Introduction of electric buses in Szeged

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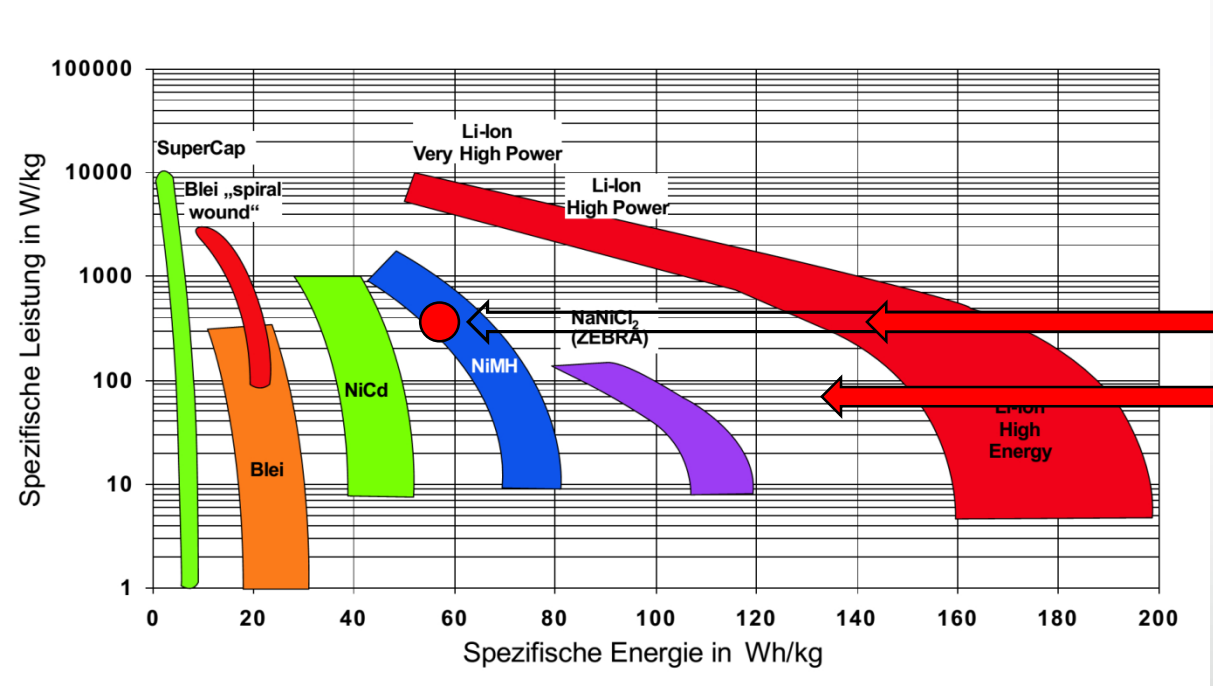
Development of the electric buses

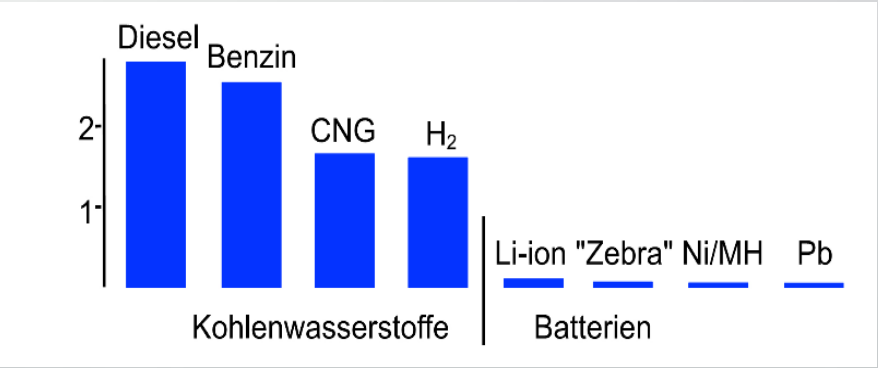
Today's battery energy density and specific power output



	Ikarus-Skoda trolley	BYD e-bus
Battery mass	575 kg (w/o frame)	2500 kg (?)
Battery output	200 kW	180 kW
Battery energy	81 kWh (only 40 % is used)	324 kWh

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



Energy density of different sources (kWh/kg)

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

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

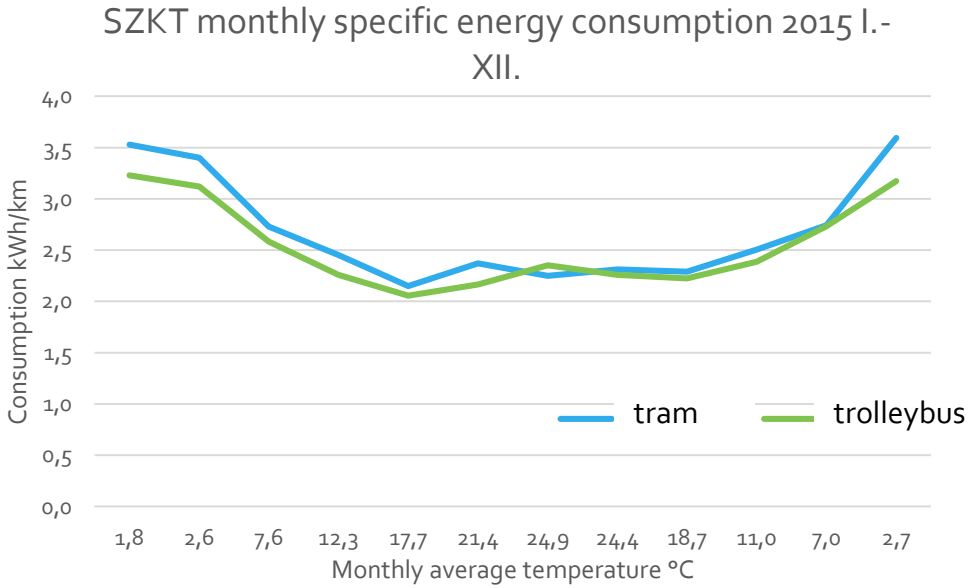
Evopro midibus (Budapest)

BYD 12 m bus (London)

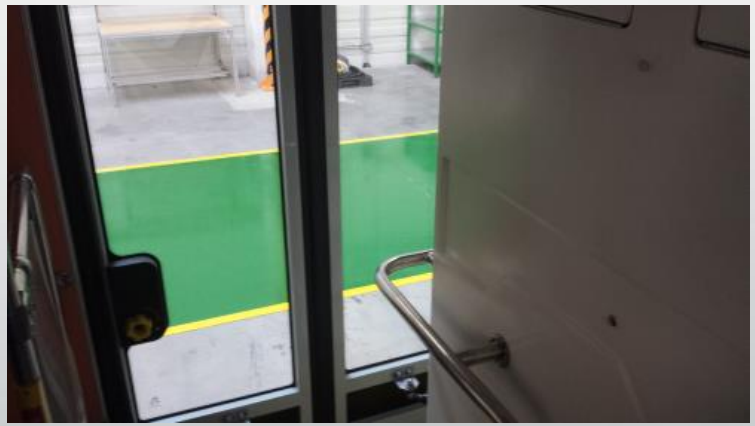
Waterloo garage **3,6 MW charging infra** (46 buses)

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)



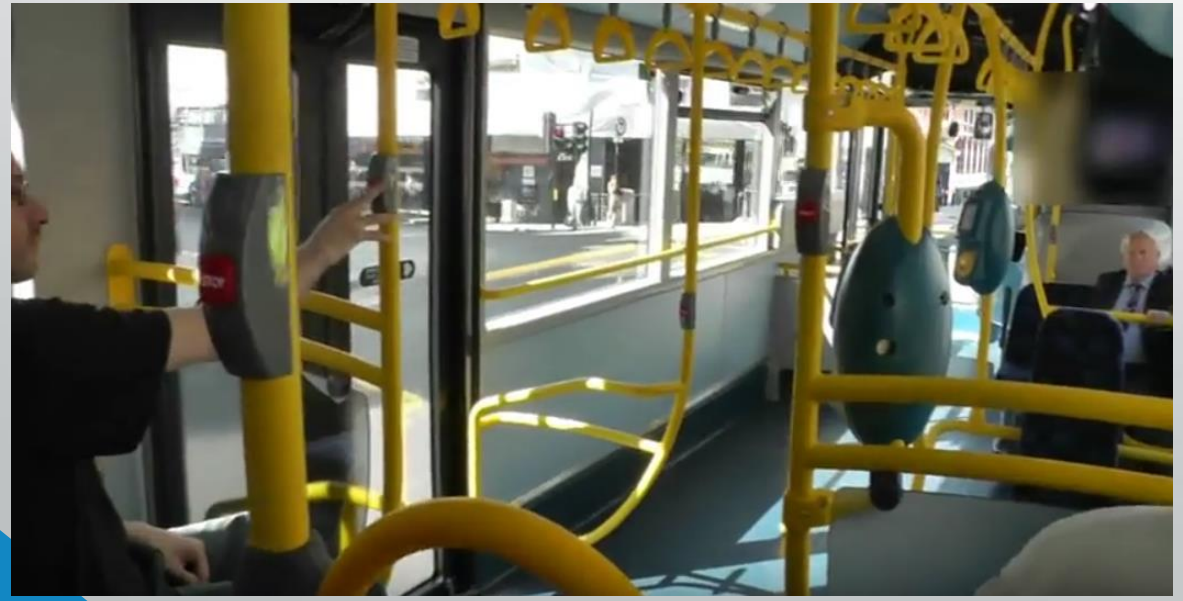
BYD 12 m electric bus interior



2012 produced BYD airport bus (Amsterdam, Schiepol), 100 % low-floor, without heating.

BYD London

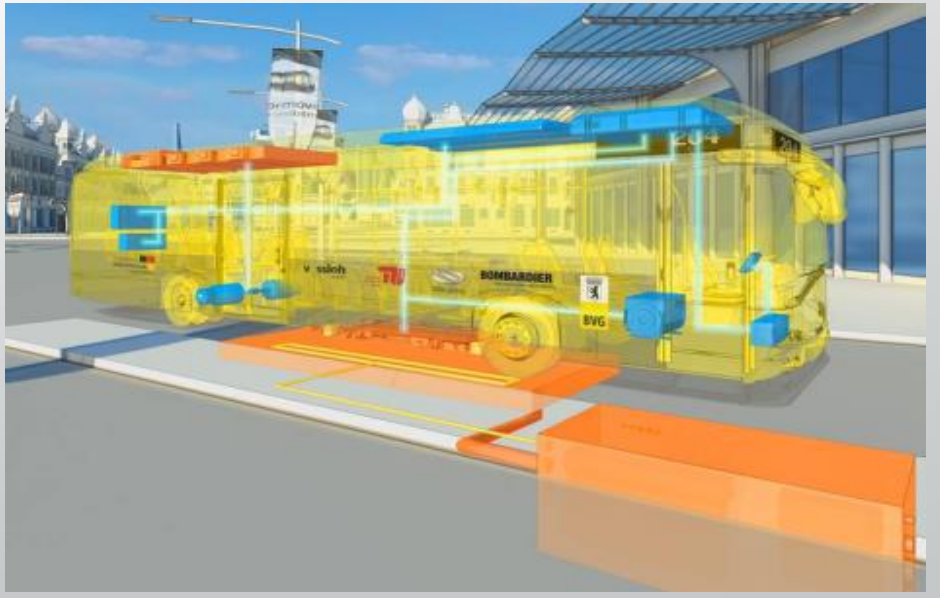
Partly low-floor, two door version



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.
- Charging infrastructure is „intelligent" (= complicated).
- Charging can be done with current collector or inductive coupling.

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”).

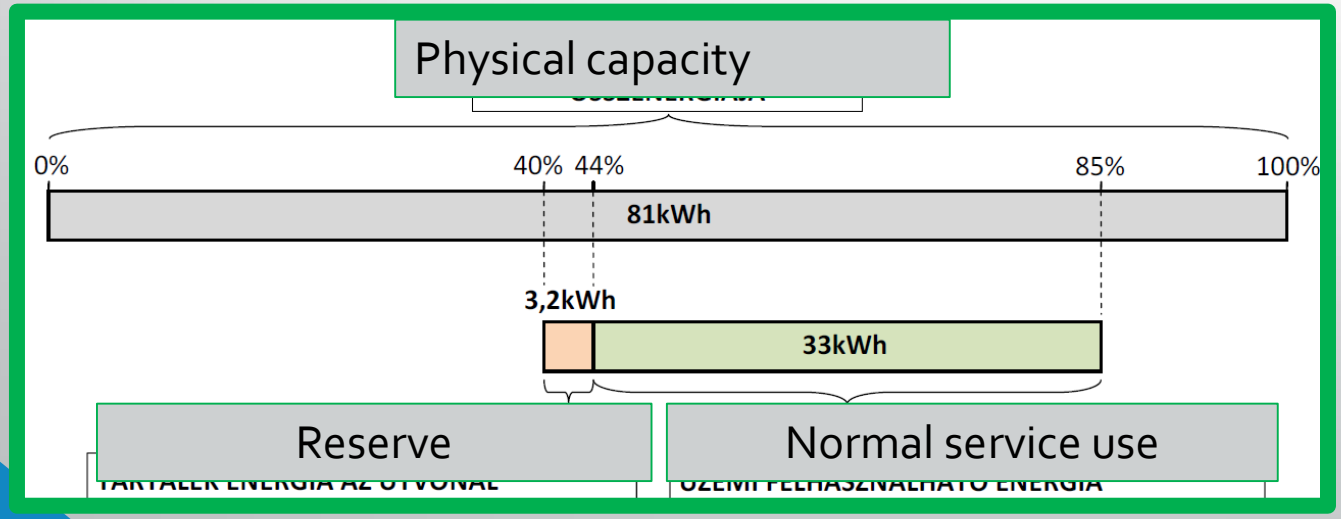
Charger type	Output	Parameters
AC charger (for cars)	~ 10 kW	Car charging for 6-8 hours
DC lightning charger	~ 50 kW	Car charging for 1 hour
DC terminal bus charger	~ **150 kW** (for articulated buses)	Articulated e-buses with 20 km range, 20 minutes charging
Waterloo garage (London)	3200 kW	46 charging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

Ikarus-Skoda trolleybus (SZKT)

Siemens-Rampini charging (Wien – from tram infrastructure, Pardubice – from trolley infrastructure

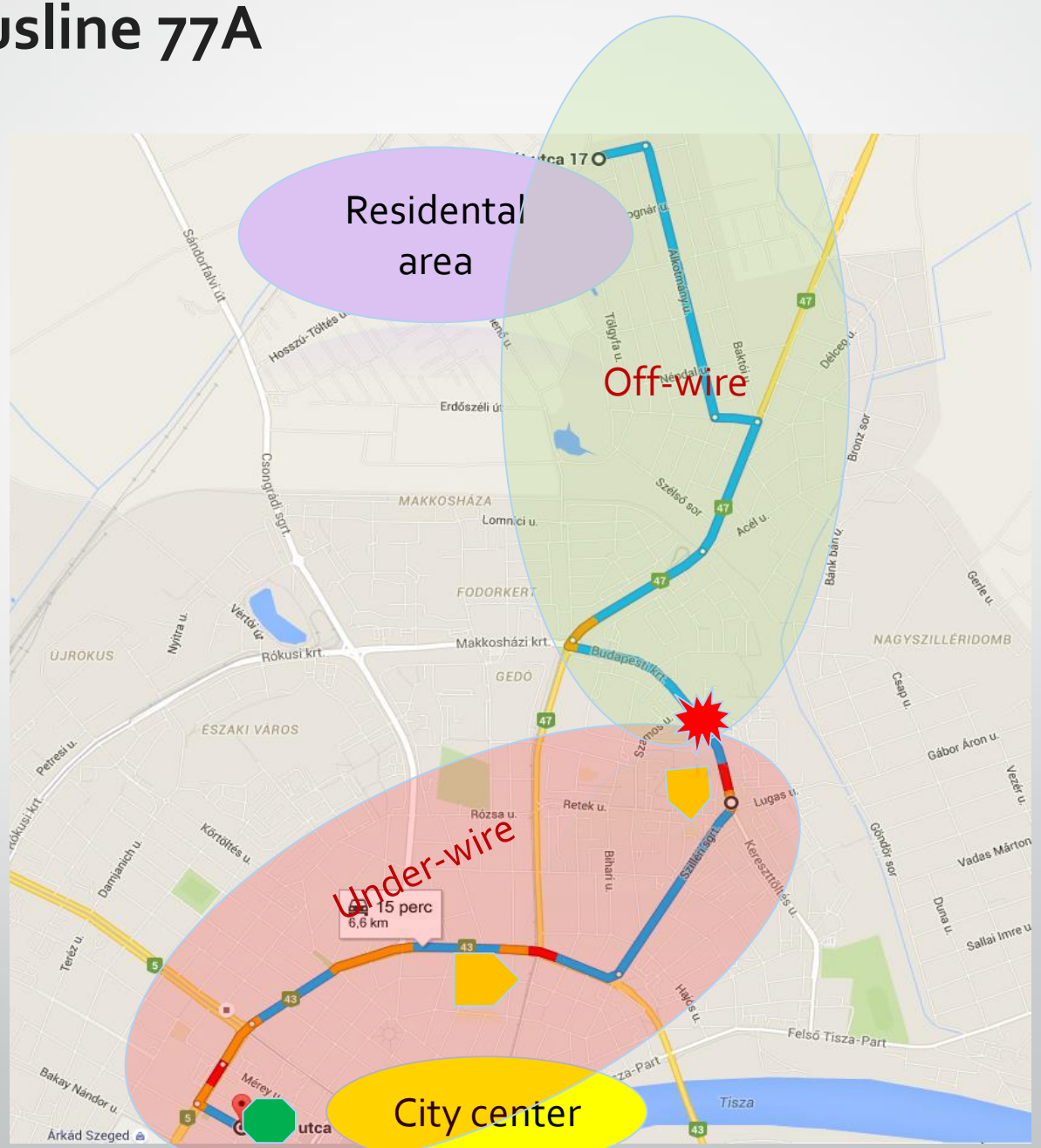
Capability – 13 Hybrid trolley **IKARUS-SKODA Tr. 187.2**

- Traction battery: 80kWh
- Output: 200 kW
- Recuperation: 130 kW
- Range w battery: 7..10 km
- Ventillated, cooled, heated
- ∑: 740 kg (2 pack)



‚TEST 1' , ‚TEST 3': busline 77A

- 13,2 km/round
- 7,4 km battery moving/ round (56%)
- 2 pair collector connection roof + at the endstation connect by hand



‚TEST 1, TEST 3' Energy consumptions

	TEST 1		TEST 3			
Line	77A	10 trolley line	77A		10 trolley line	
Vehicle nr.	T-454	T-455	T-456	T-462	T-455	T-458
Date	20/04/2016	21/04/2016	28/09/2016			
Run (km)	191,4	171,7	218,3	245,6	93,7	187,8
Energy from catenary (kWh)	341	341	374	446	180	427
Recuperated energy to catenary (kWh)	19	52	15	20	19	67
Energy consumption(kWh)	322	289	359	426	161	360
Heating (kWh)	7	11	11	14	0	9
Specific energy consumption (-heating) (kWh/km)	1,65	1,62	1,59	1,68	1,72	1,87


3
7m
T-462

‚TEST 1 - 3'Passenger surveys

- Organized by SZTE with students
- 890 filled questionnaires
- 18 questions
  - actual line / transport habits
  - Eco-mind - Social-support of trolleybus
  - Quality of transport
- KPI / standard questions and answers

(Pictures: SZTE)

Opportunity/in-motion charging

- Lower mass, lowe energy consumption
- The trolleybus current collector makes „opportunity charging" possible at places, where tram catenary is near, as well as „in-motion charging" where trolleybus catenary exists;
- The composite body can mean a step forward for insulation problems at trolleybuses;
- There is a development potential in BMS system optimization for opportunity charging, today many balancers are operating with energy losses. **The lifetime of the batteries can increase with constant recharging to 100 %;**
- The charging current can be 4x bigger than the traction current, thus **the vehicle could travel 3-4x longer route in battery mode than under catenary**.

Modulo composite frame trolleybus (Evopro group)

85 passengers, longer (9,4 m) body

Bus test operation in Szeged @ DAKK

~ 5,5 M Euro investment

- **For test operation Petőfitelep terminus is optimal, with route 20**
- **Charging system is recommended to be compatible with trolleybuses** (thus on route 20 it is possible to charge in motion when necessary, e.g. heating)
- In case one more vehicle is in operation, the charging at the terminus is possible
- In this case (with 20 min. charging time and 20 km range) approx. 150 kW charger is necessary (DÉMÁSZ?)

Route 20	Diesel/CNG bus	Electric bus
Turnover length	18,2 km	
Turnover time	57 min.	
Frequency	20 min.	
Energy need (2,5 kWh/km)	12 l gasoline	50 kWh
Vehicle need	3	4 (+1 spare in garage)

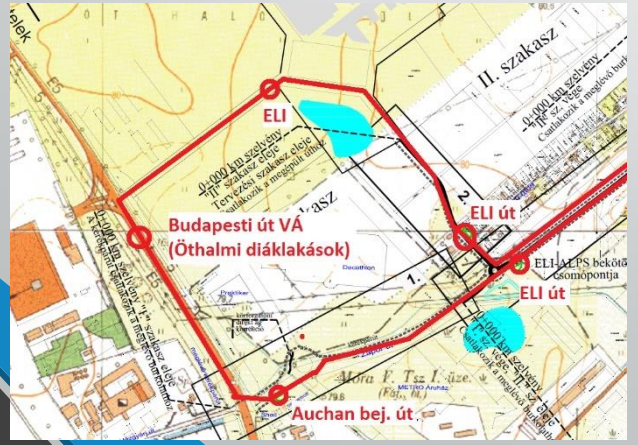
Petőfitelep

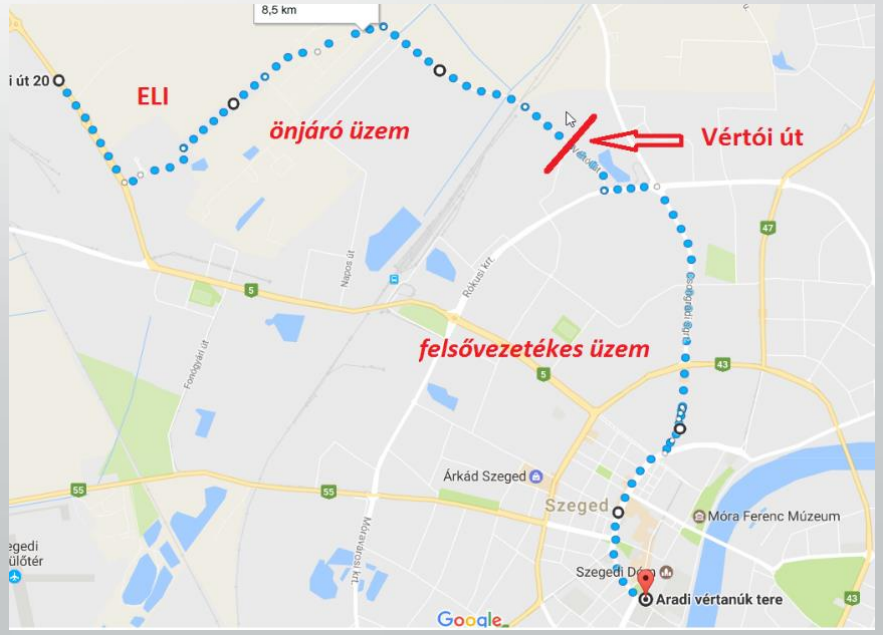
Trolleybus route extension, @ SZKT

- **For experimental operation the route Egyetem tér (TIK) – Öthalmi diáklakások (ELI) roundabout recommended**
- **Battery mode in the city center, and beyond the current terminus Vértói út**
- Current collector replacement infrastructure is needed at Vértói út and at Dugonics tér
- Terminal infrastructure and road surface construction is needed in the city center.

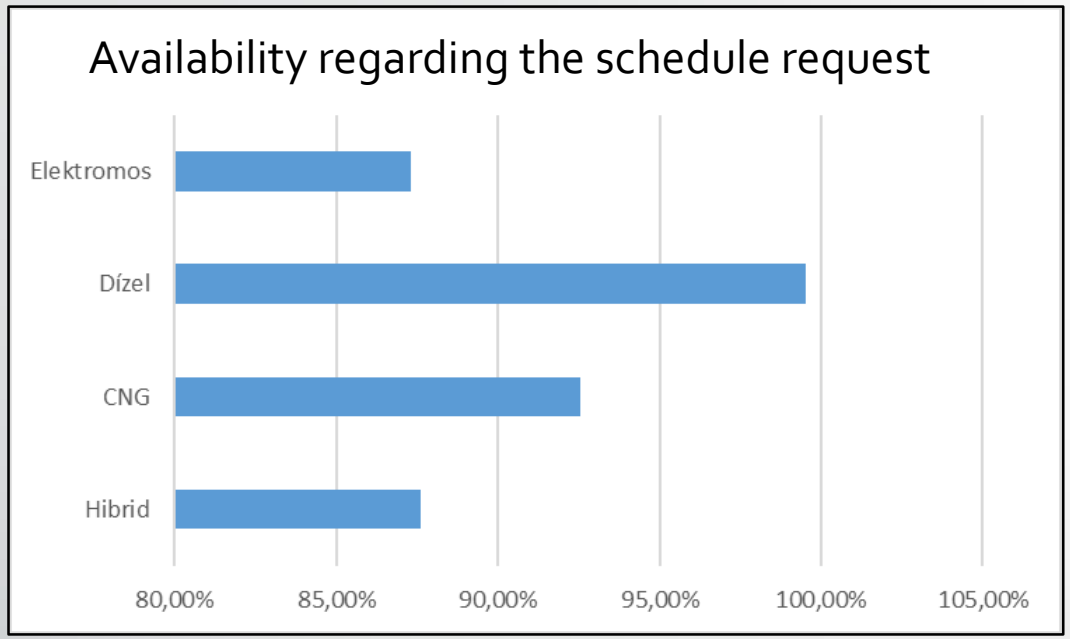
~ 3,3 M Euro investment

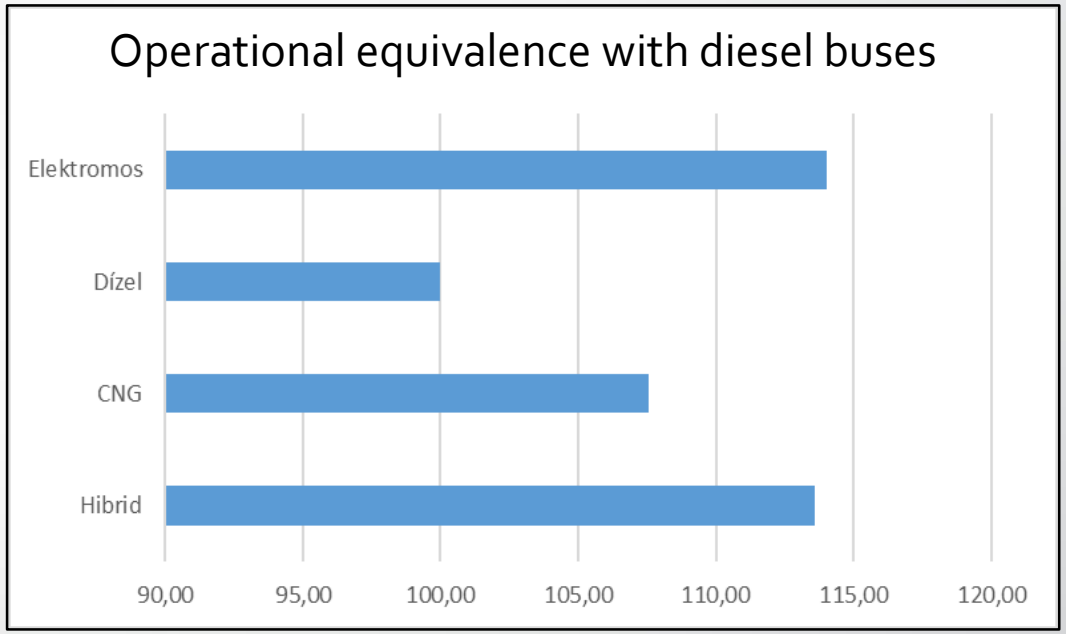
Route 6	midi-trolleybus operation
Turnover length	16,8 km (from which 8,6 km with battery)
Turnover time	50 min.
Peak hour frequency	15 min.
Vehicle need	4 (+1 garage spare)





BKV experiences with various traction systems in winter weather





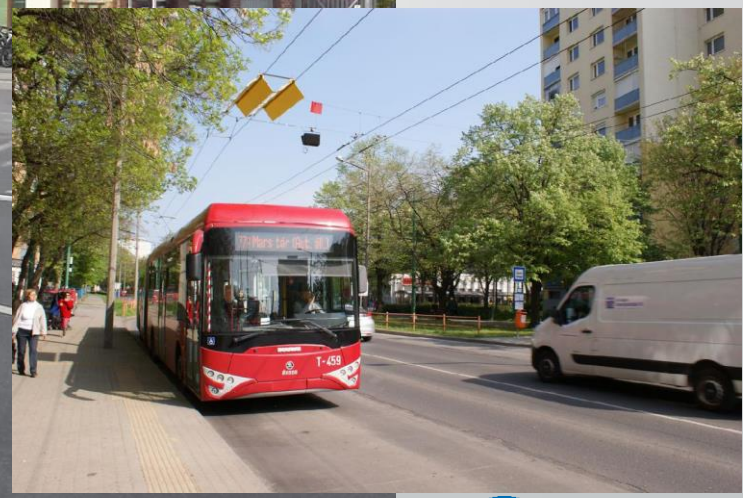
Alternative traction have advantages in environmental parameters.

Howecer, their availability is lower due to technological diabilities (less reliable), meaning more vehicles is needed to keep in operation (higher investment cost).

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

When would it be possible? Shorter range (100-120 km), smaller buses. -> driverless operation

Thank you for the attention!



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