CONTACT REPORT

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Report Number: 2002-85
Information Cutoff Date: 08-07-02
Distribution Date: 08-13-02

SUBJECT: **Bioethanol (ethanol from waste cellulosic biomass) Production Processes at Iogen Corporation and Opportunities for GM Collaboration**

PURPOSE: Background and context

SUMMARY:

- Bioethanol produced from waste biomass is energy efficient to produce and relatively CO_2 neutral, in contrast to ethanol produced from corn or other food crops.
- Iogen is a global leader in developing and producing enzymes for the textile and paper and pulp industries, as well as the emerging bioethanol industry.
- Iogen has alliances with Royal Dutch Shell, Petro Canada, and the Canadian government to promote commercialization of bioethanol.
- A follow-up meeting among Iogen, Shell, and GM is planned.

IMPLICATIONS:

- Iogen is very interested in collaboration with GM.
- Promotion of bioethanol in Europe could lead to CO_2 emission credits and assist GM in meeting voluntary CO_2 emission standards.
- Promotion of bioethanol in North America could contribute to net reductions in CO_2 and foreign oil dependency.
- Promotion of bioethanol in developing countries could support growth in vehicle sales.
- Opportunities exist to initiate programs with Iogen and others leading to GM sales and public relations benefits.

SOURCE ASSESSMENT: Participation in a half-day meeting at Iogen Corporation

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ATTACHMENTS: Summary of meeting with Iogen Corporation

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Summary of Meeting at Iogen Corporation

Meeting Attendees

A meeting with Iogen officials was arranged and led by GM Canada's VP of Corporate and Environmental Affairs, Tayce Wakefield. This meeting occurred on the morning of August 2, 2002. This meeting took place at Iogen's ethanol pilot production facility in Ottawa, Canada. Meeting attendees were:

Tayce Wakefield	Vice President, Corporate and Environmental Affairs, GM Canada
Roger Thomas	Manager, Automotive Regulatory Activities, GM Canada
Phil Petsinis	Manager, Government Relations, GM Canada
Mike Ricciuto	Manager, Vehicle Environmental Programs, GM Canada
Gary Herwick	Staff Analysis Engineer, GM Public Policy Center
Candace Wheeler	Staff Research Scientist, GM R&D and Planning
Robert Stephens	Staff Scientist, GM R&D and Planning
Brian Foody	President, Iogen Corporation
Jeff Passmore	Executive Vice President, Iogen Corporation

Iogen Partners and Production Plans

Brian Foody began the meeting by making a presentation in which he reviewed historical and current information about Iogen's business. Currently, Iogen has three alliances with corporate and government investments (in Canadian dollars) of:

Royal Dutch Shell	$46M
Petro Canada	$15M
Government of Canada	$10M

Bioethanol is the term used to describe ethanol produced from waste biomass. Iogen believes that bioethanol is the most cost-effective means to reduce CO_2 emissions from the vehicle fleet. To date, Iogen has invested $85M to develop their process for bioethanol production. This process is supported by their strength in enzyme research and manufacturing. Iogen does not believe that competing processes being developed by BCI, Arkenol, and Masada are adequately financed to reach commercialization.

Currently, Iogen's enzyme manufacturing and sales represent a $15M annual business. In addition to enzymes needed for the production of bioethanol, Iogen produces enzymes for the pulp and paper industry and the textile industry. Approximately 10% of all paper manufactured today utilizes Iogen enzymes, which reduce the amount of chlorine needed to bleach paper.

Iogen's planned path towards commercialization of bioethanol is as follows:

Process scale up	2002-2004
Commitment to first commercialization	Q4 of 2004
5-7 billion liters/year on stream	2011

The 2011 production plans include an undisclosed degree of European market penetration. To put this production volume in context, E10 nationwide in the US would require approximately 39 billion liters/year of production. On an energy basis, this would represent a decreased dependency on gasoline from foreign oil of 13%. Currently, only 5% of Canadian fuel is E10. (Note: GM vehicles are currently designed to operate on E10 – a 90/10 blend of gasoline and ethanol).

Although the potential market for bioethanol in China was discussed and recognized, at this time, Iogen is focused on large existing markets for automotive fuel. Iogen does not believe that China has adequate economic development or interest for it to be a near term target for their business. They have identified their target markets as North America and select countries in Europe, probably Germany and France. However, Iogen believes this is an issue that Shell should be consulted about.

Iogen also discussed, to a limited extent, the interests of their partner, Royal Dutch Shell. They believe that Shell is ready to acknowledge that the fuel industry should commit to CO_2 reductions and how such reductions should be accomplished. The implication is that Royal Dutch Shell will soon advocate large-scale bioethanol production for automotive fuel blending.

Iogen's Facility and Current R&D

Iogen's pilot plant is approximately $1/30^{th}$ the size of the commercial production facility they envision for a typical site. It is also approximately 30X larger in terms of capacity than the National Renewable Energy Lab's (NREL) bioethanol facility. Iogen's pilot plant has 430 m^3 of fermentation capacity and is capable of operating 24 hours/day 7 days/week. The plant has sufficient automation to reduce manpower requirements to one shift only. However, the facility does not currently make ethanol. Current bioethanol R&D at Iogen is focused on the processes to convert wheat straw to sugar, i.e. pretreatment and enzymatic hydrolysis (see **Figure 1**.). They are now running batches of wheat straw through the pretreatment and enzymatic hydrolysis processes and analyzing results. They believe these processes represent the most difficult challenges to commercial scale up of bioethanol production. Scale up of fermentation and distillation processes represent lower risks in their estimation. Going forward, they envision their plants using various forms of cereal straw (wheat, barley, etc.) as feedstock. The plants would not be switchable between a wide range of other feedstocks, e.g. straw to wood chips. This is due to the wide range of upstream pre-treatment equipment and overall operating conditions that would be needed to supply this level of production flexibility. A flow chart of the process steps in bioethanol production is shown as **Figure 1**.

Description of Process Steps in Bioethanol Production

Bioethanol produced from waste plant matter, e.g. corn stover (stalks), wood chips, or non-crop grasses, is more energy efficient than producing ethanol from food crops. The reduction in use of fossil fuels for production of fertilizers and fuel make bioethanol more CO_2 neutral than production of ethanol from feed grains.

The critical aspects of this technology are described below:

Pretreatment: This is the process of treating the feedstock to increase the surface area of the fiber, thereby reducing the amount of enzymes required at the hydrolysis stage. Several methods of pretreatment can be used. Current pretreatment processes used by various R&D and pilot facilities include steam explosion, dilute acid, and concentrated acid. Iogen uses the dilute acid method.

Enzyme Production: The goal is to develop and produce high efficiency enzymes capable of hydrolyzing the cellulose in feedstock to sugar. Iogen is using genetic engineering to optimize enzyme strains.
Enzymatic Hydrolysis: The goal is to efficiently convert the cellulose and hemi-cellulose present in feedstock to sugars, which can be converted to alcohol by the fermentation process.
Separation: Non-hydrolyzed solids are separated from the liquids and can be used as combustibles in power generation.
Ethanol Fermentation: The goal of fermentation is to convert the various sugars that are produced by hydrolysis to ethanol. This process utilizes yeasts and microbes that have been genetically modified to optimize the efficiency of this step.
Distillation: Ethanol is separated and purified from the remaining liquid.

Possible Opportunities for GM

Iogen's stated desire is to work with automotive OEMs to assure that vehicles are capable of using ethanol as a fuel at whatever concentration is needed to reach future potential mandates for CO_2 emission reductions. Iogen has requested GM's support of their position that bioethanol is the most cost-effective means of reducing CO_2 emissions from vehicles. To substantiate this position, Iogen uses data such as that shown in **Figure 2,** which shows the cost of bioethanol relative to vehicle-specific technologies for reducing gasoline consumption. (Note: the data in Figure 2 appears directionally correct but has not been confirmed and is assumption dependent). Iogen is lobbying the US government, as well as select governments in Europe, to promote tax policies that will encourage the use of bioethanol as a means of CO_2 reduction.

Iogen expressed interests in working with GM in several ways, including such efforts as 1) developing mutually agreeable policy statements, 2) providing the Royal Canadian Mounted Police with GM-produced E85 vehicle fleets that would be fueled by Shell using Iogen's bioethanol, and 3) selling an Iogen equity stake to GM. The possibility of collaboration on conducting a life cycle assessment of bioethanol production was discussed and Iogen has expressed interest in this. The importance of having accurate life cycle inventory data to assess the greenhouse gas reduction potential of bioethanol was acknowledged by Iogen, but is considered to be of secondary importance to the need to convince governments that bioethanol is a cost-effective technology for CO_2 reduction.

To advance the potential for joint efforts, Iogen has proposed that a meeting between Shell, GM, and Iogen be planned for the near future.

Figure 1. Iogen Bioethanol Process

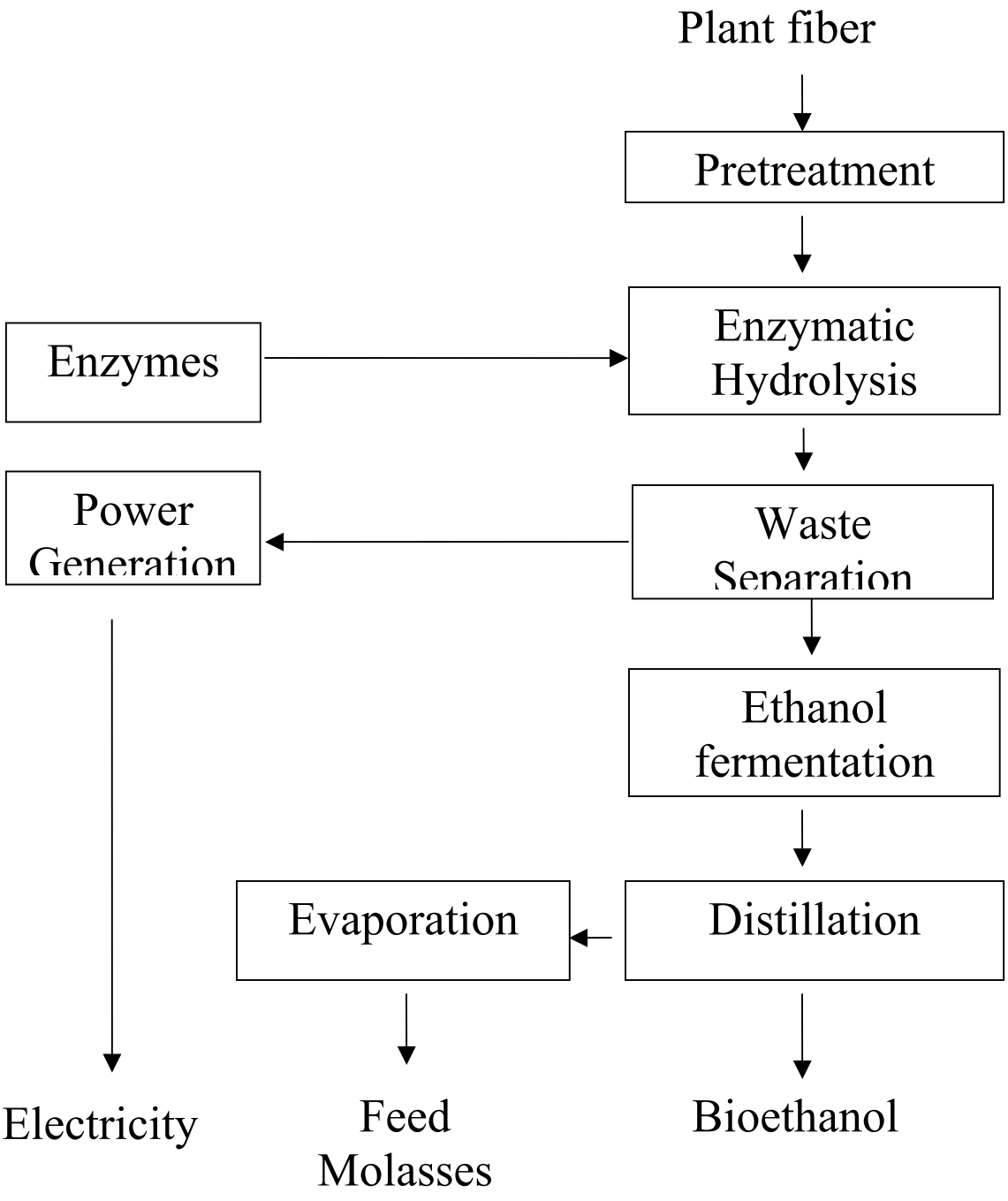
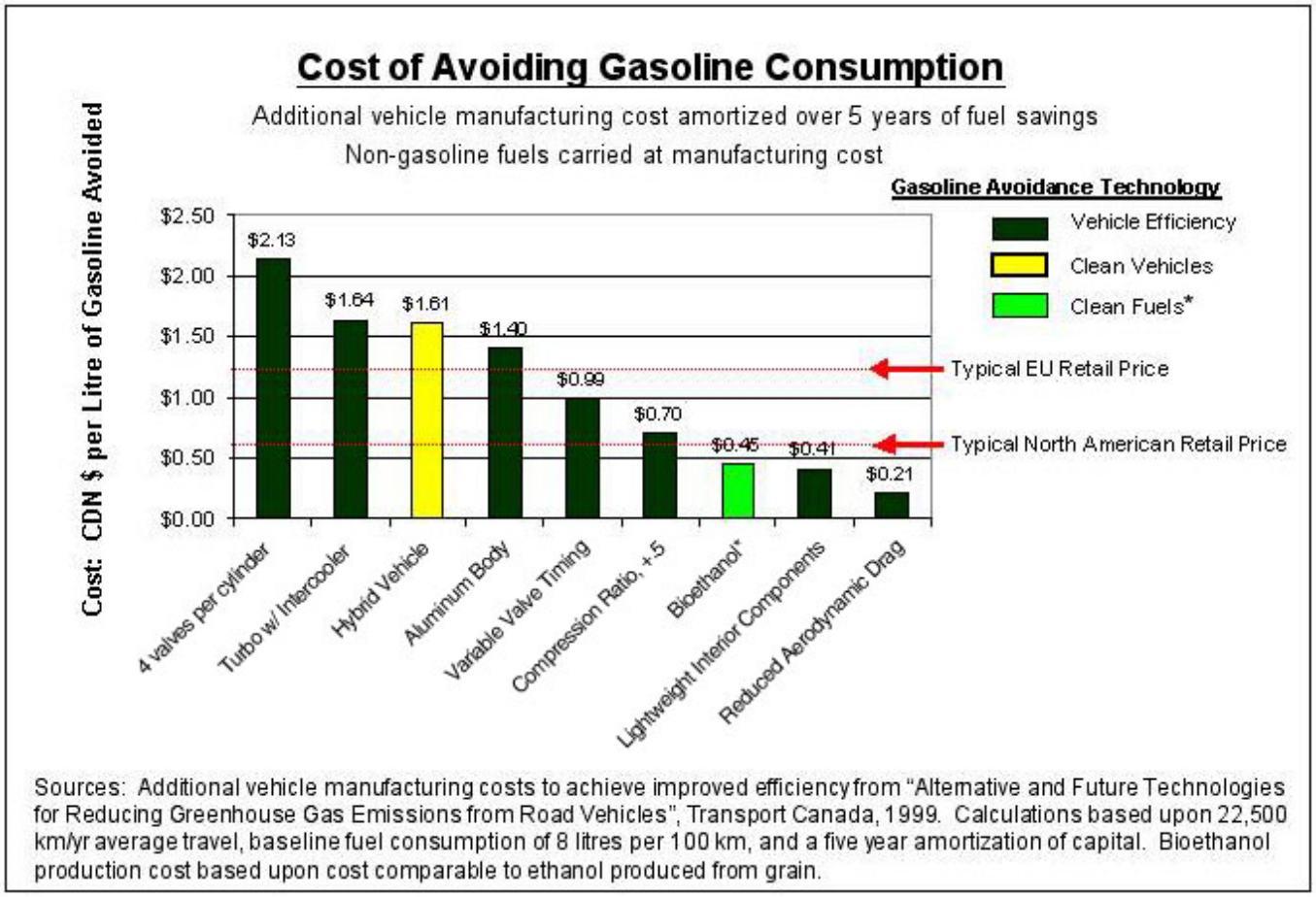


Figure 2



Sources: Additional vehicle manufacturing costs to achieve improved efficiency from "Alternative and Future Technologies for Reducing Greenhouse Gas Emissions from Road Vehicles", Transport Canada, 1999. Calculations based upon 22,500 km/yr average travel, baseline fuel consumption of 8 litres per 100 km, and a five year amortization of capital. Bioethanol production cost based upon cost comparable to ethanol produced from grain.