SA Roundtable for Oil & Gas Underground Gas Storage 101

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Director of Australia Gas Storage Ventures Pty Ltd
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Myth #1

Gas Storage is a Relatively New Concept
Gas Storage Era’s

The “Horse & Buggy” Era
Outdated Gas Holders
 Manufactured Gas Application

The “Model T” (1916-50’s)
Underground Gas Storage Facility
Utilising Depleted Reservoirs
Gas Storage Era’s

The “Mustang”
UGS utilising Pinnacle Reefs (1960’s in Michigan, US)
UGS utilising high Quality Sandstones & Horizontal Wells (Alberta, Canada mid 1980’s)

AECO Gas Storage Facility in Alberta, Canada

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working Gas Capacity</td>
<td>135.00 PJ’s</td>
</tr>
<tr>
<td>Peak Withdrawal Rate</td>
<td>3.05 PJ/d</td>
</tr>
<tr>
<td>Peak Injection Rate</td>
<td>2.40 PJ/d</td>
</tr>
<tr>
<td>Number of reservoirs</td>
<td>7</td>
</tr>
<tr>
<td>Number of compressors</td>
<td>22</td>
</tr>
<tr>
<td>Total compression Capacity</td>
<td>70,600 HP</td>
</tr>
<tr>
<td>Horizontal wells</td>
<td>50</td>
</tr>
<tr>
<td>Vertical wells</td>
<td>68</td>
</tr>
<tr>
<td>Total I/W storage wells</td>
<td>118</td>
</tr>
</tbody>
</table>

The “Ferrari”
Underground Gas Storage Facility
Utilising Salt Caverns (Germany & US Gulf Coast)
Myth #2
Depleted Reservoirs are the Best Tool for UGS
Subsurface (Underground) Gas Storage

Pore Space Storage
- Naturally occurring reservoirs
- Porosity, permeability, closure, drive mechanism, depth & size are all important variables
- Generally longer cycle less responsive storage facilities
- 1 to 3 cycles per year
- Max daily withdrawal rate is at best 2% of working gas inventory
- Traditional gas storage
- Originated in Ontario, Canada in 2015

Man Made Caverns
- Utilising either salt beds or salt domes (NaCl, rock salt or halite)
- Salt depth, thickness, purity & areal extent are all important variables
- Short cycle very responsive storage facility (many times per year)
- Max daily withdrawal rate is 10% of working gas inventory
- State of the art gas storage
- Originated in Michigan, US in 1961 (46 years after reservoir storage)
- Liquid hydrocarbon storage in salt caverns preceded gas by a decade.
Salt Cavern Storage

• Over 2,000 salt caverns used for hydrocarbon storage in North America;

• Europe has over 1,000 salt caverns

• Excellent low-cost, high performance storage containers for natural gas & liquid hydrocarbons

• Impermeable material, high pressure vessel & unimpeded flow of gas to and from the I/W wells

• Salt domes work best, bedded salt is inferior host
Myth #3

Gas Storage is Only Used for Meeting Seasonal Gas Demand in Cold Climates
Application Evolution

Original Application (1950’s & 60’s)
Gas Market Region

Gas Supply Region (post 1980’s)

- Driven by introduction of intense gas to gas competition;
- Efficiency improvement;
- Minimise capital;
- Maximise utilisation rates & profit margins
- Western Canada, Gulf of Mexico region & Russia
- Crown owners support this as royalties increase

Eastern Canada, Northern US, Europe & Russia
Primary Margin Optimisation Opportunities

**Upstream**
- Just in time well deliverability replacement
- Minimise gas production capacity level
- Just in time reserve additions to offset gas sales (R/P ratio)
- Maximise annual utilisation rate of gas production facilities

**Midstream**
- Much more ‘line pack’ available to quickly resolve imbalances
- Access quick cycle gas storage capacity
- Increases market liquidity

**Downstream**
- Maximise annual utilisation rate of LNG trains
- Lower cost of gas to domestic end users
- Reshape gas supply curve to meet fluctuating gas demand
Myth #4
Any Depleted Reservoir Will Do
Depleted Reservoirs UGS Candidates

• Vigorous screening process – lots of criteria/parameters;
• Cannot force a reservoir to cycle gas at high rates;
• Most depleted reservoirs are not commercially & technically viable;
• Orders of magnitude more complicated than simply producing gas from the original discovery;
• Many smaller reservoirs preferable to one large one.
Myth #5
Water Drive works Best
Myth #6
Large Reservoirs work Best
Myth #7
We need to Explore for Storage Reservoirs
How to Find Storage Locations

• Salt (halite) deposits show up on seismic & are confirmed by wells;
• Thickness & depth are key factors;
• High performance reservoir traps are found by screening depleted & producing reservoirs;
• Production history is vital;
• The SA Gas Storage Exploration Licence procedure may fit CO2 Sequestration development projects but does not fit hydrocarbon storage development projects
Myth #8
There are Bona Fide Gas Storage Developers/Operators in Australia
Gas Storage Evolution in Australia

Gas Cycling & Upstream Optimisation
- Bass Strait, Timor Sea, Moomba & Ballera (1960’s+)
- Liquids rich gas and/or load leveling gas plants
- JV operation to enhance profitability
- Gas Producer driven

Depleted Reservoir
- Iona & Mondarra facilities (1990’s+) in Victoria & WA respectively
- U.S. companies TXU & CMS built these facilities (not gas producers)
- Both facilities have recently been expanded
- Silver Springs (AGL) & RUGS (GLNG JV) developed in Surat Basin, Qld over past 5 years

Salt Cavern
- Yet to be utilised in Australia
- World class salt deposits in SE QLD, NT & WA
- High performance in terms of both gas cycling and containment
- Lowest cost deliverability available to gas industry (gas plant outages, price arbitrage, etc)
Benchmarking – Mondarra UGS Facility in WA

- Reservoir produced 26 PJ’s from 1972-94
- Converted to UGS in 1994 by US based company
- Acquired by APA in 2004
- 18 PJ’s of stated working gas capacity
- Max injection = 70 TJ/d
- Max withdrawal = 150 TJ/d
## UGS Facility in Alberta developed by Encana

<table>
<thead>
<tr>
<th>Current Rating</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Working Gas Capacity</strong></td>
<td>135.0 PJ 8X Mondarra</td>
</tr>
<tr>
<td><strong>Peak Withdrawal Rate</strong></td>
<td>3,500 TJ/d 23X Mondarra</td>
</tr>
<tr>
<td><strong>Peak Injection Rate</strong></td>
<td>2,400 TJ/d 48X Mondarra</td>
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- 1st reservoir converted to UGS in 1988
- Followed by many expansions over the next 15 years
- 7 depleted gas reservoirs
- 70,600 HP provided by 22 compressors
- 68 vertical I/W wells
- 50 horizontal I/W wells
- Commercial open access facility
The Gap is Huge & Growing

North America
- UGS utilising depleted reservoirs pioneered in Canada (1915), followed by the US in 1916
- >1,000 reservoirs used (up to 23 per storage facility)
- UGS utilising salt caverns pioneered in Canada (1963)
- > 500 salt caverns used for UGS (twice that for hydrocarbon storage)
- >12,000 I/W wells in US alone & up to 170 I/W wells per UGS facility

Australia
- Producer storage commenced in 1960’s
- UGS commenced in the 1990’s using depleted reservoirs
- Very small capacity relative to gas production rates when benchmarked to Russia, Canada or the US
- Old technology & relatively poor facility performance
- <50 I/W wells in <20 reservoirs
Myth #9
UGS Development Just Happens
In Reality

• Upstream petroleum companies own less than 5% of the world’s gas storage facilities (non-core business);
• Australia’s installed UGS capacity is extremely small compared to other gas rich OECD countries;
• Both Iona & Moomba exist because of past government intervention;
• Access to gas pipelines is terrible in Australia;
• No mechanism to obtain quality reservoirs (hoarding issue);
• Only rudimentary regulations for reservoir storage; no regulations for salt cavern storage.
Technical Viability

- Reservoirs – Recovery Factor, Drive mechanism, porosity, permeability, reservoir shape, cap rock integrity, hydraulic integrity, size, clusters
- Salt – thickness, depth, purity, areal extent, bedded or domal, availability of water supply for leaching

Commercial Viability

- Distance to major gas pipelines/trading hubs
- Pipeline tariff rates
- Access to uncongested capacity
- Proximity to gas hub
- Price signals
- Diversity of customers
- Capex & OC of facility
How to Attract Investment to UGS Sector

Gas Market Structure

• Summer/winter price spread;
• Liquid transparent gas market with price volatility & meaningful trading volume;
• Many market participants with access to transportation services;
• Ideally a gas futures market;

Transmission

• Pipeline tariffs that are absent market power & non-discriminatory;
• Distance based forward haul tariffs;
• Backhaul tariffs that are but a small fraction of forward haul rates;
• Access to unused capacity on a low price interruptible basis (uncongested pipelines)
How to Attract Investment to UGS Sector

**Government Policy**
- Promote the sector & encourage independent storage operators over vertically integrated companies;
- Clear & comprehensive regulations for reservoir & salt cavern storage dev & operations;
- Access to high quality depleted reservoirs & salt deposits (currently hoarding is acceptable);
- Possibly a market power test to determine if economic regulation is required;

**Social Licence**
- Public education – national interest;
- Adopt & ensure best in class health & safety standards;
- Proper reporting of UGS operations;
- Adopt & ensure best in class technical standards for UGS development & operations
Myth #10

Australia has sufficient UGS capacity
Canada’s Open Access UGS Capacity (2014) Bcf WGV

- 470 Bcf in W Canada
- 240 Bcf in E Canada
- 820 Bcf Total

2016 Canadian Average Gas Production 15.2 Bcf/d
2017 Eastern Australia Average Gas Production 5.6 Bcf/d (37% of Canada)

Current Level of open access UGS Capacity in E. Australia (5% of Canada’s WGV capacity & only 2% of its max storage deliverability)

USA has 4.9X Cdn Storage Capacity, Europe has 6.4X, Russia has 3.0X & Australia has 0.08X
Alberta gas production peaked in 2002 at 14 Bcf/d but gas storage capacity continued to grow driven by larger share of unconventional production and less prolific conventional wells. Gas storage max deliverability now exceeds 50% of the peak day production capacity of 140,000 producing gas wells. Throughout the period from 1988 to 2010 Alberta gas supplied essentially flat gas demand – the Alberta industrial market & base load pipeline exports to US & E. Canada.
Glen W. Gill

Glen has 35+ years of gas industry experience across the value chain from primarily North America and Australia. Glen commenced his career as a petroleum engineer and then moved into the commercial side of the gas business: marketing, trading, business development and M&A. He then moved into middle and senior management positions and his experience includes executive positions with a number of world leaders in the gas industry and many years providing consulting services to major end users of gas, gas producers, industry associations, Government and midstream infrastructure owners/operators. His underground gas storage experience spans 30 years and he initiated & led the pioneering of the first non-regulated gas storage facility in Canada which grew to become the largest natural gas storage facility and largest gas trading hub in Canada. Glen has been involved in the development of both the Iona and the RUGS storage facilities in Australia and he has been promoting the Boree Salt gas storage development project in SE Qld for the past nine years. Glen is also a co-founder of Australian Gas Storage Ventures which was established in early 2016 to provide a variety of storage services to Australia’s growing gas storage sector.