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Biofuels: A (carbon) balanced act

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Energy is expensive, and the cost is only increasing. Any recent visit to the gas station or grocery store can be a reminder of the challenges in providing the energy we need to power the American standards of living and the growing demands of developing countries.

Basic economics tells us that as the price of fossil fuel-based energy sources increases, alternative sources of energy become cheaper and more attractive. Indeed, investment activity worldwide indicates growing interest in alternative energy sources including biofuels, and both major presidential candidates have indicated some level of support for the development of biofuels in their campaign literature.

According to sources, global venture capital and private investments in biofuel companies totaled about $2.1 billion in 2007, and are on a similar pace in 2008.

Several San Diego companies are included among those raising investments this year. For instance, La Jolla-based **Sapphire Energy** recently announced raising over $100 million from private investors including Cascade Investments, led by Bill Gates. Biofuels company **Verenium** was recently formed from the merger of San Diego-based Diversa and Massachusetts-based Celunol. Verenium and **British Petroleum** recently announced a $90 million partnership to develop biofuel from what is known as cellulosic ethanol. In Northern California, **Amyris Biotechnologies Inc.** has raised $91 million in a second round of financing this year to develop bioengineered microorganisms that produce fuel. Also in Northern California, **LiveFuels Inc.** is developing algae that can be harvested from ponds and processed to form biofuels.

Patent application filings can also be a good indicator of the pace of innovation. According to the Cleantech Group, biofuels-related patent application filings at the U.S. Patent and Trademark Office increased from just 147 in 2002 to 1,045 in 2007. In fact, in 2007, biofuel patent application filings outpaced other alternative energy sources such as solar and wind.

Environmentally, some biofuels are attractive because of their net carbon balance. Carbon-based fuels, including fossil fuels and biofuels, give off carbon dioxide when burned, for instance to power engines. These carbon dioxide emissions add to the greenhouse gasses accumulating in the atmosphere, and burning fossil fuels increases the total carbon dioxide in the atmosphere. In contrast, the use of biofuels can approach carbon neutrality. When biofuels are burned, they give off carbon dioxide just like fossil fuels. However, biofuels are created by plants or algae. The plants or algae remove carbon dioxide from the atmosphere to create the biofuels. The carbon dioxide removed from the atmosphere in the creation of biofuels can balance the carbon dioxide emitted from the biofuels when burned to achieve a carbon neutral fuel footprint.

Further, biofuels can be made from renewable resources such as sugar cane, switchgrass and algae. Obtaining fuel and energy from renewable resources can reduce dependence on fossil fuels that are increasingly expensive and often from politically unstable regions of the world.

But as of today biofuels are not universally praised. According to a recent report from the World Bank, present use of biofuels has increased global food prices by as much as 75 percent. For instance, the use of corn for the production of ethanol has increased demand for corn. Higher demand usually means higher prices. Placing such a strain on the food supply is an undesirable and unintended consequence of the development of biofuels. The United Nations has recently urged a halt to biofuel production in view of the strain on the food supply. Further, the use of biofuels has raised potential environmental concerns, as forest and farm lands have been displaced to raise the current crop of biofuel food sources.

There is an energy cost in the production of any biofuel. A biofuel produced from sugarcane, for example, requires water, fertilizer and energy to grow, harvest and process the sugarcane plants. Some first-generation biofuels such as corn-based ethanol fuels might actually require more energy to produce than they provide in return as fuels. *Science Magazine* has postulated that current biofuels might produce more total greenhouse gas emissions than fossil fuels when one considers the greenhouse gases emitted during production and combustion of the biofuels.

Fortunately, such concerns could be limited to the first generation of biofuels — bioalcohols such as bioethanol (such as corn-based ethanol) and bio-oils (such as from food waste oils).

The disadvantages of first-generation biofuels create opportunity to innovate and develop newer, improved biofuels. This opportunity is indicated by investment activity and patent activity in the biofuel industry.

Second-generation biofuels can harness the energy and innovation of the biotechnology industry. They promise increased energy balance, reduced pressure on the food supply and reduced emissions. For instance, second-generation biofuels are being developed from food waste products (for example, cellulosic ethanol), non-edible crops (such as jatropha) and oil-producing algae. Further second-generation biofuels are being developed from bioengineered microorganisms that can produce biofuels from renewable, readily available raw materials.

Biofuels present exciting opportunities for the development of clean, renewable and economical sources of energy and represent a new frontier for the biotechnology industry.

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