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HydroMax® - Advanced Gasification Technology

Introduction

Gasification is the process of converting carbon-based materials such as biomass, coal, petroleum coke, and waste into a "synthesis gas" that c then be used for a myriad of applications including the production of liquid fuels, synthetic natural gas, electricity and hydrogen. While the conc and practice of gasification is well-known and established, existing gasification technologies have clear limitations in areas such as feedstock flexibility, capital costs, and the ability to scale economically for industrial and distributed operations. HydroMax is a breakthrough advanced gasification technology that leverages expertise and know-how from the established molten-metals industry for the conversion of multiple carbon-based feedstocks to a wide variety of energy products. In development since 2002, including several highly successful demonstrations, t HydroMax intellectual property position is protected by 4 issued patents including more than 240 claims of invention. Since licensing the HydroM technology in 2006, Diversified Energy has positioned HydroMax as a premier advanced gasification approach as evidenced by three on-going commercial prototype demonstration projects with the U.S. Department of Energy, the State of California, and the U.S. Department of Defense. While multiple uses and applications (liquid fuels, electricity, hydrogen, etc.) exist for the technology, Diversified Energy is targeting industrial natural gas users as the initial market entry strategy. With more than 14,000 potential customers in this market segment, HydroMax offers a uniq and economical process heating solution to the industrial sector by providing a means to reduce and stabilize energy costs for this critical U.S. economic pillar.

Technology Overview

Leveraging the fundamentals of molten-metal technology, the HydroMax process starts with a reactor vessel containing a molten bath consisting c an iron/tin alloy and a high iron-oxide slag heated to 1300°C with a pressure level between 1 and 3 atmospheres. Steam, carbon, and oxygen are injected into the molten bath where two primary reactions occur to produce hydrogen and carbon monoxide. As indicated in Figure 1, steam rea with the pure iron to produce iron oxide and hydrogen and carbon reacts with the resulting iron oxide to produce carbon monoxide and return the oxidized iron to its pure state. Oxygen is added to combust some of the carbon in order to maintain thermal balance within the reactor vessel. Pri demonstration tests indicate that these reactions can occur cyclically (separate streams of hydrogen and carbon monoxide) or simultaneously (a single syngas stream that includes hydrogen and carbon monoxide) within the reactor, thereby providing inherent operational flexibility dependin

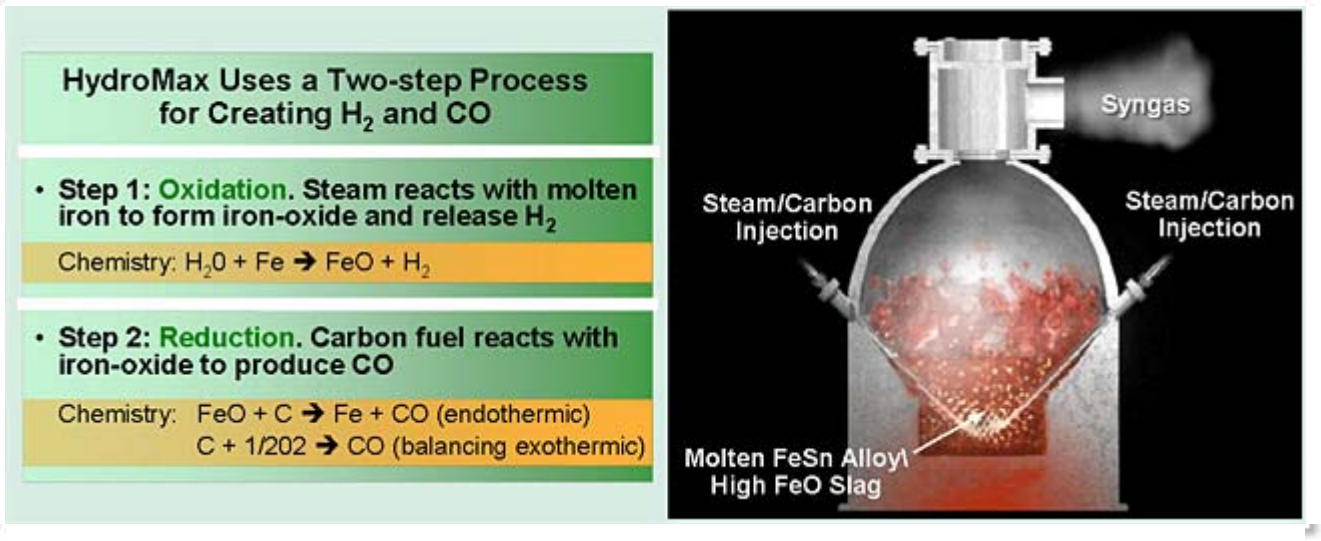

Figure 1: HydroMax Molten-Metal Technology

on the end application (liquid fuels, hydrogen, synthetic natural gas, etc.) for the gas produced. The tin component of the molten alloy results in a lower alloy melting temperature and serves as a means to remove sulfur from the system through the creation of tin sulfide. It is important to note that while the fundamental HydroMax chemistry is analogous to conventional gasification, the chemical pathway is very much unique.

Unique Advantages and Features

As a result of utilizing this unique chemical pathway for carbon feedstock gasification, HydroMax offers several key features and advantages compared to conventional gasification technology:

- **Feedstock Flexibility**: High degree of thermal inertia associated with the molten-metal bath provides the ability to tolerate low and high moisture content feedstock including all coal types, biomass, petroleum coke, and others
- **Low Capital Costs**: Simple nature and design of the molten-metal bath reactor vessel translates into less complexity and therefore lower capital costs
- **Very Clean/Pure Syngas Product**: High-temperature (1300°C) molten metal process results in an extremely clean and pure syngas, therefore reducing the amount and complexity of syngas cleanup and conditioning required
- **Economic at Industrial Scale**: Molten-metal thermal inertia enables an efficient and economical process at small/distributed scale (10MWe 40MWe)
- **Operational Flexibility**: Ability to produce separate syngas streams or one single syngas stream results in operational flexibility that can be tailored for specific end-use applications (i.e. liquid fuels)
- **Innovative Sulfur Removal**: Sulfur exits the reactor vessel in the form of tin sulfide (SnS), which is then precipitated out during syngas quench and oxidized to separate the sulfur (captured as a by-product) and tin (re-introduced in the reactor vessel). This approach makes more hydrogen available for use and enables the utilization of high sulfur content feedstocks.

Target Markets

While market opportunities for the HydroMax technology are virtually unlimited, Diversified Energy is targeting industrial natural gas consumers a the initial market entry point for the HydroMax approach. The U.S. industrial sector accounts for more than 30% of total natural gas demand in th country and, according to the U.S. Department of Energy, consists of more than 14,000 users. Further analysis of this market indicates that 2,0 - 5,000 industrial natural gas users consume between 1,500 and 5,000 MMBtu's per day of natural gas for process heat, which is an ideal production level for the HydroMax technology. The industrial natural gas consumption market is attractive for several reasons: 1) The industrial customer realizes value by stabilizing their cost of fuel gas and eliminating natural gas price volatility risk, 2) Capital investment for a single industrial-scale HydroMax gasification project is very manageable with estimated total project costs less than $10 Million, 3) Syngas cleaning and conditioning requirements are minimized for process heating applications, 4) Commercial HydroMax system is a reasonable scale-up from previous demonstrations, and 5) Many industrial operations have captive waste streams that can be utilized as feedstock for the HydroMax technology.

From a competitive perspective, HydroMax is ideally positioned to provide a high-temperature, small-to-mid scale, economical solution for industr natural gas replacement opportunities. As indicated in Figure 2, the gasification marketplace consists of two primary types of technologies: 1) High-temperature, large-scale, entrained flow gasification technologies that produce utilityscale volumes of syngas for electric power, liquid fuels and chemicals. High-temperature gasification technologies are limited by their ability to scale economically for smaller capacity applications. 2) Low-temperature, small-scale gasification technologies are also available in the marketplace. However, these systems produce a 'dirty' syngas containing appreciable amounts of tars and oils as a result of not fully cracking all of the hydrocarbons in the feedstock. Therefore, low-temperature gasifiers require expensive and complex syngas cleaning equipment to condition the syngas before being utilized. HydroMax offers a high-temperature and clean syngas solution that is economical at small scale, therefore making the technology ideally suited for the industrial process heating marketplace. In fact, Diversified Energy is currently working with two industrial companies (CertainTeed Gypsum and

Evergreen Pulp) under separate funded R&D projects to design a natural gas replacement solution for their respective operations.

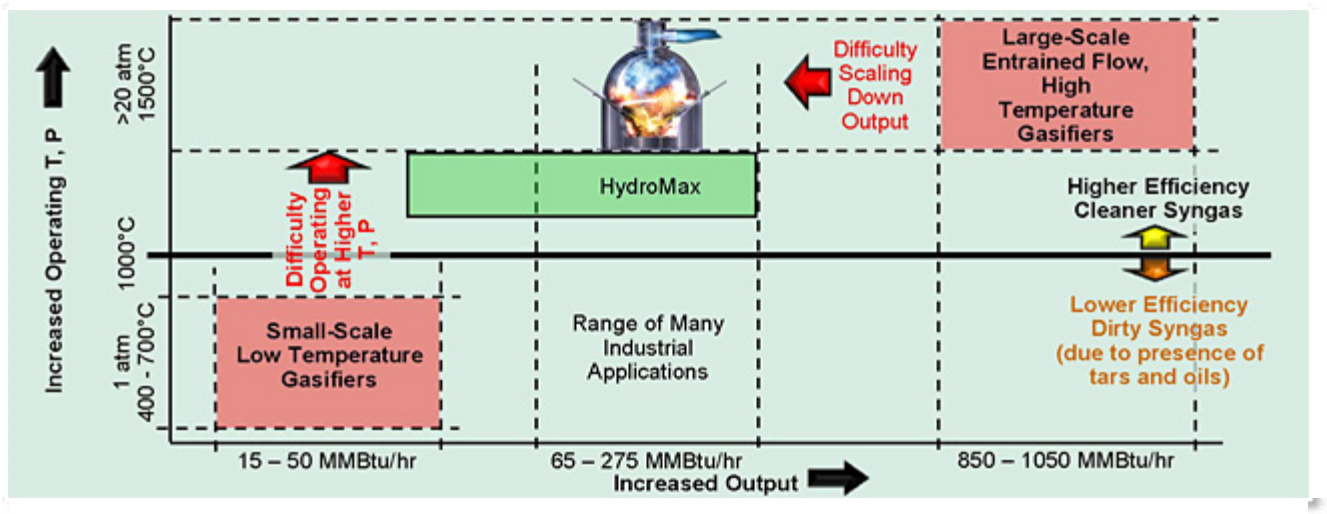

Figure 2: HydroMax Is Ideally Suited For Industrial Process Heating Applications

Development Heritage

Several highly successful, privately funded, laboratory and bench-scale HydroMax demonstrations have occurred since 2002. As indicated in Figure 3, beginning with a simple steam-injection test to demonstrate efficient hydrogen production, test activities have evolved to include conversion of petroleum coke and municipal solid waste feedstock, steam injection rate optimization, and successful operation of the 'lock-cycle' (oxidation then reduction) approach. Each of these accomplishments served to validate the fundamental science, optimize system operations, an demonstrate the commercial potential of the HydroMax technology.

From October 2007 to April 2008, Diversified Energy successfully executed a HydroMax demonstration contract funded by the Department of Energy's National Energy Technology Laboratory (NETL). As shown in Figure 4, this DOE funded project resulted in several key HydroMax development milestones including: 1) Coupon tests of potential materials for the containment vessel and injection lance revealed multiple candidat for a commercial HydroMax system, 2) Design, construction, and successful operation of two HydroMax demonstration reactors that effectively gasified two types of coal feedstock (Powder River Basin and Illinois #6), 3) Excellent carbon conversion, cold gas efficiency, CO/CO2 ratios, ar H2/water ratios indicate exceptional performance, and 4) Strong correlation between actual test data (H2 and CO production) and predicted

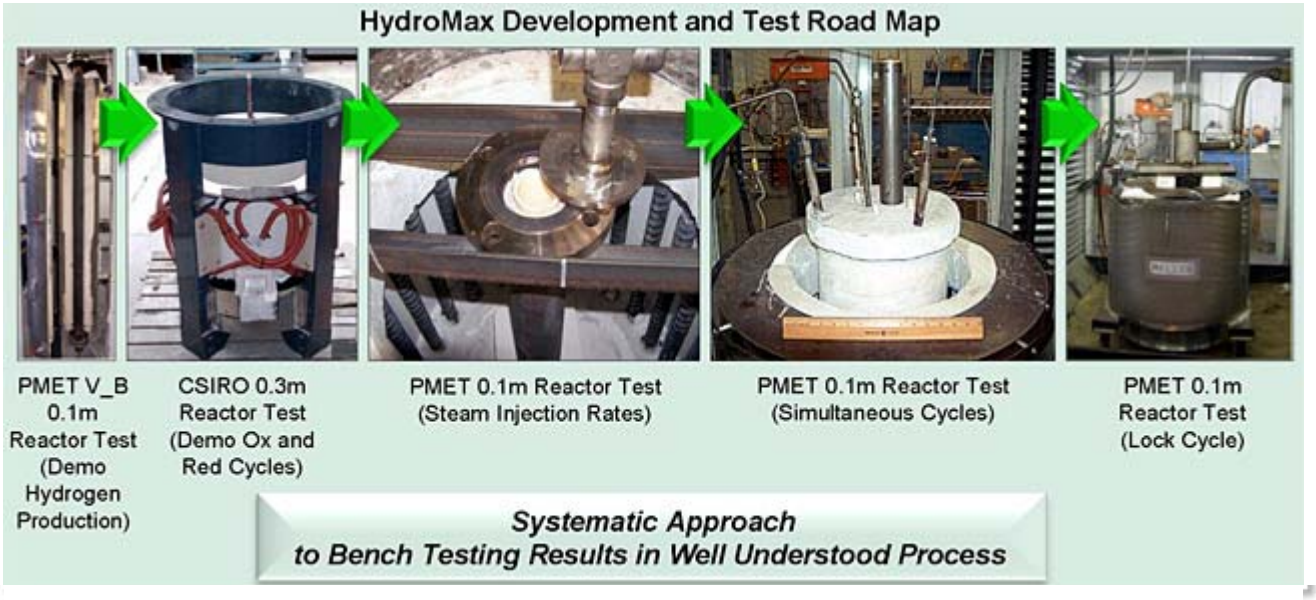

Figure 3: Successful HydroMax Bench-scale Tests Validate the Approach

performance data validated our high-fidelity AspenPlus HydroMax analytical modeling tool. As a result of the superior performance achieved duri these tests, NETL awarded Diversified Energy a follow-on contract to design and construct a commercial HydroMax prototype that incorporates a developmental lessons learned and addresses commercial engineering, scale-up, operational, and implementation aspects of the HydroMax approach.

On-going Projects

HydroMax is currently being funded by three federal and state-level agencies including the U.S. Department of Energy, the U.S. Department of Defense, and the State of California. Each funded project was competitively selected and has clearly defined development and demonstration goals.

- **Department of Energy Industrial Gasification Phase II**: Funded by the National Energy Technology Laboratory (NETL), this project leverages successful bench-scale tests completed in April 2008 to design, construct, and operate a HydroMax commercial prototype that wi gasify Powder River Basin (PRB) coal, Illinois #6 coal, and a blend of PRB coal and biomass. The primary program objective is to design a HydroMax system for industrial natural gas users and provide energy cost reductions and/or stability for the industrial sector. Diversified Energy has partnered with CertainTeed gypsum, a large North American industrial manufacturing company, and will design a commercial HydroMax natural gas replacement system for a CertainTeed operating facility.
- **State of California Public Interest Energy Research (PIER) Natural Gas (NG) Program**: With the goal of reducing natural gas consumption in California, the California Energy Commission awarded a development contract to a team led by Diversified Energy focused on biomass gasification as a source of process heat for industrial facilities. Diversified Energy partnered with Evergreen Pulp Inc., located Eureka, CA, and will design, build, and install a HydroMax prototype system at the Evergreen Pulp operation, gasify by-product wood fines the mill, and provide syngas that will be combusted in the Evergreen Pulp thermal oxidizer (see Figure 5). Following the successful completi of the California PIER project, Diversified Energy plans to scale-up the capacity of the HydroMax system to completely eliminate Evergreen Pulp's natural gas consumption.

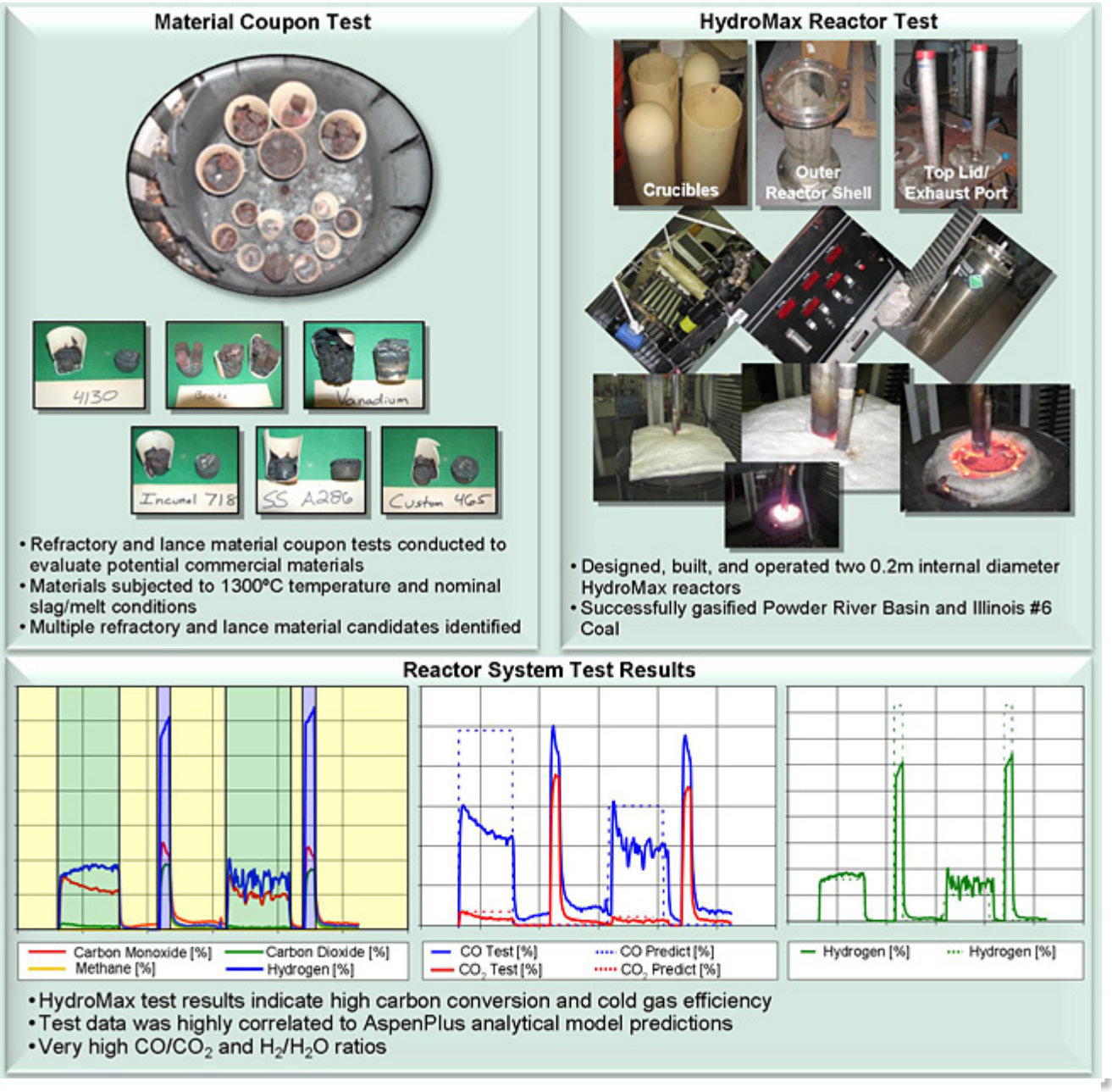

Figure 4: U.S. Department of Energy Contract Resulted in Significant HydroMax Development Milestones

- **U.S. Department of Defense Liquid Fuel Production**: Diversified Energy has partnered with Velocys Inc. (a leading developer of micro-channel Fischer-Tropsch liquid fuel production technology) to provide the Department of Defense with a modular and transportable fuel production system that can be utilized at forward deployed operating bases. Funded by the Office of the Secretary of Defense, Diversified Energy and Velocys successfully completed a feasibility study for the concept in mid-2008 and are now awaiting award notification for a follow-on contract to demonstrate the approach.

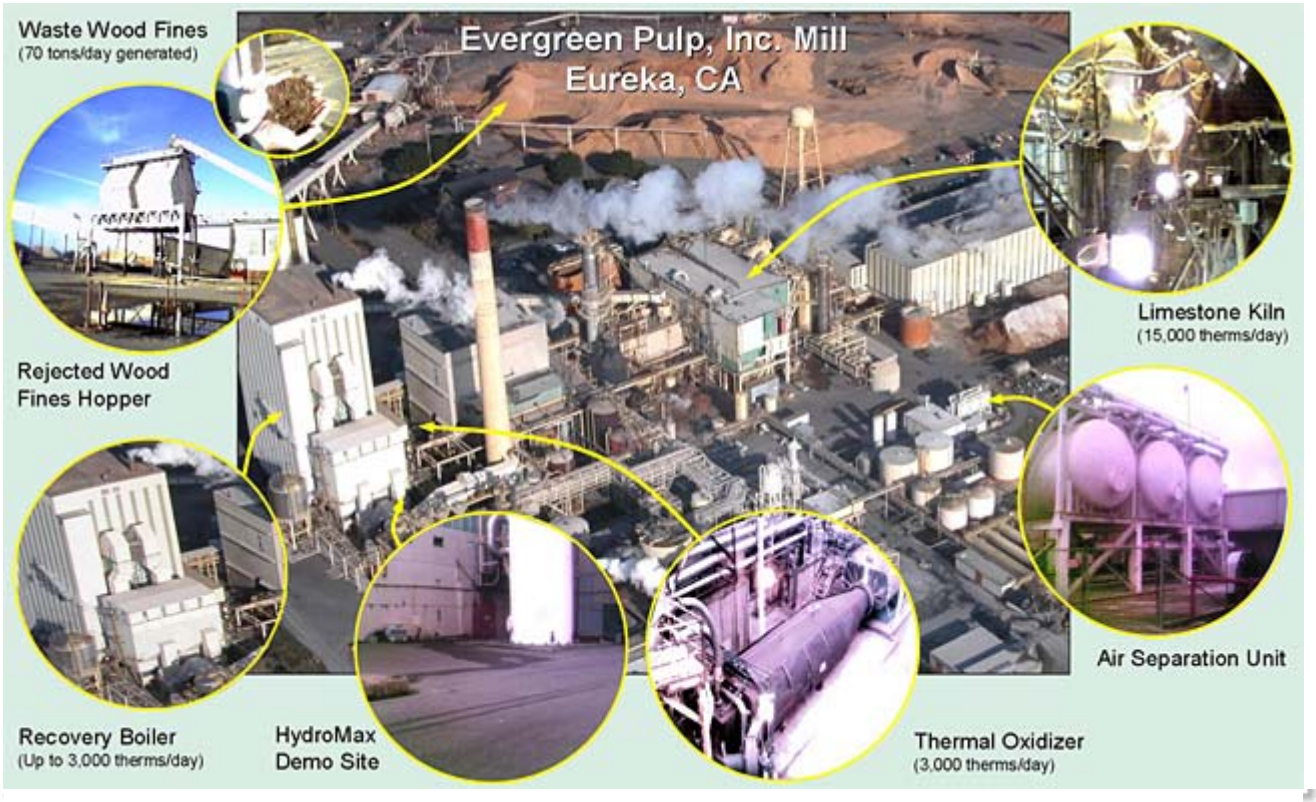

Figure 5: State of California Biomass Gasification Project

Team

As with any development activity, having the right team of people and capabilities is an essential element of a successful program. Diversified Energy has compiled a world-class team of strategic partner companies that offer in-depth experience associated with all technologies and critic areas required to commercialize the HydroMax approach.

Pittsburgh Mineral and Environmental Technology (PMET): PMET is one of the HydroMax inventors, has been involved in all previou HydroMax demonstration work, and brings a wealth of experience in areas such as metallurgy, molten-metal operations, chemical processing, and rapid prototyping.

The Energy and Environmental Research Center (EERC): With more than 50 years of gasification research and development experience, th EERC provides the HydroMax development team with gasification expertise, feed system design and implementation, system design and analysis expertise, refractory design and test capabilities, and demonstration facilities to conduct operational tests.

CertainTeed Gypsum (subsidiary of St. Gobain): A leading wallboard manufacturing company, CertainTeed provides the practical, end-user, operational perspective for the HydroMax technology and is generating integration requirements for a commercial HydroMax system.

Evergreen Pulp Inc.: Evergreen Pulp will provide the site and infrastructure for the first userintegrated commercial prototype HydroMax

demonstration system at their location in Eureka, CA.

Velocys Inc.: Velocys is maturing and commercializing a breakthrough Fischer-Tropsch (FT) conversion technology based on micro-channel chemical processing, which results in an orderof- magnitude reduction in the size and footprint of FT systems. Diversified Energy is working closely with Velocys to integrate HydroMax and the Velocys FT system to provide a small, integrated, and modular liquid fuel production technology.

Path Forward

Diversified Energy is focused on the successful execution of all on-going HydroMax projects, reducing the risk of commercial implementation, ar achieving high performance demonstration results. We are in the process of establishing key relationships with strategic partners (end-users, equipment suppliers, technology vendors, etc.), investors, equity partners, and debt providers to complete all engineering and scale-up tasks anc transition the technology to the commercial marketplace.

View Our HydroMax® Executive Summary