# Small-Scale Natural Gas Hydrate Virtual Pipeline

## Development and Applications

# Natural Gas Virtual Pipelines

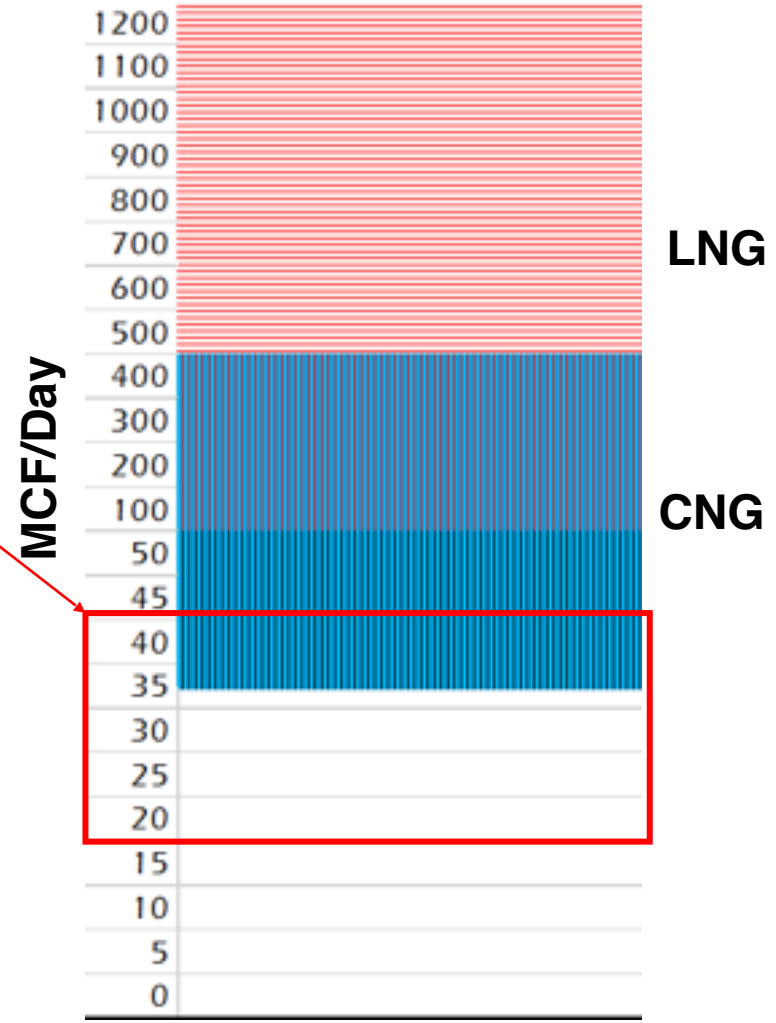
- Currently only two virtual pipeline delivery methods:
  - Compressed Natural Gas (CNG)
  - Liquid Natural Gas (LNG)
- Major issues with both methods barring adoption by low-yield fuel users
- Virtual Pipelines serve to bring natural gas to end-users without pipeline access
- Potential benefits using 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

**Avg. Daily Gas Usage – One Customer**



# 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**

**Cost Levels**

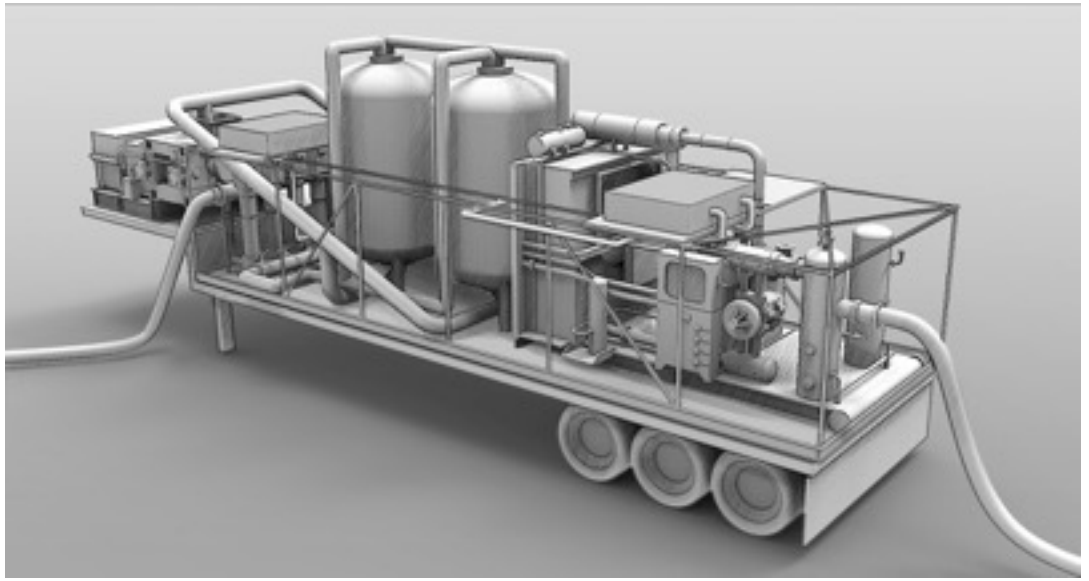
| | PURIFICATION | STORAGE | TRANSPORTATION | REGASIFICATION |
|---|---|---|---|---|
| **CNG** | MEDIUM | MEDIUM | LOW | MEDIUM - HIGH |
| **LNG** | HIGH | HIGH | HIGH | HIGH |
| **NGH** | LOW | LOW | LOW | LOW |

# Stage I: Refinement

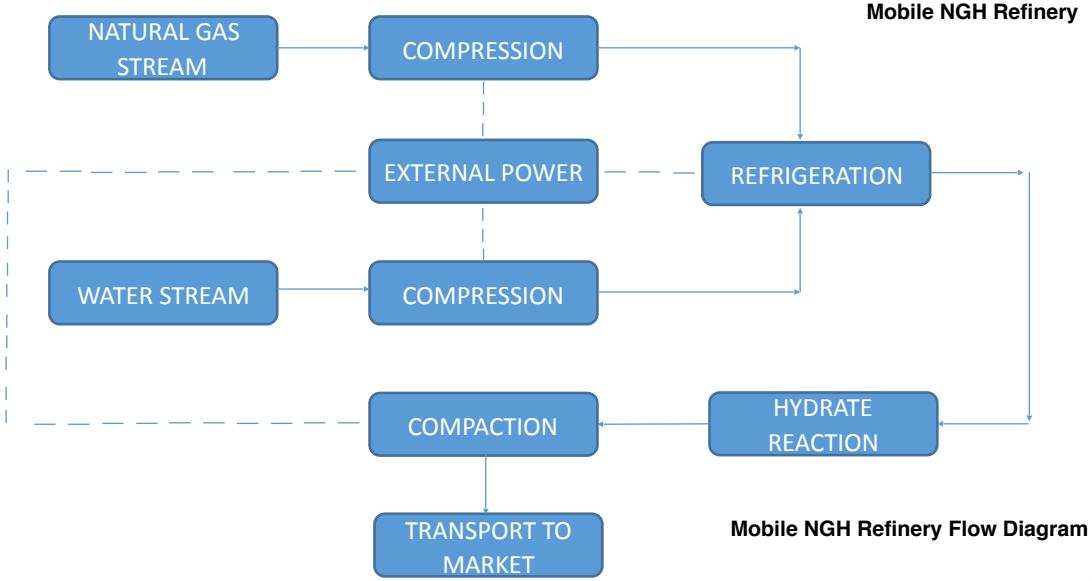
1. A portable NGH refinery is brought to a natural gas hub where pipeline quality gas is purchased at wholesale levels
2. The natural gas is fed into the refinery and compressed via three-stage compressor
3. Water is concurrently fed into the refinery and compressed via pump and pressure booster
4. The 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



Mobile NGH Refinery




Mobile NGH Refinery Flow Diagram

# 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

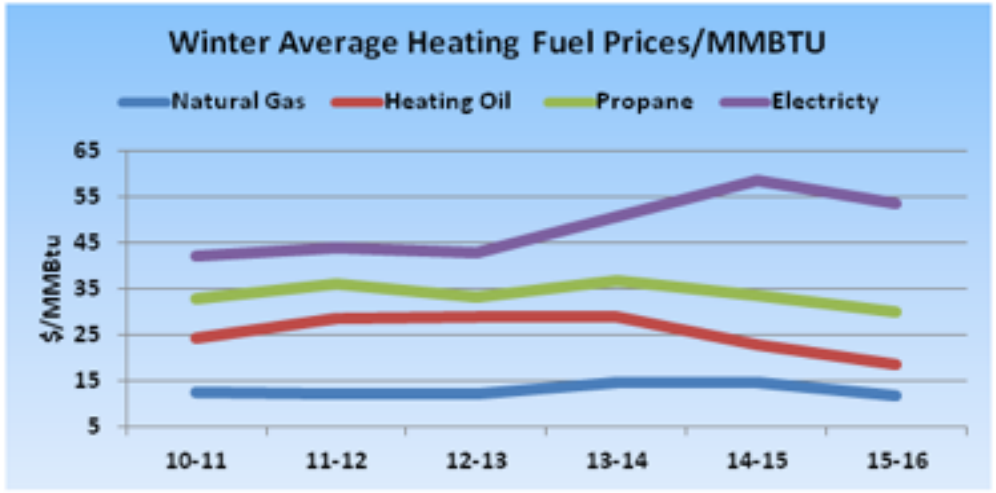
- Unpressurized tanks are dropped off, via specialized crane trailers, to the end user, omitting the need to leave the gas rig behind (CNG)
- Shipping gas in pellet form at atmospheric pressures allows the transport tanks themselves to serve as regasification vessels
- No additional infrastructure required 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:**

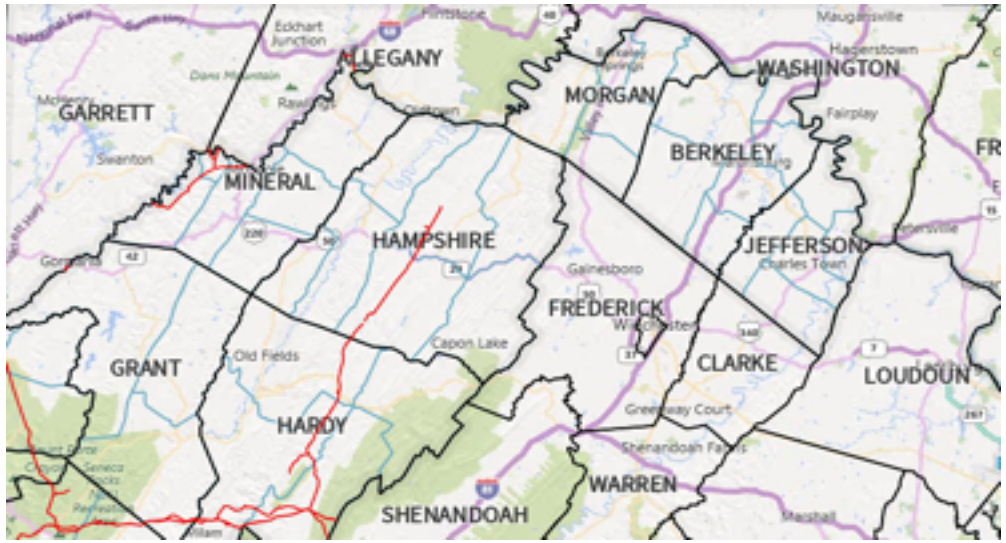
- Simply melting the hydrate via an increase in temperature allows the gas to dissociate at low pressures (maxing out at 4 bar). This low pressure gas is ideal for immediate use by the end user
  - CNG often requires additional infrastructure to revert the high pressure gas within the tanks to a usable 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**



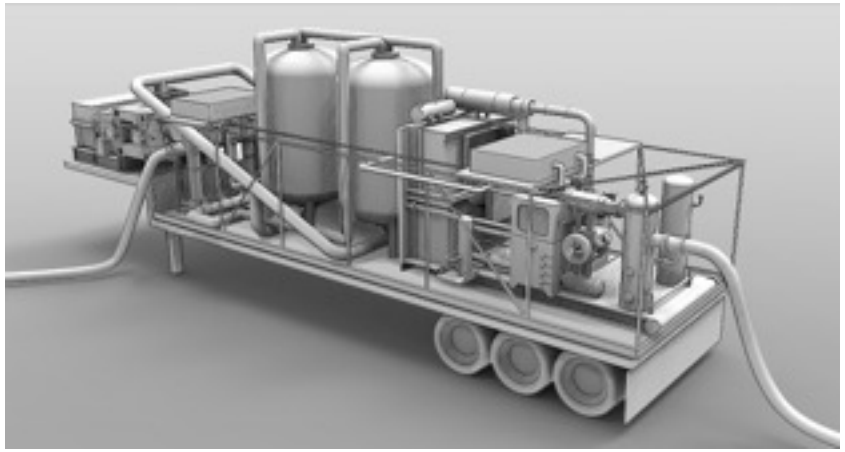

2015/2016 Data source: U.S. DOE/EIA; utility filings; and DOER analysis




Eastern Panhandle Pipeline Locations

# Cost Breakdown

| NGH Virtual Pipeline<br>Maximum of 500 MCF of natural gas daily | |
|---|---|
| **Tank Infrastructure**<br>20-30 moderate gas users using an average of 20MCF gas daily | $275k |
| **Refinery Cost Construction** | $700k |
| **External Power + Water Supply** | $300k |
| **Miscellaneous** | $250k |
| **Total Cost** | ~ $1.5 Million |

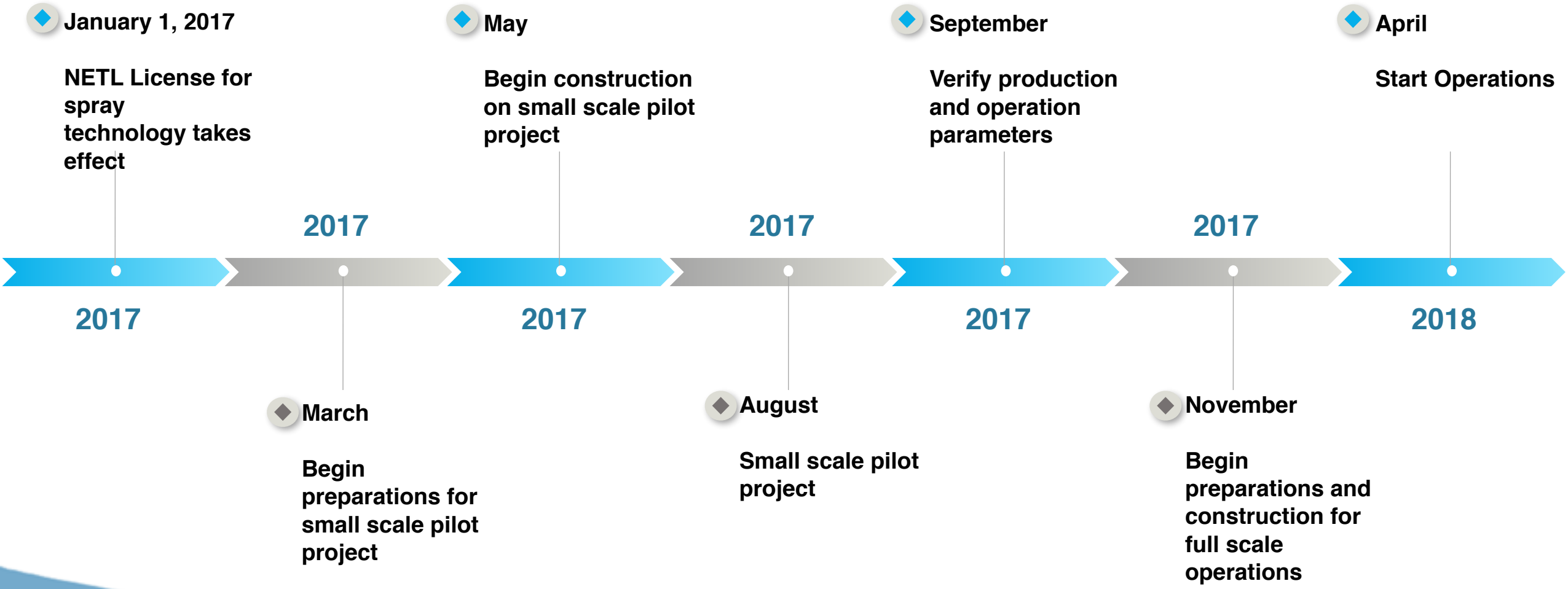


Mobile NGH Refinery

- **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
2017
March
Begin preparations for small scale pilot project
May
Begin construction on small scale pilot project
2017
August
Small scale pilot project
September
Verify production and operation parameters
2017
November
Begin preparations and construction for full scale operations
April
Start Operations
2017
2017
2017
2018

# Thank You

## Any Questions?

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