Resolving power and fuel supply imbalances with localized storage

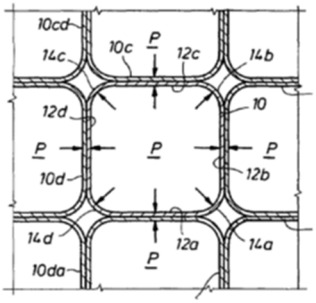
Providing innovative natural gas storage solutions that turn supply problems into real-time profit opportunities.

The US needs distributed gas storage to complement sustainable energy initiatives and many regions are underserved by existing solutions – such as subterranean or even small-scale LNG options. ezNG Solutions LLC provides new technology to efficiently enhance pipeline infrastructure in North America to meet localized needs for gas storage.

In California, increasing dependence on sustainable, but frequently interrupted power sources and systemic imbalancing in the power markets have driven undesirable peaks in natural gas prices that penalize much needed responsive generation capacity providers. At the same time, the Aliso Canyon failures have highlighted the many problems with a mega-scale subsurface storage facility – especially, in a seismically active region.

In the Northeast, extended cold weather "needle" demands in communities served by ageing infrastructure and costly small-scale LNG options have led to even more dramatic gas price spikes. Public action has made it difficult and costly to install the gas pipeline systems needed to serve expanding populations so more price shocks are looming. Increasing dependence in the region on wind and solar energy sources is likely to extend imbalance pricing spikes to the summer season.

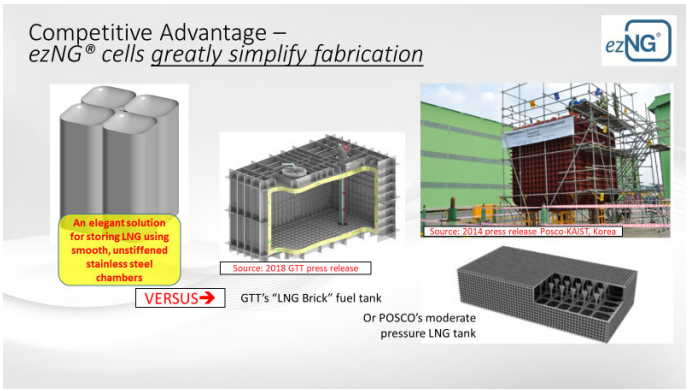
Now, ezNG Solutions LLC offers technology to dramatically reduce the cost of LNG storage. ezNG® containment costs 20-30% less than traditional LNG storage. Such savings can enable new projects.



Patented ezNG® containment concept
(US 9,033,178 B, C. White)

ezNG® containers are easy to manufacture because the walls are smooth and relatively thin even for fluid containment assemblies designed to survive pressures as high as 2 MPa (almost 300psig). Typically, large LNG tanks are not designed for pressures exceeding ~0.5 MPa.

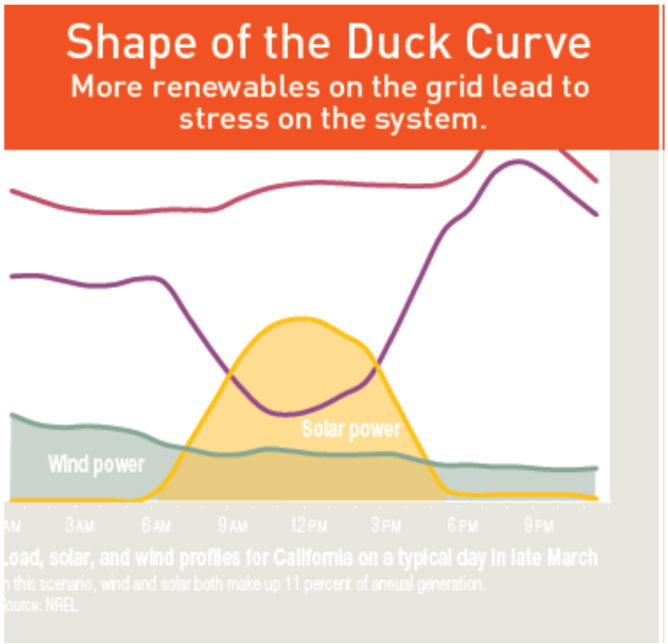
ezNG containers are typically designed for transport by truck from the fabrication shop to wherever bulk gas storage facilities are required. Units can also be designed and manufactured for any small-scale storage or fuel tank applications. The ezNG head configuration simplifies connection to foundations.



It's worth noting that in addition to decreasing the cost of LNG storage, ezNG® cell storage efficiency is an order of magnitude higher than that of steel CNG cylinders. The ezNG® cold fluid cells can be used individually or in assemblies that efficiently fill storage volume spaces (e.g., in storage vaults, ship's holds, or transportable containers).

Western Power Market Imbalances

In the years since methane leaks condemned Aliso Canyon, the role of renewables in the California market has continued to grow and stress the grid.



[ref. ASME 2018 Special Report]

Integrating renewable energy onto the grid is a well-known balance issue in the CA electricity market. The balancing falls to gas fired generation assets that are provided with little notice to generate, thus creating a gas supply problem for the generation owners (as well as other industrial consumers). Although SoCalGas has other storage available to assist generation responding to the imbalance, the delivery rate out of storage has been compromised due to restrictions on supplies from Aliso Canyon.

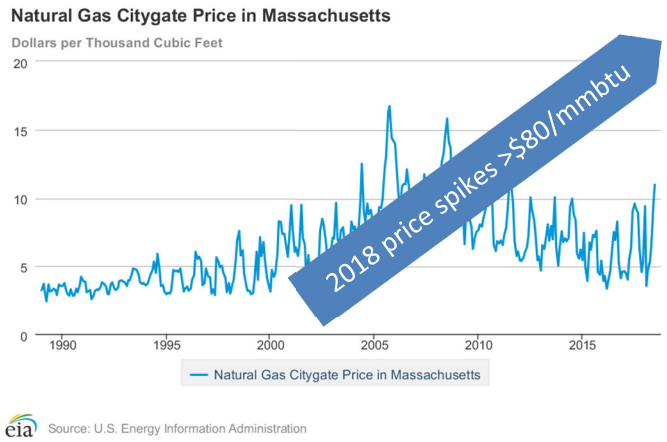
The Aliso Canyon problem also results in increased concerns about reliability of gas supply during winter months. The pipeline input to CA is approximately 2.4 BCF/day. Before the failure of Aliso Canyon, storage provided an input of ~1.6 BCF/day. Since the failure, remaining storage can manage to provide the same storage input but only for a few days… and, only when the storage system is full. Winter months rarely require just one big pull from storage, thus a supply problem is inevitable. Price spiking as a consequence of the supply shortage resulted in a gas price approximately $17 above HH prices earlier in 2018.

The ezNG Solutions storage system cannot directly replace Aliso Canyon storage but specific anticipated supply problems can be addressed. One such problem is known to us and has been modelled with favorable results in the example below. **We welcome inquiries** from CA gas users looking to avoid price spikes and/or curtailments going forward. Contact us with specifics regarding your gas supply challenges so we may jointly define a storage system to meet your requirements.

Northeasterners Can Avoid Gas Price Premiums

Shale gas production (esp. in PA) has markedly reduced the cost for natural gas in the NE region where storage is a critical part of the natural gas supply and delivery chain. Underground storage in Pennsylvania and New York is substantial representing ~10% of the U.S. total. The geology of New Jersey and New England is not suitable for underground gas storage according to the Northeast Gas Association's July 2018 report.

LNG is another important part of the Northeast storage portfolio. Total localized LNG storage in the region is almost 30Bcf, but recent history reveals that existing pipelines and storage in NE and NY are stressed. This allowed Distrigas to provide fuel from the 3.4Bcf DOMAC import terminal at the premiums seen in early 2018 (as high as $83/mmbtu in January). In the same cold spell, NYC prices reached $140/mmbtu.



Since ezNG® storage costs less than $6/gal of LNG stored, supplying just 9 days of fuel to a 200MW plant (for 10hrs/day) to avoid a $73/mmbtu gas pricing spike premium would cover the cost of a new ezNG 2.0M gallon LNG storage facility.

This facility can also support year-round LNG retail sales in the region to pay off a new dedicated liquefaction and regas facility in just 4 years. Retail LNG sales of 8 trucks per day combined with 4 turns of storage per year requires ~39M gallons of LNG production annually from a 150,000 gal/day liquefaction plant capable of producing well over 50M gpy.

Desiring payback within 4 years operations of this ezNG liquefaction/storage facility by selling 39M gpy means that the base price for LNG delivered to retail and the power generator would be ~$8/mmbtu (excluding taxes, but including $3.50 for gas supply).

It is obvious that the 150,000 gal/day plant can support more than just 4 turns per year which means that more than 39M gals of LNG can be sold if the storage is used for trading and not just for insurance to avoid spiking gas price premiums. Each turn delivers 2M gals (or 160,000 mmbtu) to the market, driving down the minimum required cost per mmbtu even if re-gassing OPEX goes up a bit.

To provide flexibility and reliability, it is assumed that the LNG plant will use nitrogen refrigeration. Not

only does the N2 allow great turn-down and re-start capability but its simplicity limits manpower costs.

If scaled up, this entire facility and operating scheme will show an improvement in economics.

Opening the Way to Dramatic Energy Savings

ezNG® technology was conceived to handle and store a very dense form of natural gas that allows dramatic cost and energy savings as compared to traditional atmospheric LNG. Companies interested in truly limiting system complexity and costs and in saving energy year after year need to understand how "warm LNG" changes the game.

Optimal conditions for storage and bulk transport of natural gas were defined by H. C. Secord and tested by R. J. Broeker of the Columbia Gas System Service Corp **in the 1960's and 1970's.** Combining the cost of containment with the cargo density and energy-cost required for compression, refrigeration, and regasification reveals the optimum for natural gas storage – at almost 100°F warmer than atmospheric LNG.

A massive R&D program by ExxonMobil in recent decades re-confirmed the advantages of liquefying natural gas at temperatures well above that of common LNG by applying modest containment pressures. ***A "Pressurized LNG (PLNG)" facility is much simpler and less than half the size, requiring only about half as much energy as conventional LNG*** *while producing a fluid nearly as dense* (ref. Bowen et al, GasTech 2005). The reduced, size, cost and complexity of a PLNG plant makes it practical to even build a "warm LNG" plant on barges.

The economics and rationale for switching from LNG as a fungible stand-by/trading storage medium to PLNG are compelling. A PLNG plant can produce the fluid for storing directly from most pipelines without introducing complex systems for CO2 and nitrogen removal. As a result, the process is simpler and much lower in cost than the N2 LNG plant described above. Since the cost of PLNG storage is significantly higher than that for ezNG's LNG storage, CAPEX for the total facility will be similar. However, a PLNG facility provides a dramatic improvement in energy consumption and waste year after year. Both of these aspects are of great concern to residents of the Northeast.

High Density Hydrogen Storage provides a Winning Formula for Sustainable Energy Capture

ezNG cells can be made of carbon steel and be used to store various products that can be liquefied under modest pressures at non-cryogenic temperatures. There is massive global trading (transport) of natural gas liquids (NGLs) for the petro-chem industry and anhydrous ammonia (NH3) for agriculture. Now, the use of NH3 as the most promising means for storing sustainably produced hydrogen as a fuel source is gaining world-wide support. NH3 itself is a viable fuel.

Further, there is growing interest in the sequestration of CO2 which requires capture, storage and transport on a scale where ezNG cellular containment and fluid handling technologies apply.

Since carbon steel costs about half as much as stainless, ezNG cells will play a big role as the preferred medium for storage in these non-cryo markets.

Summary and Recommendation

ezNG Solutions LLC has introduced new storage technology that can meet the need for low cost, localized natural gas storage that is evident in the more populous regions of the USA (and the world). Increasing dependency on frequently interrupted sustainable energy supplies and constraints on major new infrastructure projects is exacerbating the situation. So, now is the time to contact ezNG to turn your supply problems into real time profit opportunities. www.ezNGSolutions.com

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