Technology focus: Battery buses

Webinar Series 5

7th July 2022, 11.00-12.00 CEST

Anouk Hol, Product Manager Public Transport at VDL Bus & Coach bv

CLEAN BUS EUROPE PLATFORM

UITP

The Clean Bus Europe Platform is financed by the European Union.

Anouk Hol
Product Manager Public Transport, VDL Bus & Coach bv

- Master in Mechanical Engineering (Twente University)
- Started at VDL Bus & Coach in 2015 as and aerodynamics & thermal management specialist
- Product manager of the New Generation Citea since 2020

Programme

Technology focus: Battery buses		
11.00 – 11.05	Welcome & Introduction	Aida Abdulah, UITP
11.05 – 11.40	• Introduction to battery bus technology: vehicle and components • Main advantages and drawbacks • Technology state of the art and future developments • Brief look into battery technologies and safety (chemistries, pros/cons) • Charging solutions and charging strategies	Anouk Hol, VDL B&C
11.40 – 12.00	Questions & Answers	

Today's goal

- Clear and complete overview of battery bus technology
- What are the main features and main challenges of this technology?
- Which aspects should I consider upfront when considering this technology?
- Insights on battery technologies
- Which sources of information can I refer to, to further learn on a specific technology?

Etiquette for joint discussion

- Participants please mute yourself per default
- You can use the Chat to place your questions, share interesting info or make us aware of any technical issue
- Raise your hand and switch on your camera to ask to have the word
- The session will be recorded.

We count on your valuable contribution for a successful workshop. Thank You!

Technology focus: Battery buses

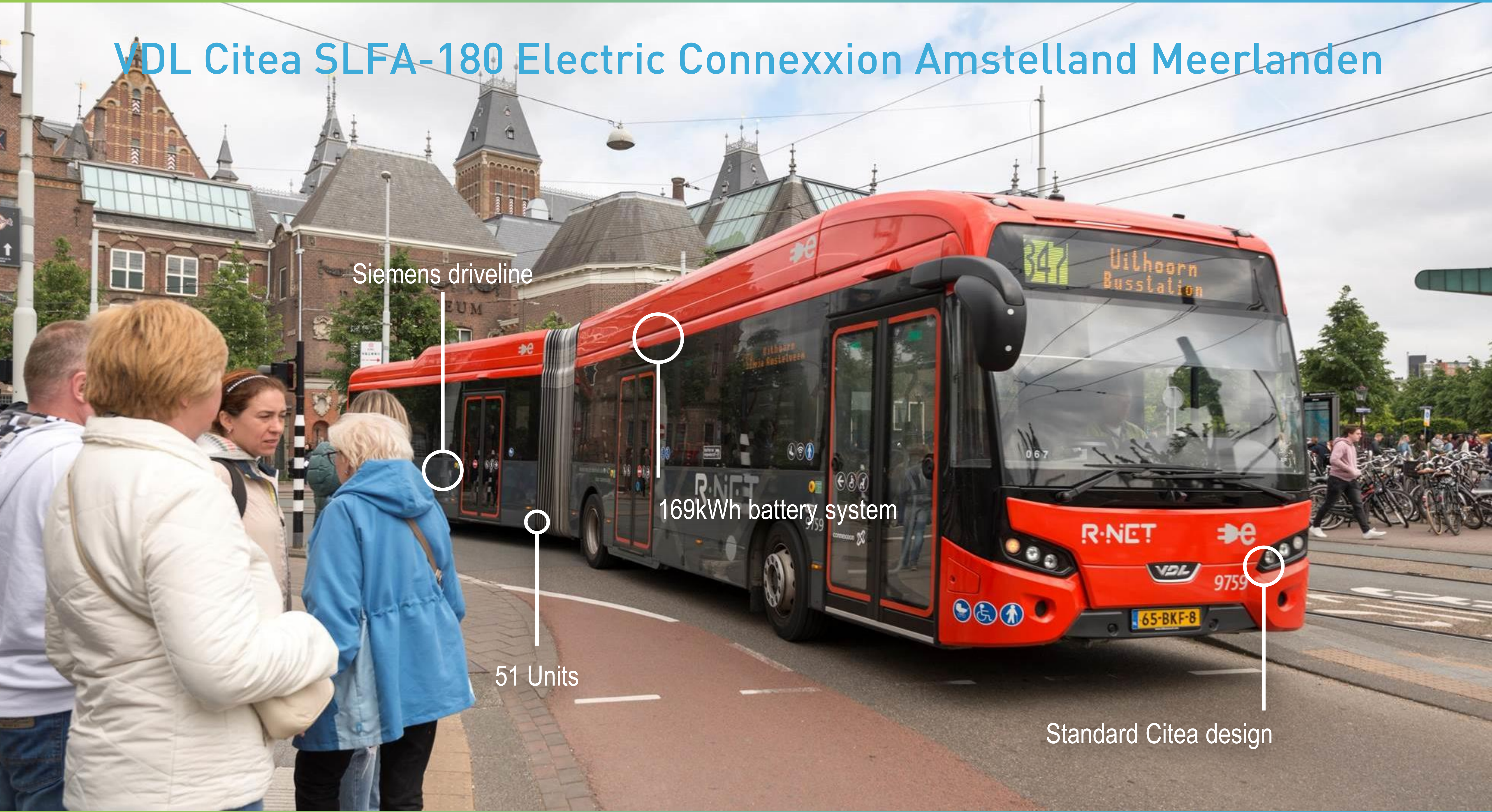
Introduction

From introduction e-bus at UITP Geneva to today

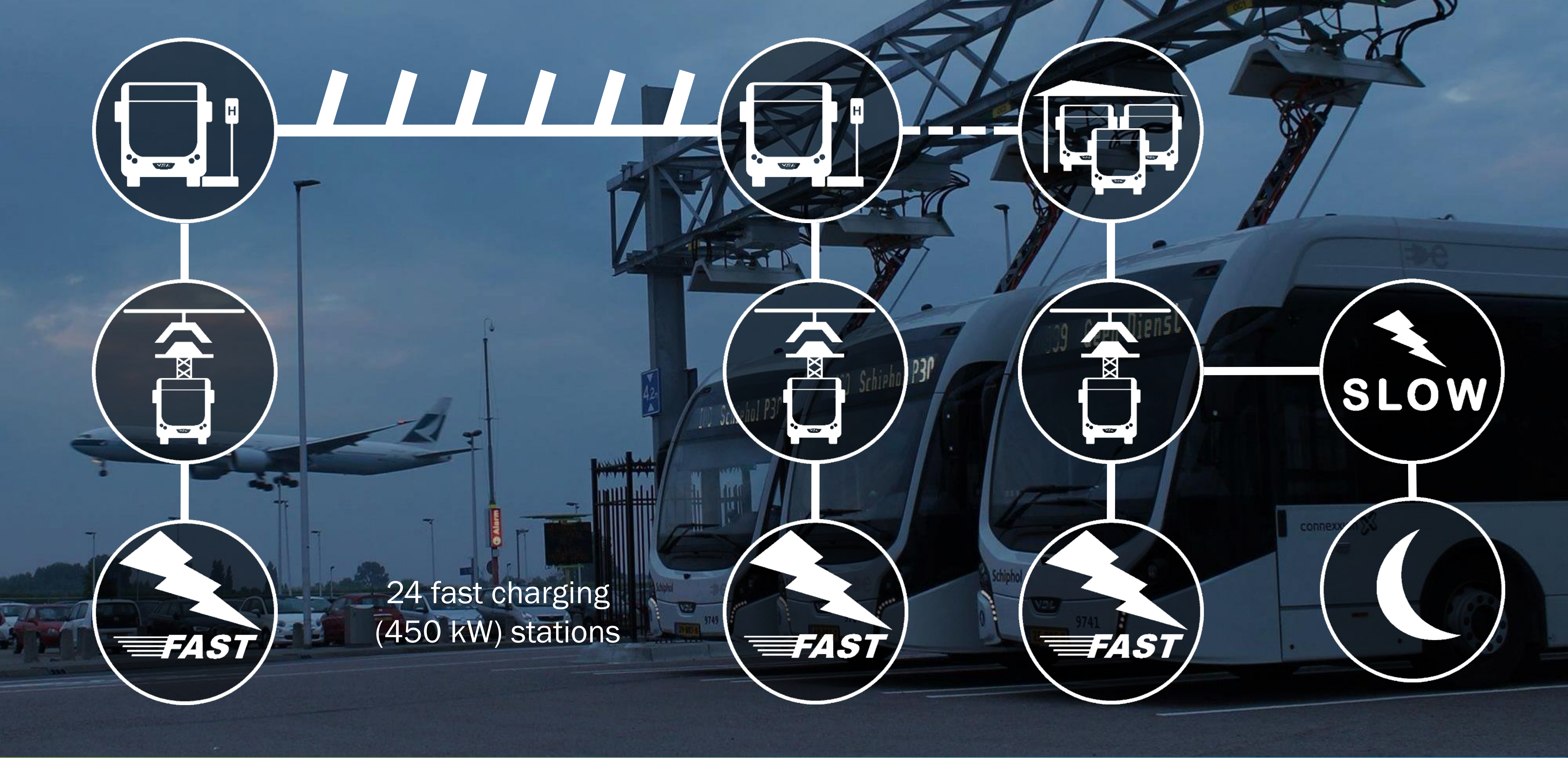
Introduction Citea Electric
UITP Geneva (2013)

More than 1,100 E-buses in operation today

VDL Citea SLFA-180 Electric Connexxion Amstelland Meerlanden



VDL Citea SLFA-180 Electric Connexxion Amstelland Meerlanden



What has influenced the design of our product?

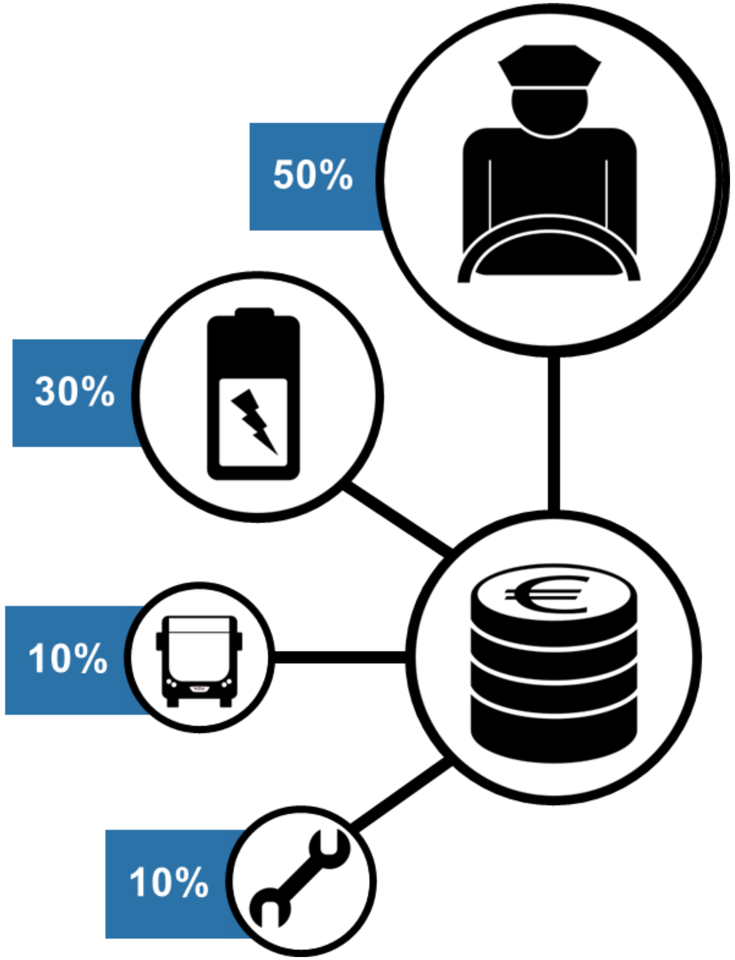
- Passenger Flow
- Total Cost of Ownership
- E-Tickets
- Emission Free
- System Approach
- Silent
- PTA
- Disruption
- Clean Vehicle Directive
- Connected Services
- Subsidies
- Fleet Management
- Environment
- Passenger comfort
- Greener
- Safety
- Autonomous
- Customers
- Ease of Maintenance
- Car Free cities

NGC

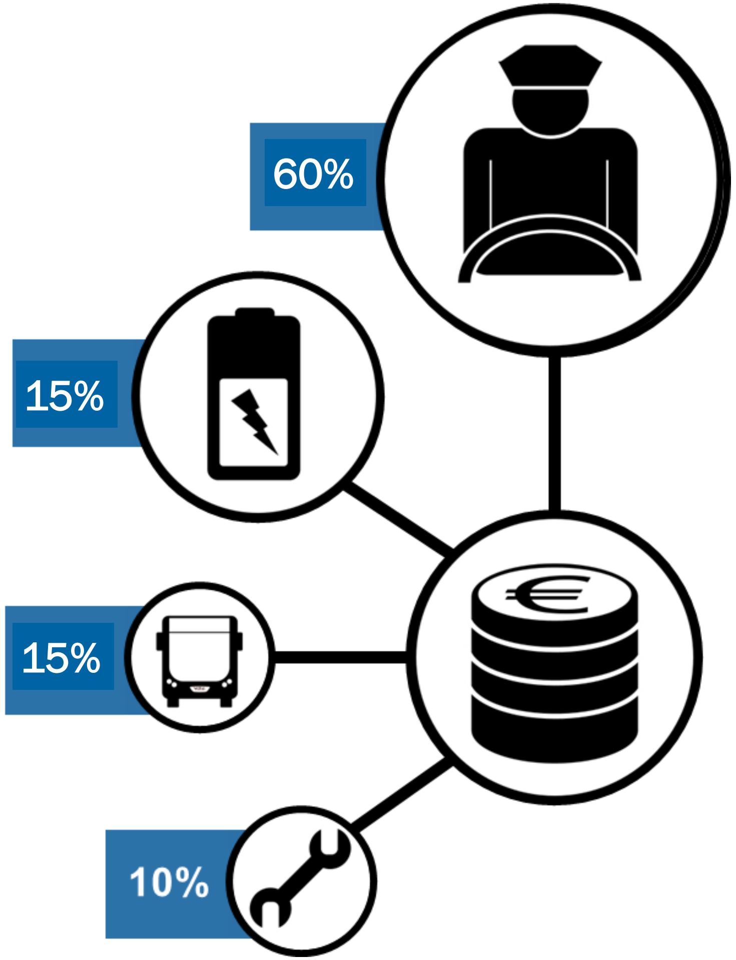
New Generation Citea

- Commercial Speed
- Smart City
- Ecosystem
- Enjoyable travel
- UITP
- (Local) Governments
- Sustainable production
- HVAC Systems
- Shared mobility
- Energy Grid
- Recyclability
- Computer on Wheels
- Well to Wheel
- Smart Charging
- Passengers
- Unions
- Less Downtime
- Turn Key
- PTO
- Availability of Drivers

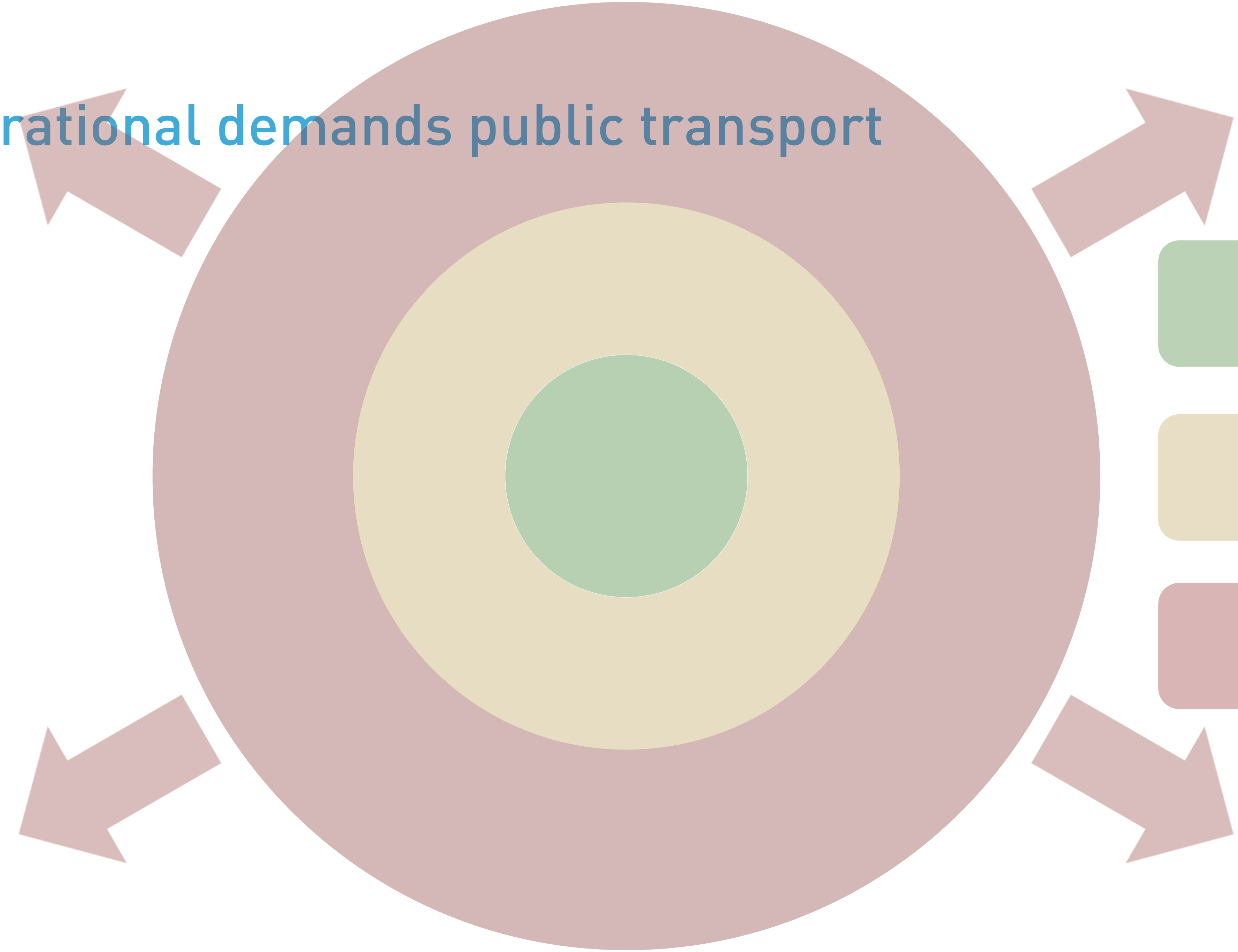
TCO focus of customer & operator



From diesel to
electric city bus



Operational demands public transport



City
10-15 km/u, Sort 1

Suburban
15-20 km/u, Sort 2

Regional
→20 km/u, Sort 3

Goals

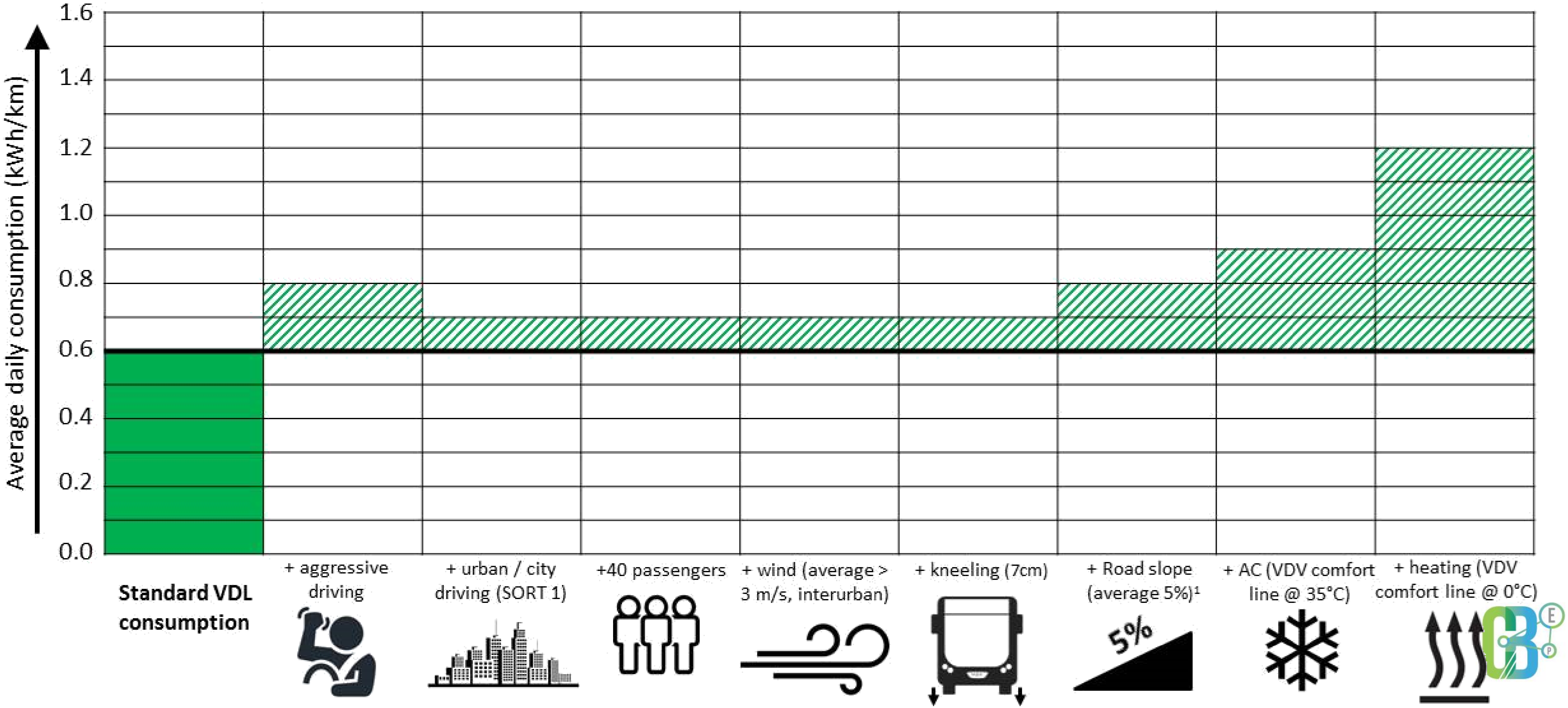
- **RANGE**
- **ERGONOMICS**
- **DESIGN & USER EXPERIENCE**
- **SAFETY**
- **CLIMATE COMFORT**
- **REPAIR & MAINTENANCE**
- **NOISE**
- **CAPACITY**

The vehicle platform is exclusively based on an **electric driveline.**

Technology focus: Battery buses

What parts make up an electric bus?

Reference consumption

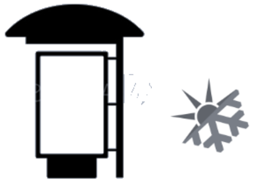


From current product to new model

Battery & climatization of e-buses

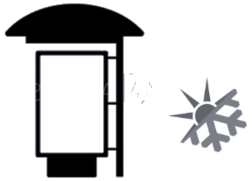
- No more heat from engines → Heat pump + electric heater
- Climate system energy consumption:

Average day



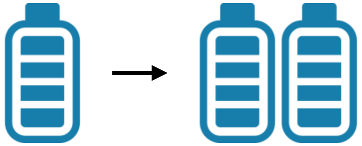
30%

Very cold/
hot day

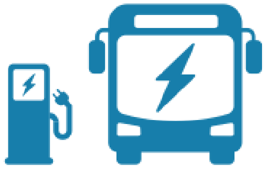


60%

- Enhancing range:



Cost and weight constraints



TCO increase

Energy efficiency → TCO decrease

Batteries

Slow charging

LFP (Lithium Iron phosphate)

Has excellent safety and long-life span but moderate specific energy and elevated self-discharge. Most used variant amongst overnight charging buses

LMP (Lithium Metal Polymer)

A solid-state technology that stands out for its high energy density, safety of use and limited sensitivity to temperature variation. Needs to be kept in a temperature-window at all-time.

Fast charging

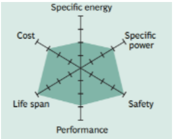
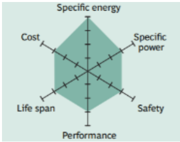
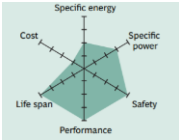
NMC (Lithium Nickel Manganese Cobalt Oxide)

Has good overall performance and excels on specific energy. This battery is the preferred candidate for the electric vehicle and has the lowest self-heating rate. Widely used in bus- & car industry

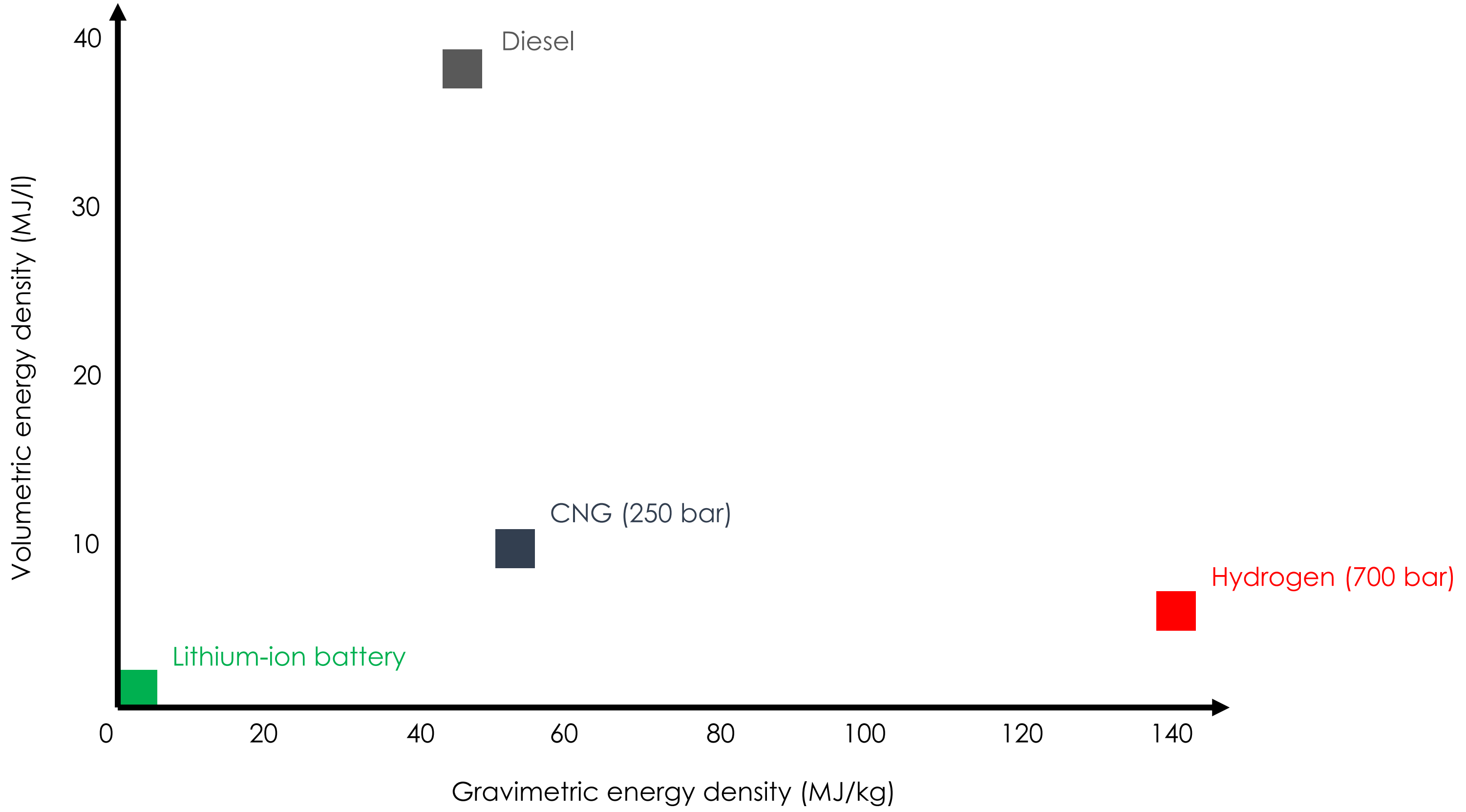
LTO (Lithium titanate oxide)

Excels in safety, low- temperature performance and life span, but has a low energy-density and high price. Efforts are being made to improve the specific energy and lower cost.

Batteries

			
	LFP	NMC	LTO
Specific Energy Density (Wh/kg)	130	150	90
Volumetric Density (Wh/l)	247	300	200
Nominal Voltage (V)	3.2	3.7	2.4
Temperature (o C)	-20 to 60	-20 to 60	-30 to 75
Charging C rate	1 C	1.5 C	5 C
Discharging Rate	3 C	2 to 3 C	5 to 10 C
Safety	Very Good	Fair	Very Good
Cycle Life for 100% DoD	3,600	3,000	15,000
Cost	Fair	High	Very High

Batteries



Underlying challenge of physics

- Batteries have far lower energy density than liquid fuels or compressed gaseous fuels
- Not enough spare weight allowance or unused space on buses

Batteries

Large batteries reduce passenger capacity

- Critical where number of passengers reaches maximum legal capacity of diesel buses

Small batteries require additional opportunity charging infrastructure

- Extra investments
- More stakeholders
- Operational costs

Battery chemistry is degenerative

- Limited depth of discharge (DOD) reduces range but extends battery life
- Initial vs. replacement cost

Driveline

Central Motor

+ Proven technology

+ Lower weight

+ Serviceability

- Less quiet (depends on configuration)

Electrified Axles

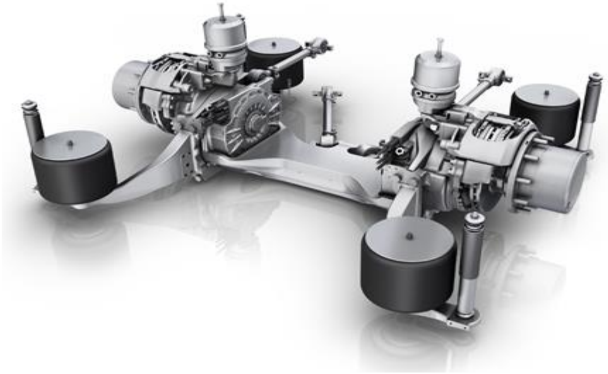
+ Less intrusive in interior

+ Similar layout to conventional axles

- HV Training required to work on brakes & tyres

- High unladen weight

- Lower grade ability



Wheel-hub motors

+ Less intrusive in interior

+ Similar layout to conventional axles

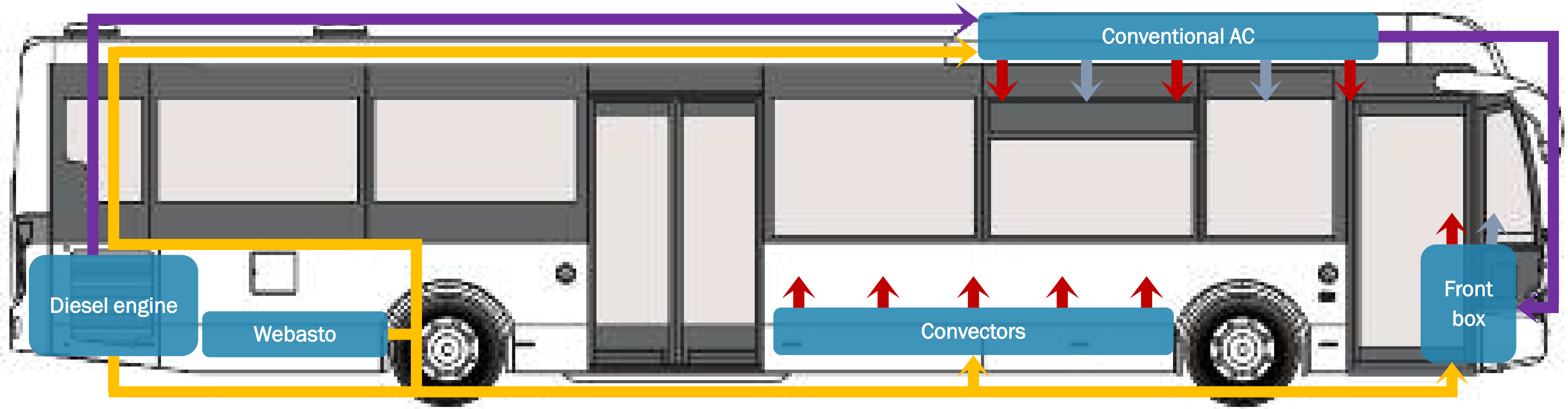
+ Less revolving parts (wear/noise)

- HV Training required to work on brakes & tyres

- Technically complex design

- High unladen weight

Climate system – Diesel bus



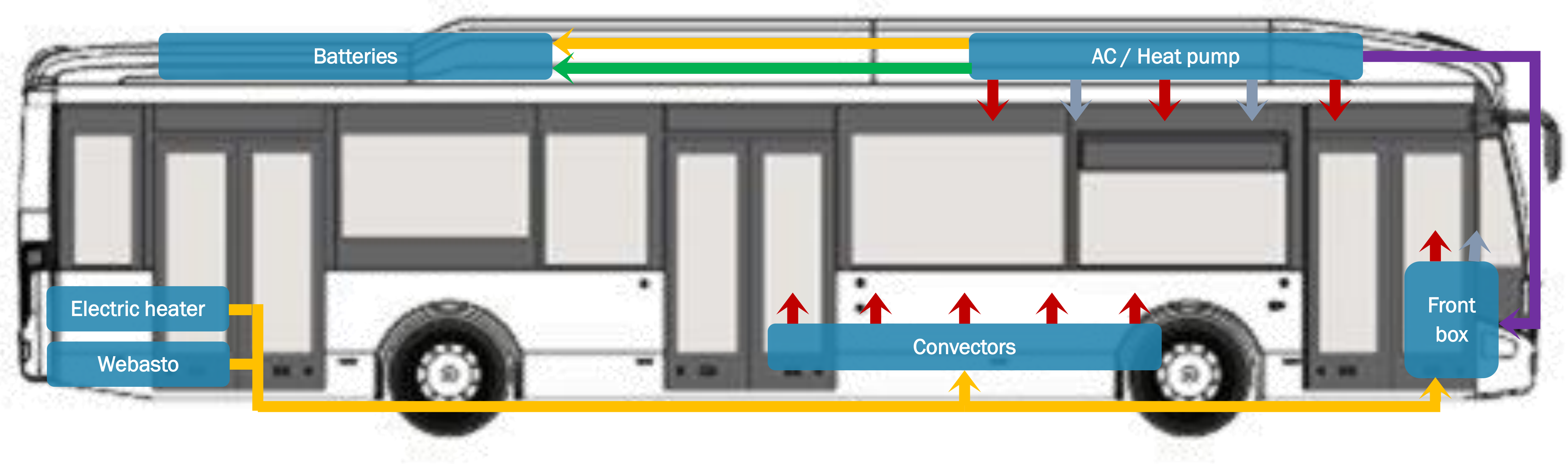
= Glycol for heating

= Refrigerant for cooling

= Warm air

= Cold air

Climate system – Current electric bus



= Glycol for heating

= Refrigerant for cooling

= Glycol for cooling

= Warm air

= Cold air

Technology focus: Battery buses

Charging solutions & infrastructure

Charging interface overview

- Charging
  - Conductive
    - Static
      - Manual Connection
        - Plug
          - AC
            - Type 1 (7,4 kW)
            - Type 2 (7,4 kW)
            - Type 2 (22 kW)
            - Type 3 (7,4 kW)
            - Type 3 (22 kW)
          - DC
            - ChadeMo
            - CCS Plug (Type 1)
            - CCS Plug (Type 2)
      - Automated Connection Devices
        - Pantograph
          - Roof Mounted
          - Inverted
        - Under floor
          - SRS
        - Robot-arm
    - Dynamic
      - IMC
  - Inductive
  - Battery swapping
  - Bus swapping

Charging interface overview

- Charging
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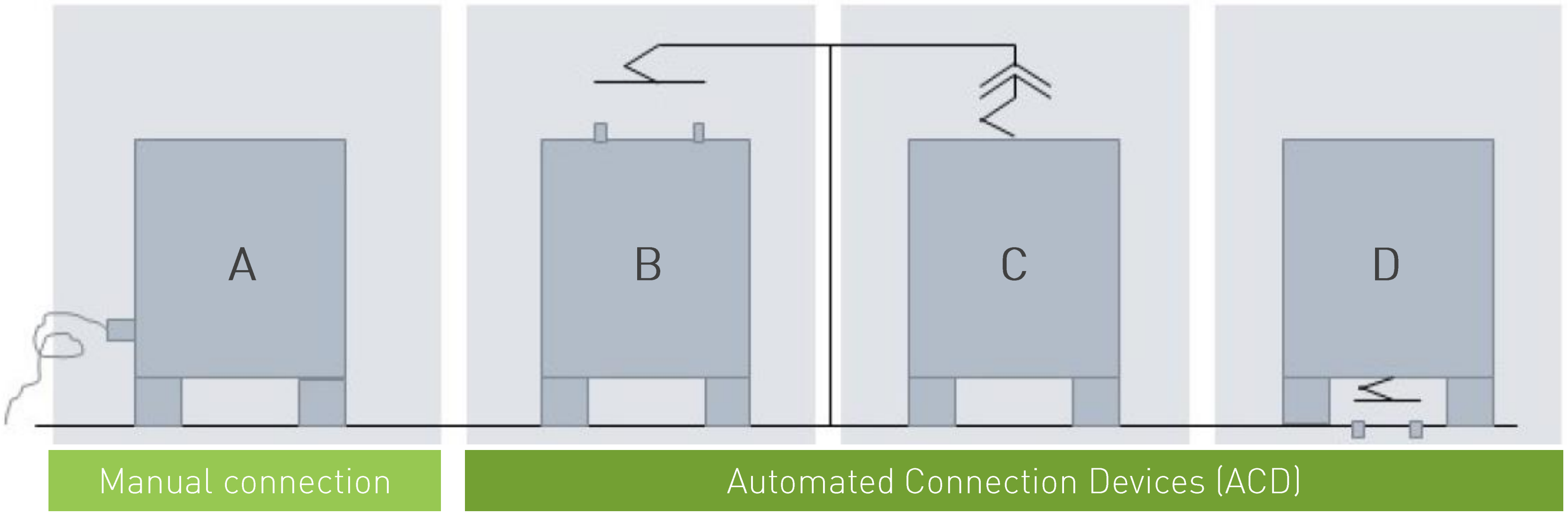
        - Robot-arm
    - Dynamic
      - IMC
  - Inductive
  - Battery swapping
  - Bus swapping

Leading technologies for BEB (yellow: Roof Mounted, Inverted, CCS Plug (Type 2))

Leading technology for Trolley (blue: IMC)

Solutions for battery electric buses



CCS combo Type 2 Mode 4 connector	Infrastructure-mounted pantograph	Roof-mounted pantograph	Underfloor-mounted ACD
Up to 200A and 1000V (Cooled version: 500A continuous current)	4 separated mechanical contact points (plus, minus, PE and CP)	4 separated mechanical contact points similar to CCS manual connector	3 separated mechanical contact points (plus, minus, PE)
Hard-wired power line communication with CP contact pin	WIFI/WLAN communication	Hard-wired power line communication with CP contact pin	WIFI/WLAN communication

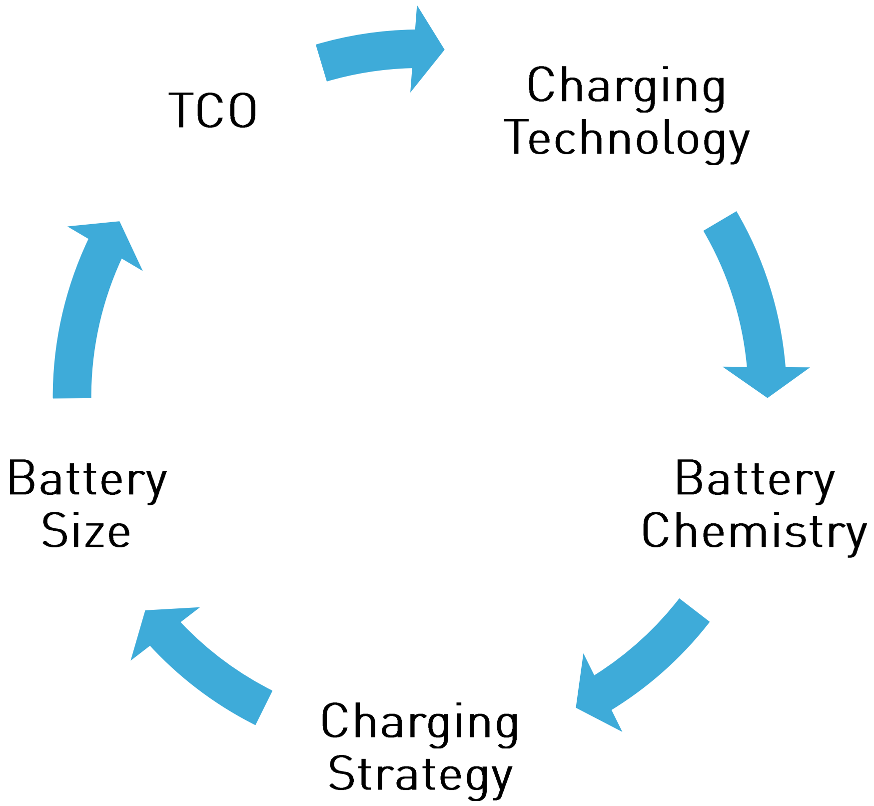
Interoperability

- European E-Bus standards under development (CEN/CENELEC)
- Market-driven "standardisation" by industry for plug and roof-mounted pantograph charging
- ASSURED Project (https://assured-project.eu/)
    - Connector (for plug & roof-mounted pantograph)
    - Positioning
    - Communication protocol
    - Performance
    - ASSURED Interoperability Reference 1.1 to be found here
- No dependence on single vehicle or technology supplier
    - Flexibility for subsequent purchases
    - Proprietary solutions not accepted by market

System dimensioning

Five questions to help you draft an E-Bus System:

1. What is my daily production per bus?
2. (What is the available time for charging in the timetable?
3. How vulnerable is the line for delays?
4. What grid capacity is available along the line & where?
5. What grid capacity is available in the depot?



Questions & Answers

Thank You!

The recording will be available soon at

www.cleanbusplatform.eu

UPCOMING WEBINAR:
Technology focus: Natural Gas

September 2022, 11.00-12.00 CEST

More info coming soon!

Jean-Marc Boucheret

IVECO Public Transport Sustainable Mobility Manager

CLEAN BUS EUROPE PLATFORM

The Clean Bus Europe Platform is financed by the European Union.