LNG DIRECTLY TO CUSTOMER STATIONS

Vaclav Chrz
Manager Engineering Technology
Chart Ferox, a.s.
Decin, Czech Republic
vaclav.chrz@chart-ind.com
www.chart-ferox.com

Claus Emmer
LNG System Product Manager
Chart-Ind., Inc., D&S Division
Minnesota, USA
claus.emmer@chart-ind.com
www.chart-ind.com

ABSTRACT

This paper analyzes technology and economy of direct distribution of LNG, with main emphasis on shore distribution from marine terminals. The results of the economical study are presented as quantities of LNG, economically transportable on the road in comparison to gas pipelines, as a function of distance and pipeline cost category. It was found, that economically transportable quantities are much larger than any project reported by now.

It is specifically advantageous to deliver LNG directly to LNG and LCNG vehicle fueling stations, because of additional advantages of using LNG instead of gas from pipelines for vehicle fueling. It can be recommended that LNG transport option and LNG distribution market potential would be analyzed with each future project of the LNG terminal and the distribution strategy. The technology is documented on existing products and projects in operation, covering LNG trailers, satellite plants and vehicle refueling stations.

INTRODUCTION

Most of natural gas transport in excess of 3000 km is in the form of LNG as a cryogenic liquid to marine terminals, where it is compressed as a liquid, vaporized, and put into overland distribution pipelines. The potential of direct deliveries of LNG to end-users is still in its infancy, but dramatic increase is reported in several parts of the world. In Europe, requirements from Norway resulted in design of very large vacuum insulated tanks and trailers. Currently, more thirty satellite stations are in operation in Norway, ten in Poland, and more than 60 in Turkey. The extensive use of satellite stations is also found in the United States, where they are primarily used for supplemental supply of gas to existing pipeline networks during peak demand. At least one town is supplied entirely with LNG, vaporized and feeding a local town pipeline net. Further growth is limited by local availability of LNG, but new sources are in process of construction or project preparation. Other projects are in operation in China, Australia, and the USA. Authors' estimate is that there is a market opportunity for up to 20% of LNG to be transported from LNG terminals by road, rail or coasting to satellite stations for energy purposes and even more, after the use of natural gas for vehicles is further developed. The ratio can be much larger in countries, where pipeline infrastructure is not developed.

WHAT IS DRIVING DIRECT ON-SHORE DISTRIBUTION OF LNG

After Liquefied Natural Gas (LNG), is unloaded at the large marine terminals, it is generally vaporized at the site and transported by long distance pipelines to regional distribution systems. After pressure reduction in several stages into local pipelines it is brought to end users. These systems typically do not deliver gas to all the potential users. Scattered population, isolated settlements and factories and geomorphologic hurdles often make building of pipelines for low demand not economical. But such opportunities represent an important segment of market. Supply of gas to these potential users can be ensured by direct LNG distribution with mobile equipment like road trailers, barges, ISO containers or smaller delivery units. This market is currently served by truck transport of propane, fuel oil, naphtha, etc.

Direct LNG distribution systems were in use by the end of 20th century in the USA and they they have started to rapidly develop in Norway, Spain, Portugal, Poland, Russia, India, China, and Australia, just to mention a few examples.

Distribution of LNG by road is used in cases where the existing pipeline grid is either incomplete or under undercapacity/ For example, in the US the mountain town of Jackson is completely supplied by LNG transport in volumes in excess of 1,000 tons per month. There are a lot of tanks along the pipeline net that feed gas into pipelines when they are overloaded during peals in the east coast of the US.

Another reason of distribution of LNG is exploitation of small scattered sources of natural gas. Capacity and limited lifetime of small wells and biogas sourced cannot justify building of pipelines for bringing gas to places of potential consumption.

Liquefaction and road transport is the only possibility of economical use of these wells and biogas sources. As some of these sources produce only low-quality gas with high content of nitrogen, nitrogen rejection purification is required. This is a cryogenic process and methane has to be liquefied as part of the process.

Although it is possible to produce high pressure gaseous methane from the plant and to deliver it further in pipelines, there is minimum capital and energy addition for production of LNG from these plants, and further distribution can be lower cost for liquid within wide range of distances and quantities. An example of this system is the nitrogen rejection plant at the Polish company KRIO, which by the way recovers also helium from the well gas. The plant was built in 1970 for nitrogen rejection from a gas with nitrogen content 50%. It produces very pure methane compressed by internal liquid pumps to 50 bar into long distance pipeline. There was no direct LNG distribution until the year 2002, when it was identified that the reserves of the heat balance of the plant make liquefaction economical to produce 50 ton/day capacity for the LNG distribution with trailers. Since then, ten satellite stations were built in distances up to 150 km, mostly for heating systems in smaller towns. This example is driving further projects of building liquefiers in Poland.

In case that local gas liquefaction is considered for distribution purposes, the quality of gas to be liquefied is important. Nitrogen on one side and heavier hydrocarbons on the other side, are typical impurities in natural gas and they require separation or cleaning equipment. require. In case, that gas in pipeline, delivered from marine terminals or from the nitrogen rejection plants is available, it is the most advantageous option, because these sources offer the most clean gas and this way a great portion of costs can be saved on front purification part of the plant or thanks to simple liquefaction process.

Another reason for implementation of LNG distribution systems instead of pipelines, as indicated by the Russian company Lentransgas for the case of the St. Petersburg area, is the presence of complex underground infrastructure and complex structure of private properties in cities and suburbs making it inordinately expensive or complicated to build a pipeline system. Consequently, further conversion of local heating centers (boiler plants) in St. Petersburg suburbs is based on LNG only. Another advantage of these systems is that LNG supplied heating centers don’t need special back up operating modes, such as one based on heating oil, e.g., as at classic pipeline supplied boiler plants. The LNG storage makes the back-up itself. This eliminates the need for complex dual fuel systems at the plants. Further, LNG can be delivered as back up to existing pipeline supplied gas heating centers, which is simpler than dual fuel systems.

VIRTUAL PIPELINE

Direct on shore distribution can work as equivalent to real pipeline; this is why Emmer [1] proposed the term Virtual Pipeline for the system, starting by liquid storage, trailer filling interface, transport by trailers on the road and unloading liquid into a satellite storage and vaporization station. Gas is delivered to a process technology (metallurgy, pulp and cellulose, e.g.) or to a local network, typically within a town. Trailer filling interface (Fig. 1) consists typically from a weighbridge, on which the trailer can be filled precisely to the maximum allowed filling, which according to ADR regulation is 95% of gross volume, when the LNG is saturated at the maximum allowed pressure of the tank, which is typically in the range 4 to 7 bar. Other codes allow different filling levels. Vacuum-multilayer insulated tanks have typical holding time (without venting of vapor) up to 80 days when filled with LNG saturated at atmospheric pressure. Unloading of the trailer is done with a pump, spraying cold liquid to the top of the satellite station tank and this way condensing the vapor in the storage tank. The whole system, if properly planned, is fully vent-less.

Most efficiently the LNG is transported on the road in semitrailers pulled by standard ADR trucks. The capacity of the semitrailer depends on local regulations.

Figure 1. Trailer filling interface with four bays.

Chart Ferox a.s., manufactured trailers according to Norwegian regulations (Fig. 2.) with a volume of 56 000 liters (which corresponds to 21300 kg or 31300 Sm3 of gas), but for most of the European states the 40 ton gross combination weight would result into 51 000 liter gross volume. Other Chart sites manufacture to DOT, AS01210, etc.

Consider possible capacities of virtual pipelines: A continuous chain of trailers, with 12 km between each other on a road at a speed of 60 km/hour have, independently of distance, a transfer capacity 1,5 billion (10^9) Sm3/year. This means sending off 120 trailers/day. Number of fill connections at the marine terminal needed would be as minimum six for continuous operation. Is the economy of such a trailer “pipeline” better than a 1250 mm pipeline? This we will analyze in the next paragraph.

Figure 2. LNG semitrailer 56 000 liter, 7 bar MAWP

Another transport option is using tandem trailers, ISO containers. 20’ ISO containers are available for smaller projects. For large projects, 40’ ISO containers are the optimum size, with a capacity of 43 m3. Large deliveries can be also ensured by trains of rail cars. In USA, railcars with capacity 76 m3 are in operation on ethylene, but their use for LNG is also possible.

A 500 km long virtual pipeline has been built in India, delivered by Chart E&C and Ferox. Five LNG trailers will be delivering LNG to a satellite station with a 210 m3 storage capacity. A 4400 km long virtual pipeline is in operation in China, transporting

LNG from the Gobi desert to the eastern coast (Dong [2]). The LNG from a Linde liquefier with a capacity 1300 ton/day is transported by up to 100 vehicles, partly trailers and partly trucks with 40'/40m3 containers of domestic manufacturers into 24 satellite stations. Example storage capacity of one of the receiving satellite stations is 1200 m3. The system includes also fueling of municipal busses and distribution in little containers for heating individual houses.

THE ENERGY CONSUMPTION OF THE LNG ON SHORE DIRECT DISTRIBUTION SYSTEMS

In general, it can be stated, that smaller quantities of LNG can be delivered with road trailers instead of building new pipelines. Authors analyzed the problem for a case, when LNG is available at the source site as stored in the LNG marine tank.

Let us first pay attention to general energy relation of this medium distance transport (considering long distance to be intercontinental pipelines or intercontinental sea transport.)

For comparison of various options of the LNG or pipeline systems authors [3] introduced the concept of primary energy consumption, expressed in % of the gas transported. Combustion of gas is used for vaporization with 100 % efficiency, while in the truck engine gas (or gas equivalent fuel) is used with efficiency 40%. Also electricity is transferred from gas consumption with 40%.

Primary energy consumption for an example distance 500 km results:

Pipeline: gas compression by liquid pump 0.1%, vaporization 2,0%, pipeline transport recompression 0,86%, Total 2,96%

Trailers: engine fuel 1,68%.

We can reasonably presume that rail and barge distribution needs much less fuel.

ECONOMY OF THE VIRTUAL PIPELINE COMPARED TO A REAL PIPELINE

Two ways of LNG getting to the customer were compared:

a) Gas pipeline:
- LNG compressed by liquid pump to 50 bar
- LNG vaporized by hot water heated by combustion of part of the vaporized gas (2%)
- Gas transported by a pipeline, pressure drop 7 to 10 bar per 160 km (defines pipe sizing).
- recompression stations placed in distances 160 km.
- gas pressure reduction station placed at the customer end.

b) LNG trailers:
- LNG transported by a pump to a trailer with 4 bar difference.
- Trailer driving on the road, distance 20% longer than pipeline.
- unloading LNG into a tank at the customer satellite station.
- LNG withdrawal, vaporization in an ambient vaporizer.
- odorization and pressure reduction from 4 bar to 2 bar, e.g.

Capital and Operational expenditures were totalized for each case.

Range of distances was 160 to 1440 km.
Range of total gas flowrates was from 1000 to 100 000 kg/hour.
It should be understood, that the comparison is done for a single pipeline and for a single direction of road transport respectively.
Several possible directions from a single marine terminal can be taken into account.
Depreciations from CAPEX was presumed 8%, while it was 16% for trailers. Prices of LNG equipment were used from up-today pricing by the end of 2006.

The most difficult part of the problem is identification of the price of the pipeline as a function of the capacity. First, seasonal variations of the capacity have to be taken into account. Based on a histogram of a yearly consumption of a concrete town, the presumption was done, that when the winter maximum is 100%, the winter average is 67% and the summer average is 33%. As a result, the average yearly flowrate is 50% of the pipeline capacity. When the pricing of the pipeline system was analyzed based on literature [4] an internet search [5] and, a great variance of price per km was found (Fig.3), caused probably by different, incomparable conditions of particular projects. Short pipelines have higher unit price, which may be caused by influence of accessories at the beginning and end, and also by the fact, that shorter pipeline projects relate mostly to industrial and heavy populated areas, where the pipelines are much more expensive, as reasoned in the Chapter 1 above. For each correlation of the cost of the pipeline an economical comparison of the capital and operation costs of each system (a) and (b) was done for the given ranges of distances and flowrates.

Break-even flowrate, at which the costs of both the systems are the same, was identified for each distance. The results are plotted in the diagram in the Fig. 4. When we used a function, which follows medium values of the variance of the range of the data gathered (the Medium cost curve), presumably good for the long distance projects, the comparison ended up with a conclusion, that for distances like 400 km there is no reason of building pipelines of such a capacity and more than 100 trailers/day (2000 ton/day) can be sent to each direction. For long distances, over 1500 km, the economical flow is still 60 trailers/day as convergent value for very long distances (see Fig. 4., curve B). This means, that the whole throughput of a marine terminal in amount 7500 ton/day, e.g., could be transported to four different directions by road trailers only, with economy comparable or better than that of Medium cost pipelines. In case of High cost pipelines, it was found, that road transport should have always preference before pipeline to any distance and for capacities 3 to 5 billions kg/year (see Fig. 4., curve A).

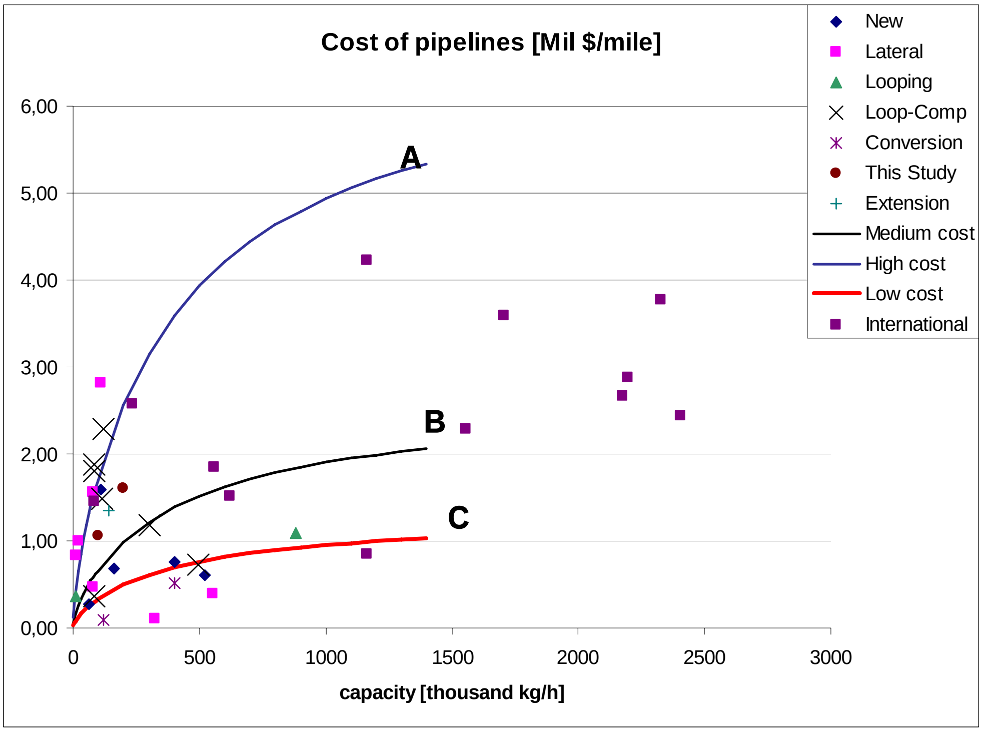

Figure 3. Plotting of pipeline price:

US domestic projects, Tobin [4]
International = Internet search from around the world, by authors, sources [5].
Curves: High (**A**), medium (**B**) and low (**C**) pipeline cost correlation by authors.

LNG systems have also preference against Low cost pipelines in the range of quite important deliveries around 138 trailers/day (2640 ton/day) for the distances of 100 km and 13 trailers/day (260 ton/day) only for distances around 1500 km and more (see Fig. 4., curve C). We also analyzed a case, when gas is available in a transit pipeline under pressure 50 bar and certain flow has to be transferred from here to another direction.

Basically, there are two possibilities:

- To build a branching pipeline.
- To build a liquefier at the pipeline and to transfer the liquid by road

For a case of Low cost pipelines the LNG version is not feasible in this case, but for a case of High cost pipelines there is certain range of parameters, under which the road transport is economical. It starts with a distance 500 km and 5 trailers/day only and it grows to 1500 km and 50 trailers/day (see Fig. 2., curve D). This may be a realistic solution in countries with not developed distribution pipelines, scattered population and limited industrial infrastructure, or for purposes, where LNG is needed at the end point in liquid state (LNG vehicle fueling, e.g.) More typically, liquefier can be built at the pipeline for peak shaving purposes and LNG can be distributed when the liquefier capacity is not used for filling the storage volume assigned to peak shaving. The optimization problem is more complex, then, and solution would be found somewhere between the above cases. (Liquefaction energy per kg would be assigned fully to the distributed LNG, while depreciation of liquefier equipment would be assigned only partly to LNG or not at all, depending on the investor’s philosophy.)

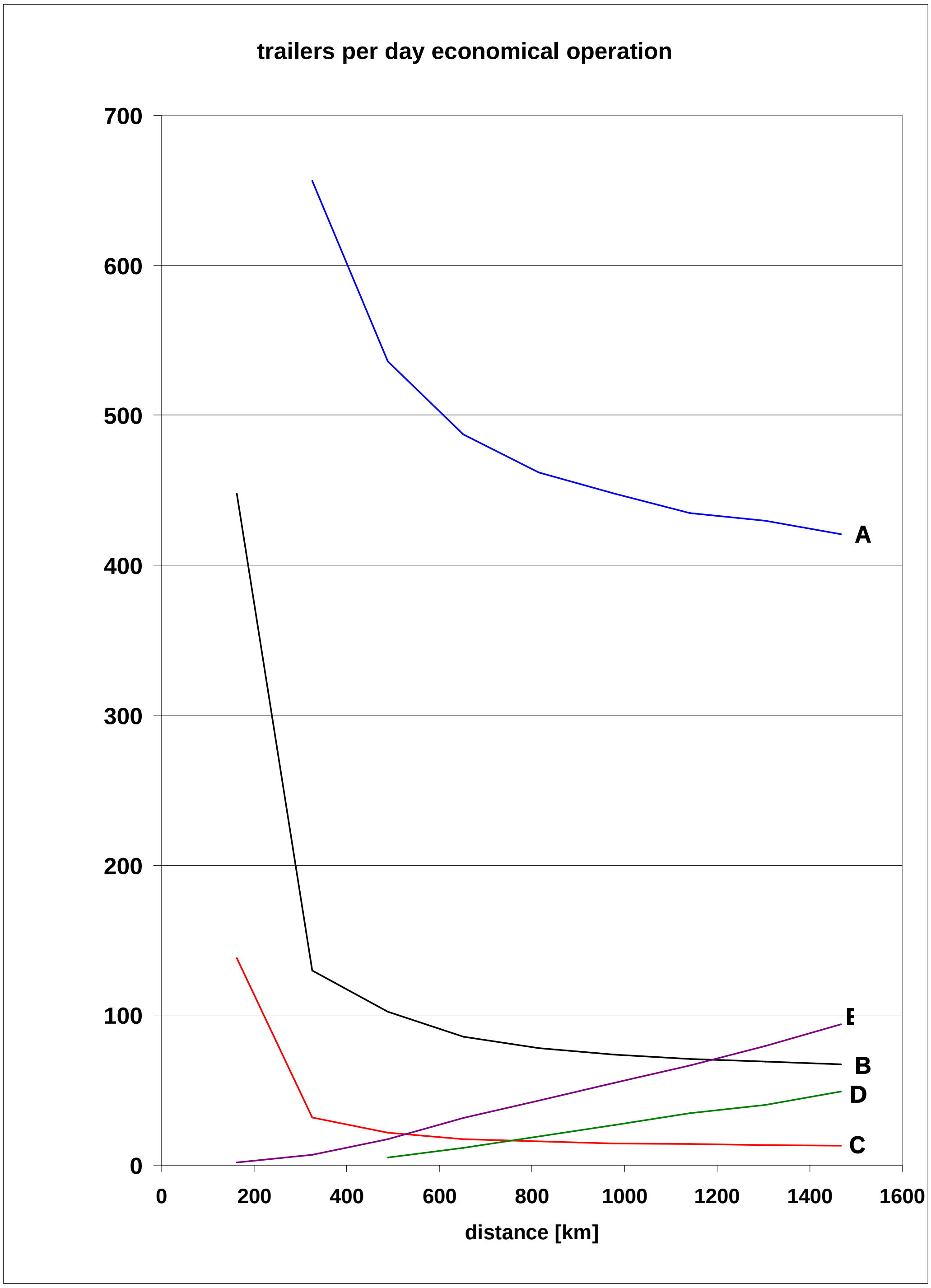

Figure 4. Number of trailers economically transportable to one direction instead of building a new pipeline.

From a marine terminal: **A, B, C** (**A:** Trailers as alternative to High cost pipelines; **B:** Trailers as alternative to Medium cost pipelines; **C:** Trailers as alternative to Low cost pipelines)
From a transit pipeline, including liquefier: **D**
From a transit pipeline, peak shaving liquefier CAPEX not accounted to the trailer distribution, **E**.

Structure of costs for one of the break-even cases can be seen in the Tab. 1. The absolute numbers are not indicated because of commercial impacts and because the absolute costs are subject of changes in time. The depreciation in the table includes interest. Remember, that all the CAPEX depreciations are calculated from maximum capacity equipment, while all the OPEX costs are calculated from yearly average 50% load, as it is typical for a mixture of heating and technology use of gas.

Table 1.: Cost structure of Gas pipeline and LNG road transport for one of the break-even points (where total costs of both the systems are equal):
It is for 480 km distance, where the break-even point is at 102 trailers per day average for Medium cost pipeline

Gas pipeline transport	**Cost**
	%
Pump and vaporizer depreciation 8%	2,9%
Liquid compression	2,6%
Cost of gas for vaporization	28,3%
Pipeline depreciation 8%	62,5%
Recompression energy	3,7%
TOTAL	100,0%
LNG road transport	**Cost**
	%
Truck and tanker depreciation 16%	15,1%
Filling installation depreciation 8%	0,8%
Filling pump energy	0,3%
Truck operation cost	76,0%
End storage depreciation 8%	7,8%
TOTAL	100,0%

SATELLITE STATIONS, THEIR SIZES AND PERFORMANCES.

At satellite stations, LNG is unloaded into vacuum insulated pressure storage tanks. The LNG has to be vaporized, odorized, and after a minor pressure reduction (for keeping the downstream pressure constant) delivered to a local pipeline or pipeline network. Typical flow scheme of a satellite station can be seen in the Fig. 5.

LNG is unloaded from trailer to the LNG storage tank by a trailer pump or by pressure discharge. Typical operating pressure in the tank is between 4 and 6 bar. This pressure can be maintained also during filling of the tank. The filling can be controlled between the upper line to the vapor space, which reduces the pressure due to condensation of vapor by a colder liquid, or the lower line into the liquid space, which increases pressure due to compression of vapor. Liquid withdrawal reduces the pressure in the tank.

Constant pressure is maintained by the three way regulator, which allows part of the liquid into the pressure build-up vaporizer where it is vaporized and the vapor enters the upper space of the tank and increases the pressure. In case of pressure increase due to heat leak from outside and minor liquid withdrawal, the three way regulator allows gas from the tank to be mixed into the withdrawn liquid, which reduces the pressure. Liquid is withdrawn into one (set) of two interchangeable (sets) of vaporizers, where the liquid is vaporized and warmed up to a temperature marginally lower than the temperature of ambient air.

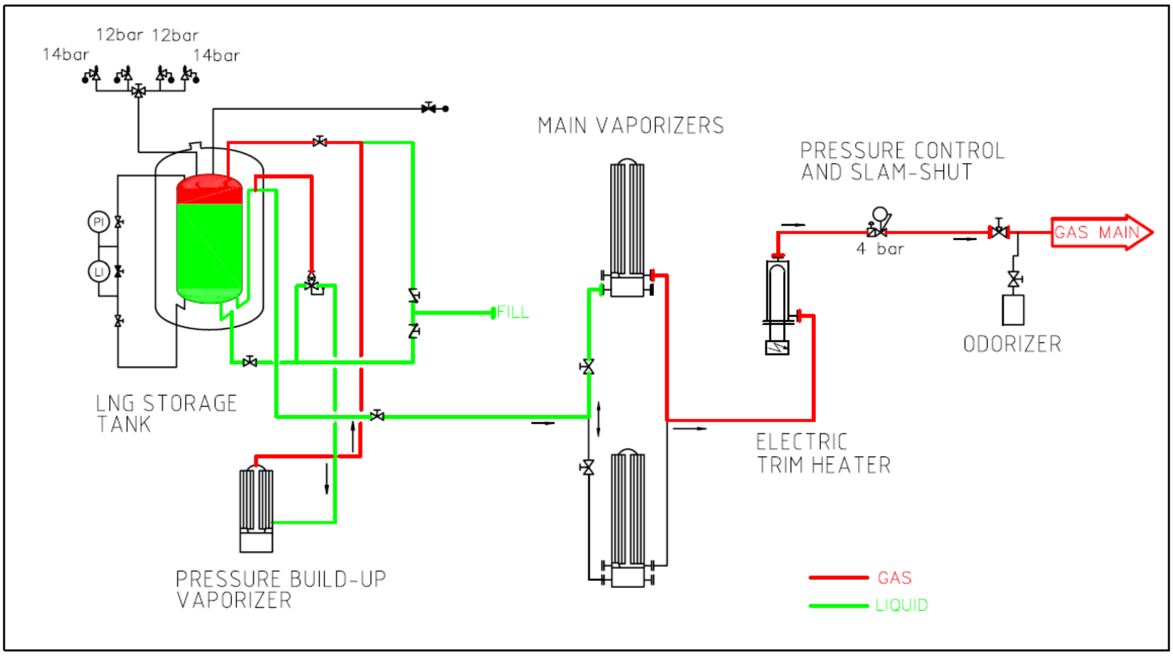

Figure 5. Flow scheme of the satellite station

In moderate and colder climates this may require further heating to a required temperature by an electric or other kind of heater. The gas enters into a pressure control, slam-shut, flowrate measuring and odorizing station, then. Two parallel branches are required typically for a high reliability. Pressure is kept on a constant value required by the needs of the gas network, typically between 2 and 4 bar. Excess-flow or fail-closed valves (not shown in the scheme) protect against excess gas leak in case of downstream pipe crack. Flowrate measuring is a normal commercial and logistics requirement. Odorization of the gas may be needed for downstream safety requirements in lieu of gas detection instruments, as the LNG can't be odorized (mercaptanes freeze at the low temperature).

Vacuum insulated tanks are typically designed to 12,5 bar pressure for sizes up to 105 m3, and to 8 bar for larger sizes. The vacuum insulation ensures keeping the LNG in the tank without venting even for several weeks without any product withdrawal, and any smallest consumption reduces the pressure in the tank very quickly.

This way a satellite plant operates fully automatically with its control and emergency system, without any operation personnel. Operation of satellite stations is followed up by wireless telemetry and control system which allows not only follow up, but actions and re-programming if needed. But the primary purpose of it is logistics – planning of refilling the tanks. The filling procedure is operated by the trailer driver only, or by a ship crew.

Satellite station may be built for a single consumer or for a local net of consumers. Storage capacity has to be adjusted to the needs of the site gas consumption. Theoretically, the size of the storage tank can be moderately larger than the size of the tanker. For example, for a 51 m3 trailer filled to 90%, considering maximum filling of the storage tank 90% and the contingency rest 14%, the appropriate size of the storage tank is 60 m3. This size tank is the “working horse” of many smaller satellite stations. For small gas consumptions even smaller tanks can be justified, where only a part of trailer filling is unloaded.

For large gas consumptions, theoretical trailer delivery periods are short and the system becomes sensitive to unexpected irregularities considering climate or infrastructure. According to the distance and local conditions, longer maximum refilling periods may be planned. For large satellite plants, instead of fleets of trailers, barges can supply LNG whenever the plant can be accessible from sea. 1000 m3 barge is in operation in Norway and 6000 m3 in Japan and in Norway soon.

When the plant is supplied by a barge or ship LNG carrier with such capacities, economy of number of the ship trips and the size of on site tanks has to be balanced, including to possible weather conditions limiting the navigation, result of which is the refilling period, then. Proportion between the storage size and the gas consumption, depending on the set maximum refilling period, can be seen in the Tab. 2. (90% maximum filling and “untouchable” 5% minimum level considered.)

Table 2. Satellite station storage capacity as a function of gas consumption and maximum refilling period.

average gas consumption	maximum refilling period	storage gross capacity needed	maximum refilling period	storage gross capacity needed	maximum refilling period	storage gross capacity needed
Sm3/h	days	m3	days	m3	days	m3
200	3	**29**	7	**67**	21	**202**
500	3	**72**	7	**168**	21	**504**
1000	3	**144**	7	**336**	21	**1008**
2000	3	**288**	7	**672**	21	**2016**
5000	3	**720**	7	**1680**	21	**5040**
10000	3	**1440**	7	**3360**	21	**10080**

1 Sm3 = quantity of gas in 1 m3 at 15°C and 1,013 bar.

Examples of complete stations of various sizes can be seen in Fig. 6 and 7.

Figure 6. Small satellite plant 21 m3 storage, 50 Sm3/hour

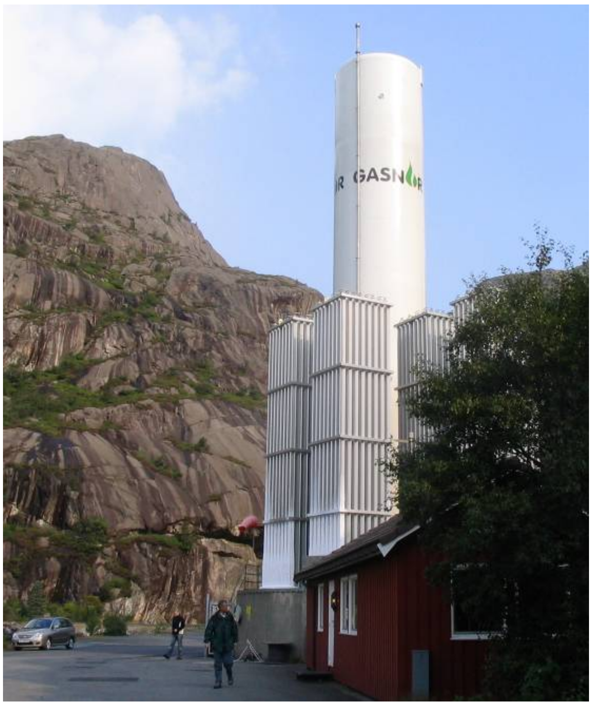

Figure 7. Medium Satellite plant 257 m3 storage, 1500 Sm3/hour

The largest example currently in operation is the Sunndalsora plant, Norway, (Fig. 8) with three tanks of 500 m3 (total gross volume 1500 m3), built in 2003 for Gasnor, supplied by a ship LNG carrier with a capacity of 1000 m3 and delivering maximum 4400 Sm3/hour to an aluminum foundry of Norsk Hydro.

Figure 8. Large satellite plant, 1500 m3 storage, 4400 Sm3/hour vaporization

Even larger system will be at the Moesjen plant, Norway, to be finalized in the first half of 2007 also for Gasnor, with five tanks 683 m3 each (total gross volume 3415 m3). It is located in the Arctic region above the polar circle. It will be also supplied by a carrier is currently being built with a capacity of 6000 m3.

These installations are raising a question, where is the limit of the total size of satellite plant storage composed from multiple-installed vacuum insulated tanks. This question was also subjected more detail analysis.

COMPARISON OF PRESSURE STORAGE OF LNG TO ATMOSPHERIC STORAGE; TECHNOLOGY, SAFETY, ECONOMY

Currently, the largest size of a single vacuum insulated tank is 683 m3, manufactured by Chart Ferox, a.s. Multiple installations of these tanks enable storage capacities in thousands of m3. In general, vacuum insulated design is lower cost than flat bottom tanks up to much larger volumes than it was believed in the past. Chrz et all [6] forecasted by a comparison of extrapolated CAPEX data, that the break-even value between the single flat bottom tank and multiple installation of vacuum insulated tanks can be expected in the range between 10 000 and 20 000 m3. They also presented an extend analysis of qualitative and safety preferences of vacuum insulated pressure storage over the flat bottom tank option [7]. From the wide list, here to be highlighted:

- Possibility of stage by stage installation according to business development, or moving the tanks after regional business depression.
- Minimum on site construction work and short time installation.
- No boil-off compressor needed, because of large hold time thanks to difference between the operation and maximum allowable pressure, because of vapor condensation during upper filling and because of economizer pressure-decreasing system.
- Higher operational reliability with more units installed.
- No need of delivery pumps, the tank delivers from internal pressure, maintained by pressure-build-up vaporizer.
- No danger of liquid roll-over at pressure storage, because of “natural” stratification with warmer liquid at the top.
- Separate vessels make possible segregation of different LNG compositions.
- Good resistance to catastrophic events thanks to pressure inner vessels and the second wall of the outer jacket.

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VEHICLES, SHIPS AND RE-FUELING WITH LNG

Special kinds of satellite stations are vehicle re-fueling stations. Natural gas vehicles are becoming popular application because of economical, energy strategic and environmental reasons. LNG vehicles use LNG directly on board. The main advantage is long range of the vehicles and smaller dead weight of tanks. This is a verified and functional option. But the umber of LNG vehicle fleets is still low because of undeveloped LNG supply systems.

The classic CNG option is using compressed natural gas on board of the vehicle in high pressure cylinders at 200 to 300 bar. Normally, CNG vehicles are filled at compressor re-fueling stations bound to pipelines. This is a great weakness of the system. General use of CNG vehicles is limited by comfort of re-fueling. Only re-fueling stations on the motorways in regular distances (20 km, e.g., as stated by Theisen [8]) can ensure the same re-fueling comfort as it is available to Diesel or gasoline car owners. Authors [9] proved, that branching from driving direction to a CNG station brings additional costs, which (depending on the set price ratio) liquidate fully the price advantage of CNG (if any) within several km distance. Also CNG transport with tube trailers cannot solve the problem sufficiently flexibly and economically.

A solution for support of already existing large number of CNG vehicles (around 1 million in Argentina and Pakistan, 400 000 in Italy, etc.) and great support to the further development with positive impact on total LNG market are LCNG stations (Fig. 9). The technology starts with an LNG tank, continues with a small single stage high pressure pump, ambient vaporizer, odorizer, and finally (as at a normal CNG station) high pressure buffers and a CNG dispenser. This all with lower cost and higher performance than an equivalent classic CNG station.

Figure 9. LNG/LCNG station, Los Angeles, CA, USA. 3 CNG dispensers, 6 LNG dispensers, serving a fleet of LNG refuse haulers and CNG-city busses.

Comfort of CNG re-fueling options is possible thanks to LCNG stations. This is very important for further progress of CNG systems in well developed industrial countries, especially in Europe with its target 20% alternative fuels in the year 2020, with a forecast, that NGV's would be half of this segment only. If this would be realized, it would require additional import capacity of 50 billion (10^9) Sm3/year (Chrz [10]) and 16 000 refueling stations will have to be built with 3 dispensers per station average.

As LNG can be transported economically to very far destinations (see above), LCNG represents the only option for some countries (Northern Scandinavia, e.g.), who have no pipelines at all, and thus, use of CNG vehicles is currently fully impossible there.

Another segment of LNG consumption are ships. From those especially ferries and fixed-route supply boats, which can be served by a single re-fueling stations. In December 2006 a refueling station for a ferry with the capacity of storage tanks 2 × 500 m3, delivered by Chart Ferox, a.s., was commissioned in Halhjem, Norway. The ferries are equipped with two LNG fuel tanks with capacity 125 000 m3 each, manufactured by Cryo AB, or (as co-operation) by Chart Ferox.

When discussing LNG for fueling, there is no alternative to LNG direct distribution. The size of future demands makes the need of direct LNG distribution from marine terminals even more urgent.

FUTURE TRENDS

From current market signals, it can be reasonably expected, that the system of direct deliveries of LNG will be broaden into the ranges of both smaller and larger sizes.

The small size is currently represented by compact satellite plants accommodated inside a standard 40' container, which includes a horizontal storage tank with a capacity of 21 m3, water heated vaporizer with a small boiler for warming the water. This is a suitable size for heating a complex of 50 family houses.

The next step would be individual cryogenic tanks for heating family houses. 600 to 2000 liter superinsulated cryogenics tanks for LNG, based on verified series for liquid nitrogen, are available for development of these systems. As example, a 600 liter vessel is sufficient for 14 day consumption of a Central European family house in January. Similar system with several thousand customers works in China, now. The containers can be filled with an exchange system full for empty, most probably as part of pilot projects, or they can be can be filled on site from small road tankers, the same way, as it is currently practiced with LPG, after the system would develop to larger sizes. The technology exists, but practical application requires appropriate LNG distribution infrastructure.

The upper boundary of current sizes of satellite stations may be broken by large intermediate storages of regional importance, which can be supplied by ships and which would serve as a cornerstone of regional distribution systems. Multiple installations of relatively large numbers of the largest sizes of vacuum insulated tanks are a promising option.

CONCLUSION

Recent development of LNG distribution technology opens door to wide application of direct distribution of LNG from marine terminals. Hundreds of LNG trailers sent per day in one direction are an economical alternative to building new pipelines. The upper limit of economy of direct LNG transport should be subject of economical analysis of every project, because the break-even value depends on the very variable costs of the pipeline. Expected development of LNG and LCNG car fueling systems will further increase demand of LNG deliveries to users' sites.

All these new aspects would stimulate change of proportions between compressed pipeline gas and LNG distributed from future and possibly from existing marine terminals. Considering these results, sufficiently sized trailer filling interface should be taken into consideration when planning new LNG terminals and downstream distribution networks.

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