1. Introduction

UAB Kauno Autobusai (KA) is a public transportation company owned by the municipality of Kaunas (Lithuania). The main activity of KA is to provide passenger transportation with bus (incl. minibus) and trolleybus vehicles, on the basis of gross cost contract with the Kaunas city.

KA was established in 1934. It is a limited liability company owned by Kaunas city municipality administration. The company has over 1200 employees. KA is also an associated partner of action H2NODES. Within this annex the Fuel cell electric bus deployment for KA will be assessed.

2. UAB Kauno Autobusai existing transport fleet

Presently, KA is servicing 67 public transport routes in Kaunas. , which make up the major part of the whole volume of Tallinn's public transportation service. The average number of passengers carried in one day reaches 220 thousands. The daily mileage of each vehicle is variable and can range from 150-400km per day depending on the route, schedule and other aspects, thus the average the average daily mileage of the whole fleet is 68 000 km.

The KA fleet consists of:

293 buses	units
Temsa	25
MB Sprinter	45
Castrosua CNG	14
Solaris CNG	24
MAN Lions City 12	54
MAN	11
Scania	9
Solaris	55

Vanhool	30
DEN	4
Volvo	16
MB Sprinter Hybrid	6

141 trolleybuses

Solaris Trollino 12	127
Berkhof Premier A	14

3. UAB Kauno Autobusai bus fleet

KA is using 293 buses for public transport operations. According to the provided information the KA vision on bus fleet renewal includes deployment of different fuel powered bus units that will substitute the existing diesel bus fleet.

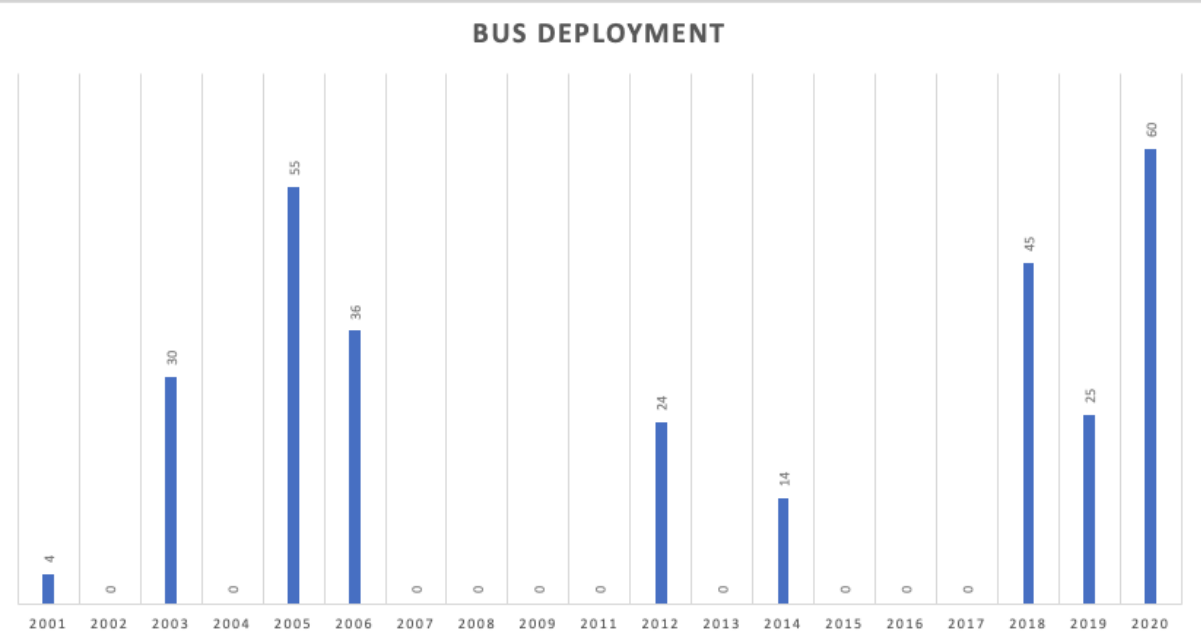


Figure 1 KA bus deployment per year.

According to the available data, the average KA bus unit is 8 years old and the renewal of the oldest vehicles in the fleet has to be made. Currently KA is focusing on deployment of CNG and hybrid buses.

100 unit new MAN Lion's city 12 hybrid bus fleet deployment will be fully commissioned by April 2021. During the 2022-2023 the KA plans to replace the 78 oldest bus units. The opportunity to deploy 78 FCE-buses will be assessed within this annex.

As mentioned prior, KA also operates a trolleybus fleet.

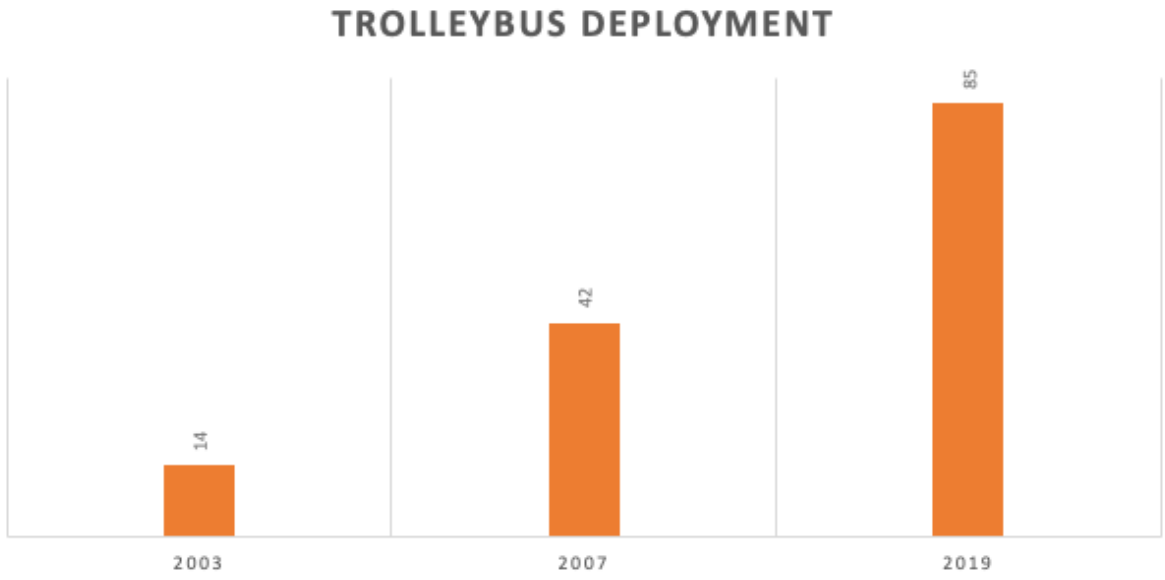


Figure 2 KA trolleybus deployment per year.

According to KA provided information there are currently no plans to substitute the existing Trolleybus units. Thus within this annex the opportunity to deploy the hydrogen refueling and production station (HRS) with suitable capacity to operate 56 HyTrolleybuses that are equipped with fuel cell genset will be included. This opportunity would allow for the KA to assess the routes of Trolleybus units, and if necessary use the HyTrolleybuses in areas where the cattery wire system is not available. This allows for the KA to use the HyTrolleybuses for at least 100km without the cattery wire system.

4. UAB Kauno Autobusai potential FCE-Bus fleet:

KA has a potential to deploy 78 Fuel cell electric buses and 56 HyTrolleybuses. These units would replace the oldest diesel buses and trolleybuses. Within this chapter the potential hydrogen demand of the fuel cell buses will be assessed.

According to provided data, KA average annual mileage of one bus is around 57 000 km. By assuming that the yearly availability of bus is around 90%, the potential daily range of diesel bus is from 174 km.

Hydrogen consumption per bus[1]
Average range per unit 174km
13,9kg/H_2

Figure 3 KA potential hydrogen consumption per FCE-bus per day

As the aim for KA is to replace the oldest 78 buses from 2022-2023 the potential FCE-bus delivery is divided for the two years. Corresponding to the FCE-bus fleet deployment the potential hydrogen demand can be assessed.

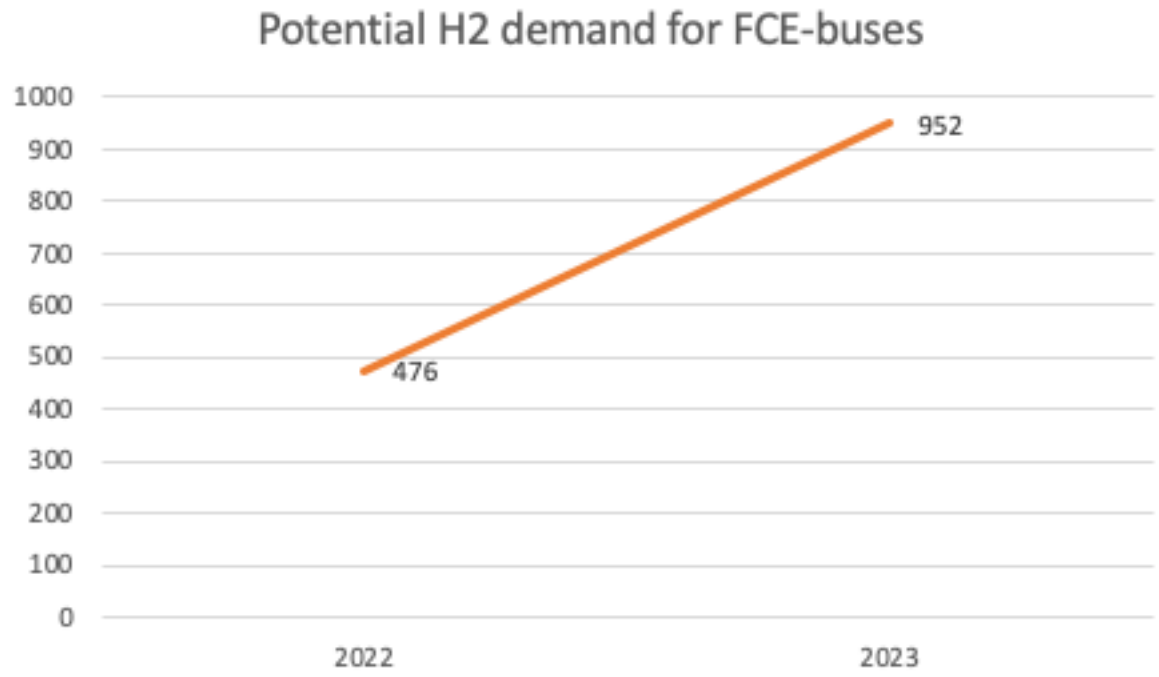


Figure 4 KA hydrogen demand per day if 39 FCE-bus units are deployed per year.

The Figure 5 indicates the KA hydrogen demand assuming that 39 FCE-bus units are deployed per year starting from 2022. According to calculations the potential hydrogen demand is from 476kg of hydrogen per day in 2022 up to 952 kg of hydrogen per day in 2023. In order to specify exact amounts of hydrogen for potential FCE-bus fleet additional data, that includes specific characteristics of bus routes and bus availabilities should be used.

As KA previously stated, the opportunity for KA to deploy HyTrolleybuses is also assessed. As there is no characteristics about trolleybus routes it will be assumed that the HyTrolleybuses would be driving on hydrogen up to100km per day. Therefore the necessary hydrogen amount per HyTrolleybus unit would reach 10kg/H_2 per day.

[1] Based on assumtion that average FCE-bus H2 consumption per 100km is 8kg.

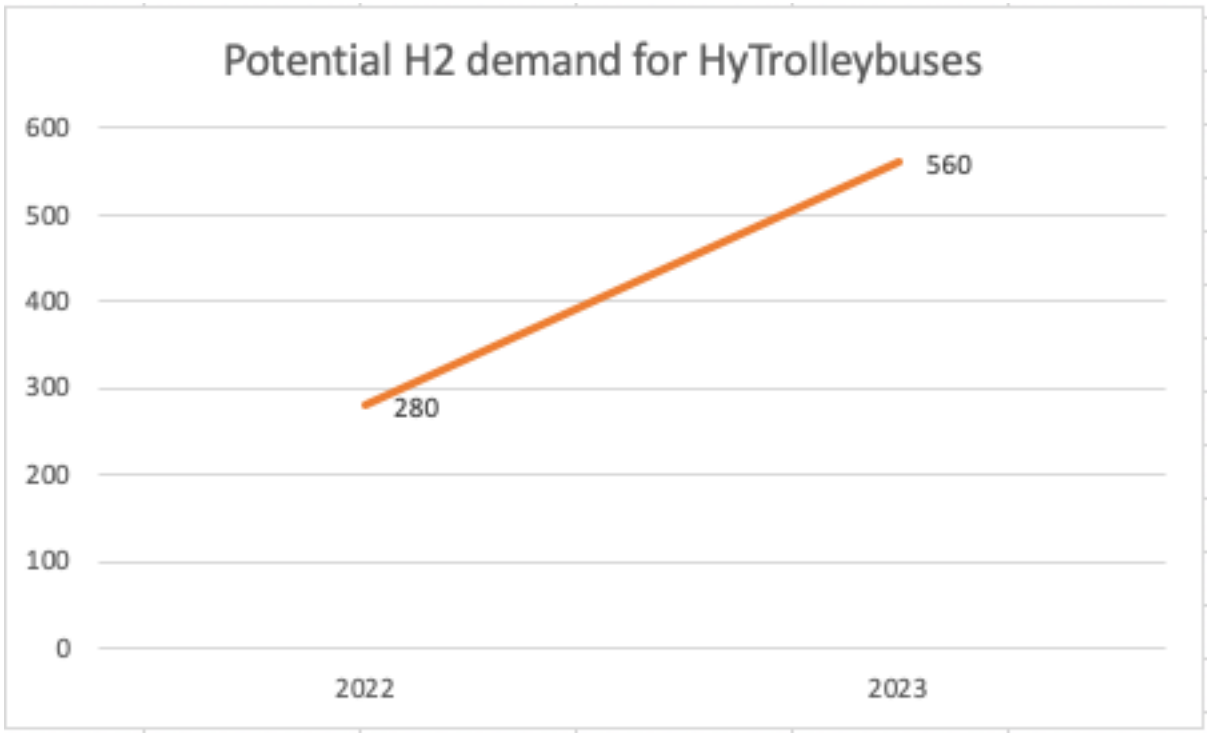


Figure 5 H_2 demand for HyTrolleybuses assuming that 28 units are deployed per year

Considering all the previously mentioned the strategy of KA hydrogen refueling and production facility deployment for further evaluations would be based on the potential hydrogen production capacity of 1000 – 1500 kg/H_2 per day in order to secure the potential FCEV refueling.

5. Hydrogen refuelling station for UAB Kauno Autobusai.

As the potential for the large-scale FCE-bus and HyTrolleybus deployment for KA can be seen, a large scale HRS deployment should be assessed. In order to achieve the hydrogen availability and considering the Figure 4 and Figure 5, the total hydrogen production for KA HRS should reach 1000-1500kg/H_2 per day. The refueling capacity must be ensured in the same amount.
It is projected that the HRS with 1000kg/H_2 production and refueling capacity would be used to refuel 78 FCE-buses that are used for public transport operations. Considering that there is a potential to deploy also 56 HyTrolleybuses, the rump-up of HRS to achieve hydrogen production and refueling capacity of 1500kg/H_2 is included. In other words, the schematics are developed in order to allow the operator to add additional equipment to achieve the 1500kg/H_2

capacity. Additionally it is taken into account that the buses/HyTrolleybuses must be refueled in 6 hours, therefore the equipment is modulated to ensure this aspect. The 6 hour refueling window is assumed based on Riga PTO Rigas Satiksme practice, that the vehicle units are refueled during night time.

The concept of the KA HRS is included in Whereas the potential hydrogen production would be performed via water-electrolysis process that is secured with two electrolizer units.

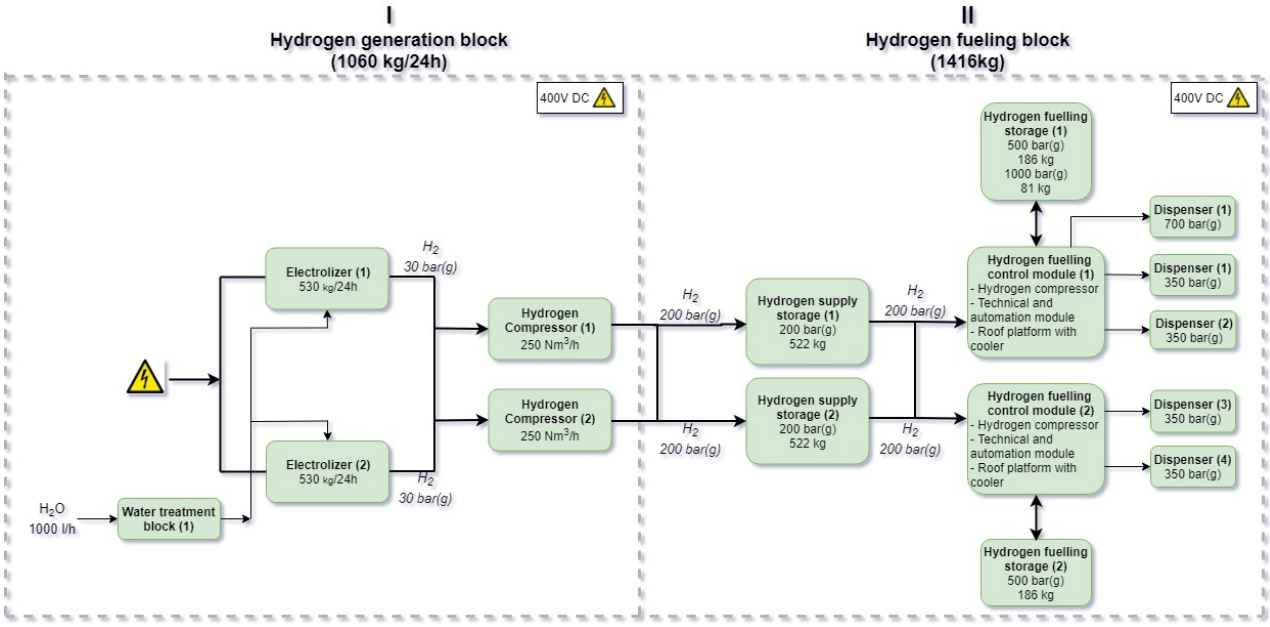


Figure 6 Concept of KA 1000kg/H_2 station

The total amount of hydrogen stored on the specific station would reach up to 1050kg of hydrogen and 4 dispensers would be required to secure the refueling. As the potential for the HyTrolleybus deployment would increase the necessary hydrogen amount. The Figure 7 Includes the potential rump-up to secure the 1500kg/H_2 production and refueling per day.

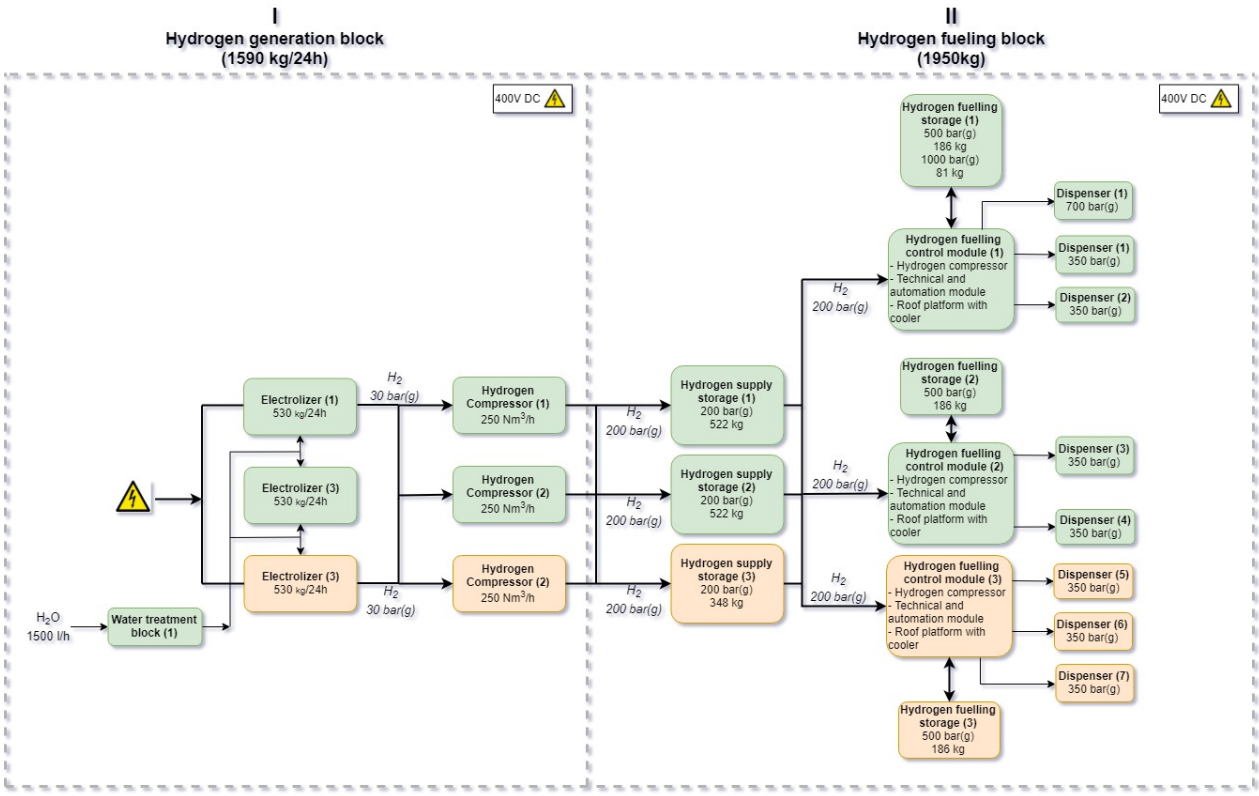


Figure 7 Concept of KA 1500kg/H_2 station

It would be required to deploy additional electrolyzer, hydrogen supply storage and hydrogen fueling control module/hydrogen fueling storage. As the number of units would increase by 56 units, it would be necessary to deploy additional 3 dispensers to secure the 6-hour refueling window. The technical specification is summarized for both stations in Table 1.

System description	Technical parameters	Quantity for 1000kg/H_2 station	Quantity for 1500kg/H_2 station
Electrolizer	Qmax = 430 kg/24h	2	3
Hydrogen compressor unit	Qmax = 250 Nm^3/h	2	3
Hydrogen supply storage	P = 200 bar V = 522 kg	2	3

Hydrogen fuelling storage	P = 500 bar V = 186 kg	1	3
Hydrogen fuelling storage	P = 1000 bar V = 81 kg	1	1
Hydrogen fuelling control module	Qmax: 48.5 kg/h Maximum design pressure: 1000 bar(g)	2	3
Dispenser	P = 700 bar	1	1
Dispenser	P = 350 bar	4	7
Water treatment block	Qmax = 1000 l/h	1	1

Table 1 Technical specification of 1000kg/H_2 and 1500kg/H_2 stations

For utility connections the specified connections must be met in order to operate the HRS.

System description	**Measure.**	**Technical requirements for 1000kg/H_2 station**	**Technical requirements for 1500kg/H_2 station**
Water connection	l/h	1000	1500
Waste water connection	l/h	1000	1500
Electricity 400V	kW	5 400	8 000

Table 2 Utility connections

According to the specification the first visualizations of both 1000kg/H_2 and 1500kg/H_2 stations are made:

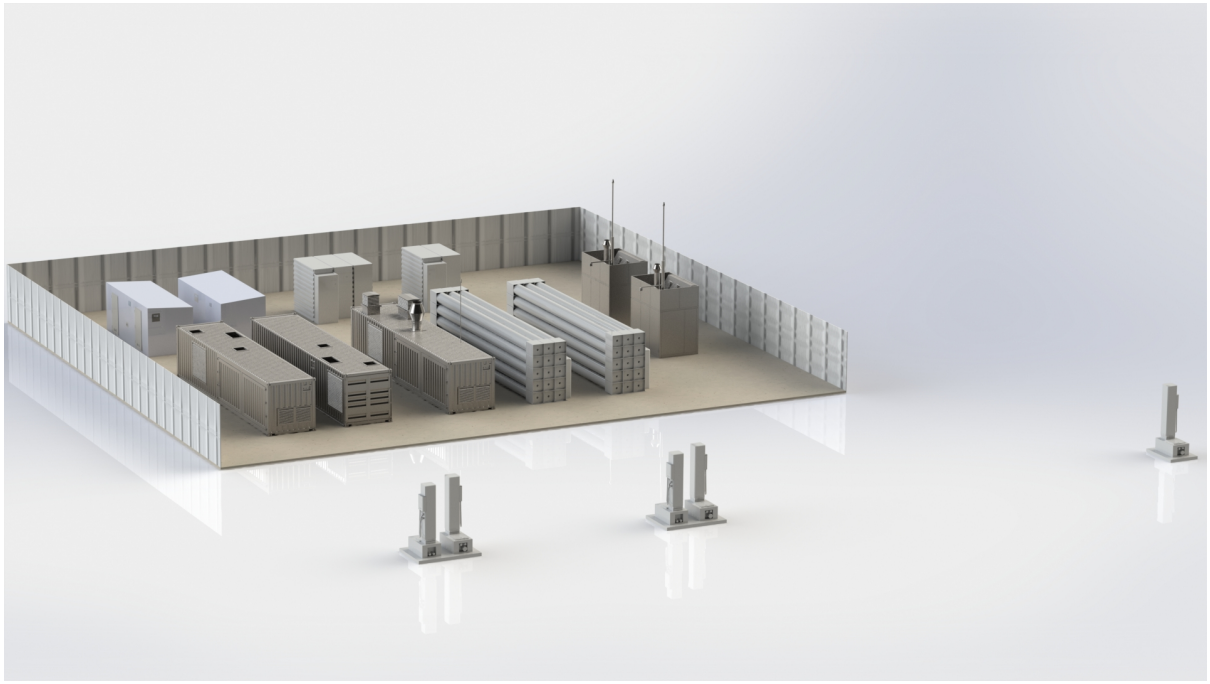


Figure 8 Visualization of 1000kg/H_2 station

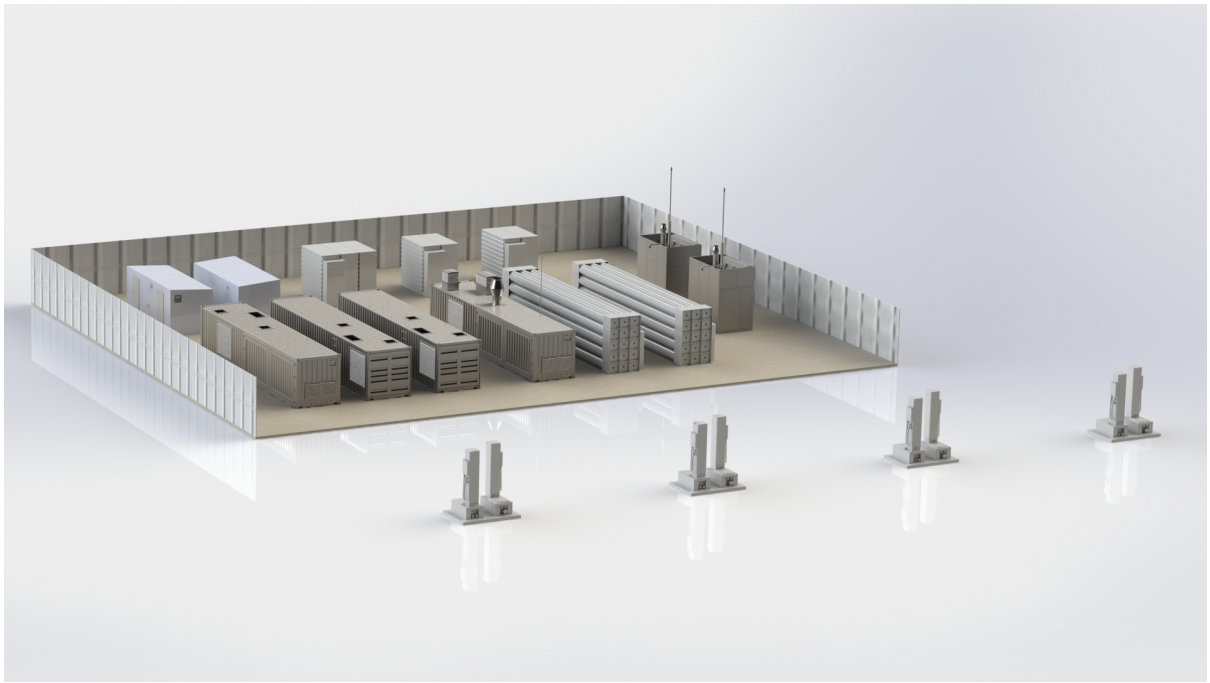


Figure 9 Visualization of 1500kg/H_2 station

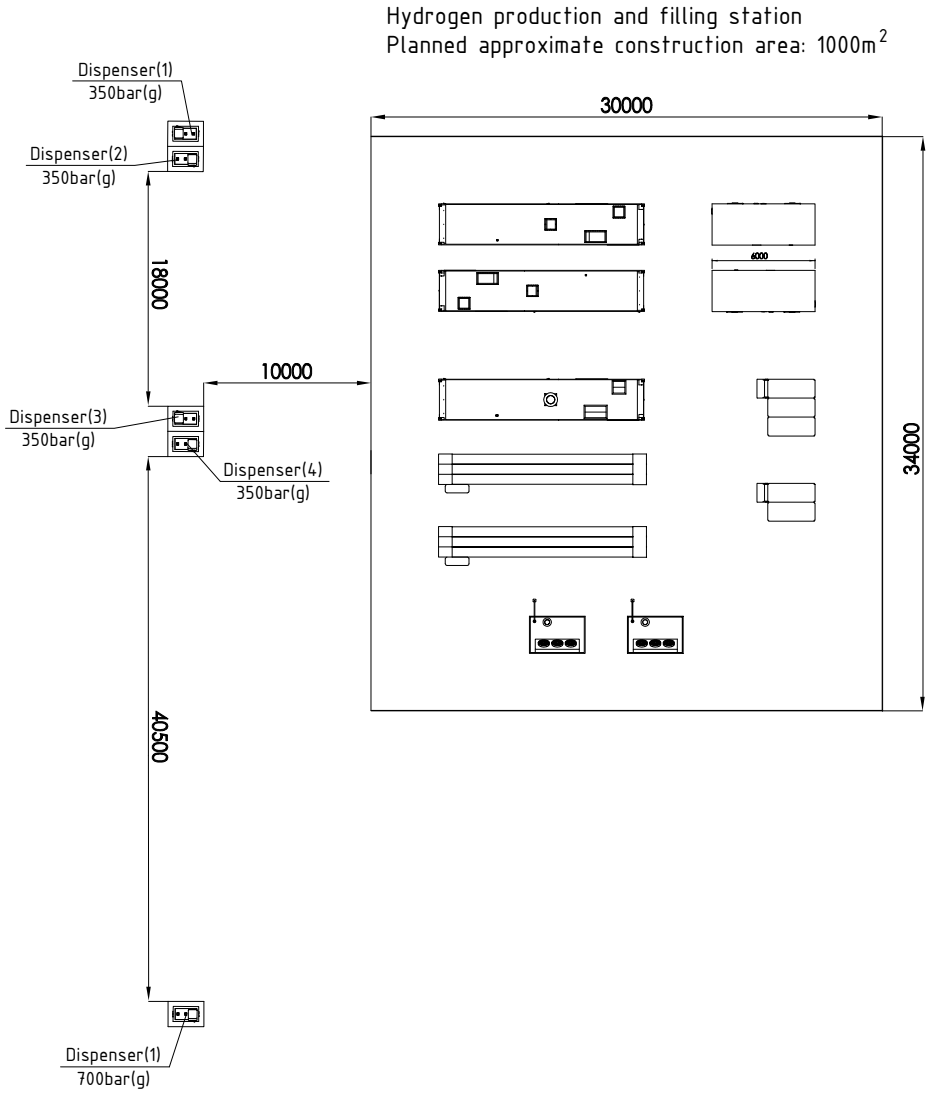


Figure 10 1000kg/H_2 HRS land-plot

Taking into account that only few additional units are necessary to increase the capacity of the HRS, the same land-plot could be used.

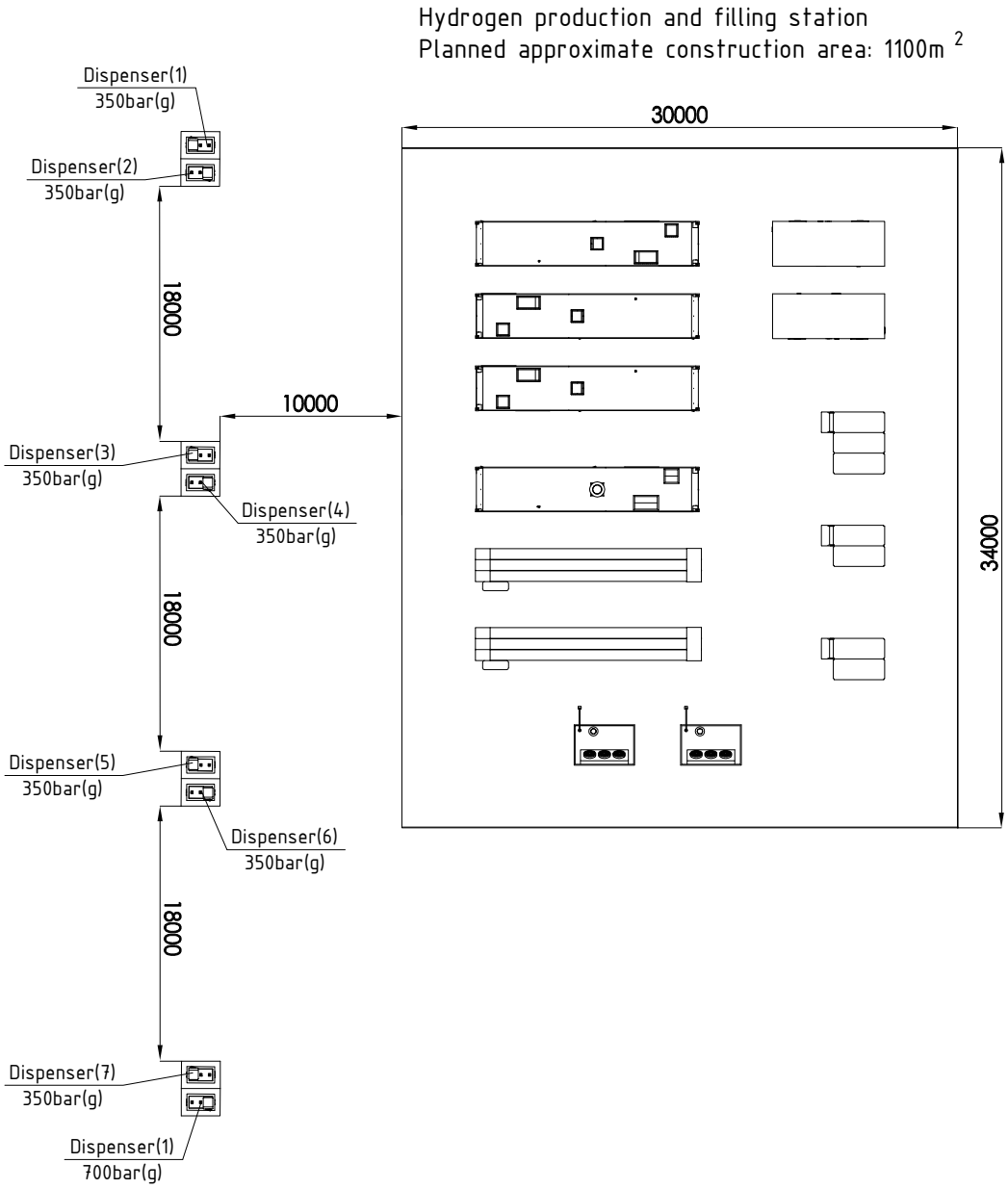
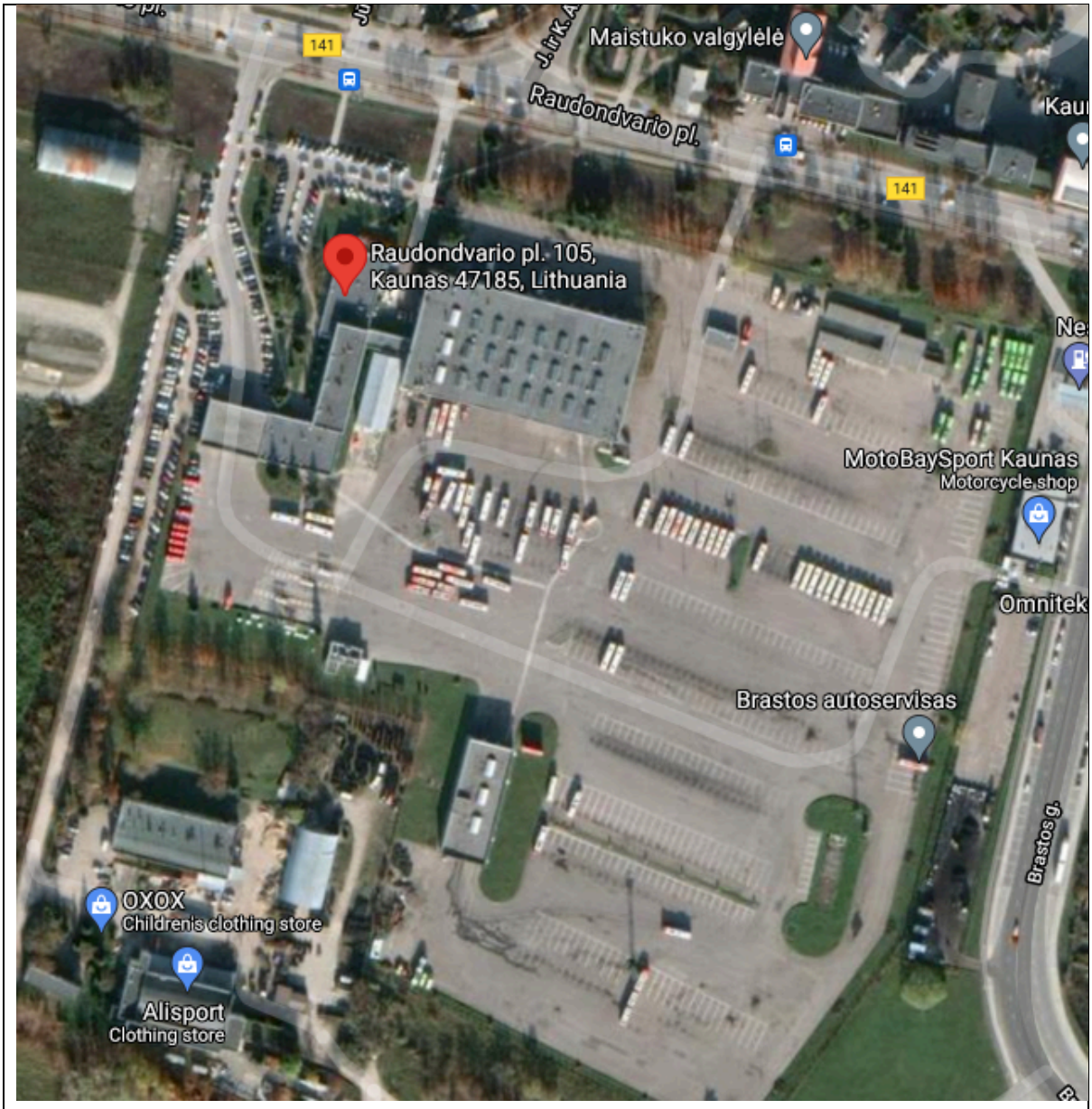


Figure 11 1500kg/H_2 HRS land-plot

The potential to deploy the HRS at Bus depot Raudondvario pl. 105, Kaunas should be further evaluated. From land plot perspective the station would occupy around 1000sq.m. and the rump-up strategy would require additional 100sq.m in order to deploy the additional dispensers for vehicle fueling.



Units deployed:	280 buses.
Refuelling possibilities:	Diesel and CNG refuelling station on-site
Size of depot	Potential to deploy additional 70 bus units

More information (space requirements, utility connection requirements, deployable technology) on other HRSs can be found in H2NODES Milestone 10 “Riga HRS upscaling” report & Milestone 12 “Parnu HRS upscaling” reports.

6. Conclusions

The total number of FCEV units, currently identified reaches 78 FCE-buses and 56 HyTrolleybuses. In order to secure the potential vehicle refueling it would be necessary to deploy a HRS with production and refueling capacity of 1000-1500kg/H_2. A potential rump-up plan can be made due to the fact that the land plot differences between the both stations would require only additional 100sq.m in order to deploy the 350bar dispensers. Further evaluations of potential 1000-1500kg/H_2 Hydrogen refueling and production station should be made, whereas the deployment site is identified.

KA seeks the opportunity to substitute the oldest bus units. Hydrogen is considered as an important candidate for source of energy in the future transport. KA are open for conversation to achieve the real-life deployment of FCEV units and HRS.