PAN-LNG Project Study – Comprehensive Analysis of NGV Penetration Increase

Henrik Domanovszky

President of the Hungarian Gas Transport Cluster Association, PAN-LNG Project Leader, Budapest, Hungary
USA (Tel: +36-70-396-7502; e-mail: domanovszky@panlng.eu).

Abstract: The first real result of the PAN-LNG Project supported by the European Commission is a comprehensive, thematic study mapping up the prospects, conditions and effects of the spread of biogas and natural gas based surface transport. During the development of the technical content of the vehicles, the background demand of the change in the demand for fuels following the spread of operation, i.e. the infrastructure network, the distribution demand and the increasing demand for the production of the source of energy were all examined together with the need for potential resources and mechanical requirements. Weighing all these and comparing the decrease of environmental load caused by the alternative fuel most suitable for widespread use today, it has been concluded that in the higher rate we facilitate this spread, the higher the total national benefit will be.

1. INTRODUCTION

Considering the strategy of the European Union on transport published in 2011 (28 03), the White Paper – "**Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system" –** determining 40 steps to make the energy intensity of Europe more efficient and dramatically reduce its petroleum dependence by the middle of the century and to reduce the carbon emission by 60 percent (compared to the 1990 level).

On the basis of this the European Commission transformed the major points of the development of core transport networks; Regulation 1315/2013 determines its uniform infrastructural content the integral part of which is the filling infrastructure for alternative fuels. Regulation 1316/2013 sets forth Connecting European Facilities (CEF) TEN-T, a € 24 billion network construction program for 7 year (later reduced to € 20.5 in the Junkers package).

After the objectives and means were set, the European Parliament and the Council issued Directive 2014/94/EC (22/10/2014) in which it specifies the compulsory minimum conditions of the availability of alternative fuels. Namely the charging points for electric vehicles, the filling stations of natural gas - CNG and LNG - and hydrogen fuelled vehicles as well as the LNG infrastructure to be constructed for sea and inland water transport. The member states must inform the Council about their national policy framework by 18 November 2016.

1.1 National Transport Strategy

Hungary published the National Transport Strategy (NTS) concept which determines the transport development objectives that Hungary wished to implement under the 7-year cycle of the CEF from the EU funds. The accepted NTS document only touches the energy of transport and does not set forth any necessary action, however it makes the following statement:

"Petroleum dependence decreases in the transport sector in the OECD countries; in 2030 gas is expected to cover 16%, biofuels 13% and electric energy 2 of the transport demands.

1.2 Efforts of Hungarian Gas Transport Cluster Association

Thanks to the parties interested in the spread of the natural gas fuel technology and the foundation and maintenance non-governmental scientific groups committed to the protection of the environment it has become possible that HGTCA can play an active role in devising and implementing the strategy and programs serving the spread of NGVs.

As the president of the HGTCA I presented the LNG development proposal in the Parliament on 20/03/2012 which is able to start the reanimation of a former key industry in addition to the environment protection and environmental health care benefits of spreading the clean source of energy. Thus in addition to machinery production, production of buses, repairing and building ships may gather new momentum by the suitably early appearance of LNG.

Following numerous intermittent events, having acquired the supporting regulation of the government (Gov. Reg. 1099/2015. (III. 5.), the HGTCA submitted the PANNON-LNG Project proposal for the 2014 (first joint) CEF tender the supportability of which was decided by INEA and the co-financeability of which was decided by the European Commission

CAETS
„IFFK 2016" Budapest
Online: ISBN 978-963-88875-3-5
CD: ISBN 978-963-88875-2-8
Paper 23

Editor: Dr. Péter Tamás

The CEF program was started with 276 proposals from almost 700 project plans with over EUR 13 billion EU support from which the separate cohesion fund supports 48 programs. Hungary was successful and spent EUR 211 million from the EUR 1075.9 million cohesion fund available.

The PAN-LNG Project stands out of the supported projects in several aspects. While the support of 23 innovation project proposals were decided from the non-cohesion fund, of which 13 projects serve the infrastructure of LNG transport, 3 contained e-charger and 2 hydrogen infrastructure solutions. All this was supplemented by the 14 projects for the development of the sea LNG infrastructure. Meanwhile the PAN-LNG Project covers more than 80 percent of the total support of almost 18 million of the 3 winner innovation projects of the cohesion countries.

1.3 Project Continued

For the 2015 tender of the CEF (second round) the PAN-LNG-4-Danube Project proposal was prepared with the support of the Government (Government Regulation: 1085/2016 (II. 29.)) and the CNG Clean Fuel Box Project proposal (Government Regulation: 1090/2016 (II. 29.)) which - based on the infrastructural background implemented in the PAN-LNG Project - widen the effect thereof to water transport as well as to the CNG infrastructure making the use of gas fuelled light vehicles possible.

Since not only Hungary played an outstanding role in the second round, ensuring the use of the cohesion fund available for Hungary with 17 winning projects, the two projects worked out by HGTCA are amongst these. The projects serving the development of the Hungarian filling infrastructure are implemented with 17 million support which is more than 40 percent of the innovation support obtained by the cohesion countries, almost every sixth Euro spent by CEF on innovation in the 28 member states, develops the Hungarian infrastructure and industry.

2. PAN-LNG PROJECT INTRODUCTION

2.1 Project Tasks

The main activities of the implementation of the project are the following:

1. Studies
2. Implementation of pilot LNG/LCNG filling infrastructure network
3. Development of distribution supplying LNG filling stations
4. Pilot small size liquefying plant development
5. Real life test of LNG fuelled vehicle

By the implementation of the project, a more or less self-sufficient base network is developed, which makes the two TEN-T road core networks suitable for use by LNG fuelled vehicles.

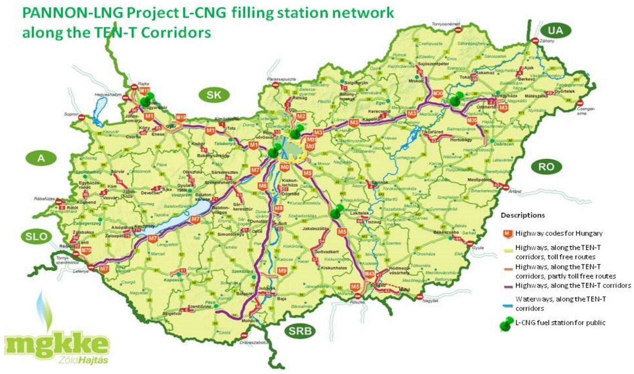

Fig. 1. PAN-LNG filling station network, locations

In addition to widening the accessibility of the Mediterranean and the Orient-East Med Core Network Corridors, the location in Mosonmagyaróvár may also serve the Baltic-Adriatic Corridor along the border of Hungary on the Bratislava-Graz axis as it is only about 30 km-s away.

In planning the distribution of the filling stations to be built, we paid particular attention to ensure domestic usability, since the major role of the filling stations is to facilitate domestic use.

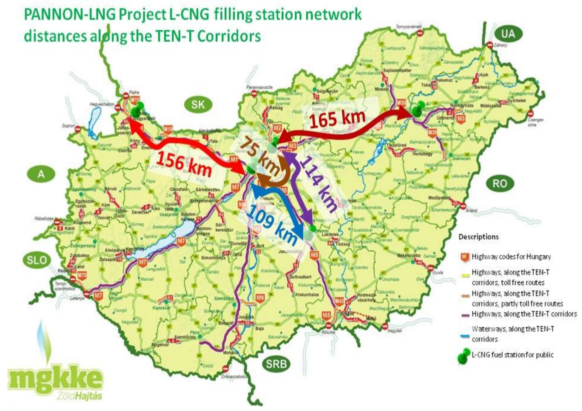

Fig. 2. The 5 LNG filling points make transport possible everywhere in the country without limitation, while at least a magnitude more filling points are required for efficient service.

With the initial turnover, the methane liquefying plant will be able to provide supply for the filling points, the primary aim of which is to obtain experience required to develop the capacities fulfilling later consumption. The liquefying plant may be established for the reserves of hundreds of smaller or bigger gas fields the extraction of which is not economical for supplying into the pipeline system; therefore the utilisation of these resources fails. Additionally the liquefying plant may be established on the basis of biogas sources. Landfills serve the most favourable solution of these, especially when the utilisation moreover, the neutralisation of the gas is missing. In this case the fuel that can be produced results in avoiding the emission of huge amounts of greenhouse gases, therefore the energy cycle of the vehicle fuelled this way runs with a significantly negative CO_2 balance.

In order to ensure the safe and economic supply of the PAN-LNG filling stations and the following infrastructures, two LNG tanker vehicles will be registered with environment friendly LNG fuel.

3. STUDIES

The first activity of the PAN-LNG Project is preparing the studies examining gas based transport. The most important reason for this order is the time limit of the task for the member states set forth in Directive 2014/94/EC according to which, the road map accepted by the government must be presented to the Commission by in November. Providing carefully established information about gas fuelled transport is fundamentally necessary in order that the policy-makers of the industry cab form balanced, objective and optimal aims.

Making efforts towards balance is particularly important since - it is hardly explainable - one side of the Government recognises the electric vehicles exclusively and works on the spread of those under the Jedlik Ányos Plan (JÁP) in complete contradiction with amongst others the NTS quoted in the introduction too.

3.1 Structure of Study

In order to examine the complex image in a sufficiently detailed way, the following areas must be surveyed and presented in order to present the alternative of the spread of natural gas based transport in its total cross-section and from all significant aspects.

- 1.1. Development potential in vehicle technology, competitiveness in the following period;
- 1.2. Potential scenarios of the spread of gas fuelled vehicles among fleet operators and other users;
- 1.3. Environmental, environmental health care and other social and economic effects following the spread of gas fuelled vehicles;
- 1.4. Size, spread and technological composition demand of the filling infrastructure required according to the spreading scenarios of gas fuelled vehicles;
- 1.5. Distribution technical background and capacity required for the supply of the LNG filling stations;
- Opportunity to ensure the LNG use accompanying the spread of gas fuelled vehicles
  - 1.6. From import sources
  - 1.8. From domestic mining activity
  - 1.7. From sources other than mining
- 1.9. Examination of mechanical technology required for the production of LNG in Hungary.

After the professional study of these the effects of the spread of the alternative fuel can be summarised, the balance can be drawn, the optimal level of spreading can be selected, to which the necessary regulators and incentives can be assigned.

- 1.10. A summarising chapter forming proposals is generated as the conclusion of the professional fields.

The group of legal specialist invited by the PAN-LNG Project prepared a collection of proposals to form the regulatory demands identified in the studies and explored in different fields as well as the necessary incentives identified in a textual form.

- 1.11. Collection of proposals for regulators and incentives required for the spread of gas fuelled transport.

Also to be published in the series of studies.

- 1.12. A summarising chapter forming proposals in the English language.

Furthermore the list of professional and scientific sources used as the basis to work out the chapters of the study also constitutes a separate publication. The more than 50 specialists and science professionals participating in the workgroups to prepare the PAN-LNG studies have analysed more than 1,100 publications, the length of which have far exceeded 80,000 pages.

4. RESULTS

4.1 Emission advantage of gas fuel

The pollutant emission in the cities of Hungary – solid particles (PM_{10}, $PM_{2,5}$), volatile hydrocarbons (VOC) – is above the Western European levels. Although we are less polluted in case of $_x$ than certain Western-European countries, the air of our large cities is intoxicated by this as well. It can be clearly seen on the satellite image (Figure 3.) in what extraordinary difference the European vehicle purchasing customs, i.e. the spread of diesel vehicles have resulted in the nitrogen dioxide concentrations in comparison with the United States, where hardly any diesel passenger cars are purchased.

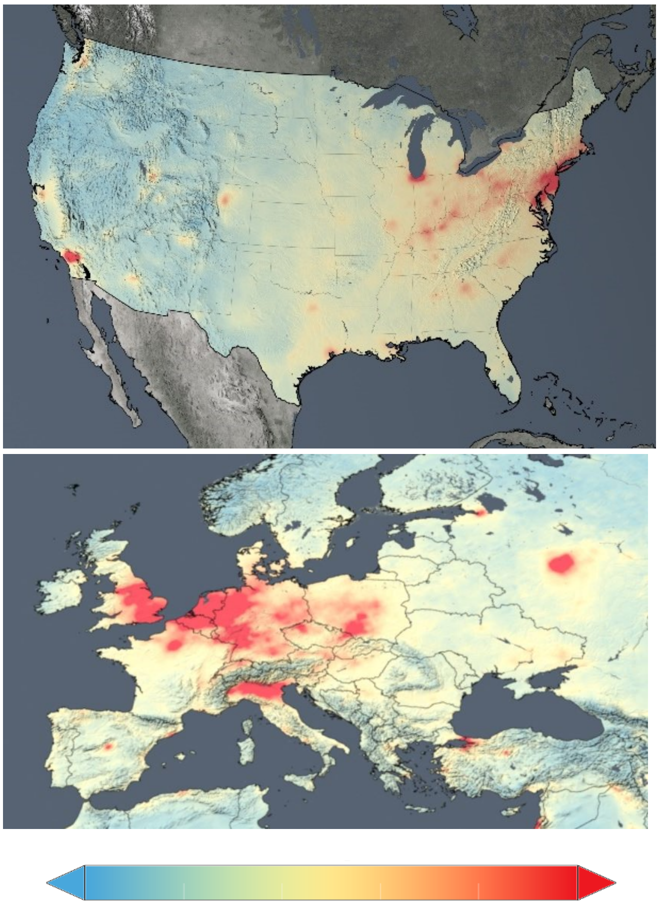

Fig. 3. Nitrogen dioxide concentration in the USA and in Europe in 2014 [scale 0-5*10^{15} molecule/cm^2], **AURA satellite, NASA Goddard Institute**

The “diesel scandal” broken out in America based on the measurements of ICCT (September, 2015), the severity if which was clearly proved on 53 vehicles by the inspection of the transport authority (KBA) ordered by the German Ministry of Transport, highlighted that the real environmental pollution of diesel engines is multiple of the strict emission values even when they are new. The concentration of nitrogen oxides causing yellowish-brownish “fog” in the low atmosphere has grown into one of the greatest air pollution problems. This problem is clearly seen if we compare the air pollution images of the United States and Europe, since only medium and heavy motor vehicles are operated by diesel engines in the USA while only the VW group, BMW and Mercedes tried to sell diesel fuelled passenger cars with little success. As opposed to this the rate of diesel engines has exceeded 50 percent in several European countries due to the taxation preferences of fuel prices in many cases. Therefore the excise tax of diesel oil and petrol must be transparently balanced in Europe without delay so that the supposed fuel cost advantage of diesel fuelled vehicles is eliminated and consumer preferences are changed.

The most important consequence of high air pollution is the unreasonably high mortality; on the basis of the study of the OECD prepared in 2014, 9,370 people die in Hungary every year due to the pollutant emission associated with transport, which is the second worst in the world, following China with infamously bad air quality. On the basis of the external damage costs accepted by the EU, this causes tens of billions of HUF cost to the Hungarian society.

The cause of high pollution levels and mortality rates may be traced back to the fuel use of transport: currently only an insignificant number of vehicles are fuelled by natural gas or electricity but most of these are railway and urban community transport (tram, underground railway, and electric bus) vehicles. This unfavourable situation may be changed by encouraging alternative transport.

Natural gas and electricity complement each other in alternative transport, since the use of different fuels is optimal for different purposes.

		Alternative technologies						
		Electric vehicles with batteries		CNG		LNG	CNG/LNG-hybrid	
		< 3.5 tons	> 3.5 tons	< 3.5 tons	> 3.5 tons	> 3.5 tons	< 3.5 tons	> 3.5 tons
Intended use	Urban	+++	+	+++	+++	++	+	+++
	Suburban	++	-	+++	+++	++	+	+++
	Regional	+	--	+++	++	+++	+	+
	National	--	---	+++	+	+++	-	+
	Long distance	---	---	+++	+	+++	-	+

+: applicable -: not applicable

Fig. 4. Fields of use for alternative vehicle-technologies

Electricity-based operation may have a role in urban or potentially in suburban passenger transport due to its limited energy density. Gas fuelled transport shows outstanding advantages in long-distance passenger transport, community transport and cargo transport. The pollutant emission of natural gas fuelled vehicles is a fraction of that of diesel engines which is verified by measurements conducted in Miskolc in 2016.

	Diesel	CNG	Change
CO_2 g/km	1,289.48	1,050.22	–19%
CO g/km	0.96	0.59	–39%
NO_2 g/km	7.39	0.06	–99%
NO g/km	9.44	0.37	–96%
VOC g/km	0.25	0.38	53%
Solid particles mg/km	5.14033	1.49375	–71%

Fig. 5. Comprehensive values of the test operation in Miskolc PAN-LNG Project, ITS, Institute for Transport Sciences, 2016

Although shows a generally favourable picture in terms of the carbon dioxide emissions measured in 1990 as a result of the political and economic changes in Hungary, it currently shows approx. +80 percent excess in the field of transport to be examined separately. As opposed to this, the White Paper prescribes 60 percent reduction by 2050 which is strengthened by the Paris Agreement ratified in New York. Natural gas engines provide an efficient solution for the reduction of the carbon dioxide intensity of Hungarian transport. The carbon dioxide emission of natural gas engines is 23 percent lower than that of diesel or petrol fuelled vehicles, irrespectively of the storing method of natural gas

(LNG or CNG). In comparison, the carbon dioxide emission is 14 percent more favourable in case of natural gas engines with LPG fuel also appearing in Directive 2014/94 but which is typically petroleum based.

The survey result of Chapter 1,1 of the PAN-LNG Project study showed a real life image in which the consumption and CO_2 emission figures in real-life use verified by statistical method of a certain model, the Volkswagen Golf VII with different engines but having the same 110 HP performance level is compared (Diagram 6.). On the basis of the large number of vehicles (342 cars in total) used and the consumption data the difference between the standard measurement (NEDC) and reality may be judged, on the basis of which the quality of the regulations can also be assessed. The excess consumption of petrol fuelled Golf users in 33 percent higher than the factory measurement, while the extra consumption is 60% in the case of diesel engines, while it is “only” 21% in natural gas users. The natural gas fuelled version emits 27% less greenhouse gas than petrol fuelled cars and 20% less than the diesel ones in urban circumstances.

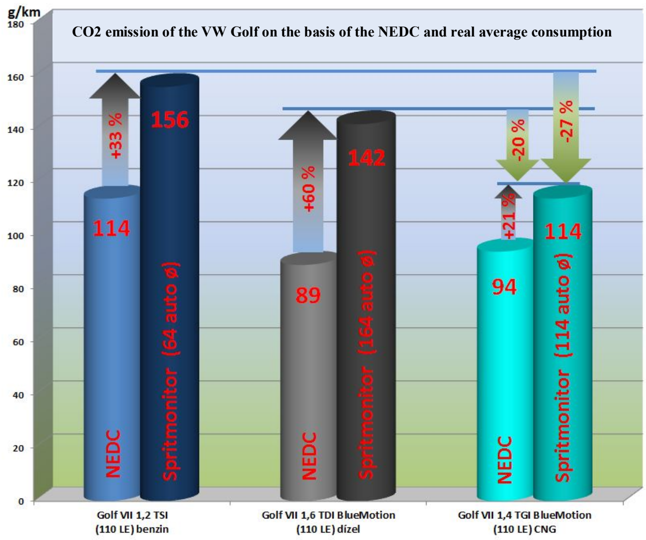

Fig. 6. Consumption and CO2 emission of VW Golf VII on the basis of the NEDC driving cycle and the statistical result of real logged consumptions on www.spritmonitor.de.

If we want to draw a realistic image of emissions, it is important to take the total life cycle of the energy source, not only the direct use of the energy. It is especially true in case of greenhouse gas emissions. “Avoiding new carbon” emissions to the atmosphere may significantly improve the performance of transport depending on the origin and the generating technology of the individual renewable fuel. In this field the renewable energy based CNG and LNG fuels are the most efficient means of reducing CO_2 emissions; they may even result in negative emissions for the total energy consumption in case of certain sources (e.g. utilisation of landfill gas as fuel). We shall draw a more detailed picture of this issue later.

Nevertheless we must not forget that the local zero emission during the use of the energy does not mean that the user becomes climate-friendly. The production of energy and making it available for example in the case of electric power has results in significant amounts of emission. On the basis of the data of the Hungarian Trade Licensing Office 127.5 g/MJ may be calculated for the CO_2 emission of making electric power available. On the basis of this it is worth adding, that the neither the CO_2 balance of the Plug-in-Hybrid Golf TGE, nor that of the purely electric e-Golf measured in real-life use is lower than that of the gas fuelled version of the Golf.

4.2 Cost and Probability of Changing to Gas Fuelled Vehicles

We can generally say that the available CNG and LNG vehicles in Europe serve the small scale demands and not the mass demands. The typical behaviour of manufacturers is seen on the one hand in the range of models and in pricing on the other hand.

On the one hand the manufacturers start offering their vehicles with natural gas engines late during the launch or the facelift of their models, frequently with two or three years delay. The interest in the model is lower this time. Nevertheless the number of models and versions marketed with CNG or LNG systems in addition to the traditional fuel systems is very low in many cases. The division of the markets is also an important problem: natural gas fuelled vehicles are found in the product range of numerous manufacturers known in Hungary, however they are only sold on certain markets so the range of CNG fuelled vehicles amongst others in Hungary is a fraction of the available range in other European countries. It is worth considering encouraging manufacturers by regulatory tools to universally market their entire range of models in the member states of the EU. The lack of the suitable range of vehicles has disadvantageous effects of the other participant of the ecosystem of gas fuelled transport, this way operating filling stations may be a less returning investment, and the infrastructure allowing for natural gas fuelled transport to be implemented by Directive 2014/94/EU will be more difficult to spread in a merely market based way.

It is also clear that the pricing of natural gas fuelled models is far above the real costs arising from technological, technical and manufacturing complexity. This is partly due to the low number of units but more to the higher margin allowed by little competition. It can be forecasted that the changes on the market of vehicles will reduce the current overpricing, till then however the return of the extra price of the technology must be taken care of in order to make it available for vehicle fleets.

Gas fuelled vehicles are currently more expensive than conventional means of transport. However this will change in the future which may be traced back to three factors:

- The spare parts currently causing extra costs - primarily the price of fuel tanks for gas fuelled vehicles (especially LNG tanks) - are continuously decreasing;

„IFFK 2016” Budapest
Online: ISBN 978-963-88875-3-5
CD: ISBN 978-963-88875-2-8
Paper 23

Editor: Dr. Péter Tamás

- The price of gas fuelled vehicles will decrease due to larger production volumes in the future;
- The costs of diesel engines will increase due to stricter environment protection regulations.

The petrol engine passenger cars are expected to be the cheapest by 2015, while CNG fuelled vehicles will be approximately EUR 1,000-1,500 more expensive, while diesel fuelled passenger cars will be EUR 2,500 more expensive than petrol fuelled ones as a result of stricter environment protection regulations. In the case of buses and vans, the procurement prices of gas fuelled vehicles are EUR 5,000-40,000 higher than those of diesel fuelled vehicles. However this difference will disappear by 2025 and gas fuelled vehicles will be available at similar prices to diesel fuelled ones. Consequently gas fuelled transport will not need support after the transition period.

One of the basic conditions of the spread of gas fuelled vehicles is the development of filling infrastructure, the specific cost of which is far more significant than that of petroleum based fuels, nevertheless long-term, predictable customer demand, i.e. stable market environment must be generated in order to stimulate investments.

The study presents three scenarios of gas fuelled road transport: In case of the pessimistic scenario (L-scenario) the energy consumption of transport will follow Fig. 7.; in case of the medium scenario (M-scenario) according to Fig. 8.; while in case of the optimistic scenario (H-scenario) the gas consumption can be calculated in accordance with Fig. 9. Considering all expenditures and advantages - including externalities - the more intensive the rate of spread is, the more significantly costs of Hungarian society caused by transport will be reduced.

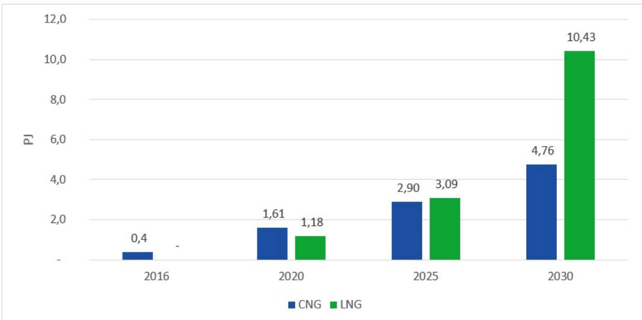

Fig. 7. Natural gas consumption for transport purposes on the basis of the L-scenario, PAN-LNG Chapter 1.4

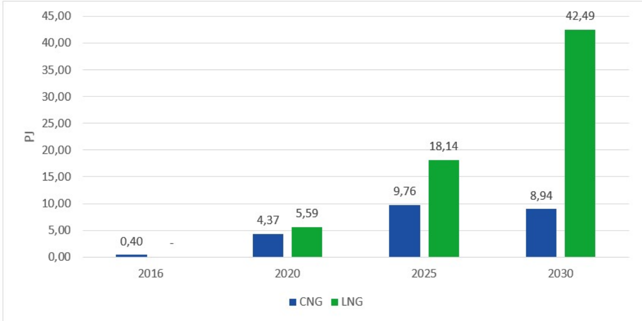

Fig. 8. Natural gas consumption for transport purposes on the basis of the M-scenario, PAN-LNG Chapter 1.4

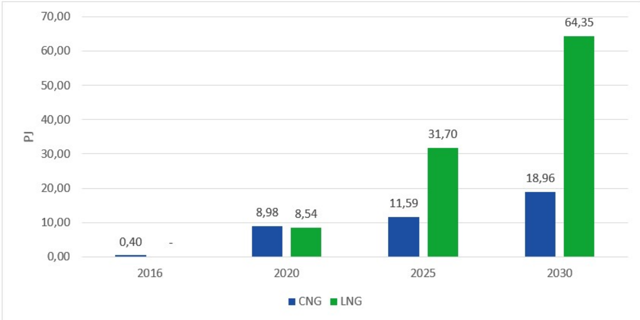

Fig. 9. Natural gas consumption for transport purposes on the basis of the H-scenario, PAN-LNG Chapter 1.4

4.3. Providing LNG Supply

Studying the economic basis of natural gas fuelled transport it can be stated that there will be significant worldwide oversupply of natural gas in the next decade because several new - primarily American and Australian - natural gas producers have entered the market which is not followed by the increase of consumption. The oversupply has appeared in Europe too, as a result of which the European stock exchange price has fallen by 30 percent last year. The supply pressure still exists, so it seems realistic that the price of natural gas remains low in the future too.

The LNG supply will significantly exceed LNG demand in the following decade, which will have three expected effects:

- Thanks to increased LNG commerce, the quotation prices at the gas markets will converge and they are expected to adjust to the exchange with the lowest prices, which is the Henry Hub in America.
- As a result of the latter, the world natural gas market expects a low price environment in the next ten years.
- Finally although the import of natural gas via pipelines will still remain determining, competitively priced LNG will appear at higher and higher proportions in the portfolio of European gas importers which will put long term negative pressure on continental gas prices.

In comparison according to preliminary data, the natural gas consumption of the 28 member states of the EU was equivalent to 16,500 (318 million tons) of LNG. The

European import terminals currently have 7,800 PJ (150 million tons) import capacity so it can be stated that even today close to half of the natural gas consumption of the Union could by fulfilled with natural gas arriving in the form of LNG, which however - in contrast with import via pipelines - could be provided by a really diversified supplier portfolio, not only a few parties. That is why the utilisation of the import opportunities hidden in LNG is also the interest of the EU which is already supported by several communications and strategic decisions at the level of the Commission, like the LNG strategy of the EU *[COM (2016) 49]*.

There are multiple options to procure natural gas for transport purposes. LNG can be procured from the European LNG-reception terminals from which transport to Hungary can be solved by tanker vehicles, on rail or ships; in the latter two cases the receiving infrastructure certainly requires development as well.

The cost per unit of LNG import to Hungary is shown on Diagram 16. Presently the most favourably priced option is transportation from the Polish terminal in road tanker vehicles, which will be implemented at the price of EUR 2.46 / GJ in 2020. Shipping on river also shows favourable transportation costs and the cost per unit is steeply falling however LNG cannot be transferred without constructing the suitable Hungarian service infrastructure. The costs of road transportation grow parallel with the distance and decrease is not expected in the distribution fees per unit due to the relatively mature technology. Presently the shipment of railway is the least competitive with a value over EUR 5 / GJ, which is unable to provide significantly more favourable shipping fees in spite of the expansion of use; economies of scale can only be experienced only in case of shipping in railway tank cars.

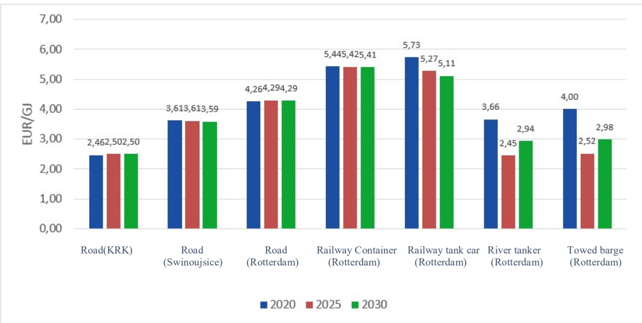

Fig. 10. Average prices of LNG distribution costs, PAN-LNG, Chapter 1.5, 2016

LNG may be produced from natural gas exploited in Hungary, providing a particularly good opportunity because there are several gas fields in Hungary which cannot be economically connected to the national gas system due to their low yield, however the exploited gas may be locally liquefied. Presently there are 1,499 known hydrocarbon reservoirs in 311 fields in Hungary. The experts of the Geological and Geophysical Institute of Hungary collected information on the reservoirs and the fields, most of it is presented in the concession sensitivity loadability study reports prepared for the Hungarian Office for Mining and Geology.

The number of reservoirs assumed to be suitable for LNG production is 421, which are connected to 115 fields. According to the report of the Geological and Geophysical Institute of Hungary (GGIH), there are small and medium size fields containing 342–406 PJ natural gas, which are suitable for the production of natural gas for transport purposes, through which 10 percent of the Hungarian energy consumption for transport purposes may be supplied for 23 years.

The natural gas production from conventional natural gas resources is however continuously decreasing in Hungary. 59.3 PJ natural gas was exploited in Hungary in 2015 covering one fifth of the natural gas consumption of the country. On the basis of the presently available forecasts the natural gas extraction entering the natural gas network will further decrease in the future as the exploitable resources of the currently producing fields are continuously decreasing.

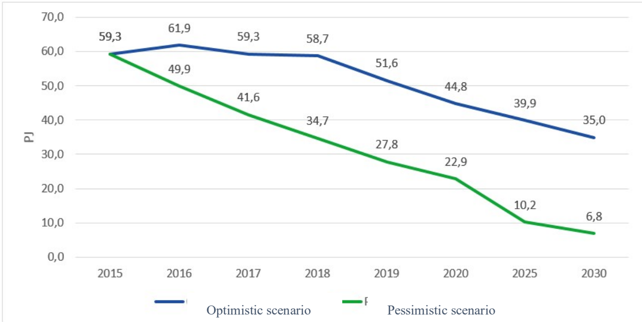

Fig. 11. Natural gas extraction forecast for Hungary, Századvég Economic Research Institute, 2016

The exposedness of Hungary to energy import may be further reduced by the use of biogas resources, nevertheless the carbon intensity of the transport sector may be significantly improved by fuels from biogas resources due to the carbon absorption characteristics of biomethane.

Fuels	Greenhouse gas emission [g CO_{2e}/MJ]
Diesel	89
Petrol	87
CNG–LNG	63–75
Biodegradable part of household waste from treated landfill	18
Degradable part of household waste from biomethane slurry and untreated landfill	–70
Biomethane from energy plant (silage maize)	40
Biomethane from secondary crops	30

Fig. 12. Emission values of Biomethane fuels, PAN-LNG Chapter 1.9, 2016

Biomethane is used in transport for a dual purpose. In case of smaller amount produced, the greenhouse gas emission of the sector may be reduced by biomethane mixed into other

Online: ISBN 978-963-88875-3-5
CD: ISBN 978-963-88875-2-8
Paper 23

Editor: Dr. Péter Tamás

natural gas for transport purposes. In case of larger amounts produced, applying the biomethane without mixing in, the emission intensity of the transport sector can be further reduced.

On the basis of the survey of the Hungarian Biogas Association, there is significant unexploited biogas production capacity in the agricultural sector which was estimated on the basis of three scenarios.

In the pessimistic version the primary energy plants are only grown on 1 percent of the arable land while secondary crops are only grown on 2 percent and all other base material is waste or by product in nature. Only the processing of maize stalks is calculated with in the agricultural secondary product category in the pessimistic version with 10 percent of the capacity.

The medium version is based on the utilisation of 3 percent of the arable land in terms of the primary energy plants while 5 percent is used for secondary crops. In the agricultural secondary product category 1/3 of the presented usable capacity is accounted for in the model.

As opposed to this, the optimistic version still does not contain the maximum potential of the agriculture; here 5 percent of arable land is used for growing primary energy plants for biogas purposes and 7.5 percent is used for secondary crops. In the agricultural secondary product category half of the presented usable capacity is accounted for in the calculation.

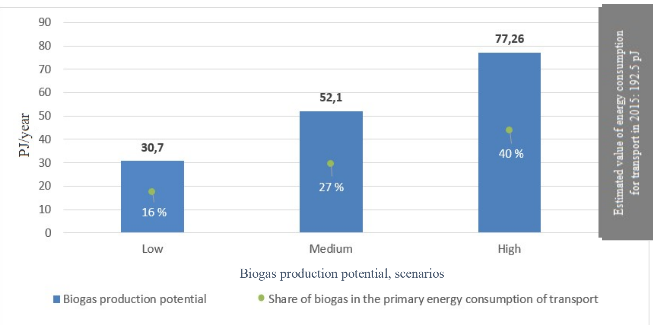

Fig. 13. Biogas production potential in the agriculture, PAN-LNG Chapter 1.7, 2016

In addition to the agricultural sector, there is great potential in the utilisation of wastes from forestry and food industry as biogas. These wastes may play an important role in Hungarian biogas production with an organised waste collection and utilisation program.

The prime cost of biomethane production possibilities examined is between EUR 13.5 and 21.9 / GJ with the following considerations:

- Increasing the plant size (raw biogas processing capacity) results in the decrease of the prime cost of biomethane in each case.
- Converting the existing biogas plants from electric energy generation to biomethane production allows for lower prime cost of biomethane (in the same size range) if the conditions of the conversions are provided anyway.
- The construction of new biogas plants for biomethane production is not a realistic alternative either in terms of capacity or prime cost.
- The conversion of existing sewage gas plants from electric power generation to biomethane production results in seemingly lower prime cost of biomethane than in the case of the existing biogas plants (the main reason for this is that the majority of base materials in the latter ones can only be obtained with extra costs) but complex aspect of the energy supply of sewage treatment plants must also be taken into consideration.

Comparing the prime cost of biomethane route with the price of LNG from import we can calculate EUR 5.5 / GJ, i.e. almost HUF 60 / cubic metre extra cost. Therefore the biomethane route price must be indispensably supplemented or compensated by the regulatory system so that this favourable opportunity from all aspects but primarily due to the need to reduce the CO_2 intensity of transport would become a realistic source of energy for transport.

It can be concluded that domestic biogas and small size, or inert natural gas fields may provide significant sources to supply natural gas for the Hungarian transport sector. The resources of the small and medium size conventional natural gas fields is 152 PJ which may fulfil the natural gas demands at the medium spread level of natural gas fuelled transport for almost ten years, calculating with 10 PJ annual production. Supplemented by the biogas resources with which 30 PJ biomethane may be produced annually from the agriculture only even with a pessimistic calculation, this would allow for fulfilling most of the energy needs of natural gas fuelled transport from domestic sources even in case of high levels of spread.

4.4 Economic and Return Indexes of the Spread of Gas Fuelled Transport

Natural gas fuelled road transport - with a potential preference supported by a governmental decision - in case of the infrastructure network presented in chapter 1.4 of the PAN-LNG Study, may achieve a far greater share than the present. A condition of this naturally is a competitive range of vehicles which has acceptable return indexes for the users in addition to a wide range of models. Assuming that the vehicle buyers decide to procure certain types of vehicles as a result of rational, economic decisions, the reduction of costs arising from their use, i.e. the relative profit is one of the greatest motifs of procurement. The shorter the return time is and the longer one may enjoy the relative profit arising from the potentially lower operation costs, the more buyers the given technology / model will have and the faster the gas fuelled vehicle will get a higher market share.

The infrastructure investment demand required for the supply of the vehicles spreading in accordance with the individual spreading scenarios are presented in Fig. 14., Fig. 17. and Fig. 20.

	–2020	2020–2025	2025–2030
Number of new filling stations [unit]	36	11	120
Investment cost [million HUF]	5,905	1,980	16,800

Fig. 14. The investment demand of the filling station network required in case of L-scenario, Chapter 1.4 of PAN-LNG study, 2016

The monetarisation of the improvement of environmental effects arising from the spread is presented on Fig. 15., Fig. 18., and Fig. 21. Adding the tax revenues and losses constituting the account of the budget to all this, an annual balance can be projected, the annual averages of which for the following twenty years can be seen according to the individual scenarios respectively in Fig. 16., Fig. 19. and Fig. 22.

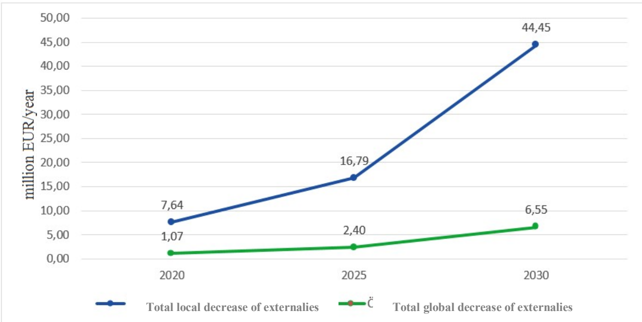

Fig. 15. Decrease of externalities in case of L-scenario, Chapter 1.3 of PAN-LNG study, 2016

Duration 2016–2036 [annual average]	Savings and profit [million HUF]	Lost profit [million HUF]
VAT revenue of CNG and LNG sales	5,329	
Excise tax revenue of CNG and LNG sales	2,785	
VAT revenue loss of petrol/diesel		8,438
Excise tax revenue loss of petrol/diesel		11,238
Annual average of decrease in externalities due to lower air pollution	13,717	
Total	**21,832**	**19,676**
Balance	2,155	

Fig. 16. Budgetary balances in case of L-scenario, Chapter 1.3 of PAN-LNG study, 2016

	–2020	2020–2025	2025–2030
Number of new filling stations [unit]	76	60	141
Investment cost [million HUF]	10,320	10,800	19,740

Fig. 17. The investment demand of the filling station network required in case of M-scenario, Chapter 1.4 of PAN-LNG study, 2016

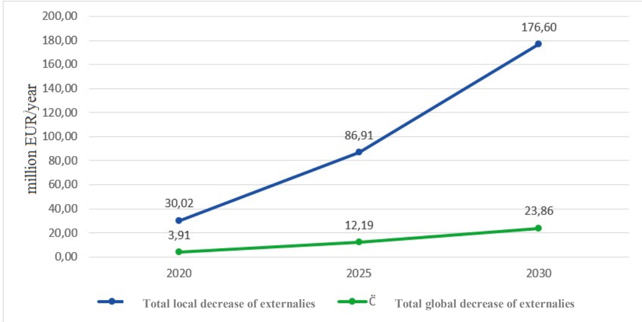

Fig. 18. Decrease of externalities in case of M-scenario, Chapter 1.3 of PAN-LNG study, 2016

Duration 2016–2036 [annual average]	Savings and profit [million HUF]	Lost profit [million HUF]
VAT revenue of CNG and LNG sales	9,221	
Excise tax revenue of CNG and LNG sales	4,821	
VAT revenue loss of petrol/diesel		14,606
Excise tax revenue loss of petrol/diesel		19,453
Annual average of decrease in externalities due to lower air pollution	47,600	
Total	**61,643**	**34,060**
Balance	27,583	

Fig. 19. Budgetary balances in case of M-scenario, Chapter 1.3 of PAN-LNG study, 2016

	–2020	2020–2025	2025–2030
Number of new filling stations [unit]	85	153	62
Investment cost [million HUF]	16,650	27,540	8,680

Fig. 20. The investment demand of the filling station network required in case of H-scenario, Chapter 1.4 of PAN-LNG study, 2016

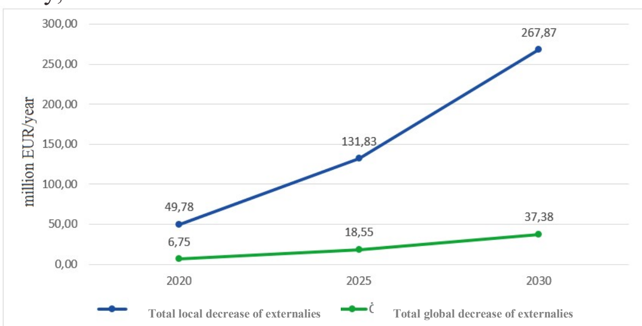

Fig. 21. Decrease of externalities in case of H-scenario, Chapter 1.3 of PAN-LNG study, 2016

Duration 2016–2036 [annual average]	Savings and profit [million HUF]	Lost profit [million HUF]
VAT revenue of CNG and LNG sales	10,722	
Excise tax revenue of CNG and LNG sales	5,608	
VAT revenue loss of petrol/diesel		16,991
Excise tax revenue loss of petrol/diesel		22,629
Annual average of decrease in externalities due to lower air pollution	73,215	

Total	89,545	39,621
Balance	49,924	

Fig. 22. Budgetary balances in case of H-scenario, Chapter 1.3 of PAN-LNG study, 2016

Summarising the data we have reached the conclusion that while L-scenario does not have perceivable economic and social positive results (HUF +2 billion / annum on average), the M-scenario bas HUF 27.5 billion and the H-scenario has HUF 50 billion on annual average for the Hungarian society and domestic economy.

4.5 Methods of Spreading Gas Fuelled Transport

We have concluded that gas fuelled transport has significant benefits against traditional fuels (petrol, diesel), nevertheless they may play a significant role in the alternative transport structure since they are easily and successfully applicable in all types of vehicles and fields of use. The latter advantage of gas fuelled transport is particularly important, since the alternative transport mode currently supported in Hungary at system level, i.e. electric energy based transport can primarily be used in individual urban transport without significant compromises. Due to these reasons, the support of the gas fuelled transport is the interest of Hungary.

On the basis of international experiences, gas fuelled road transport can be successfully spread if the procurement of vehicles, the fuel as well as the filling infrastructure are supported. In our research we modelled the effect of providing excise tax benefit on the procurement of CNG and LNG fuelled vehicles, on the basis of which it can be stated that this single incentive system is not effective alone and it needs to be supplemented by other supporting systems. On the basis of this we recommend:

- The provision of excise tax benefit in case of CNG and LNG fuels in the fields of use, where diesel oil currently has excise tax benefit;
- The exemption from excise tax for biomethane from certified biogas sources;
- Similarly to plug-in hybrid vehicles, CNG or LNG fuelled vehicles should also enjoy the benefits of using green registration numbers;
- The support of procurement costs in different vehicle categories;
- Exemption from road tariffs for natural gas fuelled heavy vehicles and buses;
- Assignment of zero, or close to zero emission urban zones;
- Extra support of government or municipal gas fuelled buses and fleet procurements;
- Facilitating the support of fleet procurements for market players from resources from Brussels (e.g. LIFE program).

5. PROPOSALS

Due to its undisputable advantages we suggest that the support of natural gas fuelled road transport shall be named János Csonka Plan (Csonka János Terv) (JCsP) after the great Hungarian inventor and automotive industry professional. The JCsP jointly with the Jedlik Ányos Program facilitating electric car use may successfully ensure the implementation of alternative transport in Hungary, and through its horizontal effect - for example boosting domestic engineering industry, automotive industry and bus production - it may be one of the engines of the reindustrialisation of the country.

It is important to highlight that the development possibilities can be determined at the level of regions within the János Csonka Plan. The use of biogas from agriculture for transport purposes on the Kisalföld and the Alföld may provide a development opportunity meeting local needs. In the Southern region of the country, the coal resources of the Mecsek may provide an excellent opportunity to procure natural gas from domestic resources, while the production from the small size and inert natural gas fields in the Eastern regions of the country may balance the negative production trends seen in the industry. These regional development opportunities may serve as the bases of international cooperations.

Following the vehicle design work of János Csonka, Hungary could further strengthen its role in motor vehicle and engine manufacturing by becoming committed to natural gas fuelled vehicles and transport. A system-level strategy, in which Hungary greatly emphasises natural gas fuelled passenger car transport within the alternative transport sector - utilising the health care advantages of the technology - is a strong message for manufacturers about the commitment to the technologies determining the future of transport. The programs facilitating the domestic development of gas fuelled transport may be determined and implemented in the János Csonka Plan, serving as the basis of the further development of motor vehicle and spare parts production as well as the establishment and development of other related green industry, energy technologies.

The research, development and innovation (R&D&I) process is an essentially important part of the automotive industry, however the production of vehicles is only a part of this. Since the transport of the future - including gas fuelled transport too - must fit in energetically sustainable systems there are several development possibilities related to gas fuelled transport, which are aimed at the long term, sustainable use of biogas, natural gas and hydrogen.

Power-to-Gas technology producing synthetic natural gas by the absorption of CO_2 from the excess electric energy of the renewable energy sources is a remarkable development opportunity. Intensifying biogas production has positive effects in rural development in addition to the engineering industry, or even as a clear coal technology the utilisation of the Hungarian coal resources in natural gas production. These routes open new and returning R&D&I areas for Hungarian universities and the already established cooperation with the automotive and the energy sectors, since the development areas have global relevance.

The construction of LNG infrastructure may attract the development of engineering industry background capacities similarly to the CNG. The widespread distribution of the product to be launched by Clean Fuel Box project, the fuel box may serve as the first major element of this. In addition to this an effective construction and service background is also needed. All this may result in the development of significant engineering skills, which may serve a stable market demand in the next ten to twenty years in Hungary as well as in the neighbouring countries.

The production of several automotive components may be started in the János Csonka Plan which may result in significant export performance. One of the identified development targets is for example the production of cryogenic tanks which may result in the generation of a yet missing capacity on a new European market; with a wide, even billion Euro future market potential in case of preparation and start-up in the right time. The favourable situation cannot be ignored that the two determining companies producing fuel supply systems have strong production capacities in Hungary. Both Bosch and Delphi are intensively developing the natural gas injection systems of the future which will result in more efficient engines in the following years both in light and heavy motor vehicles. Hungarian plants may produce millions of pieces of the highest standard parts of the internal combustion engines in the near future.

It is determining, that the engine factory of Audi after four years of development in Győr will produce from autumn one of Europe's and perhaps the world's currently most modern light category gas engines which will be first built in the A4 model than it might be used in several other models of the company, generating significant turnover for Győr. This process will hopefully take place in the Opel engine factory in Szentgotthárd too (where the diesel scandal causes problems like in Volkswagen).

The development of the LNG fuelled Ikarus bus started in the PAN-LNG project is a remarkable step towards making bus manufacturing significant in Hungary again. Thanks to its innovative nature, Ikarus may play a determining role again in the European market of urban, intercity or even long distance buses.

The pilot action implemented in the PAN-LNG-4-Danube Project allows for the implementation of clear gas fuelled operation in river shipping an then on the railway too. This project can be widened in the János Csonka Plan. Most of the existing ships require mechanical modernising which may be performed with a support program. In order to build in higher numbers of gas engines, concurrently the ship repairing and ship manufacturing capacities need to be partly revived.

Moreover, the János Csonka Plan is a means of establishing international cooperations too. Under Directive 2014/94/EU the LNG infrastructure supplying transport must be developed taking the cross border effects into consideration. The Directive required the construction of the LNG distribution infrastructure, where the utilisation of cross border opportunities is particularly important in the Eastern-Central-European region where the vicinity of the countries gives reason for the development of common infrastructure. Under the János Csonka Plan Hungary can become committed to the importance of LNG fuelled transport, with the help of which, Hungary may also become the LNG supplier of the neighbouring EU member states for transport purposes.

At the same time several international cooperations can be developed in relation with its procurement sources of natural gas with which the natural resources reaching over the border of the country may be exploited even better for the supply of natural gas for transport purposes. Such regional cooperations may fit into the development of given transport corridors, which may be identified between the important regional centres of Hungary (Miskolc, Győr, Debrecen) and the large cities of the surrounding countries (Osijek, Oradea, Košice, Bratislava). International cooperation may be especially important in LNG infrastructure since the technology may primarily replace petroleum based modes of transport therefore there may be demand for cooperation for joint development in the Carpathian Basin.

REFERENCES

The literature used in the present publication was prepared on the basis of the study chapters of the PAN-LNG Project. The technical literature used in compiling the chapters of the study were listed by items in the List of References of the PAN-LNG study.

Nyerges, Á. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study, Chapter 1.1. Arriving vehicle technologies in the transport sectors, issues of competitiveness. Page 154 HGTCA, Budapest

Pénzes, L. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study, Chapter 1.2. Potential consumers of bio and natural gas fuel, expected consumption patterns. Page 145 HGTCA, Budapest

Csonka, A. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study Chapter 1.3. External and Other Favourable Effects of the Spread of Gas Fuelled Transport Page 96 HGTCA, Budapest

Telekesi, T. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study Chapter 1.4. Distribution of Required Filling Infrastructure Taking the (CNG/LCNG/LBG) Division of the Technology into Consideration. Page 145 HGTCA, Budapest

Dr. Tóth, J. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study Chapter 1.5. LNG Distribution Capacity. Page 93 HGTCA, Budapest

Zarándy, T. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study Chapter 1.6. Potential Import Procurement Sources of LNG. Page 94 HGTCA, Budapest

Dr. Kovács, A. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study Chapter 1.7. Biogas Sources of Potential LNG Production in Hungary. Page 190 HGTCA, Budapest

Zarándy, T. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study Chapter 1.8. Natural Gas Sources of Potential LNG Production in Hungary. Page 292 HGTCA, Budapest

Dr. Bártfai, Z. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study Chapter 1.9. Available Technologies for Potential LNG Production in Hungary. Page 216 HGTCA, Budapest

Zarándy, T. and associates, leader of study Domanovszky, H., (2016). PAN-LNG Study Chapter 1.10. Study on the Regulatory and Incentive Environment of the Spread of Bio- and Natural Gas Based Fuel Page 94 HGTCA, Budapest

Domanovszky, A., leader of study Domanovszky, H., (2016). PAN-LNG Study List of References. List of technical literature used and revised in preparing the chapters of the study. Page 65 HGTCA, Budapest