Understanding the Pieces of Sustainability for MHD - "Every Part Counts"

Bosch Systems for FCEV in Diverse eMobility Use Cases

Fuel Cells for Mobility

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Why Fuel Cell EV - now ?

Fuel Cell EV | Important pillar in a diversified powertrain portfolio


Credit: emobilserver.de


Credit: autozeitung.de

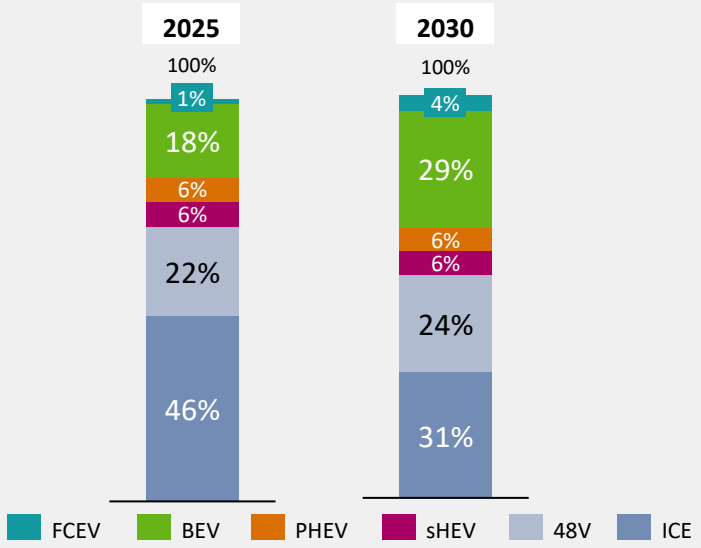

Credit: commercialfleet.org


Credit: newflyer.com

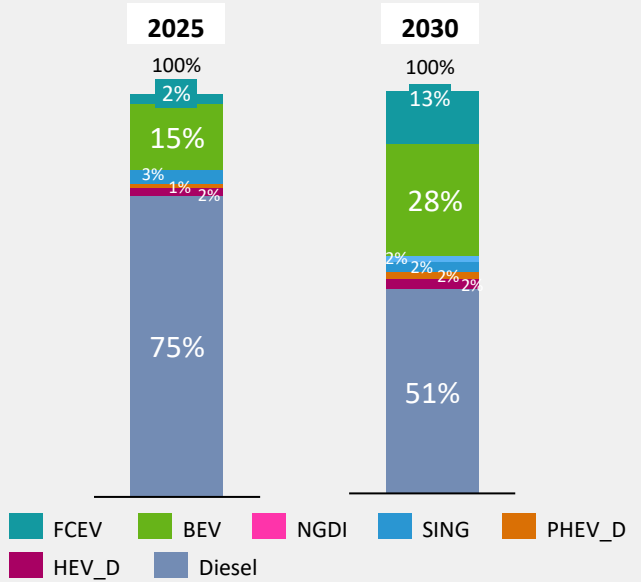

Credit: .greencarreports.com


Credit: .greencarcongress.com

New vehicles PC incl. LCV < 6t worldwide



New vehicles HD, MD & Heavy Bus > 6t



Powertrain Portfolio in 2030
(new vehicles, worldwide)

- Passenger Cars + LCV:
  1/3 fully electric t/o 12% FCEV
- CV HD, MD:
  13% equipped with FCEV powertrain

ICE keeps significant share including increasingly hybridized

*Pre-Covid estimates

Why Fuel Cell EV - now ?

PEM-FC | Convenient and exciting solutions for various e-mobility use cases

Commercial Vehicles

Weight- and space optimized e-mobility with potential for attractive TCO-case

- FCEV might be the only viable option for HD long-haul e-mobility
- In many use-cases and based on attractive Hydrogen costs FCEV will be able to offer attractive Total-Cost-of-Ownership

Passenger Cars

Attractive UX-factors in long-distance use cases

- FCEV can provide a solution for zero tail-pipe emissions in all applications for long distance use cases

- FCEV can remove range anxiety barrier in e-mobility applications
  - Refueling time in 3min
  - Driving range above 500km

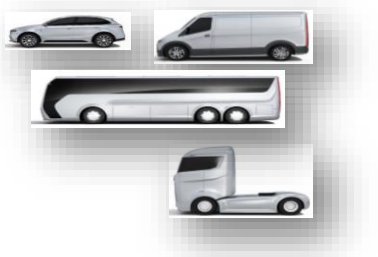
Which Fuel EV in which segment ?

Use-Cases per segment | **Power and Energy demand**

Identification of segments and use cases

- Power demand [kW] el. Drive
- Energy consumption [kWh/km] / demand [kWh]

1



Segment	PC		LCV		MD		HD		Bus	
Use case	Long range / motorway	City	Inter-urban	City	Inter-urban cool. trans.	City	Long haul	City	Coach / Intercity	City
Vehicle class / type	UC	SC	3.5to	3.5to	18to	18to	40to	26to	15m - 26to	12m - 19to
RDC range assumption[km]										
e-drive cont. [kW]										
e-drive peak [kW]										
Req. drive energy [Wh/km]										
Req. total energy [Wh/km]										
Net energy demand [kWh]										

Filling level of the "Data Bar" in each box indicates the dimension of each parameter

PC: Passenger Car
LCV: Light Commercial Vehicle
MD: Medium Duty Commercial Vehicle
CV: Commercial Vehicle

UC: Upper Class Segment
SC: Sub-Compact Class segment

Drastic difference long-rang vs. city use cases – e.g. energy demand

- **PC:** appr. 7 times higher in long-range Upper Class use case (vs. city sub-compact)
- **CV: appr.** 4 times higher for 40t Long-Haul (vs. 26t city transporter)

Which Fuel EV in which segment ?

Use-Cases per segment | **FC Power and Battery Capa**

Key Parameters for FC system dimensioning

- Peak/ cont. Power FC system [kW]
- Capacity [kWh] and type of FCEV hybrid battery; capacity H2-tank [kg]

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Source: peakoil.net

Segment	PC		LCV		MD		HD		Bus	
Use case	Long range	city	Intercity	city	Intercity Cool trans.	City	Long haul	City	Coach Intercity	City
Vehicle class	UC	SC	3.5t	3.5t	18t	18t	40t	26t	26t	12t
Selected FCS power [kW]										
H2 mass, gross [kg]										
FC-Bat. Cap., gross [kWh]										
FC power selection Cycle average → full cont.										
FCS power dynamic ($t_{90\%}$) low (~100s) → high (~1s)										
Hybrid battery type	HEV	PHEV	PHEV	PHEV	BEV	BEV	BEV	BEV	BEV	BEV
Hybridization category	**Full Fuel Cell**	**Battery dominant**	**Fuel Cell dominant**	**Balanced**	**Balanced**	**Balanced**	**Fuel Cell dominant**	**Fuel Cell dominant**	**Balanced**	**Battery dominant**

FCS: Fuel Cell System

- **Fuel Cell:** Long-range applications can be matched w/ a modular FC system
- **Battery:** capacity and type of battery needs to be adapted to the specific use case

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Which Fuel EV in which segment ?

Use-Cases per segment | **Best Fuel Cell-fit**

Identification of FCEV target segments and use cases

- Definition of use case w/ best FCEV-fit per segment

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Segment	PC		LCV		MD		HD		Bus	
Use case	Long range / motorway	City	Inter-urban	City	Inter-urban cool. trans.	City	Long haul	City	Coach / Intercity	City
Ex. vehicle class / type	UC	SC	3.5to	3.5to	18to	18to	40to	26to	15m - 26to	12m - 19to
Net energy demand [kWh]										
Selected FC S power [kW]										
H_2 mass, gross [kg]										
FC-Bat. Cap., gross [kWh]										
alc. BEV bat. Cap., BoL/gross [kWh]										
Mass advantage FCEV vs. BEV [kg]										
Volume advantage [l]										

Best-Fit Use Cases for Fuel Cell

Weight/ volume advantage or penalty determine use cases w/ best FCEV-fit

- ❑ **PC**: Clear benefit for FC in long-range Upper Class; no favored solution for city vehicle.
- ❑ **CV:** Long-haul/ inter-urban use cases in favor of FCEV; city use cases can be met w/ BEV

Bosch contributions to Fuel Cell EV

Bosch Fuel Cell Product Portfolio

Fuel Cell Mobility Solutions

BoP Components Development

Balance of Plant (BoP) Components

Anode Recirculation Blower (ARB)

Hydrogen gas injector (HGI)

Hydrogen Supply Module (HSM)

Electric air compressor (EAC)

Fuel cell control unit (FCCU)

Stack isolation control valve

Humidifier/stack bypass valve

Pressure Sensors

Pressure based air-flow meter (PFM)

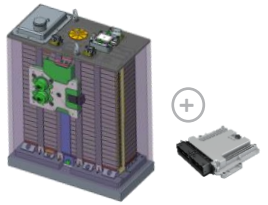
Hot film air-mass meter (HFM)

Stack and System Development

Stack

Fuel Cell Stack (Stack)

Fuel Cell Stack w/ functional housing



Fuel Cell Kit

Fuel Cell Kit (Stack + BOP + Engineering)

Engineering

Fuel Cell Systems

Fuel Cell Power Module

Comprehensive portfolio of Fuel Cell products with SOP 2021 to 2023

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Bosch contributions to Fuel Cell EV

Bosch Electrical Drivetrain Product Portfolio

eCityTruck	eRegioTruck	eDistanceTruck
Vehicles 3-8t	Vehicles 8-26t	Vehicle ≤ 40t





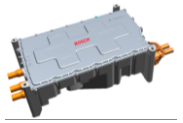

700V Portfolio with Synergy to PC Technology

400V Syn. to PC products









eAxle | **Standard Drive** | **eDM [1]** | **Separate Motor-Generator Modular kit** | **CV Inverter Gen4**

Bosch offers a scalable modular product approach for various CV topologies

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Bosch systems for FCEV in diverse e-mobility use cases

Summary

❑ **Why Fuel Cell EV - now ?**

- PassCar: **Attractive UX-factors in long-distance use cases**:
  refueling time (3 min) and driving range (500 km and above)
- Comm. Vehicle: **Weight-/ space optimized e-mobility** solution; attractive TCO-potential

❑ **Which Fuel Cell EV in which segment ?**

- Drastic difference long-range vs. city use cases (e.g. energy demand)
  → **Long-range applications offer weight/ volume advantages for FC applications.**
- **Bosch product portfolio** designed to meet **requirements from "best Fuel Cell fit"** segments – including a **modular FC system**

❑ **Bosch contributions to Fuel Cell EV**

- **Comprehensive portfolio of FC systems and components** with SOP between 2021 and 2023; one product-line for PC and CV to enable scaling benefits – adaptations to meet segment specific requirement
- **Dedicated FC organization** with global footprint and experienced partners

Back-up

Why Fuel Cell EV - now ?

E.g. PassCar FCEV | Competitive costs for long driving ranges

Fuel Cell Electric Vehicle (FCEV)

eSystem:
w/o Battery
CharCon
w/ FC DC/DC

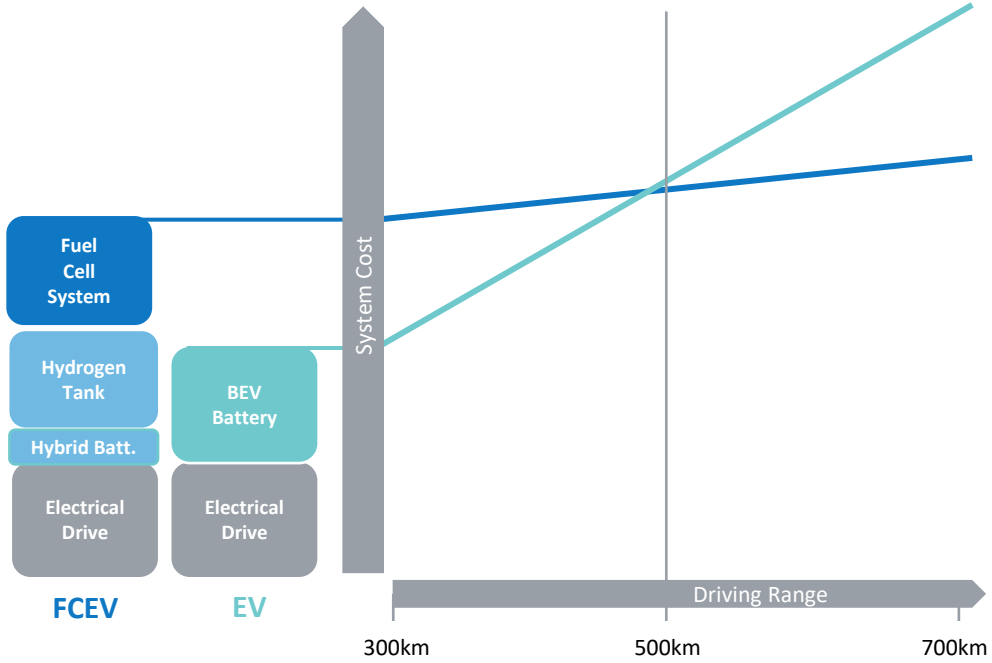
Energy supply:
Tank plus
Battery

Energy Conversion system:
Fuel Cell

Battery Electric Vehicle (BEV)

eSystem:
w/o Battery
w/ CharCon

Energy supply:
Battery



FCEV can reach competitive costs for long driving ranges

Bosch contributions to Fuel Cell EV

One Product-Line for PC and CV

- Compact design
- High dynamic
- Reliability
- Competitiveness
- Quality
- Low noise
- Efficiency

global foo

NVH design

modular solution for CV & PC

design to cost

high vol. manufacturing

compact design

robust design &validation

- Long lifetime
- Reliability
- Compact design
- Competitiveness
- Low parasitics
- Low noise
- Efficiency

Pass Car Requirements

One product-line for PC and CV to enable scaling benefits

Commercial Vehicle Requirements

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