



TEST OF ELECTRIC BUSES AND OF STATIONARY CHARGING EQUIPMENT IN THE BUS NETWORK OF GRAZ.

Project Information for a delegation of Urban Public Transport Operators of Praha, Brno, Ostrava and Ceske Budejovice

06.11.2018

City of Graz and Graz Linien

- second largest city of Austria, 305.000 citizens
- approx. 170.000 people a day commute from the greater Graz area
- 127,56 km², 40 % of which is “Green Space“
- 5 universities, approx. 50.000 students
- modal split: 20 % PT, 47 % MIV, 15 % bicycles, 18 % walkers
- 115 Mio. passengers; 279.890 people daily
- 8 tram lines (length of 61,2 km; 86 trams; 3,5 mio. tram-km)
- 28 bus lines, 8 night lines (length of 415 km; 160 buses; 9,5Mio. bus-km))



Test Results

- 👍 Implementation of test lines for fully electric zero emission buses
- 👍 Implementation of ultrafast charging at bus stations
- 👍 Proof of practicability of the SuperCap technology
- 👍 Positive evaluation of the use of Chariot buses by Holding Graz Linien

Overview of Electric Buses in Projects in Europe (1)



CHARIOT BELGRADE



VDL



SOLARIS



ADL/BYD



EBUSCO



CHARIOT TEL AVIV



Overview of Electric Buses in Projects in Europe (2)



VOLVO 9300E



SILEO S18



VAN HOOL



CHARIOT GRAZ



VDL



CRRC GRAZ

Overview of Chariot Electric Buses in Projects in Europe



Electric Buses Outlook



MERCEDES-BENZ

2018 Pilot projects in German cities,
starting rollout 2019/2020



YUTONG

Active market presence,
investment- and setup-support)



RAMPINI

Low volume manufacturer,
niche player



MAN

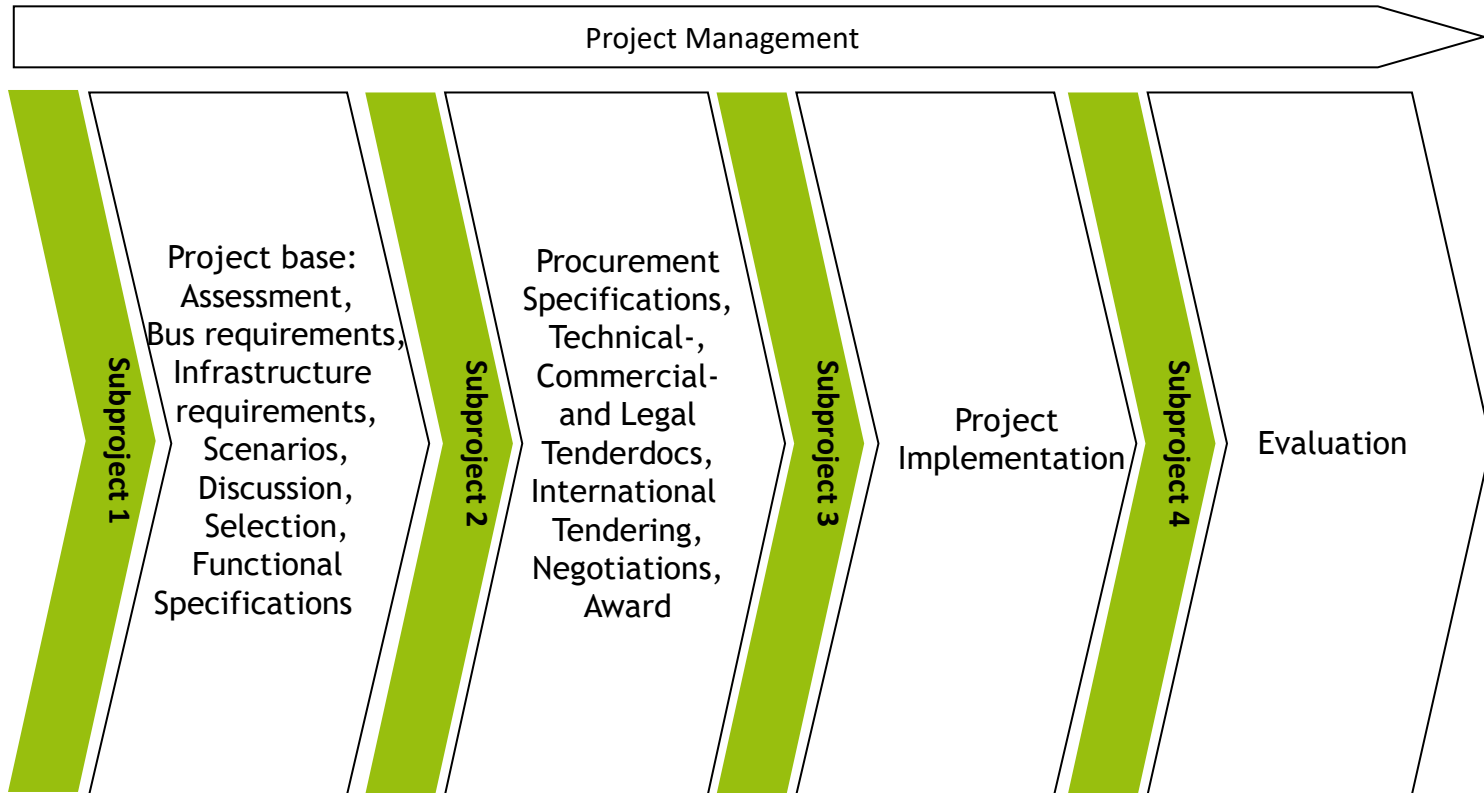
Starting rollout 2019/2020



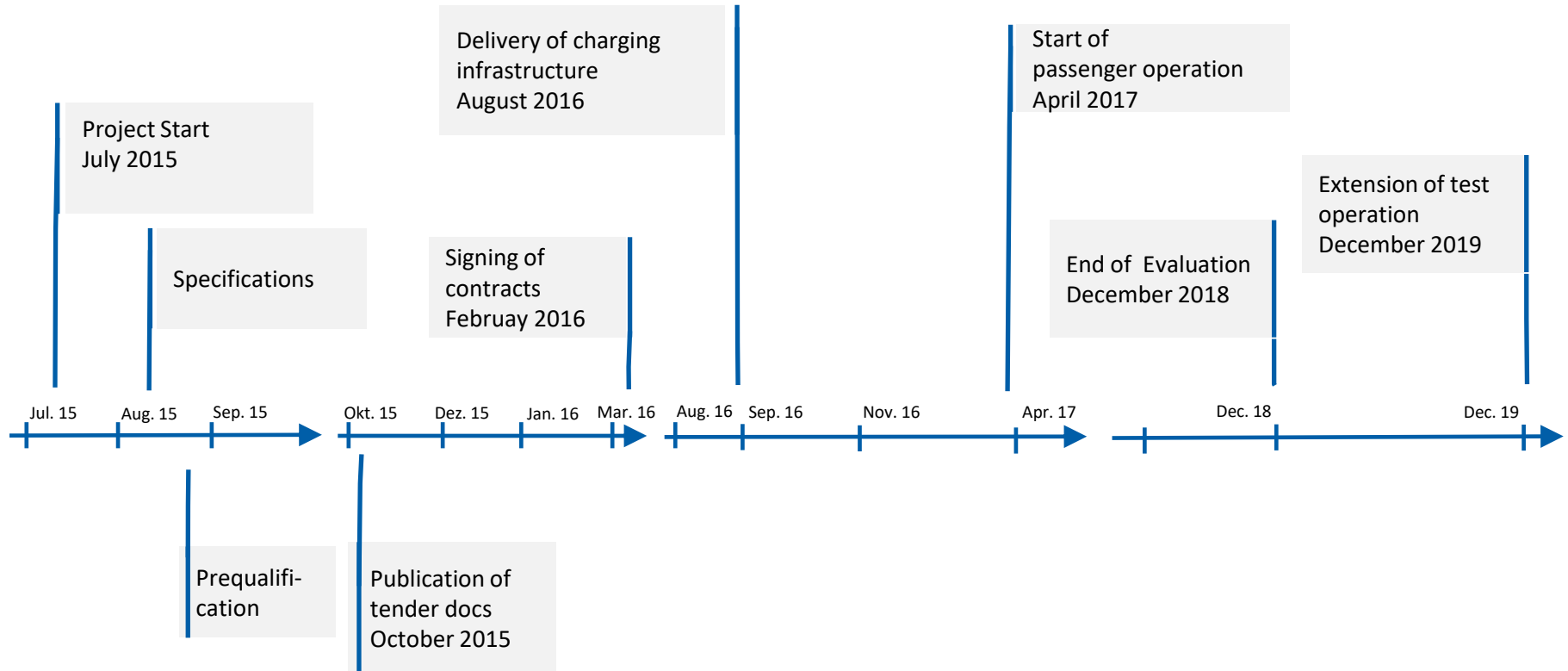
VOLVO

Starting rollout 2019/2020

Project Phases



Project Plan and Milestones



Charging Technologies

Overnight Charging with Li-Ion Batteris



Charging Technologies

Opportunity Charging of SuperCaps



Charging Technologies

H₂-Fuel Cell Bus with Batteries

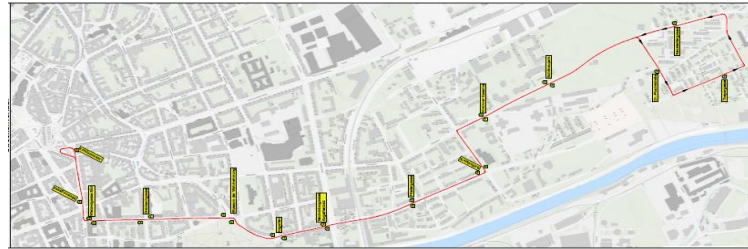


Suitability of different Energy Storage Technologies

Welche Energiepeichertechnologien erfüllen die jeweiligen betrieblichen Anforderungen			
Ladeart	ONC	ONC und OPC	OPC
Ladegeschwindigkeit	slow	fast	superfast
Speichertechnologie	Lithium	Lithium LTO	SuperCap
Ladeort und Ladezeit	Ein zentraler Standort, über Nacht mit Ladezeiten von 4-6 Stunden	Ein zentraler Standort, über Nacht und Nachladung im Busnetz mit Ladezeiten >20min	An Endstellen oder Haltestellen mit Ladezeiten <3min
Ladezyklen je Tag	1	2	10-30
Ladezyklen in 8 Jahren (3000 Verkehrstage)	3.000	6.000	30.000-90.000
Maximale Ladezyklen der jeweiligen Speichertechnologie	3.000	7.000	>200.000
Anforderungsadäquate Umsetzung	●	●	●

Charging and Energy Supply Options

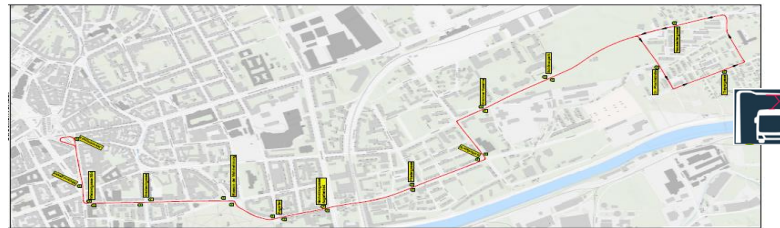
1. Overnight-charging at buscenter, each 50kW



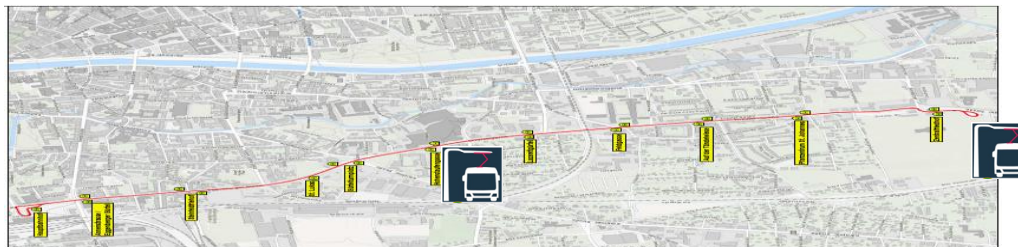
2. Opportunity charging at bus end stops during the end stop interval, 400kW



plus



3. Opportunity charging at bus end stops and at regular bus stops.



Linie 50 Infrastructure and On-site Installation



Ladeleistung
City Park: 375 kW



Ladeleistung
Zentralfriedhof:
400 kW

Chariot 12m-EBUS in Passenger Transport on Line 50: Charging at End-Station Zentralfriedhof



Chariot 12m-EBUS



SYSTEM SPECIFICATION

- 12m fully electric bus with SuperCap-based (SC) technology;
- Electro motors from ZF directly on wheels (wheel hub);
- Fast charging SC (32 kW capacity);
- Average traction energy consumption ~ 1.1 kWh/km.
- 2,5 min. Charging time for 7 km (depends on driving behaviour)

HIGHLIGHTS

- Significant technological advantage of the SC-technology versus the slow or fast charging batteries - charging factor of 10 C;
- SC fully charged within 6-7 minutes;
- Relatively small and lightweight energy storage (SC);
- Wide working temperature range of the SC (-24° to $+40^{\circ}$ C) with full 10-years' warranty;
- Performance validation from BELICON institute, Germany.

Chariot SuperCap

The SuperCap is located in a crash-proof and pressure-dense steel housing with controlled overpressure release and an automatic fire-extinguishing system, which can also be triggered manually by the driver.



Project Phase 4 Evaluation

- KPI Key Performance Indicators
 - Availability
 - Specific Energy Consumption
 - Charging Time

Project Phase 4 Evaluation of Availability (1)

Date	Weekday	Operation time	Availability of bus #8 for bus operation	Comment
02.07.2018	Montag	5:13 bis 20:38	100%	
03.07.2018	Dienstag	5:13 bis 20:38	100%	
04.07.2018	Mittwoch	5:13 bis 20:38	100%	
05.07.2018	Donnerstag	5:13 bis 20:38	100%	
06.07.2018	Freitag	5:13 bis 20:38	100%	
09.07.2018	Montag	5:13 bis 20:38	100%	
10.07.2018	Dienstag	5:13 bis 20:38	100%	
11.07.2018	Mittwoch	5:13 bis 20:38	100%	
12.07.2018	Donnerstag	5:13 bis 20:38	100%	
13.07.2018	Freitag	5:13 bis 20:38	100%	
16.07.2018	Montag	5:13 bis 20:38	100%	
17.07.2018	Dienstag	5:13 bis 20:38	100%	
18.07.2018	Mittwoch	5:13 bis 20:38	100%	
19.07.2018	Donnerstag	5:13 bis 20:38	100%	
20.07.2018	Freitag	5:13 bis 20:38	57%	Reopening doors
23.07.2018	Montag	5:13 bis 20:38	100%	
24.07.2018	Dienstag	5:13 bis 20:38	100%	
25.07.2018	Mittwoch	5:13 bis 20:38	100%	
26.07.2018	Donnerstag	5:13 bis 20:38	100%	
27.07.2018	Freitag	5:13 bis 20:38	100%	
30.07.2018	Montag	5:13 bis 20:38	100%	
31.07.2018	Dienstag	5:13 bis 20:38	100%	
Juli 2018 Total			98%	

Project Phase 4 Evaluation of Availability (2)

01.08.2018	Mittwoch	5:13 bis 20:38	100%	
02.08.2018	Donnerstag	5:13 bis 20:38	Driving with open door	
03.08.2018	Freitag	5:13 bis 20:38	Repair by Chariot	
06.08.2018	Montag	5:13 bis 20:38	100%	
07.08.2018	Dienstag	5:13 bis 20:38	100%	
08.08.2018	Mittwoch	5:13 bis 20:38	100%	
09.08.2018	Donnerstag	5:13 bis 20:38	96%	Charging problems
10.08.2018	Freitag	5:13 bis 20:38	100%	
13.08.2018	Montag	5:13 bis 20:38	100%	
14.08.2018	Dienstag	5:13 bis 20:38	59%	Drying of water entry
16.08.2018	Donnerstag	5:13 bis 20:38	80%	Air condition
17.08.2018	Freitag	5:13 bis 20:38	100%	
20.08.2018	Montag	5:13 bis 20:38	100%	
21.08.2018	Dienstag	5:13 bis 20:38	100%	
22.08.2018	Mittwoch	5:13 bis 20:38	100%	
23.08.2018	Donnerstag	5:13 bis 20:38	100%	
24.08.2018	Freitag	5:13 bis 20:38	100%	
27.08.2018	Montag	5:13 bis 20:38	100%	
28.08.2018	Dienstag	5:13 bis 20:38	100%	
29.08.2018	Mittwoch	5:13 bis 20:38	100%	
30.08.2018	Donnerstag	5:13 bis 20:38	100%	
31.08.2018	Freitag	5:13 bis 20:38	100%	
August 2018 Total			88%	

Electric Bus Lessons Learned



Detailed assessment in advance



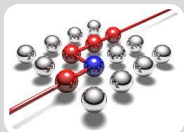
Power storage technology



The range is no limit



Compare Life-Cycle-Cost



Identify the LCC-optimized solution



Integrate the electric power utility



Charging technologies are proven



Compare against existing fleet



Set-up scenarios



Start with small scale test projects

Further Information

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