Oil and Gas Alert (TechVision)

Natural Gas Storage Technologies

“Efficient Storage Technologies Can Pave Way for Large-Scale Adoption of Natural Gas”

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D998-TV
# Contents

<table>
<thead>
<tr>
<th>Natural Gas Storage Technologies</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground Salt Cavern Storage for Liquefied Natural Gas</td>
<td>4</td>
</tr>
<tr>
<td>Underground Natural Gas Storage Facility to Secure Gas Supply for Nova Scotia</td>
<td>5</td>
</tr>
<tr>
<td>Non-pressurized Liquefied Natural Gas (LNG) Storage Tank</td>
<td>6</td>
</tr>
<tr>
<td>Vehicular Natural Gas Storage System Enabling Thermal Management</td>
<td>7</td>
</tr>
<tr>
<td>Next-generation Natural Gas Storage and Delivery Systems for Vehicles</td>
<td>8</td>
</tr>
<tr>
<td>Cryogenic Storage Tank for Supplying Liquefied Natural Gas (LNG)</td>
<td>9</td>
</tr>
<tr>
<td>Underground Gas Storage System to Store Synthetic Natural Gas</td>
<td>10</td>
</tr>
<tr>
<td>Low-pressure Adsorbed Natural Gas (ANG) Storage Technology</td>
<td>11</td>
</tr>
<tr>
<td>Strategic Insights</td>
<td>12</td>
</tr>
<tr>
<td>Key Patents</td>
<td>15</td>
</tr>
<tr>
<td>Industry Contacts</td>
<td>19</td>
</tr>
</tbody>
</table>
Natural Gas Storage Technologies
Underground Salt Cavern Storage for Liquefied Natural Gas

Liquefied Petroleum Gas (LPG) one of the prime sources of energy for both domestic and commercial applications

Technology Profile and Usability

- The gas storage cavern has been integrated with the company’s LNG receiving facility through ships.
- Freeport LNG injects gas during low nighttime demand periods, paying low nighttime electricity rates.
- Gas redelivery from underground storage allows significant variations in gas deliverability and cost effectiveness.
- Provides extra gas supply during high daytime peak gas demand for local power generation companies.
- The two sole customers of the terminal for the next 15 years will be ConocoPhillips and Dow Chemical Co.

Innovation Attributes

Salt cavern gas storage is cheaper to build than an LNG tank and it enables LNG terminal operators to get the most out of the LNG facilities and provide maximum flexibility to terminal customers.

Possess a highly favorable ratio between LNG storage capacity and the throughput capacity supplied to its customers.

Commercialization Strategy

The solution-mining process to create the cavern was completed and the cavern was placed into operation in late 2011.

Analyst Perspective

Possessing more underground LPG storage facilities is a strategic move by petroleum companies, allowing them to import large quantities of gas when price is favorable and sell it when market demand is high.
Underground Natural Gas Storage Facility to Secure Gas Supply for Nova Scotia

Alton Natural Gas Storage LP (Alton), Canada

Low-pressure gas storage driving opportunities for natural gas vehicles (NGVs)

Alton, a subsidiary of AltaGas Ltd., is building an underground natural gas storage facility and integrated pipelines near Alton, Nova Scotia. A total $100 million USD has been allotted by AltaGas for the development of the storage facility.

Competing Aspects
- Once commissioned, Alton Natural Gas Storage will be the only natural gas storage facility in Atlantic Canada and the only storage facility connected to the Maritimes and Northeast Pipeline.
- It will help Nova Scotia, providing secure, affordable and reliable natural gas supply throughout the year.
- It has been estimated that consumers of Alton natural gas will save approximately $17 million per year on purchasing natural gas once the project is commissioned.

Analyst Perspective
This new gas storage facility will connect Nova Scotia with the North American energy network while also decreasing price volatility and supply uncertainty for Nova Scotia’s natural gas consumers.

Technology Readiness Level

1 2 3 4 5 6 7 8 9

Started in Q3, 2015, the storage cavern construction work has been scheduled to be completed by Q2, 2018. It is expected to be operational by the end of 2018. Alton will be hosting a Contractor Fair in April, 2016 for the various construction aspects of the project.

Environmental Impact
The project has been designed with appropriate environmental and ecosystem measures to achieve the highest levels of safety and environmental protection to Shubenacadie River.

For the construction of the underground cavern, a well has been drilled into the naturally occurring salt formation. Tidal water from the nearby Shubenacadie River has been driven through the cavern to dissolve the salt within the well, forming a salt solution called brine. The brine is then cycled back up the deposit to form an empty space to store natural gas.

Future Plans
- Alton has just received government permits from Nova Scotia for its natural gas storage project. The company will continue to engage the Mi’kmaq of Nova Scotia and the community as it moves to the next $100 million USD gas storage project near Stewiacke.
**Technology Profile**

- The plant consists of an insulated, non-pressurized LNG storage tank that can store 30,000 tonnes or 63,000 m³ of LNG, equivalent to 1.5 petajoules (PJ) of natural gas.
- The processing plant has been designed to convert pipeline NG to LNG by cooling it to -162 degrees C with a maximum processing capacity of up to 66,500 tonnes of LNG per year.
- A 5.5 km long pipeline has been constructed to link the gas storage facility with the receiving station at Hexham where it is linked with the NSW gas network via the existing Wilton-Newcastle trunk pipeline.
- It also consists of a re-gasification unit to convert the stored LNG back into natural gas.
- The capital cost spent on the gas storage facility is $310 million USD.

**Permits and Approvals**

The New South Wales Planning Assessment Commission (PAC) granted a permit to AGL to construct the Newcastle Gas Storage Facility in May 2012.

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**Benefits**

It provides the Newcastle region a two week gas supply back up; supply of gas; tightening continuous energy security for both commercial and domestic applications of Tomago—a combined industrial/semi-rural region of the Port Stephens local government area in the Hunter valley of New South Wales (NSW), Australia.

This is the first gas storage facility of its kind in NSW and crucial, given the location of Hunter at the end of the gas supply pipeline.

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**Analyst Perspective**

The neighboring Tomago aluminium smelter will hugely benefit from AGL’s new gas storage facility in Tomago.
Vehicular Natural Gas Storage System Enabling Thermal Management

Unmet Needs/ Trends

- In gas storage applications, users want as much usable gas as possible stored inside a tank at a given pressure and temperature, while also minimizing the amount of external thermal management that is needed to have a viable system.

Potential Applications

The research work was demonstrated in the context of vehicular natural gas storage, but could potentially be extended to other mobile gas storage applications, including for fuel tanks in hydrogen cars.

Who

A research team from the University of California

Tech Profile

The research work is a part of a collaborative project between the University of California, Berkeley, Ford Motor Company, BASF, and Savannah River National Lab.

What

Innovation Attributes

This reversible expansion and contraction partially offsets heating and cooling effects in the gas storage system, providing a source of intrinsic thermal management.

Future Plans

This is a fundamental discovery. The researchers are now aiming to resolve the existing engineering challenges before these types of materials could be used in a storage tank.

Unmet Needs/ Trends

- The researchers have demonstrated a new concept in gas storage that uses metal-organic frameworks (MOFs) based flexible adsorbents to (i) boost the usable capacity of gas in a storage tank, (ii) reduce heating effects associated with filling an adsorbent-filled tank, and (iii) reduce cooling effects upon discharging gas from an adsorbent-filled tank.

Potential Applications

The research work was demonstrated in the context of vehicular natural gas storage, but could potentially be extended to other mobile gas storage applications, including for fuel tanks in hydrogen cars.

Analyst Insights

Such highly adsorbent materials can be considered an attractive way to produce viable gas storage systems with high storage densities for gases, including hydrogen and methane.

Funding

The research work is funded by the Advanced Research Projects Agency - Energy (ARPA-E) of the US Department of Energy.
Next-generation Natural Gas Storage and Delivery Systems for Vehicles

CleanNG, founded by alumni of Oklahoma State University, has developed an all composite advanced compressed natural gas (CNG) cylinder, the MagnumCel™ fuel storage system. The MagnumCel is a type 5 CNG cylinder. The storage tank is designed to operate at 3,600 psi.

Competing Aspects
✓ The liner less tanks weigh 70 percent less than type 1 CNG tanks and 40 percent less than type 3 tanks.
✓ Stores 10% more fuel by eliminating plastic and metal liners from its design.
✓ The MagnumCel exceeds its required burst pressure, even after the end of its useful cycle life. The tank has already passed US Department of Transportation safety standards.

Technology Readiness Level

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The company has already created a prototype for a liner-less fuel tank. The technology has the potential to be commercially introduced by 2020.

Funding

The start-up received a $30,000 USD TCC prize which they have used for pre-commercial campaigning of its MagnumCel design. CleanNG received several grants for research and innovation.

Application Potential

CleanNG’s MagnumCel fuel storage system offers a variety of solutions for a broad range of end users in the aerospace, marine, infrastructure, medical, and recreational domains. However, CleanNG is focused on the natural gas industry with products targeted toward fleet owners, original equipment manufacturers (OEMs), infrastructure development applications for refueling purposes, and retrofitters who convert existing petroleum-based vehicles to dedicated natural gas or bi-fuel vehicles.

Future Plans

• CleanNG has proposed a further increase in fuel efficiency of the system by further reducing the weight of its storage system. Weight savings would be profitable for fleet owners.

Analyst Perspective

All such natural gas storage technologies also need infrastructure development including refueling stations for rapid adoption of natural gas.
Liquefied Natural Gas (LNG) to replace diesel in power plants

Technology Profile

Chart Industries, a global leader in the design and manufacture of highly engineered cryogenic equipment used at every step in the liquid gas supply chain.

- Nicknamed as Chart-Ferox Giants, the vessels have been built based on the company’s HT1000 model.
- Weighing about 265 tonnes and over 53 meters long, each of these horizontal storage tanks can carry 1,000,000 liters of liquefied natural gas (LNG).
- The tank sizes can be customized depending on customer requirements and the storage medium.

Commercialization Success

- The loading of three giant cryogenic storage tanks has been performed in the winter port of Rozbelesy in February 2016. The tanks were then sent to the German port of Hamburg, via the Elbe river.
- The gas storage tanks will be used for the storage of LNG for a gas fueled power station.
- In addition to this, the company recently shipped two other giant cryogenic storage tanks to Kokkola, Finland, where the vessels will be used to store liquid nitrogen and oxygen as part of a large air separation and liquids storage plant.

Technology Benefits

- LNG has the potential to bring down the operating cost of power plant nearly 25% in comparison to diesel
- Unlike crude oil, LNG spill does not require any kind of remediation of soil, ground water or surface water; thus also safer to handle and use

Analyst Perspective

Being a cleaner energy source, LNG-fueled power plants will allow plant operators to reduce their carbon footprint in cost-effective way.
Underground Gas Storage System to Store Synthetic Natural Gas
Erdgasspeicher Peissen GmbH, Germany

### Unmet Needs
- To cut the country’s carbon emissions by 70% from 1990 to 2040, the German Government is aiming to move electricity generation away from both nuclear and fossil-fuel sources.
- To meet this goal, the country requires a large number of natural gas storage facilities to ensure reliable gas supply, especially during seasonal and daily demand peaks.

### Innovation Attributes
- The UGS facility has been designed to store both naturally-derived natural gas as well as the gas derived synthetically from renewable sources, such as wind or solar power.
- The new process for the production of synthetic natural gas will combine the technologies of hydrogen electrolysis.

### Technology Profile
The company started building an underground gas storage (UGS) facility ‘Katharina’ near Bernburg, Germany. Consisting of 12 caverns, the gas storage facility will be designed to store approximately 600 million cubic meters (mcm) of natural gas. That will be designed with feeding capacity of a maximum of 12 mcm/day and a withdrawal capacity of maximum of 24 mcm/day. In addition to this, a feed and withdrawal plant and a compressor hall are being constructed above the ground to link the new storage facility with the trans-European pipeline grid.

### Partners
The Katharina UGS facility is being built by a Joint Venture of Gazprom Export and Verbundnetz Gas – Erdgasspeicher Peissen GmbH. Salzgitter Mannesmann Großrohr, a leading steel pipe manufacturer, has been contracted to provide DN 800 spiral-weld pipes needed for the project.

### Potential Applications
The purpose of the UGS facility is to bolster reliable gas supplies to the Western European region, including supplies via the Nord Stream pipeline. The new UGS would cover the gas requirements of 300,000 households in Germany.

### Commercialization Initiatives and Future Plans
Commissioning and start up of the gas storage facility has been scheduled for 2017. By then, the project will get 7 working caverns to achieve maximum designed withdrawal capacity. The last of the planned caverns will be available by 2024 for use in storing synthetic natural gas from renewable energies.

### Analyst Perspective
Though storing synthetic natural gas is a new concept, it requires a high level of infrastructure development to move the concept to commercialization.
Low-Pressure Adsorbed Natural Gas (ANG) Storage Technology

Adsorbed Natural Gas Products, Inc. (ANGP), USA is developing onboard low-pressure adsorbed natural gas (ANG) storage technology for all types of motor vehicles. The technology uses activated carbon that can store large quantities of natural gas (NG) at a far lower pressure (<1,000 psi) than the 3,600 psi typically used in compressed natural gas (CNG) cylinders.

Competing Aspects
- ANGP’s low-pressure gas storage results in compression costs savings of approximately $0.30 per diesel gallon equivalent (DGE) in the US.
- Fueling infrastructure cost is less than 50% of what is required with CNG.

Technology Readiness Level

1 2 3 4 5 6 7 8 9

The technology is almost ready to hit the US road. ANGP will introduce the first fully integrated ANG system for NGV by the end of 2016.

Wide scale Adoption
- Lower pressure gas storage requires smaller pumping equipment that can enable fueling infrastructure to reduce both its capital and operating cost, allowing more rapid and wide-scale adoption of natural gas vehicles (NGVs).

Commercial Partners
- ANGP structured a ‘Manhattan Project’ team of expert core competencies to successfully bring ANG technology to market. MeadWestvaco, Midwest Energy Solutions and a growing, but selective number of renowned companies are the core members of ANGP’s early coalition.
- MeadWestvaco is developing high-performance activated carbon monoliths for ANGP.
- Worthington Industries is developing the first seamless ANG cylinder for ANGP’s Gen1 commercial tank.
- United Technologies Research Center is providing engineering and modeling support.

Market Potential/Opportunity
- With world leading NG production capacity and the largest cost differential between NG and petroleum, USA holds strong adoption potential for NGVs.
Strategic Insights
Strategic Insights

Natural Gas Storage

Drivers & Challenges

- Successfully competing with coal and largely replacing oil
- Cost and quality are the major barriers

Market Opportunity

Europe to lure US gas suppliers

R&D and Funding Trends

Both private and public funds driving continued growth

The 2020 scenario

Price is expected to drop, followed by increased adoption

- By 2020, prices for both natural gas as well as LNG will reduce significantly
- Commercialization of advanced NG vehicles and advances in fueling infrastructure will occur, allowing US sellers to open up new storage facilities in Asia and Europe.

- The electric power sector is the key end-use sector that is driving continued growth in natural gas followed by its use as an alternative clean fuel for motor vehicles.
- The high transpiration cost and quality differences among natural gas deposits are the two major market challenges.

- With the large number of trading hubs that can be easily reached and underused import infrastructure, Europe may lure US gas suppliers as it does not have supply restrictions on destination.
- Still the US gas supplier have to compete with pipeline gas supplies from Russia and Norway.

- Funding for bulk storage facilities mostly occurs through corporates.
- Significant government funding for technological adoption and product development for natural gas storage technologies for vehicular application has been observed.
- The US Department of Energy (DOE) Advanced Research Projects Agency—Energy (ARPA-E) is funding research projects focused on natural gas vehicles.
Analyst Perspectives

**Strong price-performance competition**

The price of natural gas declined significantly in 2015 as a result of oversupply combined with falling cost of coal and rising use of renewables.

**Storage Location and Advances in Technology**

- Where a ready supply of locally produced natural gas is not available, bulk gas storage facilities located near those market centers can meet both local seasonal demands and insurance against unforeseen supply disruptions.
- Highly porous advanced gas storage materials play a vital role in commercializing gas-driven vehicles.

**Europe is likely to be the major targeted market**

- Strong growth is likely in North America for both bulk storage and vehicular storage applications.
- With the current drop in Asian natural gas demand as new plants in Australia boost supply to Asia, Europe is becoming the target market for US natural gas sellers.

**Moderately active area for patent filing**

- Within the timeframe of 2015-2016, US and China patent offices hold the largest patent share.
- The corporate sector is more active than the academic sector in filing patents in this domain.
- Underground and cryogenic storage are some of the patent focus areas for bulk storage; whereas, finding novel highly absorbent materials are the key focus areas for vehicular storage.
Key Patents
### Key Patents

<table>
<thead>
<tr>
<th>No.</th>
<th>Patent No.</th>
<th>Publication Date</th>
<th>Title</th>
<th>Assignee</th>
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<tbody>
<tr>
<td>1</td>
<td>US9261237B2</td>
<td>February 16, 2016</td>
<td>Keyway retention system for cryogenic storage tanks</td>
<td>Lockheed Martin Corp.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>A cryogenic tank support assembly and method are provided. In one embodiment, a cryogenic tank support assembly includes an outer tank structure, an inner tank structure having a storage volume therein for storing a cryogenic material, one or more keys on an outer side of the inner tank structure, and one or more key blocks comprised of a thermally insulating material and affixed to an inner side of the outer tank structure to define one or more keyways. Each of the one or more keys may be configured to be received in a corresponding one of the one or more keyways. When the key(s) is/are received in the keyway(s), the key block(s) contact the key(s) to support the inner tank structure in a spaced relation with the outer tank structure such that the inner tank structure does not directly contact the outer tank structure.</td>
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<td>2</td>
<td>US20150377550A1</td>
<td>December 31, 2015</td>
<td>Low-temperature liquefied gas tank</td>
<td>IHI Corp.</td>
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<td></td>
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<td>A low-temperature liquefied gas tank is a low-temperature liquefied gas tank including a storage tank configured to store a low-temperature liquefied gas, and a re-liquefaction facility configured to liquefy boil off gas generated in the storage tank. A returning unit configured to return a re-liquefaction boil off gas liquefied in the re-liquefaction facility to the storage tank is provided. The returning unit has a distributor disposed under a liquid surface of the low-temperature liquefied gas stored in the storage tank and configured to eject the re-liquefaction boil off gas into the low-temperature liquefied gas.</td>
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<td>A tank for safely storing a fuel in a high-pressure gaseous state, and a method for manufacturing the tank are provided. The fuel gas storage tank includes a composite material that forms a tank shell and a liner disposed under the composite material. In addition, the liner has a structure in which a metal coil is integrally formed within the liner.</td>
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<tr>
<td>No.</td>
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<td>4</td>
<td>SG10201508443P (A)</td>
<td>November 27, 2015</td>
<td>METHODS FOR STORAGE AND TRANSPORTATION OF NATURAL GAS IN LIQUID SOLVENTS</td>
<td>SEAONE MARITIME CORP.</td>
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<td>Systems and methods to create and store a liquid phase mix of natural gas absorbed in light -hydrocarbon solvents under temperatures and pressures that facilitate improved volumetric ratios of the stored natural gas as compared to CNG and PLNG at the same temperatures and pressures of less than 80 DEG to about -120 DEG F and about 300 psig to about 900 psig. Preferred solvents include ethane, propane and butane, and natural gas liquid (NGL) and liquid pressurized gas (LPG) solvents. Systems and methods for receiving (11,13) raw production or semi - conditioned natural gas, conditioning the gas, producing (14) a liquid phase mix of natural gas absorbed in a light -hydrocarbon solvent, and transporting (16) the mix to a market where pipeline quality gas or fractionated products are delivered in a manner utilizing less energy than CNG, PLNG or LNG systems with better cargo-mass to containment -mass ratio for the natural gas component than CNG systems.</td>
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<td>Disclosed herein is an energy efficient vertical cryogenic tank, which comprises a tank body with a vacuum insulation interlayer, wherein the tank body comprises a transmission means including an air return pipe and a liquid outlet pipe, and positioning means including supporting legs provided at the bottom of the tank body, and a built-in saturation adjustment mechanism formed by a heat exchanger connected to an let of the air return pipe and a return air dispersing device. By using a saturation adjustment mechanism at the inlet of the air return pipe, the cryogenic storage tank can not only fully leverage the gasification gas produced at the pump, but also achieve the saturation function of the LNG in the tank, with such benefits as reduced energy loss, simplified tank interface settings, improved efficiency of saturation adjustment, and avoided pump cavitation.</td>
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Industry Contacts
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Fax: +49-0-345-209-330-25.
URL: http://www.ugs-katharina.de/en/unternehmen.html

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