A Feasibility Study for Fish Oil Biodiesel Production

Final Report

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for Clayoquot Biosphere Trust

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INTRODUCTION

Sustainable Community Enterprises (SCE), the for-profit branch of Vancouver-based Environmental Youth Alliance, was awarded a grant from the Clayoquot Biosphere Trust (CBT) to conduct an initial feasibility study on the production of fish oil into biodiesel. The fish oil would be derived from the fish waste generated by the aquaculture industry in Tofino and surrounding areas.

The Clayoquot Biosphere Trust is a non-profit organization which supports local research, education, and training that is consistent with a UNESCO World Biosphere Reserve's objectives of conservation and sustainable development. Tofino is located next to the Pacific Rim National Park Reserve and within the Clayoquot Sound UNESCO Biosphere Reserve.

FISH PROCESSING IN TOFINO

Fish processing operations generate a significant amount of solid waste, much of it in the form of edible protein. The goal of byproduct recovery is to attain maximum utilization of seafood processing wastes for food or feed thus reducing the amount of waste and decreasing the need and cost of waste treatment.

According to BC Ministry of Agriculture, Fisheries and Food, waste generation from filleting operations varies significantly with the species processed. For example, salmon filleting generates only 60-65 % waste while crab and herring processing generates 75-85% waste.

According to the Environment Canada report "Guide for Best Management Practices for Process Water Management At Fish Processing Plants in British Columbia" (1994), 85-90% of all offal generated in BC is used for value added products, compared to a waste utilization rate of 51% for all of Canada (Canadian Fishery Consultants Ltd., 1991).

Creative Salmon and Mainstream Canada are the two main salmon processing companies in the Tofino region. Most of the fish offal generated by these companies is sent to the Keltic Seafoods reduction plant in Port Hardy to be processed into fish feed and fish oil while the unuseable offal and morts (i.e. whole dead fish) is sent to the local landfill. The disposal of fish wastes to the aquatic environment is prohibited by law.

Besides animal feed, there are a number of uses for offal which are environmentally favourable alternatives to landfill dumping such as fish meal, bait, and fertilizer. In the 2002 report "Scoping Study to Identify B.C. Communities for Eco-Industrial Pilot Projects" by Eco-Industrial Solutions Ltd.,

it was reported that the District of Tofino and International Bio Recovery Corp (IBR Corp.), in public-private partnership, had proposed to develop a composting facility where fish processing waste and sewage bio-solids would be turned into a non-toxic fertilizer using a processor developed by IBR Corp. Though in the study it was reported that a feasibility study of the IBR plant had commenced, SCE was told by both the District of Tofino and IBR that no such study had ever been completed.

BIODIESEL IN TOFINO

The region of Tofino, along with the rest of Vancouver Island, is known throughout BC for its progressive stance on renewable energy. There are several 'backyard' biodiesel producers in the region and biodiesel has gained recognition even within the local business community as a viable alternative fuel.

In 2005, a biodiesel feasibility study was conducted for the Clayoquot and Barkley Sound region by the Tofino Long Beach Chamber of Commerce. Based on the findings of the report, it was concluded that due to a variety of factors (such as feedstock availability, by-product disposal, etc.) a small-scale biodiesel production facility was not a viable venture.

Currently, there are no biodiesel producers on Vancouver Island. The biodiesel available on the island is largely supplied by Victoria-based Millenium Biofuels, who supplies both the commercial vehicle and home heating market with biodiesel blends. Millenium currently imports its biodiesel supply from the U.S.

OBJECTIVES AND SCOPE

The objective of this report is to conduct a baseline assessment of the feasibility of a small-scale production plant using salmon oil as a feedstock in the Campbell River region. The capacity of the plant will be determined based on the assumption that all of the fish oil produced from the fish waste derived from the two main salmon processors in the area - Creative Salmon and Mainstream Canada - will be used solely for biodiesel production. Additionally, alternate options of 'outsourcing' biodiesel production at two local biodiesel production facilities in BC will later be discussed.

BIODIESEL BACKGROUND

Biodiesel is a safe, non-toxic, biodegradable, renewable fuel that can be easily used in unmodified diesel engines, and a variety of other fuel applications. Biodiesel can be used either as a substitute for conventional diesel, or as an

additive. Biodiesel reduces the emissions of air toxins, CO_2, particulate matter, carbon monoxide, hydrocarbons and black smoke from vehicles.

Biodiesel is produced by chemically reacting vegetable based oils, animal fats, or waste cooking oils with an alcohol (usually methanol), using either sodium or potassium hydroxide as a catalyst. The conversion results in pure/neat biodiesel (referred to as B100) with crude glycerine as end products. Glycerine has been used as co-gen fuel, a dust retardant in the agriculture industry, and by the pharmaceutical and make-up manufacturing industries.

Fish Oil Biodiesel

Fish oil high in essential fatty acids such as omega 3 is highly renumerative commodity in the pharmaceutical industry. However, since salmon has a low content of omega 3 fatty acids, the resulting oil is more applicable for the production of biodiesel.

The process required to extract the fish oil from raw fish waste materials is an energy intensive process whereby the raw material is heated in a cooker to enable oil extraction during pressing. Pressing removes approximately 70% of the raw material mass as water and 10% as oil. The oil removed as a result of pressing is centrifuged to remove any solids. The oil is further heated to a certain grade purity, with no more than 0.5% water and solids or better, by weight.

Salmon oil used as a feedstock for biodiesel production is processed in a similar fashion to other animal based feedstocks. However, due to the high acid value of salmon oil, an additional pre-treatment step for the feedstock is required, where sulfuric acid is used to reduce the acid value of the oil. After this step is completed, one can proceed with the usual trans-esterification process.

The "cloud point" (i.e., the temperature below which wax crystals that can plug filters form) of biodiesel made from fish oil is 1°C, near the freezing point of water. The cloud point of #2 diesel is much lower, around -9 to -10°C. Potential biodiesel cold flow issues may be addressed by warming the fuel in winter or blending with other fuels, common practices for using #2 diesel.

BIODIESEL PRODUCTION

In this section, the feasibility of a modular, automated, pre-fabricated biodiesel production system operated in Campbell River will be considered. The reason why this particular location was considered versus Tofino was that Mainstream Canada, the larger contributor of fish oil of the two salmon processing companies, has a fish hatchery located just north of Campbell River. The Little

Bear Fish Hatchery is a large consumer of biodiesel (estimated 2008 consumption of B100 for this site alone is 100,000 L) and since the feedstock for the biodiesel will come largely from Mainstream's operations, it is likely that Mainstream would be interested in being a potential buyer of the product. As well, if the facility is located in Campbell River, this cuts the transportation cost of the feedstock drastically since Campbell River is only 200 km away from Port Hardy, whereas Tofino is located over 500 km away from Port Hardy.

Below are some of the assumptions that have been made for this scenario:

- The facility will be built and operated in Campbell River;
- The fuel does not have to meet ASTM D6751 quality;
- The feedstock will be derived from fish offal generated at the Creative Salmon and Mainstream Canada salmon processing facilities in the Tofino region;
- The fish offal from the salmon processing companies will be transported to Keltic Seafoods in Port Hardy, BC (at no cost the salmon processing companies), where it will be processed into the fish oil feedstock for biodiesel production; and
- The biodiesel produced will be used to supplement Mainstream Canada and Creative Salmon's current petro-diesel supply.

FEEDSTOCK

Fish offal - the less valuable edible part of a carcass (i.e heads, tails, fins, organs, etc.) - is generated through fish butchering and cleaning. Creative Salmon, the smaller of the two salmon aquaculture companies, produces approximately 1700 MT of Chinook salmon per year. According to Spencer Evans of Creative Salmon, 500 MT of offal is generated each year from the company's aquaculture sites in Clayoquot Sound. Mainstream, the larger of the two salmon processing companies, produces anywhere from 4500 - 5900 MT of farm-raised King and Atlantic salmon annually. Approximately 1500 MT of offal is generated from the company's operations each year. Assuming that fish waste pressing yields 10% oil, it is estimated that the salmon oil production yield from the salmon waste is equivalent to 220,000 L. (Note: this amount is subject to change due to seasonal varation).

Cost to deliver to proposed facility

The following assumptions underpinning the analysis of the cost are as follows:

- Biodiesel production facility would be located in Campbell River;
- Available feedstock is approximately 220,000 L;
- A round-trip distance from the facility to the Keltic Seafoods in Port Hardy is 472 km;
- A fuel efficiency of 25 liters/100 km and a fuel cost of $1.00/liter;
- And a vehicle purchase and outfitting cost of $10,000 (payments at 7% over 24 months).

Table 1.0 - Cost to collect fish oil using a leased, used truck

Description	Collection Location	unit	source
	Port Hardy		
WVO Levels			
Number of pickups	1	reduction plant	calculation
Fish oil produced by region (weekly)	4400	L/week	calculation
Fish oil produced by region (annually)	220000	L/year	calculation
WVO un/loading time			
Average number of liters per stop	4400	L/stop	calculation
Speed of oil collection (loading/unloading)	15	L/min	estimate
Speed of oil collection (set up of pumps)	10	min/stop	estimate
Fish oil collection time per stop	303	min/stop	calculation
Number of stops	1	stops	calculation
Time to load WVO (monthly levels)	5.1	hours	calculation
Time to unload WVO	4.9	hours	calculation
Total time to load/unload WVO	9.94	hours/week	calculation
Driving time (Delivery)			
Average distance to facility (return)	472	km	guess
# of return trips to facility w/ 2000L tank	3	trips	estimate
Average highway speed	60	km/hr	rough estimate
Total facility delivery time	23.6	hours/week	calculation
Fuel Costs			
Fuel efficiency of truck	0.25	L/Km	guess
Fuel cost at pump	1	$/L	estimation
Total cost of fuel	118	$/week	calculation
Truck costs			
2 tonne / 2000L diesel truck (w pumps & tanks)	10000	$	estimate
Payments at 7% interest for 2 years	$445	$/month	calculation
Payments per week	51	$/week	calculation
Insurance costs per year	1500	$	estimate
Insurance costs per week	14	$	calculation
Maintenance costs per year 10% of vehicle	1000	$	
Maintenance costs per week	10	$	
Total truck costs (weekly)	75	$/week	calculation
Labour costs			
Total hours related to collection	34	hours	calculation
Average cost of labour with MERCS	15	$/hr	estimate
Total labour costs	488	$/week	calculation
Total Vehicle related costs	193	$/week	calculation
Total cost of fish oil collection service	682	$/week	calculation
Average cost of collection	**0.15**	**$/liter**	

The analysis revealed a cost of $0.15/L of biodiesel produced to collect the 220,000 Liters of fish oil from the Keltic Seafoods reduction plant in Port Hardy using a financed, used truck (price includes tank and pumps).

CAPITAL EQUIPMENT ACQUISITION OPTIONS

The objective of this section is to determine the likely costs for a pre-packaged biodiesel processor with a 250,000 L/year production capacity.

The choice of the technology greatly affects the capital and operational cost balance and in turn, the financial feasibility of the project. It is assumed that there is a reasonable time frame allowed for pay back on capital investment; therefore, the ratio of capital cost to revenue cannot be too high. On the other hand, if the equipment requires much labour, space, or consumables to operate, the fuel becomes too expensive and revenues are reduced. The study examined various options to determine the optimal capital and operational balance.

The suitability of the following systems were assessed:

1) A self-built, base trans-esterification system using Magnasol:
2) A fully automated acid/base two stage model using water wash;

Note: In assessing the three options, the following additional equipment required for biodiesel production was considered as well. This applies specifically to option 2, as option 1 accounts for these costs.

1. Fish oil storage vessels, pumps and heating system for lines and tanks;
2. Fish oil pre-treatment to remove water and particulates;
3. On-site laboratory for titration and quality control;
4. Wastewater treatment (for water wash system);
5. Glycerin/ methanol by-product handling pump and storage containers; and
6. Final biodiesel settling and storage tanks.

It was estimated that the additional equipment listed above added approximately $5,500 to $7,000 to options 1 and 2.

OPTION 1: Self-built base trans-esterification system using Magnasol

Capacity	The system would be capable of processing 250,000 liters per year or 5000 liters per week (excluding 2 weeks holidays).
Labour	The estimated attended hours per week would be 24 hours. This would require a part-time workweek for an operator (i.e. 10 - 12 hours/week).
Feedstock	The design requires fish oil to have low free fatty acid and low water content.
Waste	Methanol recovery is included. Magnasol and filter media are solid waste products. Vessel and facility clean up related wastewater is not included.
Space	The facility would occupy around 1200-1500 ft^2 of indoor and outdoor space.
Quality	No claims to ASTM quality.
Costs	The facility costs approximately $130,000 plus $7,000 in infrastructure and other costs.
Benefits	• The system can be expanded by adding more settling vessels or through improved separation technology; • No water treatment facility capital and operational costs; and • Quality control can be improved as operator has access to all systems.
Drawbacks	• No automation therefore it is a labour-intensive operation. • Difficulties in finding an effective Magnasol filtration system; • Large amount of space is required; • No manufacturer to help with production issues; • Limited to feedstocks with low free fatty acid content; and • Cannot be leased.

OPTION 2: A fully-automated acid / base two stage model with water wash

Capacity	The manufacturer, Pacific Biodiesel, claims its system can produce 200 gallons (757 liters) every 1.5 hours. If the plant operated for 30 weeks throughout the year, running just 2 days a week, it could produce 227,100 L/year.
Labour	Minimum labour requirements estimated at 24 hours/week including fish oil pre-treatment and wastewater treatment.
Feedstock	The design can accept high or low free fatty acid content oil because it uses both the acid and the base process.
Waste	Methanol recovery is not included. Methanol, caustic and biodiesel contaminated wash water must be treated. Glycerin handling equipment is not included.
Space	The processors would occupy around 1000 ft^2 of indoor and outdoor space with an additional 200 ft^2 for additional equipment.
Quality	ASTM D6751 quality biodiesel can be attained.
Other costs	Wastewater processing; feedstock pre-treatment to lower free fatty acid content and to remove water; glycerin, feedstock and biodiesel storage and handling. These cost are estimated at $17,000 and are included below.
Costs	The system costs $350,000 plus $17,000 in feedstock pre-treatment, material handling and water treatment and other infrastructure costs related to space such as potentially a shipping container, generator, spill guards etc.
Benefits	• Low labour costs; • Low space costs (could be operated within the footprint of a 20' shipping container); • Higher degree of flexibility in feedstocks; • Manufacturer support in case of problems; • Modularity (i.e. can buy one and expand); • Less regulatory interaction; • Customer testimonials can be acquired; • Can be leased from dealers and banks may also provide financing; and • Dealers will allow you to test your feedstock in the system before purchasing.
Drawbacks	• Slow operation; • Production of wastewater will have to be treated; • No methanol recovery system (higher chemical costs).

PRODUCTION COST ASSUMPTIONS FOR OPTIONS 1 & 2

OPTION 1: Self-built system production costs at 250,000 liters per year

Operational Perspective

Capacity	250,000 L/year or 5,000 L/week (excluding 2 weeks holidays).
Yield	85% volume of fish oil is converted into biodiesel.
Feedstock	$0.15/L using a used, leased truck and collection from Port Hardy reduction plant.
Chemicals	- Methanol at $1.06/L delivered in 1000 L totes, used at 20% of fish oil volume - Catalyst assumed to be sodium hydroxide (KOH) at $4.53 per kg, used at 0.012 kg/L of fish oil; and Magnasol at $3.00/kg, used at 0.01 kg/L of fish oil.
Space	1200 ft^2 at $13/$ft^2$/year.
Labour	One operator working five 8 hour days per week at $15/hour (plus 13% MERCS) or $678/week.
Energy	Estimated to be $0.03/L of biodiesel produced with a 200% safety margin.
Water	No process water required.
Solid waste	2.5% of fish oil volume is solid waste disposed of at $75/tonne.
Liquid waste	- 0.1% of fish oil volume is liquid waste from vessel cleaning; - Wastewater disposal is estimated to cost $1.00/L;
Quality	Assumed no quality control costs.
Glycerin	Assumed glycerin was sold to wholesaler.

OPTION 2: A fully-automated acid / base two stage model with water wash

Operational Perspective

Capacity	227,100 L/year or 7,570 L/week (for 30 weeks a year)
Yield	95% volume of fish oil is converted into biodiesel.
Feedstock	$0.15/L using a used, leased truck and collection from Port Hardy reduction plant.
Chemicals	- Methanol at $1.06/L delivered in 1000 L totes, used at 20% of fish oil volume - Catalyst assumed to be sodium hydroxide (KOH) at $4.53 per kg, used at 0.012 kg/L of fish oil; and - Magnasol at $3.00/kg, used at 0.01 kg/L of fish oil.
Space	1000 ft^2 at $13/$ft^2$/year.
Labour	One operator working three 8 hour days per week (for 30 weeks a year) at $15/hour (plus 13% MERCS) or $406/week.
Energy	Estimated to be $0.03/L of biodiesel produced with a 200% safety

	margin.
Water	No process water required.
Solid waste	2.5% of fish oil volume is solid waste disposed of at $75/tonne.
Liquid waste	- 0.1% of fish oil volume is liquid waste from vessel cleaning; - Wastewater disposal is estimated to cost $1.00/L.
Quality	Assumed no quality control costs.
Glycerin	Assumed glycerin was sold to wholesaler.

For the option 1, it was calculated that the total production cost was $0.97 per liter of biodiesel produced, whereas for option 2, the total production cost was $ 0.89.

If the biodiesel was sold at a price of $1.10 per liter (including $0.09 per liter of tax at 6% GST, assuming the biodisel was sold as a blend under 50% biodiesel to 50% diesel), the profit per liter (for the option 1 scenario) would be $0.13. The profit realized per year would be $32,500. Given a capital cost of $ 137,000 for option 1, the payback time would be 4.2 years.

For scenario 2, the profit per liter would be $0.21 with a yearly profit of $47,691. Given a capital cost of $367,000, the payback time would be 7.7 years.

GLYCERIN

The amount of glycerin produced from biodiesel production can be quite significant and should not be overlooked. Theoretically, the glycerin produced from biodiesel production is 20% of the volume of feedstock processed, or in this case, 44,000 L/year. Usually, the cost of glycerin disposal through a waste recycler (who then refines the material into fuels and oils) is approximately $0.10 per liter of biodiesel produced.

However, glycerin is becoming increasingly sought after by pharmaceutical companies. These companies usually offer to cover for the handling and transportation of the crude glycerin from the production facility to their site. Therefore, the glycerol simply needs to be stored on-site (i.e. in recycled 200 liter drums at $5 each) until they can be shipped off to the buyer. In this scenario, the cost of the drums is $0.0044 liters per biodiesel produced, a significant decrease from the cost that would have been incurred if the glycerin were sent to a recycler.

DISCUSSION

As mentioned previously, Mainstream Canada is a large consumer of diesel, and recently, biodiesel. If Mainstream Canada considered taking ownership of the biodiesel production facility and had it built and operated at one of their sites (i.e., the Little Bear Fish Hatchery), they would not only have a renewable fuel source at their point of consumption, but by having it located on the company's own property, this would eliminate both space and energy costs. If both the space and energy costs were eliminated, this could reduce the payback time for options 1 and 2 to 2.4 and 6.4 years, respectively.

Also, they would not have to pay delivery surcharge imposed by biodiesel distributors; as well, it would reduce the pollution generated from transporting the biodiesel purchased from the distributors to their site.

Other potential options

In the spring of 2008, BC's first biodiesel production facility, City-Farm Biofuel, will open in Delta, BC. The facility can produce over 10 million liters of ASTM quality biodiesel from a variety of feedstocks, including animal fat. One option which the salmon processors might consider is to sell their fish oil (pressed at Keltic Seafoods in Port Hardy) to City-Farm Biofuel to supplement the biodisel producer's feedstock supply. Mainstream could then purchase biodiesel from City-Farm Biofuel at a reduced wholesale price.

(Mainstream currently uses B5 and plans on using B20 in their generators, compressors and boats at all 39 of their BC fish farm and hatcheries. At their Little Bear hatchery, located just north of Campbell River, the company anticipates that its use of biodiesel will be 100,000 liters of B100 in 2008. Mainstream currently purchases its biodiesel from Millenium Biofuel).

The obvious advantage of this option is that no investment would be needed for the construction and operation of a biodiesel facility. The other benefit is that the biodiesel produced at the City-Farm Biofuel facility will be guaranteed ASTM quality. The disadvantages of this option is that there are associated transportation costs which could negate the overall savings gained from purchasing the biodiesel at reduced cost. As well, pollution generated from the transportation of the feedstock to the biodiesel facility may negate the overall greenhouse gas reductions obtained from the use of biodiesel. Further, due to the seasonality of the industry, the fish processing companies may be unable to guarantee a consistent supply of fish oil.

The other option which Creative Salmon and Mainstream Canada could consider is to transport the fish oil from Keltic Seafoods to the Cowichan Biodiesel Co-op in Duncan BC. The members of the Co-op currently produce non-ASTM quality biodiesel on a smaller scale (approximately 50,000 L/year), using recycled vegetable oil as their feedstock which they collect themselves. They are currently awaiting approval for a federal grant which will allow them to increase the capacity of their production in 2008. They intend on producing their biodiesel from a self-built system, with a yearly capacity of over 100,000 L.

Again, the advantage of this option is that the production of the biodiesel would be 'outsourced', thereby eliminating the cost of building and operating a biodiesel plant. If the Co-op is supplied with feedstock, this eliminates the need of having to collect the feedstock themselves. The Co-op could potentially pass the savings gained from collection and transportation costs onto the buyer (the salmon processing companies). There is also a relative advantage over the aforementioned option as the fish oil feedstock would not have to be transported as far a distance to its production location. The disadvantage of this option is that the biodiesel produced would not be of ASTM quality. However, if the intended end use is to fuel generators and compressors, these types of equipment do not demand as high of quality of biodiesel as would vehicle engines.

CONCLUSION

Based on the baseline analysis provided in this report, it was determined that at a price of $1.10 per liter of biodiesel, the payback time for a self-built biodiesel processor, producing 250,000 liters per year for 4.2 years. The payback time for a fully-automated acid / base two stage model with water wash producing 227,10 liters of biodiesel per year is 7.7 years. If the facility is located at one of the salmon processing companies, this would reduce the cost for space and energy, yielding a quicker payback time for both scenarios.

Producing biodiesel from fish oil derived from waste generated by the local aquaculture industry supports the UNESCO Biosphere principles in that it involves processing the region's natural resources to the greatest degree, achieving maximum value for those resources, while providing greater economic opportunity and employment, and reducing waste production.

The fuel would also minimize impacts to Clayoquot Sound's natural areas, such as the Pacific Rim National Park Reserve. Having a biodiesel production facility located on the island would increase the accessibility of the renewable fuel to remote island communities as well.

RECOMMENDED NEXT STEPS

It is recommended that more precise data in terms of the average frequency and quantities of which the offal from Creative Salmon and Mainstream facilites is transported to Keltic Seafoods in Port Hardy. This data will enable one to assess the regularity of the feedstock supply to the biodiesel producer.

Additionally, it is recommended that samples of the fish oil be obtained and test batches of biodiesel be produced. The test biodiesel should be run through all types of equipment and vehicles (i.e. generators, compressors, boats, vehicle engines), for which the biodiesel will be used to ensure performance standards are met.

Discussions should be initiated with both City-Farm Biofuel and the Cowichan Biodiesel Co-op to determine their receptivity to the proposal of supplying feedstock to their production in exchange for a reduced price on the biodiesel produced. Additionally, both Mainstream Canada and Creative Salmon should be involved in discussions to determine their receptivity to owning and operating a biodiesel plant at one of their facility locations.