# Hydrogen buses on the Veluwe

Interim report of the deployment of 2 hydrogen buses for passenger transport at Keolis, September 2018 – March 2020

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Date: 7 April 2020
Confidentiality: none
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## Contents

# Summary

Following on from the 1st project involving hydrogen buses undertaken between 2015 - 2017, a start was made on a 2-bus project in September 2018, as part of Keolis' service timetable. With this project, the existing Solbus from the 1st project was deployed, alongside a hydrogen-powered bus from Ursus, built as a forerunner to serial production.

The buses operate in regional public transport, mainly on longer journeys of approx. 90 km including several sections of motorway travel. Refuelling journeys to Arnhem are also completed via the motorway. The average daily speed is approx. 50 km/h. Deployment availability of the Solbus was 96% and the Ursus bus 92%, comparable to the rates achieved by diesel buses. This includes the refuelling journeys, each lasting 2 hours. After one year of problem-free refuelling at the temporary refuelling facility operated by HyGear, the project switched to the public filling station operated by PitPoint.

Consumption by the Solbus is 6.1 kg hydrogen/100 km, irrespective of the season. For the Ursus bus, consumption in the winter months is 2.2 kg/100 km higher due to the use of the electric heater. Consumption is approx. 40% lower (4 kg/100 km) than for the hydrogen buses referred to in the final report of the European project HIGH V.LO-CITY, with information about projects in various European cities.

The leasing of buses including maintenance and fuel is a new concept for the carrier. There is particular demand for removal of concerns about daily hydrogen supply, which at this stage are still present. A realistic estimate for the total cost of ownership (TCO) for a hydrogen bus is € 0.99 per kilometre. This is based on 100,000 km per year, 2.5% interest, a purchase price of € 475,000 and a standardised green hydrogen price of € 5 per kg.

In summary, it can be concluded that the hydrogen buses selected by Keolis can be deployed problem-free in public transport operation. With their large operating radius and short refuelling times, these hydrogen buses represent a one to one replacement for diesel or CNG buses. The flexible deployment capacity of these buses means that no adjustments have to be made to the timetable, and as the need arises, they can be deployed to replace any other bus in public transport operation. The extremely low hydrogen consumption moreover results in such a low TCO that the threshold for switching from conventional buses to hydrogen buses is relatively low.

# 1 Deployment of H2FC buses by Keolis in public transport operation

## 1.1 Project specifications

Case number : 2017-016415
Name : Deployment of 2 H2FC busses in the Keolis timetable system

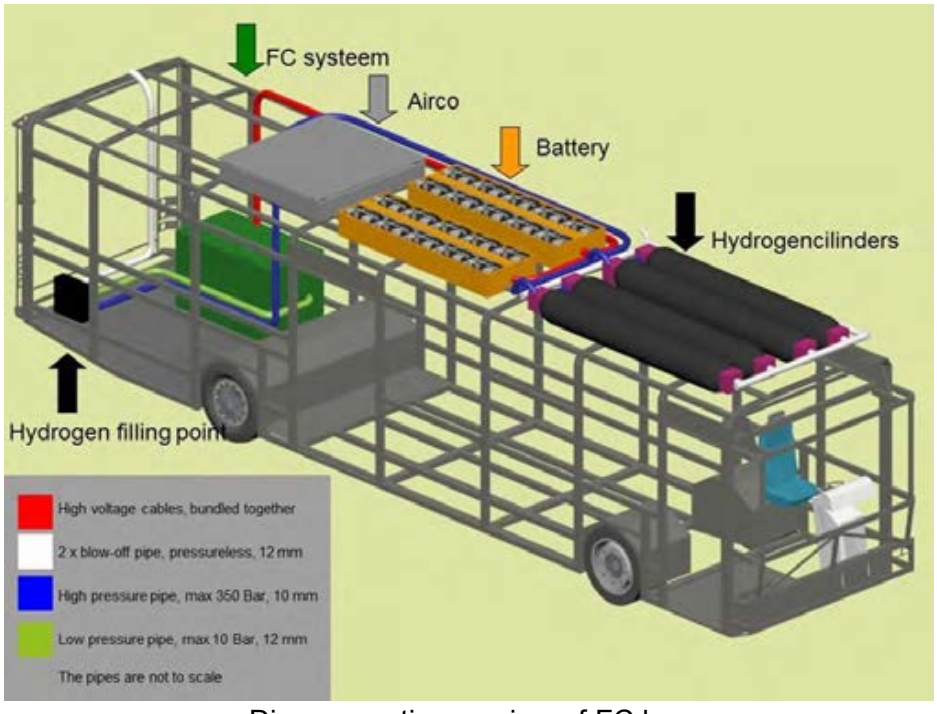
## 1.2 Brief project description

The Province of Gelderland commissioned Keolis to operate two hydrogen buses in the Veluwe concession for the period 1 September 2018 through to 13 December 2020. For the overall project period, an average mileage per bus per year of 55,000 km is assumed. For implementation of this project, Keolis called upon the services of ZETT (rental, hydrogen supply and project support). For all bus engineering issues, Keolis included the buses in its own regular maintenance programme. ZETT in turn called in HyMove for the specific maintenance activities (drive train) and technical and organisational support.

## 1.3 Information about hydrogen buses

One hydrogen bus (fuel cell bus) was built by Solbus. Solbus has ceased operations as a bus builder, and future hydrogen buses will be built by Ursus. Both buses are equipped with Ziehl-Abegg wheel motors, with two 37 kWh battery systems from BMZ, 4 pressurised containers each with a capacity of 7.5 kg of hydrogen at 350 bar, electrical components from e-Traction and the 60 kW H2FC range extender from HyMove. This range extender is equipped with fuel cell stacks from Nedstack. Both buses have the same drive train. The Solbus uses the heat generated internally, for heating. The Ursus bus has a 30 KW heater on the roof for heating purposes. Appendix 1 contains more information about the buses.





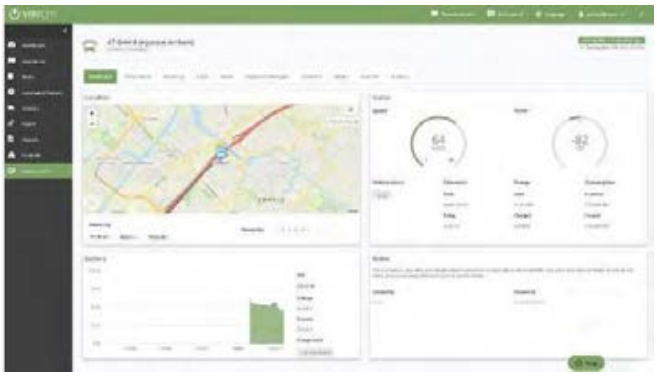

Diagrammatic overview of FC bus

# 2 Driving experiences, deployment, availability, and refuelling

## 2.1 Driving experiences

During the course of the project, Syntus provided around 30 drivers to drive the buses. These drivers received instructions on safety, the technology behind the buses, the requirements for driving with the buses and refuelling in Arnhem at HyGear and later at PitPoint, the protocols in the event of a breakdown and general information about hydrogen and the project.

The Syntus drivers were above all enthusiastic about the way in which they are able to make use of recovery of braking energy, through conscious use of the brakes. The feedback received can be summarised as *You do not have to pay special attention to any aspects of 'new driving', or do anything special, it's more or less automatic and you are used to it within just a few hours.* Because the bus delivers rapid acceleration performance and as a result is easily able to merge with traffic, the driving experience for the drivers is very positive. The record for driving economy was achieved by one driver on a return trip to Amersfoort driven almost completely without using the brakes. On that trip, fuel consumption amounted to approx. 1 kg H2 for 22 km (4.5 kg/100 km). The effect of driving style on fuel consumption is the same as with diesel buses.



Supervision for the drivers was provided with backup from ViriCiti. This enabled real-time observation of various parameters including location, speed, route followed, current energy consumption, recovered energy, status of the battery pack, FC capacity, hydrogen pressure in the tanks and defects.

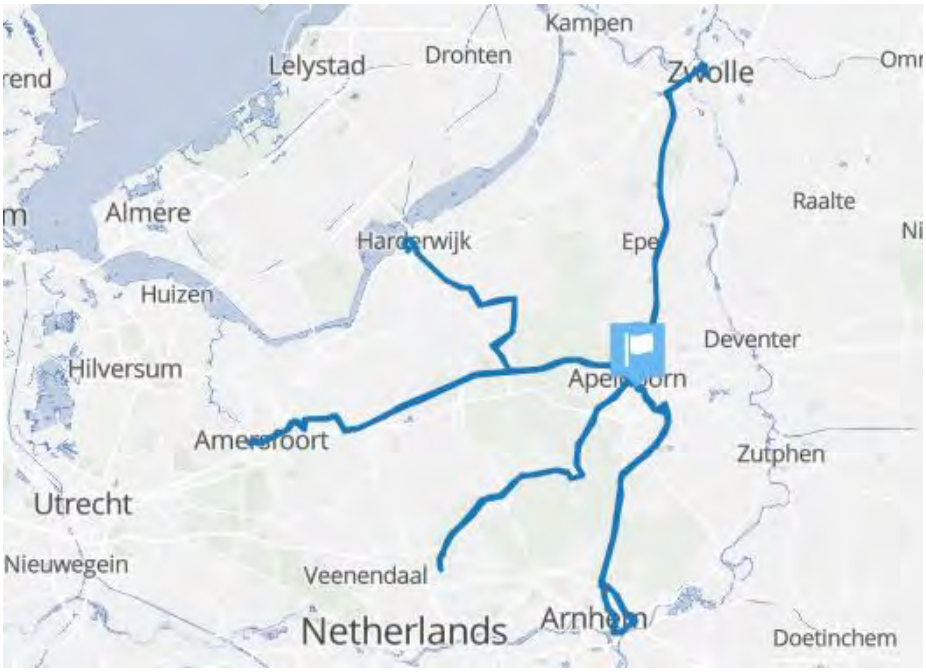
The use of a WhatsApp group for the approx. 30 users of the hydrogen buses ensured regular communication as well as additional short lines of communication with the supervisors at Syntus and HyMove. One a daily basis this generated information about deployment, questions between the various parties about the buses and technical issues that could be adjusted. These contacts were also used to map out satisfaction.

## 2.2 Deployment

In 2017, the bus was deployed for the whole year on city routes in Apeldoorn. The experiences gained during that project were recorded in a public report (case number: 2015-001969; deployment of an H2FC bus on the Arnhem-Apeldoorn service timetable).
In this project, both buses are deployed daily in the regular service timetable of the current concession holder Keolis, on regional lines between Apeldoorn, Zwolle, Amersfoort, Harderwijk, Ede and Barneveld. The buses are deployed on early morning and busy rush hour lines and during the off-peak hours, in almost equal proportions. Starting in mid-September, the buses were deployed for one full day, covering a daily distance of approx. 440 km. Above all the early morning journeys to Zwolle are then always full for both sitting and standing room.

The buses are driven to Arnhem every day, for refuelling. The journey distance to Zwolle is 42 km, Arnhem refuelling journey 35 km, Harderwijk 35 km, Amersfoort 51 km, Veenendaal 43 km. Because the Municipality of Arnhem currently has insufficient understanding of the potential risks of stopping hydrogen buses below the new central station building, these journeys were not included in the service timetable. An investigation is currently underway to map out this potential risk.

Overview of journey pattern in May 2019, from ViriCiti:




Each day, and for each bus, a record is kept of which distances are travelled, for which activity. It is also possible to consider ViriCiti to determine which route is followed by the buses on the day in question. See Appendix 2.

## 2.3 Availability

The underlying principles for determining availability are:

- During this reporting period from 01-09-2018 to 01-03-2020, the bus is only deployed on working days.
- The buses are available for deployment 8 hours a day, with 1 refuelling stop per day. From mid-September 2019 onwards, the buses were available for deployment 16 hours a day, with 2 refuelling stops per day.
- Problems at the filling station that resulted in limited deployment are not included.
- The journey to the filling station takes approximately 40 minutes, and in a regular situation, refuelling takes approximately 30 minutes. 2 hours were set aside for a complete refuelling journey.
- Maintenance, repair work and MOT were carried out at the Syntus depot in Zwolle.

The availability for deployment for both buses was determined on this basis. For the Solbus, availability amounted to 96% (including transport and refuelling 17%) and maintenance 4%. For the Ursus bus, availability was 92% (including transport and refuelling 9%), maintenance 8%. Appendix 3 contains deployment information broken down for each month and Appendix 4 lists additional information about breakdowns and maintenance.

### 2.4 Refuelling

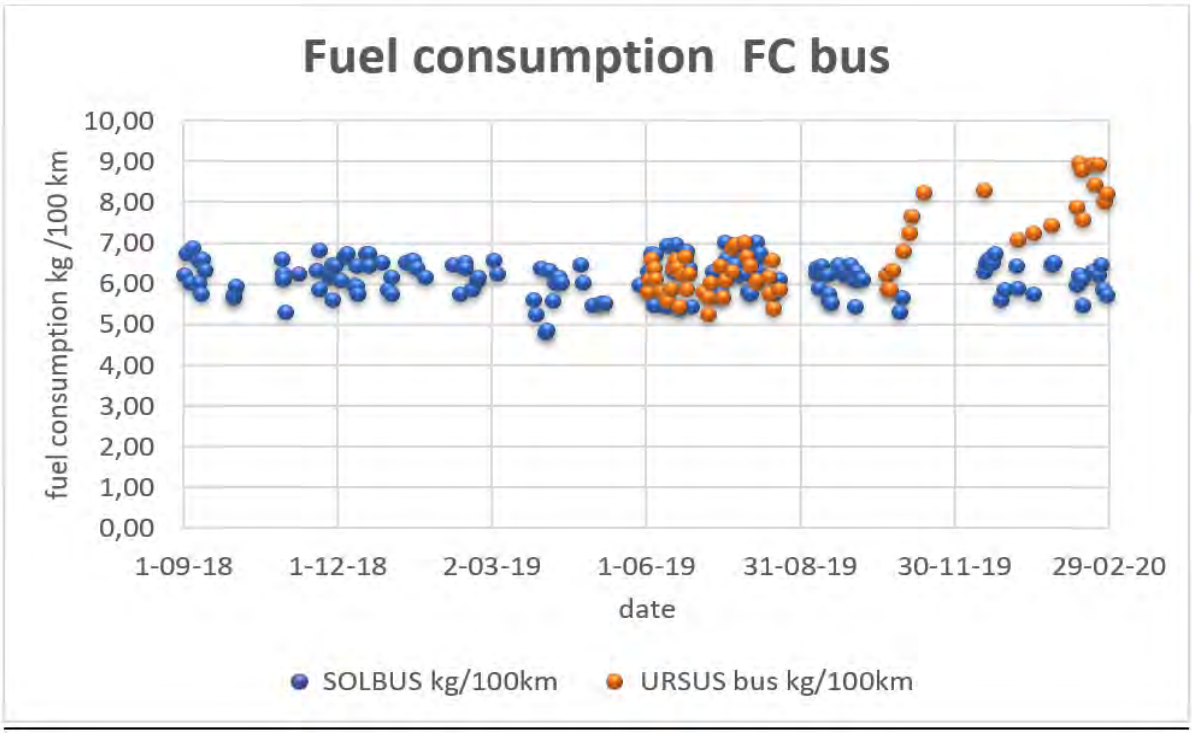
Refuelling in Arnhem was carried out by the Syntus drivers, as part of their journey pattern. Refuelling was a separate journey. Each bus has its own fuel card. During the first months at the new filling station, drivers often needed more than 30 minutes for refuelling. In late October, the disruptions at the filling station became such that for a time, deployment of the buses was restricted.

## 3 Fuel consumption

The measured period covers deployment between 1 September 2018 and 1 March 2020. Starting on 1 June 2019, two buses were deployed in public transport. The buses carried out local journeys with an average speed of approx. 50 km/h. Some sections of approx. 25 km were completed on the A50 motorway, with a maximum speed of 85 km/h. Fuel consumption was calculated based on the information for a longer journey of at least 150 km. The measured pressure difference was used to determine the hydrogen consumption, subject to the condition that the temperature of the hydrogen remained unchanged. The distance travelled over a long period was used, in conjunction with data from the filling station, as a means of backup check.

For the Solbus, there were 146 measurement points. The average measurement distance was 190 km. Approx. 80% of the measured values fall within a range of 0.4 kg/100 km. The primary reason for the range is the difference in driving style between drivers. The average consumption for summer and winter amounted to 6.1 kg/100 km.
For the Ursus bus, there were 58 measurement points. The average measurement distance was 172 km. Approx. 80% of the measured values in the summer months demonstrated a range of 0.4 kg/100 km with respect to 6.1 kg/100 km. In the winter months, the average value was 8.5 kg/100 km. For both buses, consumption is reproduced in the following graph:





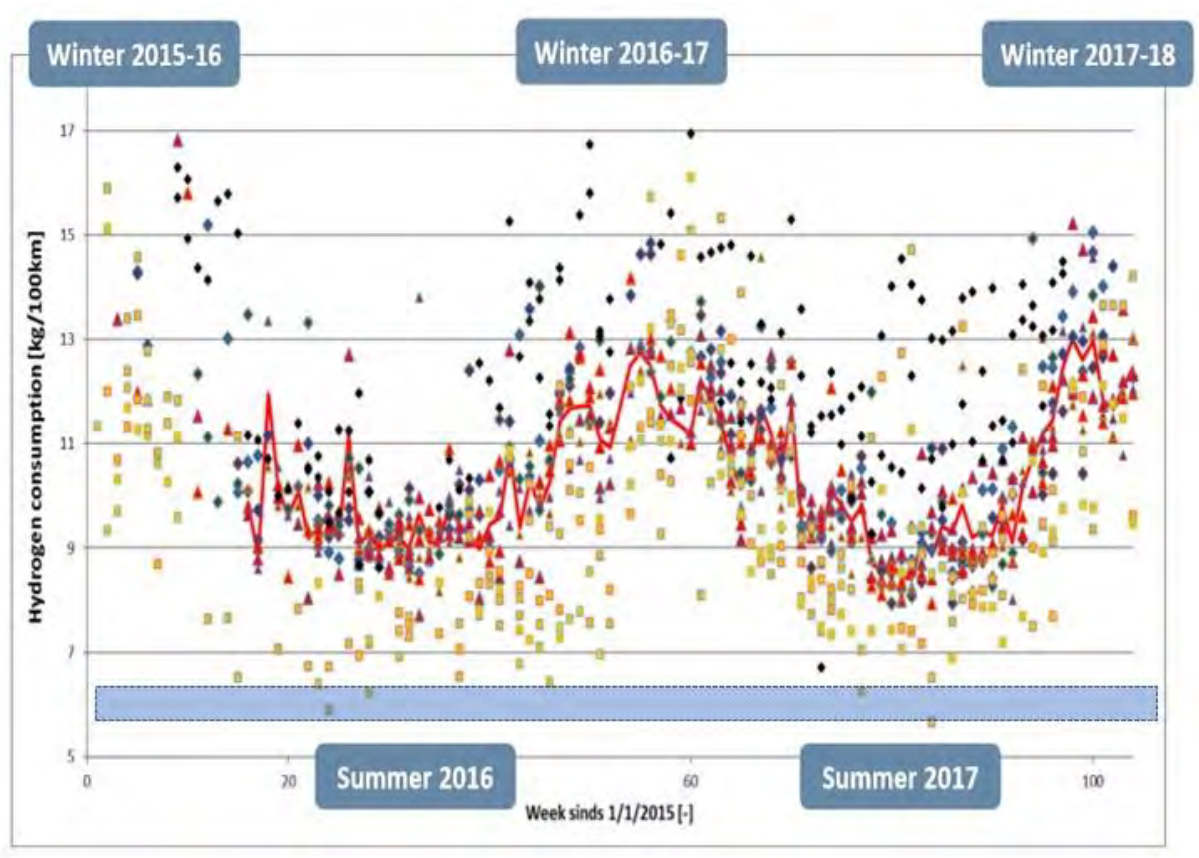
Consumption was also calculated based on refuelling values provided by PitPoint. For the period 20 September 2019 through to 22 February 2020, a total of 926 kg of hydrogen was taken on board which, including the 2 refuelling stops in Belgium, amounts to a total of 957 kg, and a distance travelled of 15,702 km. For the Solbus, for this period, this results in an average fuel consumption of 6.09 kg/100 km. This value ties in with the calculated values based on the pressure difference.

For the Ursus bus, the refuelling data from PitPoint in October for the period 30-10-2019 to 14-11-2019 reveal that 118 kg of hydrogen were taken on board, for a total distance of 1686 km. The consumption calculated on that basis in that period amounted to 6.99 kg H2/100 km. In 2020, for the period 27-01 to 21-02, a distance of 2909 km was travelled, and a total of 241 kg H2 were taken on board. In February 2020, consumption amounted to 8.29 kg H2/100 km.

The difference between energy management and the effect on fuel consumption of both buses is abundantly clear. During the winter period, the heat generated by the fuel cells in the Solbus is used for heating, making consumption independent of seasonal variations. For the Ursus bus, in the winter month February 2020, consumption was 2.2 kg/100 km higher, due to the use of the electric heater.

A comparison of the measurement results against the extensive High-Velocity project in Europe for the deployment of FC buses in various cities reveals that the consumption of the buses in the project in Gelderland is less seasonally dependent and in quantitative terms, is approx. 4 kg/100 km lower. The figure below shows the bandwidth of the own consumption measurements by the Solbus, with a pale blue background:

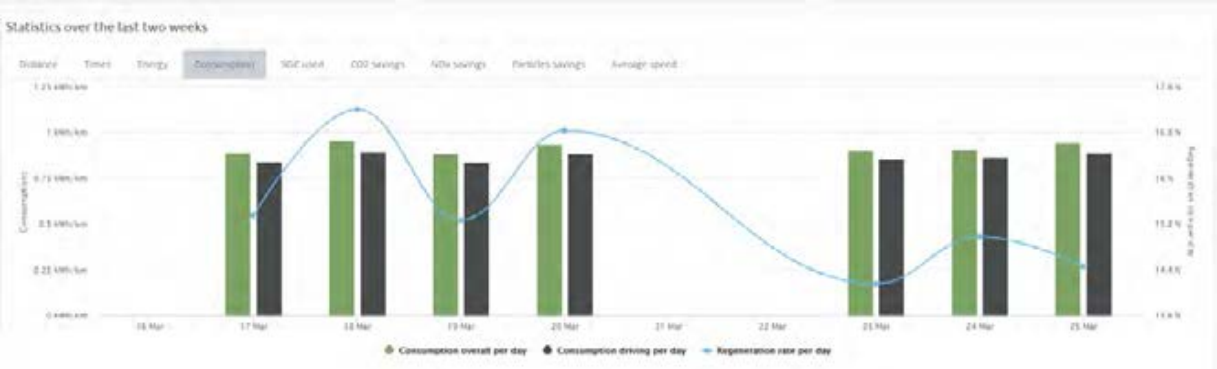





Source: presentation van Hool, results during Final conference High VLO city, 27-11-2019 Groningen

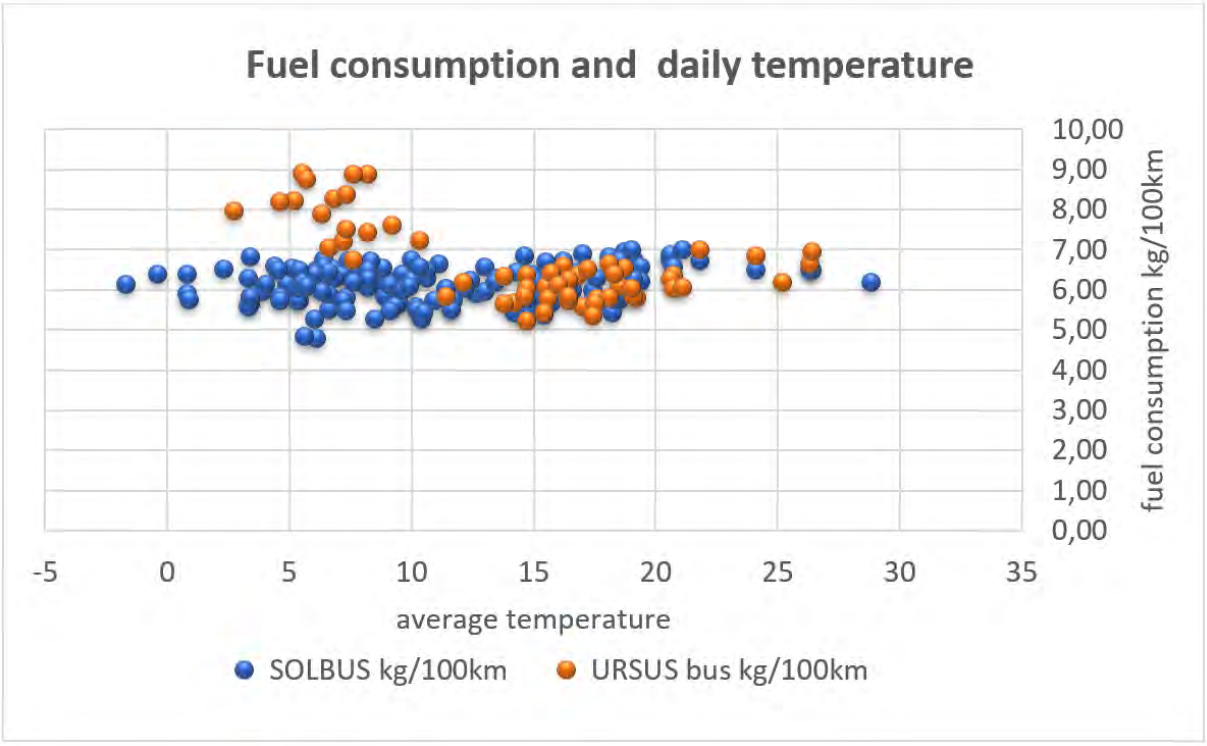
The recovery of braking energy for regional or city transport demonstrates almost no difference. In the months September 2019, January 2020 and February 2020, for regional journeys with an average speed of approx. 50 km/h, braking energy recovery amounted to 18%, 17% and 16% respectively, as compared with the generated energy. In the months June, July and August 2017, the Solbus was deployed in Munster for city services, with an average speed of 23 km/h and demonstrated a recovery percentage of 19%, 14% and 17% respectively.

This is displayed in the daily review in ViriCiti, as follows:




Fuel consumption for both buses is also presented in a graph against the average temperature on the days in question, as recorded at the De Bilt weather station. These figures reveal clearly that the Ursus bus consumes more fuel in lower outdoor temperatures, while the Solbus maintains the same consumption levels.





# 4 PR and media


New look with clearly legible text

Daily work

A group of Ministers in the bus, Zwolle 15-05-19

Journey to Belgium

Students want to see everything

A full bus; the best PR

# 5 Project progress

## 5.1 Project starts with status of buses

The hydrogen bus built by Solbus was already deployed by Keolis between mid-2016 and the end of 2017 in public transport, as part of a project for the Province of Gelderland. In 2018, the bus was loaned to the city of Munster (Germany) for a longer period, and from 1 September 2018 onwards was deployed for public transport. The Solbus is the property of HyMove.
The other hydrogen bus was built by Ursus in 2017 for a potential bus project in Gelderland. The financing for this bus was borrowed from a Polish bank. Because the project did not eventually take place, the bus was mothballed by the builder and not used for any journeys. At the end of 2018, the bus was put into operation by HyMove for limited deployment during the UN Climate Conference in Katowice in Poland. The bus arrived in the Netherlands at the start of 2019 but was received in damaged and badly functioning condition.




Repair work lasted until April 2019, at which point test journeys were made. The bus was put into normal timetable service starting in June 2019. The Ursus bus shares the same driveline as the Solbus, but uses a 30 kW electrical heater, unlike the Solbus, which uses the heat from the fuel cell systems. This choice was made at the moment of construction. Afterwards it emerged that the link to the heat exchanger from the fuel cells was not included.

Because the company Ursus experienced financial difficulties during the negotiation period, the bus formally became the property of the bank. ZETT subsequently entered into a lease contract with the bank.

## 5.2 The refuelling facility

At the start of the project, an agreement was reached with HyGear according to which refuelling at HyGear would be possible until the end of the project. This was possible because PitPoint – a client of HyGear – had no plans to equip the filling station with a 350 bar facility. This did in fact take place eventually, which resulted in major problems in refuelling the buses during the period from June 2019 to February 2020.

Between September 2018 and July 2019, the refuelling facility at HyGear functioned well. Reliability was almost 100% although capacity was restricted to 300 bar. From 1 June, two buses were able to refuel once a day.




The new PitPoint filling station was opened on the Westervoortsedijk on 1 July 2019, and the temporary location operated by HyGear was closed on that same date. During the months of July and August, the buses were above all deployed for testing all refuelling systems and procedures. In September, a start was made on refuelling two buses, twice a day. However, the system proved less reliable, and new breakdowns occurred in mid-October, resulting in a loss of delivery reliability. Following a breakdown, the main compressor was repaired and a backup compressor installed. The refuelling facility continued to experience serious problems until mid-December and the main compressor broke down completely. In January, the backup compressor also turned out to be faulty. Following urgent repair, limited capacity was once again made available from mid-February onwards, for 4 refuelling stops a day.

## 5.3 Lease and TCO calculation

The way in which this project was undertaken deviated so much from a regular lease construction that it is only possible to draw limited conclusions from the project as concerns the lease concept. The problems surrounding the Ursus bus and the service station resulted in considerable essential preparation costs, coordination costs and additional maintenance costs. On the other hand, a clear picture was obtained of the (regular) maintenance costs and the hydrogen consumption of the two buses. At an expected purchase price of € 475,000, an interest rate of 2.5% and a standardised hydrogen price of € 5 per kg, a TCO for a hydrogen bus of approx. € 0.99 per kilometre is realistic.

# 6 Conclusions for the period 1 September 2018 – 1 March 2020

1. It took more than six months before agreements with Ursus bus could be put into practice. Subsequently, spending eighteen months stationary in sun, rain and snow had made the bus considerably less reliable. Only after 4 months of intensive repair work could the bus be deployed for public transport operation.
2. As with the 2016-2017 project, access to a reliable refuelling facility is of fundamental importance. The fact that the HyGear refuelling installation was staffed ensured optimum deployment throughout this period. The opening of the new filling station led to many teething difficulties, which sometimes required long repair times. The fact that the filling station was simultaneously used by passenger cars during the period of limited compression capacity also resulted in extra refuelling times for the buses.
3. Each refuelling run required 2 hours operating time and a 70-km round trip. This time was included as part of the daily programme for the 'hydrogen bus drivers'. To allow large-scale deployment of hydrogen buses in public transport, the availability of refuelling facilities within 5 kilometres of a bus depot is required.
4. The buses are suitable for regional transport. The longer distances and higher average speed represent no problem. This confirms that fuel cell buses can be deployed in the same way as and demonstrate comparable behaviour to diesel buses.
5. Fuel consumption by the Solbus broke all records. Just 6.1 kg of hydrogen are needed for every 100 kilometres. In addition to the technology, consumption also depends on the individual driving style. On the Ursus bus, the use of an electric heater in the winter resulted in 30% higher fuel consumption.
6. As well as a number of technical bus breakdowns, the Solbus suffered one breakdown involving the fuel cell system. It should be pointed out that the bus had driven only around 100,000 km. There were numerous teething problems with the Ursus bus because of the 18-month downtime.
7. The project was disrupted seriously by two issues: the late delivery of the Ursus bus and the subsequent period of repairs, and the fact that no correctly functioning filling station was available for a long period. As a result, the buses were unable to travel the intended number of kilometres. At this interim assessment moment, it is therefore not possible to make a good estimate of the TCO on the basis of the project data. We do expect to achieve a better insight by the end of the project period on condition deployment goes according to plan. During the period when the filling station was functioning correctly, the buses demonstrated their ability to easily cover 400 km a day (i.e. 100,000 km per year). With the expected purchase price of € 475,000, an interest rate of 2.5% and standardised (green) hydrogen price of € 5 per kg, the TCO of a hydrogen bus amounts to € 0.99 per kilometre.
8. Project costs up to 1 February 2020 amount to approx. € 560,000. This is lower than originally budgeted because fewer kilometres have been travelled than planned (<55,000 km/year/bus). As a result, hydrogen costs and costs for refuelling runs were lower than budgeted. On the other hand, the minimum 40,000 km per bus per year was achieved. Based on sufficient availability of hydrogen and the possibilities (given the corona situation) to complete a sufficient number of journeys, we expect the buses to complete around 55,000 km per year in the project .The problems surrounding Ursus bus and the filling station meant that preparation and project coordination costs were higher than budgeted.

# 7 Appendix 1

Technical specifications:

| **Solbus SM12H2F** | |
|---|---|
| | |
| **Basic Data** | |
| | |
| **Passenger capacity** | 63+1 (driver) |
| Seated | 35+1 |
| Standees | 28 |
| **Dimensions** | |
| Length | 12,100 mm |
| Width | 2,550 mm |
| Height | 3,100 mm |
| Unloaded weight / GVW | 12,550 / 18,000 kg |
| Wheelbase | 4,450 mm |
| Front / rear overhang | 2,700 / 3,450 mm |
| Angle of approach / departure | 7 / 7 degrees |
| | |
| **Chassis** | |
| | |
| **Engines** | 2 electrical in-wheel engines, integrated in the drive axle. Permanent magnet synchronous motors. |
| Power | 226 kW continuous<br>364 kW peak |
| **Front axle** | ZF RL82 EC (independent) |
| **Rear axle** | Ziehl-Abegg integrated axle, ZF suspension arms, shock absorbers and air bellows |
|  | |
| **Suspension front** | 2 air bellows and 2 shock absorbers + stabilizing rod |
| **Suspension rear** | 4 air bellows and 4 shock absorbers |
| **Suspension control** | ECAS with kneeling function (about 80 mm) based on 3 sensors |
| **Central greasing** | BEKA-MAX (front axle only) |
| **Wheels** | 275/70 R22.5 – Michelin XZU 2<br>455/45 R22.5 – Michelin X one XDU TL |
| **Steering system** | RBL C700 |
| **Brakes** | Knorr disc brakes front and rear, dual circuit EBS (Wabco). EBS = ASR + ABS |

| | |
|---|---|
| **Electronics** | 24 volts CanBus system, J1939 compliant, 275 Ah |
| **Super structure**  | Self-supporting superstructure flat floor with no steps at all the entrance doors, made of stainless steel (1.4003) |
| **Power supply** | |
| **Batteries** | BMZ 37.8 kWh, 2 pack on the roof |
| **Fuel cell system** | HyMove 60 kW Fuel cell system |
| Nominal Power | 60 kW |
| Voltage | 630 VDC |
| Operating temperature | 65 °C |
| Ambient temperature[1] | -20 °C to +40 °C |
| **Hydrogen Storage** | 30 kg |
| Number of H2 tanks | 4 on the roof |
| H2 storage pressure | 350 bar |
| Filling time | 15 min |
| **Total weight of power supply** | 1,800 kg |
| **Total range** | 450 km |



[1] during operation the module keeps itself warm. When the system is not operative, the temperature of the system must be kept above 0 °C.

**Technical specifications Ursus bus**

# URSUS CITY SMILE FUEL CELL ELECTRIC BUS


## Technical specification

**BASIC DATA :**
- Total passenger capacity: 75+1
- Seats: 28+1
- Standing: 47

**DIMENSIONS:**
- Length 12 000 mm
- Width 2 550 mm
- Height 3 500 mm
- Kerb weight 13 000 kg
- Wheelbase 5 950 mm
- Front overhang 2 800 mm / rear overhang 3 250 mm
- Approach / departure angle 7°/7°
- Door arrangement 1-2-2

**CHASSIS:**
- Two Ziehl-Abegg in-wheel engines in rear axle
- nominal voltage 150-700VDC, rated power 2x110 kW
- Fuel cells: two HyMove 30 kW power modules
- Hydrogen storage capacity: 30 kg
- Front axle ZF RL-82EC
- Rear axle: Ziehl-Abegg
- Front suspension: 2 bellows and 2 shock absorbers
- Rear suspension: 4 bellows and 4 shock absorbers
- Wabco ECAS II suspension control with 90 mm kneeling function
- Wheels front 275/70 R22,5 city type tyres
  rear 455/45 R22,5 single tyres
- Steering system ZF 8098, mechanical with integrated hydraulic assistance
- Pneumatic disc brakes with automatic slack adjustment. Equipped with EBS with ABS+ASR. Retarder serving as generator for energy recovery.
- Electronics: 24V, single cable installation, two 220 Ah batteries

**BODY:**
- Integral body, made of 1.4003 stainless steel
- Fully low floor, each entrance at 320 mm height
- Manually-operated ramp for the handicapped in second doors (electric ramp optional)

**EXTERIOR COVERING:**
- Dibond panels, single-glazed windows glued to side walls

**INTERIOR COVERING:**
- Side walls: laminate
- Ceiling: laminate

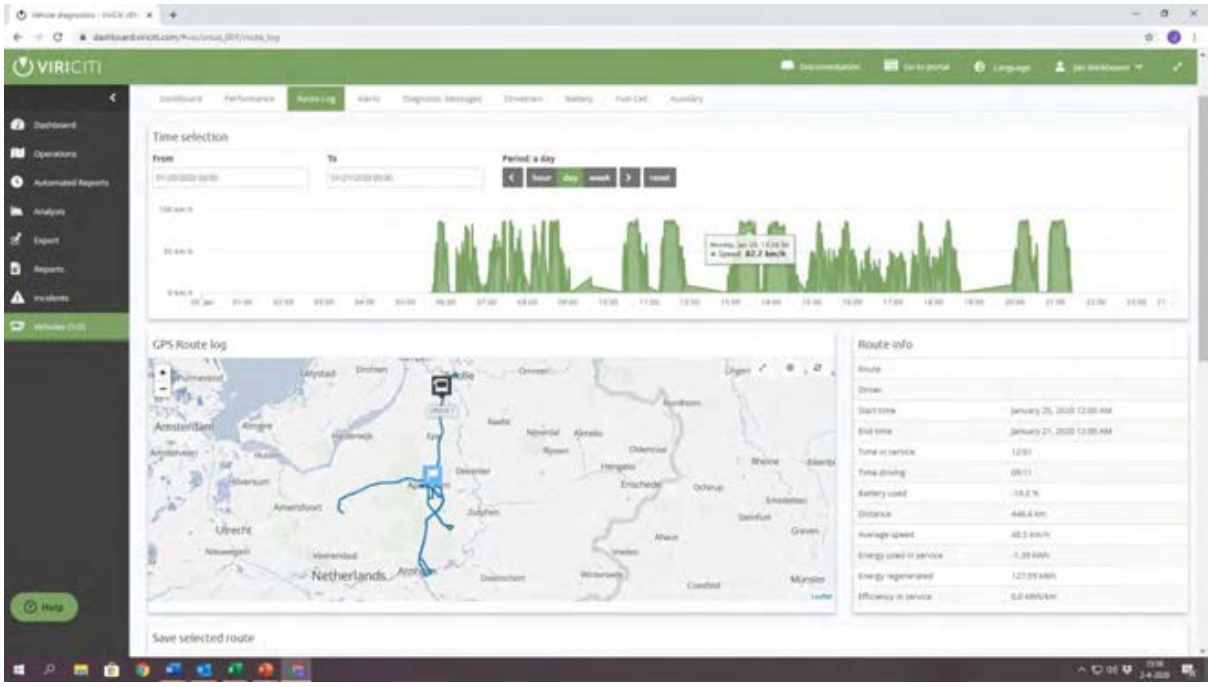
**ADDITIONAL INFORMATION:**
- Waterproof, 15 mm plywood floor. Anti-slip carpeting with high-contrast colour in the door area. Ventura doors: first door inward-swinging, second and third doors plug sliding with "reverse" feature; Ventura door steering.
- Passenger information system: Mobitec
- Central lubrication system, PICO
- Passenger compartment monitoring: Eko-moto
- Automatic fire detection system in the engine compartment
- CD Radio with MP3, USB

2

HYDROGEN VEHICLE

# 8 Appendix 2

Journey information per day as retrieved from ViriCiti:






This is an overview of a journey by the Ursus bus on 20 January.

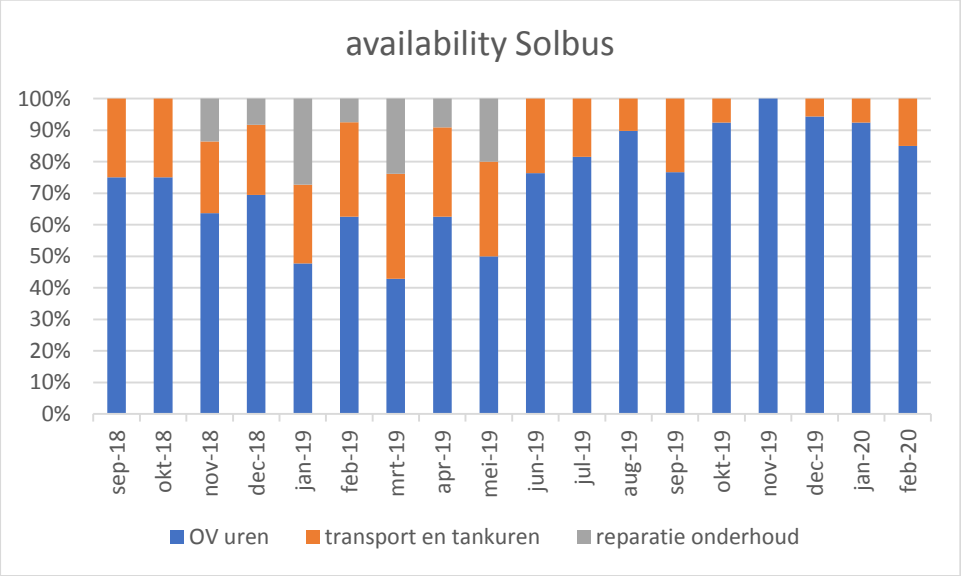
Start 05.35; end 21.30. Total 446.4 km of which 140 for refuelling.

The journeys in question:
Public transport to Amersfoort, refuelling in Arnhem, public transport to Zwolle, 2 public transport journeys to Eerbeek, refuelling in Arnhem.

No information was recorded per journey concerning the number of passengers. During the peak-time journeys, the buses are full.

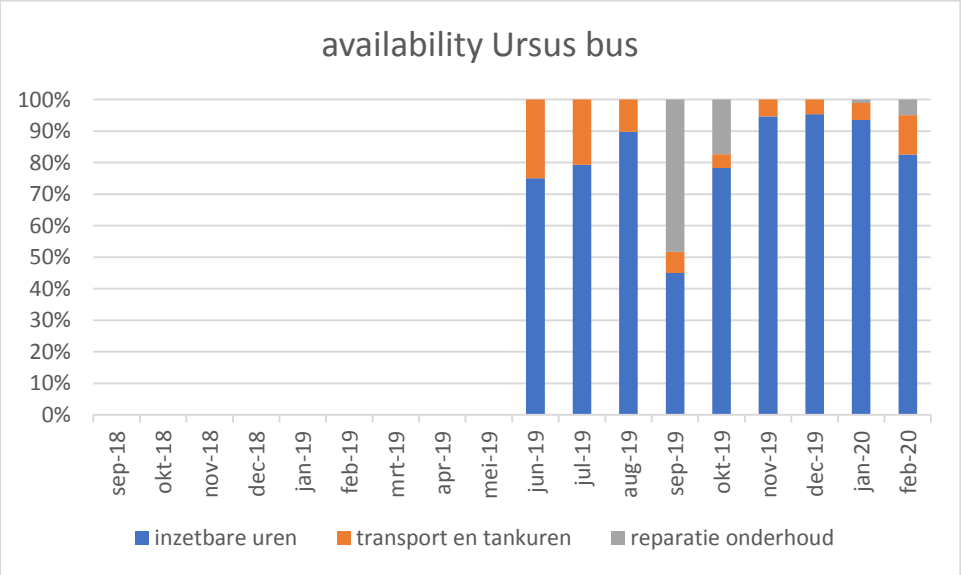
# 9 Appendix 3

## Availability in percentage per month




O public transport hours O transport and refuelling hours O repair and maintenance






O deployable hours O transport and refuelling hours O repair and maintenance

# 10 Appendix 4

## Overview of maintenance and breakdowns

Work in the workshop was carried out at locations provided with hydrogen sensors, as specified in the first project. For work involving removal of the fuel cell systems from the bus, the bus was placed on jacks, by Syntus staff.

**Maintenance**

With regard to maintenance, consultation was undertaken with the workshop about the points submitted by drivers and from the manual.
The example below is a list of maintenance points for the Solbus for 29 May 2019. Regular maintenance on the bus is the same as for diesel buses, without driveline issues.

| | wat | status | info | who |
|---|---|---|---|---|
| 1 | Check 2 air filters compressor Hydrovane | MUST | Reg. | Syntus |
| 2 | Maintenance inspection Hydrovane pump | MUST | Reg. | Syntus |
| 3 | Replace Wabco air drier with filter | MUST | Reg. | Syntus |
| 4 | Check steering oil and top up if necessary | MUST | Reg. | Syntus |
| 5 | Check door closure and rubbers, adjust front door | | Reg. | Syntus |
| 6 | Lubrication bearing adjustment on time, action point to Besselsys | | | HyMove |
| 7 | Fix holder for driver's lamp | | | Syntus |
| 8 | Tidy and replace discharge hose FC exhaust | | | HyMove |
| 9 | Folding chair at disabled seat area | | | Syntus |
| 10 | Foil on corner left front window | | | Syntus |
| 11 | Install 4th air bellow | | | Syntus |
| 12 | Calibrate speedometer, tachograph | | | HyMove |
| 13 | Change rear tyre due to wear pattern | | | external |
| 14 | Install new rims for rear wheels | | | external |
| 15 | Install new shock absorbers rear wheels | | | Syntus |
| 16 | Install mass strip between rear axle and chassis | | | Syntus |

The designation 'Reg.' indicates that this is part of regular annual maintenance as described in the maintenance manual.
Designation 'MUST' indicate that this action must be carried out during the maintenance inspection.

For the Ursus bus, there was no MOT or regular maintenance during the reporting period. These are planned for April/May 2020.

## Breakdowns

Breakdowns on the Solbus:

1. Windscreen wiper motor problem; replaced at Zwolle workshop, no standard article.
2. Problems with public transport ticket machine in the bus; repaired at the depot.
3. Battery problem with BMS; repair by engineers from BMZ in Poland.
4. FC support systems replaced, new support brackets made and installed in Zwolle.
5. Problem with accelerator pedal resulting in replacement of complete cabling. This was a very difficult problem to localise; on occasion it caused total failure of the bus while there was no sensor that indicated the type of problem.
6. FC problem with CVM; FC fully removed from the bus at the Zwolle workshop for replacing the CVM on one stack.
7. Friction and blocking of a brake disc. These are mounted on a special axle on the wheel. This was solved by the supplier by replacing a wheel at the Zwolle workshop.

Breakdowns on the Ursus bus:

1. EMC problems because the control unit for the high-power electronics was mounted just above the FC systems. These problems caused the FC system to shut down. This problem was difficult to localise and had to be tackled by a range of different repair options. Eventually, several problems were corrected by auto-reset and a number of software changes.
2. Due to the absence of a cooling system for the battery, the battery packs overheated during journeys of longer than 4 hours, causing power delivery to fall to 50%. An airco unit was subsequently installed on both battery packs in September. This solved the problem.
3. At the end of February, one of the doors stopped working. A software adjustment by the supplier solved the problem.