IBP1191_17

LNG AS A SUSTAINABLE ALTERNATIVE FUEL FOR HEAVY GOODS VEHICLE TRAFFIC IN GERMANY

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Abstract

The mobility has to reduce the fossil CO_2-emissions because of the government's targets. Therefore a first step could be the use of LNG in the sector heavy goods vehicle traffic. A second step could be the substituting the fossil LNG by renewable gases as biogas and SNG from power-to-gas process. In comparison to diesel the reduction potential of $CO_{2,equi}$ emission of an optimized process chain for LNG is approx. 30 % in first step. The second step can lower the $CO_{2,equi}$ emission to nearly zero.

Another advantage of LNG is the reduction of the traffic-related pollutant emissions noise, particles and NOx. In a first estimation, reduction potentials of > 37 % for NO_x emissions and approximately 43 % for noise emissions (by both passenger cars and HGV) seem feasible. Traffic-related particulate matter emissions (caused by passenger cars and HGV) could possibly be reduced by about 14 %.

The effort for the infrastructure is manageable. Only 40 fuel stations are necessary to guarantees a minimum of supply for heavy goods vehicle traffic in Germany.

In summary, it was demonstrated that LNG as a fuel is a viable alternative to diesel fuel for HGV traffic requiring a comparably small investment in infrastructure while bearing a significant potential for carbon dioxide, nitrogen oxide, and noise emission reduction. Regarding the decarbonization, the change to LNG as a fuel is sustainable as its fossil fraction is fully substitutable by biogas and other renewable gases.

1. Introduction

Globally, LNG (liquefied natural gas) is regarded as an alternative to conventional liquid fuels for road goods transportation. In Germany and Europe, LNG from fossil sources could furthermore serve as interim solution for the transition to a decarbonized European transport sector, without requiring large investments in additional infrastructure. Even the German government's targets of a 95 % $CO_{2,equi}$ emission reduction could then be achieved without a system change by fully substituting the fossil LNG by renewable gases, especially if considering SNG (substitute natural gas) from biomass and power-to-gas processes.

HGV (heavy goods vehicle) traffic of gross vehicle weights greater than 12 metric tons accounted for approximately 45 % of the domestic diesel fuel consumption for road transportation in Germany in 2015 [1, 2]. 2015's mileage is expected to increase by 50 % [1] in the future thus preventing total emission reductions despite an expected increase in efficiency. In the light of $CO_{2,equi}$ emission targets, absolute $CO_{2,equi}$ emission reductions will have to be achieved in all sectors. This requires a paradigm change towards fuels with low carbon content such as LNG/CNG and/or substantially more efficient vehicle technologies. Moreover, improvements regarding particle, nitrogen oxide, sulfur and noise emissions are also mandatory, especially but not only in metropolitan areas. Road construction measures (e.g. noise protection) in combination with notable engine improvements (e.g. exhaust after-treatment) or the drafted fuel substitution might be able to contribute to achieving these targets.

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2. LNG's reduction potential of traffic-related pollutant emissions (noise, nitrogen oxides, particle matter)

Implementing LNG technology for HGV transportation and CNG (compressed natural gas) for other freight and passenger transportation could lead to substantial improvements regarding traffic-related pollutant emissions. In comparison to the most recent diesel engine generation, which surpasses even the Euro VI emission restrictions, emissions could potentially be reduced by 23 % (NO_x), 92 % (particle matter), and 50 % (noise), respectively (Figure 1). Because of the advantageous combustion properties of LNG and CNG, these improvements are likely to be achieved through less technical effort in comparison to diesel engines.

Freight haulage is likely to be responsible for 47 % and 41 % of traffic-related noise and NO_x emissions, respectively [18 - 22]. As few as 51 % of the HGV that are under way in Germany comply with Euro V standard, even 33 % do not outmatch Euro III standard, according to Germany's Federal Motor Transport Authority. Concluding these findings, in a first estimation, reduction potentials of > 37 % for NO_x emissions and approximately 43 % for noise emissions (by both passenger cars and HGV) seem feasible. Traffic-related particulate matter emissions (caused by passenger cars and HGV) could possibly be reduced by about 14 %.

Considering the more advanced technical maturity of diesel engines in comparison to gas engines, it can be estimated that the emission reduction potentials of gas engines will further increase in the future

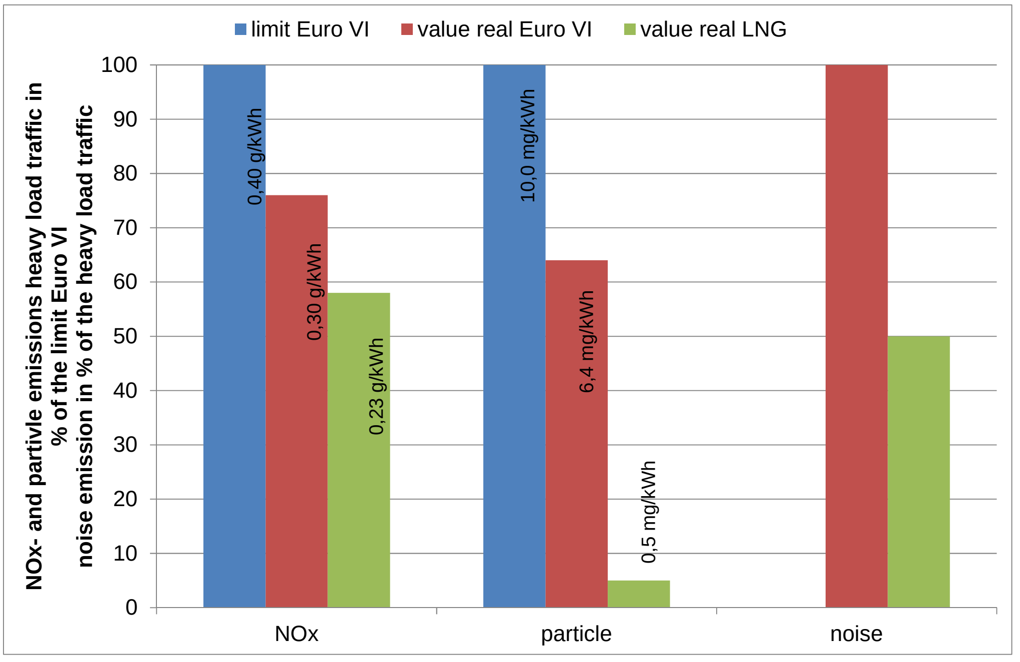

Figure 1: Reduction potential of diesel and gas engines compared to Euro VI limits [15 - 17]

2.1. LNG's reduction potentials of traffic-related GHG (greenhouse gas) emissions

LNG, which is essentially methane, has a 25 % lower carbon fraction compared to diesel fuel. Despite the currently higher specific energy demand of gas engines, LNG vehicles have considerably lower specific carbon dioxide emissions. A comprehensive approach, however, has to consider the process chain from pre-processing the natural gas after the extraction to the fuel provision at a gas station (well-to-tank). Amongst others, the energy required for transport and liquefaction or compression, respectively, in terms of its associated CO_2 emissions as well as the methane slip during transportation and handling, were taken into account. As an example, two optimized process chains for the LNG supply from fossil gas were evaluated with respect to energy demand and greenhouse gas emissions (figure 2).

In scenario A ("maritime vessel"), natural gas is liquefied near its wellsite and the produced LNG is then transported by ship to Europe over a distance of 10 000 km (e.g. from Trinidad or the USA). For scenario B ("pipeline"), natural gas is transported 5 000 km from the well (e.g. in Russia) to Europe by pipeline; the liquefaction process is set up in Europe near the point of use. All relevant process and transport steps from the natural gas extraction to the LNG consumption in a gas engine are taken into account for both scenarios.

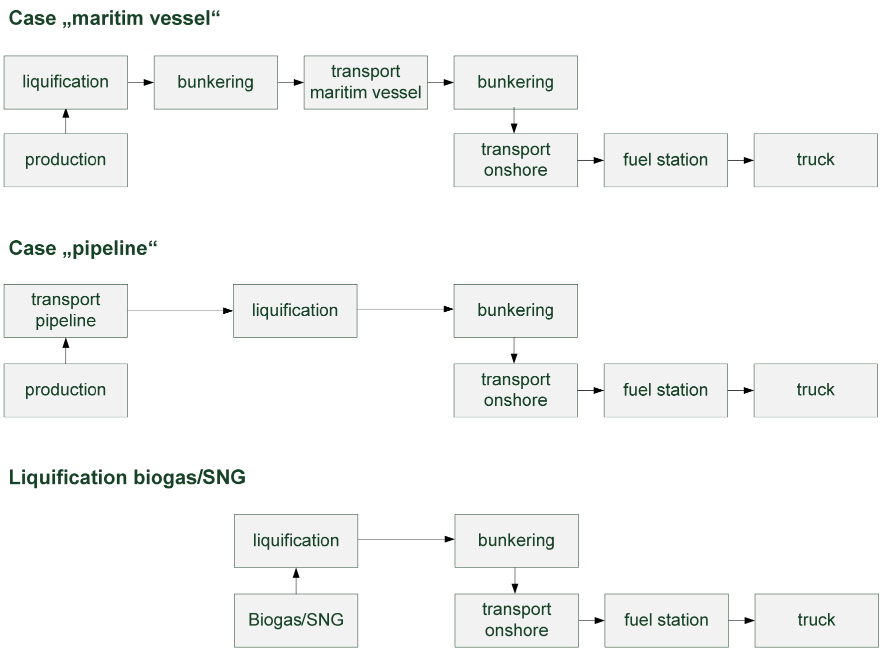

Figure 2: Evaluated process chains for scenario A and B

The following three measures to further reduce the fossil carbon dioxide emissions have been considered:

1) Substitution of a certain fraction of natural gas by biogas or renewable SNG
2) Utilization of waste heat (nearby industry or space heating)
3) Liquefaction using renewable electricity

In principle, these arrangements are considered possible for all LNG production site locations. However, at first they are expected to be realized in Europe. Hence, for scenario A (“maritime vessel”) only the partial substitution of biogas for NG (natural gas) in Germany has been evaluated while for scenario B (“pipeline”) all three decarbonization approaches have been studied (Table 1). These logistic chains were then compared to two state-of-the-art processes, a conventional LNG process chain with maritime transport and a diesel process chain, both taken from JRC’s technical report on future automotive fuels. [45].

The specific GHG emissions for the evaluated process chains were calculated from the specific GHG emissions for the individual process steps listed in table 2 [16, 23, 24, 50-64] and the specific fuel demand for LNG HGV and diesel HGV of 0.29 kg/km and 0.3 L/km, respectively [46 - 49] (Figure 3).

The adjusted process chains P0 and S0 have the potential to reach GHG emission reductions of 13 % and 19 %, respectively, compared to RLNG [45].

These advantages largely date from the assumptions that modern and highly efficient plants and maritime vessel are being used. The reduction potential compared to diesel could be as high as 30 % (process chain RD [45]). The benchmark LNG process chain (RLNG) reported in [45] shows a possible GHG reduction of approximately 14 % compared to diesel (RD). The additional substitution of 50 % of the fossil LNG’s energy content by LBG (liquefied biogas) as in P1 and S1 leads to a GHG emission reduction of up to 64 %. The gradual replacement of fossil LNG by biogas or renewable power-to-gas SNG does not require adjustments for the transport vehicles or the distribution infrastructure. Hence, gradually increasing the share of renewable gases does not lead to additional investments for the process steps distribution and usage.

Table 1: Evaluated scenarios with and without measures for GHG emission reduction

Scenario	ID	LNG composition	Production of LNG/LBG and SNG in Germany	Measures for $CO_{2,equi}$ emission reduction	
				Ratio of waste heat utilization	Liquefaction with renewable electricity
Pipeline without any measures for GHG reduction	P0	100 % NG	yes	-	no
Pipeline with measures for GHG reduction	P1	50 % NG 50 % biogas	yes	20 %	yes
Maritime vessel without any measures for GHG reduction	S0	100 % NG	no	-	no
Maritime vessel with measures for GHG reduction	S1	50 % NG 50 % biogas	NG: no biogas: yes	NG: no biogas: 20 %	NG: no biogas: yes
LNG Benchmark [45]	RLNG	100 % NG	no	-	no
Diesel Benchmark [45]	RD	100 % diesel	-	-	-

Table 2: Specific GHG emissions (CO2,equi) of the individual process steps [16, 23, 24, 50-64]

	Reference to	Unit	Value
Natural gas production	LNG	g/kWh	2.5
Large-scale Liquefaction	LNG	g/kWh	15.2
Maritime transport LNG	LNG	g/kWh	9
Pipeline transport natural gas	LNG	g/km/kWh	0.005
Small-scale Liquefaction	LNG	g/kWh	45
Wind power production	Strom	g/kWh	15
Biogas production from waste	Biogas	g/kWh	22
SNG from wind power	SNG	g/kWh	27.3
LNG usage in HGV	LNG	g/kWh	198.5
Diesel usage in HGV	Diesel	g/kWh	266.7

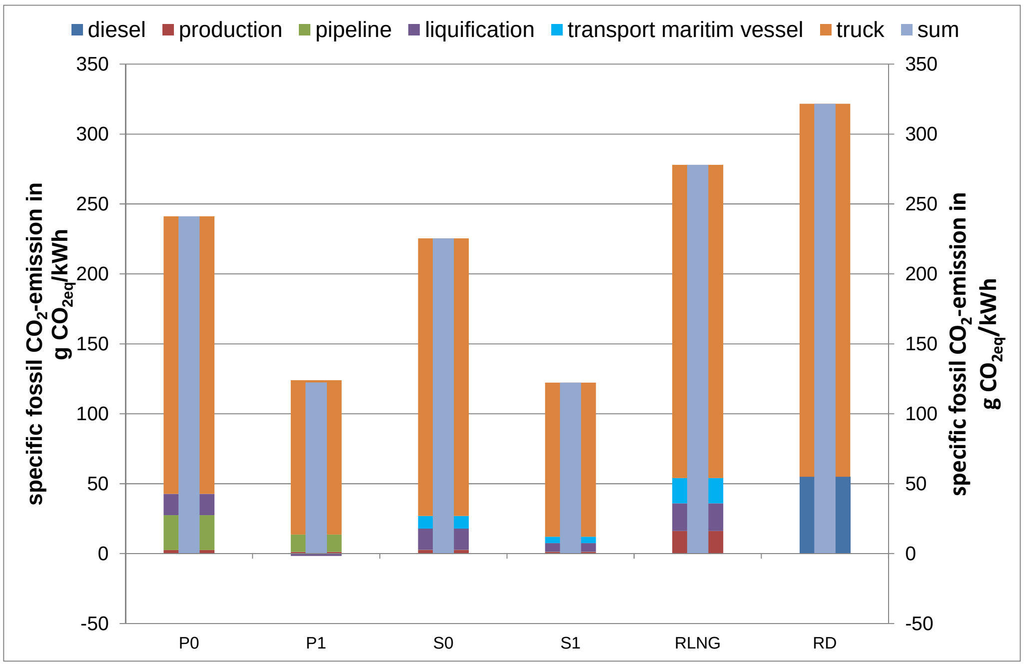

Figure 3: Specific GHG emissions of evaluated process chains

3. Infrastructure

The existence of the required infrastructure is essential for a successful commercial launch of a new technology. In a first step, the following constraints for the gas station infrastructure had been defined:

- maximum distance of five kilometers between gas station and transport routes or distribution centers
- consideration of gas stations in border zones
- maximum distance of 400 kilometers between domestic and international gas stations for HGV traffic
- maximum distance of 100 kilometers between domestic and international gas stations for regional transport traffic
- integration of inland ports into infrastructure

Then, relevant data regarding on-road traffic flow, distribution centers, LNG transport routes, and motorway service stations was geotagged and evaluated to identify possible locations for gas stations and the mandatory number of gas stations. From the potential locations that fulfill these constraints, a minimum gas station infrastructure was derived.

A number of six gas stations fulfill the pre-defined criteria for HGV traffic. To additionally satisfy the requirements for the regional transport traffic, further 34 gas stations are needed (Figure 4).

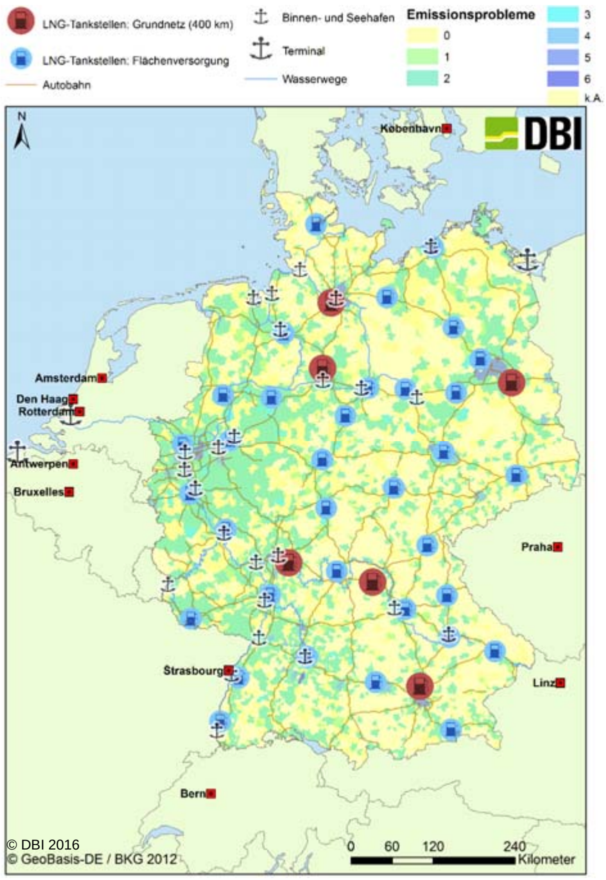

Figure 4: Potential locations for LNG gas stations in Germany

4. Conclusions

As an alternative to diesel fuel, LNG (liquefied natural gas) even without any addition of renewable gases leads to a reduction of 30 % in equivalent carbon dioxide emissions. If the entire HGV (heavy goods vehicle) traffic in Germany switches to LNG, approximately 14 million tons of fossil carbon dioxide emissions could be avoided. The short-term substitution of biogas and methane produced by power-to-gas processes in the long run for fossil LNG is rather simple from a technological point of view. Lowering the particle emissions that are directly related to on-road traffic by approximately 14 % and the nitrogen dioxide emissions even by ca. 37 % compared to diesel fuel is a significant advantage. The traffic-related noise level of gas engines is approximately 43 % lower than for diesel engines. Implementing only six gas stations that are accessible from the main highways allows tapping this potential for the HGV traffic in Germany. Building another 34 gas stations nationwide guarantees a minimum supply for regional transport traffic. These measures allow a prompt contribution to reaching the government's target of decarbonizing the mobility sector.

In summary, it was demonstrated that LNG as a fuel is a viable alternative to diesel fuel for HGV traffic requiring a comparably small investment in infrastructure while bearing a significant potential for carbon dioxide, nitrogen oxide, and noise emission reduction. Regarding the decarbonization, the change to LNG as a fuel is sustainable as its fossil fraction is fully substitutable by biogas and other renewable gases.

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