



# ZeEUS Demonstrations



**ZeEUS**

Zero Emission Urban Bus System

# Barcelona (ES)

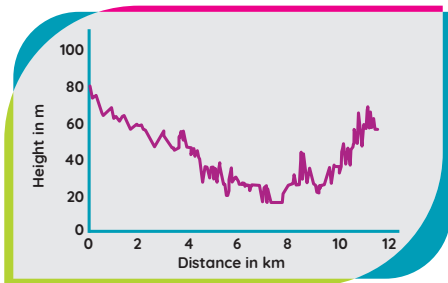
## DESCRIPTION

The ZeEUS Demonstration in Barcelona is investigating the feasibility of two opportunity-charged 18m articulated buses and two overnight-charged 12m buses.

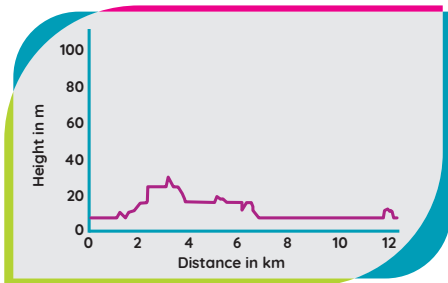
The 18m buses are charged at the depot for 2-6 hours and run under normal Barcelona conditions for 16 hours.

The opportunity-charged buses recharge their batteries each 12km (half of the route) to up to 80% of total capacity. This allows the buses to run all day.

The test in hilly routes shows that consumption is similar to that on flat routes. The energy consumed ascending is almost completely recouped when descending.



Elevation map of the line route L34



Elevation map of the line route H16

## OPERATIONAL CONDITIONS

**Line number:** H16, L34

**Typology:** City centre

**Topography:** Flat

**Length:** H16: 12km; L34: 12km

**Average commercial speed:** 11km/h

**Total daily hours of operation:** 16h

**Total km driven/vehicle/day:** 180km

**Av. no. of passengers/day:** 650 passengers

**SORT type:** 1



Solaris E18

## DEMO IN BRIEF

### Vehicle technology:

2 x Full Electric

### Brand and model:

Solaris E18

**Bus length:** 18m

**Capacity:** 115 passengers

### Charging technology:

Opportunity

### Duration:

From May 2016 and ongoing

### Vehicle technology:

2 x Full Electric

### Brand and model:

Irizar i2e

**Bus length:** 12m

**Capacity:** 75 passengers

### Charging technology:

Overnight

### Duration:

From Sept 2014 and ongoing

## KEY TOPIC

The idea is to test the viability of operating these types of buses in warm Mediterranean weather and to test the two charging strategies.

TMB's objective is to evaluate the reliability and feasibility of this solution. It will provide information that allows comparison of total cost of ownership, operational requirements, limitations and opportunities offered by these charging strategies.

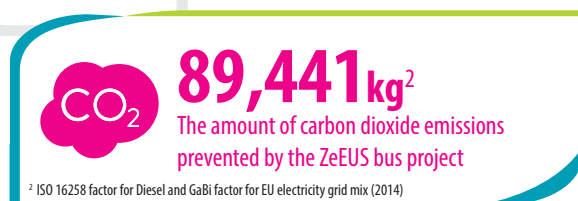
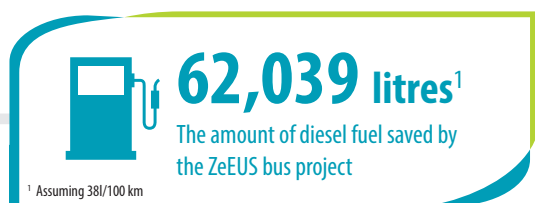
## DEMO TIMELINE

- Oct 2016 - Solaris test ride
- Sept 2016 - Fast charger installed
- May 2016 - Fast charger reception
- Sept 2014 - Irizar start of operation
- March 2016 - Solaris bus reception
- Aug 2014 - Irizar bus reception



Irizar i2e

## FIGURES FOR THE BARCELONA DEMO FROM AUGUST 2014 TO AUGUST 2017



## RESULTS AND LESSONS LEARNED

- Currently, opportunity charging is the best option for TMB operations. However, the costs and delays of infrastructure installation are the next challenge. Working hand-in-hand with city council is essential.
- Powertrain, batteries and motors technologies are sufficiently mature to allow implementation.
- Batteries lose power at the predicted rate; LTO batteries provide the optimum solution for opportunity charging application
- ‘Zebra’ (Sodium Nickel Chloride) batteries lack reliability.

“Opportunity charging is the best solution for TMB. Urban route conditions offer the ideal environment to realise the advantages of electric buses.”

Mario Canet, Engineering New Development Responsible, Transports Metropolitans de Barcelona

## FUTURE PLANS

Electrify new lines with opportunity charging; ‘wait and see’ for overnight charging.

In July 2018, TMB will receive seven 18m articulated e-buses from Irizar and Solaris with opportunity charging.

In 2019, line H16 will be fully electric (with 22 buses) and TMB will begin electrifying another line.

[www.zeeus.eu](http://www.zeeus.eu)



The ZeEUS project is coordinated by UITP. ZeEUS is co-funded by the European Commission under the 7th Research & Innovation Framework Programme, Mobility & Transport Directorate General under grant agreement n° 605485. The ZeEUS project has been launched by the European Commission in the frame of the European Green Vehicle and Smart Cities & Communities.



# Bonn (DE)

## DESCRIPTION

Stadtwerke Bonn (SWB Bus und Bahn), the local transport operator, plans to convert its bus fleet from diesel to electric propulsion. The ZeEUS Demonstration, using six electric buses, is viewed as a first step towards this ambitious goal.

The 12m battery buses operate on all lines, providing a comprehensive overview on the opportunities and challenges of operating buses using an overnight charging approach.



E-Bus in Bonn, connecting Central Station with Headquarter of DHL and UNFCCC

## DEMO IN BRIEF

### Vehicle technology:

6 x Full Electric

### Brand and model:

Sileo S12 (Bozankaya)

**Bus length:** 12m

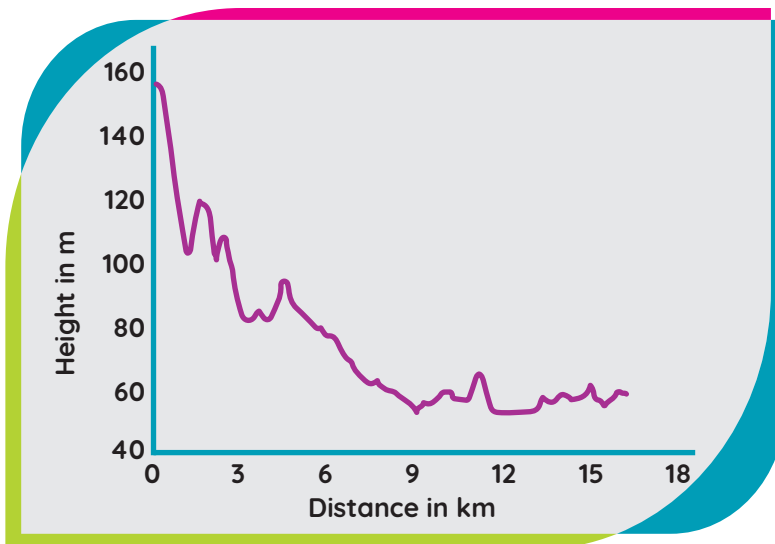
**Capacity:** 80 passengers

### Charging technology:

Overnight at depot

### Duration:

April 2016 – March 2018



Elevation map of the line route 606

## OPERATIONAL CONDITIONS

**Line number:** mainly 606/607, also other lines

**Typology:** City centre and suburban areas

**Topography:** mostly flat with moderate hills

**Length:** 17km

**Average commercial speed:** 16.6km/h

**Total daily hours of operation:** 13.5h

**Total km driven/vehicle/day:** 200km

**Av. no. of passengers/day:** 7,250 passengers (Mon-Fri)

**SORT type:** N/A

## KEY TOPIC

From the outset, any considerations about operating electric buses SWB Bus und Bahn had to meet three essential preconditions before any project launch:

- Full integration of electric buses into the existing fleet
- One-for-one replacement of diesel buses
- No adaptations to lines and service schedules

The major challenge was to identify the most suitable electric bus for these parameters.

During the demonstration period, the focus was on proving the operational suitability during daily service while monitoring the development of range, reliability and frequency of repairs.

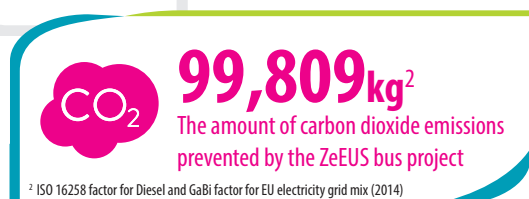
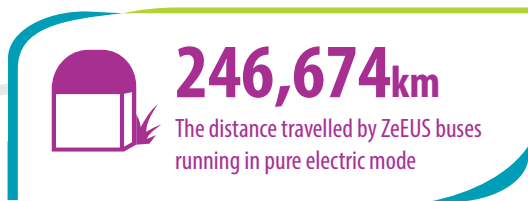
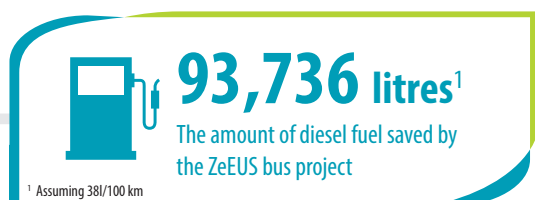
## DEMO TIMELINE •

- **Apr 2016** - Start of operations
- **Nov 2015** - Beginning of training
- **Nov 2015** - Preparation of depot/garage
- **Jul 2015** - Procurement
- **Feb 2015** - Start of tender process
- **Jan 2014** - Feasibility study report
- **Feb 2012** - Project launch



Six electric Sileo buses in Bonn

## FIGURES FOR THE BONN DEMO FROM MARCH 2016 TO DECEMBER 2017



## RESULTS AND LESSONS LEARNED •

- The ZeEUS-Project has provided valuable experience for shaping our future approach
- From an ecological perspective, we would prefer to convert to electric propulsion as soon as possible. However, from an economic perspective, we need to be patient
- The reliability and range of the vehicles has to be improved, particularly for low-temperature operations
- A key challenge in the depot is to ensure effective interaction between vehicle and charging infrastructure

**Conclusion:** Currently, it is not feasible to replace diesel buses with electric buses on a one-to-one basis

“Bonn is home to UNFCCC and is the German Capital of Sustainability. Zero emissions in public transport are our aim and ambition.”

Anja Wenmakers, CEO SWB Bus und Bahn

## FUTURE PLANS •

We will persist with the chosen approach, with the aim of finding the optimum technical solution for balancing economic efficiency with environmental sustainability.

[www.zeeus.eu](http://www.zeeus.eu)



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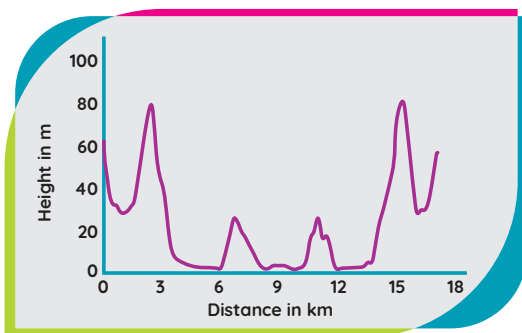
# Cagliari (IT)

## DESCRIPTION

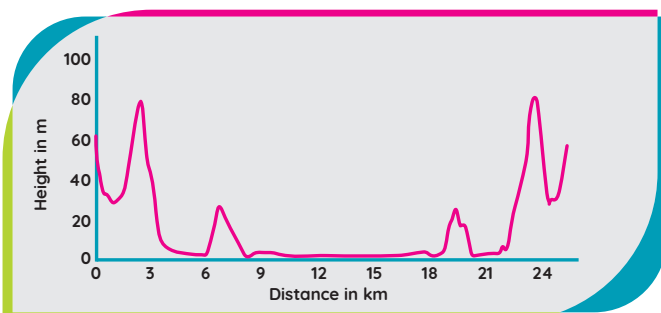
CTM evaluated the performance (efficiency, reliability, etc.) of six battery trolleybuses against both traditional trolleybuses of the same brand and model equipped with a diesel auxiliary power unit (APU) and diesel buses. The demo was undertaken during normal service (line 5-ZeEUS) using all vehicles simultaneously. A section of the route was driven using the trolleybuses with the auxiliary system only (batteries, diesel APU).



Kiepe Van Hool A330T while running the Line 5-ZeEUS by batteries



Elevation map of the line route - winter configuration



Elevation map of the line route - summer configuration

## OPERATIONAL CONDITIONS

**Line number:** Line 5 ZeEUS

**Typology:** City centre – suburban (seafront road)

**Topography:** Moderate

**Length:** 17.1km (winter configuration), 25.6km (summer configuration)

**Average commercial speed:** 13.3km/h

**Total daily hours of operation:** 15 - 18h

**Total km driven/vehicle/day:** 180 - 220km

**Av. no. of passengers/day:** 8,000 passengers

**SORT type:** N/A

## DEMO IN BRIEF

### Vehicle technology:

6 x Battery Trolleybuses

### Brand and model:

2 x Solaris Trollino T12,  
4 x Kiepe - Van Hool A330T

**Bus length:** 12m

**Capacity:** 82-86 passengers

### Charging technology:

Trolley poles (in-motion charging – at charging station)

### Duration:

March 2016 – Sept 2017

## KEY TOPIC

The core of the Cagliari Demo test was to assess the technical-economic feasibility of trolleybuses. Equipping these vehicles with traction batteries provides all the advantages of trolleybuses - less noise, no local pollution, lower energy costs, etc. - with the flexibility of traditional buses.

With a properly-designed system of vehicle and charging infrastructure, battery trolleybuses make it possible to extend the full-electric public transport service without the need to install new infrastructure such as overhead lines. This brings environmental benefits, with significant savings in investment costs and implementation times.

## DEMO TIMELINE •

- **Sept 2017** - end of Cagliari Demo test
- **April 2017** - Demo test extension
- **August 2016** - charging station completed, start of service of four Kiepe-Van Hool A330T
- **March 2016** - start of the Cagliari Demo Test with entry into service of two Solaris Trollino T12



Solaris Trollino T12 while running the Line 5-ZeEUS by batteries

## FIGURES FOR THE CAGLIARI DEMO FROM MARCH 2016 TO SEPTEMBER 2017



**131,837 litres<sup>1</sup>**

The amount of diesel fuel saved by the ZeEUS bus project

<sup>1</sup> Assuming 38l/100 km



**346,940 km**

The distance travelled by ZeEUS buses running in pure electric mode



**105,100kg<sup>2</sup>**

The amount of carbon dioxide emissions prevented by the ZeEUS bus project

<sup>2</sup> ISO 16258 factor for Diesel and GaBi factor for EU electricity grid mix (2014)

## RESULTS AND LESSONS LEARNED •

- During 501-day test period, the battery trolleybuses covered around 346,944km, including 95,865km by battery.
- The reliability of the battery trolleybuses proved excellent, with reliability values comparable to CTM's existing bus and trolleybus fleet
- Energy consumption is considerably lower than diesel buses and traditional trolleybuses
- According to a number of surveys, the passengers appreciate the ZeEUS project and the battery-driven trolleybuses
- The battery trolleybus is a viable and mature technical option that is reliable, flexible and clean

“The participation of CTM in the ZeEUS project represents a major step towards transforming the city and in improving citizens' quality of life.”

Massimo Zedda, Mayor of Cagliari

## FUTURE PLANS •

Future plans envisage using battery-powered trolleybuses and associated infrastructure for regular transport services.

CTM will use the results of the trial to improve various aspects (procurement, maintenance, etc.) and to design extensions to the trolleybus network in areas where the catenary is not available.

[www.zeeus.eu](http://www.zeeus.eu)



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# Eindhoven (NL)

## DESCRIPTION

The Zuid-Oost-Brabant concession covers a region with 750,000 inhabitants. Its main cities are Eindhoven and Helmond.

The 43 electric buses of Transdev fleet form part of a fleet of 215 in this concession. All 43 electric buses were included in the ZeEUS demo in order to test different pre-heating strategies as from December 2016.



The electric bus in the centre of Eindhoven



Elevation map of the lines 400-407

## OPERATIONAL CONDITIONS

**Line number:** 400, 401, 402, 403, 404, 405, 406 and 407

**Typology:** City centre and suburban

**Topography:** Flat

**Length:** 4.4 - 12.3km

**Average commercial speed:** 18.5 - 27.5km/h

**Total daily hours of operation:** 20h

**Total km driven/vehicle/day:**  
av. 200km - max 300km

**Av. no. of passengers/day:**  
11.500 passengers per line

**SORT type:** E-SORT

## DEMO IN BRIEF

**Vehicle technology:**  
43 x Full Electric

**Brand and model:**  
VDL Citea SLFA-E181

**Bus length:** 18.15m

**Capacity:** 136 passengers

**Charging technology:**  
Combination of opportunity (40 min.) and overnight charging at the bus depot (4-5h)

**Duration:**  
Dec 2016 - Sept 2017

## KEY TOPIC

Eindhoven is the ZeEUS demo for smart pre-heating of electric bus interiors and batteries.

The e-buses are scheduled to drive 71,000 km per vehicle per year.

Opportunity charging is through roof-mounted pantographs and fast chargers within the bus depot during the day. There are 22 slow chargers of 30kW and 10 fast chargers of 300kW available at the bus depot in Eindhoven, situated only 1km from the bus transit station.

During the contract period (2016-2026), the remaining diesel buses will be replaced with electric buses (12m - 13m and midis).



## DEMO TIMELINE

- Dec 2017 – 3,000,000km driven
- April 2017 – 1,000,000km driven
- Dec 2016 – start of operations
- Nov 2016 – training of 560 drivers



The buses during the charging and pre-heating of the battery

## FIGURES FOR THE EINDHOVEN DEMO FROM DECEMBER 2016 TO JANUARY 2018



**1,298,586 litres<sup>1</sup>**

The amount of diesel fuel saved by the ZeEUS bus project

<sup>1</sup> Assuming 38l/100 km



**3,417,331 km**

The distance travelled by ZeEUS buses running in pure electric mode



**1,167,054 kg<sup>2</sup>**

The amount of carbon dioxide emissions prevented by the ZeEUS bus project

<sup>2</sup> ISO 16258 factor for Diesel and GaBi factor for EU electricity grid mix (2014)

## RESULTS AND LESSONS LEARNED

- Battery temperature is an important parameter when choosing fast-charging and air-cooled batteries
- Training drivers in e-bus operations is an important feature in extending the limited range
- The bus is so quiet that there is a (tram)bell installed to warn pedestrians and prevent accidents
- Choosing the best charging strategies demands developing new mindsets
- New heating strategies are being developed to improve the quality of fast-charging sessions

“Our drivers did well. Lots of things could have gone wrong, because driving an e-bus is completely different. I am proud of our enthusiastic team of drivers.”

Juul Van Hout, Managing Director, Hermes

## FUTURE PLANS

- Development of phase 2: adding the next 65 e-buses during the period 2019-2021
- Development of phase 3: adding of the next 65 e-buses during the period 2022-2024
- Upgrading the chargers and expanding charging facilities to further locations or other depots

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# London (UK)

## DESCRIPTION

As part of the ZeEUS project, the London demo trialled three plug-in electric-diesel hybrid double-decker buses on route 69. These ran between two major city transport hubs, Canning Town Bus Station and Walthamstow Central Bus Station.

The buses charged wirelessly at either end of the route, where they were parked over a 100kW charging plate. In addition, the batteries were fully charged by overnight plug-in charging at the bus station.



Bus positioning for charging



Map of the line route

## DEMO IN BRIEF

**Vehicle technology:**  
3 x Plug-in Hybrid-drive electric range extender

**Brand and model:**  
Alexander Dennis, E400 VE

**Bus length:** 10.3m

**Capacity:** 83 passengers

**Charging technology:**  
Overnight plug-in charging, and route termini inductive wireless charging

**Duration:**  
Nov 2015 - April 2017

## OPERATIONAL CONDITIONS

**Line number:** 69

**Typology:** City Urban

**Topography:** Flat

**Length:** 11km

**Average commercial speed:** 12km/h

**Total daily hours of operation:** 16h

**Total km driven/vehicle/day:** 160km

**Av. no. of passengers/day:** 26,966 passengers

**SORT type:** N/A

## KEY TOPIC

Approximately two-thirds of the London bus fleet is in double deck configuration. This poses a technical challenge for pure electric vehicles, given the current state of battery technological maturity. Although permissible maximum gross vehicle weight has now been increased to 19,500kg, this still presents significant challenges in maintaining passenger capacities while carrying sufficient battery capacity to achieve and maintain route schedules.

## DEMO TIMELINE •

- **April 2017** - buses transition from demonstration trial status and into normal operation
- **April 2016** - Entry into service
- **April 2016** - Acceptance testing
- **Jan 2016** - First reporting
- **Dec 2015** - Official launch
- **Nov 2015** - All buses delivered
- **Oct 2015** - ADL delivery, driver and engineering training



Official Launch of the London Demo

## FIGURES FOR THE LONDON DEMO FROM APRIL 2016 TO DECEMBER 2016



**16,592 litres<sup>1</sup>**

The amount of diesel fuel saved by the ZeEUS bus project

<sup>1</sup> Assuming 38l/100 km



**43,664km**

The distance travelled by ZeEUS buses running in pure electric mode



**33,582kg<sup>2</sup>**

The amount of carbon dioxide emissions prevented by the ZeEUS bus project

<sup>2</sup> ISO 16258 factor for Diesel and GaBi factor for EU electricity grid mix (2014)

## RESULTS AND LESSONS LEARNED •

- The project achieved more than 60% in EV mode. This can be further improved by consistent overnight top-up charging at the bus garage.
- Improved understanding of the plug-in range extended wireless charged bus technology, and its operational performance.
- Positive feedback from both drivers and passengers.
- Installing the charging infrastructure proved to be the greatest challenge.
- A great deal of the demonstration trial focused on optimising technology performance; there will be equal focus on the human aspects in future trials

“The demonstration trial provided TfL with a valuable opportunity to run wireless-charged buses under real world operating conditions. The lessons learned will inform London’s future zero-emission bus strategy.”

Colin Gerald, Engineering Manager, TfL

## FUTURE PLANS •

The buses and infrastructure will continue to operate in service to test operational performance and durability further. A key design requirement for future solutions will be charging interoperability, providing the flexibility to move buses between routes.

A number of different charging solutions and strategies, such as opportunistic high-power induction (wireless) and conductive (pantograph) charging solutions, will be explored further to optimise and extend the range of the electric double-deck bus configuration.

[www.zeeus.eu](http://www.zeeus.eu)



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# Münster (DE)

## DESCRIPTION

The Münster demo consists of five full-battery electric buses built by manufacturer VDL. These use an opportunity fast-charging system at terminal stops and slow charging at the depot. With a battery capacity of 62.5kWh, the buses run as a full-day service on an urban line, serving the city centre and central railway station with the zoo and suburban districts.

Zero-emission vehicles, funded by the ZeEUS project, support the Münster clean air plan.



The electric buses pass through Münster's historic city centre

## DEMO IN BRIEF

### Vehicle technology:

5 x Full Electric

### Brand and model:

VDL Citea SLF-120 electric

**Bus length:** 12m

**Capacity:** 80 passengers

**Charging technology:** Ultra-fast conductive via pantograph

### Duration:

Sept 2015 – April 2017



Elevation map of the line route

## OPERATIONAL CONDITIONS

**Line number:** 14

**Typology:** City centre and suburban

**Topography:** Flat

**Length:** 11km

**Average commercial speed:** 14km/h

**Total daily hours of operation:** 16h

**Total km driven/vehicle/day:** 150km

**Av. no. of passengers/day:** 5,000 passengers

**SORT type:** 2

## KEY TOPIC

Clean air is a key component of healthy living. However, many German towns face high nitrogen oxide levels from road vehicles emissions. Although each diesel bus efficiently reduces air pollution by replacing up to 100 cars during rush hour, high demand remains for zero-emission public transport.

ZeEUS enabled local energy supplier and transportation company Stadtwerke Münster to operate electric buses at an early stage. This has provided a great deal of insight into bus, battery and charging infrastructure technologies. This expertise will help manage the transition from diesel to electric operations within the next years.

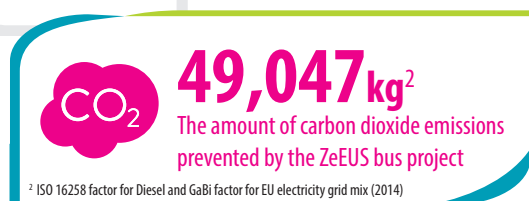
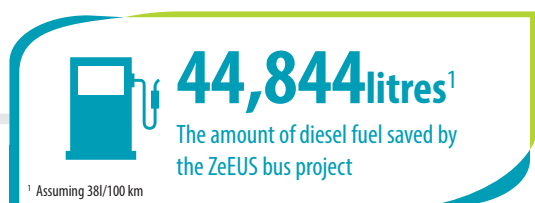
## DEMO TIMELINE •

- **Since Sept 2016** – continuous operation
- **Sept 2016** – change of charging solution from side coupling to overhead pantograph system
- **Sept 2015** – extended operation with fast-charging side-coupling system at the terminal stations and slow charging at the depot
- **May 2015** – start of short-range operation until completion of fast charging stations



Charging by pantograph. The substation imitates an electric bus

## • FIGURES FOR THE MÜNSTER DEMO FROM NOVEMBER 2016 TO AUGUST 2017



## RESULTS AND LESSONS LEARNED •

- Electric buses are perceived positively by passengers, residents and bus drivers
- The charging infrastructure is key to the reliability of the buses
- Many of the frequent technical failures related to operating errors or vehicle malfunctions rather than to the electrical propulsion technology
- On-board support from a trainer during real-world operation helps instil driver confidence in the vehicle technology
- Integrating e-buses into a diesel fleet takes time

“Electric buses represent the future of public transport. The ZeEUS projects gave us a head start, enabling us to support cities from near and far.”

Eckhard Schläfke, Public Transport Manager, Stadtwerke Münster

## FUTURE PLANS •

Stadtwerke Münster will continue on the “zero emissions” path started with ZeEUS. Two hydrogen fuel cell and five additional VDL electric buses will operate in Münster from 2018. The latter will use the same charging infrastructure but their larger batteries offer greater flexibility, whilst the former have 400+ km range.

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# PILSEN (CZ)

## DESCRIPTION

The project was designed to test full-electric buses in combination with rapid-charging infrastructure in real-time operations. The objective was to assess the potential for replacing diesel buses. This is considered a landmark in Pilsen's and Skoda's history of cooperation with PMDP (Plzeňské městské dopravní podniky/Pilsen City Transport Company) as a bus, tram and trolleybus operator, Plzeňská Teplarenska as an energy provider and West Bohemian University as an academic and research partner.



Battery Bus SKODA PERUN

## DEMO IN BRIEF

### Vehicle technology:

2 x Full Electric

### Brand and model:

ŠKODA PERUN E-BUS

**Bus length:** 12m

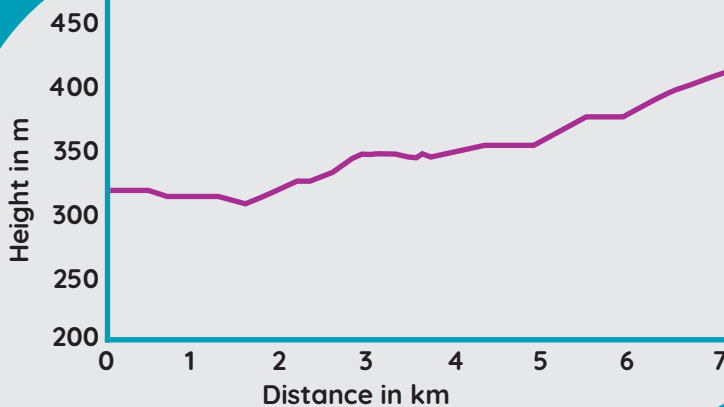
**Capacity:** 82 passengers

### Charging technology:

Fast charging at the terminal and slow charging at the depot

### Duration:

May 2015 - April 2017



Elevation map of the line route

## OPERATIONAL CONDITIONS

**Line number:** 27, 33

**Typology:** City centre, suburban area

**Topography:** Hilly

**Length:** 6km

**Average commercial speed:** 25km/h

**Total daily hours of operation:** 7.5-18.5h

**Total km driven/vehicle/day:** 80 - 200km

**Av. no. of passengers/day:** 1258

**SORT type:** SORT1, SORT2

## KEY TOPIC

The goal of the project was to test pure-electric vehicle operations on the most frequently-used bus line to compare the environmental and financial performance of electric buses in public transport. The ŠKODA vehicles were pure-electric, 12m-length full low-floor city buses with an advanced battery system allows rapid charging at one terminal station. The rapid-charging solution selected was the most effective given the combination of the length of the bus line, the time needed for charging and the required vehicle parameters such as passenger capacity.

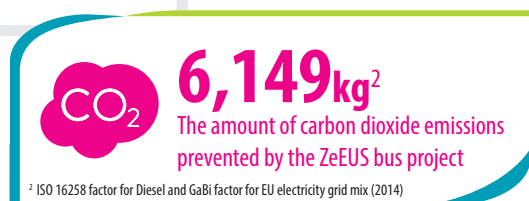
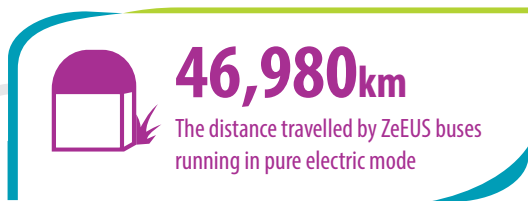
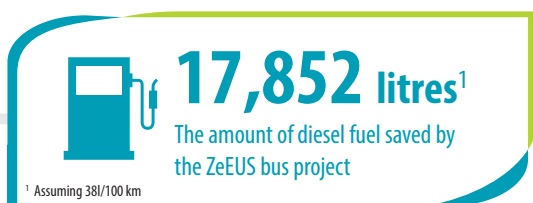
## DEMO TIMELINE •

- April 2017 - end of e-bus demo operation
- May 2015 - e-buses enter service
- Sept 2014 - start of e-bus testing
- March 2014 - installation of the charging infrastructure
- March 2014 - detailed e-bus and charging station-technical specifications



The ŠKODA PERUN battery buses operated in Pilsen

## FIGURES FOR THE PILSEN DEMO FROM MAY 2015 TO APRIL 2017



## RESULTS AND LESSONS LEARNED •

- The technical approaches for batteries and battery cooling need to be redesigned
- The installation of charging station is complicated from an administrative perspective
- Comparison between IMC and fast-charging buses; Pilsen prefers more IMC buses
- Useful feedback for improving the charging solution, which needs to be improved
- Positive feedback on the vehicle from passengers
- Blueprint for expanding the complete smart city project in Pilsen
- Reinforced the value of zero-emission buses both in and outside the EU
- Extended e-mobility opportunities for the city and for suppliers

“The future is silent and pollution-free. Thanks to e-mobility, we are ready to offer cities a complete solution.”

Pavel Kuch, International Sales Director, ŠKODA ELECTRIC

## FUTURE PLANS •

The goal of the project partners is to continue extending the e-mobility projects.

Pilsen city would like to extend the global strategy for smart city solutions.

The Pilsen transport company would like to increase the number of electric vehicles, mainly IMC trolleybuses.

Identify further areas for cooperation with the energy provider and municipalities to support zero-emission vehicles.

[www.zeeus.eu](http://www.zeeus.eu)

Pilzeňské městské  
dopravní podniky **PMDP**

**PLZEŇSKÁ  
TEPLÁRENSKÁ**  
Více než energie

**ŠKODA**

**ZÁPADOČESKÁ  
UNIVERZITA  
V PLZNI**



The ZeEUS project is coordinated by UITP. ZeEUS is co-funded by the European Commission under the 7th Research & Innovation Framework Programme, Mobility & Transport Directorate General under grant agreement n° 605485. The ZeEUS project has been launched by the European Commission in the frame of the European Green Vehicle and Smart Cities & Communities.

**UITP**  
ADVANCING  
PUBLIC  
TRANSPORT

# STOCKHOLM (SE)

## DESCRIPTION

This was part of the EU-funded ZeEUS project led by UITP. Volvo, Vattenfall, Viktoria ICT and Stockholm County cooperated to demonstrate eight opportunity-charged electric hybrid buses.

The demonstration was in standard traffic conditions, replacing existing Keolis-operated buses on route 73 in central Stockholm.

The objective was to demonstrate these buses in public transport operations with low emissions, energy consumption and noise levels while maintaining high performance and cost efficiency.



Two Volvo Electric hybrid buses driving in Stockholm

## DEMO IN BRIEF

### Vehicle technology:

8 x Plug-in Hybrid Electric

### Brand and model:

Volvo 7900 Electric Hybrid

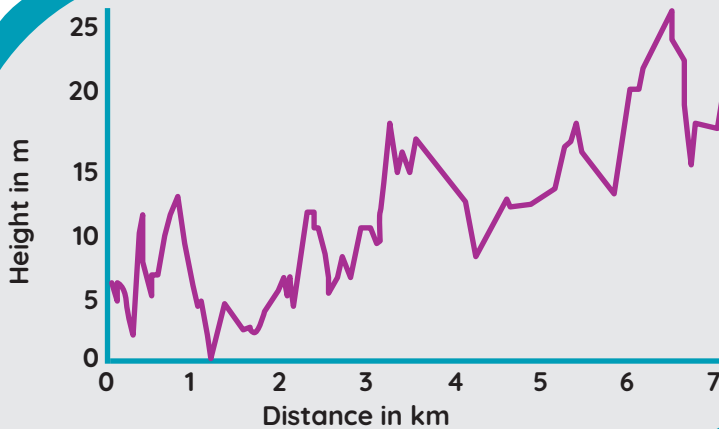
**Length:** 12.13m

**Capacity:** 71 passengers

**Charging technology:** Two opportunity fast chargers with descending arm pantograph

### Duration:

March 2015-Dec 2016



Elevation map of the line route

## OPERATIONAL CONDITIONS

**Line number:** 73

**Typology:** City centre

**Topography:** moderate

**Length:** 8.5km

**Average commercial speed:** 12km/h

**Total daily hours of operation:** 14h

**Total km driven/vehicle/day:** 124km

**Av. no. of passengers/day:** 4,654

**SORT type:** SORT 1, Urban

## KEY TOPIC

The demonstration in Stockholm focused on testing an automatic fast-charging bus with a pantograph on a charging pole at each end of the route combined with overnight charging at the depot.

In addition, the demo explored the possibility of operating a plug-in hybrid bus on a combination of electricity from wind power and 100% HVO (hydro-treated vegetable oil).



## DEMO TIMELINE •

- **Dec 2016** - end of operation
- **April 2016** - second charging station operational
- **Nov 2015** - construction of second charging station begun
- **April 2015** - all eight buses operating in full traffic
- **March 2015** - start of operations
- **March 2015** - first charging station operational
- **Sept 2014** - construction of first charging station begun
- **Dec 2014** - first bus operational
- **Nov 2013** - start of project



Charging Volvo Electric hybrid bus at the end station of route 73, at Ropsten in Stockholm

## FIGURES FOR THE STOCKHOLM DEMO FROM MARCH 2015 TO DECEMBER 2016



**61,015 litres<sup>1</sup>**

The amount of diesel fuel saved by the ZeEUS bus project

<sup>1</sup> Assuming 38l/100 km



**160,565 km**

The distance travelled by ZeEUS buses running in pure electric mode



**170,163 kg<sup>2</sup>**

The theoretical<sup>3</sup> amount of carbon dioxide emissions prevented if fossil diesel had been replaced

<sup>2</sup> ISO 16258 factor for Diesel and GaBi factor for EU electricity grid mix (2014)

<sup>3</sup> Low actual reduction due to ZeEUS buses replaced biogas buses

## RESULTS AND LESSONS LEARNED •

- The buses and the charging functions exceeded expectations
- Approx. 27,000 fast-charging sessions
- Physical size of charger and pole combined with local underground conditions created problems. Charging can be difficult in the city centre
- As this technology is new, not all aspects are currently regulated. This means certain regulations need to be cleared with responsible authorities during the course of the project
- We recommend that other cities planning for similar projects pay special attention to the charging infrastructure installation

“The ZeEUS Stockholm demonstration provides valuable input to SL’s work planning for future implementation of electric buses in Stockholm”

Maria Övergaard, Project Manager, SL

## FUTURE PLANS •

- Continued operation with 100% renewable fuels
- Stepwise electrification of the 2,100 buses in the county
- Focus on electrification in next inner city contract beginning 2022 or 2026
- The majority of electrified bus development is currently in city buses, making it harder to create operational electrified solutions for suburban buses designed for highways. This will be a next step

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VATTENFALL



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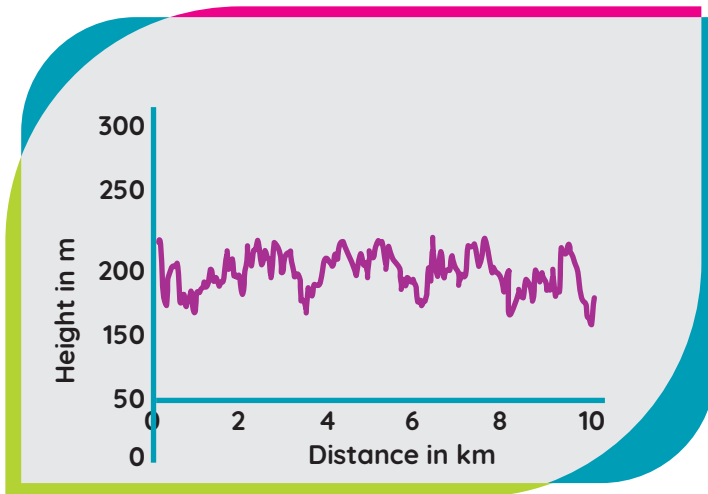
# WARSAW (PL)

## DESCRIPTION

MZA purchased 10 Solaris Urbino U12 e-buses as the first phase in electrifying city centre transport. Currently, the buses operate on line 222, which passes through the congested centre as well as the historic part of the city. The entire line is operated solely with e-buses. Passengers appreciate the comfort and driving dynamics, despite the fact it can sometimes be crowded (for obvious reasons). An efficient HVAC system completes the positive overall opinion of the vehicle.



Solaris Urbino 12 electric in service



Elevation map of the line route

## DEMO IN BRIEF

**Vehicle technology:**  
10 x Full Electric

**Brand and model:**  
Solaris Urbino 12 electric

**Bus length:** 12m

**Capacity:** 70 passengers

**Charging technology:**  
Plug in at depot, pantograph at terminal

**Duration:**  
Since June 2015 to present

## OPERATIONAL CONDITIONS

**Line number:** 222

**Typology:** City centre

**Topography:** flat

**Length:** 13.75km

**Average commercial speed:** 12km/h

**Total daily hours of operation:** 16h

**Total km driven/vehicle/day:** 160km

**Av. no. of passengers/day:** 581

**SORT type:** SORT 1

## DEMO TIMELINE •

- **Dec 2016** - Pantograph charger was built on the terminus of line 222 (fed from commercial energy provider)
- **Dec 2016** - All e-buses equipped with roof pantographs
- **June 2015** - Start of operations begun
- **Dec 2014** - first bus operational
- **Nov 2013** - start of project

## KEY TOPIC •

The objective of the Warsaw project has been to demonstrate that electric buses are fully substitutable for their diesel counterparts on the same route. The environmental benefits have been realised through using electric buses with the ability to charging either in the depot or at the end of the line (terminus).

The MZA Warszawa has an impact on the environment through diesel fuel savings and reducing CO2 emissions, GHG emissions, SO2 emissions as well as other pollutants. Noise pollution is also reduced.



Opportunity charging at the end of the line

## FUTURE PLANS •

In 2018 MZA will operate a total of thirty 12-meter electric buses.

Between 2019 and 2020, MZA intends to purchase further 130 articulated e-buses.

## RESULTS AND LESSONS LEARNED •

- Charging at the bus end (instead of in the depot) allows better use of electric buses - maximizes operational time
- Construction of the charging infrastructure is time-consuming (obtaining the right to dispose of land, permissions, arrangements with the energy supplier) and therefore needs to be planned in advance - at least 1.5 years
- Driver education is also essential for working with new technology. Training should be carried out in advance so that the drivers are ready when the project launches

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# ZeEUS in brief

<b>Scope</b>	Testing electrification solutions at the heart of the urban bus system network through live urban demonstrations and facilitating the market uptake of electric buses in Europe.
<b>Duration</b>	Nov 2013 – April 2018 [ 54 Months ]
<b>Budget</b>	22.5m EUR [ 13.5 EU Funding ]
<b>Coordinator</b>	UITP, the International Association of Public Transport



## Partners



[www.zeeus.eu](http://www.zeeus.eu)



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