Deliverable 2: Analysis of Demonstration of HDEV Projects & Use Cases

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1. Introduction

This report focuses on Research & Development (R&D) projects and industry trends in the transportation and logistics industry. The contents are organised as follows.

First, R&D projects aiming at new solutions to increase the energy efficiency of current state-of-the-art Heavy-Duty Vehicles (HDVs) are reviewed (Ch. 3, Driving efficiency and Ch. 4, Hybrid powertrains). The review includes solutions for both diesel and hybrid HDVs and helps to assess the extent to which energy efficiency, hence primary energy consumption, can be further improved in the next decade.

Then, a review of the state-of-the-art projects for fuel cell (FC; Ch. 5, Hydrogen) and battery HDEVs (Ch. 6, electric vehicles) is given. The goal is to compare these two technologies regarding the technological maturity achieved for transport application and the barriers they face towards widespread adoption.

Finally, a review of Transmisson System Operators' (TSOs') most important outcomes from undergoing projects concerning the planning and realisation of Mega-watt scale recharging stations for HDEVs is given. In addition, some preliminary points of attention acquired via a dedicated questionnaire are included (Ch. 7, ENTSOE's questionnaire and TSO projects).

2. Executive summary

Up to now, few European projects on Electric Vehicles (EVs) have involved grid operators such as TSOs or Distribution System Operators (DSOs), and flexibility services specific to electromobility have not been addressed in detail. This is probably due to more emphasis being placed by industry on vehicles, propellers and batteries rather than on grid impact, in addition to the fact that the size of the projects was relatively small with respect to DSO / TSO usual operation boundaries. This situation is changing, with depot charging becoming a relevant reality by 2030 as a consequence of the rapid adoption of HDEVs for local public transportation and goods delivery.

Driving efficiency: regarding the current state-of-the-art Internal Combustion Engine (ICE) trucks, a further 10% reduction in the primary energy consumption for the transport of people/goods per km due to optimised mechanics and aerodynamics can be expected. This is because (1) much of the mechanics has already been optimised for savings on fuel costs and (2) further gains could be achieved by enabling longer/bigger trucks, but there are infrastructure/regulation constraints on weight and length that do not allow such solutions. The conclusion is that the future energy demand for HDV road transport will be determined primarily by:

- the share of HDV road transport for people/goods with respect to the entire transport sector; and
- the adoption of more efficient powertrain technologies such as battery electric buses and trucks.

Hybrid powertrain: Few hybrid vehicles are being actively developed for transport applications. As discussed in Deliverable 1A, due to the non-availability of synthetic biofuels at the scale required by the transport sector, hybrid vehicles are only considered a short-term solution before full electric HDEVs become market mature. Regarding impact for the power grid, the deployment of hybrid vehicles is negligible and in fact their market share in 2022 is much lower than that of pure electric HDEVs.

Hydrogen buses: FC buses for public transportation are being developed by several international companies and are being adopted in major European cities, with approximately 200 FC buses in operation. The results are mixed: some cities such as Wiesbaden and Montpellier are withdrawing from the projects due to excessive costs and technical difficulties, whereas other cities, such as Frankfurt are happy with the results and have plans to upscale their fleet of hydrogen buses. From the infrastructure perspective, public transport on hydrogen buses only requires depot charging as the driving range of FC buses is already over 400 km.

Hydrogen trucks: FC trucks are quite early technologies. There are a significant number of FC truck models market available in 2022 which are based on gaseous hydrogen (H2) as fuel, and EU pilot projects reports difficulties with the recharging operations and safety/driving regulations at local level. In addition to gaseous H2, some liquid H2 propelled vehicles are also under investigation, but are not market available yet. The demonstrated driving range of FC trucks is below 500 km, which is not yet competitive for long-haul operations, especially without the availability of a public refueling infrastructure. The ongoing project H2Haul reports that *'the technical maturity is at a very early stage and needs to be demonstrated in a truck*'.

Electric buses: electric buses are a mature technology for public transport operations. According to the European Commission, there are already approximately 10,000 electric buses in operation on European roads covering an exhaustive range of use cases. Depot charging is the main charging strategy, but opportunity charging has also been validated as a mature technology and can be used to extend the driving range when needed. The rapid uptake of electric buses is expected to have a significant impact on the power grid already in 2030, due to the significant amount of depot charging (see Deliverable 3) operations. In fact, major EU cities in the C40 network plan to deploy full electric public transportation no later than 2030.

Electric trucks: Several logistic companies such as Amazon and DHL have already started using Battery Electric HDEVs for local and regional operations and have announced the target of becoming carbon free by 2040. For power grid operators, the impact is expected to be significant, with depot charging for local and regional operations adding an aggregated demand of > 10 MW per (primary) substation every night (see Deliverable 3).

ENTSOE questionnaire and TSO projects: Most TSOs are aware that HDV electrification is going to happen and think that the network development plan will consider this reality. However, the degree of expertise with this matter is not uniform among TSOs and common guidelines are required. Among the few TSOs with direct experience in the realisation of new connections for MW recharging stations, a list of issues have emerged that have the potential to hamper the project realisation. This list spans from regulatory aspects to details of the planning and execution of the work.

3. Driving efficiency

Regardless of the powertrain technology, which can be diesel, hybrid, fuel cell or battery electric, trucks' energy efficiency can be achieved by improving the vehicle aerodynamic and by reducing to the minimum the frictions when the vehicle is travelling at a constant speed on the highways, which is how they spend most of their operational time. As the fuel cost is the biggest component of the Heavy-Duty diesel trucks Total Cost of Ownership (TCO) (see also deliverable 1B, fig. 15), such research activities have since long been investigated, and in fact, it can be shown (see figure below) that driving efficiency has constantly improved during the years.

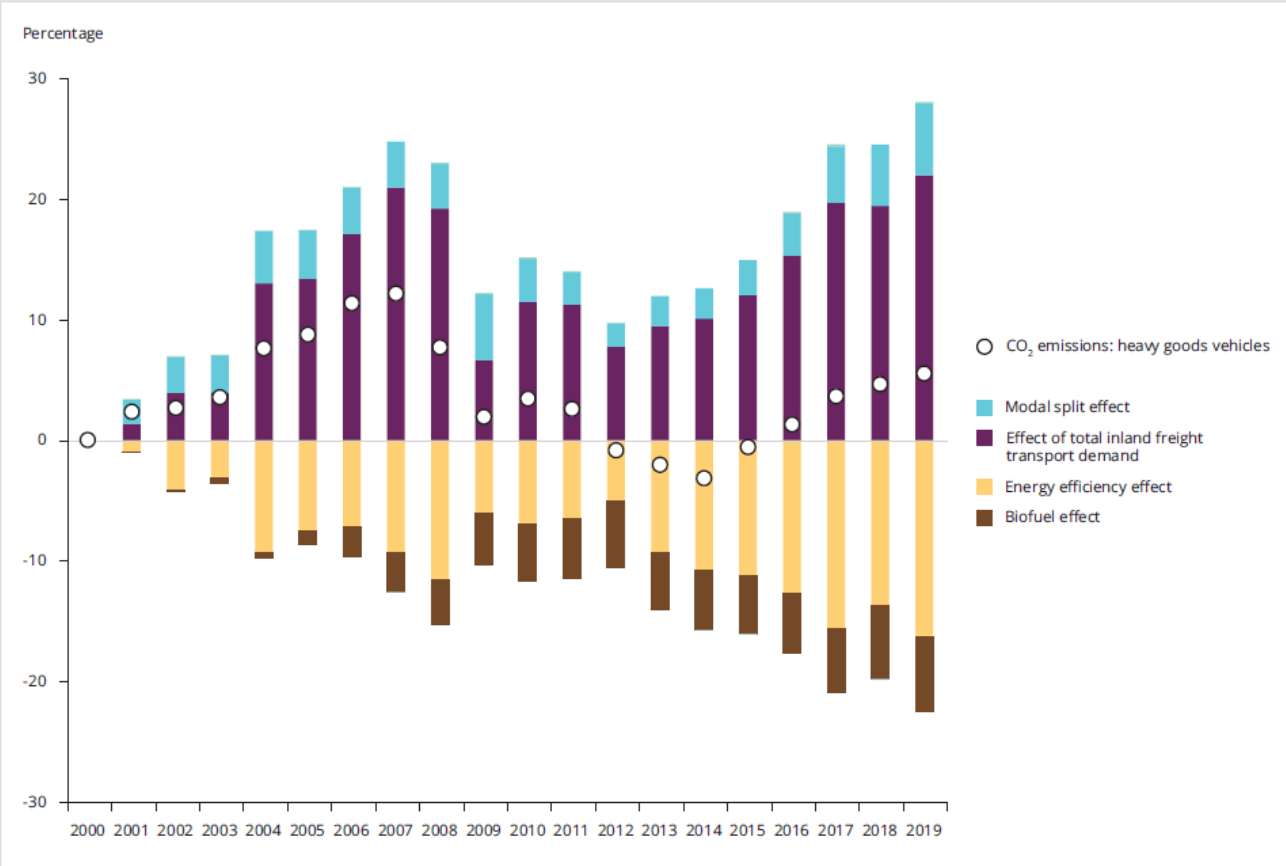


Figure 1: Decomposition analysis of CO2 emissions of HDV in the EU 27 from 2000 to 2019, percentage contribution, figure from the Environmental Energy Agency report 2/2022, 'Decarbonizing Road transport — the role of vehicles, fuels and transport demand'

There are currently two approaches under way to further improve heavy-duty trucks' driving efficiency. The first is to keep increasing the mechanics and aerodynamics of trucks and lorries (project **Aeroflex** – market mature solutions). The second is related to using new digital solutions and AI techniques to implement self-driving trucks which travel hundreds of miles in a compact formation, so called *platoon*, in such a manner as to reduce the overall aerodynamic friction (project **Ensemble** – early-stage technology).

The projects analysed here are useful for quantifying how much further we can expect driving efficiency to be pushed in the next years.

3.1. Aeroflex

Aerodynamic and Flexible Trucks for Next Generation of Long-Distance Road Transport

Timeline: finalised in 2021

Transport use cases: HDV long-haul goods transport

Results: according to results and recommendations out of the Aeroflex project (and its predecessors):

- In 2020, the European Union has modified truck regulations to allow for more aerodynamic cabin shapes and truck length;
- Up to 33% fuel saving have been / can be obtained with better aerodynamics/mechanics for some specific truck configurations and loading distributions; and
- The adoption of heavier/longer trucks, which could further increase driving efficiency, is limited by infrastructure constraints and regulations.

Figure 2. Images from the Aeroflex final event presentation (available online)

Project context: The project Aeroflex, closed in Sept. 2021, demonstrated **up to 33% diesel fuel reduction** for long-haul road transportation of the traditional diesel tractor + trailer system due to better mechanics and aerodynamics. The key features for achieving the target are:

- The use of an additional e-dolly for the trailer;
- Better truck aerodynamics (especially skirts), for avoiding air turbulence below and behind the wagons; and
- The use of smart loading units to optimise the cargo distribution.

Impact on power system: None

Main Partners: The project involved a large consortium with most European truck and bus makers, among which: MAN, DAF Trucks, IVECO, SCANIA, VOLVO Group and research institutes such as the Fraunhofer IT.

Website: https://aeroflex-project.eu/

3.2. Ensemble

ENabling SafE Multi-Brand pLatooning for Europe

Timeline: finalised in May 2021

Transport use cases: HDV local/regional goods transport

Results: According to reports of the Ensemble project:

- for trucks travelling in a compact formation, vehicles in the inner part of the platoon can **benefit from a 5–10% reduction in fuel consumption** at the constant speed of 80 km/hr.
- The benefits of implementing *platooning* solutions are mostly oriented towards road safety and ease of operation rather than directly reducing trucks energy consumption.

Figure 3 visual representation of the 'platoon' concept. Picture from the Ensemble website.

Project context: The project **Ensemble**, closed in 2021, demonstrated several features of interoperable trucks platooning during a 3 hr demo involving trucks from different manufacturers driving under real world traffic conditions in different platoon configurations. The key outcomes of the project are as follows:

- Development of interoperable V2V communication protocol (**pre-standard**); and
- Demo with 7 trucks for 3 hr test under real traffic conditions in different platooning configurations

Definition of the legal framework for autonomous/assisted driving across European countries requires harmonisation.

Before platooning can be implemented on European roads, the harmonisation of the legal frameworks shall take place across member states, especially concerning the extent to which autonomous driving can be allowed on heavy duty vehicles.

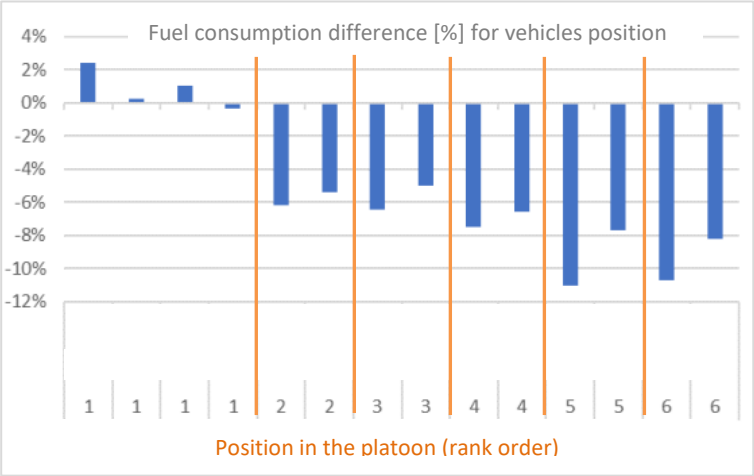


Figure 4. From 'Impact on fuel consumption and emission', a presentation shared on the Ensemble website by TNO.

Impact on power system: None

Main Partners: TNO (Leading Partner), DAF, DAIMLER, IVECO, MAN, SCANIA, and VOLVO Group

Website:
https://www.platooningensemble.eu/

4. Hybrid powertrains

Hybrid vehicles are more energy efficient than traditional ICEs, and this is true even for HDVs:

- the electric powertrain allows for the recovery of the braking energy; and
- the electric engine covers all low speed / low gears operations, for which the ICE engine is less efficient

Although hybrid vehicles shall only be considered a 'transition technology' before 2050 in a decarbonisation scenario, they might play a role in the next 10–20 years. Furthermore, R&D results for hybrid vehicles have a very quick time to market (1 to 2 years from prototype validation, project ORCA). However, according to the European Alternative Fuel Observatory, the share of hybrid HDV is much lower than the share of battery electric HDEV, and the same holds true for the number of vehicles available, suggesting that the cost opportunity to develop hybrid HDVs for transport application is low.

The project LONGRUN, started in January 2020, has the goal of developing different hybrid engines, drivelines and demonstrator vehicles with 10% energy saving (Tank-to-Wheel), 30% lower emission exhaust (NOx, CO and others), and 50% Peak Thermal Efficiency. There are no results yet from this project.

4.1. ORCA project

Optimised Real-world Cost-Competitive Modular Hybrid Architecture for Heavy Duty Vehicles

Timeline: finalised in Sept. 2021

Transport use cases: Local/Regional passenger transportation (IVECO) and goods transportation (VOLVO)

Results: ORCA has developed an IVECO multimodal hybrid bus and a VOLVO distribution hybrid truck with an extended full electric range from 30 to 50 km. Both vehicles are equipped with innovative plug-in hybrid electric vehicle (PHEV) rechargeable energy storage systems, designed specifically for each vehicle application. Commercial hybrid buses are expected to hit the market in less than 2 years after prototype validation, with the following conclusions:

- downsize the engine by at least 50% compared to the actual IVECO hybrid bus and VOLVO conventional truck; and
- TCO remains the same compared to their conventional counterparts.

Impact on power system: None

Main Partners: TNO (Leading Partner), IVECO, BOSCH, Centro Ricerche FIAT, JRS Micro – Semiconductor materials, Fraunhofer LBF, and VOLVO Group

Website: https://h2020-orca.eu/

Figure 5. Image of the IVECO hybrid vehicle from the ORCA website

5. Hydrogen

Hydrogen Fuel Cell HDVs are not yet a fully mature technology, however a distinction shall be made between buses and trucks. **FC Buses** for public transportation are quite a mature technology and have been used for a few years in real pilot projects in several European cities, whereas long-haul operations with **FC trucks** are starting pilot projects in 2023. The focus of R&D activities is on demonstrating reliability for long-haul operations and the real-world feasibility of hydrogen refueling operations, both from the regulatory aspect in addition to safety and operational requirements.

5.1. Fuel Cell buses

FC buses are developed at the commercial level, and there are already different models that cover different use cases. As of 2022, according to the European Alternative Fuel Observatory, there are 200 hydrogen buses registered in the EU27. The key advantage of FC buses over their battery electric competitors is the driving range, which already exceeds 400 kms. Consequently, many European cities have already started pilot activities with hydrogen buses, which is a relatively simple solution that only requires depot charging. Two corner cases are referenced here:

- Frankfurt[1]: the city is currently using 13 hydrogen buses and has plan to expand its hydrogen buses fleet up to 140 vehicles in the next ten years. The 13 buses transport over 10,000 passengers per day and have a real driving range of approximately 400 km.
- Wiesbaden[2]: the city has decommissioned its fleet of 10 hydrogen buses and has committed to wait for when battery electric buses with > 400 km range will be available, expected in 2025. The reasons for decommissioning: excessive costs and difficulties of operations.

The same issue of excessive operational costs of FC buses caused the sudden withdrawal from purchasing of 52 hydrogen buses by the city of Montpellier[3] in 2020 in favour of battery electric buses. The limited range of battery electric buses was not an issue in this case and operational costs (mostly fuel) were found to be six times cheaper than for hydrogen vehicles, as detailed in the next paragraph.

TCO of hydrogen vs battery electric buses: from the interview with the mayor of Montpellier Michael Delafosse on the decision of cancelling the purchase of hydrogen buses:

> '*Hydrogen technology is promising, but we were helped on the investment, not on the operation. However, it would be six times more expensive than with electric buses. So, for the moment, we are giving up on hydrogen buses; we will see in 2030 if hydrogen is cheaper*.'

Furthermore, Julie Frêche, vice-president of Montpellier municipality and in charge of transport, reported that:

- **OPEX:** the operation of the hydrogen buses would cost €3m per year, compared to €500,000 with electric ones — or €0.95 per km versus €0.15.

[1] https://www.faz.net/aktuell/rhein-main/frankfurt/keine-zweifel-an-wasserstoff-antrieb-in-rhein-main-18537514.html
[2] https://www.faz.net/aktuell/rhein-main/region-und-hessen/wiesbaden-mustert-wasserstoffbusse-wieder-aus-18534937.html
[3] https://objectif-languedoc-roussillon.latribune.fr/politique/politiques-publiques/2022-01-06/pourquoi-la-metropole-de-montpellier-renonce-aux-bus-a-hydrogene-899735.html

- **CAPEX:** hydrogen buses were €150,000–200,000 more expensive to buy than their electric counterparts.

Given the early stage of hydrogen technology, the high operational costs related to refuelling/managing hydrogen FC buses can be expected to decrease with time due to acquired practical knowledge and widespread adoption of best practices for organising the routine work and maintenance operations. However, from a fundamental perspective, it shall be acknowledged that, at parity of operation, FC vehicles are generally consuming more than twice the amount of primary energy than battery electric vehicles.

5.2. Fuel Cell trucks

For FC **trucks**, hydrogen vehicles are just starting to appear on the market, with a few examples of models available in 2022:

- Hyundai XCIENT Fuel Cell[4], advertised range: 400 km; and
- Quantron QHM FCV[5], advertised (max) range: > 1000 km.

There will also be a few other models announced by 2025.

Two European projects, one just finished and the other just started, are reported here, describing the *state-of-the-art* for the deployment of FC HDVs. The H2Share project, closed in March 2022, conducted few preliminary tests for using FC trucks on European public roads for real delivery operations, reporting (1) feasibility of regional operations at regional level (250 km per day), (3) some technical difficulties with refueling operations and (3) very high operational costs. The H2Haul project, that started in late 2021, will be the first to launch a number of different real testbeds for different use cases for testing hydrogen trucks and the deploy of commercial hydrogen refuelling stations.

5.2.1. H2Share project

Hydrogen Solutions for Heavy-duty Transport Aimed at the Reduction of Emissions in North-West Europe

Timeline: finalised in March 2022

Transport use cases: Local/Regional HDV goods transportation

Results: One 27-ton rigid truck run on hydrogen and one flexible low energy mobile refueler were built and tested. The mobile refueler was built only to allow the tests while lacking a real hydrogen refuelling infrastructure.

Figure 6 Photo of the mobile hydrogen refueling station. Picture from the H2Share project

The test was conducted in collaboration with DHL, and an interview on the outcomes is available[6]. The most important features are summarised as follows:

- The driving range was approximately 200 km per day (less than real long-haul operations);
- There were several technical problems during the refuelling operations, which shall be assisted by specifically trained personnel;
- Local authorities were mostly concerned with safety regulations and required ad hoc documentation for allowing the tests; and
- The TCO was deemed by the DHL project manager as *'non reasonable'.*

Impact on power system: Not in the project scope

[4] https://trucknbus.hyundai.com/hydrogen/en/hydrogen-vehicles/xcient-fuel-cell
[5] https://www.quantron.net/en/q-truck/q-heavy/qhm-fcev/
[6] https://www.nweurope.eu/projects/project-search/h2share-hydrogen-solutions-for-heavy-duty-transport/news/dhl-revisits-its-experience-with-the-h2-share-truck/

Leading Partner: WaterstofNet knowledge and collaboration platform (unites the hydrogen industry in Flanders and the Netherlands via the Waterstof Industrie Cluster).

Partners: Deutsche Post DHL, DHL International BV (NL), VDL Bus Chassis (NL), Wystrach (Germany), TNO (The Netherlands), Hydrogen Europe (Belgium), e-mobil BW (State Agency for New Mobility Solutions and Automotive – Germany) and others

Website: https://www.nweurope.eu/projects/project-search/h2share-hydrogen-solutions-for-heavy-duty-transport/#tab-4

5.2.2. H2Haul project

Hydrogen Fuel Cell Trucks for Heavy Duty Zero Emissions Logistics

Timeline: started in late 2019, closing in 2024

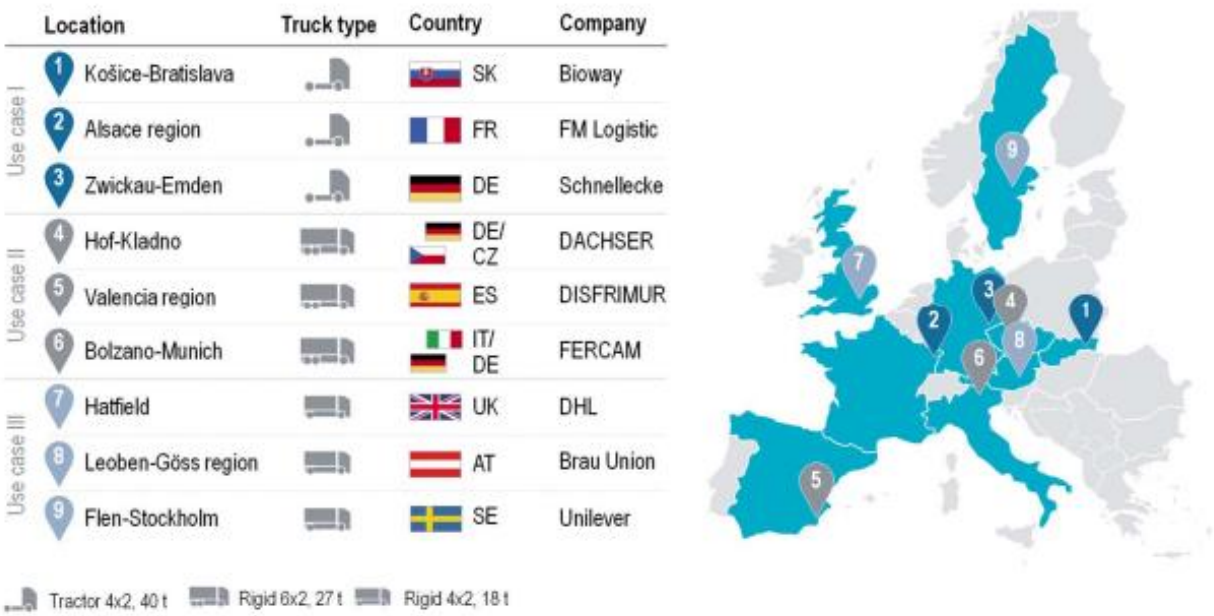


Figure 7. Overview of geographical distribution of H2Haul project case studies in Europe

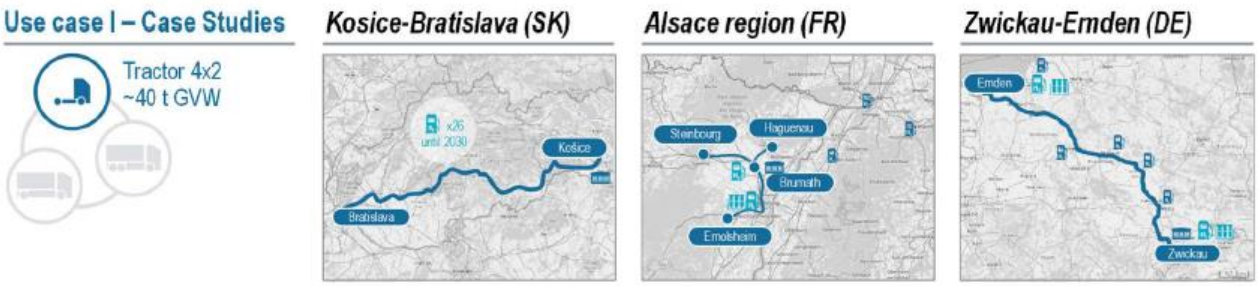
Project objectives: the project started in 2020 and will run until 2024. It aims to develop and deploy 16 zero-emission FC trucks at four sites. In addition, new high-capacity hydrogen refuelling stations will be installed to provide reliable, low carbon hydrogen supplies to the trucks. The main goals are as follows:

- Develop long-haul heavy-duty (26 and 44t) FC trucks that meet customer requirements in a variety of operating environments;
- Drive the FC trucks for more than one million kilometres during normal commercial operations, demonstrating the viability of the technology;
- Approve three types of FC trucks to certify that they are safe for use on Europe's roads;
- Install a hydrogen refuelling infrastructure and establish highly reliable hydrogen supply arrangements to maximise environmental benefits; and

- Monitor vehicle and infrastructure performance throughout the operational phase to provide definitive, third-party validated evidence of the availability, efficiency and environmental benefits of FC trucks.

Transport use cases: the project identifies 3 use cases (one per truck type, as illustrated in figure above) that cover approximately 50% of the European HD road transport of goods:

1. **4x2 tractor (+ trailer) of 40 t** gross vehicle weight, used by international logistics companies and manufacturing industries with their own trucking fleets. This use case represents the long-haul segment with an annual mileage of 110,000–160,000 km.
2. **6x2 rigid trucks of 27 t** gross vehicle weight, used by wholesalers with their own trucking fleets. This use case represents the mid-haul segment with an annual mileage of 50,000–150,000 km.
3. **4x2 rigid trucks of 18 t** gross vehicle weight used by regional logistics companies and retailers with their own trucking fleets and represents the short-haul, regional distribution segment with an annual mileage of 40,000–85,000 km



	Kosice-Bratislava (SK)	Alsace region (FR)	Zwickau-Emden (DE)
Daily range	406 km	~270 km	607 km
Annual mileage	~130,000 km	~100,000 km	~130,000 km
Payload	10 t	26 t	~25 t
Fleet size	15	8	2
H_2 consumption	0,08 kg/km	0,083 kg/km	0,08 kg/km
of fleet	500 kg/day	180 kg/day	100 kg/day
Route characteristics	Cross-country route with further operation in other countries	24h warehouse logistics operation with refrigerated trailers	Long-haul automotive logistics service in a go-and-return route

Figure 8. Details of the use cases for the 4x2 tractor + trailers. Picture taken from the project documentation available online.

Impact on power system: not assessed

Website: https://www.h2haul.eu/

6. Electric vehicles

Similarly to hydrogen FC-HDV, the market maturity of BE-HDV is quite different for buses used for public transportation and trucks for goods transportation. The major limitation for BE-HDV is in the driving range, which is related to the huge battery size required for long haul operations. Research is focusing on new batteries with higher energy density and thus of lighter weight. This branch of research is not examined here because it does not have a direct impact on the power grid.

Battery HDEV: electric buses are a fully mature technology booming worldwide, and the TCO is already competitive with diesel buses for most use cases. **Electric trucks** are almost a mature technology, with many different models commercially available. However, their driving range and the lack of a recharging infrastructure limit their application. This is changing, and several logistic companies, such as Amazon and DHL, have already started using electric trucks for local/regional business operations globally.

6.1. Battery Electric buses

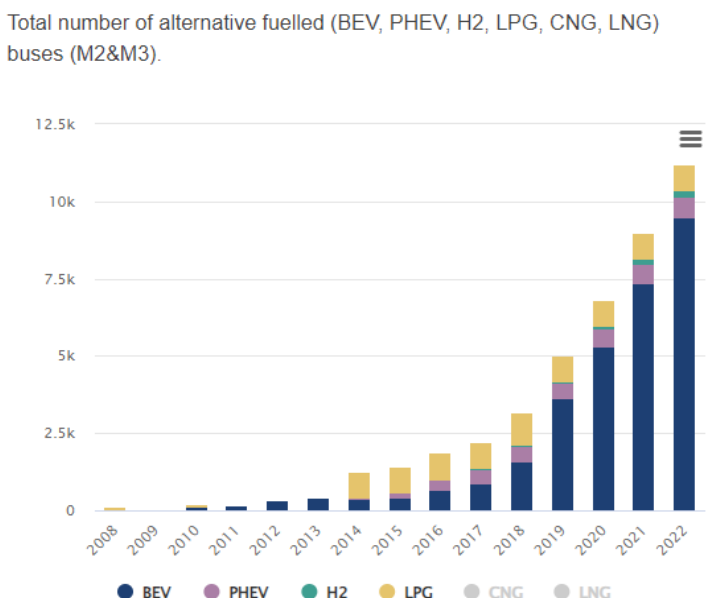


Figure 9. Total number of BEV, PHEV, H2 and LPG buses in Europe according to the European Fuel Observatory.

As also mentioned in Deliverable 1B, electric buses are a fully mature technology, adopted in hundreds of European cities and available in a widespread number of models.

According to the European Fuel Observatory (figure below), in 2022 there were already about 10,000 fully electric buses registered on European roads, a share much higher than Hybrid Plugin EV of FC hydrogen vehicles. Battery Electric Buses have reached full market maturity and R&D activities are mostly carried out directly by vehicle manufacturers (Fig. 9).

For the recharging infrastructure, most international providers of electrical equipment such as ABB and Schneider are able to provide a wide range of recharging solution for both:

- Depot charging – slow overnight; and
- Opportunity charging – fast.

The ability to successfully deploy the recharging infrastructure for opportunity charging also means that the operational range of BE buses is already above 300 km/day.

Consequently, major cities in the C40 network worldwide have already announced that public transport will be full electric by as early as 2030, for example:

- Milano: full electric by 2030[7] (see also Deliverable 3 – Depot charging); and
- Oslo: full electric by 2024[8].

For a comprehensive overview of the outcomes of European projects on electric buses, the result of the ZeUS project (2014-2018) are reported here.

6.1.1. ZeUS project

Zero Emission Urban Bus Systems

Timeline: started in 2013, closed in 2018, **Website:** https://zeeus.eu/

Transport use cases: local public transportation

Results: ZeUS was the most important EU project on urban mobility, testing innovative electric bus technologies with different charging infrastructure solutions in ten demonstration sites across Europe. Key outcomes are as follows:

- Validation that high-capacity batteries are a viable technology;
- Validation that opportunity charging is a viable solution for range extension during normal operations; and
- Observatory platform on e-buses deployment in the EU (https://zeeus.eu/demonstrations-activities/observatory-of-electric-bus-systems-activities)

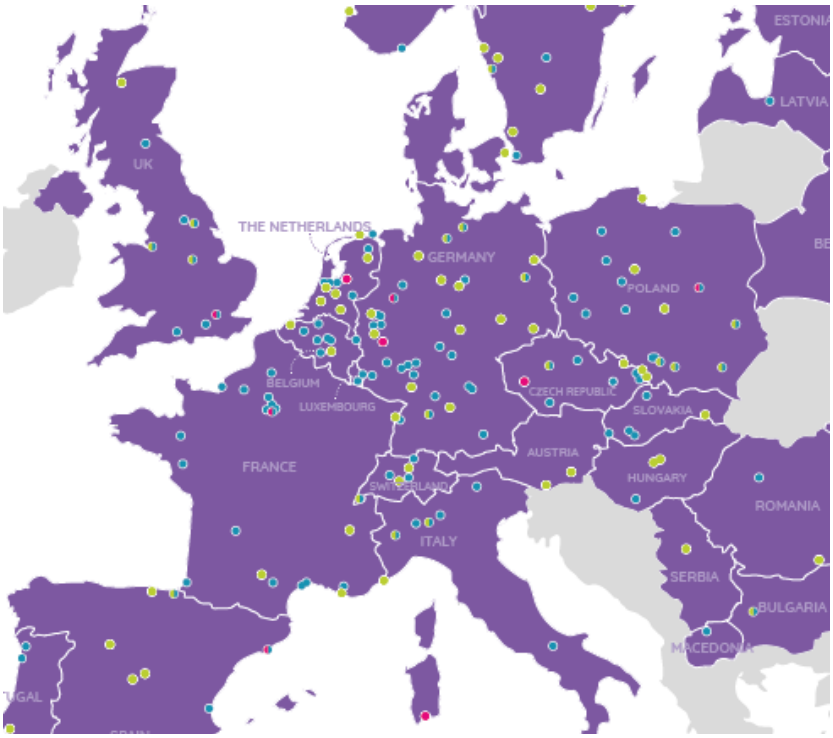


Figure 10. Map of the European cities monitored during the Zeus project (from the project Zeus e-Bus report #2 available online)

Fig. 10 shows the map of European cities that have adopted electric buses for public transport, from the ZeUS Observatory (Last update in 2018).

[7] https://www.atm.it/it/AtmNews/Comunicati/Pagine/ATMDAL2030FULLELECTRIC.aspx
[8] https://www.weforum.org/videos/oslos-zero-emission-public-transport

Impact on power system: as illustrated in Fig. 11**,** a preliminary quantification of the ration between depot charging and opportunity charging was measured on a relevant subset of municipalities in the project. The results are summarised below. No other observation was described with regard to the role of power system operators.

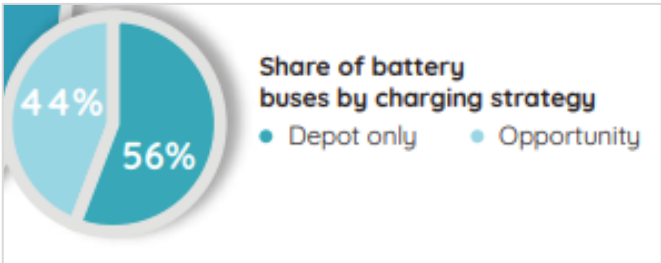


Figure 11. The share of depot charging to opportunity charging as measured during the ZeUS project in a relevant subset of the observed municipalities.

6.2. Battery Electric trucks

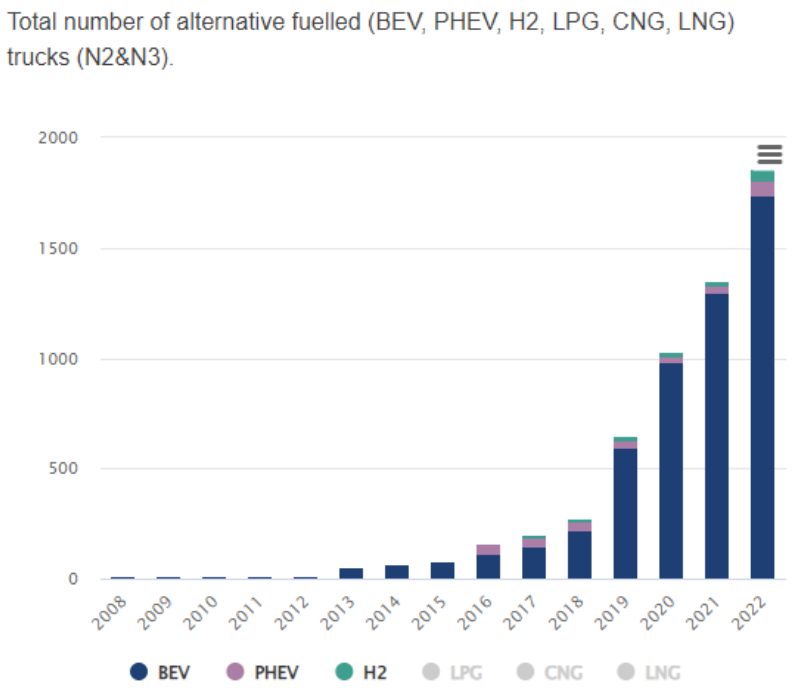


Figure 12. Total number of BEV, PHEV, H2 and LPG trucks in Europe according to the European Fuel Observatory.

As of 2022, according to the European Fuel Observatory (figure on the left), there are already approximately 2000 BEV trucks on European roads.

The vast majority of them belongs to the N2 category, which is the 'light' segment of HD vehicles, comprising vehicle gross weight in the rage 3.5 to 12 Tons, which are mostly used for local and regional delivery. However, battery electric trucks with more than 12 Ton gross weight are also available with an operational range just below 400 km/day, and this makes them already suitable for operation at local and regional level.

University research activities related to battery electric trucks are currently focusing on:

- **More powerful batteries** for extending the driving range for long haul applications; and
- **Standards and prototypes** for MegaWatt chargers to guarantee the interoperability of the public recharging infrastructure. The MegaWatt charging standard is already a draft under discussion at IEC level and is expected to be officially released by 2024. It is also expected to be single solution for all HD vehicles, including ferries, cargo ships, airplanes, and all other kinds of HD vehicles[9].

[9] https://www.charin.global/technology/mcs/

There is little research at university level on the development of electric trucks themselves as the technology for the electric power train is already well understood and optimised. The most innovative projects for the deployment of battery electric trucks are carried out directly by private companies in the logistic sector, because at this point the most important aspects are not primarily technological but more related to the actual implementation of the new solution within the business routines of logistic operators. Below are reported the most significant projects involving electric trucks from international companies operating in Europe and the world.

Key takeaways:

- > 800 km full load on single recharge achieved by TESLA;
- Logistic set to go carbon-neutral by 2040; and
- First steps already under way for regional HD transportation.

6.3. TESLA

Dec. 2022 (US) – Tesla has just announced the release of a battery electric truck with a driving range of approximately 800 km[10] fully loaded. The first tests were conducted on real world driving conditions and a few trucks have already been delivered to the commercial partner Pepsi.

Key points advertised during the conference press:

- Charging with electricity is approximately 2.5 times cheaper per mile than refueling with diesel (US prices, Dec. 2022). Estimated fuel savings of up to $200,000 within their first three years of ownership; and

- With remote diagnostics, over-the-air software updates and fewer moving parts to maintain, operators will spend less time at service centers and more time on the road.

Figure 13 Image from the Tesla website where the key performance indicators of the 'Semi' model are indicated.

[10] https://www.tesla.com/semi

6.4. Amazon

22 Oct. 2022 – Amazon has announced plans to completely decarbonise its logistic chain in Europe by 2040[11], which is 10 years before the EU goal of 2050. The plan is to go **full electric,** and the investments in the next 5 years amount to approximately 1 billion euros. The targets for 2027:

- 10,000 electric vans (3000 today);
- 1500 e-heavy-good trucks;
- Thousands of chargers inside own logistic facilities; and
- > 40 micro mobility city hubs for e-cargo bikes and light mobility (20 hubs already in operation as of 2022).

6.5. DHL

Since 2020, DHL has been running a pilot test of a **full electric** FH Truck with gross combination weights of up to 60 tons[12]. The electric truck regularly travels between two DHL Freight logistics terminals in Sweden at a distance of approximately 150 km. After this test, DHL has announced in May 2022 the purchase of 44 electric trucks from Volvo.

6.6. MAERSK

Maersk will add 300 electric trucks to its North America network, making it the largest HD electric truck deployment to date. The trucks will be delivered between 2023 – 2025. From their website[13] '*Maersk's long-term goal in North America is to move toward a **fully electric trucking fleet** to offer customers an environmentally-friendly alternative for short-haul trucking*.'

6.7. IKEA

From their website,[14] IKEA Industry, Volvo Trucks, and Raben Group have joined forces in Poland to deploy zero-emission Volvo FM Electric trucks. The trucks will handle the internal flow of goods between two IKEA Industry factories 12 kilometres apart in Zbąszynek and Babimost in western Poland. The trucks will be charged at the IKEA Industry production facilities using renewable electricity from an external source. The first electric truck will begin operation during autumn, and the plan is to expand the fleet based on the learnings from the pilot.

6.8. HOLA project

High performance charging for long-haul trucking.

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[11] https://www.reuters.com/business/autos-transportation/amazoncom-invest-over-1-bln-euros-european-electric-van-truck-fleet-2022-10-09/

[12] https://www.dhl.com/global-en/delivered/sustainability/volvo-electric-trucks.html

[13] https://www.maersk.com/news/articles/2022/03/24/maersk-to-deploy-300-electric-trucks-in-partnership-with-einride

[14] https://about.ikea.com/en/newsroom/2022/09/14/ikea-volvo-trucks-and-raben-group-accelerate-zero-emission-transport-in-poland

Timeline: started in Sept. 2021 and will run until 2024

Website: https://www.hochleistungsladen-lkw.de/hola-en/project/

Project context and objectives: Battery-electric trucks are a technology able to decarbonise the HD sector, and all major manufacturers have announced series production models for the coming years. However, charging long-haul trucks during the statutory 45 minutes of break after a driving period of 4.5 hours poses challenges regarding charging systems, energy supply and locations. The Hola project is finalised to plan, construct and operate a selected high-capacity charging infrastructure for long-haul trucks and demonstration sites along a section of motorways between Berlin and the Ruhr area. In the project two Megawatt Charging Systems (MCS) will be set up, operated and used in real logistic operations at each of the four sites along the Federal Motorway A2. Hola will consider different charging sites as motorway service stations, logistic centres and depots.

Partners:

- Fraunhofer ISI – consortium leader
- P3 Automotive – project manager
- EnBW mobility - operator of the charging locations
- ABB, Heliox and Siemens - charging infrastructure suppliers
- Daimler Truck, Traton, Man, Scania and Volvo –commercial vehicle manufactures
- Fraunhofer IAO, the University of Stuttgart, the University of Weimar, and the Technical Universities of Berlin and Dortmund – support for implementation and demonstration
    - E.Dis Netz GmbH – grid connection of the sites
    - Ionity – integration into existing sites
    - Meyer & Meyer – use of the trucks
    - Tank & Rast – locations of rest areas
    - Netze BW – grid connection
    - VDA Association of the Automotive Industry - patronage

6.9. NEFTON project

Timeline: Project started in 2022

Websites: https://www.mos.ed.tum.de/ftm/forschungsfelder/smarte-mobilitaet/nefton-nutzfahrzelektrifizierung-zur-transportsektoroptimierten-netzanbindung/

Transport use cases: HDVs for long-haul goods transportation, MW recharging station and grid integration

Project context and objectives: The Project NEFTON aims to develop a fully electric transport system consisting of a truck, charging infrastructure and power grid connection, which is centered around the MCS with up to 1.5 MW charging power. The principal industrial partner is MAN, which states[15]:

> '*MAN Truck & Bus wants to analyse the system consisting of a fully electric truck, charging station and grid connection and design it for various applications in long-distance transport. The central goal of NEFTON is the demonstration of the Megawatt Charging System (MCS) in the MAN eTruck'*

Results: yet to be disclosed

Impact on power system: a highly efficient, bidirectional charging station in the megawatt range (> 3 MW) will be developed.

Partners: the project is funded by the German Federal Ministry of Economics and Climate Protection and, beyond several research centers, has MAN as the principal industrial partner.

[15] https://press.mantruckandbus.com/corporate/nefton-man-conducts-research-in-joint-project-for-battery-electric-freight-transport-of-the-future/

7. ENTSOE's questionnaire and TSO projects

This chapter attempts to summarise the key observations gathered from the questionnaire prepared by RSE on behalf of ENTSOE and shared with ENTSOE stakeholders. The final part of the chapter gathers the information received directly by TSOs regarding the mobility projects in which they are involved.

Key conclusions from the questionnaire:

- The degree of expertise regarding the electrification of HDVs varies significantly from country-to-country. The majority of respondents declare a lack of expertise or knowledge only at research level;
- The CAPEX for power grid upgrade investments related to new infrastructures for electromobility is non negligible (>1%) for the 5 respondents;
- The majority of TSOs believe that the HDVs recharging infrastructure should be a specifically separate segment in the scenario setting / network development plans of both TSO and DSOs;
- The majority of TSOs have not yet included HDV recharging into their network development plans; and
- TSOs began acquiring relevant knowledge mainly either through internal and/or external research. However, only one stated having hands-on expertise on the different electrified powertrains and their recharging needs.

TSOs with experience in the realisation of new MW connections for charging stations, depot charging and logistic hubs have reported the following criticalities:

REN, Portugal

Regulation: The existing applicable national regulation only foresees the power supply to public EV charging either in low voltage or in medium voltage. REN's innovative solution considers a direct connection to the Very High Voltage grid: existing regulation should be adapted to explicitly consider the possibility of a very high voltage direct supply.

- The AFIR proposal does not mention the transmission system; it is advised to elaborate a position on this as most recharging stations along major European highways are expected to be in the countryside, where the distribution grid is less present and would be: 1) expensive to deploy reinforcements and 2) unfair on those who undertake the burden for grid reinforcements costs.
- There are areas where TSOs can operate connection points at the MV level without being in direct competition with DSOs.

ELES, Slovenia

Regulation: ELES as a public service that is responsible for building and operating a HV transmission power system cannot invest in recharging points or the required power infrastructure at 20 kV voltage range. A new public service company responsible for establishing and running high power charging parks was promoted by ELES.

- Slovenia is to pass new legislation by April 2023 to allow the TSO to directly auction location and power availability for high power (> 3 MW) recharging stations for HDVs.

Execution and planning: Finding the right locations in terms of both power availability and transport HDV demand is critical. A long multiyear procedure is required to prepare a state space plan with environmental compliance for all investments into the HV infrastructure. ELES solved this by actively including local municipalities and also fostering the deployment of electric public transportation. These projects were proposed as common interest projects (state-municipality), which required preparation of much faster municipal spatial plan. The critical points highlighted the following:

- It should be recognised that there is strong sector coupling and a need for a comprehensive electro-transport model to 1) identify early in advance proper locations and 2) Perform traffic flow / power demand forecast;
- TSOs better move first; otherwise they will have to cope with a huge amount of new connection requests in locations where it is difficult/expensive to operate;
- Many gas stations on the MV distribution grid can host up to 3 Megawatt chargers but this is not up-scalable after 2030 when power demand is expected to hit the 20 – 60 MW range; and
- Empty space was left for one single H2 refueling point, but as of 2022 it is unclear if it will be required to deploy H2 refueling points.

Project design: The third obstacle is to properly identify optimal locations of charging parks for transport needs, proximity of highways and available power connection. ELES solved this by preparing (still under development) a planning tool – a digital twin of an electro-transport system that comprises five crucial models (road, mobility, space, power, price) and an AI-based orchestration service that combines models into a powerful analytical tool.

- 2 locations (out of the 40 expected from AFIR requirements) were identified with the use of the analytical tool, and 40 KPIs were used. Locations were found at less than 1 km from HV lines, at the intersection between highways and HV lines;
- For the future, it would be helpful to also have analytic tools for cross border traffic information; and
- The need for local battery storage systems or PV plants was not deemed a huge benefit to the charging stations.

7.1. Speed-e project

Status: Project accomplished, EU patent.

Website: https://www.speed-e.pt/en/index.html

Project context: The Portuguese TSO REN has developed an innovative grid connection solution to supply EV charging directly from existing transmission lines. The solution includes a tap to an existing transmission line and a special small substation that transforms directly from Very High Voltage to Low Voltage using Power Voltage Transformers, to supply EV charging points. This solution complements the conventional solution of supplying EV charging from the distribution grid, contributing to solving potential constrains in the distribution grid induced by the new power demand associated to EV adoption. In addition, it enables the TSOs to have an active role in contributing to address the challenges associated with the electrification of mobility. This solution (Speed-e) was granted a patent currently valid in 32 European countries and is under examination for patent requests in the US and Canada.

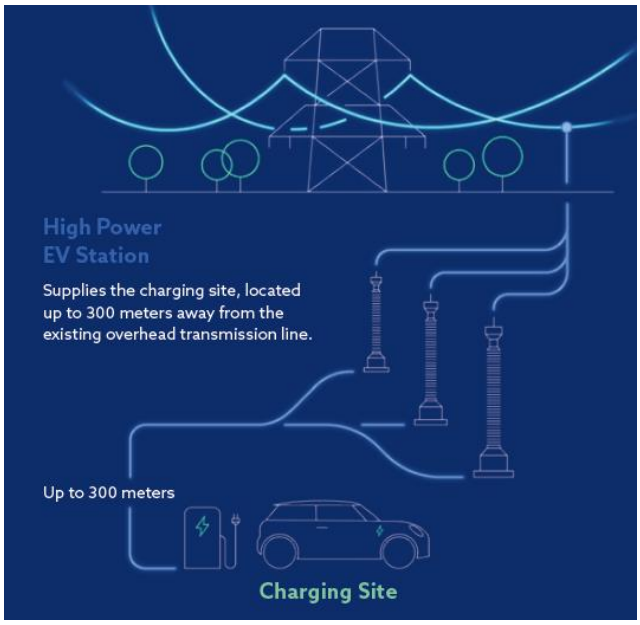

Figure 14. schematic of the architecture of the REN solution (from the project website)

Results: The realisation of a new connection solution to enable feeding Megawatt charging stations directly from HV lines in locations where the distribution grid is absent.

Impact on power system: A reduced need for reinforcement at the distribution level and a minor impact (<5%) on HV transmission lines' capacity.

7.2. Green Switch project

Status: planning phase

Website: https://www.greenswitchproject.eu/

Project context and objectives: Transmission and distribution systems and network operators from Austria, Croatia and Slovenia have a long history of cooperation, both cross-border between TSOs and between DSOs, and within each country between TSO and DSO. The Green-Switch project will provide additional cross-border capacity and optimisation of grid

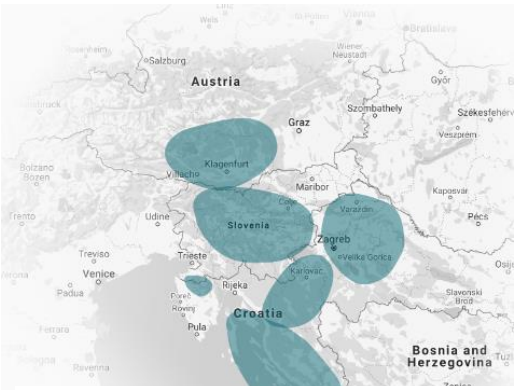

Figure 15 location of the areas of interest for the Green-Switch project

operation, extending to lower voltage levels. Many new technologies and techniques will be rolled out on this project, including:

- locational use of battery storage;
- power flow prediction and control systems;
- optimal supply of physical islands; and
- advanced approach to providing distribution grid resilience by cross-border connection.

Results: the planning and ongoing realisation of 2 recharging stations with MW capacity as discussed previously.

7.3. LogiBat project

Status: started in June 2021

Website: https://vil.be/en/project/logibat/

Logibat is a VIL (Flemish Innovation cluster for logistics) project, financially supported by Flanders Innovation & Entrepreneurship.

Project context and objectives: The aim of LogiBAT is to prepare the Flemish transport sector for the application of battery technology to realise emission-free road freight transport. In Logibat, VIL has investigated the operational and economic conditions that make battery-electric transport feasible and what the requirements are to roll out a nationwide charging network, both at shippers and depots and at (semi-) public stops. During the project, the role of the logistics companies as providers of charging infrastructure was explored. In addition, the potential for Catenary Solution in Road Systems within Flanders was also studied.

Results: yet to be disclosed