Small-Scale Natural Gas Hydrate Virtual Pipeline
Development and Applications
Natural Gas Virtual Pipelines

• Currently only two virtual pipeline delivery methods:
  • Compressed Natural Gas (CNG)
  • Liquid Natural Gas (LNG)

• Major issues with both methods barring adoption by low-yield fuel users

• Virtual Pipelines serve to bring natural gas to end-users without pipeline access

• Potential benefits using virtual pipelines:
  • Deliver a more affordable fuel to end-users (displacing propane or diesel use) – saving businesses' on industrial fuel costs
  • Provide a low-investment delivery method until pipeline infrastructure is available
Limitations with CNG & LNG

- Price vs. Volume
  - In order to justify costs associated with implementing and operating a CNG or LNG Virtual pipeline, the end user must use high volumes of fuel
    - As cost of implementation/operation increases, so does the minimum allowable gas usage
  - High volume requirements lead to the omission of a large potential customer base

- Factors affecting cost:
  - Gas Purification Requirements
  - Production Time
  - Storage
  - Transportation
  - Regasification Requirements
Mnergy’s System

- Developed a safer and cheaper alternative to current virtual pipeline methods in order to target low-volume gas users
  - Transporting gas in solid form rather than its liquid or compressed forms (Natural Gas Hydrates – NGH)
  - Key to this virtual pipeline is our novel patent pending mobile refinery that refines pipeline quality natural gas into small egg-sized pellets
- Our NGH virtual pipeline can be broken down into three stages:
  - Refinement
  - Transport
  - Delivery / Regasification

<table>
<thead>
<tr>
<th></th>
<th>PURIFICATION</th>
<th>STORAGE</th>
<th>TRANSPORTATION</th>
<th>REGASIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNG</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
<td>LOW</td>
<td>MEDIUM - HIGH</td>
</tr>
<tr>
<td>LNG</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td>NGH</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
</tr>
</tbody>
</table>
Stage I: Refinement

1. A portable NGH refinery is brought to a natural gas hub where pipeline quality gas is purchased at wholesale levels
2. The natural gas is fed into the refinery and compressed via three-stage compressor
3. Water is concurrently fed into the refinery and compressed via pump and pressure booster
4. The compressed water and gas streams are fed into respective auto-cascading refrigeration systems
5. The cooled streams are then injected into a mixing zone; the resulting mixture is then sprayed through an orifice into pressurized temperature controlled reaction chamber – licensing a mixing zone/orifice combination from the National Energy Technology Laboratory (NETL)
6. A hydrate slurry is formed almost instantly (think snow machine) – process verified by NETL
7. This slurry is then sent via conveyor pipe into a briquette/compacting machine in order to compact and dewater the slurry into pellet form
8. The resulting pellets are placed in tanks for transport

- The unique design of the NGH refinery produces a system that can be sized to fit within the dimensions of a regular 53’ semi-trailer
  - Throughput of approximately 500MCF/D
  - A separate embodiment places system in a standard 40’ shipping container with a throughput of 200MCF/day
- Benefits of our system
  - Reduce production time when compared to CNG and LNG production
  - Utilizes available off the shelf parts which are cheaper
  - Scalable to increase redundancy and meet demands higher than 500MCF/D
  - Rapidly deployed
  - Ability to switch hubs based on current gas prices (decreasing chance of market price spikes)
  - Removes need for additional on-site gas storage
Stage II: Transport

• After forming the pellets at the refinery, they are placed in tanks for transport to the end user

• Transporting gas in hydrate form allows the exploitation of the “self-preservation effect”. Once the pellets are formed, this self-preservation effect allows them to be transported and stored at atmospheric pressures.
  • No need for expensive pressure vessels – CNG, LNG
  • No possibility of cracks or rupture failure if tank is pierced – CNG, LNG

• Only transport requirement is that the pellets stay frozen (-20C)
  • As pellets are pre-cooled during production, this feat can be easily accomplished via a moderately insulated tank (unlike the -196C LNG is transported at)
  • Tanks with the ability to hold 22.95MCF of NGH pellets are expected to cost around 5-10k each (vs the 150k+ for an equivalent CNG transport system)
Stage III: Delivery / Regasification

- Unpressurized tanks are dropped off, via specialized crane trailers, to the end user, omitting the need to leave the gas rig behind (CNG)
- Shipping gas in pellet form at atmospheric pressures allows the transport tanks themselves to serve as regasification vessels
- No additional infrastructure required at the end user, simply connect the tank to your gas meter and start burning gas
- Equipment that runs off propane already has the ability to run off natural gas

How the storage / regasification tanks work:
- Simply melting the hydrate via an increase in temperature allows the gas to dissociate at low pressures (maxing out at 4 bar). This low pressure gas is ideal for immediate use by the end user
  - CNG often requires additional infrastructure to revert the high pressure gas within the tanks to a usable low pressure gas
- Melting the pellets within the tanks is accomplished by recirculating heated water within the tank
- Done via a thermosyphoning coil (pump and electricity free coil) that burns excess gas from the tank
- The water left over from full tank dissociation may be reused for production water in the mobile refinery
- After a small price markup, gas is sold per MCF burned; once a tank is low on gas it’s replaced with a new one
Market

• Industrial companies using between 15-45MCF/D equivalent of propane, oil, or diesel located in off pipeline rural locations
  • paper mills, construction, breweries, concrete production, food processors, schools, and other manufacturing facilities

• Market research conducted on the eastern panhandle of West Virginia (Morgan, Berkeley, Jefferson Counties)
  • Lack pipeline access
  • Home to a number of small manufacturing businesses
  • Initial estimates place a gas user in our target volume every 3,500 residents around population centers
  • These small business’s are at a massive competitive disadvantage to their counterparts on pipeline; paying 40% more annually on fuel

2015/2016 Data source: U.S. DOE/EIA; utility filings; and DOER analysis

Eastern Panhandle Pipeline Locations
Cost Breakdown

NGH Virtual Pipeline
Maximum of 500 MCF of natural gas daily

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tank Infrastructure</strong></td>
<td>$275k</td>
</tr>
<tr>
<td>20-30 moderate gas users</td>
<td></td>
</tr>
<tr>
<td>using an</td>
<td></td>
</tr>
<tr>
<td>average of 20MCF gas</td>
<td></td>
</tr>
<tr>
<td>daily</td>
<td></td>
</tr>
<tr>
<td><strong>Refinery Cost Construction</strong></td>
<td>$700k</td>
</tr>
<tr>
<td><strong>External Power + Water Supply</strong></td>
<td>$300k</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td>$250k</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td>~ $1.5 Million</td>
</tr>
</tbody>
</table>

- Comparable to a CNG system of equal capacity which can cost between 10-20 Million

- Purchasing the gas at Dominion South natural gas hub at $1.22/MCF of natural gas, and reselling it to industrial off pipeline companies at $8/MCF, allows yearly revenues approaching 1.5 million while still saving companies upwards of 40% on industrial processing fuel costs
Timeline

- **January 1, 2017**: NETL License for spray technology takes effect
- **March**: Begin preparations for small scale pilot project
- **May**: Begin construction on small scale pilot project
- **August**: Small scale pilot project
- **September**: Verify production and operation parameters
- **November**: Begin preparations and construction for full scale operations
- **April**: Start Operations
Thank You

Any Questions?

Sean Miller
Sean@Mnergy.com

Mnergy Corporation
721 Domain Drive
Morgantown, WV