

REACTWELL - UNDERGROUND GEOTHERMAL BIOMASS-TO-OIL PRODUCTION PLATFORM

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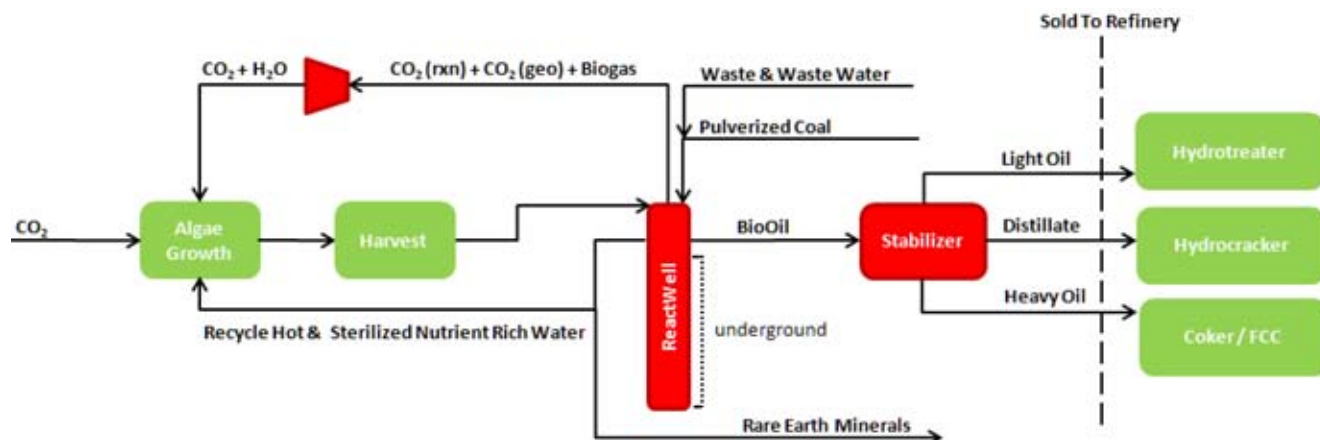


Figure 1. ReactWell Process Flow Diagram.

ReactWell's (RW) internationally patent pending technology produces liquid crude oil in the presence of water by combining biomass, gravity and geothermal heat in an underground geo-thermochemical reactor system. Geo-thermochemical technology naturally generates the pressure and temperature required for sub-surface biomass conversion reactions to proceed through to completion by using the injected biomass' hydraulic head for pressure and geothermal energy of the surrounding rock for heat. Additionally, biomass productivity is increased by feeding algae geofluid CO_2 , reaction by product CO_2 and geofluid carbonates.

R&D

ReactWell is pursuing R&D to determine the economic feasibility of producing synthetic crude oil using underground geo-thermochemical technology. Underlying hypotheses and technical concepts guiding the approach include:

Reactor Modeling & Simulation. Underground temperature, pressure and residence time provides sufficient reaction zone to convert biomass into synthetic crude oil.

Reactor Experiments, Analytical Work and Impact on Biomass Productivity. Kinetics, yields and selectivity for geo-thermochemical algae, waste, wood and lignite produce synthetic crude oil and byproducts in volumes of commercial interest. Recycling of reaction byproduct CO_2 , geofluid CO_2 , carbonates, and mineral rich water boosts feedstock biomass productivity levels, which in turn produces more net oil to sell for profit.

Reservoir Modeling, Simulation, Integration and Application of ReactWell. Known geothermal heat resources, permeability and water flow rates are sufficient to economically farm geothermal heat to satisfy required reactor heat input for oil.

INNOVATION & IMPACT

Performance of current State-of-the-Art in the field. Current algae firms extract lipids and then sell the remaining biomass as animal feed. ReactWell converts total algae biomass with lipid, proteins and starches into synthetic crude oil and gas in the presence of water, produces warm mineral nitrogen, phosphorous, and potassium (NPK) rich water for use as algae feed and recycles process byproduct CO_2 and geothermally produced carbonates, trace metals and CO_2 as algae feed and growth medium.

ReactWell is a departure from currently available technology and differs from others under investigation in the field. ReactWell overcomes the shortcomings of current algae industry state-of-the-art by converting total biomass in water into oil and gas. There is no need for costly lipid extraction and solvents. The technology uses earth's waste heat and gravity to de-couple fossil fuel production from consumption with water as the solvent. ReactWell is a significant departure from available technology and others under investigation because the platform is applicable to multiple biomass feedstocks (algae, septic, plastic, rubber, lignocellulosic) along with mineral scavenging, waste water sterilization, lignocellulosic material and coal liquefaction.

ReactWell represents a significant advancement relative to the state-of-the-art by increasing oil yields, while decoupling fossil fuel production from consumption. By using geothermal heat for chemical reactions vs. power production ReactWell avoids Carnot thermodynamic limitations and transmission line losses incurred when wheeling power. Additionally, ReactWell digs deeper into biomass and not only converts the lipid portion of the feedstock into synthetic oil, but also portions of the protein and starches.

ReactWell's impact on system-level performance metrics, including adverse effects. Increased biomass

productivity levels due to hot NPK rich water recycling, CO₂ (source: biomass byproduct), CO₂ (source: geothermal fluid) and carbonates (source: geothermal fluid) are anticipated. Expected oil yields are greater than current lipid-based technology due to multiplicative interaction of CO₂ recycle/recovery, NPK recycle/recovery & HPHT conversion.

Estimated 50% reduction in anticipated fossil energy for heating, feedstock and cap-x when compared to pyrolysis conversion, methanol-to-gasoline and fisher-tropsch technology creates a disruptive cost-performance learning curve vs. state-of-art.

ReactWell translates into a substantial impact on the economic and energy security of the United States by reducing energy imports, reducing energy-related emissions, improving energy efficiency by using earth's abundant geothermal heat to drive chemical reactions using geothermal wells with productivities too low to economically generate power.

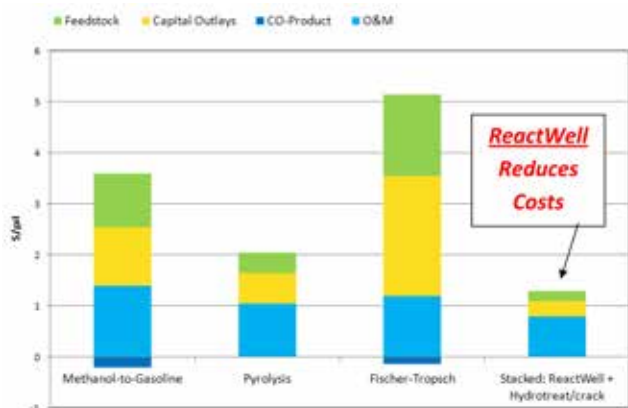


Figure 2. ReactWell Expected Cost Advantages.

REACTOR MODELING & CFD SIMULATION

Based on drill plan, temperature, pressure and residence time profiles were determined.

The reactor's casings were modeled with three, four, five and six casing neck down segments as illustrated in Figure 3 with four and five casings.

Modeled casing depths include:

- 1 and 3 km shallow depths
- 4, 6, 7 and 10 km deep depths

Note: The 10 km depth is based on Northern Louisiana geothermal resources up to 350°C per Southern Methodist University (SMU) Google Grant Datasets available using Google Earth & EGS plug-in

CASE A: Direct injection single reactor Autodesk 3D model and CFD SIM

Locate injection pipe [i] within the casing at target temperature and pressure depth. Then inject aqueous biomass into high temperature and pressure geothermal fluid. Let reacted oil and geothermal fluids flow out through

annular gap and exit with geofluid. Note: CASE A Process & Geothermal fluids mix.

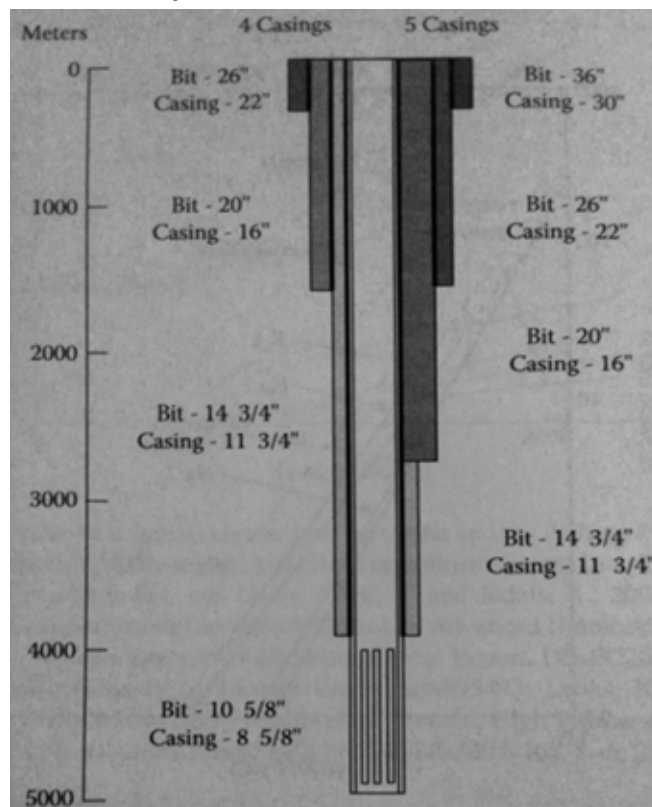


Figure 3. Well Casing Basis Set.

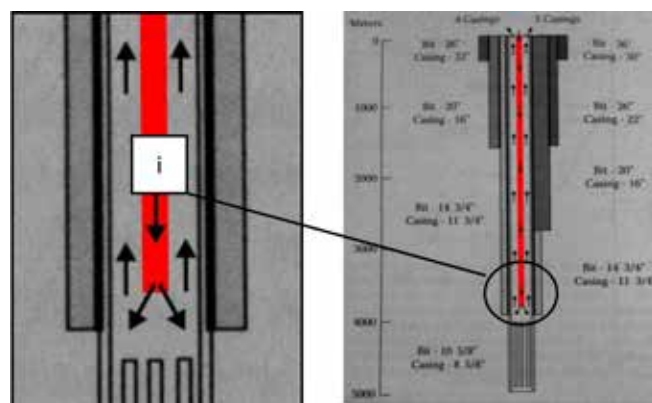


Figure 4. CASE A: Single Biomass Injection w/Mix.

Geothermal Data & Graphs for Currently Accessible Temperature & Pressures. Liquefaction depolymerizes (hydrogenates / hydrolyzes) and decarboxylizes biomass in the presence of high temperature and pressure water. Liquefaction yields range from 20 to 70 wt% liquid hydrocarbon per lb of biomass.

EXPERIMENTAL DESIGN & EQUIPMENT

HPHT system includes 300 cc Continuously Stirred Reactor (CSTR) with inlet head flange tap and bottom tap to provide steady-state tubular flow, controller, cooling loop and air-drive to power the stirrer. The experimental setup was acquired from Amoco Oil's former R&D laboratory and was originally manufactured by Autoclave Engineers.

Geothermal Data & Graphs for Currently Accessible Temperature & Pressures

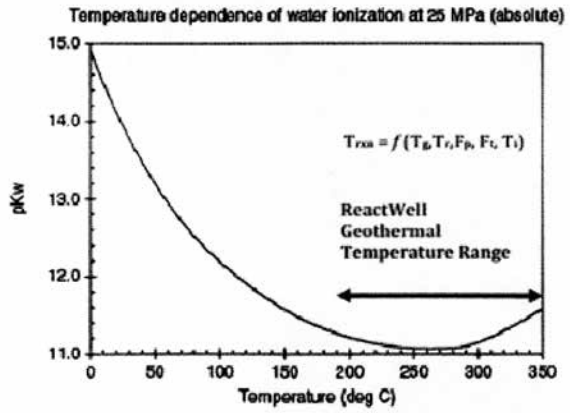


Figure A $pK_w = -\log_{10}(pK_w)$ Source: IAPWS 2004

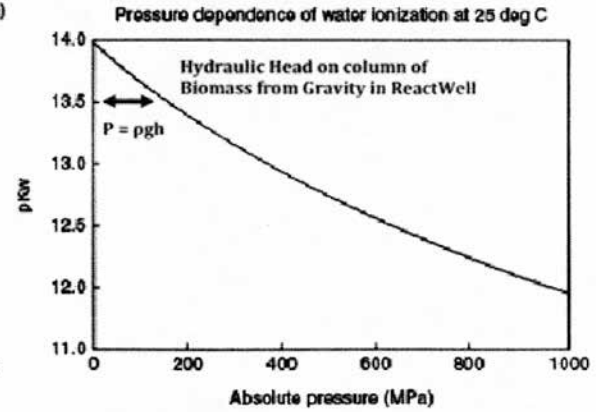


Figure B $pK_w = -\log_{10}(pK_w)$ Source: IAPWS 2004

Figure 5. Steam Table graphs for temperature and pressure dependence of water ionization.

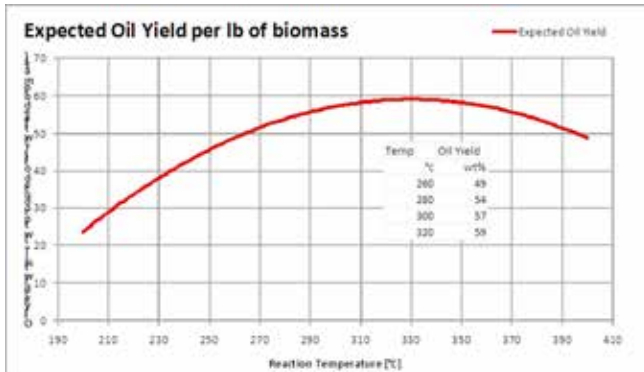


Figure 6. Bio-Oil yield per lb of biomass feedstock

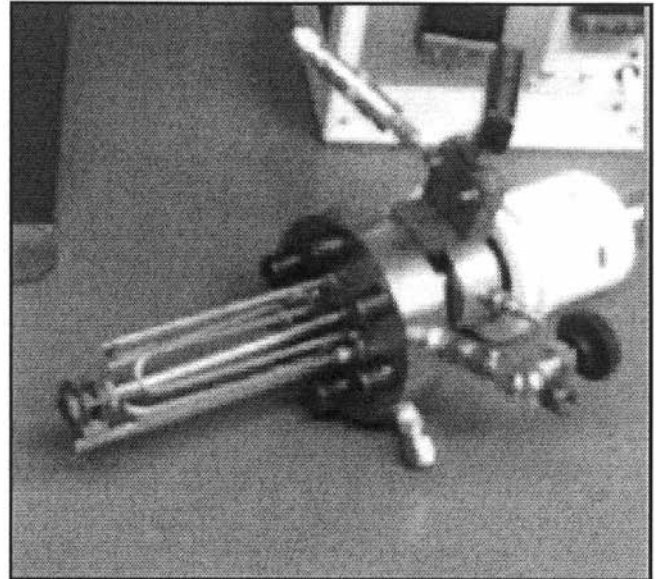


Figure 7. (top) Flange with cooling coil and CSTR (bottom) HPHT System



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WORKS CITED

Oil production of algal cells of Dunaliella tertiolecta by direct thermochemical liquefaction, Tomoaki Minowa, Shin-ya Yokoyama, Michimasa Kishimoto and Toru Okakura, NIRE, Onogawa 16-3 Japan

Resource demand implications for US algae biofuels production scale-up, Ron Pate, Geoff Klise, Ben Wu, SNL

Systems and economic analysis of microalgae ponds for conversion of CO₂ to biomass, Benneman J. Oswald W

Hydrothermal Liquefaction to Convert Biomass into Crude Oil, Yuanhui Zhang, Biofuels from Agricultural Waste and Byproducts

Hydrothermal Conversion of Biomass. II. Conversion of Wood, Pyrolysis Oil, and Glucose in Hot Compressed Water, Dragan Knezevic, Wim van Swaaij and Sascha Kersten, University of Twente, The Netherlands

Large Scale Open Algae Ponds, Ami Ben-Amotz, National Institute of Oceanography Israel

Future of Geothermal Energy Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century, MIT, Jefferson Tester, Brian Anderson, Anthony Batchelor, David Blackwell, Ronald DiPippo, Elisabeth Drake, John Garnish, Bill Livesay, Michal Moore, Kenneth Nichols, Susan Petty, M. Toksoz, Ralph Veatch

Interaction of Light, Geothermal Water and Nutrients on Production of Chlorella sorokiniana Microalgae (CS-101), J. Rastegary, New Mexico State University, US

“Use of Geothermal Energy for Aquaculture Purposes, Phase III, No. 10990128”, *Final Report*, Johnson, William and Kenan Smith, Geo-Heat Center, OIT

Industrial Applications of Geothermal Direct-Use Engineering and Design Guidebook, Chapter 16, 3rd Edition, Lienau, Paul, Geo-Heat Center OIT

DOE:EERE Biofuels Design Case, Zia Haq, April 24, 2012

ReactWell Asia Pacific Clean Energy (APCE) Summit Project Finance Connect Presentation, Honolulu, HI August 14, '12