DECARBONISATION OF BUSFLEETS OF URBAN PUBLIC TRANSPORT OPERATORS. ELECTRIC BUS PROJECTS IN EUROPE - AN OVERVIEW OF PROJECTS, TECHNOLOGIES AND MANUFACTURERS.

A3PS Eco-Mobility 2017 Conference, November 9th and 10th, 2017

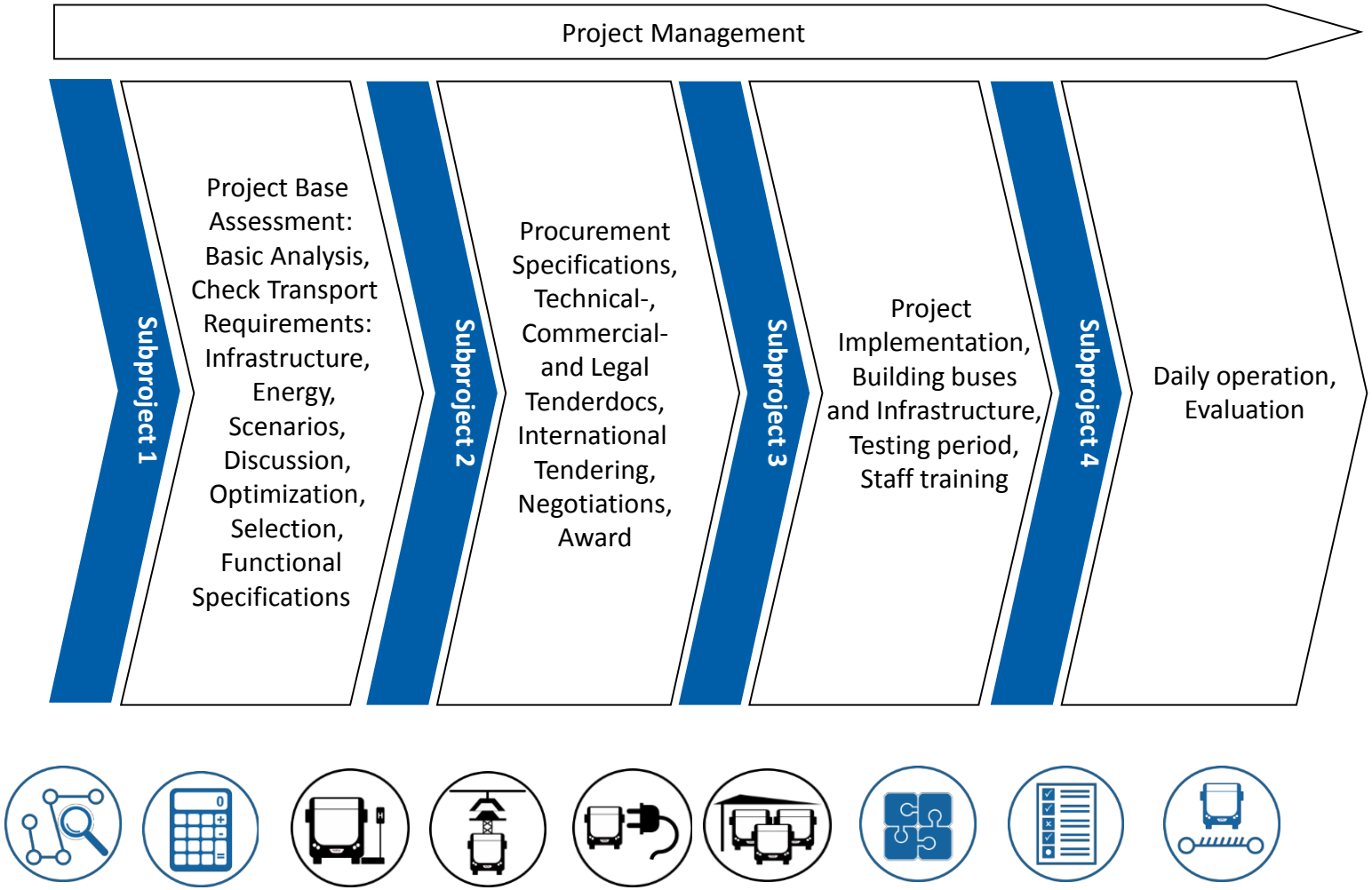
Solutions for Clean Mobility

- Founded 1992, privately owned and independent
- Serving all stakeholders of urban public transport
- Feasibility studies
- Base analysis
- Requirements analysis
- Holistic System solutions
- Functional specifications
- Procurement support
- Project management
- Implementation support
- Validation, Coaching and Training





Electric Bus Project Phases



Objectives of Urban Public Transport Operators

- Test of the implementation of 100% emission free mobility into urban public bus transport.
- Test of the acceptance of passengers and of the public.
- Proof of suitability of the system setup of technologies in daily use.
- Define the decarbonisation strategy and action plan.
- Creation of knowledge-bases for future bus procurement projects.
- Verification of KPI Key Performance Indicators
- Implement the impact of major socio-economic, technological & political developments

Key Urban Public Transport Drivers

Urbanisation

People move to cities and live urban lives. Mobility behaviour is changing. Individual cars are no necessity.

Decarbonisation

The attractiveness of the area focuses on environment and sustainability. 100% zero emission.

Digitalisation

New digital technology strongly influences all aspects of operation, development and use of integrated mobility services. This creates new needs and new services

Individualization

People focus on themselves and take responsibility for their own lives

Innovation

Inventing and perfectioning transport technologies. New energy storage tecs. Autonomous public transport on demand. Reorganisation of the public transport market. Lack of competencies.

Care and Culture

People care for one another and take responsibility for the relevant communities. Cooperation between public and private players. Changes in demography lead to new needs.

Transport Sector Decarbonisation Target 2030

Bases on the Paris Climate Conference 2015

Overall reduction targets are assigned to 5 sectors.

Transport sector

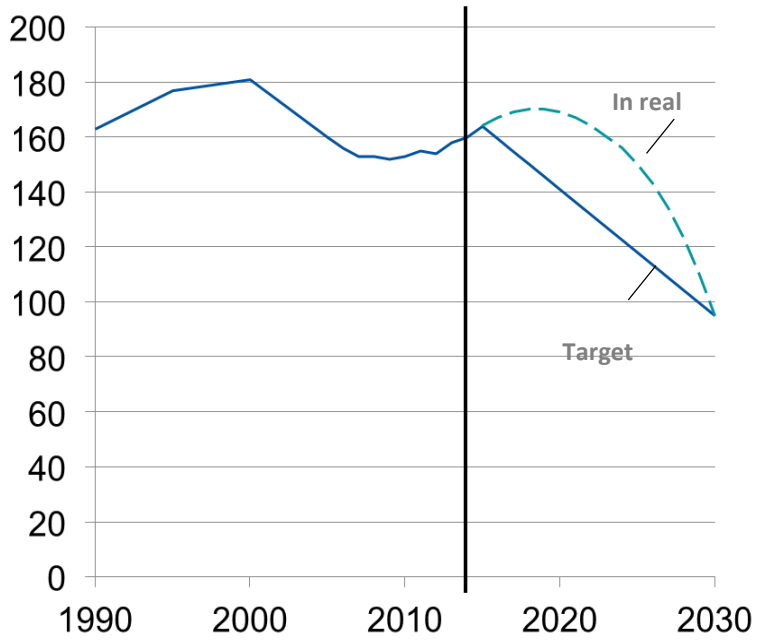
Transport needs

Total: 910 TWh_{th}

Transport of persons: 640 TWh_{th} (70%)

Transport of goods: 270 TWh_{th} (30%)

Target to reduce emissions to 60% ín 2030



There is no alternative to electric buses to implement 100% decarbonisation

Source: RWTH University Aachen, 2016

An Overview of Battery Electric Buses in Europe

- 60 cities
- 540 buses
- 30 bus manufacturers
- 6 charging infrastructure suppliers

Source: UITP 2016

The Leading Electric Bus Suppliers in Europe

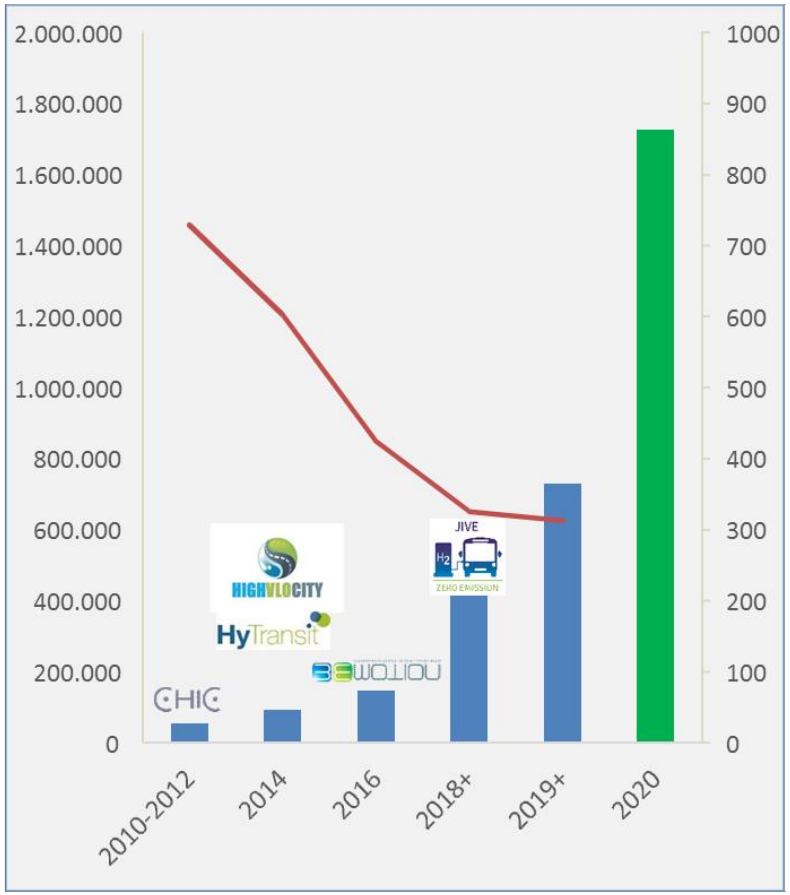
110 units

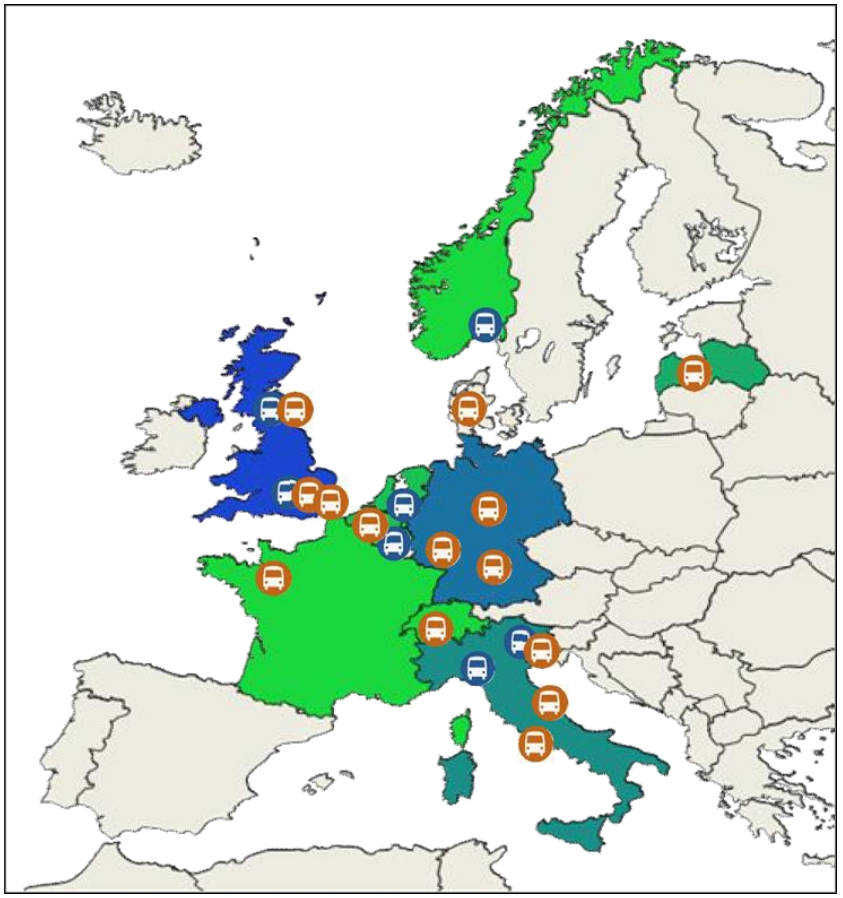
100 units

90 units

Data: Installed base 2016

Fuel Cell Buses Market Forecast





Source: FCH Fuel Cells and Hydrogen joint undertaking

Newsflash Hartmut Schick, CEO of Daimler Buses 24.10.2017, BUSWORLD, Kortrijk

„Current investment in a battery production site“

„No electric bus prototypes“

„Bus tests with lead customers 2018“

„Production start 2019“

„Production capacity up to 3.000 units in Mannheim“

„Substantial tenders are expected 2020“

„Citaro Electric bases on a dedicated totally new platform - beside the body“

„A new business unit „Mobility solutions“ shall provide best solutions“

Battery Electric Vehicles (1)

VDL

Solaris

Chariot

Bombardier

EBUSCO

BYD

Battery Electric Vehicles (2)

Volvo 9300E

SOR

Eurabus

TOSA

Rampini

Irizar

Battery Electric Vehicles (3)

Volvo 7900e

MAN

CRRC

HESS/Bombardier

ADL/BYD

VDL

City decarbonization strategies and projects (1)

Paris (*4600 buses)*

Decision: no purchase of new diesel buses on 2016
Intense test phase of different E-Bus-System alternatives.
Real life trials 2017: 75 buses.
After evaluation a decision will lead to a large-scale tender end of 2017

Oslo

Beschluss: ÖPNV ab 2020 CO_2-neutral
TED
2017/S 184-378173
Electric buses. Ruter is investigating a transition to emission free public transport

Paris Umland

Beschluss:
keine neuen Dieselbusse
From 2018 on purchase of 1000 buses

Staat Luxembourg

Beschluss:
Ab 2020 CO_2-neutraler Busverkehr

Hamburg

Beschluss:
ab 2020 werden nur noch fossil-freie Antriebslösungen beschafft;
Test von VOLVO-Bussen mit OPPCHARGE Ladetechnik.
Decision towards Overnight-Charging in 2017. Investment in a new E-Bus depot, meeting the power needs for overnight charging

London

Beschluss:
Alle Busse in den 12 Umweltzonen werden 100% elektrisch
Entscheidung Dez. 2016
ADL/BYD Electric Bus Fleet Waterloo Station

The Hague

Pilot Emissionfree Bus
2017/S 185-378491
Integrated zero.emissiom concept of buses, battery technologies, charging technology and system layout

Berlin

Beschluss:
CO_2 + Partikel neutraler ÖPNV
Test von Solaris 12m-Elektrobussen
TED 2017/S 169-347650
Teilnahme an Markterkundungstests von elektrisch betriebenen Stadtlinien-Omnibussen (vorzugsweise 12m und/oder 18m)

City decarbonization strategies and projects (2)

Braunschweig
BMVBS Projekt

Oberhausen
Test auf Linie 962
und 966 seit 10/2015

Regensburg
Test ab 2017
Test of 8m Rampini

Köln
Test auf Linie 133
seit Anfang 2017

Drammen
Norway,
2016/S 165-298459
4-6 electric buses and 2 pantographs with option for the purchase of additional

Wien
Test of 8m Rampini Electric buses since 2012
2017 Procurement of 12m electric buses, ongoing project

Warschau
Test seit 2014

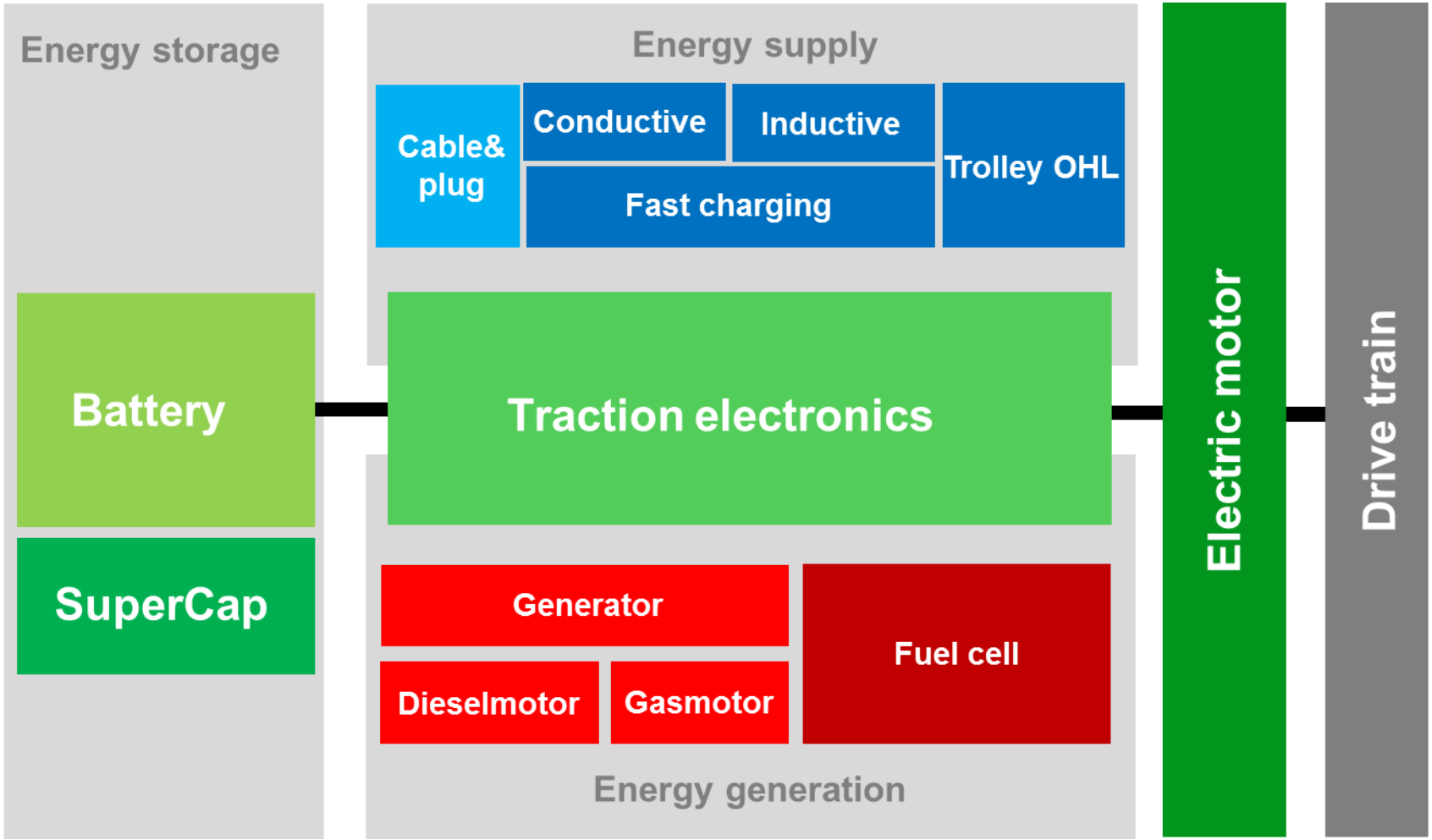
Bonn
ZeEUS Projekt seit 2016

München
Test ab 2017
Test of Solari

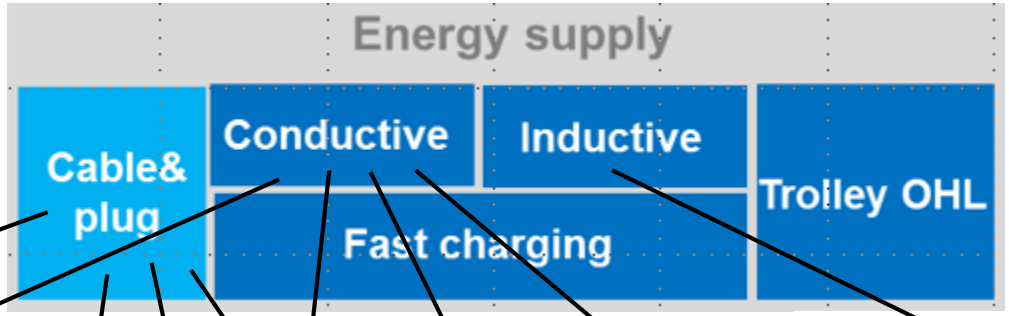
s and BYD-Buses.

Graz
Test auf Linie 50 (12m) seit April 2017. Test auf Linie 34E (18m) ab November 2017
2016/S 165-298459
Test operation of electric buses and of stationary charging equipment for 2 buslines with 2 buses each

Electric Bus Concept in General
Generic Sub-Systems



Overview of Charging Technologies



Opportunity Charging Technologies

Hamburg

Stockholm

Dresden

Graz

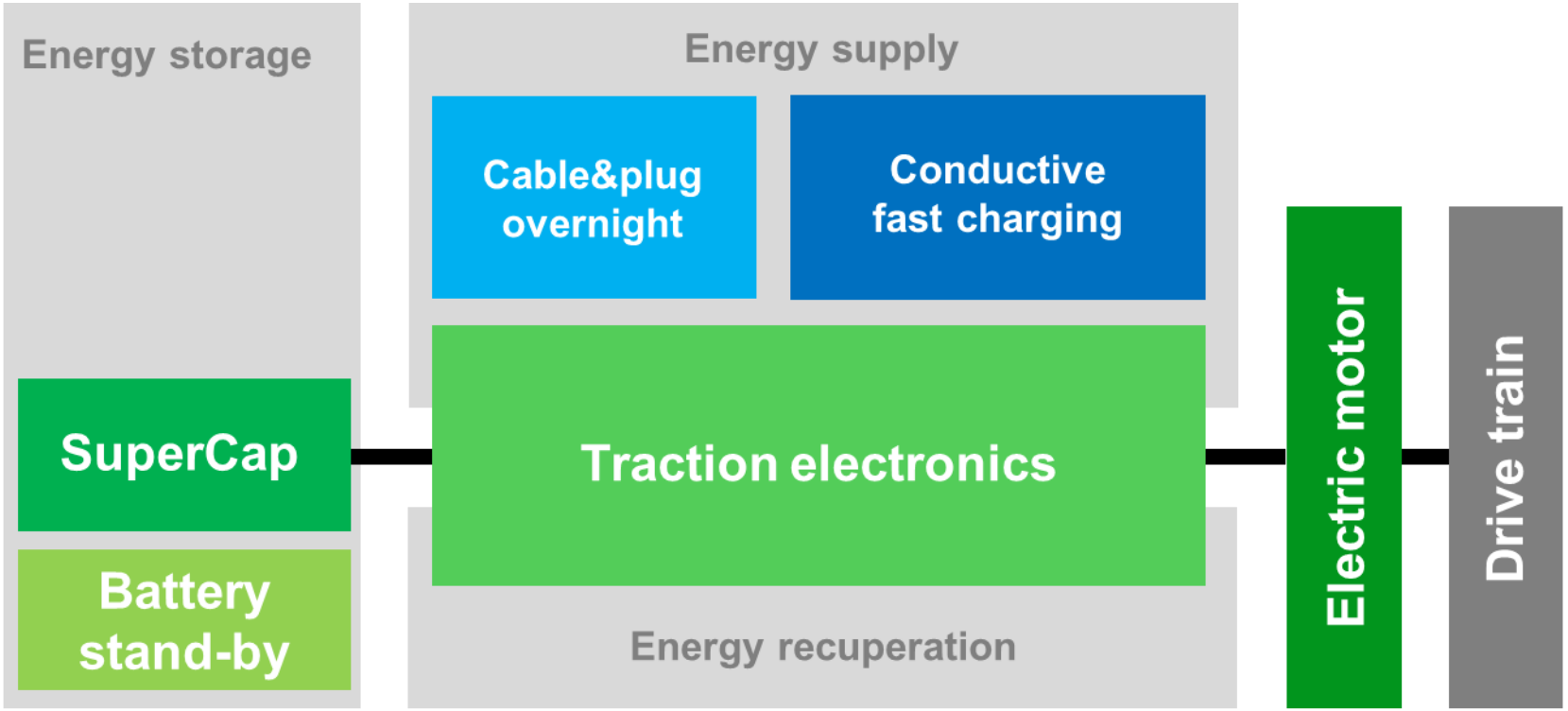
Graz

Genf

Electric Bus Test Project Graz, Austria

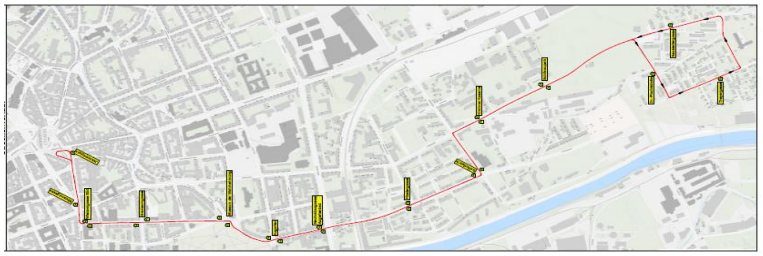
- second largest city of Austria, 280.000 citizens
- approx. 170.000 people a day commute from the greater Graz area
- 127,56 km², 40 % of which is considered „Green Space“
- 5 universities, approx. 40.000 students
- modal split: 20 % PT, 47 % MIV, 15 % bicycles, 18 % walkers
- 115 Mio. passengers p.a.; 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)

Electric Bus Concept of Graz Linien
Basic Energy Storage and Energy Supply



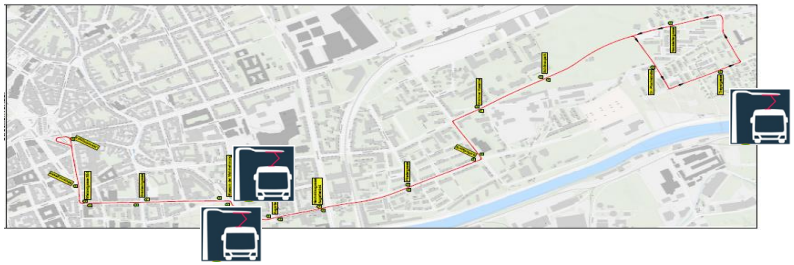
Charging Technologies in Use at Graz Linien

1. Overnight charging.

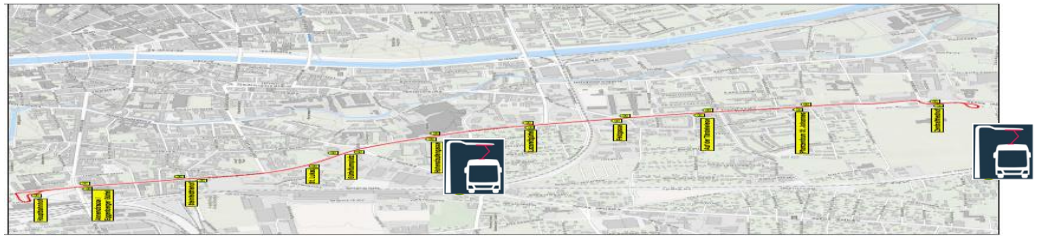


2. Opportunity charging at bus end station.

plus



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



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

Chariot 12m-EBUS

SYSTEM SPECIFICATION

- 12m fully electric bus with ultracapacitor-based (UC) technology;
- Electro motors from ZF directly on wheels (wheel hub);
- Fast charging UC (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 UC-technology versus the slow or fast charging batteries - charging factor of 10 C;
- Relatively small and lightweight energy storage (UC);
- Wide working temperature range of the UC (-24° to +40°C) with full 10-years' warranty;
- Performance validation from BELICON institute, Germany.

CRRC 18m-EBUS in Test Operation on Line 34E: Charging at Bus Stop Museum der Wahrnehmung

CRRC Articulated 18m-EBUS

SYSTEM SPECIFICATION

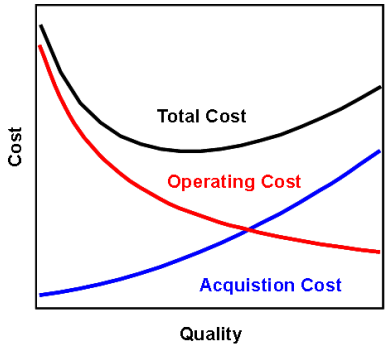
- 18m electric bus integrated with CRRC ultracapacitor as the primary power source
- Direct-driven transmission mode of CRRC motor and ZF axle
- Super fast charging ultracapacitor (25kWh capacity)
- Average energy consumption (1.8 kWh/km)
- Aluminum body
- 3 min. Charging time for 7 km (depends on driving behaviour)

HIGHLIGHTS

- Zero pollution and zero emission of the ultracapacitor technology
- High transmission efficiency of direct-driven motor system ≥94%
- High brake energy regenerative rate (≥80%)
- Suitable for super rapid charging and discharge mode of public traffic system (within 30 seconds)
- Wide operating temperature range of the ultracapacitor (-30℃~+55 ℃)
- The lightweight design reduces 800kg in relation to a steel body

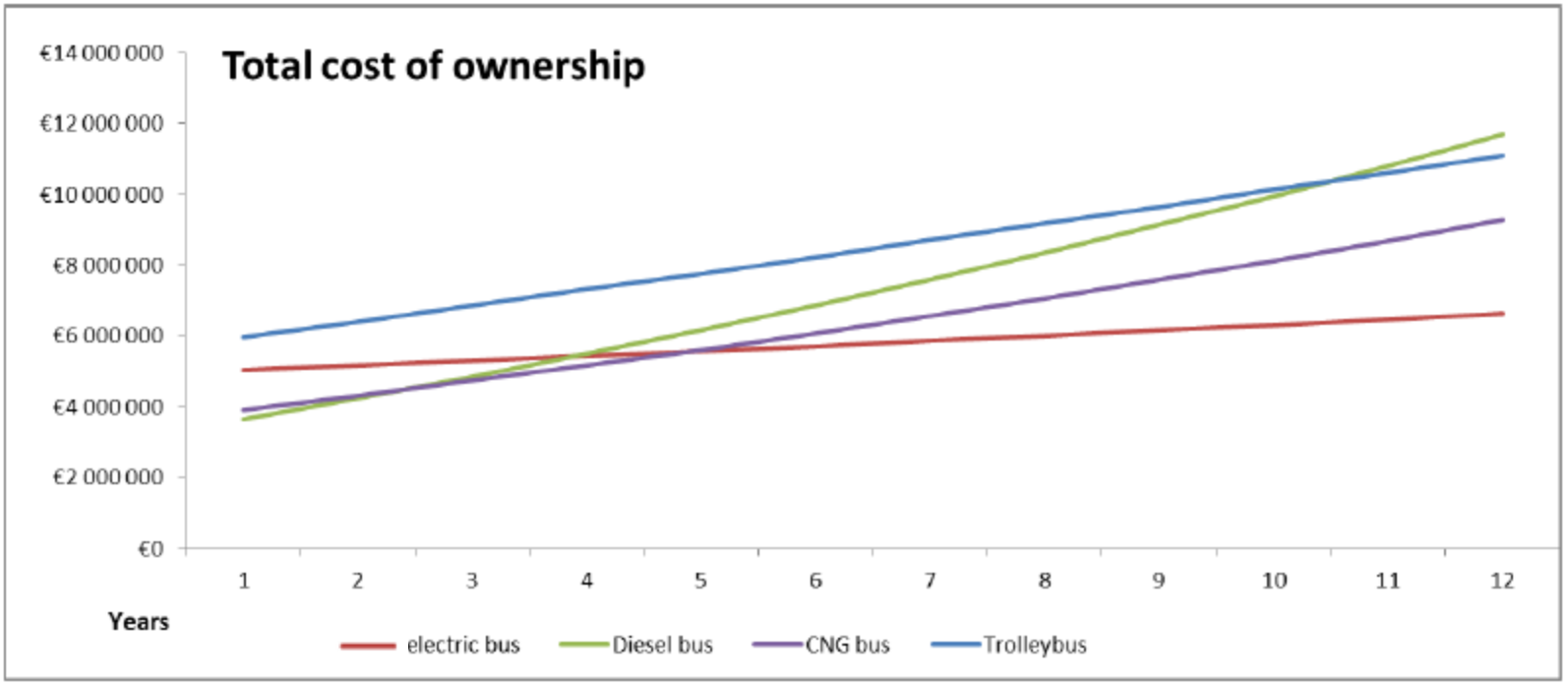
Electric Bus Project Facts (12m-Bus)

Diesel		BEV
100 km: 116 kg CO_2	Emissions	Zero (100km: 2,6kg CO_2*)
100%	Noise level	25%
100% (100km: € 32,--)	Energy cost	20% (100km: € 6,--)
100%	Maintenance cost	50%
See carbon price	Pollutants	Zero
See calculation	LCC	See calculation



*) Green current footprint

Life-Cycle-Cost Comparison



Challenges in Our Projects

- Multicultural project management
- Characteristics of works in public areas
- Delay of delivery by contracting partners
- Manufacturing deficiencies in production
- Planning of a test period for new busses
- Service workshop upgrade
- Budget constraints

Electric Bus Needs

- Standardization of the charging interfaces
- Serious political will and substantial financial subsidies from public
- Rethinking Business Models, flexible Leasing, syndicated procurement
- Inclusion of environmental cost and indirect cost in a LCC calculation
- Functional specifications with Technical Performance Indicators
- Apply GPP (Green Public Procurement) mandatory in tenders
- Standard Tender Files

Electric Bus Lessons Learned

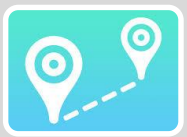
TECHNOMA

Detailed assessment in advance

Integrate the electric power utility

Power storage technology

Charging technologies are proven

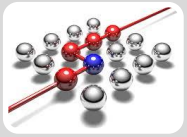


The range is no limit

Compare against existing fleet

Compare Life-Cycle-Cost

Set-up scenarios



Identify the LCC-optimized solution

Start with small scale test projects

Further Information

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