Trolleybus 2.0
new hybrid trolleybus concept

TROLI40 SZEGED

Ikarus-Škoda trolleybus (from 2013-14)
the first (?) Li-ion battery trolleybus in Europe

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SZEGEDI KÖZLEKEDÉSI TÁRSASÁG

Trolleybus roadmap to hybrid e-bus @ SZKT

2010. Conventional trolleybus	2014. Battery mode	2016. Diesel route test	2019. New hybrid trolley	2021. Hybrid trolley experimental operation	2024. Hybrid trolley regular operation
Convince public that trolleybus is a viable electric bus	New trolleybuses with (7 km) auxilliary battery mode **50 % PT electrification in Szeged**	Replacing an existing diesel bus route where there is long catenary section	Hybrid electric bus prototype development Driverlessness possible?	3-4 years operation, feasibility measurements	Commercial operation **100 % PT electrification in Szeged**

Trolley

ebus the smart way

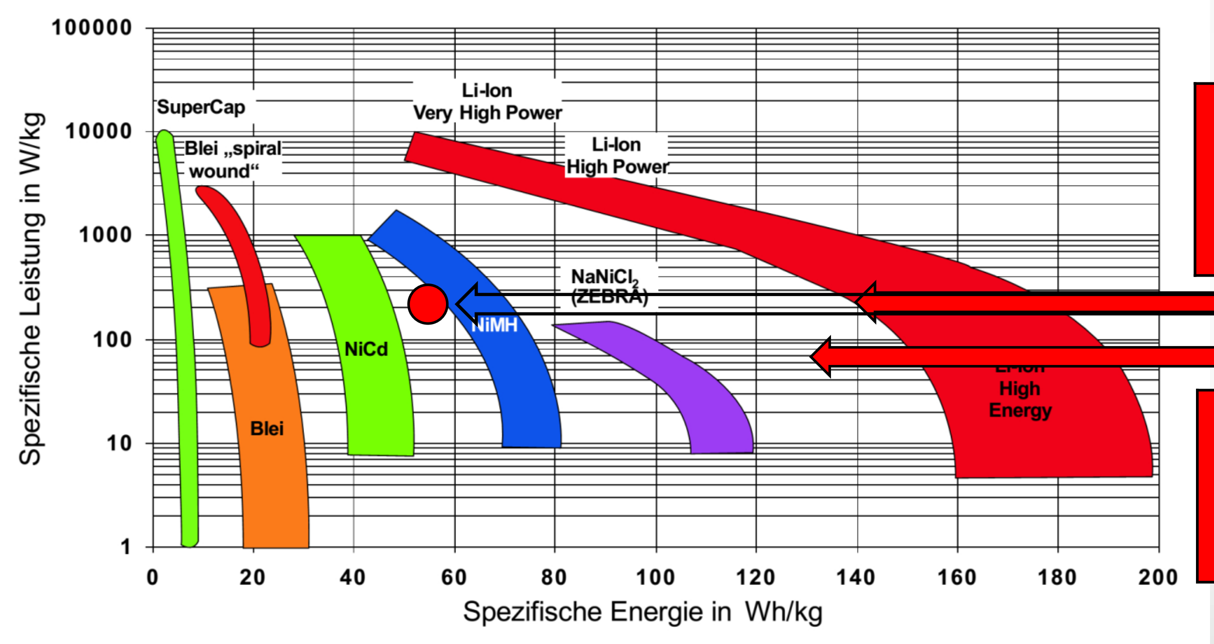
Új pályán

ELIPTIC electrification of public transport in cities

trolley:2.0 for smart cities

Development of the electric buses

Today's battery energy density and specific power output

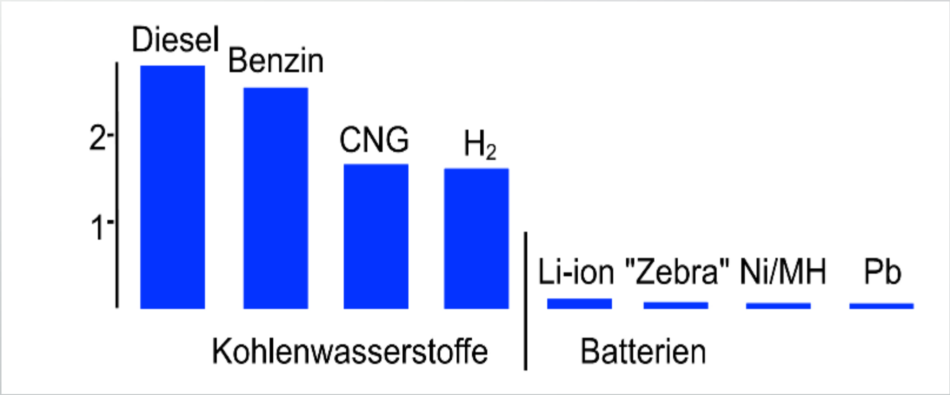


Ikarus-Skoda trolley (SZKT)	140Wh/kg (only 40 % is used)
	350 W/kg

BYD e-busz (Fe-P battery)	133 Wh/kg
	72 W/kg

Can one expect a radical increase in battery specific energy (with chemical energy storage)? **NO**

How about power output? **YES**



carbohydrogens | battery (kWh/kg)

1 kg petrol -> 14 kg air

Energy density of different sources (kWh/kg)

Overnight charging

bus category (200 km/day range)	midi (6-8 m length)	solo (12-13 m length)	articulated (18-19 m length)
typical empty/full weight	8/11 tons	13/18 tons	19/28 tons
Consumption (w/o heating)	0,6-0,9 kWh/km	1,2-1,5 kWh/km	2,0-2,5 kWh/km
nominal Li-battery weight for 250 km range (w/o BMS & frame)	approx. 1600 kg	approx. 3000 kg	approx. 4700 kg
remark	The Evopro midibuses consume 0,6 kWh/km in all geographical circumstances in Budapest	Consumption of solo trolleybuses in Budapest and Szeged	Consumption of articulated trolleybuses in Budapest and Szeged

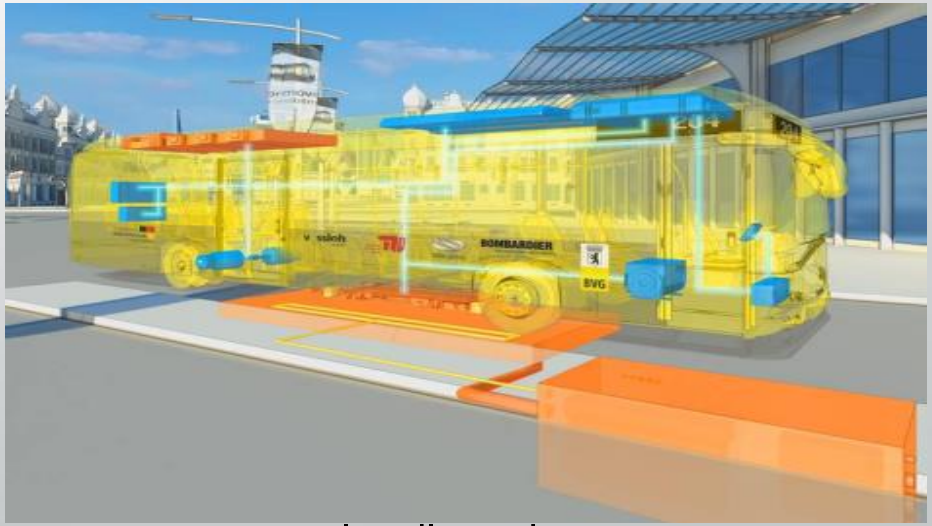
Around 30 % of the load is used to carry batteries instead of passengers.

Heating is with individual diesel stove (for electric heating + ~ 0,3-1 kWh/km)

Opportunity/in-motion charging

- Mass of the battery can be decreased, if charging is done on the termini or in motion.
- With high-capacity autobuses this seems to be the only option, if we don’t want to carry 4-5 tons of battery on the vehicles.
- By the West-European charging systems the battery balancing function is partly done by the charger (different from the car-chargers).
- Charging infrastructure is „intelligent” (= complicated).
- Charging can be done with current collector or inductive coupling.
- Charging time is dead time for traffic, and can cause problems in case of delays.

VDL articulated bus (Köln)



Bombardier Primove system (Berlin, Mannheim)

Opportunity/in-motion charging

Important problem is the construction of the charging infrastructure. That is why it is worth to use the existing trolleybus and tram catenary infrastructure.(„unintelligent charging”).

Charger type	Output	Parameters
AC charger (for cars)	~ 10 kW	Car charging for 6-8 hours
DC lightning charger	~ 50 kW	Car charging for 1 hour
DC terminal bus charger	~ **150 kW** (for articulated buses)	Articulated e-buses with 20 km range, 20 minutes charging
Waterloo garage (London)	3200 kW	46 charging slots in the garage
SZKT small converter	1600 kW	In Szeged there are 10 converters, with approx. 60 % power usage

Göteborg charger infrastructure

Siemens-Rampini charging Pardubice – from trolley infrastructure

Infrastructure, infrastructure, infrastructure …

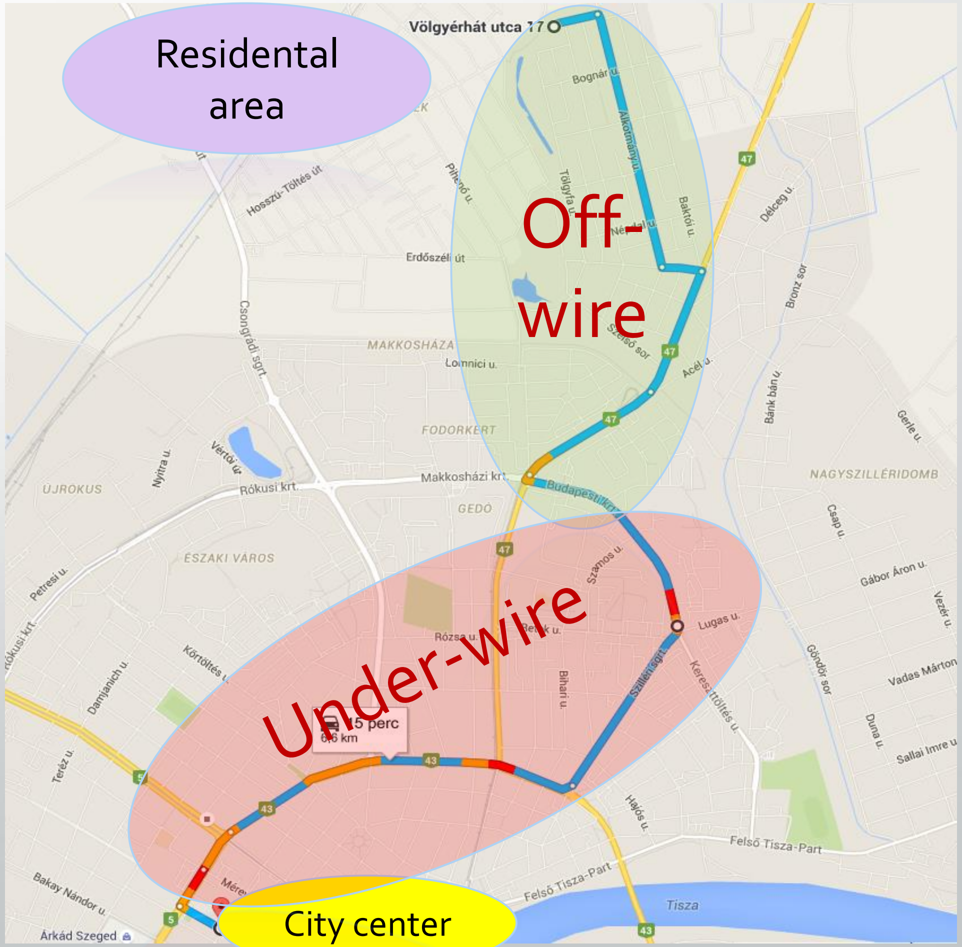
Hamburg, Depot Alsterdorf

Eliptic activity by SZKT

Test operation for **2x2 weeks** on route 77A in 2016

- 13,2 km/round
- 7,4 km battery traction/round (56%)
- 2 „rooftop type connection” + at the terminus re-wire by hand

Battery capacity: 81 kWh



Eliptic activity by SZKT

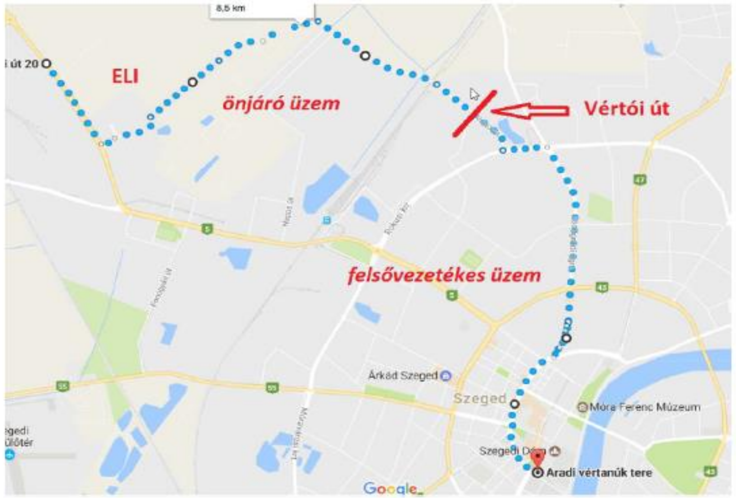
We purchased a modified DC charger for cars, which was convereted to multipurpose charger.

- DC charger (50 kW)
- Trolley charger (30 kW – needs to be improved to higher output)
- 230 V AC
- USB

Can be used at the termini far from the 600 V network.

Planned experimental operation

6-os trolibusz: Klinikák VÁ - Aradi vértanúk tere – Dugonics tér – Tisza Lajos krt. – Anna kút – Vidra utca – Szent István tér – Csongrádi sgt. – Rókusi krt. – **Vértói út (szedőlehúzás/felrakás)** – Zsámbokréti sor – Vinkler László utca – Zápor út – ELI út – **Budapesti út (Öthalmi diáklakások) VÁ**.



Útvonal hossz: 8,4 km (ebből önjárással 4,3 km)
Becsült menetidő: 25 perc
Részmenetidők: Klinikák – Vértói út: 15 perc (csúcsban),
Vértói út – Budapesti út: 10 perc, 3 perc vasúti átjárós várakozással
Becsült fordulóidő: 60 perc

Javasolt maximális menetrend (az utasforgalomhoz képest a követési ütem csökkenthető):

időszak	munkanap		iskolaszüneti munkanap		szombat/vasárnap	
	követés	menetszám	követés	menetszám	követés	menetszám
5:00-6:00	30 p.	2	30p.	2	60 p.	17
6:00-8:00	15 p.	8	20 p.	6		
8:00-14:00	30 p.	12	30 p.	12		
14:00-17:00	20 p.	9	20 p.	9		
17:00-20:00	30 p.	6	30 p.	6		
20:00-22:00	60 p.	2	60 p.	2		
össz:		2 x 37		2 x 35		2 x 17
össz km:		621,6 km		588 km		285,6 km

Éves össz teljesítmény: (2017-es naptárral): 187.068 jkm (197 MN, 55 IS, 52 SZ, 61 MSZ)

„ ... to use trolleybus catenary as charger”

It is „common knowledge”, that trolleybus and ebus technology will converge. This has not happened yet.

Main difference: double insulation for trolleybuses.

Within trolley 2.0 we want to finish the evopro **composite** bodied *„hybrid battery trolleybus”* prototype.

- It has the exact same eqipment as the overnight charging ebus type. It runs from battery, not directly from the catenary.
- It has 2/5 battery capacity (150 km -> 60 km).
- *It has a current collector and the DC-Link (60 kW)* ***only*** *under double insulation. The rest of the electronics is galvanically separated.*
- It has remarkably low consumption (0,6-0,8 kWh/km).
- We expect with 60 kW DC-Link to spend 1:1 under/without catenary (tests in Trolley 2.0).
- With increasing the DC-Link power to 200 kW we expect to reach 1:3, 1:4. (Range will be less an issue.)

Battery capacity: 140 kWh

56 kWh

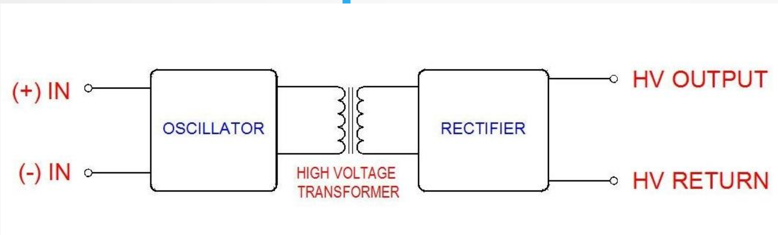
it's possible! evopro

„ … to use trolleybus catenary as charger"

Double insulation

e-bus
(with overnight charging)

+



DC Link (galvanic separation)

+

current collector

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- With increasing the DC-Link power to 200 kW we expect to reach 1:3, 1:4. (Range will be less an issue.)
- It will be a bus under Hungarian law.

Question: how do we regulate current consumption? This concept separates traction from charging.

Trolleybus catenary has also limits. (also subject in Trolley 2.0)

- **Max. 50 A (?) standing and at insulations.**
- **Max. 400 A (?) in motion (also by braking!)**
- **We don't want GPS regulation.**

Using renewable energy

SZKT plans to use solar panels for feeding to the DC traction system

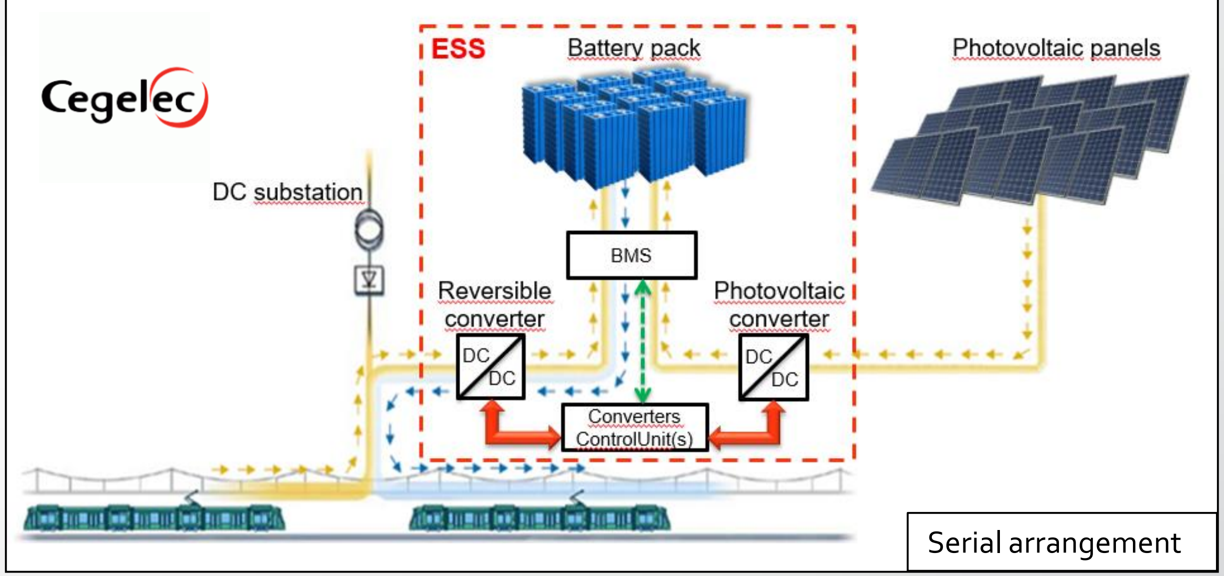
Photovoltaic panels

⬇

Battery storage
(i.e. buffer station – existing product)

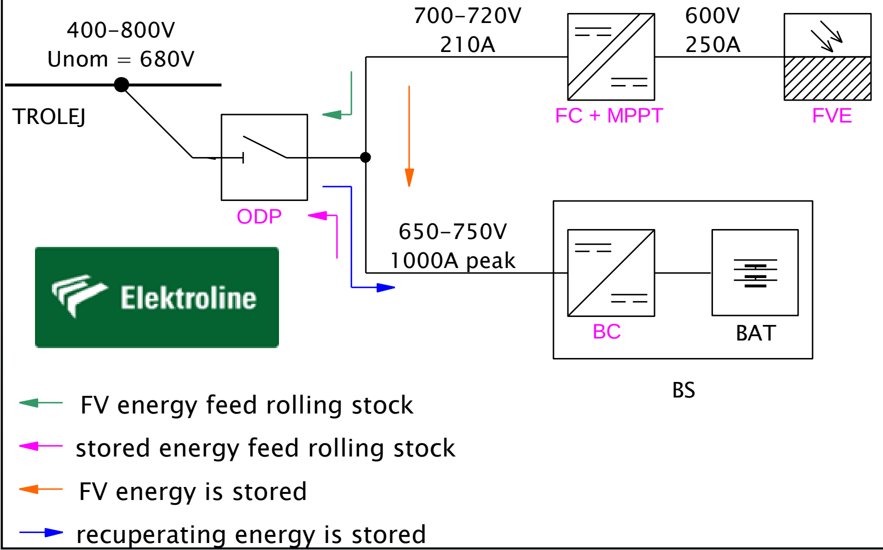
⬇⬆

600V network



Serial arrangement

Parallel arrangement



Can we use 2nd hand batteries (e.g. used traction batteries?) If we have a fleet of hybrid trolleys, we will have a lot of old batteries!

- **150 kWh capacity needed for**
- 400 kW peak charging power (1 tram recuperating)
- 200 kW continuous charging from photovoltaic panels (≈ 800 m²)
- 1-2 % SOC oscillation in operation (very good for used batteries!)

250,00 kWh/year expected (2,800,000 kWh/year is currently used in Csáky substation ≈ 10 %)

Summary

Long term goal: 100 % electric public transport.

It is impossible today to exchange diesel buses to electric buses one-to-one in typical operations.

Maybe battery trolleys can – where the route is aligning the existing infrastructure.
(Planned experimental operation in Szeged, 2021-2024)

As trolleybuses leave more the catenary, it is worth to use hybrid battery trolleybuses (Gdynia has already put out the first tender for such vehicles).

The trolleybus catenary has other advantages: **solar panel farms directly can feed to 600 V DC network.**

We need from the Industry *automatic trolleybus reconnection,* without „rooftops”.
(also subject of Trolley 2.0)

evopro it's possible!

SZEGEDI KÖZLEKEDÉSI TÁRSASÁG

Thank you for the attention!

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evopro it's possible!

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SZEGEDI KÖZLEKEDÉSI TÁRSASÁG

Electric Mobility Europe

trolley:2.0 for smart cities

Innovációs és Technológiai Minisztérium