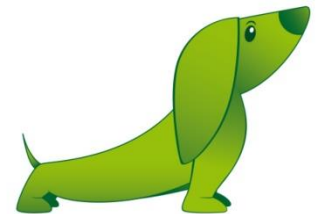


# Solaris Electric Buses

## experience and further development

**Electrické autobusy  
pro město II**



Brno 18.3.2014

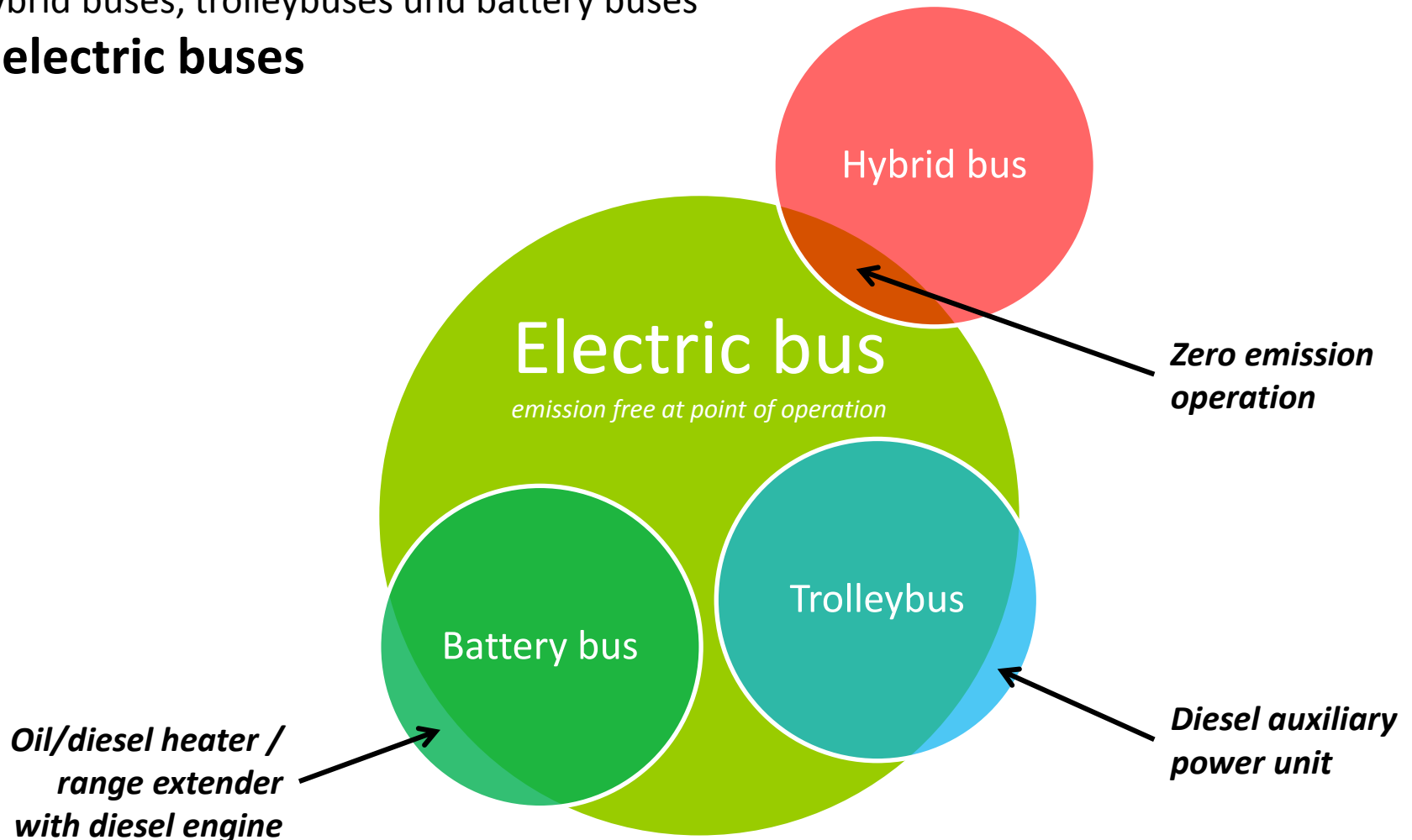


## Solaris Bus & Coach

- Founded in 1996
- **Electric mobility since 2001 (trolleybuses), 2006 (hybrid buses) and 2011 (battery buses)**
- Building trams since 2009
- **2,200 employees in Poland and 200 in international sales and after sales subsidiaries**
- Headquarters and four production sites in Greater Poznań region
- €358 million turnover (2013)
- **Largest independent city bus builder in continental Europe**
- **Production capacity 40 buses/week and 1 tram/week**



Hybrid buses, trolleybuses und battery buses  
**= electric buses**



## Trendsetter for hybrid buses in Europe

- **First European city bus with volume-production hybrid technology (2006)**
- **Offer of different diesel-electric hybrid technologies gives operators the choice of suitable hybrid drive systems**
- **Fuel consumption reduced by up to 29%, emissions by up to 78%**



## Market leader in trolleybuses

- Solaris Trollino trolleybuses have provided electric mobility since 2001
- Available in **three lengths** (12, 15 & 18 metres)
- Choice of **four traction equipment suppliers** (Škoda, Medcom, Cegelec, Vossloh Kiepe)
- EU & EFTA **market leader** with 40% market share



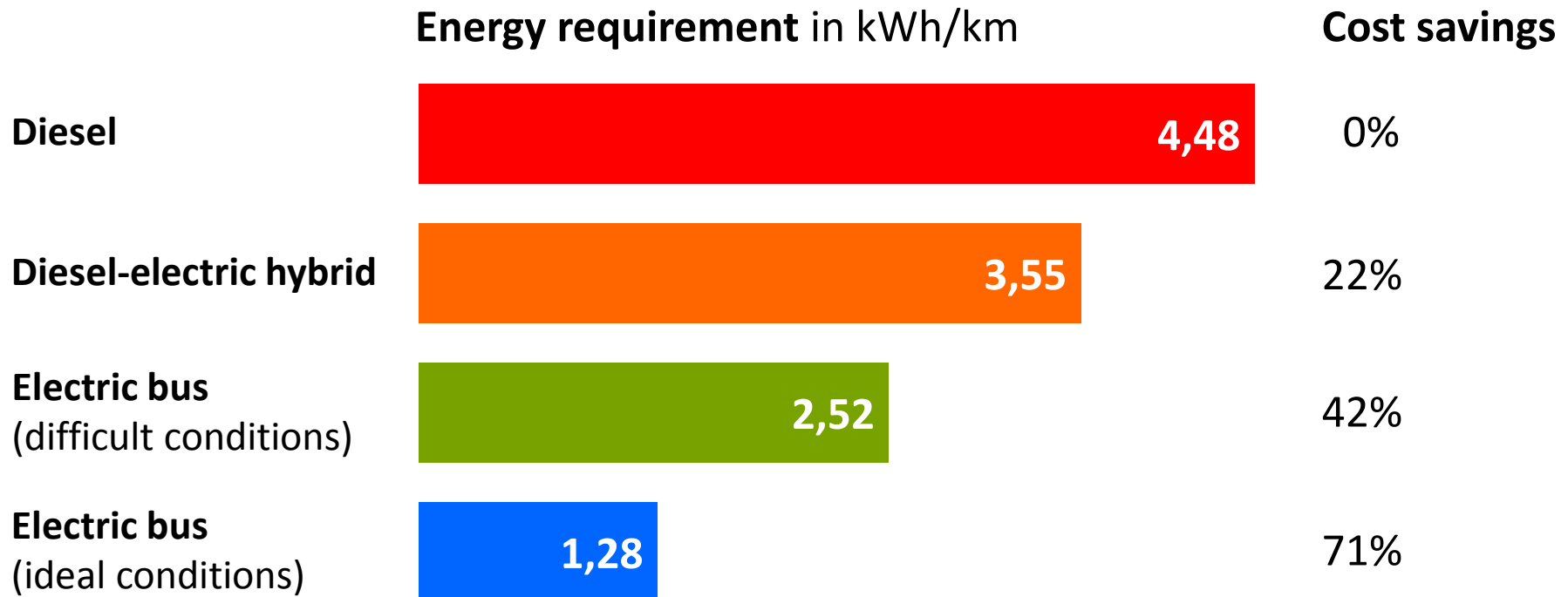


## Hybrid trolleybus with batteries and supercaps

- **Demonstrator in Eberswalde**  
as part of EU-funded TROLLEY project
- Battery (72 kWh) for 4 km independent operation per 18 km round trip
  - Fits into existing space on the bus
  - Other battery sizes are possible
- **Energy cost per km for hybrid trolleybus is 32% lower than for reference vehicles** (fitted with diesel auxiliary units and supercaps)
- **New possibilities for electric bus systems**
  - Route extension without infrastructure cost
  - New networks with infrastructure only on highly-used main sections



## Electric buses are energy-efficient



Data for **12-metre standard bus**, according to **SORT 2** (without heating), own measurements  
Cost of 1 litre diesel 5.52 PLN, cost of 1 kWh electricity 0.56 PLN



### Choice of partner for traction system



- Joint experience from 50 trolleybuses (with auxiliary batteries) and 46 trams
- Based in Warsaw, Poland
- **International service assured by Solaris**



- Joint experience from hybrid buses, trolleybuses and trams
- Based in Düsseldorf, Germany



- Also marketed & sold as *Škoda Perun* by Škoda Transportation
- Joint experience from 230 trolleybuses and hybrid buses
- Based in Plzeň, Czech Republic





## Current specification options for battery buses

*More options in the next years*

- **Choice of vehicle length**
  - Midibus (low entry, 8.9 metres)
  - Standard bus (low floor, 12 metres)
  - Articulated bus (low floor, 18 metres)
  - Extended articulated bus (low floor, 18.75 metres)
- **Choice of battery size**
  - From 60 to 240 kWh
- **Choice of electric motor type**
  - Central motor
  - Electric drive axle
- **Choice of charging technology**
  - Cable & plug connection
  - Conductive fast charging via pantograph
  - Inductive fast charging
  - Fuel cell range extender

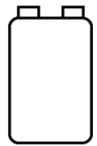


## Batteries designed for electric buses

- **In-house expertise in designing battery packs for electric buses**
  - **Use of multiple 40 kWh packs**  
= batteries from 80 to 240 kWh
  - **Packs connected in parallel**  
= buses can still run if individual packs fail (minimum 80 kWh required)
  - **High power or high energy batteries**
  - **Standardised dimensions and connections**  
= assured availability of replacement batteries and upgrades even after years
  - **North American and Japanese suppliers for cells**  
= consistent quality at cell level
  - **Production in close cooperation with existing partner for wiring looms**  
= assured quality
- Optional cooperation with external suppliers of fully-packaged batteries

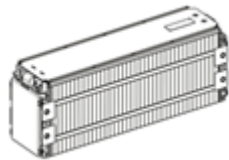


## Battery architecture



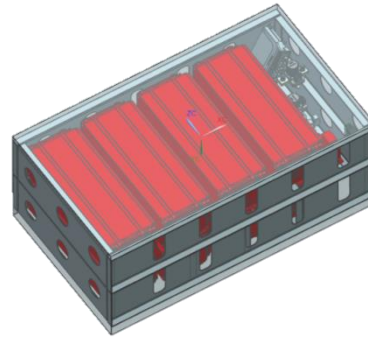
**Cell**

2.74 Wh



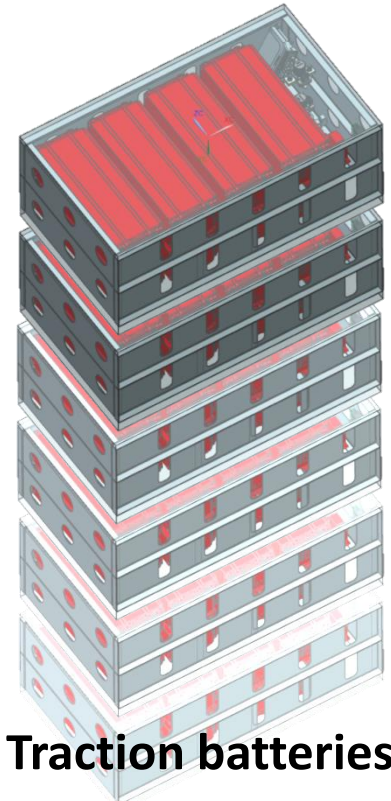
**Module**

1827 cells  
5 kWh



**Pack**

8 modules  
40 kWh



**Traction batteries**

2–6 packs  
80–240 kWh



## Available battery sizes

	High Power <sup>1</sup>			High Energy <sup>2</sup>						
kWh	Bombardier 60	90	80	80	105	120	160	200	210	240
Cable & plug	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pantograph			✓		✓	✓	✓	✓	✓	✓
Induction	✓	✓								

<sup>1</sup> Lithium-titanite ( $\text{Li}_4\text{Ti}_5\text{O}_{12}$ ): warranty for 10,000 cycles within 5 years

<sup>2</sup> Lithium-iron-phosphate ( $\text{LiFePO}_4$ ): warranty for 3,300 cycles within 5 years



## Choice of charging technologies

- **Cable & plug**
  - **16–200 kW** charging power
- **Pantograph**
  - **200 kW** charging power
  - Choice of two systems
    - Solaris (with Eko Energetyka)
    - Schunk Smart Charging
- **Induction**
  - **200 kW** charging power
  - Bombardier Primove system





## Cable & plug

Power output	16 kW	32 kW	100 kW	200 kW
Voltage	3x400 V, 50 Hz	3x400 V, 50 Hz	3x400 V, 50 Hz	3x400 V, 50 Hz
Grid connection	3-phase plug, 32 A	3-phase plug, 63 A	5-pole cable	5-pole cable
Rated current	22 A	44 A	138 A	277 A
Plug	Harting, Combo	Harting, Combo	Harting, Combo	2x100 kW Harting, Combo
Dimensions	~1000x800x 600 mm	~1200x1150x 600 mm	~1800x1350x 1000 mm	~2000x1350x 1000 mm
Weight	~200 kg	~320 kg	~850 kg	~950 kg



## Pantograph: Solaris

- **Solaris-developed technology**  
in conjunction with Eko Energetyka
- Up to 200 kW charging power
- **Four-pole, earth & control connection**
  - Designed to allow additional communication poles to be added
- **Large stopping tolerances**
  - 2 metres lengthways
  - 1 metre sideways
- Wireless communication between bus and station
- Same charging station as used for 200 kW cable & plug connection



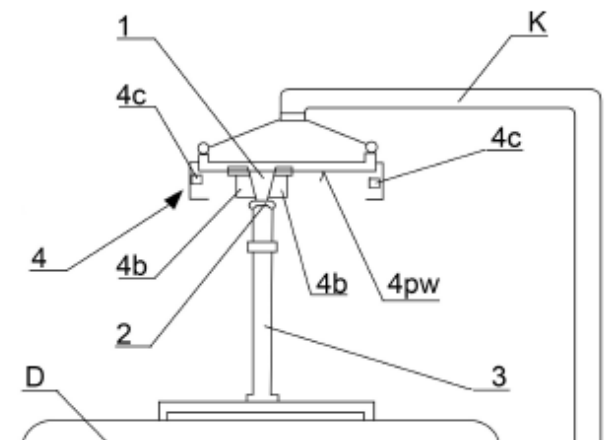
## Pantograph: Solaris (continued)

### ▪ Contact head

- Active vertical raising and lowering
- Passive horizontal adjustment through ball joint
- Balanced against vehicle kneeling through suspension in pantograph arm

### ▪ Contact plate

- Active closing and opening of contact rails
- Plate can be suspended from dedicated pole or from existing bus station roofs



## Pantograph: Schunk Smart Charging

- Independent system
- Up to 200 kW charging power
- Four-pole, earth & control connection
- Different adjustment concept
  - Active vertical & horizontal movement of pantograph arm & head
  - Fixed contact funnel



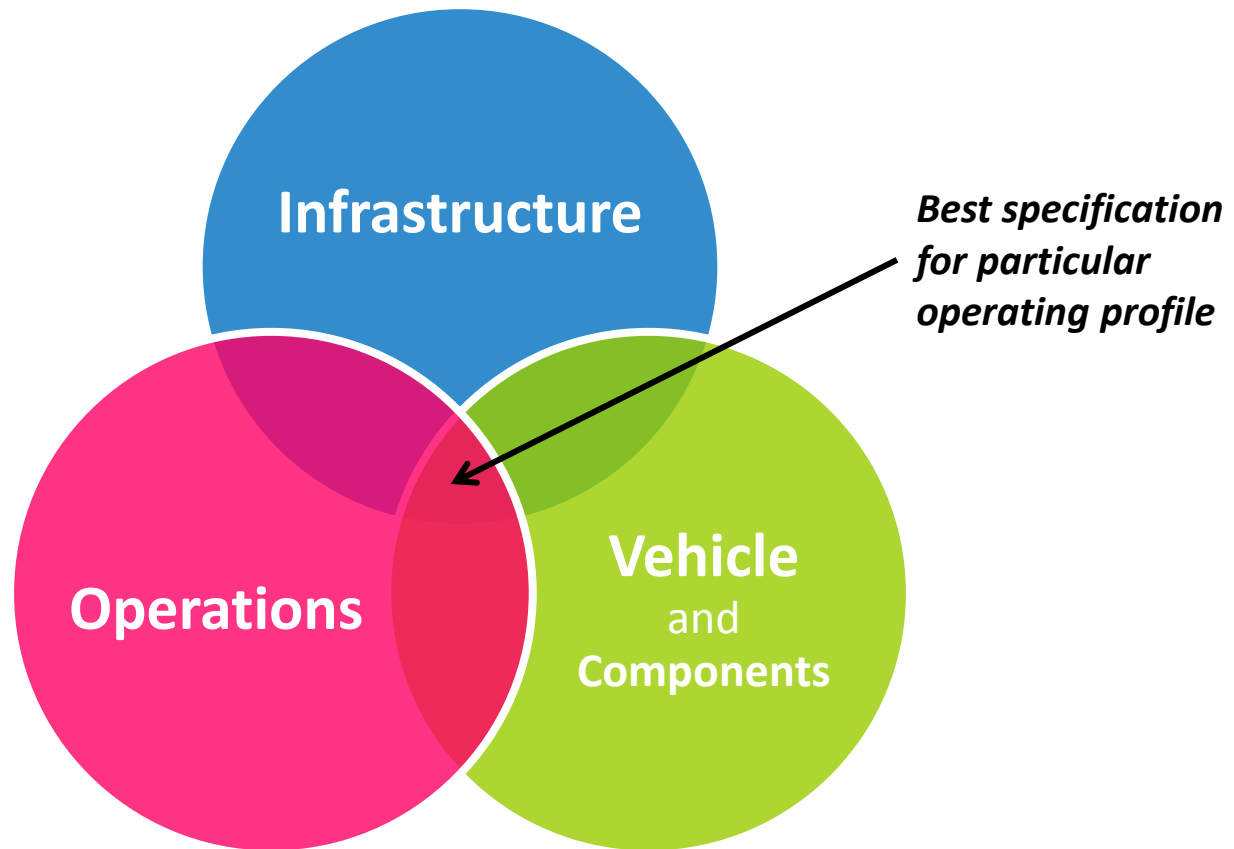
## Induction: Bombardier Primove

- **Wireless charging**
- Up to 200 kW charging power
- Bus-mounted pick-up coil is lowered and raised automatically
- Charging coil under road surface = **minimal visual intrusion**





## Electric buses have to be tailored to operating profiles





## „Emil“ project : electric mobility line M19 in Braunschweig



Gefördert durch:



Bundesministerium  
für Verkehr, Bau  
und Stadtentwicklung

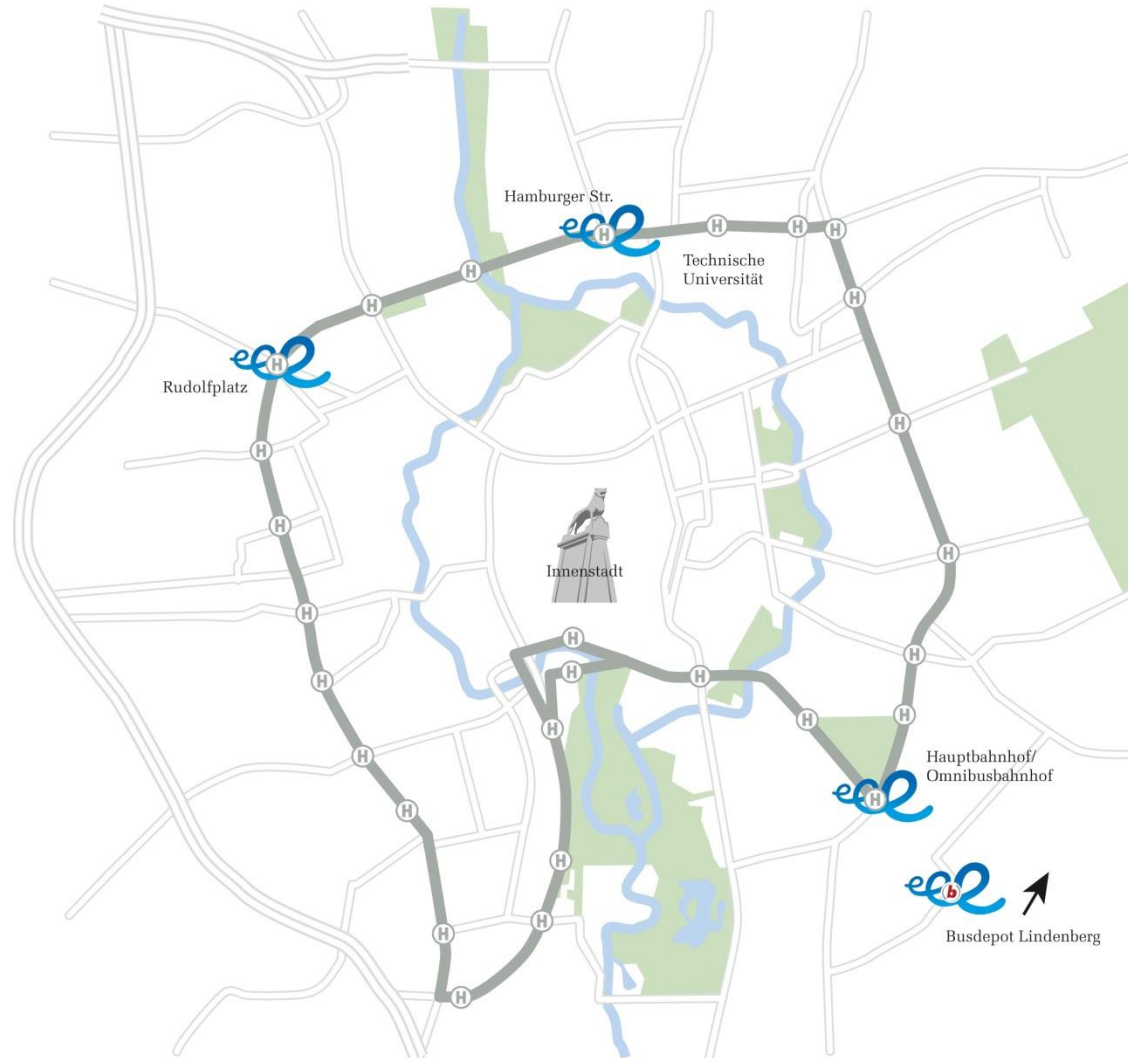




## Line M19

- 12 km distance
- 1 end stop
- 25 stops on route
- 18 km/h average speed
- Operating frequency  
every 10 minutes (working days)  
every 15 minutes (weekends)

*More often charging operations allows to use smaller and lighter battery. Thanks to this we can keep high passenger capacity of the bus*



## Battery charging

### ■ Inductive charging

Bombardier Primove system

- Dedicated pick-up coil under bus floor
- Dedicated inductive coil under the surface of the street
- Charging station integrated with advertising column

### ■ 200 kW charging power

### ■ 4 charging points/stations

with different charging times

- 1 at the end stop (up to 11 minutes)
- 2 at the bus stops (up to 30 seconds)
- 1 at depot (up to 15 minutes)





## Vehicles



### 1 standard bus

- Inductive fast charging
- 60 kWh battery
- In service from March 2014



### 4 articulated buses (+ 1 option)

- Inductive fast charging
- 90 kWh battery
- In service from late 2014





## 7th Framework programme

### 40 partners representing all stakeholders categories:

- **Associations:** UITP, EURELECTRIC, VDV, UTP, ASSTRA, POLIS
- **Bus Manufacturers:** Alexander Dennis, Irizar, VDL, Volvo, Skoda, Solaris
- **PT Operators and Authorities:** PMDP, SL, SPT, SWMU, SWBN, TMB, TfL,
- **Energy Suppliers, Company:** ENDESA, PT, SSE, VATTENFAL
- **University and Research Centers:** FH LA, FRAUNHOFER IVI, RWTH, SAPIENZA, UPC, UWB, VTT
- **Technology Suppliers, Engineering, Consultant:** BERENDS, D`Appolonia, ENIDE, GMV, IDIADA, PE, TTR, TRL, VIKTORIA



- **Barcelona:** 2 battery buses, Irizar
- **Bonn:** 4 battery buses, Solaris (plan)
- **Glasgow:** 4 plug-in hybrid buses, Alexander Dennis
- **London:** 4 double deck, plug-in hybrid buses, Alexander Dennis
- **Munster :** 5 battery buses, VDL
- **Plzen:** 2 battery buses, Skoda
- **Stockholm:** 8 plug-in hybrid buses, Volvo
- **Italy:** not decided





# ZeEUS

Zero Emission Urban Bus System

- Time line 2014 – 2017
- Total budget 22,5 mln EUR
- European Commission funds 13,5 mln EUR



## Stadtwerke Klagenfurt



### 1 midibus

- Cable & plug charging
- 121 kWh battery
- In service since May 2013

## Rheinbahn Düsseldorf



### 2 standard buses

- Cable & plug charging  
(prepared for pantograph charging)
- 210 kWh battery
- In service from spring 2014





## Västerås Lokaltrafik



### 1 standard bus

- Cable & plug charging
- Biogas heating
- 160 kWh battery
- In service from summer 2014

## DP Plzeň



### 2 standard buses

- Sold & serviced by Škoda Transportation
- Pantograph charging
- 80 kWh battery
- In service from early 2015





## Hamburger Hochbahn



...more to come



### 2 articulated buses

- Cable & plug charging
- Fuel cell range extender
- 120 kWh battery
- In service from late 2014



**...in your city?**

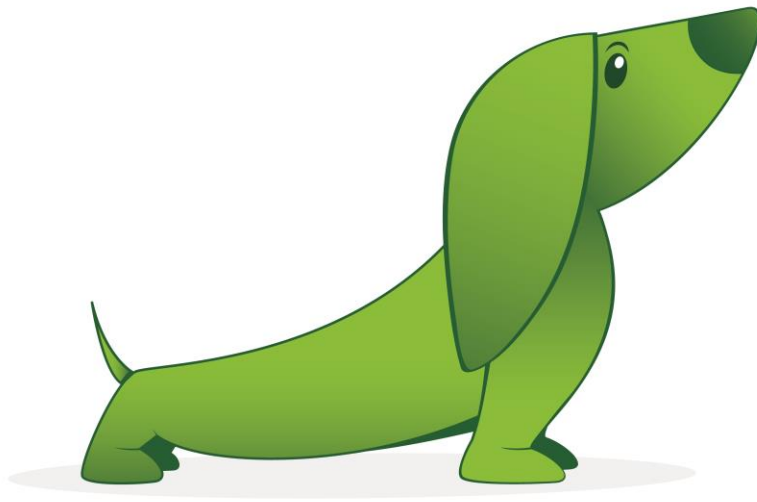


- Tailored to your operating profile
- Developed with extensive expertise in electric mobility
- Based on reliable Solaris Urbino buses
- Leasing options available



# Thank you!

Any questions?



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