December 1991

bio-joule

PUBLISHED BY THE BIOMASS ENERGY INSTITUTE

ANNUAL REPORT FOR BEI

- Gasifier
- Anaerobic Digestion
- News
- Book Reviews
- Saskatoon Workshop

The American Power and Waste Management Gasifier System

M. Yuen, Marketing, American Power and Waste Management LTD., Suite 250 - 780 Beatty Street, Vancouver, B.C. V6B 2M1

NovaTec Consultants Inc. (Suite 300 - 40 Powell Street, Vancouver, B.C. V6A 1E7) earlier this year, prepared a report for American Power and Waste Management Ltd. on the APWM gasification system. This downdraft gasifier system has many technical advantages over other gasification systems, according to the report. One of the main advantages is the production of a clean, tar free gas stream suitable for direct use in internal combustion engines or boiler systems. The APWM gasifier shows great promise for applications in the cogeneration of heat and electricity from waste materials.

A recent report completed for the Provincial Government of British Columbia estimates that there is 4.6 million Bone Dry Tons of bark residues and 11.6 million m^3 solid wood equivalent of non-bark materials produced per annum in the province. Of these volumes of materials, only 41% of the bark and 46% of the non-bark materials are currently utilized in the generation of power or process heat. The majority of the material is incinerated or disposed of to landfills. The waste of energy value is of growing concern. These disposal options are becoming less and less viable as environmental regulations tighten on incinerators and landfill space becomes more expensive and more scarce.

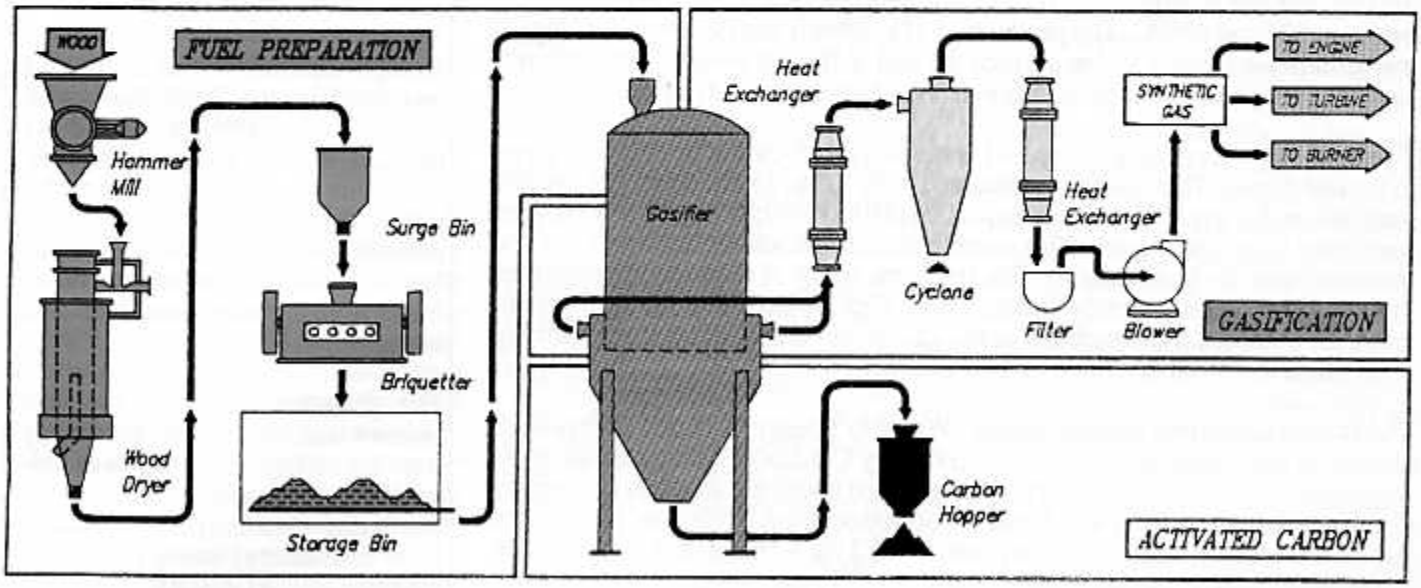
Alternatives to the indiscriminant burning or disposal of wood waste and other combustible or cellulosic materials are being sought. Gasification processes which convert the materials from solid materials to gaseous fuels through a pyrolysis process are being developed as a potential solution to the biomass problem. This is both an economic and environmental issue.

Pyrolysis

Pyrolysis is the conversion of feedstock materials to smaller compounds using heat. The heat can be supplied either by using some of the heat generated by the feedstock or from an external source, such as steam. Waste residues from primary company operations can be converted to various products, such as oils, carbon, and other derivatives and have uses different from the parent materials. Temperature, pressure, degree of oxidation and reaction times are used to control the product mix.

Gasifier

A pyrolyser which maximizes gas production is generally referred to as a gasifier. The end products consist of char (or ash) and a combustible gas (synthesis gas) suitable for use in internal combustion engine or boiler systems. In many gasifier designs available today, pyrolysis reactions are allowed to progress to the point that the maximum amount of feed material is broken into simpler gaseous hydrocarbon molecules which may be used in combustion units.



The Patented APWM Gasification Process

This design produces a cleaner gas than other gasifier designs currently available. The APWM gasifier is a downdraft design and utilizes a concurrent flow of gas and solid fuel to effect the pyrolysis process, and optimizes the production of clean, tar free synthesis gas through the char bed. The char, which results from the pyrolysis of the feed materials, increases the residence time of the tar materials in the bed and results in a greater breakdown of the tars to a tar free synthesis gas. Maximization of the gas quality at the expense of complete utilization of the feed material results in the production of an activated carbon byproduct suitable for sale for many filtration purposes.

Feed Preparation

The feed must be in pellet form. Biomass must be shredded and dried to provide a uniform feed that can be converted into briquettes or pellets to be used as fuel. In tests conducted at B.C. Research, the moisture content of the wood wastes (sawdust) was reduced to less than 20% before pelletizing. Mechanical pressure or chemical binders, such as glues, are required to provide satisfactory pellets. The resulting pellets were further dried prior to use in the gasifier. Sewage and primary digester sludges were oven dried from a 40% moisture content. Clarifier sludge from a pulp mill was suitable for use in the gasifier as received.

The Gasification Process

The feed goes directly into the gasifier and pyrolysis immediately. In the experimental programs completed to date, fuel pellets have had a moisture content between 8% and 14%.

An initial charge of charcoal must be placed into the gasification unit and ignited. When the temperature of the charcoal has achieved relative uniformity over the cross-sectional area of the gasifier, the organic pelletized fuel is added on the top of the charcoal layer. Air is drawn down through the bed to provide the oxygen needed to facilitate the combustion and to draw the product gas through the bed into the outlet gas stream.

The top layer of the bed consists of mainly unreacted input material recently added by the solids feeder. Below this there is an intermediate layer of approximately 10 to 15 cm where the organic fuel pellets are actively undergoing the pyrolysis reactions. The temperature of this layer remains between 400 and 500°C. The production of synthesis gas occurs in this region and volatiles are drawn down through the bed in the gas stream. Temperatures are low enough in this region to prevent the formation of clinkers.

The bottom layer of the gasifier bed is the activated carbon or charcoal layer, in the test device. This layer was estimated to be 2.5 to 15 cm deep. The organic material in this layer undergoes partial oxidation limited by the low oxygen remaining in the gas stream. This combustion causes additional volatiles to be released from the bed material. The reactions result in temperature increases in this layer to approximately 900°C. These high temperatures are sufficient to crack the complex hydrocarbons in the gas stream and activate the remaining solid materials to an activated carbon product.

The British Columbia environmental "Waste to Energy" technology has been chosen by the Canadian Government (Forestry Canada) for demonstrations in Saskatchewan. These demonstartions took place under the auspices of Forestry Canada and the Saskatchewan Farm Wood Association in Hudson Bay, Prince Albert and Meadow Lake - October 16th to the 21st. Contact in that region: Jim Johnston, Forestry Canada, 1288 Central Ave., Prince Albert, SK S6V 4V8.

IN THE CHIPS

Employing six people, including himself (Lawrence Feilberg) his company, Reynolds Wood Products Ltd., has been operating for six months now.

Feilberg recently got a $37,375 loan from the federal government to cover some of the more than $215,000 in start-up costs for the company, which he says is the only supplier of tongue depressors and wooden stir sticks in Western Canada.

The plant has so far shipped about 2,000 cases of tongue depressors to it's Canadian customers, as well as several thousand cases of coffee stir sticks, which he says are essentially a byproduct. The Whitemouth resident has aspirations of breaking into the huge American market with his wood products, for which he already has customers accross Canada. (Winnipeg Free Press August 28, 1991)

ENERGY CONSERVATION BILL UNVEILED

Energy Minister Jake Epp has introduced the long awaited legislation designed to steer Canadians to a more efficient future. Under the proposed legislation, any appliance imported into Canada or moved across provincial borders could be seized and destroyed at the owner's expense if it failed to meet federal efficiency standards.

Energy-efficiency standards were promised in the Green Plan; with this bill, legislation would be enabled to allow the government to introduce regulations followed by public consultations. Epp said the consultation might take a year or so. Louise Comeau of the Ottawa based Friends of the Earth said it should not take that long.

The proposed legislation would require manufacturers to clearly state the energy consumption of new appliances. This would remove the confusing and currently existing (non-mandatory) energy labeling program ENERGUIDE.

Anaerobic Bioconversion of Organic Solid Waste

by **Mark Heffernan**
CONVERGENT BIOMASS TECHNOLOGIES INC., BUTLER SQUARE STATION
P.O. BOX 3254, MINNEAPOLIS, MN 55403-1503 USA

Anaerobic Digestion (AD) is an old process and quite widespread. Systems are used in waste water treatment, agricultural waste treatment, the paper industry, food processing and others. But AD of solid wastes in high solids reactors is still relatively new.

Yet many respectable bench and small pilot scale studies have been done. These have shown the digestability of the organics in solid waste, the energy production of the systems, the time the process takes and have pointed to the size of full scale systems and the kinds of material handling systems which must be incorporated in the scale up.

However, the scale up from bench (10's of lbs, per day) to full scale (100's of tons per day) is quite a leap as others have found. Therefore, CBT propose building a respectable pilot plant, 50-60 tons per day, to show the material handling capabilities of the system and the company. This plant will be capable of being expanded to larger capacity because of its modular design. The timetable of the pilot project is estimated at two years, but the plant itself is projected to be economically viable on its own for 15 years into the future.

This suggests that AD plants can be built to handle smaller volumes of source separated clean organic waste streams as they become available either voluntarily or legislatively. Currently many States in the United States are legislating parts of the waste stream out of the general stream, and this will continue to become more specific. Relatively small agricultural systems, such as a 300 cow dairy operation, which are driven by the energy production of the technology, can be built to cash flow in many locations around the country where the co-generation rates or the commercial energy rates are favorable. AD systems of solid waste have the added economic advantage of tipping fees the waste industry offers which the agricultural industry does not. Even modest tipping fees of $40/ton make this technology attractive and very affordable. Also, because of the modular design of our systems, one can scale up or down to accommodate different volumes of waste in a particular area and still be economically viable. Add to this the environmental benefits of AD vs landfilling and/or incineration and one can see why the time has come to incorporate the AD process into the solid waste industry.

Benefits

Some of the benefits of this process combined with recycling and source separation of materials are these:

Anaerobic bioconversion does not pollute the air for it deliberately produces and captures all the methane produced in the decomposition process, which if done in a landfill site is only 25% efficient. That is, landfills only effectively capture 25% of the methane produced allowing the rest to be vented to the atmosphere.

Anaerobic bioconversion produces a clean fuel in the form of methane gas. While methane is a carbon based fuel, it is cleaner burning than gas or diesel. The gas can be used as a gas to fuel vehicles or other uses, or it can be used to power electrical generators. Steam can be produced from the exhaust heat generated by the engines firing turbines, offering another by-product of the system. The other gas produced in the process, carbon dioxide, can be marketed to greenhouses or bottling companies or other uses. One can see that the energy options with this system are many. Incinerators have only electricity and/or steam to offer, and at a very high cost both in terms of building and operation and to the environment.

Anaerobic bioconversion does not pollute ground water for it stabilizes the soluble organic solids. If the material going into the digester is clean, it will be clean coming out.

This process reduces the volume of the waste steam. In some proposed systems the volume reduction is as much as 90% (this however, requires the combustion of the dried digestate). In systems where a clean feedstock goes in, the digestate is clean coming out and can be land applied giving the same soil building features of compost. There is a great need for these materials in the soils of most of the world. The possibility of getting these clean waste streams gets closer every day with some of the terrific recycling and source separation efforts people are making. In other circumstances where the feedstock is too contaminated for dispersal of the digestate into the environment, one still has the option of landfill disposal with at least a 50% volume reduction thereby extending greatly the life of the landfill. This is a great benefit to the industry by itself.

The fact that these systems rely on clean feedstocks for their successful environmental operation means that they provide jobs for the community to separate the different waste streams with different collection. This also addresses the recycling needs in our

communities, for none of the inorganics of the waste stream are of value to the decomposition process, (or for that matter to the landfill) and they are therefore made available to the markets where they are valued. Furthermore, anaerobic systems do not have to rely on the high volume of paper in the waste stream for their successful operation, though paper will digest quite well. The anaerobic process also does not have a problem with the wet organics which cause incinerators headaches for the process is wet to begin with.

Incinerators

Incinerators, on the other hand, rely quite heavily on the paper content of the waste stream to provide them with a high enough BTU fuel and do not like to handle the wet organics for these reduce the BTU content of the feedstock. Therefore, incinerators are not friendly to the efforts to recycle paper, for these efforts rob the incinerator of its fuel. And in many cases where incinerator plants were built before recycling had the chance to mature, successful recycling efforts actually cost the local communities in higher disposal costs to offset the loss of volume of wastes expected to be received at the incinerator which was to have gone toward the debt service of the plant. When the markets for recycled paper and other products mature, incinerators will be out of business, and digesters will flourish.

The Company

Convergent Biomass Technologies, Inc is not out to re-invent the wheel. As the name suggests, experts in the field have been gathered together and are working toward bringing this proven, clean and reliable process to the problems of the solid waste industry. They are familiar with the strengths and weaknesses of anaerobic systems that have been built and/or studied in the past and are prepared to utilize the best of these systems in the design of future systems.

CBT is negotiating with several landfill operators and other waste treatment companies to enter into contracts for siting and operating facilities. These facilities are being investigated both for the profitability they offer in and of themselves and for the energy production they offer to be used in other processing plants which are heavy energy users. These other plants are quite profitable now, but become even more so when one generates one's own energy. Discussions have begun with a midwest company whose automated recycling system produces an organic stream and a hotel chain whose terrific recycling efforts have cut their garbage bill in half and now produce an almost exclusively organic waste stream for disposal. Our process can take this stream and give the company an energy stream in return.

CBT is working with government and solid waste agencies in several states seeking low interest loans and grants from technology demonstration programs and are able to privately finance projects from internal sources based on contracts for waste streams. The company is looking for investors and/or generators and handlers of large volumes of organic wastes whose current disposal method is hauling, landfilling or incineration.

More from the journals

BIOCYCLE Vol.32, No.8

Landfill Gas Recovery by A. MacDonald p.40

Project engineers deal with a variety of challenges to produce about 12.3 megawatts of electricity at Rhode Island landfill.

Biogas from Waste in Belgium. p.42

New plant will utilize dry conditions and thermophilic temperatures to produce biogas and a soil amendment from the organic fraction of municipal solid waste.

Agricultural Utilization of Yard Waste. p.54

A pilot project in Lancaster County, Pennsylvania demonstrates that spreading grass clippings directly into farm fields is a viable yard waste recycling option.

BIOCYCLE Vol.32, No. 10

The Farm Scene has a Great View of Sludge by G. Logsdon. p. 40

Experiences of Municipalities, applicators and farmers in Ohio illustrate continued progress in methods and results of utilizing wastewater biosolids.

How much can Farmers pay for MSW Compost? by A.R. Collins. p.66

Of the more than 420 million acres of cropland in the U.S., 80 million are in the same counties as urban areas. These calculations assess the value of farmland application of compost.

Anaerobic Gasification Advances by J. Skajaa with E. Hannibal p.74

Biogas facilities in Denmark process a greater volume of agricultural, industrial and municipal wastes. One full scale plant solely for source-separated household organics is now under construction.

Science Vol.251, March 15 1991, p.1318-1323

FUEL ETHANOL FROM CELLULOSIC BIOMASS

Ethanol produced from cellulosic biomass is examined as a large-scale transportation fuel. Desirable features include ethanol's fuel properties as well as benefits with respect to urban air quality, global climate change, balance of trade, and energy security. Energy balance, feedstock supply, and environmental impact considerations are not seen as significant barriers to the widespread use of fuel ethanol derived from cellulosic biomass. Conversion economics is the key obstacle to overcome. In light of past progress and future prospects for research-driven improvements, a cost-competitive process appears possible in a decade.

From an energy perspective I will quote part of one paragraph from the paper.

"A key factor in considering the energetics of ethanol production from cellulose is the energy available from residues remaining after fermentation. It is thought that unfermentable raw material components, in particular lignin, can be mechanically dewatered and burned to provide 30,000 to 40,000 Btu per gallon of ethanol, an amount in excess of processing energy requirements for current designs with a wood feedstock (current SERI wood feedstock-based simultaneous saccharification and fermentation process design) . The excess energy can be used to produce electricity in a cogenerative fashion."

This paper is authored by an impressive array of notables in the ethanol fuel field. Lee Lynd is with the Thayer School of Engineering, Dartmouth College, Hanover, NH 03755, Janet Cushman manages the Biofuels Feedstock Development Program, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, Roberta Nichols is with the Environmental and Safety Engineering Staff, Ford Motor Company, Dearborn, MI 48121 and Charles Wyman manages the Biotechnology Research Branch, Solar Energy Research Institute, Golden, CO 80401. For anyone interested in a brief overview of this subject, documented with many references and useful tables and diagrams, get a copy of this article.

• • • • • • • • • • • • • • • • • •

R & D Bulletin

Contractor	Summary	Value($)
September 1991, No. 222		
EMPLOYMENT AND IMMIGRATION CANADA		
The Canadian Labour Market and Productivity Centre (CLMPC) Ottawa, ON	A study to assess the environmental impact on employment within the primary forest, pulp and paper, primary metals and transportation industrial sectors along with related concerns of social partners.	64 200
October 1991, No. 223		
NATIONAL DEFENCE		
Jacques Whitford Environment Ltd. Dartmouth, NS	Environmental clean-up study - CFB Goose Bay.	427 997
GCG Dillon Consulting Ltd. Edmonton, AB	To perform an environmental baseline study Canadian Forces Base Edmonton, AB.	255 948
M.M. Dillon Ltd. Ottawa, ON	To perform an environmental baseline study Canadian Forces Base Ottawa, ON	224 382
Hardy BBT Limited Calgary, AB	Environmental baseline study, Canadian Forces Base Cold Lake, AB.	217 709
ENERGY MINES AND RESOURCES		
University of British Columbia Vancouver, BC	Development of hydrodynamic, chemical and control models and evaluation of combustion of chars from gasification processes of Western Canadian fuels.	430 000
Prairie Agriculture Machinery Institute Humboldt, SK	Development of a system to long-haul chaff.	169 623
AGRICULTURE CANADA		
T. Bouman Swift Current, SK	Impact of fallow replacement with annual legumes for green manure or feed on energy and soil conservation.	32 726
FORESTRY CANADA		
Geomatics International Burlington, ON	Impact of biomass harvesting on the nutrient status of boreal mixed wood stands in Northern Ontario - phase III	39 305

Trees Stock up for Winter

Just as a bear gains weight to prepare for winter, hardwood trees bulk up and store nutrients in anticipation of spring. A University of Guelph research team has discovered that, for survival, trees store unique proteins, in addition to lesser amounts of sugars and fats.

Botany professor John Greenwood, students Suzanne Wetzel and Lianne Todd and technician Cobi Demmers have found that trees store proteins in their bark and new wood prior to winter, so they can be used for new growth as early in the spring as possible.

"This is a hot topic in botany," says Greenwood. "Guelph is near, if not at, the lead in research."

The protein, stored in bark and new wood, is generally three to five times greater during the overwintering period — the time between leaf shedding and bud formation — than at any other times of the year.

Contact: John Greenwood, University of Guelph, Tel. (519) 824-4120 ext. 6004.

Fuel Ethanol Workshop was a Success!

The Fuel Ethanol Workshop sponsored by the Canadian Renewable Fuels Association and Energy Mines and Resources Canada was held in Saskatoon on October 15 and 16 at the Saskatoon Inn. The surroundings at the Inn were great, speakers participated in other sessions, and the ninety people in attendance learned about Canadian and U.S. research and development programs, industry details and the new Lanigan facility. About 40 of the Workshop participants toured to Lanigan to have a first-hand look at the integrated feedlot-ethanol production enterprise.

There was a group of fifteen farmers from Flatbush, Alberta who drove to Saskatoon for the Workshop and drove home well satisfied with the workshop, but not so well satisfied with the early winter storm they encountered for their return trip!

Research and Development

Sheldon Duff, Alternative Energy and Efficiency, CANMET, Energy Mines and Resources Canada, Ottawa and **Richard Moorer**, Office of Conservation and Renewable Fuels, Office of Alternative Fuels, Biofuels Systems Division, U.S. Department of Energy, Washington, D.C. reviewed government research and development activity in their respective countries.

Richard Moorer

Both countries are giving most support to improving the economics of ethanol production from lignocellulosics. A variety of feedstocks will become available for ethanol production when these technologies are cost competitive. The feedstocks investigated include municipal solid waste, paper in particular, straw, energy grasses and energy plantations (agroforestry).

Attitudes of various industry players from major oil companies to automobile manufacturers and auto-mechanics were reviewed by Bryan Dykes, Federated Co-op, Saskatoon and Don O'Connor, Mohawk Oil Company Ltd., Burnaby, B.C.

Preliminary antagonism to ethanol-containing fuel to tolerance as experience was gained was a recurring theme and was emphasized again in a presentation by Neil Koehler, Parallel Products, Davis, California.

Paul Bonnet, Corporate Project Coordinator, Saskatchewan Wheat Pool, Regina, Saskatchewan and Mylles Wildeman, Pound-Maker Ethanol Ltd., Lanigan, Saskatchewan talked about the development, construction and operation of the new Lanigan feedlot/ethanol facility.

Mr. Bonnet said the project was a good example of the benefits of ethanol/feedlot integration. The by-products from the ethanol plant (6000 tonnes of wet distillers grain and wet stillage, which is wastewater) go directly to the feedlot, eliminating the need to dry the distillers grain, or to "treat" the wet stillage. This reduces both capital and operating costs of the ethanol plant. "In addition," said Mr. Bonnet, "much of the grain handling and milling equipment required for the ethanol plant was already in place being used as a feed mill in the existing feedlot.

The effects of using ethanol fuel on the environment were explained by Frank Vena, Environment Canada, Ottawa and Terry Daynard, Ontario Corn Producers, Guelph, Ontario. Frank talked about the current regulations and how ethanol fits into the established as well as the evolving system. Ethanol fuel from renewable crop sources uses carbon dioxide during the crop production portion of the cycle and Terry Daynard had numbers to show the value of this carbon dioxide utilization to mitigating global warming.

Honourable Bill McKnight, Canada's Minister of Agriculture was the banquet speaker. The Minister is very familiar with Saskatoon and the agricultural area surrounding Saskatoon. Mr. McKnight started off his speech reminding us that Canada is still a young country and needs pioneers. We have traditionally depended on our bountiful natural resources and thrived on markets characterized by borders and minimal competition. "All this has changed." said the Minister,"Markets are integrated world-wide, trade barriers are coming down and the world wants processed, not raw, products."

Mr. McKnight went on to say that in many ways we are pioneers in the 90's and trying to find the right balance between competing and the equally important demands of the economy, the environment and energy. "Our job," he said,"if we are to prosper as a country, is to find new ways to give equal weight to those three key issues. That's why ethanol is an idea for the 90's, an idea whose time has come."

Touring the Pound-Maker Ethanol facility

Jim Johnson, President, Canadian Renewable Fuels Association, chaired the session on Wednesday morning. The second morning of the workshop got off to a rousing start with a lively presentation by Mike Bryan, National Corn Growers, St. Louis, Missouri. The Biomass Energy Institute organized the Saskatoon workshop and our Saskatoon Director, Ewen Coxworth, gave a popular talk on alternative crops for fuel as well as chairing the Tuesday morning sessions. Ewen is retiring from the Saskatchewan Research Council, but like many retirees sounds as though he is going to be very busy. Certainly, Ewen's enthusiasm for sustainable, renewable resource production and utilizing all segments of the crop has increased if anything over the years.A report reviewed on p.20 provides details of the processing centre concept.

Jim Johnson and Hon. Mr. Bill McKnight at the Banquet

Murray Brown, Sypher:Mueller, Winnipeg, Manitoba, followed Ewen and described a project in Regina, Saskatchewan. In the Spring of 1991, a demonstration project of the first ethanol-fuelled transit buses was inaugurated by Regina Transit, supported by the joint efforts of CANMET, Motor Coach Canada Ltd., Mohawk Oil, and SYPHER: MUELLER International Inc. As the first North American heavy-duty vehicles to use almost 100% pure ethanol, the buses highlight the potential of this fuel for such applications.

CANMET's Efficiency and Alternative Energy Technology Branch is contributing $330 000 to the project which SYPHER:

MUELLER of Winnipeg, Manitoba is coordinating on CANMET's behalf. Motor Coach Industries of St. Eustache, Quebec, supplied the converted buses; Detroit Diesel of Canada Ltd. provided engines and technical support; Mohawk Oil of Burnaby, B.C. is supplying the ethanol; and Regina Transit is operating the vehicles. Monitoring of the fuel consumption, engine reliability and durability, and maintenance for a minimum of one year will be done by SYPHER:MUELLER.

George Virgil, IBIS, Decatur, Illinois explained the function of enzymes in the production of ethanol, the parameters which must be considered and the "new technology on the horizon". A new process development, a unique batch or continuous fermentation process, has the potential of lowering the basic manufacturing costs from a cent to as much as 5 cents per litre of ethanol produced. This process combines the yeast and glycoamylase into a single immobilized bead that can be recycled many times before being discarded.

The last speaker before lunch and the tour to Lanigan, was Norman Hinman of NREL, Colorado (also see "Name Change Must be the thing to do! p.22). Dr. Hinman discussed the many new cellulose sources being researched at the Laboratory. Some interesting environmental benefits could come from using waste paper to produce ethanol for fuel. New energy crops are being tested and evaluated from both the ethanol production side and biomass production.

The trip to Lanigan took about an hour and a half and gave participants from outside Saskatchewan an opportunity to view the fall countryside in addition to seeing the new installation at Pound-Maker. The potash plants along the way were particularly interesting to those who were new to the area.

Speeches are available from the Biomass Energy Institute at a cost of 20 cents per double-sided page.

FEASIBILITY OF REGIONAL RURAL PROCESSING CENTRES

E. Coxworth and G. Olsen. 1990. 116 pp. Saskatchewan Research Council, 15 Innovation Blvd., Saskatoon, SK S7N 2X8. BEI 1299.

Integrated rural processing centres could be profitable and competitive with larger non-integrated processing plants by linking several processes together. Savings would result through sharing infrastructure, skilled labour and management, and one operation's waste products could become the other operations raw materials. One example is given of a successful operation in Kansas, Reeve Agri-Energy. Pound-Maker Ethanol Ltd. at Lanigan, Saskatchewan has just opened (October 16, 1991) an ethanol plant integrated with a feedlot.

Harvesting costs could be reduced with whole crop harvest. In Western Europe specially designed harvesting equipment is used to collect grain, straw and chaff in one operation and to transport the mixture a short distance (a few kilometers) to a processing centre which would process about 10,000 tonnes/year of grain and the same amount of straw and chaff. The chaff and leaf fraction of the straw would be processed into cattle feed and a portion of the crop residue could be pelleted for fuel use.

Examples were found of cropping systems which would be more profitable than common Saskatchewan wheat production systems and would produce crops and crop residues that could be processed in a regional processing centre and be more environmentally desirable than the wheat-fallow system. These systems increase profits to the farmers, tend to improve soil fertility and reduce soil erosion, and create new products, or increased yields of products, suitable for processing in a regional centre.

1. Use of red clover or sweetclover as hays, increases yields for following cereal crops and has cost savings.

2. Use of annual legumes, such as Indian Head lentil, Tangier flatpea, chickling vetch and Sirius feedpea, as hays for the drier brown and dark brown soil zones of the province (where 1. is not recommended because of insufficient water).
Both 1 and 2 are based on a beef industry.

3. Organic food production not dependent on animals using a sweetclover green manure system one year in three.

4. Agroforestry by growing wide shelterbelts, such as green ash and Siberian larch, that produce income from forest products as well as sheltering crops.

Recommendations in the report include:
- examining the detailed economics of the cropping systems by agricultural economists;
- reviewing the crop rotations suggested and others by crop and animal scientists;
- finding farmers practising these types of rotations and comparing economics of their systems with conventional systems; and
- finding entrepreneurs to identify regional opportunity sites and develop business plans.