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D4.2.4 Electro bus involvement into public transport fleets

Responsible Partner

The Romanian Sustainable Energy Cluster - ROSENC

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Key conclusions and Future Outlook

- High upfront cost still remains a major obstacle for rapid and comprehensive market adoption of hybrid and electric transit buses.
- Chinese market and Chinese OEMs emerging as major forces in the market. European OEMs increasingly developing global competitiveness and will benefit more in long term
- Distinct trend of vertical integration and Tier I supplier partnerships seen to emerge among Western and Chinese OEMs respectively.
- Uncertainty in government funding and incentives favouring hybrid and electric transit buses to continue. This is necessitating recalibration of business models.
- Growth in parallel hybrid adoption driven by price sensitivities in both developed and developing markets and economies of scale gained from truck market.
- Providing market-specific solutions and maintaining good relation with local transport authorities will be key to win in these markets. Developing global product platforms with flexible architecture to meet local specifications will help to keep check on cost and respond quickly to competition.
- Price competitiveness of parallels will continue pulling the market towards this technology. This is gaining momentum as BAE and Allison are gravitating towards offering parallel hybrid solutions in their portfolios. This will bode well for the market as it will ensure focused technology and market growth and evolution.
- Ultra capacitors hold the potential to disrupt energy storage systems market and their superior power density can threaten expensive Li-ion technology. Li-ion and Ni-MH technology focused OEMs and suppliers must step up battery technology focused R&D to reduce prices faster than before.

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List of abbreviations

AER – All Electric Range

BAS – belted alternator starter

BEV – Battery electric vehicle

eBus - Electric Bus

FCEV – Fuel Cell Electric Vehicle

GHG – Green House Gases

GPP – Green Public Procurement

H&E – Hybrid and Electric

HD – Heavy-Duty

HEV – hybrid electric vehicle

ICE – Internal Combustion Engine

ISG – integrated starter-generator

Li-ion – Lithium-ion

OEM – Original Equipment Manufacturer

PHEV – plug-in hybrid electric vehicle

UC – ultra-capacitors

Introduction

In recent years, urban mobility has been high on the agenda due to increasing urban populations and the associated transport-related congestion and pollution in cities. With intense competition for urban space, transport planning has significant impacts on quality of life for citizens. The notion that mobility is about more than simply moving vehicles and people is recurring theme for researchers, planners and policy makers alike acknowledging the potential for mobility to transform cities into more sustainable, liveable areas.

The study is structured in 6 chapters as it follows:

1. Introduction

Introduction includes a basic description of the feasibility study about electro bus involvement into public transport fleets.

2. Review and a brief description of existing projects and studies

This section covers an overview and description of existing projects and studies on electro bus involvement into public transport fleets. Overview of existing projects and studies will be the basis for the preparation of eGUTS standards and local action plans. Partners contributed with an overview and description of existing projects and studies at a local level (by country).

3. Development of electro buses

Review of the development of electro buses is a very important part of the feasibility study from the standpoint of preparation of eGUTS standards and the local action plan. It contains a very short overview of how electro buses have developed over time, describes existing technologies (technological solutions, infrastructure requirements) and characteristics (range vs charging time, top speed, etc.), required infrastructure.

This section describes:

- Existing solutions, trends and specifications of electro buses and required infrastructure
- The state of development of electric public transport in their country/region.
- Brief description of involvement of electro buses in public transport in each country/region and its expected use.

4. Necessity and opportunity of electric buses

- This chapter includes:
- Main advantages and disadvantages of electro buses (SWOT analysis).
- Key barriers for implementing electro buses into public transportation system in each country/region.
- Cost-benefit analysis
- Main solutions to overcome barriers

5. Plans and incentives for further development

This section includes:

- Plans and implementation steps for utilization of electro buses in public transport systems in your country/region.
- Incentives for the development of use of electro buses in public transport system.

6. Conclusion

The conclusion of the feasibility study.

7. References

2 Development of electro buses

2.1 Worldwide state of development

The development of electric buses is growing from year to year in terms of both technology and acceptability. Worldwide, the technology is metamorphosing yearly becoming more suitable for public use and need. One of the most important issues that tackle the electric transportation is the high level of CO2 emissions generated by all means of transportation. The following graphic shows a report of 2014 GHG emissions given by transportation per passenger-km:

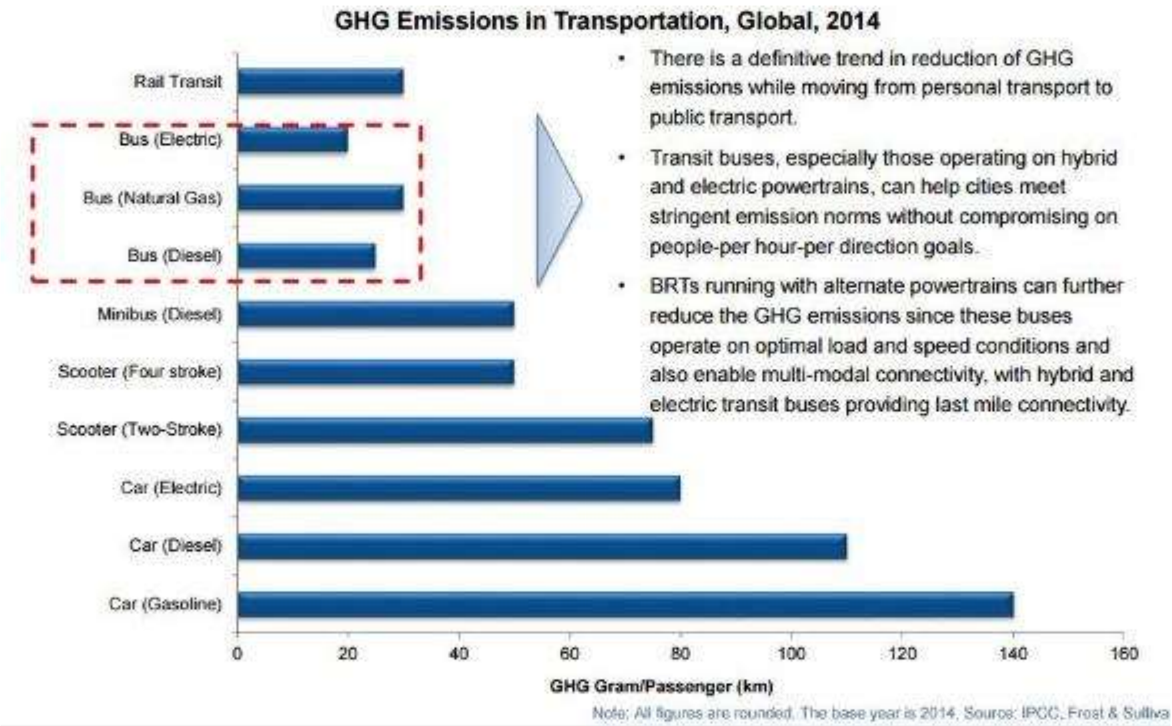

Figure 1. GHG Emissions in Global Transportation ***Source:*** ***https://www.slideshare.net/FrostandSullivan/strategic-analysis-of-global-hybrid-and-electric-heavy-duty-transit-bus-market?next_slideshow=1***

The 2015 global electric bus stock is estimated to be close to 173.000 vehicles, almost entirely located in China. Close to 150.000 of these are battery electric buses, running 100% on electricity.

The electric bus stock grew nearly six fold between 2014 and 2015, demonstrating support for rapid public transport electrification from the Chinese government, which is driven by the urgent need to limit air pollution levels in Chinese cities. By 2020, China plans to have over 200.000

electric buses on its roads, accompanied by a network of close to 4.000 charging stations dedicated to buses.

In other countries, electric bus fleets do not reach the level of China – in the EU-28 there are more than 500 battery electric buses with the highest numbers in Austria, Belgium and the Netherlands (European Environment Agency, 2016). Still the bus fleets are moving towards alternative fuels - only in there are currently 2.307 hybrid buses, 8 hydrogen fuel cell buses, and 71 pure electric buses in use out of a total bus fleet of 9.588.

A variety of models of hybrid vehicle are currently used. These include Alexander Dennis Enviro200H, Wright Electrocity, Optare Tempo and BYD electric bus single-deckers and Volvo B5LH, Wright Gemini 2, Alexander Dennis Enviro400H, New Routemaster and Wright SRM double-deckers.

The ***Strategic Analysis of Global Hybrid and Electric Heavy-Duty Transit Bus Market*** show some interesting perspectives, for the transition to hybrid and electric buses:

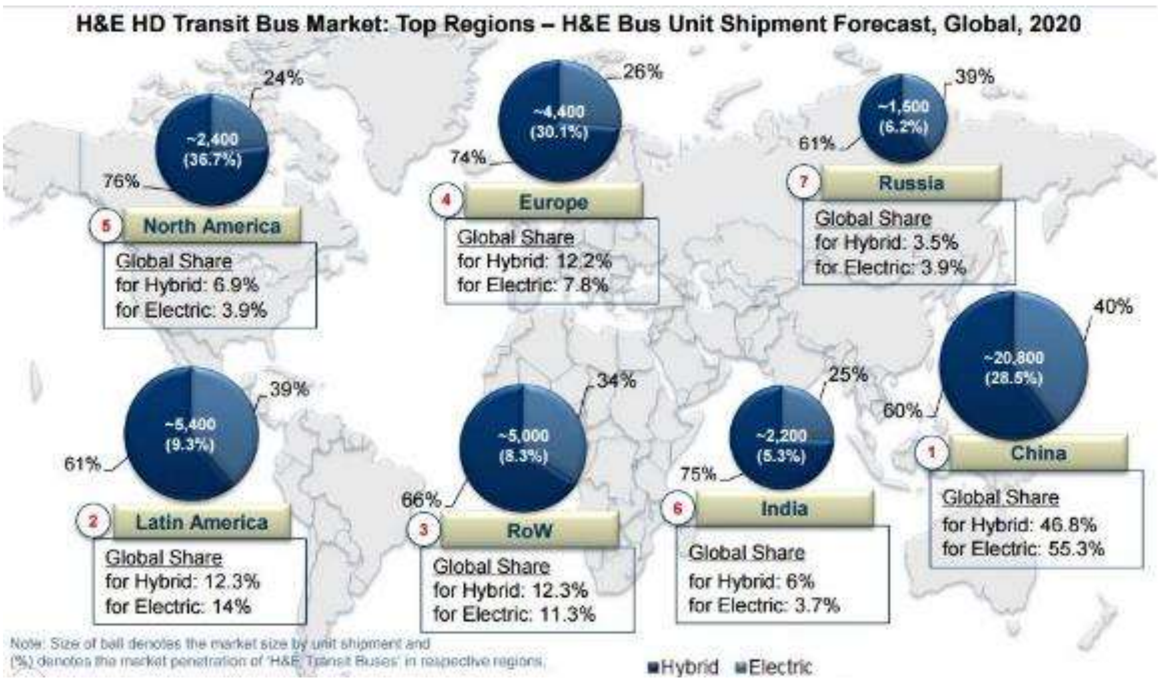

Figure 2: Hybrid and Electric Transit Bus Market/Regions

Source: [***https://www.slideshare.net/FrostandSullivan/strategic-analysis-of-global-hybrid-and-electric-heavy-duty-transit-bus-market?next_slideshow=1***](https://www.slideshare.net/FrostandSullivan/strategic-analysis-of-global-hybrid-and-electric-heavy-duty-transit-bus-market?next_slideshow=1)

As shown above, the share of H&E buses is likely to increase to 15% from the current 5.5% of total transit bus sales.

In terms of Unit Shipments of electric and hybrid buses, the graphic bellow show the main OEMs from 2014:

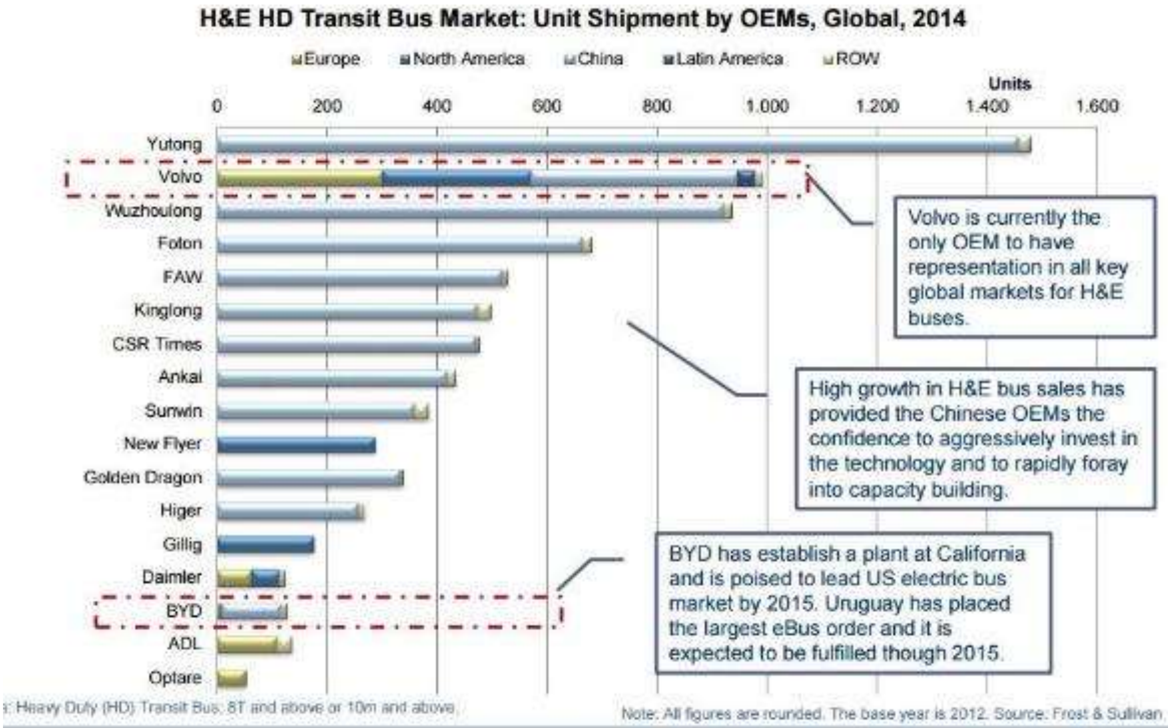

Figure 3: Bus Market - Unit shipments by the main OEM's

Source: ***https://www.slideshare.net/FrostandSullivan/strategic-analysis-of-global-hybrid-and-electric-heavy-duty-transit-bus-market?next_slideshow=1***

The biggest manufacturer in Europe is the VOLVO Company. According to the company's state report, their policy involves a path to Energy Efficiency and Green Efficiency:

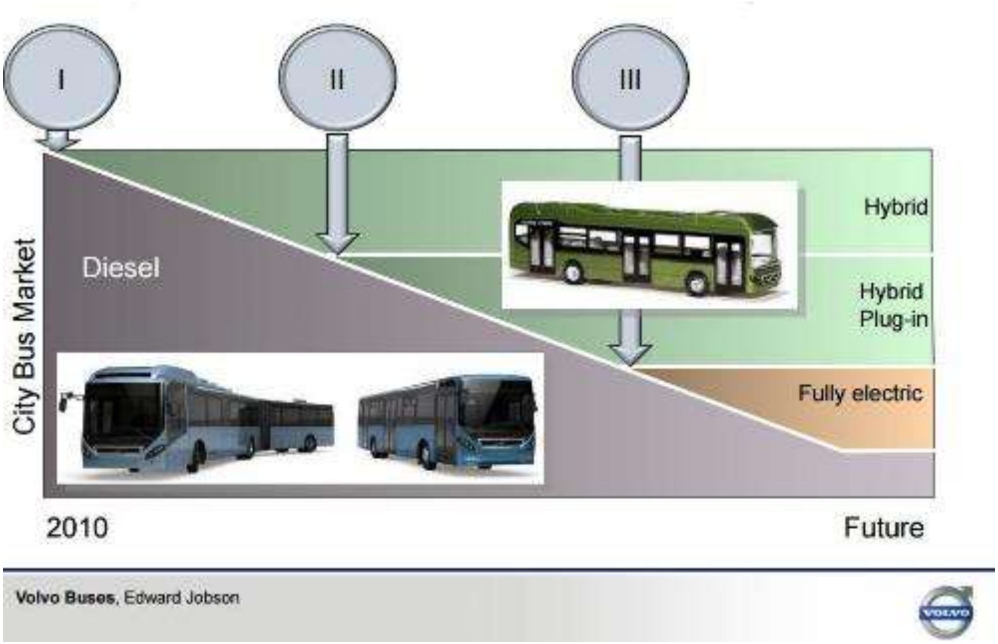

Figure 4: VOLVO's direction in bus manufacturing ***Source:*** http://nho-transport.no/getfile.php/Filer/Foredrag%20og%20innlegg/Seminar%20GF%202012/VOLVO%20Buss%20Environmental_Jobson.pdf

In 2016, Volvo sold 533 electrified buses, encompassing hybrids, electric hybrids, and all-electric buses. The largest single market for Volvo's hybrid buses thus far is the UK, which accounts for almost half (1.425) of the total of 3.000 sales. Other major markets are Colombia (468), Sweden (196), Spain (137), Germany (135), Switzerland (129) and Norway (109). Over the past two years, demand for Volvo hybrid buses has also increased in Eastern Europe, with a healthy sales trend in Estonia (44) and Poland (48).

2.2 Technology Definition

An electric vehicle (EV) is a vehicle that is powered, at least in part, by electricity. EV configurations include battery electric vehicles (BEVs) which are powered by 100% electric energy, various hybrid-electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs). This summary presents the differences between these basic EV configurations.

1 Battery Electric Vehicles

A battery electric vehicle (BEV) is a vehicle that is powered entirely on electric energy, typically a large electric motor and a large battery pack. Based on the type of transmission; the use of a clutch, gearbox, differential, and fixed gearing; and the number of battery packs and motors there are many variations on the BEV design. However, a basic BEV system is shown in the figure below. Configurations below apply to all multi-wheeled EVs including buses.

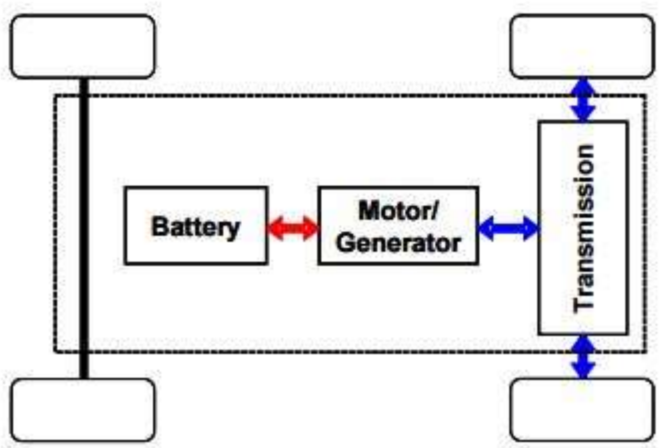

Figure 5: Schematic of a battery electric vehicle (BEV) powertrain ***Source:*** http://web.mit.edu/evt/summary_powertrains.pdf

2 Mild Hybrid Electric Vehicles

Unlike a BEV, a hybrid electric vehicle (HEV) relies on two energy sources, usually an internal combustion engine and an electric battery and motor/generator. A Mild Hybrid is the least electrified type of HEV. A Mild Hybrid is a conventional internal combustion engine (ICE) vehicle with an oversized starter motor that can also be used as a generator, usually called an integrated starter-generator (ISG) or a belted alternator starter (BAS), and an oversized battery that powers and is recharged by the motor. A simple Mild Hybrid system is shown in figure below. In a Mild Hybrid, the engine must always be on while the vehicle is moving. However, the motor/generator can be used to enable idle stop in which the engine is turned off while the vehicle is at idle. The motor/generator can be used at high loads to assist the engine and increase vehicle performance. At low loads, it increases load on the engine and recharges the electric battery.

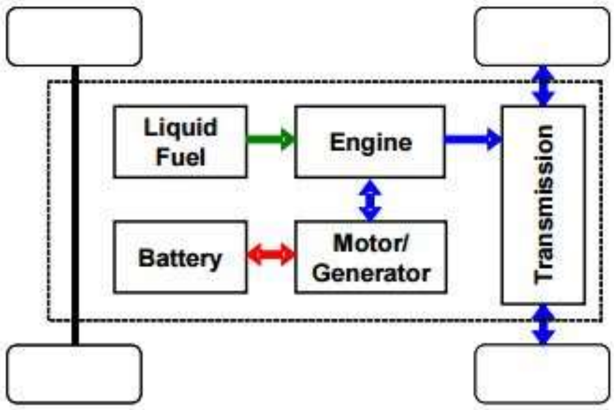

Figure 6: Schematic of a Mild Hybrid powertrain ***Source:*** http://web.mit.edu/evt/summary_powertrains.pdf

3 Series Hybrid Electric Vehicles

In a Series Hybrid there is a single path to power the wheels of the vehicle, but two energy sources. As shown in figure 7, the fuel tank feeds an engine which is coupled to a generator to charge the battery which provides electrical energy to a motor/generator to power the wheels through a transmission although a direct coupling can also be used.

The motor/generator is also used to recharge the battery during deceleration and braking.

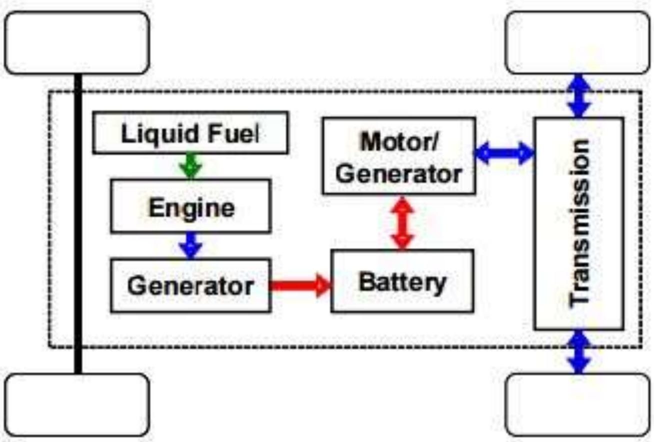

Figure 7: Schematic of a Series Hybrid powertrain ***Source:*** http://web.mit.edu/evt/summary_powertrains.pdf

The Series Hybrid can operate in the following seven modes:

- Engine only traction
- Electric only traction
- Hybrid traction
- Engine Traction and Battery Charging
- Battery Charging and No Traction
- Regenerative Braking
- Hybrid Battery Changing

Although most Series Hybrids use an ICE, it is also possible to design a Series Hybrid using a Fuel Cell powered by hydrogen, creating a Fuel Cell Electric Vehicle (FCEV).

4 Parallel Hybrid Electric Vehicles

In a Parallel Hybrid, there are two parallel paths to power the wheels of the vehicle: an engine path and an electrical path, as shown in figure 8. The transmission couples the motor/generator and the engine, allowing either, or both, to power the wheels. Control of a Parallel Hybrid is much more complex than of a Series Hybrid because of the need to efficiently couple the motor/generator and engine in a way that maintains driveability and performance.

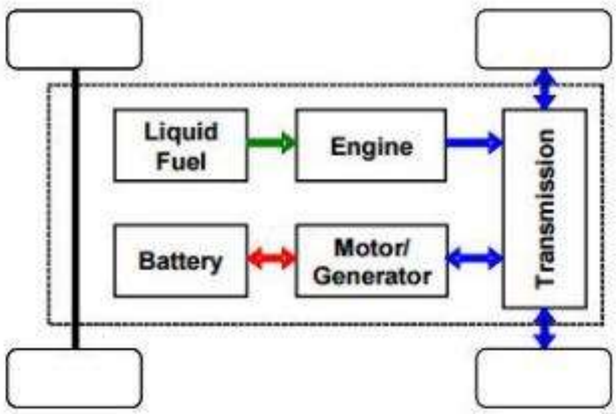

Figure 8: Schematic of a parallel hybrid powertrain ***Source:*** http://web.mit.edu/evt/summary_powertrains.pdf

The Parallel Hybrid can operate in the following five modes:

- Engine only traction
- Electric only traction
- Hybrid traction
- Regenerative Braking
- Battery charging from the engine

5 Series-Parallel Hybrid Electric Vehicles

A Series-Parallel HEV has both Series and Parallel energy paths. As shown in figure 9, a system of motors and/or generators that sometimes includes a gearing or power split device allows the engine to recharge the battery. Variations on this configuration can be very complex or simple, depending on the number of motors/generators and how they are used. These configurations can be classified as Complex hybrids (such as the Toyota Prius and Ford Escape Hybrids), Split-Parallel hybrids, or Power-Split hybrids.

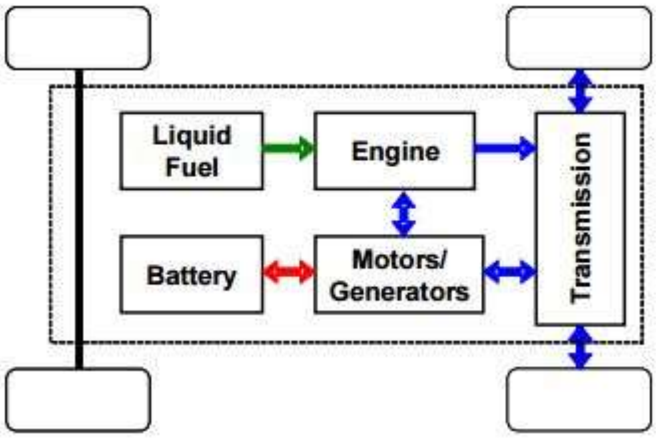

Figure 9: Schematic of a series-parallel hybrid powertrain ***Source:***

http://web.mit.edu/evt/summary_powertrains.pdf

6 Plug-in Hybrid Electric Vehicles

A plug-in hybrid electric vehicle (PHEV) is an HEV that can be plugged-in or recharged from wall electricity. PHEVs are distinguished by much larger battery packs when compared to other HEVs. The size of the battery defines the vehicle's All Electric Range (AER), which is generally in the range of 50 to 80 kilometres. PHEVs can be of any hybrid configuration. Although no PHEVs are available on the market today, a number of companies have begun to sell conversion kits and services to convert a standard HEV into a PHEV by adding additional battery capacity and modifying the vehicle controller and energy management system.

2.3 State of development per country / region

2.3.1 Romania

The state of development in Romania in terms of Electric buses is relatively low, some technological concepts have been assessed by some municipalities, in terms of engaging in "try-it-out" programs.

The first, in 2015, was the test of Chinese manufacturer BYD K9 electro bus. The routes accessed by the electric bus were in-town-routes, of about 200 km/ day.

Technical specifications

BYD's official specs publication on its electric bus includes:

- Electric power consumption: less than 100kWh/60mins
- Acceleration: 0–50 km/h in 20s
- Top speed: 96 km/h
- Normal charge: 6h for full charge
- Fast charge: 3h for full charge
- Overnight charging: 60 kW maximum power for 5h full charge
- Range: 249 k (299 km according to some reports)

- Length*Width*Height: 12,000mm*2,550mm*3,200mm
- Standard seats: 31+1 (31 for passengers and 1 for driver)
- Weight: 18,000 kg
- Clearance between one-step entry and ground: 360mm

The results of bus testing were not the best, since there appeared many unwanted situations across the country: most common was the discharge of batteries due to low temperatures.

Nevertheless, there are two cities in Romania (Bucharest and Cluj- Napoca) that are in the process of documentation preparation for the public acquisition of 100 e-busses (Bucharest) and 30 busses in Cluj – Napoca. This will set a big precedent for Romania and will allow other municipalities to use their example in terms of investments and technological requirements. The acquisition of electric buses will also allow private companies to generate venture capital for the development of needed infrastructure.

2.3.2 Czech Republic

1 Technological concepts for electric buses

A. Škoda Electric Plzeň

a. Škoda PERUN HE 26BB

Is a standard 12 m three-door, low-entry urban bus, with electric drive using the bodywork of a Polish producer Solaris Urbino 12 electric. Seating capacity is 27 and standing capacity 58. The entry floor height is 320 mm at the first and second doors, and 340 mm at the third door; lowered floor for the passengers along the whole length. Air conditioning available only at the driver's seat.

The bus is equipped with a traction motor Škoda 4ML 3444 KK/4 with power of 160 kW located in front of the rear axle. The bus uses lithium-polymer (Li-Pol) high energy batteries. Total number of battery cells in the vehicle is 1 134 which are divided into 54 modules with 18 cells. In order to optimize occupancy, two boxes are located at the rear part of the bus and 1 box close to the front wheel. Battery capacity: 222 kWh – driving range per charging 150 km. Charging is made with a standardized connector COMBO II through the socket from the grid 3×400 V. The vehicle is conceptually designed to be charged within 70 minutes; night balanced charging takes 6 – 8 hours.

b. Škoda PERUN HP 26BB

It is a similar conception vehicle to Škoda PERUN HE 26BB. The difference is based on an ability of opportunity charging with driving range around 30 km.

The bus is equipped with a motor 4ML 3444 KK/4 with power of 160 kW located in front of the rear axle. The bus uses lithium-ion (Li-ion) high power batteries using nanotechnologies for faster charging (anode covered with a nano-layer of titanium dioxide). Total number of battery cells in the vehicle reaches 560 which are divided into 56 modules with 10 cells, located in three battery boxes identical to those in the type HE 26BB. The capacity of batteries is 76 kWh – driving range per charging 30 km. Fast charging is made in terminuses from consoles using electric current of up to 1000 A for 6 – 8 minutes, night balanced charging takes 6 – 8 hours.

c. Hybrid trolleybuses Škoda

Škoda has produced trolleybuses with an auxiliary diesel generator for a long time. The diesel generator allowed a ride outside the overhead line, although this is not a zero emission solution. The first hybrid trolleybus produced by Škoda was a vehicle designed for the operation in Landskrona (Sweden). The trolleybus Solaris Trollino 12 with electric equipment Škoda uses a battery Altair Nano 450V with capacity of 54 kWh, which allows a driving range of approx. 20 km off the traction overhead line. The daily mileage is approx. 170 km, out of which 60 % is the battery ride and just 40 % of rides are under the traction grid. Since then subcontracts have been made for electric parts of contracts for Salzburg, Budapest, Szeged, Cagliari and Castellón. Regular production of fully zero-emission vehicles of Škoda 26Tr and 27Tr, (although design is identical to Solaris/Škoda Trollino 12 and 18) with an auxiliary battery drive, started in 2016. The trolleybus uses nLTO (Lithium-titan-oxide) batteries which manage higher charging currents without life span degradation with total capacity of 80 kWh (can be changed on requests by customers) with 414 cells in two boxes at the rear of the vehicle with the weight of 760 kg.

B. SOR Libchavy[1]

a. SOR EBN 10.5 and SOR EBN 8

The basic model and the first electric bus of the manufacturer SOR is the 10.5 m three-door low-entry urban electric bus, from which a later shorter 8 m version was derived. The electric bus SOR EBN 10.5 is a low-entry urban bus designed for zero-emission transport of passengers, particularly in urban and environmentally sensitive areas. Transport capacity is 85 passengers (19 seats) and corresponds with standard urban buses with the length of 10.5 – 11 meters. The bus can be modified for transport of skis and bicycles for the operation in tourist centers.

The traction system contains an asynchronous three-phase motor with nominal power of 120 kW and traction inverter based on IGBT transistors. The traction Li-Ion accumulators Thunder-Sky have the total capacity of 172 kWh. The durability of accumulators defined by a decrease to 80 % of the original capacity is set for assumed durability of the whole bus, i.e. approx. 400,000 km.

The electric bus SOR EBN 10.5 driving range is approx. 130 km in common urban traffic (average occupancy rate of 50 %) at the consumption of approx. 0.87 to 0.9 kWh/km. A common electric socket 3x400V-32A is sufficient for slow charging. Reaching the full capacity takes approx. 7.5 hours (the capacity for driving approx. 25 km is reached within 1 hour). A charging station 3x400W-250A with safety and control functions is supplied for fast charging. The charging current is set on the basis of the available time for charging. The minimum charging current of 250 A fills the capacity for approx. 100 km of driving within 0.5 hour. A drawback of this model series is not entirely zero emission operation, since the vehicles are equipped with an auxiliary diesel heating generator. This model series is not produced anymore; it was replaced with an enhanced conception described in the next Chapter. In common traffic these vehicles can be seen in the following localities: Ostrava, the Jeseníky mountains, Krnov, Košice (SK), Kassel (DE) and Grevesmühlen (DE).

[1] http://www.sor.cz/

b. SOR EBN 8/9.5/11

Currently offered portfolio of SOR in the field of eMobility is represented by an innovated production range, whose flagship is an electric bus with 11.1 m length, capacity of 93 passengers, and driving range of 130 – 150 km per charging. In contrast to the previous generation of vehicles, this is a fully zero-emission traffic solution, including the use of electric heating and air-conditioning. The vehicle with maximum speed of 80 km/h uses an electric motor with output of 120 kW (max. 180 kW) and lithium-ion batteries with capacity of 172 kWh. Electric equipment was supplied by Cegelec. The offered versions include either fast charging with connection to the power grid 3x400V, or a bipolar pantograph using the energy from the tram/trolleybus network.

The electric bus SOR EBN 9.5 is based on the previous model. It is a two-door bus with the length of 9 790 mm, width of 2 525 mm and height of 2 920 mm, with capacity of 26 sitting passengers and 43 standing passengers with a wheelchair or stroller accessible area. The vehicle is equipped with the identical drive technology, the driving range per charging ranges between 140 and 160 km, the kerb weight is 9 600 kg.

c. SOR ENS 12

A new vehicle in the manufacturer's production programme, introduced in September 2016 with a new design. Apart from the electric bus, other versions will be derived, including trolleybus, diesel, LE (low-entry), and articulated buses, so that the manufacturer could cover the whole portfolio of customers' requirements. There are currently two prototypes designed for presentation purposes.

d. Hybrid trolleybuses[2] SOR

In 2016 the company presented its own solution of a hybrid vehicle based on the trolleybus SOR TNB 12, using electric equipment from Rail Electronics CZ. Trolleybuses SOR have their bodywork derived from the bus SOR NB 12 City (prospectively from electric bus SOR ENS 12). Semi-automated collectors are supplied by Faiveley (ex Lekov). Electric motor TAM 1050C6S has the power of 175 kW. Batteries Li-Pol from EVC Hulín are assembled from 228 cells in boxes on the vehicle roof with the capacity of 56.4 kWh. The assumed driving range is 10 – 15 km and duration

[2] *Technology where the bus connects to an overhead power line and charges the battery whilst driving*

3000 charging cycles. The prototype was completed in DP public transport company Brno, where the vehicle is being tested.

C. Ekova (Ostrava)

a. Ekova Electron

A new Czech manufacturer introduced their own 12 m bus in 2016. Its specific feature is that the electric bus has the electric motor directly inside of the rear axle wheels. Several vehicles were supplied to German and Swedish market, but the vehicles in the Czech Republic are still in intensive testing phase in Ostrava.

In the past, Ekova, a subsidiary of Ostrava Transport Company, participated in the construction of the first hybrid trolleybus in Europe, designed for Eberswalde. In 2014, the company acquired a production documentation from a manufacturer Tedom, which they modified for their own production of electric buses. Therefore, it is not an electric version of an existing diesel bus. A specific feature of Ekova Elektron is a version with the use of synchronous motors Ziehl-Abegg in wheel hubs (each 113 kW), which provides higher efficiency (lower consumption, better recuperation). A more conventional version with a single synchronous electric motor TM4 with output of 155 kW (drawbacks of this solutions are higher noise, lower reliability, and more complicated maintenance) was developed for Eastern Europe, where price is often preferred to utility properties. The vehicle is standardly equipped with batteries of total capacity of 190 kWh (840 cells Li-Ion with technology NMC=nickel-manganese-cobalt in five boxes; driving range 150 km) or 265 kWh (7 boxes with 168 cells; the same battery type, driving range 220 km), which is reflected in passenger capacity.

Charging has four solutions; all of them work with four-pole connection

- night with power of 43 kW COMBO2 (voltage 600 V and current 70A) – takes 5 or 8 hours, charger output can be increased to 90 kW
- socket type II directly on vehicle – also 43 kW, voltage 3x400V and current 63A, charging time similar to COMBO 2
- fast charging – fast charging robotic arm DAAS – 600 V and current 300 to 400 A, i.e. approx. 3 kWh is stored within one minute

- fast charging – using aluminum collector which is connected to a console placed on a pole. Allows current up to 1000 A at 600 V DC. Transfers up to 10 kWh within a minute.

Vehicles of lengths of 10.5 m, 12 m and 18 m are offered in the market. In some countries Ekova has its own distributors offering the vehicles in their markets under their own brands, thus Elektrons can be seen under names Hybricon Bus System (HBS) or Blue City Bus. Apart from the two prototypes, there are 5 vehicles in Germany and 7 vehicles in Sweden in regular traffic.

D. SKD Trade

a. Stratos LE 30E

Electric bus STRATOS LE 30e is a low-capacity vehicle with the length of nearly 7 meters based on Iveco Daily chassis. The capacity is 15 standing passengers and 13 sitting passengers. Its drive is an asynchronous four-pole motor (liquid cooling, two-bearing with output of 84 kW, voltage 340 V) with reduction transmission with constant ratio.

Traction accumulators contain 174 cells LYP 160AHA with the voltage of 3.18 V/cell at maximum battery discharge. The charging and discharging process is controlled by BMS from EVC Group. The accumulators allow the driving range of the minibus according to UITP, cycle SORT 2 max. 148 km per charging. Charging of accumulators is made through a charging cable RS400-32 with a control unit. At one side of the vehicle, the cable is equipped with a 7-pin plug, at the side of the power grid 3x400V/50Hz normalized 5-pin plug with rated current 32 A. Charging time is max. 8 hours, fast charging to 70 % takes 165 minutes.

This model has just a prototype which is used for presentation and testing purposes, it has never been put into regular traffic so far.

E. EVC Group

a. Rošero First Electric FLF/BLF

A battery minibus developed by a Czech battery producer in cooperation with a Slovakian bodywork company Rošero-P on a Iveco Daily chassis. Technical specification: Maximum electric motor output of 150 kW, its power supply is four battery cells NMC with capacity of 100 kWh placed under the vehicle floor. Slow charging to full capacity takes up to 8 hours. Using a fast charger reduces the charging to 1.3 hours. Highest speed 100 km/h; driving range per charging 170 or 212 km; total capacity by the type 22-31 passengers including a wheelchair.

A single vehicle is registered in the Czech Republic, produced in 2012 and rented by a dealer ZLINER for presentation purposes to different Czech towns and cities. Other vehicles are operated in Sweden.

F. Experimental vehicles

a. Electric bus Škoda 21Eb

The first concept developed in the Czech Republic and one of the first in the world. The bus has a low entry floor with a ramp for the impaired, and with a bodywork of a trolleybus Škoda 21TrAC. The source for an asynchronous three-phase electric motor is an Ni-Cd accumulator with nominal capacity of 180 Ah and voltage 650 V. Total weight of the vehicle is 18,000 kg, driving range is 110 – 130 km, maximum speed 70 km/h.

Traction accumulators are charged by a power supply of 500V/200A. The rectifier is formed by a controlled thyristor bridge. The bridge is controlled by a special fast processing unit which allows communication with a PC and the vehicle monitoring system. The chassis was designed took into account the use of power supply. The installed power supply 500V/200A works with outlet voltage of 500 V and output current of 200 A. Separate parts of the accumulator are used for controlled fast charging.

A single vehicle was produced as a functional prototype, which was used in regular operation by ČAS Service MHD Znojmo. Serial production fell through, allegedly due to missing subsidy support from the government. In addition, the bodywork supplier (Škoda Ostrov) terminated the production.

b. TriHyBus

A world unique vehicle with a triple hybrid drive system. The TriHyBus can use energy from three different sources – from a fuel cell, from accumulators, and from ultra-capacitors. The energy flow is designed so that the bus motor would always use the most suitable mix, which guarantees lower consumption of expensive hydrogen, and still longer driving range than similar hydrogen buses elsewhere in the world. The TriHyBus works very efficiently with recuperation: the energy which is wasted in common operation is captured in ultra-capacitors and used when higher output is necessary. The basic source of energy for the TriHyBus is the electricity from fuel cells (Proton Motor manufacturer, output approx. 50 kWe), Li-ion battery (10 kWh, 40 kW), and ultra-capacitors (1.2 kWh, 200 kW). A control system was developed for the cooperation of all energy sources. The control system optimizes the flow of energy in the system of traction motor charging and allows the recuperation of energy into secondary sources.

The only produced vehicle is owned by Nuclear Research Institute (ÚJV Řež), and has been tested for a long time in operation by Arriva Praha in the public transport network in Neratovice.

2 Operation of electric buses in public transport systems

The first regular operation in public transport in the Czech Republic (and one of very first in the world) took place as early as in 2003. Along the whole time of increasing the awareness of electric buses for the professional community and the public, individual producers have been trying to present their vehicles to individual transport operators as well as to the travelling public. Some of the electric buses were tested in virtually all Czech cities with larger city public transport networks, as well as by small operators. Apart from the presentation of zero-emission transport potential, the idea was to test the properties of vehicles in specific routes in real operation. Virtually all domestic models described above can be mentioned, as well as some foreign vehicles, such as AMZ City Smile 10E, BYD ebus-12, Solaris Urbino 8.9 Electric, and Siemens Rampini Alé EL.

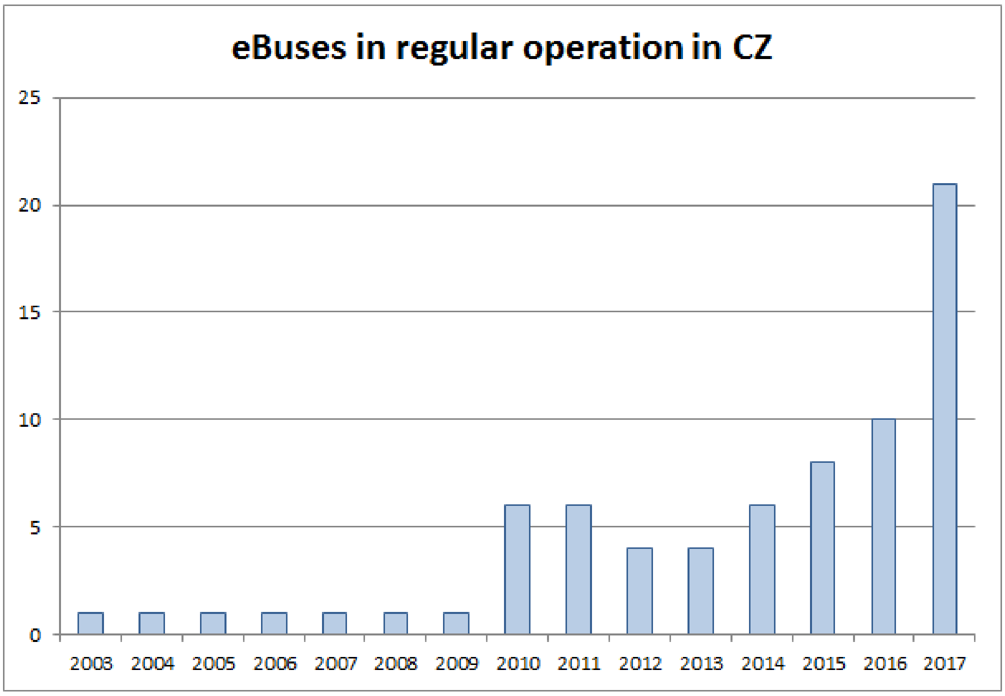

Figure 10: Number of electric buses in regular operation in CZ (as of 25 April 2017)

Only some of the concepts were used in regular operation, some of them were just used for testing and demonstration rides. Figure 10 shows the historical trend in the number of electric buses used in regular operation by the transport operators, i.e. without the vehicles in testing operation and hybrid trolleybuses.

The following chapters summarize basic information and findings from long-term testing as well as regular operation in different Czech and Moravian towns and cities.

a. Testing operations - long-term Praha

In cooperation with the manufacturer SOR, Prague Public Transport Company performs long-term testing of an electric bus SOR EBN 11 in real operation. Since September 2015 a vehicle has been tested in urban type routes Nos. 213 and 163, where it covered 70,000 km within the first year of testing. A special charging station for fast charging with the use of bipolar pantograph was established in the terminal Želivského. When using charging operation breaks, standard driving range of the electric bus with passengers is between 265 and 350 km. The first results are shown in Figure 17. The complex evaluation of the operation should be available after the end of the two-year testing cycle, i.e. autumn 2017.

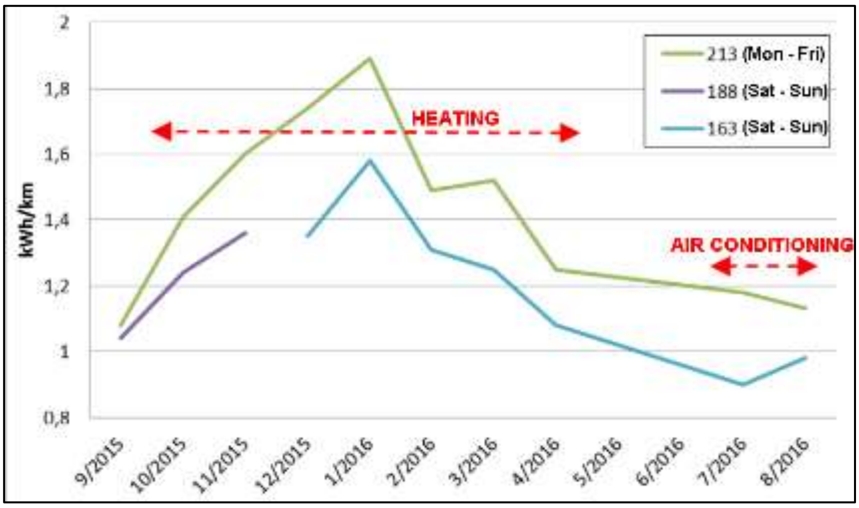

Figure 11: Average electricity consumption during testing on different lines, *Source: Daňsa (2016)*

b. Testing operations - long-term Plzeň

Two full electric buses ŠKODA PERUN HP 26BB are being tested in combination with fast charging infrastructure in order to show the possibility of substituting diesel buses within the ZeEUS project. The system for fast charging was selected as the best effective solution for the combination between the distance of the bus route, time for charging and also required passenger capacity. The buses are operated on standard city bus route No. 33 with the length of 7 km each way. The route 33 was chosen for multiple reasons: it starts in the historical centre, passes around the university hospital before reaching the terminus at one of the most densely populated suburbs of the city. It has an elevation about 100 m, so it allows effective testing of recuperation of the braking energy into the batteries.

c. Testing operations – long-term Neratovice

An experimental TriHyBus is irregularly used on a public transport service in the town of Neratovice, operated by Arriva Praha according to the requirements of the vehicle owner, which is Nuclear Research Institute (ÚJV Řež). The vehicle is mostly used for testing of technology and developing of individual components. In order to allow the operation of the vehicle the first hydrogen filling station in the Czech Republic was opened. The station allows the vehicle to cover 300 km after a 10-min refueling.

d. Regular operations – Znojmo

In 2003 to 2009 a transport operator ČAS Service operated a single vehicle, developed as a functional sample within a research project. The operating costs specified by the operator reached CZK 0.78 per 1 km. The vehicle has only been used sporadically after 2009, since the public transport operation has been taken over by another operator.

e. Regular operations – Prague

Two Italian minibuses Breda/Menaribus ZEUS M 200 E 5.9 meters were in operation by Prague Public Transport Company in 2010 to 2012. Both vehicles took turns in operation after every 4 hours. Daily driving range reached approx. 110 km at the consumption of 0.44 kWh/km under full load. They were used for service on a short route No. 292 with a high elevation difference to a hospital under Petřín hill. After a two-year operation before the end of the warranty period, both vehicles were returned to the manufacturer due to high breakdown rate, particularly of mechanical parts. The reason was the expected high costs after the end of the warranty period.

Electric buses came back to Prague after several years. Apart from a long-term test of a vehicle SOR EBN 11, Arriva Praha used a pair of vehicles SOR EBN 9.5 in 2016 for a service connecting a business administration center with a nearest underground station.

f. Regular operations – Ostrava

Ostrava Public Transport Company became an owner of four electric buses SOR EBN 10.5 in 2010. Shared shifts on route No. 38, which runs through the city centre and services a new shopping centre, were selected for their operation. In 2011 and 2012 the vehicles covered 175 km daily (75 km in the morning, 100 km in the evening), while using fast charging between the morning and afternoon divided shift. After the morning shift the battery charge drops from 100 % to approx. 68 % and the vehicle is recharged to approx. 95 % within an hour by the current of 100 A, and after the afternoon shift the charge drops down to 48 % on return to the depot. The vehicles is charged with the current of 32 A for approx. 5 hours back to full 100 % charge. The average consumption is 0.91 kWh/km (vehicle has diesel heating).

g. Regular operations – Hradec Králové

Transport Company in Hradec Králové currently owns three electric buses. Vehicles SOR EBN 9.5 and Škoda Perun HE 26BB were acquired in 2014 and 2015 after a long-term rent; then a prototype vehicle SOR EBN 11 is on a long-term rent from the manufacturer.

The electric bus EBN 9.5 is used in shared shifts on different routes. It covers around 150 km every day, despite no charging during the break. In the evening approx. 30 % energy is still in the batteries, which are slowly charged overnight. The bus covers the distance between 130 and 140 km over weekends. Similarly, Škoda Perun is used in shared shifts with a daily mileage of 142 km, and 130 km at weekends.

EBN 11 was originally used for a shared shift with the mileage of 130 – 140 km. Its use changed with an installation of a fast charging station (RNS 10) in March 2016. A long-term testing operation is currently under way, the RNS 10 stand is the property of SOR. The energy in accumulators increases by up to 40 % within 15 minutes of charging. The energy supply is the trolleybus grid, maximum charging current is 250 A, although 150-200 A is usually used. Therefore, the electric bus can be used for a daily operation with the mileage of 278 km, while charged twice or three times a day by the charging stand. In the evening at the return to the depot the batteries still have 46 % capacity, which are balanced by overnight slow charging back to 100 %. Furthermore, the city expects an acquisition of hybrid trolleybuses.

h. Regular operations – Arriva Morava (The Jeseníky Mountains, Krnov, Třinec)

With 14 vehicles Arriva Group is currently the biggest electric bus operator in the Czech Republic (12 in Arriva Morava and 2 in Arriva Praha). The first electric bus in the ownership of the operator has been SOR EBN 10.5 since 2014. Apart from occasional rents for presentation or testing purposes, until the end of 2016 the vehicle was used on a mountainous route with an extreme elevation difference (500 elevation metres in 6 km in a hilly terrain) connecting a ski centre Ovčárna with the car park in the valley. A drawback of this type of operation was a lack of storage room. In addition, a charging station on the car park Hvězda was not built. Since the electric bus was unable to cover the transport performance with its capacity, it always had to be backed up by a diesel vehicle. It was the first use of an electric bus in the Czech Republic outside urban areas with a relation to the environmentally sensitive natural Protected Area Jeseníky. An identical vehicle, acquired by Arriva as a used vehicle in 2016, was used for similar purposes in Slovakian High Tatras. Both electric buses SOR EBN 10.5 are currently used on public transport routes in the town of Krnov, which is, with a few exceptions, fully operated by electric vehicles at weekends.

In March 2017, 10 vehicles Perun HE 26BB started operation in the town of Třinec. It is the biggest use of electric buses in Central and Eastern Europe. The newly acquired vehicles are particularly used for shared shifts due to the mileage, although based on the first experience the transport operator considers using the vehicles on longer routes, since there is a sufficient increase of electric energy in the batteries during the charging breaks between services.

i. Regular operations – hybrid trolleybuses

In some Czech towns trolleybuses equipped with a separate power supply appeared at the turn of the century in relation to putting Škoda 21Tr in operation. Before, there were only specific attempts to deal with the dependence of trolleybuses on the overhead line, such as an additional battery trailer in Transport Company Hradec Králové. Regarding the type 21Tr, the manufacturer offered a version with a built-in auxiliary diesel generator, which allowed the vehicle movement outside of the overhead distribution line. The same solution was offered with the vehicles Škoda 24Tr and 25Tr with Irisbus bodywork.

3 Zlín

The city of Zlín has had long-term experience with the operation of trolleybuses with auxiliary diesel generators, and performances for this type of vehicles are directly specified for routes. In the second part of 2016, first hybrid trolleybuses Škoda 26Tr were acquired with the aim to eliminate the flaws of the previous solutions. Direct test were performed which compared the hybrid vehicle with the previously acquired trolleybus Škoda 24Tr with auxiliary diesel generator in the same conditions. The test results show that the operation of a vehicle with built-in nLTO batteries is more economical and favorable in all evaluated issues than the previous solution with an auxiliary diesel generator.

4 České Budějovice

Two articulated trolleybuses were acquired in November 2016 (CZK 31.69 million, excl. VAT), which are used conventionally at the moment. They only run on batteries exceptionally, since there have never been trolleybuses with a separate drive in České budějovice. They were initially considered for use during traffic closures and extraordinary situations (similarly to Salzburg). However, route No. 15 is planned to be replaced. There is a missing small part of the overhead grid in the route of No. 15, which would require a construction of a new converter station and thus inadequately high funding. The part without the overhead grid makes 30 % of the route and there are 4 operated vehicles. Since there is a lack of vehicles, the public transport company asked for financial support from IROP (85 % of acquisition costs) for the acquisition of 11 hybrid trolleybuses. Therefore, the service could be fully replaced in 2019. Apart from that, the public transport company plans to acquire two hybrid trolleybuses annually from their own budget. All trolleybuses will be acquired in hybrid versions from now on – 25 hybrid vehicles are planned until 2022.

The city plans to use electric buses that would either use the trolleybus overhead line for charging at terminuses. The plan is to create two routes in the city center – regarding the layout of the historical centre, 11 shorter vehicles are considered (8 to 9 meters).

5 Pilsen

The third city which put hybrid trolleybuses to operation was Pilsen. This city has long-term experience with the operation of trolleybuses equipped with a diesel generator, there are parts of services regularly running off the overhead line. The majority of the existing bus routes are at least partially run under the overhead trolleybus line. The new hybrid trolleybuses are used on those routes, as well as on routes which are detoured from their regular routes due to extensive reconstruction works in the area of the main railway station. The tests of the optimization of energy use in hybrid operation mode are currently in progress.

2.3.3 Croatia

The development of electric buses is lagging the development of electric cars. There are several reasons for that:

- Cost of batteries is still a major cost item of the electric vehicles. Electric buses require much more electricity storage due to their size i.e. weight. This makes them relatively expensive.
- Large battery packs demand large and powerful charging facilities which are more expensive or different charging infrastructure that would enable fast charging during short stops to cover travel over large distances in one day.

Croatia, as a small country with only one city agglomeration over 1 million people and three cities above 100 thousand inhabitants has a relatively small potential for the use of innovative transport solutions and therefore the existing examples of the use of electric buses in public transport are rare.

The only city in Croatia that has implemented electric buses into a public transport system is the City of Koprivnica, which has purchased two electric buses in the scope of the FP7 project, Civitas

Dyn@mo. The purchased buses were converted buses i.e. a conventional bus without the diesel power train was bought by the manufacturer of the electric bus, which has equipped the bus with all the necessary components. The manufacturer of the electric buses was a Croatian based company, Dok Ing. Of all of the important components, the power train and the battery pack were bought outside Croatia, while the managements system and other necessary components were produced by the manufacturer, Dok Ing, in house.

The result of that was the first electric bus produced in Croatia, called Dok Ing eBuzz112. It has a capacity of 12 + 1 seats, with a vehicle’s mass of 3,250 kg, a 76-kW synchronous electric motor with permanent magnets and a battery pack of lithium iron phosphate batteries of 55 kWh and a fast charging option.

Figure 12: Dok Ing eBuzz112, source: www.epodravina.hr

Vehicle type	*Bus, class B*
Vehicle producer	*DOK-ING*
Vehicle model	*eBuzz (eBuzz1, eBuzz2)*
Colour	*White*
Year of production	*2015*
Seating places	*12*
Empty vehicle mass	*3,250 kg*
Maximum speed	*80 km/h*
Highest allowed mass	*5,000 kg*
Type of engine	*Synchronous motor with permanent magnets*
Engine power	*76 kW*
Type of battery	*LiFePO4*

Figure 13: eBuzz112 technical specifications, source: Dok Ing

The vehicles have a minimum range of 160 km, they include all elements that are needed for being used in public transport, charging options AC (slow charging) and ChaDeMo (fast charging), the battery pack which in combination with the fast charging network that is located in Koprivnica can be charged in 12 hours in AC mode and 2.5 hours in ChaDemo mode. The vehicles have an electric heating system that is using the power of the battery pack. The price per vehicle was 91,666.67 €. According to the manufacturer, this was a relatively low price for such an electric vehicle.

The buses are being used in the public transport system of the City of Koprivnica on one line that is connecting the eastern and western part of the city. The line was chosen so it utilizes the characteristics of the vehicles and does not affect the overall functioning of the vehicles. Namely, inclination or other stressful elements, high temperatures which require air conditioning or low temperatures which require heating have an impact on the range of the vehicle.

Figure 14: Dok Ing eBuzz112 management components, source: Dok Ing

This is the only electric bus produced in Croatia and used in public transport in Croatia, therefore, a larger base for data collection is limited.

2.3.4 Slovakia

In Slovakia, there are currently the biggest experiences with two types of Czech electric buses (SOR EBN 10,5 and SOR EBN 11), which are used in a busy operation in the city of Košice and are also tested in other cities in Slovakia (Bratislava, Žilina, Poprad).

1 Technical specification of the SOR EBN 10.5

The electric traction system consists of an asynchronous three-phase motor with a rated output of 120 kW and a traction transducer based on IGBT transistors.

Traction lithium ion batteries Tunder - Sky have parameters 2.5 ÷ 4.25V / 300Ah - 180pcs. The lifetime of the batteries defined by the drop in capacity to 80% of the original one is set at half the service life of the whole bus, i.e. about 400 thousand km.

The electric bus range is about 130 km in city traffic (average occupancy 50%). The empty electric bus has a range of up to 250 km in intercity traffic.

The average urban traffic is 0.87 - 0.9 kWh.

For slow charging, a conventional 3x400 V socket with adequate safety and control functions is sufficient. The full capacity is recharged in about 7.5 hours (1 hour of charge is sufficient for about 25 km).

2 Technical Specification of SOR EBN 11

The electric traction system consists of an asynchronous six-pole TAM1052C6 engine with a power output of 120 kW.

The electric motor is powered by 180 lithium - ion batteries with a capacity of 172 KWh, which provides the occupant with a range of 120 to 150 km (without recharging).

This basic capacity will ensure a slow charging of the parked vehicle from the el. 3 x 400 V, 32A sockets for approximately 8 hours. Fast-charging is carried out using a two-pole pantograph collector located on the roof of the vehicle and takes about an hour.

The electrical system allows the recovery of traction energy.

3 Development of E-bus by the Slovak company Troliga Bus, LtD.

The technical specification of the electric bus, which is currently the only one developed in Slovakia by Troliga Bus, LtD. is shown in the table below.

Leonis EV as an urban E-bus is designed for passenger transport in towns and cities over shorter distances with a range radius of 250km per charge. The bus interior and arrangement of seats conform to city transport requirements. Seats are comfortable and feature fabric upholstering from the manufacturer. The vehicle's distinguished style features a new design incorporating glazed surfaces to allow better visibility and to make a lighter impression. They provide a perfect view of the surroundings, which is appreciated by passengers. Passengers can board the bus using three double doors. The first door is in the front, the second in the middle, and the third in the rear (past the rear axle) of the bus. The bus is furnished with a mechanical boarding ramp; a hydraulic ramp is available as an option. The bus meets all requirements for modern city passenger transport. The bus capacity is 32 seated and 67 standing passengers

Technical Parameters of Citibus Leonis EV (Toliga Bus, spol. s.r.o.) (presently in the development and manufacture stage)- *(http://www.troligabus.sk/-coming-soon)*	
Vehicle dimension [mm]	• *Length: 12 000* • *Width: 2 550* • *Height: 2 720* • *Wheelbase: 5 900* • *Front wheel gauge: 1 930* • *Rear wheel gauge: 1 800*
Vehicle weight [kg]	• *total/service: 18 000* • *front axle load: 6 500* • *rear axle load: 11 500*
Bodywork	• *Mounted frame, welded from thin-walled sections, with a bonded sheathing made from zinc-plated sheet metal, front and rear parts,* • *Front and rear components: plastic - fibreglass, ABS boards and aluminium.* • *Bodywork glazing - hardened glass.* • *In the near future replaceable plastic side panels will be added*
Powertrain technology	*Ziehl Abegg Gearless Singlewheel Direct Drive*
Main features	• *Power: 182 kW peak / 113 kW nom.* • *Torque: 2700 Nm nom., 6000 Nm peak* • *Voltage: 400 V – 700 V* • *Current: max. 500 A* • *Electronic: integrated power electronic* • *Cooling: Water (Motor & Elektronic)* • *Brake: Support for disk-brake at rear axle via E-maschine (incl. Recuperation)* • *Efficiency: up to 94%* • *Tire size: SuperSingle 455/45R22.5* • *Rim size: 22,5" x 15"* • *Sensors: Temperature (for Motor and Electronics), Speed*

Battery system	• *Samsung SDI 60Ah 630V prismatic cell* • *charging 3-4 C* • *BMS module* • *lifespan of the battery system is 20 years* • *warranty 8 years* • *operating temperature charge from -40°C up to +60°C* • *operating temperature discharge from -40°C do +60°C* • *no maintenance* • *slow and quick charge options* • *no need for the heating or air-conditioning of the battery system*

Table 1. Technical Parameters

4. Brief description of involvement of electro buses in public transport and its expected use

In Slovakia, a total of 14 electro buses from Czech manufacturer SOR Libchavy, LtD. (SOR EBN 11 and SOR EBN 10,5) are in operation in Slovakia. Their introduction into full operation took place in Kosice in the years 2014-2016.

At the same time, other Slovak towns joined the testing of electric buses in public passenger transport (Bratislava, Poprad, Žilina).

The first, in 2013, was the test of Chinese manufacturer BYD electro bus presented by the Slovak Bus manufactures, Troliga Bus, LtD. Its initial drive from the bus station, due to the battery discharge because of the low temperatures, was delayed by about half an hour. The tested electric bus goes on one charge cca 400 km in out-of-town regime and 250 km in city traffic, with 48 seats and 48 standing places. It lasts 19 hours of ride, while the stamina depends on the capacity of the batteries, which then derives the overall cost of the electric bus.

In February 2014, the operation of the electric midi bus EVC First Electric from ROŠERO-P / EVC manufacturer with a total capacity of 32 people was tested in Bratislava. The electric bus has a manual gearbox and two doors. Bus ride with fully charged batteries ranges from 150 km in urban environment to 165 km outside the city, with charging time of 8 hours. In October 2016, a Czech SOR EBN 11 electric bus was tested in Bratislava, which is currently also operated in the Košice by the Košice Transport Company.

In 2016, the transport company of the town of Žilina got SOR EBN 10.5 low-floor electric bus from SOR Libchavy for testing. The same electric bus was used for testing during the winter season in the High Tatras where it was used as a skibus.

In accordance with the strategies adopted on the national level (i.e. **Strategy for the Development of Public and Non-Motorized Transport of the Slovak Republic by 2020)** , cities and self-governing regions in the Slovak Republic have developed their own strategies for the development of public passenger transport, setting out their own goals in the area of e-mobility development in cities, including the inclusion of electric vehicles in the public passenger transport fleet. The aim to extent the fleet of electric buses announced the capital of Bratislava, the regional cities of Nitra and Žilina and the district towns of Šaľa and Poprad, which plan to use financial resources from the European Union for the purchase of electric buses, but the experience of other cities does not exclude the involvement of more municipalities in this type of green transport.

2.3.5 Austria[3] and Burgenland

1 Development of e-buses in Austria and Burgenland

Bus systems are today to a very large extent driven with fossil engines in Austria. In the field of alternative engines only already proven mechanics come regularly to use. In Linz, for example, the entire bus fleet is used and operates with natural gas. Current individual projects are based on non-constrained electric motors (independent motors like wheel hub motors - https://en.wikipedia.org/wiki/Wheel_hub_motor). So the classic big built-in motors in front or behind a bus are not subject of research for electric driven eBus. These are used in most cases only on selected routes.

The first electro busses used in Austria were produced by Siemens and are still operational in Vienna since 2013. The innovative concept and the drive technology was at that time the first series-produced electric buses in Europe, whose entire energy needs is based on a battery system. The essential advantages compared to diesel or gas buses lie in the energy supply, which is around

[3] *https://www.bmvit.gv.at/verkehr/elektromobilitaet/downloads/emobil_monitoring_2015.pdf*

25% lower, in minimal maintenance and completely emission-free business.[4] Transport companies want to benefit from high energy efficiency and reduced maintenance. The city population should also benefit from reduced carbon dioxide and noise emissions. The increased switchover from diesel engines to electric motors has been clearly evident for around two years.[5]

However, the responsible persons of transport companies have a great deal of incentive to deal with the difficult handling with the overhead lines, of which a certain danger arises from the 600-volt voltage, as well as the overhead lines themselves are very endangered. In addition, a bus needs two wires, in contrast to the tram. In short, an electric bus is an environmentally friendly means of transport, but the charm of using it is still low. In Vienna the idea of an electrically operated bus with the Wiener Linien (https://www.wienerlinien.at) was not to be abandoned. Lithium ferrite batteries were chosen because it was also important to find the right battery type. The frequent recharging of the lithium-ferrite batteries does not matter, it is important here that the charge state never drops below 40 percent.

In Graz for example the lines 34E (Jakominiplatz - Theyergasse) and 50 (Central Station S - Zentralfriedhof) have been operated electrically in test operation (for the time being without passengers) since 6 December 2016. For this, systems from the Bulgarian manufacturer Chariot Motors (12-meter Solobus used on line 50) and the Chinese manufacturer CRRC (18-meter articulated bus used on line 34E) are used. The charging time is only 10 to 20 seconds and the charging takes place at the stops. On 28 September 2016 the first bus was presented in Hanover. The holding company, Graz Linien, plans to convert its entire bus fleet step by step to electric drive starting in 2018. Due to safety-related shortcomings, the use in passenger operation will be delayed.[6]

To reduce fine dust in the urban area alternative engine are still a big issue. In the coming years the proportion of electrical operated buses should be regionally dependent over one percent to more than 40 percent from the currently scarce. Most of these buses may be hybrid vehicles but also purely electric buses are increasingly being used.

[4] https://www.siemens.com/press/pool/de/events/2013/infrastructure-cities/2013-03-UITP-PK/hintergrund-ebus-wiener-linien-d.pdf
[5] https://futurezone.at/digital-life/elektrobusse-kommen-in-fahrt/135.351.313
[6] http://steiermark.orf.at/news/stories/2794460/

In rural areas such as Burgenland electric busses are currently only used through societies. Small - scale mobility offers are a contribution to the quality of life in regions, they reduce the private expenses for collection and delivery services contribution to climate protection. The association law allows the provision of mobility services, provided that these are not carried out on a commercial basis or are limited to the members of the Association. It is suitable primarily in operating areas, mainly locals and a consistent group of people to take. The membership can be linked with a membership fee or a be free of charge. A formal (documented) entry is required. The founding of the association and the organization of the company are significant in organizational expenses. Involving volunteers is possible without problems with this solution. The municipality can also act as a "transport company" or become a new one established community facility. Operator is in this case a commercial association acquiring a concession for the car industry. The licensed association is the manager and organizes the traffic according to the requirements of the members of the association. Leading municipal representatives (for example, mayors) are executive bodies in the acting association. The municipality also takes the financial risk of the company. It is necessary to order a suitable operational manager. Involvement of volunteers is not possible with this solution. The drivers are at the "club". Another way to organize micro-public transport is to order a service provider from a mobility service provider. Similar to the public transport system, an existing concessionary company orders precisely defined transport services. Depending on the desired model of operation and required capacity of the vehicles, this can be done with a bus company (for traditional scheduled services) or with a taxi and car rental company (for demand-oriented offers). The basis of the order is a clearly defined in an operating program and quality criteria for the service provision. It is also important to ensure sufficient flexibility in the order contract so that the offer can always be adapted to changing needs. Involving volunteers is not possible with this solution, the costs in the operation correspondingly high. [7]

2 Promotion samples in Austria

Klima: aktivmobil (Ministry of the Environment)

[7] https://e5-salzburg.at/downloads/downloads-wissen-service/hf6/infoblatt-buergerbusse.pdf

The promotion relies on CO2 savings through municipal mobility management, which also means citizenship and needs-oriented offers. Planning costs are supported, investment and operating expenses for the first three years.

Micro-public transport systems in rural areas (bmvit)

Within the framework of the Climate and Energy Fund, the Ministry of Transport promoted in 2012 demand-oriented mobility services in rural areas. The operating costs of the first three years into which the initial investment is accounted for through leasing or depreciation can preference is given to house-house systems with the involvement of volunteers in the business process. Information promotion campaign: http://www.e5-salzburg.at/news/2012/06/mikro-oev-foerderung.php

2.3.6 Slovenia

In Slovenia electro buses aren't really involved into public transport yet. But in the last past years some changes started to happen.

In the capital city of Slovenia, Ljubljana, on-demand service Kavalir is implemented in public transport system. The service is intended for transfers across the city centre for citizens, tourists and other visitors using special electric vehicle. Kavalir (Cavalier) is a free form of urban transport that is friendly to humans and the environment. Cavaliers are intended mainly for the elderly, physically handicapped persons and tourists. They are driving through the old town of Ljubljana, which is closed to traffic. Due to low speeds they can be stopped right on the street or their services can also be ordered by phone. In Ljubljana so called "Urban, the electric train" (actually a bus) operates on a circular route in the centre of Ljubljana.

Figure 15: Cavalier Transport System

Figure 16: Urban electric transport in Ljubliana

Maribor based company Marprom (managing public transport in Maribor) was the first to introduce an electric bus in public transport fleet in April 2013. New electric bus was procured from Durabus. In January 2017 a hybrid bus, driven by an electric motor was introduced in Maribor public passenger transport as part of extensive trials. The objective of the Municipality of

Maribor is the modernization of public transport with environmentally and passenger friendly buses.

Figure 17: Electric Bus in Maribor

A speciality in Slovenia is also the City of Piran, which is completely closed for personal cars of visitors. They implemented 2 public services for citizens, tourists and other visitors, since the car parking lot is outside the City of Piran. Maestro is a small public bus intended for local inhabitants an visitors that is free of charge and completely electric. You can just stop Maestro vehicle on the street or you can even call and reserve it. The other service is Dostavko. With Dostavko the municipality encourages citizens and visitors to leave their cars outside of Piran and thereby help to reduce traffic jams in the city and contribute to lowering greenhouse gas emission. Dostavko is designed to deliver small cargo, such as furniture, home electrical appliances, luggage and other.

Figure 18: Electric Transport in city of Piran

2.3.7 Hungary

Regarding the development and manufacturing of electric buses, Hungary has something to show for itself.

Engineers in Hungary have designed the world's first electric composite bus. Modulo is a range of bus models built in a modular fashion that can accommodate a varying number of passengers and can be ordered with various powertrains. The Modulo Constructed from one single self-carrying piece made of plastic, covered by simple but heavy-duty coating instead of complicated sheathing the bus is two tonnes lighter than conventional models made from metal. The design of the bus and electric engine means that it is much quieter and more environmentally friendly than other conventional buses. The structure of the bus also allows for less frequent maintenance, thinner walls and a more spacious passenger area. The bus also has a low floor making it accessible for all passengers. Carrying up to 65 passengers the bus has a range of 100 kilometres on a single electrical charge. In addition, the Modulo is bus models can be ordered with four different powertrains. This allows the vehicle to be adjusted to its operating environment in every situation. The electric version is recommended for downtown environment, where quiet and zero emission operation is a requirement. The CNG and Euro 6 diesel powertrains are recommended for suburban environment, while the hybrid version is recommended for bus lines running in both downtown and suburban environments. All these powertrains conform to the strictest European emission norms, and there is opportunity for conversion between the different types. The project, which took three years to complete, cost a total of one billion Hungarian forint (€ 3.25 million), including around € 400,000 in EU funding. The Modulo Ultra-lightweight Electric City Bus was developed by the EVOPRO group.

Table 2. Technical specifications on different eBuses type

		c48 (MINIMO)	c68 (MEDIO)	c88 (OPTIMO)
DIMENSIONS & BODYWORK	Frame	Glass fiber composite, unibody		
	Door arrangement	0 ; 2 ; 0	0 ; 2 - 2 ; 0	0 ; 2 - 2 ; 0
	Door opening (mm)	1200	1200 + 1200	1200
	Passenger capacity (8 person/m2)	45	65	85
	Access ramp	semi-automatic		
	Length (mm)	6 507	7 982	9 457
	Width (mm)	2 550		
	Height (mm)	2740 / 2980 (with air conditioner)		
	Wheelbase (mm)	4 026.50	5 000.50	6 976.50
AXLE LOAD	Axle 'A' (t)	2.60	3.80	4.50
	Axle 'B' (t)	5.50	6.55	6.55
	Total weight (t)	8.30	10.35	11.05
SUSPENSION, BRAKES & STEERING	Steering system	Csepel C-300		
	Brake mechanism	Knorr-Bremse		
	Brake system	Knorr-Bremse EBS5S + EPS		
	Axle 'A'	RÁBA 270 (independent suspension)		
	Axle 'B'	RÁBA 361		

		c48 (MINIMO)	c68 (MEDIO)	c88 (OPTIMO)
MISC.	Air conditioning	Eberspächer Sütrak AC520-I	Eberspächer Sütrak AC520-II	Eberspächer Sütrak AC520-III
	Heating	Eberspächer Hydronic M12		

Figure 19: Variation of 4 types of modules offering various bus categories

Another positive step toward the popularisation and use of electric buses is the 2017 opening of the Chinese manufacturer's, BYD's first bus plant in Europe. The official name of the business is 'BYD Electric Bus and Truck Hungary Kft'. The €20 million factory will employ 300 people when at full capacity, turning out up to 400 electric buses a year for the European market.

It will focus initially on electric bus and coach manufacture, but the company says it also plans to produce electric forklifts and light commercial vehicles. The Hungary plant will also produce the bus chassis for the UK, for assembly under the BYD ADL partnership, as well as chassis for a new BYD factory in France.

2.3.8 Montenegro

Currently there is no electric public transport (including electric buses) in Montenegro and there are no official initiatives in terms of introducing electric transport vehicles (including electric buses) in public transport fleets.

2.3.9 Serbia

In the Republic of Serbia, in most of the cities, public transport fleets consist of diesel powered buses. Many transport companies have started converting their buses for the use of natural gas in order to reduce costs. Additionally, the capital city Belgrade has started to deploy electric buses into its public transport fleet. In 2016 five new low-floor electric buses were purchased from the Chinese manufacturer "Higer Bus Company Ltd". The bus is 12 meters long, has capacity of 80 passengers and the total power of the towing engines is 120 kWs with electric power recuperation (energy from braking recharges its batteries). The engines are specified to operate in outdoor temperature range of -20°to +50°C. The charging time at the terminals is only 10 minutes and the electro-bus is ready to drive for next 20 kilometres. The purchase price of a single bus is about 460.000€. Belgrade is one of the first capitals in Europe that has one line of city transport with electric buses.

The city of Čačak has purchased 10 Volvo hybrid city buses that generate 30% savings in fuel compared to conventional diesel engines. At the same time emissions of exhaust gases are reduced for the one third as well.

3 Necessity and opportunity of electro buses

3.1 Advantages and Disadvantages

In order to understand all the advantages, but also the disadvantages of using the electro buses for public fleet, the consortium has analysed the situation in their own countries, and all the results have been assessed in the following section.

3.1.1 SWOT ANALYSIS

STRENGTHS

- Reduction of emissions.
- Less noise pollution.
- Electricity is at the moment cheaper than fuel.
- modern technologies promoted by political representation
- reduction of direct operating costs in comparison with conventional buses
- simple relation to ITS systems and integration to the Smart City concept
- Independence on fossil resources, which often come from politically unstable regions in the world
- enhancing image for operators

WEAKNESSES

- High initial purchase price.
- High price of battery rental/purchase
- Environmental unfriendly production of battery.
- Battery cycle life.

- Indirect environmental emissions.
- Missing standardization in the field of charging technologies;
- Limited driving range, which is incomparable to conventional buses – necessary charging during the day
- Limited battery life span – necessity to replace battery sets approx. in the half of the vehicle life span
- Little experience with optimum setting of vehicle properties for a given traffic characteristics – risk of insufficient capacity (or over dimensioned capacity) of batteries, power of motor, etc.
- Missing interconnection of electric bus projects with conception documents of towns and cities – strategic plan, SUMP, etc.
- Lower transport capacity in comparison with conventional vehicles

OPPORTUNITIES

- Financial incentives in some countries (Slovenia, Romania)
- Extended tourist offer.
- Good alternative for short distance travels.
- High variability for routing – independence on route closures, extraordinary situations, etc. Potential fast introduction of electric public transport in developing urban areas where the routes and passenger transport flows are not yet stabilized.
- Protected areas will be more accessible - development of tourism.

THREATS

- Limited range and lack of charging stations specific for public transport electric buses.
- There is still a large number of travels with passenger cars.
- Dispersed human settlement outside the major cities makes public transport difficult.

- The number of passengers is steadily declining.
- Lack of public transport services in non-peak hours: evenings and weekends.
- Low series, no scale effect

3.1.2 Key Barriers

1. Romania

E-Mobility in Romania is at the very beginning, so considering the slow rate of growth in this area, we will assume that the interest at this moment is in different directions; this happens mainly because of the financial barriers that come with infrastructure development, also with the initial costs of electro- busses.

The key barriers, as seen by the Romanian partners are:

- Batteries are not tested in a period of 10 years. Producers declare batteries will last for 10 years however this was not yet proven. Experiments showed that the battery capacity decay is more accelerated than initially anticipated.
- Lack of infrastructure for charging: cost for building charging stations around the cities hinder implementation of e-buses.
- High costs for replacement batteries: the battery is 45% of the total cost of the e-bus while the electric motor is 3-5% of the total cost.
- Low passenger capacity: capacity needs to be around 100 passengers, currently e-buses mostly offer capacity of about 61 passengers (both siting and staying).
- Cost barriers: changing an entire fleet of busses into electro would require a big investment and even though some of the funds can be covered by national and European support funds, the municipalities will still need a big investment for the purchase of electric buses.
- Limited number of manufacturers: As the number of existing manufacturers is not very big, the offers for electric buses procurement are relatively few.

- As seen by Romanians, the implementation of electric busses would be acceptable, if the costs of one way ticket would be lower, or would remain the same for them

2. Czech Republic

EMobility in city public transport was summarized in a study which was produced with the support of the Association of Public Transport Operators (Slavík, 2015). Similarly to the text of the previous chapters, its conclusions find that there is neither technological nor transport-operational conception of vehicles and their use for purely electric public transport operation that would be universally usable in all urban areas. It is always necessary to evaluate specific conditions of a given locality, traffic character, passenger flows, orography, facilities of transport operators, etc. In addition, the experience with conceptual mass introduction of electric vehicles in operation is missing. At the moment, there are rather one-off solutions for given moments and given lines with the effort to present a given urban area as friendly area to progressive forms of urban public transport. A specific use of electric buses can be seen in their operation in environmentally sensitive areas, e.g. national parks. In addition, some of the important properties, crucial for making decisions on the selected conception, have not been verified in real traffic due to a short time of experience, e.g. battery degradation process and necessary replacement with new ones.

A special part of electric mobility in public transport, partially specific for Central and Eastern Europe, is the development of trolleybus systems. While in Western Europe most of the trolleybus systems disappeared in the 1960s and 1970s, their occurrence in Eastern Europe is surprisingly extensive, even though a wave of their non-conceptual discontinuations with the aim of immediate economic savings while neglecting long-term benefits of this transport mode appeared in this region after the social changes in 1989.

A great hope for maintaining and potential further development of urban electric traction in the form of trolleybuses is the concept of the partial (or hybrid) trolleybus, which is an electric bus that uses dynamic charging from the overhead line during operation. Electric batteries eliminate the biggest disadvantage of common trolleybuses, i.e. complete dependency on the overhead line. At the same time, the necessity of construction and maintenance of overhead lines in the areas with lower intensity of transport services or for complicated overhead line crossings is reduced, which leads to a considerable reduction of fixed costs of trolleybus transport. In addition, the vehicles do not need to idle at charging devices for a part of the day, since they can be charged during regular operation under the overhead line (some of the studies show that they need just 50 % or even lower part of the line to run under the overhead line). Furthermore, such hybrid equipped vehicles are nowadays more expansive than common trolleybuses by just 10 %.

The problem in the Czech Republic is the legislation aspect of hybrid trolleybuses. Common trolleybuses dependent on the overhead line are subject of the Act on Rail Systems (together with railways, trams, and funiculars), but the trolleybuses equipped with an auxiliary independent drive (battery or diesel generator) are not clearly specified whether they are rail or road vehicles, even though they partially use the rail infrastructure.

3. Croatia

Based on the experience of the vehicles that were used in the only example in Croatia, mentioned in the sections before, conclusions were as follows:

- Driving experience of the electric bus is similar to conventional ones but it requires some technical knowledge from the person that is operating the vehicle.
- Maintenance of the vehicle is less demanding in comparison with the conventional ones, but with the low number of vehicles that are produced at this moment, purchase of spare parts and certain expertise can be scarce.

The limiting factors of the vehicles are:

- The battery pack, not only in terms of range and price, but also in the longevity. It is known that the batteries lose their full potential after a certain cycle of charging/recharging. The replacement of the batteries is a very expensive operation.

Overall, the buses used in the Civitas Dyn@mo project have proven to be successful by:

- keeping the operational costs low, due to the lack of conventional maintenance costs (i.e. for oil, filters etc...) and because of the current price of electricity
- the carbon footprint of the vehicles is also low, but only in the case if the electricity used for powering the buses is not produced by high carbon producers, like coal plants etc.

- have a positive impact on the reduction of noise levels in the parts of the city where they operated

Also, the barriers that do not enable the use of a larger number of vehicles were;

- high purchasing cost of the vehicles in relation with the conventional vehicles,
- small number of market ready products/vehicles offered on the European market,
- poor maintenance possibilities in smaller countries,
- uncertainty of how the batteries will respond after a longer period of usage
- lack of best practice examples
- and the need for an expensive charging infrastructure.

Regarding the public procurement that was done in Croatia for the purchase of the mentioned vehicles, no special or innovative solutions in public procurement were used in this process. This approach was a rather false one, because the product itself was very innovative and required a great deal of communication with the manufacturer of the vehicles in order to develop the product that suited the specific needs of the tenderer. A very important thing, that has to be considered when purchasing innovative and new technologies, electric buses, is the warranty. Since this is a new technology, there is a higher possibility that some elements of the vehicle will not work as expected. So, the warranty, its range and period, is a very important element that has to be taken into account when conducting the public procurement process.

Also, it is very important to conduct a Europe wide public procurement process, in order to expand the choices, and to ensure a competitive price for the vehicle. Regarding this, it is very important that the technical specifications must be more detailed to avoid unsuitable products. Therefore, an extensive survey must be undertaken before each process.

A very important issue, especially for public institutions and authorities, who manage public funds, is the media approval of the implementation of such a concept. This is important since the price of the vehicle and the needed infrastructure is very high, and if the results of the implementation are not adequately presented and tailored to the specific context in which the buses are implemented, this can have a negative media response especially in smaller communities.

4. Slovakia

The main benefits of electric buses:

- Simplicity of maintenance (lack of gearbox, clutch, gearbox and related problems such as cooling and lubrication, with up to 70% of faults occurring on vehicles)
- Passenger transportation convenience
- Silence and no emissions
- In the long run, electric buses may have lower operating costs compared to conventional buses
- The environmental benefit in the environmentally encumbered areas of the city is an advantage

Key barriers for implementing e- buses into public transportation system.

- High purchase price

5. Austria/Burgenland

The one of AustriaTech and the Vienna City conducted consultation of 2015 on clean energy in transport showed that a majority of the 70 participating institutions mostly need a clear regulatory framework for the market development of alternative fuels in public transport.[8]

Besides that, only concrete goals would be important to industrial enterprises such as the vehicle industry, infrastructure operators or power supply units. Prerequisite for the efficient use of purely electrically operated systems buses need a dense network of stations, charging infrastructure as well as an adequate electricity mix. Other forms of electric buses are inductively charged buses, which make contactless charging possible.

Electric buses are quiet, but they call for considerable additional infrastructure, maintenance costs and are completely inflexible in line management. In addition the investments of a change to electric busses mostly are seen not to be adequate to its practical use.

[8] https://www.bmvit.gv.at/verkehr/elektromobilitaet/downloads/emobil_monitoring_2015.pdf

What the change of diesel buses to electric buses brakes, is not just the fact that bus fleets have to renew every ten to twelve years, it is also the fact that one kilometre with battery electrics costs around one third more than one with diesel engine. The main focus on investment in buses and charging infrastructure are: charging points with high power, rectifiers, transformers and safety technology.

The winters turned out to be also a challenge. In the cold, the chemical circuit in the battery comes to a standstill. For example, heating elements in the batteries provide for a flawless winter operation. That is, the essential technology and charger is in the bus, so, to put it simply, only a piece of wire had to be led from the tram to the bus line.

Individual buses are relatively expensive, but there are considerably lower energy costs, especially since an electric bus consumes only one-fifth of the energy of a diesel bus, according to Wiener Linien. The trend away from fossil fuels is getting powerful feed. And the problem of the number of parts can be solved by itself, if the idea prevails. An extension of the concept to larger buses is becoming more and more likely. [9]

6. Slovenia

Since the development of electric public transport in Slovenia is still in its pioneer phase, implementation of electro buses in Slovenia, has been assessed through a short and simple SWOT analysis, with an emphasis on threats.

STRENGHTS

- Electric public buses are environmentally friendly.
- Almost zero CO_2 emissions.
- Some are free of charge.
- They are quite, so there will be less noise pollution and more comfortable drive.
- Electricity is at the moment cheaper than fuel.

WEAKNESSES

- High initial purchase price.
- High price of battery rental/purchase

[9] http://derstandard.at/1395363369224/Wiener-Elektro-Busse-Darueber-staunt-die-Welt

- Environmental unfriendly production and battery.
- Battery cycle life.
- Indirect environmental emissions.

OPPORTUNITIES

- Financial incentives from the Slovenian Eco Fund.
- Extended tourist offer.
- Protected areas will be more accessible - development of tourism.
- Good alternative for short distance travels.
- New innovations – business opportunities for high tech companies in Slovenia.
- Co-financing of lines for electric bus transport

THREATS

- Mindset of inhabitants of Slovenia will have to change drastically.
- Limited range and lack of charging stations specific for public transport electric buses.
- There is still a large number of travels with passenger cars.
- Dispersed human settlement outside the major cities makes public transport difficult.
- In Slovenia, in general, public transport time is uncompetitive compared to personal cars, due to walk time to the station, stopping at bus stops, waiting time…
- The number of passengers is steadily declining.
- Lack of public transport services in non-peak hours: evenings and weekends.

7. Hungary

While the advantages of using electric buses should be evident, no exhaust fumes, higher passenger comfort, environmentally-friendly technology and low operating costs, there are still many factors that stand in the way of integrating electric buses into public transportation systems. Currently the price of electric buses is relatively high, which already hinders readiness to purchase them. Municipality development plans often place other fields (e.g. healthcare, education) in the forefront. The preparation of Sustainable Urban Mobility Plans (SUMP) might be helpful in this regard. The general population would be open to using alternative fuelled buses, as long as they "work" – environmental protection is a popular topic, but people don't like getting stranded at bus stops because of the (electric) bus running on their line has broken down. From the side of public transport companies, this is one of the biggest barriers for purchasing electric buses. The lack of available testing information on the performance of electric buses is a concern for the transport companies, since the procurement of electric buses is not an inexpensive task, and they are afraid that their investment will not pay off if the purchased buses cannot perform as well as they should, or not perform at all. A solution to overcome this barrier would be the organisation of dissemination events among transport companies, and implementing pilot programmes where buses could be tested along actual city lines and thus they can gain first-hand experience in this field. Government grant schemes would mean a substantial incentive and aid for transport companies in investing in their own electric bus fleets.

8. Montenegro

The regulations and rules on national level for transport and traffic and defining of special conditions for public transport of passengers does not recognize any recommendations nor incentives for introduction and use of electric buses within public transport of passengers. All of these are affected by the slow administration on national level within the context of introducing law regulations reform and not recognizing the importance of organized public transport within urban and rural areas by use of electric powered vehicles.

Within eGUTS an initiative will be directed at the Ministry of Transport and Maritime Affairs for reform of law regulations within the context of public transport of passengers, with special conditions set for use of electric vehicles. Furthermore, it will be suggested to initiate the process towards defining procedures for import and use of electric vehicles for public transport with a special focus on use of electric buses for public transport of passengers. The initiative will be addressed towards the Government of Montenegro, for ratification of decrees on offering incentives for use and purchase of electric vehicles for public transport of passengers.

9. Serbia

The key barriers for implementing electro buses into public transportation system in Republic of Serbia:

- lack of a clear legal framework;
- high purchase price of the buses;
- expensive charging infrastructure; high initial price;
- lack of a systemic approach to subsidizing the infrastructure and vehicles;
- lack of unique vehicle and battery quality standards;
- requires specific technical knowledge for vehicle operator/driver;

- replacement of the batteries is very expensive; the batteries lose their full potential after a certain number of charging/recharging;
- not adapted public procurement system in Serbia; the product itself was very innovative and required a great deal of communication with the manufacturer of the vehicles in order to develop the product that suited the specific needs; the technical specifications must be more detailed to avoid unsuitable products;
- insufficiently developed citizens' awareness of the advantages of electric buses in the public transport system;
- insufficient number of pilot projects;
- lack of media campaign - media approval of the implementation of such a concept; the price of the vehicle and the needed infrastructure is very high and this can have a negative media response;

3.1.3 Possible solutions for overcoming barriers

Possible solutions for overcoming barriers, as seen by the consortium:

- Clear legal framework, with involvement of national policy-makers for subsidizing the required infrastructure and the acquisitions of electric buses fleet
- Initial cost of electric busses is still hindering implementation, easily accessible and transparent information on subsidies/grants are of great benefit
- Lower costs for batteries and battery replacements
- Better assessment and real-life information on batteries' life-time and performance during lower temperatures seasons are needed
- Initializing an infrastructure program for countries that are not so well developed in terms of e-chargers (like Romania)
- Creating an awareness program for mitigation towards an electric future in terms of transportation
- More intensive involvement/contribution of private companies in infrastructure development (private investments for an electric future)
- Organisation of dissemination events among transport companies
- Implementing pilot programmes where buses could be tested along actual city lines and thus they can gain first-hand experience in this field.
- Government grant schemes would mean a substantial incentive and aid for transport companies in investing in their own electric bus fleets.

- Involvement of citizens in decision- making process

3.2 Cost- benefit Analysis

For the comparison of lifetime cost of electric and diesel bus a study data and studies of USA based Altoona Bus Research and Testing Centre were used. The information are based on tests simulating 636.000 km of service over 12 years including testing of fuel economy. Tests were performed on a Proterra BE40 bus at the Center with result of 1.05 kWh/km. The test was also performed on a BYD 40-foot bus with a resulting fuel economy of 1.23 kWh/km. This information was used for calculation of life-time costs.

Table 3: Costs ICE vs. eBus

	Price	Running cost	Yearly running costs		Maintenance
	[EUR]	[EUR/100km]	km/year	[EUR/year]	[EUR/year]
ICE Bus	400,000	41.8	53,000	22,154	41,000
E-Bus	700,000	8.8	53,000	4,664	24,600

The assumptions are based on:

- Market price analysis, for both ICE Buses and Electric Buses. [10] [11]
- Average EU costs for fuel
- Kilometres covered by buses in major urban areas (examples: London, Vienna, New York, etc.)
- Average maintenance costs as shown by studies for ICE buses and specialists declarations on maintenance costs for E-buses, compared to ICE buses.

[10] http://www.columbia.edu/
[11] https://www.researchgate.net/

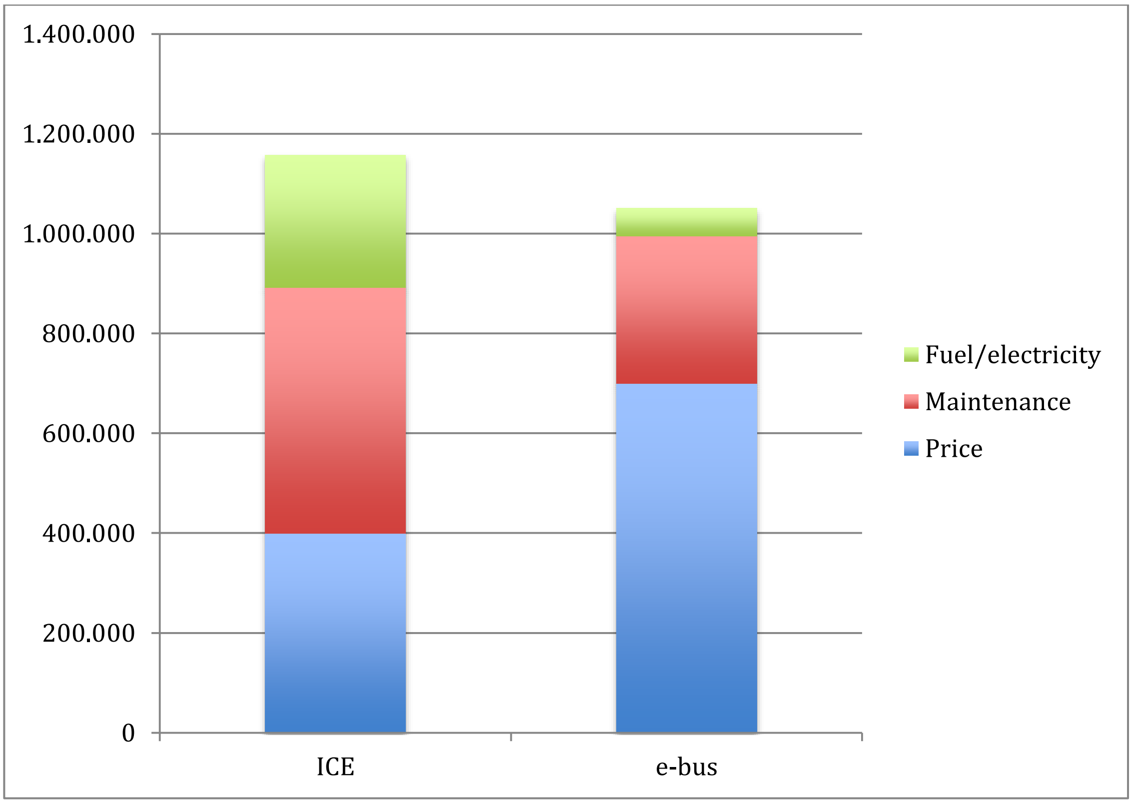

Figure 21: Lifetime Cost of Electric vs. Diesel Bus

The outcomes of comparative calculations, such as the one shown in Figure 21, are heavily dependent on assumptions about vehicle costs, amortization period, and yearly mileage. Therefore the cost comparison should only be seen as indicative. However, what should be clear is that, while electric buses may currently be on the verge of competing with other systems, a situation where vehicle and infrastructure costs are reduced by 25 percent (https://network.wsp-pb.com/article/electric-buses-the-next-step-for-sustainable-public-transport) would make electric buses highly competitive. This holds even when only monetary costs (fixed and variable) are considered.

3.3 Infrastructure Requirements, Development and implementation steps

At the consortium level we see a lot of different stages of development in terms of electric vehicle and electric bus use and in terms of infrastructure development stages.

Charging infrastructure requirements are being largely debated in the context of urban energy planning for transport electrification. As electric vehicles are gaining momentum, the issue of locating and securing the availability, efficiency and effectiveness of charging infrastructure becomes a complex question that needs to be addressed.

The major public bus transport hubs connecting to the train and subway system show the highest concentration of locations chosen by the model for charging station installation. The total costs for the operation of a partially electrified bus system in both optimization cases considered (cost and energy) differ only marginally from the costs for a 100% biodiesel system. This indicates that lower fuel costs for electric buses can balance the high investment costs for building charging infrastructure, while achieving a reduction of up to 51% in emissions and up to 34% in energy use in the bus fleet.

Infrastructure and implementation requirements

The infrastructure required to support electric bus implementation has a number of challenges. Each bus route is unique, and implementations will be least costly if they are tailored to the specific needs of the route. The parameters that need to be decided include the size of the battery that is required for the implementation, as well as whether fast charging, slow charging or some combination is most effective for that particular route.

As an example, assume that a route is 15 km long, takes 30-45 minutes, has a 15-minute stop at the end of each loop, and the route is run 8 times in a day. The city might consider purchasing a small battery for the bus and using fast charging after each bus loop. Alternatively, the city might prefer to purchase a larger battery and just charge it up once slowly overnight.

The equipment for recharging slowly vs. quickly has some differences that could impact cost and battery performance. A quick charge may not fully recharge the battery. But if the battery is large enough, it will not matter. Alternatively, batteries that are sufficiently large to manage the full route for the day without recharging can be purchased.

Case study – Vienna

In the case of Vienna, Austria, a unique set of requirements was established. Vienna decided to switch to all electric buses for their routes in the old district, which is covered by 12 buses. The requirement was that the buses use fast recharging during stops at the end of each loop. However, rather than setting up new charging equipment, the city required that the charging equipment makes use of the infrastructure that already exists for trams. The vendor created unique equipment to comply with the city's request.

Another possible consideration could be the frequency with which buses are switched between routes. If buses are switched frequently, then the bus configuration would need to be flexible enough to handle different routes. If buses are not switched frequently, then it may be worthwhile to understand the time, effort and cost that would be required to change configurations when moving a bus from one route to another, rather than over-engineering every bus. Batteries have unique performance characteristics that will be discussed in the next section. In addition, infrastructure requirements and battery type will vary by vendor. These differences need to be understood.

Considering that infrastructure has to be adapted for each type of technology, we foresee three major steps for the implementation of infrastructure and for the assessment of the needs of infrastructure:

1. Vehicle (eBuses) considerations

- The number of eBuses required for customer service at peak periods;
- The timeline and routing of the lines and the traffic environment of the other vehicles sharing the same routes;
- The type and performance characteristics of the electrical energy charging, storage and management systems;

- The performance characteristics of the e-chargers;
- The type of connection to the e-charger.

2. Charging infrastructure and network considerations:

- Identification of the different routes to be connected;
- Identification of the various operational, technical and urban factors that may influence the location of the charger
- A preliminary assessment of the required electrical energy supply system;
- The type of connection to the e-bus.

3. Socio-political considerations:

- The introduction of eBus system can be a very powerful sustainable and urban development tool. It is a structured network around which existing communities can be revitalized and new communities developed.

3.4 Procurement of electro buses for public fleets

Europe's public authorities are major consumers. By using their purchasing power to choose environmentally friendly goods, services and works, they can make an important contribution to sustainable consumption and production - what we call Green Public Procurement (GPP) or green purchasing.

Although GPP is a voluntary instrument, it has a key role to play in the EU's efforts to become a more resource-efficient economy. It can help stimulate a critical mass of demand for more sustainable goods and services which otherwise would be difficult to get onto the market. GPP is therefore a strong stimulus for eco-innovation.

To be effective, GPP requires the inclusion of clear and verifiable environmental criteria for products and services in the public procurement process. The European Commission and a number of European countries have developed guidance in this area, in the form of national GPP criteria. The challenge of furthering take-up by more public sector bodies so that GPP becomes common practice still remains. As does the challenge of ensuring that green purchasing requirements are somewhat compatible between Member States - thus helping create a level playing field that will accelerate and help drive the single market for environmentally friendly goods and services.

Some general guidelines to be taken in consideration when applying GPP

- Commit to the process, and secure political support, by adopting a GPP policy with clear definitions and targets appropriate to your organisation
- Set priorities for the product and service groups you will address by consulting existing GPP criteria, eco-labels and other sources
- Put in place information, training, networking and monitoring activities to ensure you reach your goals
- Consider how green requirements will affect the procurement process for the goods and services you have chosen, and how you will implement them in line with legal obligations
- Get an overview of the products and services available on the market by engaging suppliers and make a business case for GPP based on life-cycle costing
- When tendering, define the subject matter and technical specifications for contracts in a way which takes into account environmental impacts throughout the life-cycle of the goods, services or works you are buying, and consider using labels to define your requirements
- Apply, where appropriate, selection criteria based on environmental technical capacity or environmental and supply chain management measures, and exclude tenderers who do not comply with applicable environmental laws
- Set contract performance clauses which underline the environmental commitments made by contractors, and provide appropriate remedies where they fall short. Ensure there is a system for monitoring these commitments and that they are also applied to subcontractors

Currently the European Commission (EC) is revising the EU Green Public Procurement (GPP) criteria for Transport

4 Review and a brief description of existing projects and studies

This chapter covers an overview and description of existing projects and studies on electro bus involvement into public transport fleets. Overview of existing projects and studies will be the basis for the preparation of eGUTS standards and local action plans

4.1 EU projects and studies

4.1.1 ZeEUS, the Zero Emission Urban Bus System

Testing electrification solutions at the heart of the urban bus system network through live demonstrations and facilitating the market uptake of electric buses in Europe. ZeEUS, the Zero Emission Urban Bus System, aims to be the flagship EU project to extend the fully-electric solution to the core part of the urban bus network. It follows on recommendations from fellow UITP European bus system projects [EBSF and 3iBS] to apply the electric solution to urban bus systems. The project has a total budget of €22.5 million with €13.5 million provided by the European Commission’s Directorate General for Mobility and Transport through the FP7 Programme.

The key objectives of the ZeEUS project are to:

- Extend fully-electric solution to the core part of the urban bus network composed of high capacity buses
- Evaluate the economic, environmental and societal feasibility of electric urban bus systems through live operational scenarios across Europe
- Facilitate the market uptake of electric buses in Europe with dedicated support tools and actions
- Support decision-makers with guidelines and tools on "if", "how" and "when" to introduce electric buses

The ZeEUS Observatory closely follows the evolution of urban bus system electrification around the globe and brings together the widest set of direct experiences with electric urban buses that are running or will run in the next years in Europe through the Group of Observed Sites.

Taking part in the ZeEUS Observatory provides with a platform for collaborative discussions about the progresses of the electrification of high capacity urban bus systems. Additionally, participating cities and companies can benefit from:

- strong visibility through the wide distribution of the only European publication dedicated to high capacity e-buses: ZeEUS eBus Report,
- good dissemination and communication about of the experience through the publication of the e-bus experience on the ZeEUS website,
- support to the development of the Electric Bus Roadmap.

4.1.2 Environmentally friendly Efficient Electric Motion - 3Emotion

The project bridges the gap between current fuel cell bus demonstration projects and larger scale deployment and the procurement foreseen by the FCH-JU Bus commercialization study. A targeted expansion of the EU fuel cell bus demonstration activities, in five key EU bus markets, demonstrates the potential value of this technology for bus fleets.

Through the exchange of information about the experiences from daily FCB operations in these locations in Europe (Antwerp, Cherbourg, London, Rome and Rotterdam) decisions makers, transport authorities will be informed about:

- the movement towards cost effective integration of FC Buses in local bus fleets
- the enhancement of the technical availability of the buses
- the common technical and safety specifications for Refuelling Infrastructure are
- the toolkit for the identification of a proper mix of incentives to support the market demand side
- the evolution of fuel cell buses (from CHIC to 3Emotion)

- 3Emotion will also develop a transferability plan and inform about the effective development strategy towards the FCB and HRS commercialization.

Locations

3Emotion presents the deployment of 21 new and the further use of 8 existing fuel cell buses with the required refuelling infrastructure. These buses will be deployed in 5 sites and operated by 6 public transport operators located all over Europe. Each of these sites has its own constrains for the buses, what makes them all unique and covers the entire range in which fuel cell buses can be a valuable replacement for fossil fuelled buses.

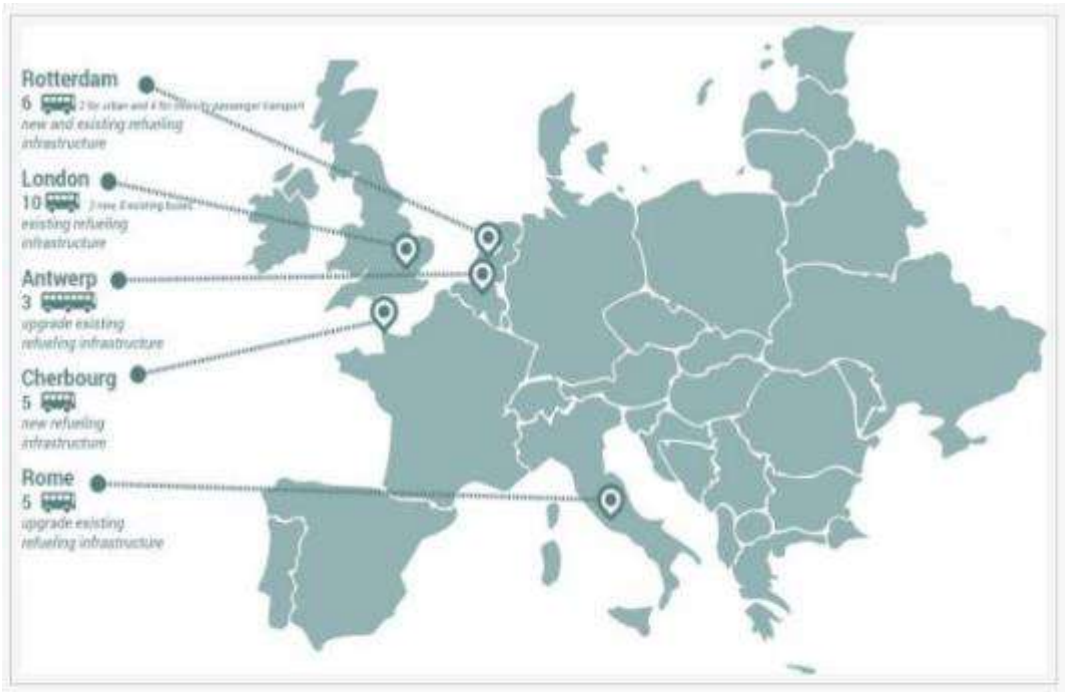

Figure 25. Locations of project implementation

4.1.3 The European Bus System of the Future (EBSF) and The European Bus System of the Future 2

The European Bus System of the Future (EBSF) project was a major opportunity for local authorities, bus manufacturers and operators to transform the image of bus travel, and thus, passengers' perception of it. With the support of the European Commission, European partners worked together to increase the quality of bus services in Europe. EBSF acted as a trend driver to speed up the pace of change in urban mobility behaviour, an important priority for the new generation of people and cities. To respond to the challenge of increasing and changing mobility needs, EBSF based itself on the provision of high quality services. The bus service must be reliable and efficient, accessible, easy to understand and user-friendly.

In the frames of the **EBSF_2 project**, innovative solutions for urban and suburban bus systems were tested and evaluated in order to improve the efficiency of operations and the image of the bus. By involving 12 demonstration sites with more than 500 vehicles, the project validated in real operational scenarios the potential impact of technological innovations – almost ready for application – and develops efficient answers to both citizens and bus stakeholders' needs.

4.2 National studies

4.2.1 Romania

As Romania is at the very beginning of the electric transport use or development this period was marked by some testing periods, in different cities across the country.

The first manufacturer whom included Romania in its targets was BYD. In this sense, the busses were first tested in Bucharest. Apart from Bucharest, the BYD K9 electric buses were tested in Braila, Timisoara, Suceava, Galati, Ploiesti and Brasov. The tests in Suceava took place for a week, with the authorities wanting to get financing for the acquisition of a batch of 40 buses, with a view to expanding metropolitan public transport and the EU 2020 Strategy on Climate Change and Energy Efficiency. Timisoara had the opportunity to test the bus for a month, but there is no plan to buy such models in the near future, the city hall is still indebted to the acquisition of diesel buses.

The tests in Brasov have successfully demonstrated that buses can be a good economic solution with a consumption of 60 lei for 170 km. However, due to budget problems, the authorities have not yet considered the start of procurement procedures for electric buses. The authorities in Galati were also happy with the tests, but they did not come up with an acquisition plan, the reasons being the high costs and the reserves for the autonomy of the buses on some longer routes. Also, after the tests, the authorities in Ploiesti did not express their desire to buy electric buses.

Bucharest

In 2015, electric buses from SOR Libchavy and BYD were tested in Bucharest. The first tested was the SOR EBN 10.5, manufactured by SOR Libchavy, one of the largest manufacturers of buses, trolleys and coaches in the Czech Republic. The bus is powered by an asynchronous engine produced by Skoda Electric powered by a Winston Battery / Lithium-ion battery pack. With a capacity of 85 seats, the tested bus has an autonomy of 250 km and a charging time of up to 8 hours. The bus tested for two weeks on a 25 km routes, managing to run 6 round-trip races along the route. Authorities were pleased with the bus, tests and studies, and are due to decide on a future for the existing capital of investment.

The electric buses test project continued with two BYD K9, 100% electric buses, which ran for two months on line 381. Last generation battery technology provides a 250 km autonomy with a single traffic load Urban normal. Following testing of all the buses presented, the public transport representatives have declared themselves satisfied with the tests, confirming the economic benefits of these models. Advantages start with 20% reduced fuel consumption compared to normal fuel buses and are continued with cheaper and easier maintenance but also with quieter operation. It remains to be seen if in the future the local public transport supplier will benefit from the necessary financing for the implementation of such buses and the necessary power infrastructure.

Oradea

The SOR EBN 10.5, manufactured by SOR Libchavy, reached 2015 to be tested by OTL Oradea. The tests lasted a week on route 14C, but the authorities said they did not intend to purchase electric buses in the near future. In their view, the acquisition costs are too high, the budget being currently oriented towards the extension of the tram network in University areas.

Cluj Napoca

After several years of plans and studies, the Cluj City Hall launched the tender worth 23.7 million lei for the acquisition of the first 10 electric buses in a series of 30. They will equip 4 public transport lines that will be served Exclusive of electric buses. Thus, Cluj becomes the first

Romanian city to buy electric buses. The total value of the investment is 71.2 million lei, funds obtained through the EU Mobility Fund, Swiss funds and local budget. The specification provides for the purchase of low-floor buses and normal equipment for a modern bus, as well as air conditioning in the passenger compartment. The buses will have a 70 km range of autonomy and will be fed from 5 charging stations, 3 of them with fast loading mode. Buses will run on the routes connecting the Train Station of the city or the nearby Airport.

The auction for the new electric buses has been cancelled and will be resumed. The auction was cancelled due to the fact that Astra Arad, which came with the only conformable offer, did not have the fully approved vehicle.

Targu Mures

Targu Mures is the second city in the country that takes steps to a first acquisition of electric buses. In May 2016 the amount of 3 million lei was approved for the purchase of electric buses. Following studies in the field, the authorities were due to finalize the tender specifications for launching the auction by the end of 2016, but there is no clear schedule of procedures.

Timisoara

The testing period in Timisoara showed technology lacks in the Chinese BYD K9. The bus was tested on one of the busiest routes of Timisoara, of about 20 km long. The eBus crashed couple of times, giving the local public transport supplier hard times and engaging in a low acceptance for the inhabitants of Timisoara.

Nevertheless, in terms of financials, the public transport company declared that they are open to new solutions, as they find electric transport the future; they consider opportune the engagement of electric buses with charging infrastructure, realising that one without the other is kind of useless. The high costs of the electric bus, with no insurance on battery lifetime expectancy make the local decision-makers of Timisoara to wait a bit longer in taking a decision implying electric buses in local transport.

In the context of much tougher legislation on vehicle emissions, the electric bus market for public transport will be on the rise with the development of energy conservation technologies. The main challenge in the field of electric buses is the charging infrastructure and the autonomy of the batteries. Also, transport operators are booked because of higher purchase prices, but later studies and tests have shown a faster damping of them through reduced energy consumption of buses.

4.2.2 Czech Republic

Technological projects

FD-K/111 – Research of buses and their components for city public transport. (R&D MPO – FD; CEP/2004/MPO/MPO4FD/U/N/7:2; 2001 - 2003)

Consortium: ČAS Service, Elis Plzeň, Eprona Rokytnice nad Jizerou, TBS Truck Bus Servis, TÜV SÜD Auto CZ, VŠB-TU Machinery Engineering Faculty, VUT Brno Faculty of Electrical Engineering

During the project a functional sample of an electric bus with accumulator drive was developed. In individual stages in individual years R&D activities were focused on optimum drive variants, optimization of power supply voltage, controlled fast charging of accumulators, use of alternative, including renewable, energy resources.

FCZ-H2Bus I + FCZ-H2Bus II (OP Infrastructure - measure 2.3 – support of introduction of alternative fuels; 2005 – 2009)

Recipient: ÚJV Řež, IFE Halden (Norway). ŠKODA Electric, Proton Motor Fuel Cell (Germany), Linde Gas ČR, Arriva Praha

Both projects were co-funded from ERDF (European Regional Development Fund) and from the budget of the Ministry of Transport, Czech Republic (programme of Saving of Energy and Use of Alternative Fuels in Transport) and from sources of project partners.

The aim of the project was to develop and demonstrate hydrogen driven means of transport to the public and to test the ability of this modern drive concept in real conditions of urban traffic. The result was a prototype TriHyBus.

Research and development of light bodywork (R&D TAČR – programme Alfa TA02031296, 2012-2014)

Consortia: ČVUT Machinery Engineering Faculty, SOR Libchavy, Vision Consulting Automotive

The aim of the project was to develop and put in production a standard urban electric bus with transport capacity of 95 to 100 passengers, which is among the most demanded vehicles in the market. A concept of light bodywork was developed, since the existing electric buses with the length of approx. 12 m has their capacity reduced by 20 to 25 passengers due to considerable weight of accumulators. The new bodywork design used a sandwich roof and thin wall Duplex profiles. Based on the research results, an innovated production series of electric buses, was put into a production programme of the manufacturer.

Research and development of a unified series of high-capacity electric buses (R&D TAČR – programme Epsilon TH01021172, 2015-2017 - ONGOING)

Consortium: ČVUT Machinery Engineering Faculty, SOR Libchavy, Vision Consulting Automotive

The aim of the project is to develop and produce prototypes of high-capacity electric buses which would replace the existing diesel buses of 12 to 18 m of length thanks to their transport potential. The project is particularly to deal with maximum lightening of bodywork through using of high-strength and non-conventional materials. Furthermore, the lightening will be reached by the optimization of traction battery sizes in relation to the used charging infrastructure and the frequency of fast charging during a shift, or potentially by using a suitable range extender.

Organizational projects

No national projects focused on the organizational aspect and direct promotions of the development of electric mobility in public transport have been performed in the Czech Republic yet. However, Czech partners are actively involved in international projects, particularly within the initiative Civitas (ELAN, 2Move2) and within activities of UITP (project ZeEUS).

CIVITAS ELAN addresses topics of specific interest to Central and Eastern European cities. These cities face particular challenges such as fast motorisation, capacity problems in public transport, infrastructure renewal and rapidly changing cityscapes. The project helps them with extensive experience in energy-efficient technologies in public transport. The Czech Republic was represented by the city of Brno in the project.

2MOVE2's main objective is to improve urban mobility by advancing or creating sustainable, energy-efficient urban transport systems in participating European cities for the benefit of all citizens, society and climate policy, respecting environment and natural resources. Public transport company DPMB from Brno is a member of the project consortium with main focus on electric public transport.

ZeEUS is a project that involves real-life testing of electric bus systems – no matter plugin hybrid or full electric – and aims to come up with an A-Z guide for cities and operators to adopt 100% electric fleets. Testing of different innovative electric power train systems solutions for buses is currently taking place in Plzeň.

4.2.3 Croatia

The implementation of electric buses in Croatia is a complete novelty. The reasons why there have been so few attempts is the price of the vehicles. Since already, electric vehicles (electric cars) have problems with a mass implementation due to the high prices, mostly of the battery components, electric buses are even more expensive due to the need for a large battery pack.

Therefore, the implementation of buses into the regular public transport system is not feasible without any external co-financing. The only example so far in Croatia, where electric buses were implemented into a public transport system was with the funds of the European union in the framework of FP7 project Civitas Dyn@mo that was conducted by the City of Koprivnica, Croatia.

The goal of this project was to develop, through six different measures, a pilot city area of innovative transport solutions which could be implemented in cities of a similar size. The project was implemented between December 2012 and November 2016. The six different measures that were implemented were the following:

1. Development and adoption of a Sustainable Urban Mobility Plan for the City of Koprivnica

2. Zero CO2 University campus
3. Development of a public transport system
4. Development of a curricula in clean urban mobility
5. Development of a car sharing system with electric vehicles
6. Development of a public transport system with electric buses

The measure no.6 was the only similar measure in Croatia where electric buses were purchased and implemented into a public transport system.

In the scope of this measure, the City of Koprivnica has bought two electric buses and implemented them into the public transport system of the City of Koprivnica that was also established in the scope of this project. The purchased buses were produced by a Croatian company that develop electric vehicles, Dok Ing. Since the company did not produce vehicles in a serial production, they offered a converted conventional vehicle, which they equipped with their own technology. The final product was a 12+1 seats minibus, called Dok Ing eBuzz 112 with a battery capacity of 50 kWh, a range of 160 km and with the possibility of fast charging.

Charging of the buses was done on the charging network in the City of Koprivnica, that consisted of five fast charging stations with a capacity of 22 kW that allowed the charging of the buses from 20 to 80 % in under hour and a half. The chargers were set up by the Croatian national electricity company HEP as a part of the ELEN programme. The City of Koprivnica and the HEP company signed a contract where the City provides the basic infrastructure (land and the distribution of electricity) and HEP provides the chargers.

The vehicles were bought in July 2015 and were used in one test line that was running in the administrative area of the City of Koprivnica. The test bus line was set up so that it allows the buses to charge their batteries during their operation since one of the conclusions of the project was that range and the speed of charging of the vehicles played a great role in the everyday operation of the buses.

Figure 26: eBus test line in Koprivnica, source: www.koprivnica.hr

As an overall conclusion of the project, electric buses in everyday operations were a feasible endeavor, showing that electric buses in public transport can have great potential in cost reduction and environmental benefits, but only if the price of the buses is drastically lower. The price for the electric buses in the case of Civitas Dyn@mo was 3-4 time higher than conventional buses.

At the moment, there are no national studies in Croatia that would deal with the issue of electric buses in public transport operations.

4.2.4 Slovakia

As the first and only project implemented in the Slovak Republic focused on introducing electric buses into public passenger transport, the project entitled "Reduction of Pollutant Emissions from Public Transport in Košice" was supported under the Operational Programme Environment 2007 - 2013, Priority Axis 3 - Air Protection and Minimization of Adverse Effects of Climate Change, OP-PO3-15-2.

The subject of the project was the purchase of 9 electric buses, which subsequently replaced 9 diesel buses with an average age of 14 years. The deadline for project implementation was June 30, 2016.

The total eligible expenditure for the project was € 4 050 800, of which co-financing by the Transport Company of Košice represented a mandatory 5% stake in the total amount of € 189 000.

Within the project, one type of electric bus from the Czech manufacturer SOR Libchavy, Ltd., SOR EBN 11 was purchased. This is a three-door, low-floor electric bus, with a length of 11m 10 cm. It is powered by a TAM 1052 C6B Pragoimex electric motor with a power of 120 kW, with a range of 150 km on one charge. The vehicle was developed in cooperation with the Ostrava Transport Company and Cegelec Company, which supplied electrical equipment. One of its main advantages is the comfort of passenger transport, in the electric bus there are 29 seats, total (even standing) is 93. On each electric bus, the Košice Company has a classic charger and fast charger.

At present, there are 14 electric buses in operation in Košice. The City of Košice was the first in Slovakia in the field of development of green transport and bought in October 2014 five new SOR EBN 10,5 low-floor electric buses of the same manufacturer for emission-free transport of persons in the city with a transport capacity of 85 persons (19 seated). Experience with these electric buses has several locations in the Czech Republic, also in London, Budapest, Copenhagen and others, and is in operation in Ostrava since 2010.

4.2.5 Austria

E-Mobility Monitoring report 2015

The report is a detailed study about the implementation of e-mobility in Austria and was finalised by AustriaTech in March 2016. For electric busses this study gives a brief description of the overall current state of their development and also about the requirements in infrastructure, promotion and legal framework. Decisive for investment decisions are clear political framework conditions for increasing the use of alternative engines in bus fleets.

Holding Graz electric bus project

For electric busses Austria's second-largest city draws some attention. The holding company Graz[12] announced their entire change from fossil fuel to electric driven busses.

With a technology from China, this was in that time new to Europe, public transport in Graz will be converted from 2016 onward. The management of the holding company Graz has been negotiating with the company China South Locomotive & Rolling Stock (CSR) in Ningbo.

The pilot project was presented, which initially went into the test operation with four to five buses. The electric buses, which have only recently been launched in Ningbo, can be recharged in just 20 seconds at recharging stations which are to be parked at every second Grazer bus stop. One charge is enough for about seven kilometres. The charging stations can also be used in multimedial mode. The conversion of the entire fleet (about 160 buses) to e-buses during the next years is the next step in this direction.

So a bus is powered by a "supercondenser" made of carbon. These are reminiscent of their round form of beverage cans, in the square version of olive oil cans. 2700 of them are needed for a bus. The driving force for the holding company Graz to negotiate with CSR was the EU White Paper on Climate and Energy Policy 2030. By 2030 80 percent of public transport should be carried out with non-fossil engines, up to 2050 hundred percent. Graz, which is struggling with particularly high particulate matter values, is confident that these quotas will be met by then.

E-Busses in Klagenfurt

As the Stadtwerke Klagenfurt Group (STW) is set to work on low-pollutant transport, the CEMOBIL project involved the purchase of an e-bus which now operates on the streets of Klagenfurt. The bus is free of emissions and quiet and is used on line 43 between Heiligengeistplatz and Fachhochschule.

Low-floor entrances provide barrier-free and convenient access, and a multi-purpose area for the children's caravan and wheelchair user is available opposite the second door. The heart of the electric bus is a 120 kW, four-pole asynchronous electric motor with a torque of 1,400 Nm and the lithium-ion batteries. These accelerate the electric bus gently and steplessly in the usual 50 km / h traffic. The batteries supply not only the drive but also all other systems in the bus, including air

[12] http://www.holding-graz.at/elektrobusse.html

conditioning, heating, servo steering and door control. All these systems, which are operated on conventional buses by compressors powered by the internal combustion engine, are equipped with electrical solutions. Thanks to its environmental friendliness, the air quality of Klagenfurt is increasing. The bus driver is equipped with a touchscreen, which displays the most important data as well as information about the work of the electric system and the battery status. With this touchscreen, the driver can control the heating or switch other driving functions. This clever system allows the bus driver to concentrate only on driving.

4.2.6 Slovenia

VIVO -100% Electric bus

VIVO is an electric bus, which was made and renewed from a used bus with internal combustion engine. Company VIVO designs the final product (100% electric bus), so that it is completely adjusted to the requirements of the customer in terms of the desired range, application method (tourist bus, public transport bus, mini bus…), number of ordered buses, lower maintenance costs.

Only high end components are used – Siemens motor and control electronics and Toshiba batteries with 5 years guarantee. All buses feature fast charging and a custom designed central control system with a user interface. Production of large series of electro buses is offered

Figure 27: Example of VIVO -100% Electric bus

HOA project

Hoa project l.l.c. is a one of the leading companies in the region in terms of sales of organic light electric vehicles. Under one roof they combine sale of electric vehicles, electric charging stations and technical support. In the last few years they have managed to approach their products to Slovenian citizens and institutions. Company offers comprehensive solutions and advice for transport and internal transportation in tourist, urban, industrial areas and parks, including conception of vehicles, selection of an appropriate model of financing, fleet management and rehabilitation of disused means of transport.

Figure 28: Example of HOA vehicle, source: http://www.hoaprojekt.com/vozila/attiva-8l-4/

MOBINCITY

The aim of the project was to optimize the route from point A to point B with the aim of reducing energy consumption and harmful emissions. Intermodal forms of transport, with an emphasis on the use of electric vehicles and public transport were used in the project. On the physical level, the data from different databases (location and status of charging stations for electric vehicles, weather and traffic conditions, the state of the energy networks, transport timetables…) is used with help of mobile devices in order to select the most appropriate form of transport from initial to the final location.

4.2.7 Hungary

Since e-mobility is still in its infancy in Hungary, to our knowledge there are no studies dealing solely with electro buses.

There are also no nation-wide projects promoting the use of electric buses, bit a few local projects are under way. There are also tie-ins to international projects as well.

SMART-MR Interreg Europe project

The project thesis is that a metropolitan region of tomorrow should provide its residents with a safe, functional and resilient environment. Low-carbon transportation and mobility are vital components of such smart urban areas.

However, transportation in metropolitan regions today generates congestion and vast greenhouse gas emissions. This imposes enormous challenges upon local and regional authorities in providing healthy living conditions for inhabitants and a supportive environment for businesses.

SMART-MR finds solutions and helps local and regional authorities improve transport policies.

The key project outputs include a guide on sustainable measures for achieving low-carbon and resilient transportation in metropolitan regions, selected good practice descriptions, and policy recommendations. Through these outputs, as well as dissemination events (such as political meetings, the final conference, and regional stakeholder meetings), SMART-MR contributes to Europe 2020 goals, Cohesion Policy, and the Interreg Europe Program.

The Hungarian project partner is the Centre for Budapest Transport (Budapest Közlekedési Központ – BKK). In the initiative to integrate electric vehicles into their fleet, the transport agency has purchased 20 electric buses, with the help of government grants for use in downtown traffic.

The **ELIPTIC** (Horizon2020 project) activities in Szeged are led by SZKT (Szegedi Közlekedési Társaság – Szeged Transport Company), with support of University of Szeged.

ELIPTIC aims to develop new concepts and business cases in order to optimise existing electric public transport infrastructure and rolling stock, saving both money and energy. The project strengthens the role of electric public transport, leading to reduced fossil fuel consumption and improved air quality.

ELIPTIC will focus on the use of existing electric public transport systems (including light rail, metro, tram and trolleybus) for the electrification of multimodal mobility approaches in the urban, sub-urban and also less urban context. The overall concept and main assumption underpinning ELIPTIC is that further take-up of electric vehicles can be supported cost-efficiently by integrating existing electric public transport infrastructure for multi-purpose use.

Szeged is participating in the development/implementation of the project's Pillar A and Pillar C.

Pillar A - Replacing diesel bus lines by extending trolley bus network with trolley-hybrids

The Szeged study models the case of replacing diesel bus lines with extension of the trolley bus network with trolley-hybrids without the need for additional infrastructure. The charging in this use case comes from the existing catenary network and the battery trolley buses runs in accumulator mode in between the existing and extended network. Possible/alternative route definitions, the effects of such a system on the traffic as well as external effects are explored at first. Then, the stakeholders will select the test route from the alternatives and define the transport service and required vehicle fleet.

Pillar C - Multipurpose use of infrastructure for (re)charging trolley-hybrids & e-vehicles

The aim of this Use Case is to test the first public electrical multipurpose charging station for trolley-hybrid-buses, e-bikesand and e-cars in the city of Szeged. It includes localisation of the station, testing its use with trolley-hybrid-buses, e-cars and e-bikes, which will eventually lead to developing concepts for electric intermodal e-mobility. This first multipurpose charging station supports the long term transport strategy plan of the Municipality in Szeged, promoting e-traffic mobility modes.

The City of Paks has submitted its Protheus project proposal to the European Investment Bank's ELENA (European Local Energy Assistance) initiative. The Protheus project will be an ambitious regional undertaking. The Protheus project’s goal is to implement electro mobility in Paks and municipalities within a 60 km radius. Further objectives are the generation, storage and distribution of electricity and smart grid integration of the sub region network. This supports the promotion of a new conditionality that insures a more liveable and healthy environment, as well as the development of a sustainable, recoverable model for effective operation of resources.

4.2.8 Montenegro

No analysis has been made, nor feasibility studies in terms of use of electro buses into public transport fleets, weather on local or on national level. Also, no analysis has been made in terms of decrease of CO2 emissions for urban or rural areas by use of electric buses in public transport.

4.2.9 Serbia

The transport development planning is not regulated by the existing legal framework at either national or local level, but indirectly.

No studies have been conducted in the Republic of Serbia on the topic of electro bus involvement into public transport fleets.

Strategic planning of traffic development, based on SMART goals, defines the following indicators:

- Efficiency of traffic,
- Safety in traffic,
- Economics,
- Accessibility,
- Environmental Protection.

In strategic documents, taking into account the environmental protection, strategic objectives of sustainable development put emphasis on e-mobility.

The available strategic documents are:

- at the national level: ″Strategy for development of railway, road, water, air and intermodal transport in the Republic of Serbia by 2015″
- at the local level: ″Strategy for the development of traffic in the city of Kragujevac 2012-2021″

5 Plans and incentives for further development

5.1 Further developments world-wide

Studies show that the electric industry will grow in the following years, both in terms of usage and of developing sector. In this sense, the scenarios of the following years refer to hybrid/electric powertrain component price, while the second scenario refers to green powertrain and energy storage standards.

Scenario 1: Hybrid/Electric Powertrain Component Price Forecast

Figure 29: Graphic of Hybrid/Electric powertrain component price forecast
(Source: http://academy.busworld.org)

The time period overseen in this scenario is 2014- 2030. The graphic above shows that up until 2030, the electric busses components will suffer changes in terms of costs. While supplier- level costs for batteries, inverters and motors will decline over the forecast period, the cost of controllers is expected to rise due to a shift in propulsive power from diesel engine to electric motor, thereby increasing the complexity of power management.

Scenario 2: Powertrain and Energy Storage Standards

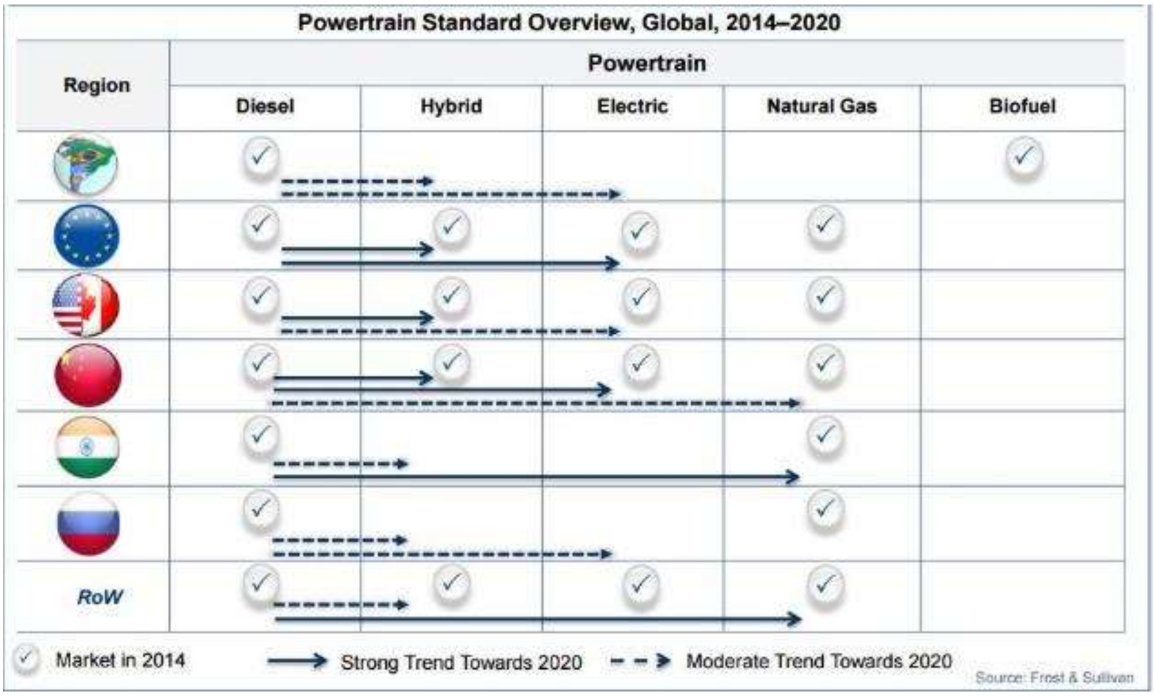

Figure 30: Graphic on Powertrain Standards (Source: http://academy.busworld.org)

Diesel powertrain systems will be gradually replaced by alternative powertrain systems. Hybrid & Electric buses will experience competition from Natural Gas buses if Compressed Natural Gas/Liquid Natural Gas prices fall due to the proliferation of shale gas.

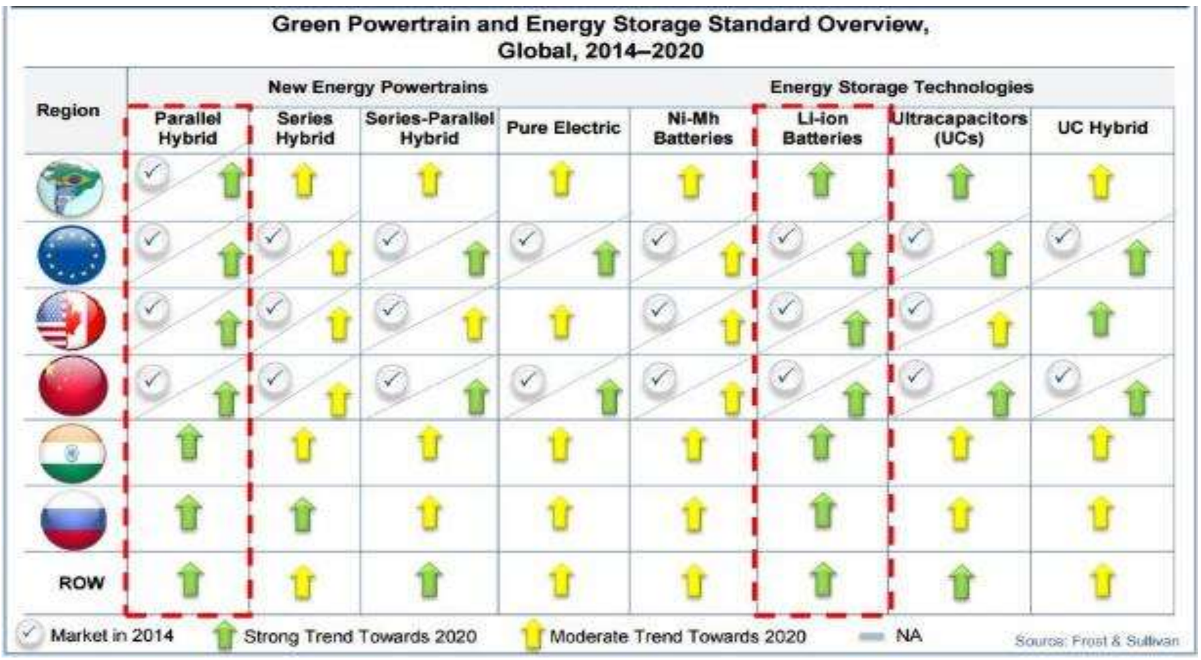

Figure 31: Graphic on Green Powertrain and Energy Storage Standards

(Source:http://academy.busworld.org)

Parallel hybrids are expected to strengthen its market position due to the cost advantage over other systems. Hybrids will gain prominence as primary energy storage systems, especially in hybrid buses.

6 Conclusion

Electric buses have great potential for the future, especially in cities and urban areas. The advantages of electric buses adoption into urban transport systems are indisputable – no exhaust fumes, less noise emissions and low operation costs. Still there are many factors hindering the integration of electric buses in public transportation systems – high initial purchase price, battery life cycle and reliability of information for determination of optimum setting for specific operational circumstances. At the moment, electric buses are most useful for inner city short distance transport as their range is severely limited in comparison to conventional (diesel powered) buses. Thus e-buses are not functional for transport between regions of for regions with dispersed settlement. In order to advance penetration of e-buses into urban transport systems following findings should be taken into account:

- Clear legal framework, with involvement of national policy-makers for subsidizing the required infrastructure and the acquisitions of electric buses fleet is needed.
- Easily accessible and transparent information on subsidies/grants in all Danube region countries would be of great benefit.
- Initializing an infrastructure program for countries that are not so well developed in terms of charging infrastructure (like Romania)
- More intensive involvement/contribution of private companies in infrastructure development (private investments for an electric future)
- Better assessment and real-life information on batteries' life-time and performance during lower temperatures seasons are needed
- Standardized, real-life information/support for defining optimal configuration for specific needs of individual stakeholders/organisations procuring e-buses is needed.

Despite predominant role of diesel powered buses hybrid and electric buses are slowly taking their place in transport fleets in EU with some countries being more advance than others. This is especially true in Danube region where Austria is leading the way while other countries are at different pace following behind. Even though the consortium is formed by countries with a different state of development in terms of infrastructure, legal frameworks, use of electric bus, etc., we can say that the direction taken by the European Union (including the consortium region) is to increase the number of cities to turn to electric buses, to help reduce their public transport carbon footprint.

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