

## **PETROLEUM COKE & GASIFICATION OVERVIEW**

---

Diversified Energy Corporation, formed in 2005 in Gilbert, AZ, is a privately held company specializing in the advancement and commercialization of a series of alternative and renewable energy technologies. The Company is focused on completing research and development on these technologies, building first-of-a-kind pilot commercial plants, and constructing, operating, and/or selling large-scale projects based on these technologies. The business approach relies heavily on forming strategic ventures with leading industrial technology, construction, and engineering companies.



### **THE MARKET FOR PETROLEUM COKE GASIFICATION**

The Petroleum Coke (“Pet Coke”) market is a prime target for gasification technology where a refinery waste/by-product can be utilized for the generation of Hydrogen (H<sub>2</sub>) rich syngas which is in ever increasing demand for hydrotreating and hydrocracking processes. Approximately 60 million tons of petroleum coke was generated in 2008 in US oil refineries, with almost 2 million tons currently stockpiled (Energy Information Administration, August 2009).

Hydrogen management has become a priority for current and future refinery operations as consumption continues to rise for greater hydrotreating processes, and processing of heavier and higher sulphur grade crude oils. In many cases the hydrogen network is limiting refinery throughput and operating margins. The current main source for hydrogen is the Steam Methane Reformation (SMR) of refinery off-gases and natural gas, an inefficient and cost incurring process. Energy consumption (including natural gas) for feed and fuel is the largest component for H<sub>2</sub> production, almost 70% of the operating cost of a standard 50 million cubic feet (scfd) SMR plant (David & Patel, PTQ, 2004). Gasification using the molten metal technology is attractive to refiners in reducing a hazardous waste issue and providing an additional on-site source of hydrogen to help address ever increasing demand.

- H<sub>2</sub> consumption in refineries is ever increasing in the current and future clean fuels environment (Davis & Patel, PTQ, Spring 2004).
  - Deeper hydrotreating – average of 47% of SMR produced hydrogen
  - Hydrocracking – average of 50% of SMR produced hydrogen utilization
  - Processing heavier and higher sulphur crude grades.
- Existing improvements and/or expansion of Steam Methane Reformation (SMR) plants and systems will not address the increasing demand for high purity H<sub>2</sub> demand alone.
- Integrated management of hydrogen generation, processing and recycling improves the efficiency of refineries and reduces waste but does not provide alternative sources for additional volumes.
- New sources for Hydrogen are required to meet the needs for future cleaner hydrocarbon fuels.

***The Diversified Energy Market Niche***

While many gasifiers utilize established technologies such as entrained flow and fluidized bed gasifiers, such technologies from GE, Siemens, and Uhde require large footprints and capital costs of several hundred million dollars. Diversified Energy has created a smaller scale solution for:

- Space or development constrained facilities (including industrial facilities other than refineries);
- Lower volume generators of petroleum coke;
- Drastically lower capital costs for the Diversified gasifier of less than \$10m.

The Diversified Energy OmniGas® gasifier can utilize up to 1,500kg/hr of pet coke as a feedstock with the generation of over 60% hydrogen in the produced syngas.

***DIVERSIFIED'S OMNIGAS® PLATFORM***

OmniGas® is the name of Diversified Energy's technology incorporated in the design of next generation molten metal gasifiers that can utilize a petroleum coke waste product to generate much needed hydrogen.

- Is based on improvements to the HydroMax® molten metal technology for which Diversified has obtained a license
- Uses 1300°C molten bath of iron oxide and ash slag to gasify hydrocarbons
- Technology developed by Diversified Energy
  - Licenses, owns, or has patent applications pending on seven US Patents in four diverse areas comprising 349 claims.
  - Filed a Patent Cooperation Treaty for OmniGas and the Glycerol burner, preserving the right for future international filings.
  - Several unpublicized and protected "trade secrets" related to the components, design and operation of these technologies.
  - Substantial process and design "know-how" and similar IP that is not readily available to, or readily copied by others.
  - Owns substantial proprietary dynamic technical and financial models of its processes, using customized software tools that took over three years to develop.
- Key advantages:
  - Feedstock flexibility
    - Petroleum Coke, Coal, biomass and MSW
    - High moisture, high sulfur contents
  - Syngas free of tars and oils, sulfur removed
  - Efficient generation of Hydrogen through water-shift reactions
  - Simplicity – high reliability and availability



- Economical at industrial scale
  - 1k – 3k MMBtu/day, \$5 – \$7/MMBtu syngas
- Development status:
  - 6 years of private development funding
  - 3 government contracts in progress
    - Dept of Energy – coal and coal/biomass to syngas for industrial process heating applications
    - State of CA – biomass to syngas at a pulp mill to offset natural gas usage
    - Dept of Defense – transportable waste to FT fuels system
  - Now scaling up from 0.2m to 0.5m (internal diameter) reactors
  - Commercial design is in the 1.5m – 2.5m range
  - 1,500kg/hr –feedstock volume design range



**DISTINGUISHING FEATURES OF OMNIGAS**

- Successful Demonstrations Have Proven OmniGas® Viability
- High Quality and Ultra-Clean Syngas: No Tars or Oils
  - Ideal for industrial natural gas replacement
  - Less syngas cleaning requirements
- Multi-Feedstock Capability
  - High thermal inertia of molten metal enables utilization of high moisture content feedstock
  - Excellent solution for biomass/coal gasification
  - Ideal for entities with operations at different locations
- Combining Two Well-Known and Controllable Industrial Processes
  - Steaming iron and Metal bath smelting
- Operational Flexibility
  - Can produce separate streams of CO and H<sub>2</sub> or a single high-btu content syngas
- Scales Economically For Industrial Applications
- Benefits of the “slag-only” approach

**The Omni-Gas™ Technology Utilizes Two Primary Chemical Reactions to Gasify Carbon Feedstock**

- **Reaction 1.** Carbon in Feedstock Reacts with Iron Oxide in the Molten Mass to Produce Carbon Monoxide  
 Chemistry:  $FeO + C \rightarrow Fe + CO$
- **Reaction 2.** Steam Reacts with Iron to Produce Hydrogen  
 Chemistry:  $Fe + H_2O \rightarrow FeO + H_2$

Oxygen is added into reactor vessel to maintain thermal balance

Temperature	1300°C
Operating Pressure	1-3 atm
Molten Mass	FeO (50%) Ash/flux (50%)

- Eliminates tin and the “leakiness” issues associated with containing tin in the reactor vessel (the most complex issue we have associated with the refractory material)
- Homogenous mass eliminates the “Marangoni” water-line refractory wear issues observed during the DOE tests
- Enables higher pressure system operations
- Simplifies slag management and removal procedures
- Greatly simplifies containment and refractory material selection

### **OMNIGAS® COMPLETED MILESTONES**

The OmniGas® technology has been validated and achieved significant developmental progress over the last 3 years. Pilot scale projects funded through internal investment, DoE and DoD contracts have achieved the following milestones:

- Small Scale HydroMax® (a precursor technology licensed to Diversified) testing completed with Petroleum Coke, PRB and Illinois #6 coal
- OmniGas gasification process validated for feedstocks with varying chemical compositions
- Test results repeatable from cycle to cycle
- Excellent CO & H<sub>2</sub> production
- H<sub>2</sub> production during Oxidation Cycle >60%
- Excellent CO/CO<sub>2</sub> ratios observed (>14:1)
- H<sub>2</sub>/CO measured production in good agreement with model predictions
- Coupon Sample tests that had no degradation during gasifier testing resulted in lance material (Inconel 600) selection
- New refractory lining design and casting process to address reactor corrosion.
- Injection of steam and carbon simultaneously (continuous operation) resulted in accelerated kinetics and very attractive syngas compositions



### **OMNIGAS® COMMERCIALIZATION PATH**

Diversified has validated the science behind the gasifier and the technological design of the molten metal slag gasifier, including refractory materials and lance designs. The Company is now seeking a partner that will assist in taking the OmniGas® technology to the next stage of refining the existing designs and manufacturing a commercial reactor design. The commercialization path over the next 12 to 24 months will target the following key milestones:

- Build the ½ meter diameter demonstration gasifier.
- Complete the final detailed design on the 1.5 meter diameter commercial unit.
- Design and analyze performance of the end-to-end/turnkey plant production architecture for Hydrogen production.
- Build and validate the 1.5 meter commercial-scale unit.

**STRATEGIC PARTNER OPPORTUNITY**

- Diversified Energy is seeking a strategic partner to assist in the commercialization of the OmniGas® platform.
- Diversified's partner will be:
  - committed to the development and commercialization of the OmniGas® gasifier
  - aggressive in market development and technology sales strategies in one or more identified vertical markets (e.g. Petroleum coke, biomass, waste)
  - focused on creative marketing to fully exploit the advantages of OmniGas®
- Diversified Energy is willing to consider various levels of partner involvement in the development and commercialization program.