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LNG BUS DEVELOPMENT

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Abstract

Having a holistic approach of the LNG fueling infrastructure network development under the PAN-LNG Project, which one is co-financed under the European Commission CEF infrastructure development program, the systematic establishment of the consumer side is also part of the work. The previously non-existing category an LNG powered city bus family are under the development.

Keywords

LNG, Bus development, PAN-LNG Project

1. Introduction

The new Trans-European Transport Network development plans feature 3 main TEN-T CORE Network, going through Hungary. It is described in the proposal COM(2011)650, published at 19.10.2011, and revised at 19.12.2011, as the Union guidelines for the development of the trans-European transport network.

The newly developed European corridor system effectively connects the Western member states with the routes coming into Hungary. It precisely shows that Hungary lies in a cargo transport and logistic centre, where the most important Western, Northern and Southern sea ports are the gates to the corridors leading to it. This is the reason why so many logistics centres have settled in Hungary in the past decade. For building up the alternative fuelling infrastructure in Europe, as allowing to evaluate the main goals of the communication COM(2013) 17 in 24.01.2013 by the European Parliament and Council about reducing the dependency of the oil in the transport sector, the busiest roads, the most important CORE Networks have to be prioritized.

The PAN-LNG project aims to implement the first five road LNG & LCNG Liquified and Compressed Natural Gas vehicle filling station, based on liquefied natural gas tank, where in addition to serving vehicles with LNG tanks, the compressed natural gas (CNG) vehicles with can also be supplied high filling capacity, to serve heavy and light duty vehicles) vehicle filling stations, equipped with liquefied natural gas tank as well as the safe fuel supply of these on major European road transport lines, the Mediterranean and Orient-East-Med corridors of the TEN-T core network and the Hungarian territory along the Rhine-Danube corridor.

By the installation of LNG filling stations on the corridors in Hungary, the PAN-LNG Project significantly increases the value of the role the other Europe-wide ongoing projects. Based on the Connecting European Facility co-financed projects, there are 33 known individual projects, delivering new LNG, as well CNG infrastructures. The almost 0,4 billion € investment, of which just over 0,2 billion € is a European co-finance, will deliver at least 180 new LNG filling point (more than the today existing figure) and roughly 140 CNG points on our common roads.

It is more than impressive how these figures are improving the availability of the LNG fuel. However, if we consider on the task of sending the diesel to retire as laid down in the White Paper (COM (2011) 144 White Paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system), need at least 10-fold as many station in the EU. And this story isn't only an investment needs of 3 billion € in total only for completing the LNG infrastructure to available for everyone. From one side, the LNG vehicles need to be in action anywhere in Europe and needs to be driven without having any extra trip for refuel them, because that destroy the acceptance of the vehicle operators. LNG filling station investment needs return of capital, understand it; needs customer, which securing the daily consumption. The responsibility of the vehicle manufacturers equal at the CNG and the LNG case, need to make the infrastructure network profitable [1].

2. Today's Needs

Till the speed of the NGV economy tune up, needs to go ahead with the LNG infrastructure network development. After the corridors, at the cities and at the main routes need to be equipped. Therefor need business case for the infrastructure developers, ergo need to be able let finance their 0,5-1,5 million € high investments according to a strict CBA, which must be acceptable for banks as well. And mostly here the trucking industry is a bit difficult. If the LNG powered trucking fleet to be established, not owned by the station developer, then the consumption is hardly predictable and even weaker chance stay to secure a long-term sales volume. One 40 t truck should consume daily 100-120 kg of LNG, quite exact number, however the problem is, that long-haulage means, but also the middle range missions are not refuelling always at the same place [2].

Needs to establish a constant base consumption to run the business, but it is essential also from the side of the gas-technology. Thinking on that, two solutions are popping up. Extending the target of the sales by the CNG vehicles can help a bit through the so-called L-CNG filling-station technology. Could be improved the economy, if there a certain number of lorries, locally used light- or heavy-duty vehicles can put into the consumer heap. That is however not for ever can secure the consumer side, because if the business is running, then a newcomer can pillage the profit. The situation is a bit different if such a professional consumer is providing the base load for the LNG station, like a public transport service. Buses are running on a same route, consuming predictable quantity even for years ahead. Also, the growth of the fleet can be predicted, if the PT-company is satisfied and if not, the whole fleet have been changed for the first moment, but the changes are coming naturally as the vehicles arriving to a certain lifetime, when they get renewed [3].

The good thing in the bus fleet, that it is exist at every major city, so based on that, every important location where any concentration of industry exists, so bigger good transport needs take place, there for sure has got PT needs and a bus fleet, which can be served by LNG. And based on that, can find the way to establish a useful network of LNG fuelling stations.

3. Having LNG & LCNG station instead of CNG is a newly available position for decision

There are roughly 800 thousand buses in the EU to be changed from diesel to environment friendly alternatives, where at least for two-third no any other fuel could pop up than the methane. Any newcomer fleet operator now dreaming on purchase a CNG bus fleet, already can decide, having gas from the pipe, placing compressor stations or let to establish an L-CNG station. I would highly recommend the second option, because of many reasons, but first of all, the accessibility for the LNG fuel too.

If the L-CNG station has got not only CNG dispenser, but equipped with LNG dispenser too, and a submerge pump which supply the liquefied gas into, then station is ready for fill the LNG vehicles too. Here to be cleared, the flow rate of the LNG at the dispensers can go up to 150 l/min, that refill theoretically in 7 minutes the IVECO for over 1500 kilometres range. That is roughly 500 kg of gas, in case of CNG this quantity would take roughly 20 minutes at the station of Miskolc, if the vehicle standing alone, but even only through the NGV2 nozzle system [4].

For those, who are new to establish a station for refuel a CNG bus fleet, the L-CNG system versus the old CNG compressor technology can compare in these (Table 1.).

If the filling station technology to be selected is clear, and it is based on the LNG, then comes a question:

– Why not an LNG bus instead of CNG?

And the simple answer is:

– Because it is hardly existing in Europe.

4. The sense to produce an LNG-powered bus instead of ZNG-powered one

Let's suppose first, the LNG refuelling possibility exist with equal chance to a compressor station. If the selection based on the principles, Table 2 shows some of the main points.

Beside of so many positive arguments, there are some negative ones at the CNG buses. Mostly concerns around the bodywork.

If a bus bodybuilder has a product for diesel, to redesign it to an LNG version is significantly simpler then construct a CNG version. Modify the body structure at CNG version for holding the tubes on the roof is not simple. Not only supporting the weight increase and avoid any tendency for frame cracking somewhere else is complicated, but the vehicle driving characteristics are also deeply modified, since the leverage from the vehicle natural momentum are very long. It effects the suspension characteristics and the brake force distributions. Since the rollover protection of the vehicle, effected by the carried weights on the top, serious modifications need by the constructers and new rollover tests also must be done.

If the designers would like to develop a bus type, which has a dedicated city version and beside of, wish to implement an intercity arrangement, the effects on the drag force makes the CNG hunch an important barrier, or at least an undesirable parasitic. This increase in highness can be also strange at a low tunnel.

The weight increase at CNG versions compare to the diesel is also on the negative side of the arguments. The almost 500 kg to the 1,2 tonnes surplus exist on the market, what makes the vehicle thirstier. But also, less passenger can host, according to the registration [4].

Compare to the CNG versions, LNG tank is lighter, the structure of the vehicle need no improvement, no newly designed suspension need. No increase in dimension and the passenger capacity is also just with 2-3 people less than a diesel one. Without excrescence on the roof, the LNG vehicle has no drag increase, ergo overconsumption. This is an important point at tempo 100 for instance.

5. Assume all the above-mentioned reasons, there is a need for LNG bus on the market

As developing the PAN-LNG Project, establish 6 LNG filling-stations in row in Hungary with the acceptance of following a few dozens of the similar investments, strongly looking for customers. To catch them, need some good vehicle offer. One of the best option can be a good and reliable bus. In Hungary and at most of the post-communist countries, the brand name of Ikarus means a really reliable bus. Many countries are still using their 30+ year old buses, and renew them. Even in Germany can find some veterans with 50 years, however they are not serving anymore just for shows. In the eighties, Ikarus was the biggest bus producer on the world, the 200-series and the later introduced low-floor 400-series were built in over 250 thousand pieces. Above 100 thousand of them are still on the road. For sure, it was possible under the socialist Comecon regime, which was far not a free-competition market, so after the revolution, the market and the production collapsed from the 14 thousand in a peak, to a level of 3, if not a 2-digit quantity per a year [5].

To develop a prototype with the aim of producing the new model, without an existing large-scale production is something, what also challenging. From the other hand, this can also revitalize the company, which has a lot of good potential. The decision made, agreed on the cooperation between the owner of the company and the investor of the LNG-station network, Pannon Fuel Kft. Based on that, the actual diesel type will be refurbished to an LNG one.

For the new engine had to redesign the supporting frame structure, finding a better angle, a more durable structure. But not only this were changed compare to the basis version. The supplier ZF modified the front axle compare to the previous design, and for this had to redesign the area of the connections. Based on the experiences, the frame structure designers were improved the inertia of the used stainless-steel profile on the lower longitudinal frame section, making the frame resistant to any brittle fracture, what is actually a weak side at most of the stainless-steel framed buses on the todays market.

It was clear from the beginning, that the position of the fuel tank will skip the small window on the backside, which request a new panel design. The designers were also newly furnishing the inside of the passenger area, finding some more space not only because of the out falling of the two diesel tanks. Despite the more space inside, the reduced spacious back front made the vehicle shorter to 12,5 m instead of the 12,7 m from the diesel version. The available space supporting the unique large passenger capacity. In figures: 30 seating plus 78 standing passengers can get in, 12 more as at the new Citaro NGT. For a future intercity purpose, we have a design for elevated flor behind the second door and the third door is falling out. This way can we reach 49 seating places in the 12,5 meters frame [6].

Table 1. Comparison of L-CNG and CNG technologies

Topic	**L-CNG technology**	**CNG technology**
Choosing a location	Needs only space where the safety distances are secured, only small amount of electric power	Beside of space and safety distances, needs high pressure and capacity gas pipeline, enormous electric grid connection (mostly new transformer)
LNG source	If an importing terminal within 500 km it is fine, if within 1000 km, can live with, only small extra cost, >1000 km let think on another LNG source to be found	Don't need to have it, but if it is existing, secure the gas supply for the gas grid
Gas price includes charges	LNG over production makes the gas cheap for long, that makes good business perspective for all of the LNG consumers. Strongly influenced by European trading level	LNG pricing are treated the prices for the pipe exporters, like Russia, this is however seeming well, where the competition to LNG exist, at those European markets, where the transporting routes are topping up the LNG prices, there the pipe gas is also more expensive. The capacity fees at the connection points are affecting the gas price and the national distribution fees can treat the attractivity of the CNG. Strongly influenced by the national trading and politically based regulatory issues
Electric consumption	Max. 1/10 of the CNG	Min. 10x of the L-CNG
Having redundancy	Install 1 high pressure pump + 1 vaporizer	At least N+1 compressor to install
Increase the filling capacity by 1500 Nm3/h	Install 1 high pressure pump + 1 vaporizer	Install at least 2 compressors and extend the gas grid and electric grid capacity, if it is possible
Can have barriers to establish a capacity above 1000 Nm3/h	No	Yes, upon the capacity of gas grid, less often at the e-grid
Cost to establish a right station for a fleet of 50-100 buses	Including LNG vehicle filling, budget 1,2 million euros	Budget 1,5 million euros
Cost of doubling the size of the fleet	Budget altogether 0,2 million euros, no barriers	Budget of 1 million euros, if possible
Timeframe to deliver a station from scratch	~ 5-7 months	~ 5-18 months
Demand for maintenance	Less intensive	More intensive
Designed lifelong	>20 years	>20 years
Inert gas in the fuel	Depends on liquefier technology, but higher than 1 % Nitrogen is rarely	Depends on the composition of gas sources, easily can go even up to the range of 15 %
Existent of longer hydrocarbons	C2-C4 possible	up to C6 is commonly exist
Energy content, indicative Wobbe index	54-55,5 MJ/kg	40-49 MJ/kg
Business prospect to sell fuel for the public	Important role and have a big sales potential in LNG, but CNG exist as well	Important role for those regions, where public CNG stations are rarely available

Table 2. Comparison of LNG and CNG technologies

Topic	LNG bus	CNG bus
Driveline	Same	Same
Pressure reducer	For LNG version (up to 25 bar)	For 200 bar CNG
Gas tank	Cryogenic for LNG	High pressure for CNG
Size of the tank	310-460 l	910-1820 l (MB offers 4-6 pc for Solo, 5-8 pc for Articulated)
Empty weight of the tank	250 – 350 kg	280 – 560 kg + structure ~70 kg
Gas capacity	131 – 196 kg	130 – 260 kg
Compliance with body stability UN ECE-R66.02 regulation	Same structure as diesel version	Need improvement compare to the diesel version
Brake and suspension	Same as diesel	Need to be adjust compare to diesel
Effect on the frontal area	No	Significant A modification, but also different on c_w
Intercity and highway applicability	Yes	The increased C_w makes barriers
Average overweight to diesel	~150 kg	485 kg (MB) - ~1200 kg (MAN)
Average loss in pass. capacity	3 people	8 people
Energy efficiency	Minor disadvantage on the weight increase	Higher disadvantage on the weight increase as well on the drag force
Different in highness to diesel	None	Up to 45 cm
Average time of a refuel at a well-established Station	3 min	10 min, if filled alone
Needs of personnel training	Yes	Yes

The selected engine for the solo Ikarus is the ISLG9, an 8,9 litre, 224/302 kW/LE (2100/min) Euro VI homologated one, with a peak 1167 Nm torque, with a flat curve between 1300-1600/min. Nice, that the engine has constantly over 87 % of the maximum torque available between 1000 and 2100/min RPM, means above 1000 Nm are constantly available from the slightly increased idol to the peak point of the power curve. This engine family has got in the top version 320 horsepower and +200 Nm torque. That is pretty good for the next coming articulated city version. But also, can serve an up to 49+1 seating capacity, intercity solo vehicle, which one keeps within our next plans. Not the engine is the only gas consumer, but the heating system for the passengers are also equipped with gas-powered heater. As opposed to others, we didn't accept an alternative fuelled vehicle with a diesel-powered heater, however that system inclusive with its extra diesel tank would cost far less, than the gas heater. The engine is paired with the ZF Ecolife 6AP gearbox. In Europe the widely applicated modern gearbox also with the TopoDyn function can be ordered, as a customer option.

There was a strategical decision at the end, which producer should be preferred for the LNG tank. As having different objectives, like:

- keeping the most possible share of the European production,
- having the lowest cost for the bus, to keep it as good in competitiveness as possible,
- destroy the producer hegemony, to make free market situation in Europe for finally, in the favour of the customers, fleet owners.

At the time of the project start there were only one known producer with the R110 certificate for LNG bottle in Europe, however that was not for buses, just for trucks homologated. Finally decided, to import LNG tank from China, where the production is far bigger for these bottles, then in the whole rest of the world. Just to not, the LNG vehicle market in China comes close to 100.000 unit (!) this year, as reports are showing it.

The selected size of the first solo bus keeps a rounded 150 kg of gas, good for up to two days in a city mission. For customer preference, or for the articulated version this can be exceed the 200 kg mark with the today available tubes.

6. Conclusions

The result of our tank selection is finally coming serious, compare to another offer from Europe, the price advantage reaches the 3 % mark of the total vehicle. If we compare to our LNG bottle to a set of a CNG cylinders, we can find an advantage level of 3-4 % a price of a solo CNG bus. If we consider the price disadvantages for the customers, what we have at CNG buses compare to the diesel ones, we can realize 20 + percent. According to our analyses, this is a result from market pricing mechanism, the products cost as much, as the customer intend to pay for. Not an equalized possibility for the NG vehicle penetration growth and not supporting sufficiently the infrastructure developers.

The proto vehicle is already finalized, the new type approval is on the way. The orderbook is going to be open soon and up on the serious interests from different markets beside of the local one, the production capacity can be established up to the 3000 per annum level.

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