Analysis of the technical capacity of fuel cell buses for route between different geographical heights

Presentation of project results

06 OCT 2021 – Public Webinar

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

CONSULTING ENGINEERS

BELICON Fahrzeugforschung

ludwig bölkow systemtechnik

Agenda

Welcome by GIZ

Presentation of project results

Panel discussion

Welcome by GIZ

Rodrigo Vasquez (GIZ)

Presentation of project results

Hubert Landinger (LBST)

Introduction project team

Dr. Uwe Albrecht

Managing Director

LBST

Hubert Landinger

Senior Project Manager

LBST

Reinhold Wurster

Senior Consultant

LBST

Prof. Dr.-Ing. Ralph Pütz

Managing Director

Belicon

Fernanda Durán Sievers

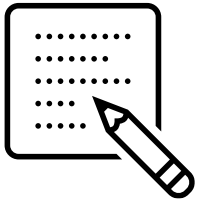
Business Development Engineer

ILF

Notes

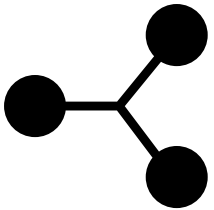
Wording used | Availability of slides & report

Wording was kept with “buses”, both in report and this presentation
(also in the meaning of “coaches”)



Slides will be shared;

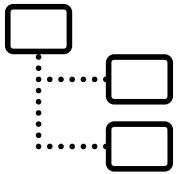
report available at
https://www.4echile.cl/publicaciones/analysis-of-the-technical-capacity-of-fuel-cell-buses-for-route-between-different-geographical-heights/



Scope of work

Structure

- Compilation of route specific characteristics of fuel cell buses
- Compilation of appropriate fuel cell buses available on world market
- Compilation of technical characteristics under mining route conditions
- Recommendations regarding partners for pilot project and roll out

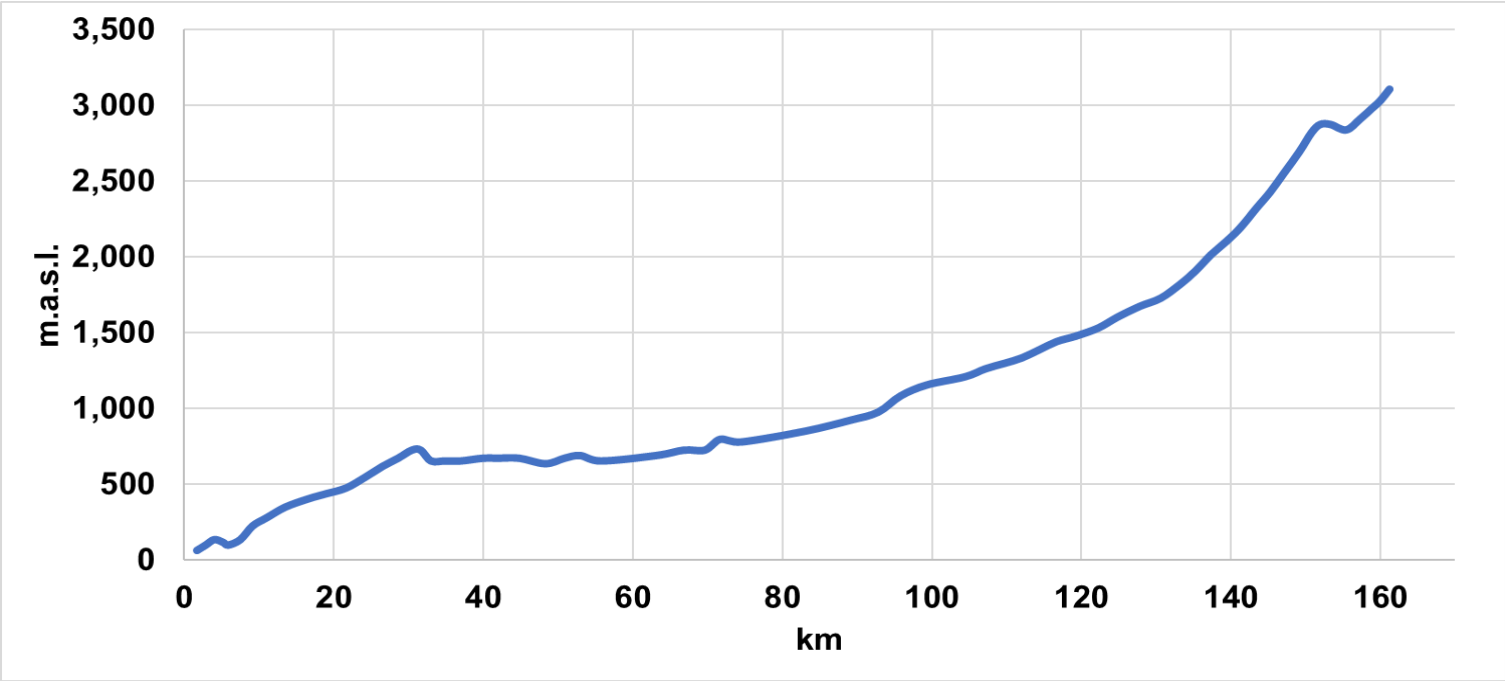


Route specific characteristics

Main route characteristics	
Length Antofagasta Airport to Antofagasta City Center [km]	~25
Length Antofagasta City Center to Minera Escondida and Minera Zaldivar [km]	~160
Total route length [km]	~185
Minimum altitude [m.a.s.l.]	10
Maximum altitude [m.a.s.l.]	3,200
Maximum gradient (Mineras Escondida & Zaldivar / for this analysis (Candelaria))	15 % / 18%
Average gradient	2.5%
Maximum allowed speed [km/h]	90
Average speed uphill [km/h]	50
Minimum temperature [°C]	-20
Maximum temperature [°C]	40

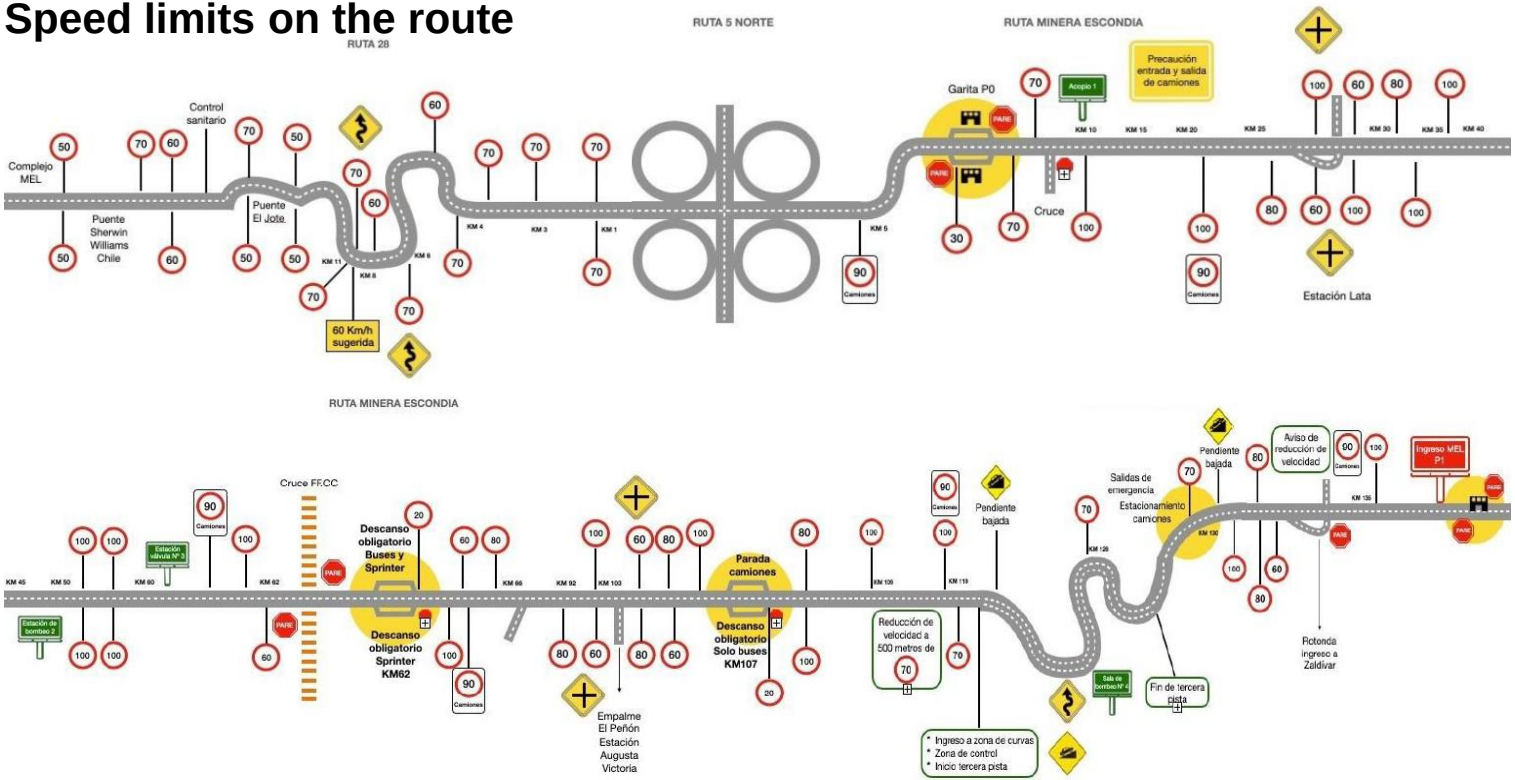
Route specific characteristics

Elevation profile Antofagasta City Center - Mineras Escondida & Zaldivar



Route specific characteristics

Speed limits on the route



Route & vehicle simulation

prepared by Belicon

Simulation of route and vehicle operation

Intermediate results – drive train only

The FC operates at a stack target temperature of 60°C.

Based on the driving resistances at the drive axle, the route profiles constructed above result in an average hydrogen consumption of about **14.5 kg H_2/100 km** for the uphill ride traction (at 100% passenger load), including cooling pump and air compressor consumptions.

At an efficiency of 50%, the FC generates around 365 kWh of electrical energy at the drive axle with this hydrogen consumption, corresponding to **2.4 kWh/km**.

This energy consumption may increase significantly with higher stop-and-go shares!

Simulation of route and vehicle operation

Overall results – including HVAC

In addition to traction consumption, energy consumption for heating/ventilation/air conditioning (HVAC) must be taken into account.

Here, heating represents the case with the greatest influence.

At an ambient temperature of around 21°C, the fuel cell and passenger compartment do not need to be cooled or heated.

At an ambient temperature of -20°C an average heating power of about 22 kW is necessary to keep an adequate ride comfort for the passengers (at 0°C about 12 kW).

In contrast, at about +30°C ambient temperature the cooling power demand merely equals 15 kW.

As a result, even with energy management of HVAC to minimize consumption, an **extra consumption for HVAC** may rise to an average of **0.2 kWh/km** additional to traction consumption.

This equals an increase in overall energy consumption of **up to about 10%**.

The less the operational speed, the higher the relative share of energy for HVAC!
(For urban operation, at an average operational speed of about 15 km/h, heating power at -5°C to -10°C may equal traction consumption.)

Fuel cell bus manufacturers

prepared by LBST

Comparison of appropriate FC buses available on the world market

Approach of fuel cell bus manufacturers

Buses4future *spec received & pub. confirmed*	Hyzon *spec received* *interest in ~1year*	New Flyer / ADL / MCI *currently no interest*	*VDL* *offering no H_2 solution at the moment*
Fanalca *spec received & pub. confirmed*	King Long *no feedback*	Solaris *currently no interest* *focus on Europe*	Wrightbus *NDA signed*
Foton *spec received & pub. confirmed*	Lightning eMotors *general interest, but no further feedback*	Toyota / Caetano *spec received*	Yutong *currently no interest* *focus on China*
Hyundai *interest; input provided*	Mercedes / Evobus *currently no interest*	Van Hool *currently no interest* *focus on Europe & USA*	Zhongtong *contact could not be established*

Buses4Future (B4F)

FC bus / coach experience	**Prototype operating for 2 years** in real world public transport application (see also https://www.kfw.de/stories/economy/start-ups/buses4future/); Q4 2021: delivery of 3 FC buses to the city of Münster / Germany; Production capacity: 40 buses p.a. from 2022
FC bus / coach types available	Type I (12 m LF)
FC bus / coach types under development	Type I (12 m LE, 18 m LF)
Fuel cell partner	HyMove / Netherlands

Fanalca

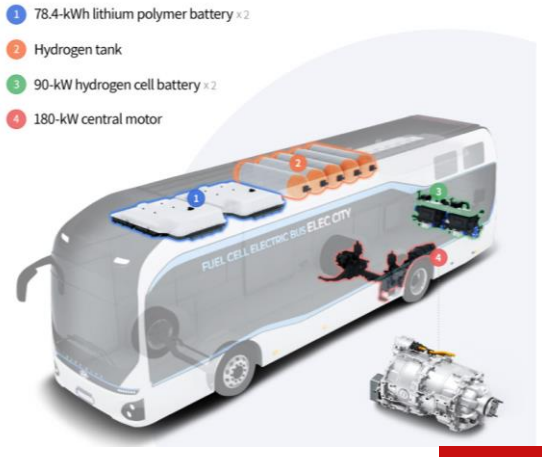
FC bus / coach experience	**Fanalca expects to have a prototype available by JUN/JUL 2022** for performance testing
FC bus / coach types available	-
FC bus / coach types under development	Fanalca prepares to offer Class I, II or III FC vehicles
Fuel cell partner	Toyota

Foton

FC bus / coach experience	In 2008, Foton successfully developed the first-generation hydrogen fuel cell bus and served the Beijing Olympics; in 2014, it produced the second-generation 12-meter hydrogen fuel cell bus; Foton has shipped several hundred FC buses to Zhangjiakou, alpine events city of the Beijing Winter Olympic Games 2022; then, Foton developed the third-generation 8.5-meter hydrogen fuel cell bus. **In 2021, Foton will ship its first 12m 70 MPa fuel cell city bus to Australia.**
FC bus / coach types available	Currently Foton has 12 m fuel cell urban bus / inter-urban buses in their portfolio which they plan to export to the Chilean market
FC bus / coach types under development	On demand
Fuel cell partner	SinoHytec (Toyota technology)

Hyundai

FC bus / coach experience	In South Korea, **112 units** of the Elec City Fuel Cell Bus have been **on the road** since the model was launched in 2019. The XCIENT fuel cell truck has already been sold commercially in Switzerland with 50 of these trucks deployed in 2020. An additional 140 vehicles will be deployed in 2021, with the goal to put 1,600 trucks into service by 2025.
FC bus / coach types available	Elec City Fuel Cell Bus (11m) travels ~430 km (~550 km from 2nd half 2022) on single charge (exports to Saudi Arabia; trials in Germany)
FC bus / coach types under development	**Hyundai is preparing** for three additional models: STARIA (7-11 seater van) Solati (15-16 seater van) **Universe (express intercity bus)**
Fuel cell partner	Hyundai



Hyzon

FC bus / coach experience	Hyzon (through the Horizon HVBU) has deployed **ten 12 m city buses** accumulating over 250,000 km to date (JUL 2021). Hyzon has developed a 50-seat coach bus (the first of 10 for Fortescue Metals Group in Australia) and completed 64 days of testing, consisting of 15,300 km loaded to ~19 t
FC bus / coach types available	Hyzon currently offers 40’ and 60’ (12 m and 18 m) low-floor city bus models and 50-seat coach buses available for several global markets
FC bus / coach types under development	**Fortescue Metals Group has contracted for up to 10 of Hyzon’s custom-built coach buses**
Fuel cell partner	Horizon Fuel Cells (Parent company of Hyzon Motors)

Recommendations

Hubert Landinger (LBST)

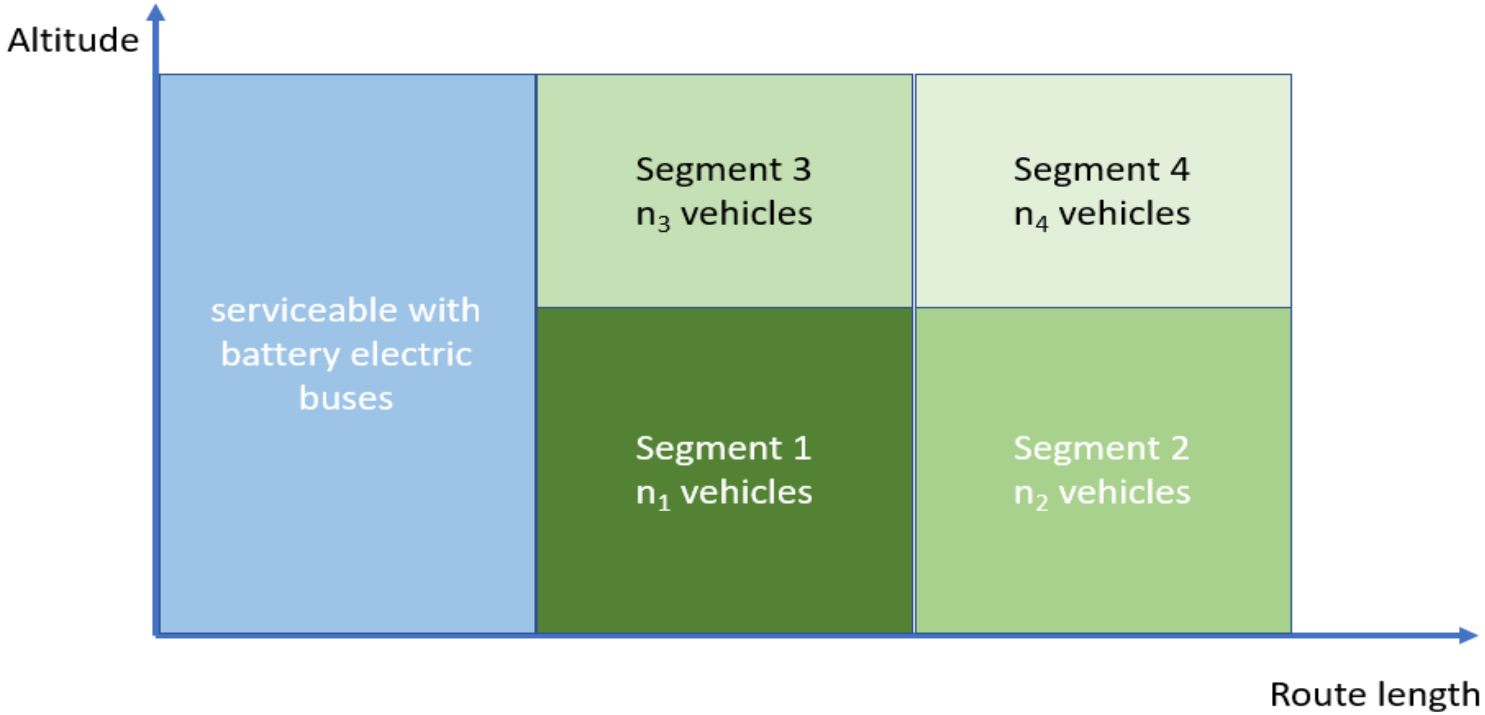
Recommendations regarding partners for pilot project and roll-out

Study on market potential

- Initiation of study on market potential for this specific bus type
- Should provide market sizes for specific segments defined by requirements
- Allows manufacturers to compare efforts with potential turnover
- Segment definition constitutes key specifications for later FC bus designs
- Compromise to be found between wide range of applications and overengineered product

Recommendations regarding partners for pilot project and roll-out

Study on market potential – segmentation of potential market



Recommendations regarding partners for pilot project and roll-out

Initiation of pilot project – required consortium

- Successful consortium should comprise:
  - Mining company and/or fleet bus operator ➔ driving force !!
  - FC bus manufacturer
  - HRS manufacturer / operator, hydrogen supplier
- Hydrogen refuelling station manufacturer, hydrogen refuelling station operator and hydrogen supplier:
  - all in one hand or
  - split up into up to three entities

➔ Will be defined by the early birds

Recommendations regarding partners for pilot project and roll-out

Initiation of pilot project – fuel cell bus manufacturer (1/2)

B4F

- Fast reacting start-up with very high commitment
- Fully dedicated to FC drivetrains and potential access to German funding schemes

Caetano / Toyota

- Toyota is one of the most advanced manufacturers of fuel cell vehicles with FC passenger cars on sale for many years
- Manufacturing and sales of zero emission buses are in the core business of Caetano since DEC 2020

Fanalca

- Very high commitment and regional proximity
- Convinced that current technology is already appropriate to serve high altitudes with some derating that can be compensated with batteries

Recommendations regarding partners for pilot project and roll-out

Initiation of pilot project – fuel cell bus manufacturer (2/2)

Foton

- Extremely interested in Chilean market and preparing to offer products to Chile
- FC coach bus product already available

Hyundai

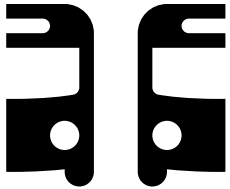
- Highly interested in participating in a pilot project
- FC coach bus (model Univers) to be introduced into the Korean market in 2022 and FC trucks already in commercial operation

Hyzon

- Fully dedicated to FC drivetrains and has large experiences in heavy-duty FC applications
- FC coach bus product already available

Recommendations regarding partners for pilot project and roll-out

Initiation of fleet deployments



- Depending on previous activities e.g. pilot project(s)
- Hand-in-hand roll-out of vehicles and infrastructure is key
  - Infrastructure falls behind ➔ refuelling not safeguarded
  - Vehicle roll-out too slow ➔ underutilized H_2 infrastructure
- Financial viability for fleet operators to be assured ➔ core business
  - on its own or with public support or industrial cross financing
- Watch out for synergies

Recommendations regarding partners for pilot project and roll-out

Immediate pilot project

- Stakeholders keen on initiating pilot project immediately?
- Select FC buses already available on market
- Choose appropriate, less demanding route
- Results in numerous lessons learned and real-world experiences
- Of enormous value for hydrogen supply and infrastructure build-up
- Commercial contacts can be established

Contact

Pablo Tello
Technical Advisor, GIZ
pablo.tello@giz.de

Hubert Landinger
Senior Project Manager
Ludwig-Bölkow-Systemtechnik GmbH
hubert.landinger@lbst.de
T +49 (0) 89 60 81 10 37

Thank you for your attention

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

ILF CONSULTING ENGINEERS

BELICON Fahrzeugforschung

ludwig bölkow systemtechnik