Executive Summary

CNG for commercialization of small volumes of associated gas

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The study has analysed current Compressed Natural Gas (CNG) technology for its potential to monetise small volumes of this gas (1-15MMscf/d) and avoid or reduce the gas flaring.

Introduction

Compressed Natural Gas (CNG) is natural gas transported and stored in compressed form (pressurised to between 100 and 250 barg) in order to reduce the volume to be transported or stored by between 150 to 300 times that of gas at atmospheric pressure.

Historically, CNG has been used onshore for gas supply over short distances and in relatively small volumes. While the cost of delivered CNG depends on project specific conditions such as gas volume, in general CNG can be economically viable for volumes up to around 5 MMscf/d and distances up to 800 km.

Compressed Natural Gas (CNG) is mainly used as an alternative fuel for vehicles. Natural gas vehicles are very popular worldwide, particularly in countries such Pakistan, Argentina, India and China. Use of CNG as fuel for road vehicles has been driven by two main factors: rising gasoline prices and increased environmental concerns.

Use of CNG at a larger scale is not yet commercially viable but is being investigated by several companies as a potential economically viable alternative to Liquefied Natural Gas (LNG).

The CNG Chain

The CNG chain is composed of four elements: Production, Transportation, Receiving and Storage.

Production

CNG production consists of gas pre-treatment and compression. The pre-treatment process is simpler than in an LNG liquefaction plant and is generally set by the requirements of the end users. The main pre-treatment activities are:

- Removal of heavy hydrocarbons to avoid condensation when storing as CNG,
- removal of contaminates: hydrogen sulphide, carbon dioxide, etc., and
- dehydration.

The amount of compression required depends on the delivery pressure of the source gas reservoir and gas quality.

Transportation

CNG may be transported on-shore or off-shore (marine). There are a number of different options available for each alternative.

Marine CNG Transportation

Transportation cost is the most important factor in the CNG chain. The cost of CNG marine transport is directly proportional to the volume of gas and distance between the gas source and the consumers.

Since the early 1960's the marine transport of CNG has been investigated and analysed by various developers. The current marine CNG developers and their transportation concepts are as follows:

	CETech	**EnerSea Votrans™**	**Sea NG Corporation Coselle™**	**TransCanada CNG Technologies**	**Knutsen OAS Shipping**	**Trans Ocean Gas**
Type of Containment	Composite or X80 pipe steel ; composite (Iso container)	X80 steel cylinders	coiled X70 line pipe forming a carrousel (Coselle)	Composite reinforced steel Gas Transport Modules (GTM)	X80 steel cargo tank cylinders (CTC)	Composite HDPE and fibreglass cylinders (MEGC)
Development status	concept stage	advanced concept stage	advanced concept stage	concept stage	concept stage	Concept stage for MEGC container only
Transport capacity (MMscf)	85-319 (+ 60 to 120,000 m^3oil) 200 – 1,200 variable (container)	75 – 1,000 (ship) 10-100 (barge)	51 - 531 (ship) ?-80 (barge)	12 - 100	70 - 1,200	Variable as a function of the number of containers

On-shore CNG Transportation

On-shore CNG transportation is a proven technology that has been used for decades. The on-shore CNG transportation system consists of:

- gas compression and truck loading at the gas source location;
- truck offloading, heating, let-down and metering at the customer site.

Analysis of the cost of delivered CNG for a number of volumes and distances (see below) shows that, for production capacities higher than 5 MMscf/d, delivery of CNG by truck becomes difficult not only due to the substantial number of vehicles required (especially for longer distances), but also the significant extent of loading and offloading facilities required.

The CNG storage type used for transportation is the main difference between the various suppliers. The main characteristics are as follows:

	Tube type	Luxfer-GTM type III	Lincoln type IV	Galileo MAT
Container material	Steel – High strength steel	Aluminum inner wall wrapped with carbon fiberglass	Carbon fibre/epoxy composite	ISO 9809 steel cylinder
Trailer max capacity (MMscf)	up to 0.29	up to 0.44	up to 0.36	up to 0.25
Pressure (barg)	187-227	248	250	200-250
Corrosion resistance	-	?	++	-
Gas/container weight ratio (t/t)	0.24	0.41	0.79	0.2
Comparative cost	base case	++	++	+

Examples of CNG chain costs

The sizing and cost of the different elements of the chain depend on the specific characteristics of each project such as: gas volume and composition, distance to consumers, storage and infrastructure requirements, geographical location etc.

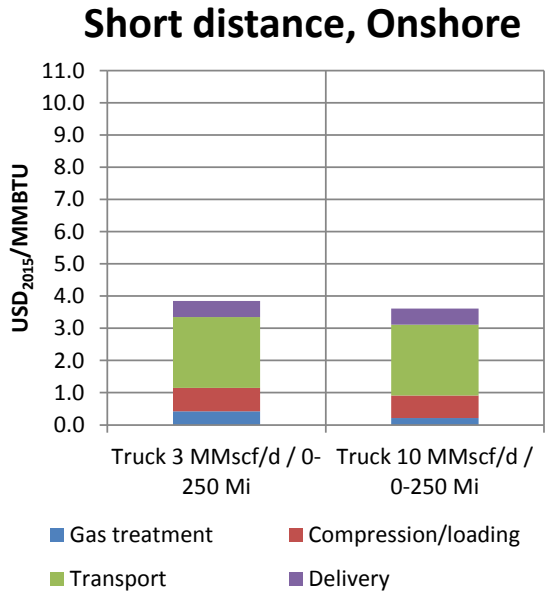
The unit cost (capital and operating) for four scenarios have been evaluated: Gas volumes of 3 and 10 MMscf/d, and short and long distances to customers. It must be noted that these cost estimates are only indicative as specific circumstances (e.g. a challenging physical environment, high labour costs in an overheated business environment such as the Bakken in N. Dakota), can affect the costs and hence economics significantly.

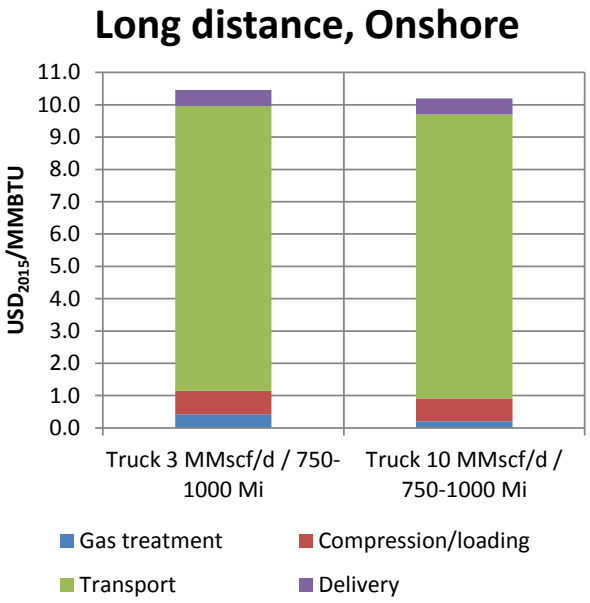
Transport method	**Long distance**		
Offshore	**Capital & Operating cost, USD_{2015}/MMBTU**		
	Item	**Marine 3 MMscf/d / 550-800 MN**	**Marine 10 MMscf/d / 550-800 MN**
	Gas treatment	0.42	0.21
	Compression/loading	0.73	0.70
	Transport	6.43	5.22
	Delivery	0.50	0.50
	Total	**8.08**	**6.63**

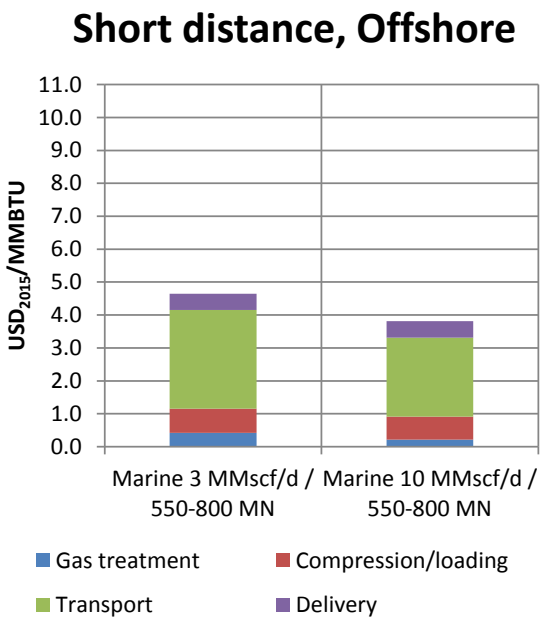
Onshore	**Capital & Operating cost, USD_{2015}/MMBTU**		
	Item	**Truck 3 MMscf/d / 750-1000 Mi**	**Truck 10 MMscf/d / 750-1000 Mi**
	Gas treatment	0.42	0.21
	Compression/loading	0.73	0.70
	Transport	8.81	8.79
	Delivery	0.50	0.50
	Total	**10.46**	**10.20**

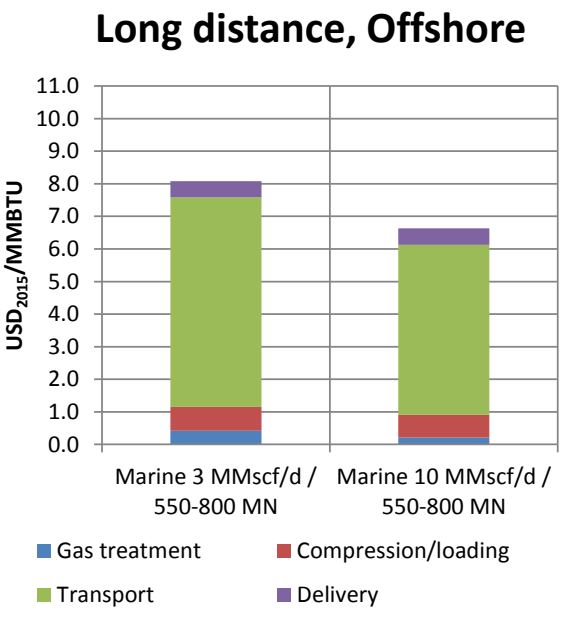
Transport method	Short distance		
Offshore	Capital & Operating cost, USD_{2015}/MMBTU		
	Item	Marine 3 MMscf/d / 55-150 MN	Marine 10 MMscf/d / 55-150 MN
	Gas treatment	0.42	0.21
	Compression/loading	0.73	0.70
	Transport	3.00	2.40
	Delivery	0.50	0.50
	Total	**4.65**	**3.81**

Onshore	Capital & Operating cost, USD_{2015}/MMBTU		
	Item	Truck 3 MMscf/d / 0-250 Mi	Truck 10 MMscf/d / 0-250 Mi
	Gas treatment	0.42	0.21
	Compression/loading	0.73	0.70
	Transport	2.20	2.20
	Delivery	0.50	0.50
	Total	**3.85**	**3.61**

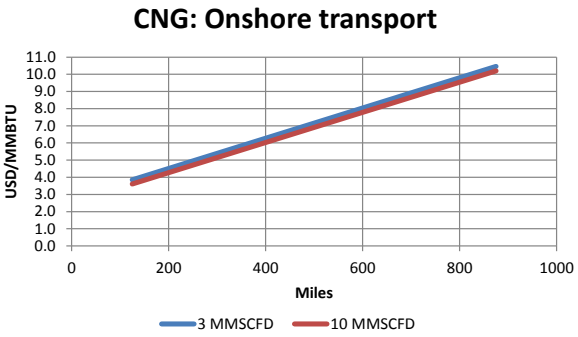


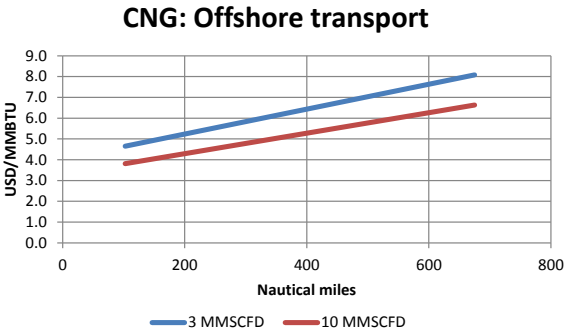






The above cost estimate examples can be summarized as follows:





CNG market overview

Onshore

There are currently almost 20 million road vehicles in the world in a wide range of countries using CNG as fuel. The ten countries with the largest CNG vehicle fleets (in millions) are:

Rank	Country	Registered fleet	Rank	Country	Registered fleet
1	Iran	3.50	6	India	1.50
2	Pakistan	2.79	7	Italy	0.82
3	Argentina	2.28	8	Colombia	0.46
4	Brazil	1.75	9	Uzbekistan	0.45
5	China	1.58	10	Thailand	0.42
World total = 18.09 million vehicles					

The fast growth of CNG as fuel for vehicles has been to a large extent driven by government subsidies and initiatives to promote conversion to CNG for environmental and economic reasons.

Other uses of CNG, such as for power generation; industrial consumers etc., are currently less developed mainly because the gas volumes required are often too high for truck distribution.

Offshore

The lack of proven commercial options for marine transportation of CNG is the main obstacle to faster business development in these areas.

Indonesia may become the first-mover in marine transportation of CNG. A 2,200m³ CNG carrier is currently being built to supply gas to a CNG storage facility in Lombok. The project is planned to start commercial operations in 2016.

Conclusions

CNG on-shore transportation is well established in a number of countries since the 1990s. Marine CNG transportation, however, is still under development and with no units yet in commercial operation.

While the cost of delivered CNG depends on project specific conditions such as gas volume and composition, in general:

- On-shore delivered CNG can be economically viable for volumes up to around 5 MMscf/d and distances up to around 500 miles (800 km).
- Marine CNG is not yet commercially proven but could be economically viable for large volumes and distances up to around 2000 nautical miles.