6LQFH ZKHQ WKH ÀUVW SLORW /1* OLTXHIDFWLRQ SODQW ZDV VHW XS L
Cleveland, US, the LNG industry has amassed a huge body of experience that has enabled the near perfect public safety record that it has earned. Today, the global LNG supply capacity has grown to more than 240 million tpy, with over 430 LNG carriers in operation, with a projected growth to approximately 350 million tpy by 2020.

In those early days of the industry, equipment was not available for handling LNG, so a new special equipment industry was born. These developments largely originated from the experience of a group of scientists and engineers based at California Institute of Technology (Caltech), who were involved with the early US aerospace industry.

The LNG supply chain has been growing ever since with the latest new market segments being the small scale LNG plant and LNG as a transport fuel [Figure 1]. These developments have resulted in the introduction of new technologies and solutions over the traditional large scale LNG approach. The potential size of the ‘direct consumer product’ LNG fuel market varies greatly, with claims ranging from 80 million tpy to 240
PLOOLRQ WS\ 7KH PRVW UHFHQW %3 (QHUJ\ 2XWORRN SUHGLFWV QDWXUD
gas as a transport fuel to grow steadily at approximately 1.2% / year and to account for approximately 15% of the total demand growth during the period to 2035. This potential market size is predicted to be one of the key drivers in the growth of the overall LNG industry in the coming years. With growth and new development comes risk. The developers of this consumer sector will need to be cognizant of the damage that an incident, such as the Three Mile Island nuclear accident, could have on the growth of this valuable source of clean and economical energy.

Globally, LNG has been safely handled in large volumes over the last 40 years. Generally there are three types of LNG facilities (export, import and peak shave). These facilities are scattered throughout the world some times near population centers where natural gas is needed. This is compounded further by the prevalence of mobile facilities due to the smaller scale and

resulting size. It should be noted that this excellent safety record has b
largely based on ‘cold LNG’ (atmospheric pressure storage). [Figure

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high pressure gas vapor releases is greatly enhanced in the case of tank rupture and during normal operational connections.

Early adaptations of high pressure storage have largely been due to the availability and competitive price of pressure building storage tanks and equipment. This was compounded further by the lack of availability RI RWKHU /1* VSHFLÀF ORZ SUHVVXUH VWRUDJH GHVLJQV RI WKLV VFDOH Additionally, it is possible that in some cases the builders/designers lack of familiarity with the suppliers of such LNG equipment played a role. New suppliers with an extensive LNG background are now entering the market, offering low pressure storage design options, specially adapted for this small scale market. As a result, more options are available for evaluation, which can be based on life cycle performance, especially in terms of the LNG delivered volumes, quality and safety, and not only on cost and availability, as may have been the case with the early adapters.

6RPH RI WKH DGGLWLRQDO FKDOOHQJHV LGHQWLÀHG LQ GHDOLQJ ZLWK ¶K 'cold' LNG include the following:

- All large scale LNG plants and ships operating to date are dedicated facilities, which typically include 3 to 10 year project lead times, and are built by specialist engineering, procurement and construction (3& FRPSDQLHV RU VKLS\DUGV ZLWK FRPSOH[UHJXODWRU\ VLWLQJ DQG approval processes. Small scale LNG plants, however, are generally mobile, standardized and commodity-driven in terms of budget, schedule and construction.

- ‡ 3URGXFW WUDQVIHUV WKDW GHPDQG KLJK SUHVVXUH ZLOO LQFUHDVH temperature of the LNG and decrease the density and its associated fuel heating value, while increasing the risk of venting and, potentially, product loss.

- When tank pressure is maintained at a low level, as in a pumped transfer system, the entrained heat energy (known as enthalpy NHSW ORZ DQG LV QRW DYDLODEOH W the risk of unwanted emissions.

- Adherence to a zero emissions policy by maintaining a low press tank strategy helps to future-proof the facility owner's investment emissions regulatory policy requirements escalate.

- ‡ 7KH ORZ SUHVVXUH VWUDWHJ\ VLPSO to tank by ensuring that all tanks are always at a common press [Figure 3]

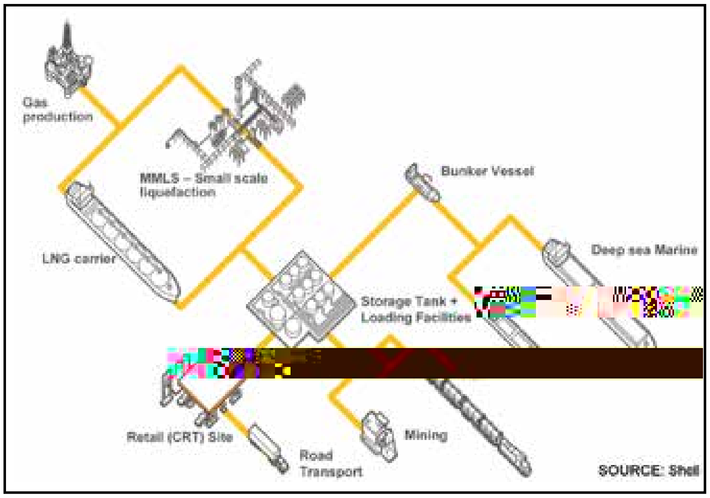
- Where no such commonality exists, the standardization of handli SUDFWLFHV, VWRUDJH HTXLSPHQW DQ limits interoperability when transferring fuel at different facilities [Figure 3]

- High pressure end user storage demands that the vapor returns storage and increases venting risks and heat loss to storage.)LJXUHV DQG DOVR VKRZ YDULRXV I

A number of factors need to be considered when deciding whethe supply LNG by pumping, pressure transfer or both.

The inclusion of pumps and, in particular, submerged motor pum 603V LV ZHOO SURYHQ ZKHQ RSHUDWL SXPSV DUH UHOLDEOH HIÀFLHQW DQG FROG /1* SXPSLQJ LQFUHDVHV WKH ÁH transfer, vaporizer feed and road/train/barge tankers cargo off-loadin This is especially the case where various interface conditions ap >)LJXUHV @ 603V DOVR SHUPLW LQF reduce transfer cycle time, which is critical in many of the LNG-fuelli cases, especially where bunkering is involved.

603V FDQ DOVR EH XVHG IRU SXPSLQJ including some alternate fuels such as propane, butane, methanol ethane, as well as downstream chemicals and petrochemicals (liq



Another concern relates to what happens when the vehicle or mobile VWRUDJH IDFLOLW\ KDV WR UHWXUQ WR WKH GHSRW RU VKLS\DUG IRU XQ durations, or where maintenance must be carried out. Again, the LQFOXVLRQ RI ERWK 603V DV ZHOO DV IRUFHG YDSRUL]HUV SURYLGHV \ QHFHVVDU\ RSWLRQV WR HQVXUH IXHOV FDQ EH RIÁRDGHG VDIHO\ DQG QHF works can be undertaken safely and expeditiously.

LNG fuel was originally supplied to low pressure LNG engines (up to 18 bar) through vaporizers by pressure transfer only (i.e. by supplying pressurized vapor to the top of the tank and supplying LNG to the YDSRUL]HU IURP WKH ERWWRP 3UHVVXUH WUDQVIHU ZDV DOVR XVHG IU a suction pot to the high pressure pumps for the high pressure LNG engines (400 bar).

There were multiple problems with the strategy of only using pressure transfer for these mobile applications, including the following:

- When extraneous conditions create an environment in which the /1* IXHO LV DJLWDWHG ZLWK VLJQLÀFDQW OLTXLG VORVKLQJ DFWLRQ RU W pocket is affected by spraying, the gas pressure can collapse in the supply tank or suction pot.

‡ :LWKRXW WDQN JDV SUHVVXUH /1* IXHO ÁRZ VWRSV

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‡ 6WRUDJH WDQN DSSOLFDWLRQV H[FOXVLYHO\ XVH LQ WDQN 603V 7KLV eliminates the need for tank bottom penetration, and puts in place the 'over the top pumping standard' (i.e. no tank liquid nozzles are located below the tank liquid level).

‡ 5HPRYDEOH SXPS LQVWDOODWLRQ FRQÀJXUDWLRQ DOORZV IRU WKH maintenance of pumps without gas freeing and entering the storage tank. The system is simple to operate and the crews / operators can EH HDVLO\ WUDLQHG WR SHUIRUP WKHVH WDVNV VDIHO\ DQG HIÀFLHQWO\

‡ ,PSURYHG 1HW 3RVLWLYH 6XFWLRQ +HDG 136+ SURSHUWLHV ZKLFK XVH special inducer designs, enhance storage utilization, handle marginal liquid conditions and can more effectively deal with possible 'water KDPPHU· SUHVVXUH VXUJHV GXULQJ WKH VWDUWLQJ RI KLJK ÁRZ SXPSV

- Low level starting capability optimizes inventory management and allows for the re-starting of pumps, even at low tank levels.

- Dual process feed through for electrical and instrument supply to 603V DQG JHQHUDWRUV SURYLGHV KHUPHWLF JDV WLJKW VHDOV ZKLFK VW any possible migration of gas from inside the process to the outside supply side. The power, or instrument, cables inside the tank are connected to the solid bus bar, thus breaking any gas migration pathway. The two termination header seals are designed for the same pressure and temperature that would exist in the instance of a failure of the primary termination header seal. The space between the two termination headers is monitored to detect failure of the primary termination header and to provide alarmed protection against possible gas migration.

7KH LQGXVWULDO JDV VPDOO VFDOH /1* PRGHO ZLOO EHQHÀW E\ LGHQWLI\L opportunities to standardize its own practices through the establishment of industry practice groups of system designers and pump buyers. Some possible outcomes include:

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