help more school districts adopt V2G solutions as they embark on their fleet electrification journeys. The project is a critical step in demonstrating how governmental support for V2X technology can help support its scale adoption. As for replicability for the European context, this project will provide data and field experience to support similar school bus bidirectional charging projects. Findings may also translate to other Heavy-Duty segments such as public transport buses and trucks.

Company

Fermata Energy

Fermata Energy, founded in 2010, is a leader in intelligent Vehicle-to-Everything (V2X) bidirectional charging technology, including Vehicle-to-Grid (V2G), Vehicle-to-Building (V2B) and Vehicle-to-Home (V2H) solutions. Our proprietary platform enables customers to manage EVs as distributed energy resources, dynamically responding to grid signals and selling excess energy from parked EV batteries to economically support the grid.

Conclusion and recommendations for scale up

HDVs are emerging as valuable assets for the integration of renewables, the grid, and fleet managers, driving a surge in collaborative projects among OEMs, system operators, local authorities, and energy solution providers. To fully unlock their potential, supportive regulations and incentives are crucial for integrating HDVs into the grid and scaling up smart and bidirectional charging.

smartEn recommends to:

- Make HDVs smart and bidirectional-ready with the swift implementation of the communication protocol 15118-20
- Make the charging infrastructure smart and bidirectional charging-ready for specific use cases, when it is the most relevant. This should include depot charging for buses and trucks, and other cases where HDVs have a limited and cyclic route with predictable long-duration parking time
- Prioritise grid connection of flexible HDVs. As flexible assets, HDVs would require less grid capacity than non-smart HDVs and other EVs, and can release the pressure on the grid thanks to flexibility services. This would be even more relevant at low and mid-voltage level where grid congestion is growing the most.
- Implement provisions from the EU Electricity Market Design, notably:
    - Dynamic pricing options and/or time-of-use power prices for consumers
    - Open access to wholesale and balancing markets
    - Implementation of local flexibility markets, with specific remunerations for congestion management services
    - Time-varying network tariffs, which would reflect the true cost of the grid use, incentivising HDVs flexibility

This paper was possible thanks to the contribution of:

The smarter E Europe

Accelerating Integrated Energy Solutions…

… this is the mission of The smarter E Europe, Europe's largest alliance of exhibitions for the energy industry. The aim is to create a future-oriented energy world by shining a spotlight on renewable energies, decentralization and digitalization as well as cross-industry solutions from the electricity, heat and transport sectors for a sustainable 24/7 energy supply.

Spanning four exhibitions, The smarter E Europe brings together relevant players from around the world, showcasing the latest market developments, trends and technologies. The four exhibitions will take place from May 7–9, 2025, at Messe München.

- **Intersolar Europe** – The world's leading exhibition for the solar industry
- **ees Europe** – The continent's largest and most international exhibition for batteries and energy storage systems
- **Power2Drive Europe** – The international exhibition for charging infrastructure and e-mobility
- **EM-Power Europe** – The international exhibition for energy management and integrated energy solution

Spotlight on Bidirectional Charging

In 2025, The smarter E Europe will shine a special spotlight on bidirectional charging and its pivotal role in the energy transition. For the first time, a dedicated special exhibition will explore the potential of bidirectional charging technologies. This showcase will highlight already available products, applications, and solutions, while also fostering a forward-looking discussion about the future of this transformative field.

Attendees can expect an engaging program featuring sessions and panel discussions, providing opportunities for knowledge exchange, debate, and networking among industry leaders, experts, and innovators.

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Our membership consists of the following companies:

The positions expressed in this document represent the views of smartEn as an association, but not necessarily the opinion of each specific smartEn member.
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