Anaerobic Digestion of Abattoir Offal on Salt Spring Island

prepared for the

Salt Spring Island Agricultural Alliance

June, 2012

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Executive Summary

The Salt Spring Island Agricultural Alliance (SSIAA) is interested in locally treating the offal from their new abattoir. Despite being perhaps less than appealing, organs and entrails (offal) are considered here as a resource which can provide clean, renewable fertilizer products and renewable energy.

The offal waste stream is estimated in quantity and quality, and treatment requirements and techniques are considered. An anaerobic digestion system dedicated to the SSIAA abattoir offal is sized and outlined, and capital and operational costs and benefits are estimated.

If the SSIAA pursues an anaerobic digestion system for the abattoir waste, it is recommended that they first invest in a small and inexpensive pilot system, which will provide critical data on the waste stream and on the local value of the derived fertilizer products. Once this data has been assessed, the SSIAA will be in a good position to decide whether to invest in the design and construction of a full-scale anaerobic digestion system for the abattoir offal.

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1. Background

For several years, the Salt Spring Island Agricultural Alliance (SSIAA) has been investigating and planning an abattoir facility for the Gulf Islands.

There are numerous merits to local preparation of meat, including opportunities for the local re-use of various animal (by)products. For example, it is expected that the existing local demand for bones, fat, meat waste, and hides will put such products to good use on the Gulf Islands (Thomson, 2012).

Other by-product streams for which there is currently no local demand are considered to be waste. This includes

- Wastewater
- Specified risk material
- Stomach, guts and organs

A facility for the treatment and infiltration of wastewater has already been designed and will not be considered in this document. The abattoir is planning to carefully source-separate specified risk material, defined as animal tissue that could be infected with BSE (Mad Cow Disease). Because of the very small quantity of specified risk material, the SSIAA plans for it to be shipped off-island for treatment or disposal elsewhere, and this is considered to be a satisfactory long-term solution.

The remaining waste stream is the entrails, stomach and gut contents, and organ meats for which there is currently no demand, defined here as "offal". Note that the word offal is also sometimes used to refer to just the edible organ meats.

The current solid waste disposal solution for offal involves cold storage (4°C) on-site and a pick-up service once every 2 or 3 weeks provided by West Coast Reduction. West Coast Reduction then transports the waste to a specified risk material landfill in Coronation, Alberta (FTGU 2009).

The SSIAA is keen to pursue local options for the reuse of this waste for several reasons, including reduction of cost, local benefit, and indirect environmental benefits. An important advantage of on-site, decentralized waste treatment facilities is that they can ensure uncontaminated, source separated waste streams. This vastly improves the potential for recycling and guaranteeing a clean end product.

The following section will outline the quantity and quality of the offal waste stream from the Salt Spring Island Abattoir for the purpose of considering local treatment options, in particular anaerobic digestion.

1.1. Quality of Waste

As described in the previous section, the waste stream considered in this document is the offal, defined here as entrails, stomach and gut contents, and organ meat for which there is currently no demand. This waste stream does not contain much bone or meat, and contains no specified risk material.

The waste is soft and wet and can be assumed to contain numerous animal and human pathogens from the intestine such as E. Coli & Enterobacteriacae, and may also contain Salmonella and other entero-bacteria that are present in animal manure. Apart from the risk of pathogens, the material is very clean and is unlikely to contain high levels of organic toxins or heavy metals.

Some of the offal material may contain synthetic hormones, vaccines, antibiotics, herbicides or toxic feed-additives. These organic toxins would also be present in the manures from the animals in question and to the author's best knowledge there are no regulations on these kinds of organic contaminants for recycling organic waste into soil amendments in Canada. In the Netherlands, where fertilizer regulations are among the strictest in the world, limits on these organic toxins are significantly higher than what is present in human excreta and blood. Given that humans bio-accumulate the organic toxins present in the meat we eat, it is expected that the levels in humans are higher than those in other animals, and the toxins present in animals would be well below the Dutch limits. Thus with sufficient interruption or containment of pathogens, it is expected that recycling this material into safe soil amendment/ fertilizer products will be possible.

1.2. Treatment Requirements and Technologies

Depending on the preferred end use of the offal material, treatment requirements will differ. There are opportunities to recover nutrients and organic matter as soil amendments, and there are also opportunities to recover energy during the process. This section will consider treatment requirements related to (1) the reduction of biological risk, (2) the chemical stabilization of the material, and (3) the physical quality of the end product.

1.2.1. Biological Risk

The reduction of biological risk is defined here as the reduction or destruction of pathogens which may infect animals or people. In BC, the regulations regarding treatment and disposal of slaughterhouse waste fall within the BC Environmental Management Act (B.C. Reg. 381/2010). Acceptable methods of disposal listed in this act include composting, landfill and incineration. Further methods of pathogen destruction are also recognized in Canada such as pyrolysis, thermal hydrolysis and chemical hydrolysis (FTGU 2009), but are aimed at stabilizing specified risk material, which will not be present in this waste stream.

The BC Environmental Management Act states that composted animal material must reach temperature-time requirements of 55°C for 4 hours and 40°C for 5 days (section 23). In addition, there are requirements for containment and handling of finished compost, including that livestock should not graze land within 5 years of spreading compost from specified risk material, (section 27). There are also requirements for the containment of nutrients from amended land and the avoidance of environmental pollution. In the opinion of the author, meeting the BC requirements would be the bare minimum in terms of reduction of biological risk in land application, and a more cautious approach should be considered for the Gulf Islands.

Partly due to recent animal by-product related disease outbreaks in Europe, including BSE (Mad Cow Disease), the EU passed the Animal By-Products Regulation (ABPR) in 2002, which has been amended several times since and is interpreted differently in each EU member country. The ABPR classifies all animal by-products as Category 1, 2, or 3 material.

Category 3 is any food-waste that is not vegan, including catering waste that may have come in contact with cooked dairy products or eggs. Category 3 material must be shredded into particles of less than 12mm and reach 70°C for 1 hour (usually by pasteurization), or alternatively comply with performance indicators of numbers of indicator microbes per gram (E.Coli and Salmonella).

Category 2 material is meat-processing and slaughter waste, not considered to be specified risk material. Category 2 material must reach 133°C at 3 bars of pressure for 20 minutes, or similar methods including those based on bacteria reduction performance.

Category 1 material includes specified risk material, wild animal carcasses and unknown risk material. Treatment requirements for Category 1 & 2 material are similar except that following treatment, Category 1 material must be incinerated or land-filled, whereas Category 2 material may be composted or used in a biogas plant following treatment, and applied as an agricultural soil amendment, like Category 3 material. Despite these seemingly extreme requirements, small and medium sized composting and biogas systems are common in the EU and generally comply with the ABPR through pasteurization (70°C, 1 hour) or sterilization (133°C, 3 bars, 20 minutes). Once this interruption of pathogens takes place, the material is considered safe to be composted or used in a biogas plant, where it becomes chemically stable and in a preferred physical condition for use in agriculture.

Pasteurizers and pressure vessels capable of pasteurization or sterilization are commonly used in dairy processing, food and agri-processing, and in hospitals/ health care facilities. The Community Composting Network of the UK has extensive experience with small pasteurizers for Category 3 food waste, which have met British inspection (the UK interpretation of ABPR is among the strictest in the EU). Many of these pasteurizers are based on the "old fashioned" technique of a sealed vessel in a double boiler or water bath maintained at a given temperature. Temperature loggers are required and detailed records must be kept of both temperature-time treatment and also regular tests of the pasteurized material for the presence of indicator bacteria.

A pasteurizer at 70°C and atmospheric pressure is a much simpler and more common piece of equipment than a pressure vessel for 3 bars and 133°C. The author proposes that if temperature-time treatment is employed to interrupt pathogens that a simple pasteurizer be used and indicator bacteria performance used to verify its effectiveness (thus meeting EU standards).

Numerous other methods are available for disinfection and reduction of pathogens, including chemical treatment, drying, burning or pyrolysis, however for re-use in agriculture, temperature-time treatment is the simplest and most common method used in the EU and in Canada. For further reading, a good review of sanitization of sludge was published in the Journal of Applied and Environmental Microbiology (Arthurson 2008).

1.2.2. Chemical Stabilization

In order to be acceptable for agriculture, the end product must be stable (low biological oxygen demand), must have low odour, must not attract animals, and must not harm crops or soil. In addition the process of chemical stabilization must not release odour or otherwise contaminate the surrounding environment, and should maximize the retention of nutrients and recalcitrant carbon for the benefit of the amended soil.

In general there are two methods of reducing biological oxygen demand, one being aerobic biological treatment and the other anaerobic biological treatment. Both involve the consumption of unstable, readily degradable organic matter by small organisms. In both cases energy can be recovered, usually as heat from aerobic treatment and as biogas from anaerobic treatment. A well-executed aerobic or anaerobic treatment process can stabilize organic material such as meat and slaughter waste to the point that it has very low biological oxygen demand and is considered stable and will not attract animals. The end-product from a well-executed aerobic treatment will have no odour and will certainly not harm crops or soil.

Anaerobic treatment on the other hand produces ammonium /ammonia and therefore, depending on pH and application technique, can have an odour and can also lead to anaerobic conditions in soil if it is over applied. Using anaerobic digestate (finished product from anaerobic digestion) is much like using aged liquid manure, which may be separated into dry fibre and pure liquid. The liquid fraction must be applied with consideration for ammonia, which when used properly can be of high value to crops. At a rate of 200 kg N per hectare, most digestates do not have a negative effect on crop growth, when applied in one dose at the time of crop seed germination. Problems in soil can be due to over-application of ammonia, high salinity (entirely dependent on feedstock), and instability (incomplete digestion). Stable compost or aerobically treated material on the other hand is unlikely to cause any problems in the soil, no matter how much is applied, again, unless there is high salinity in the feedstock or instability (incomplete treatment).

The process of chemical stabilization must be well contained. Aerobic treatment is inherently more difficult to contain, because it requires the constant consumption of oxygen or air and constant release of CO_2. An aerobic system will therefore require an odour filter of some kind to reduce the odour of effluent air. In addition to CO2 and odour in the effluent gas, some nitrogen is lost during composting as nitrogen gas, nitrogen oxide, nitrous oxide and ammonia, which is not ideal for the atmosphere or for nutrient recycling. Composting (aerobic treatment) also requires high carbon bulking material such as wood chips or leaves, whereas anaerobic treatment can use pure offal. Because of the very high moisture content of the offal, leachate is also expected from an aerobic process, so the leachate will require containment and treatment of some kind. In comparison, anaerobic digestion does well with wet feedstock, and retains all carbon, water and nutrients either as biogas or as digestate. Anaerobic digestion must be contained in a gas-tight vessel to ensure no oxygen is introduced into the process and also to ensure biogas is contained.

As mentioned, energy can be recovered either as heat from aerobic degradation or as methane from anaerobic degradation. Although methane gas handling introduces complexity to the system, it is a much higher value energy source than heat, and can be used to run a boiler or any natural gas or propane device. There are also energy inputs to both processes, as aeration and mixing to compost and as heat and mixing to anaerobic digestion.

Before chemical stabilization, the offal will stink. Therefore, the loading area and waste storage must either be refrigerated or have dedicated venting and bio-filters on exhaust air. In both composting and anaerobic digestion, the first stage of treatment including pasteurization and particle size reduction should take place in a sealed area with exhaust air treatment. This can be as simple as a composting toilet where a tiny fan creates a constant negative pressure around the offal. At the end of the process, the finished product will not have a strong odour, although digestate that is high in nitrogen will smell of ammonia (like stable liquid manure does).

1.2.3. Physical Quality

The physical quality of aerobically treated material is generally very pleasant. A dry compost product (30% dry matter) is often a saleable item and is easily used by gardeners or farmers. Liquid-manure like digestate in its raw form is not as easy to use. It can be spread or injected by tractors in its raw form (like liquid manure), but it can also be improved by a “separator”, a device which produces a dry compost-like separated fibre and a liquid fraction, also called digestate, which can be used in place of a synthetic soluble liquid fertilizer. It has high levels of ammonia, orthophosphates, free potassium (soluble NPK), and ionic forms of all macro- and micro-nutrients present in organic matter. Delivering nutrients in this form can be very simple, low in labour (automatically mixed with irrigation water), and is effective for improving plant growth but can also cause the same problems associated with other soluble fertilizers such as leaching if it is over-applied.

1.3. Quantity of Waste

The quantity of offal that will be produced, per head by the Salt Spring Island Abattoir is estimated in Table 1. Based on the business plan for the abattoir, numbers of animals and total quantity of waste is presented in Table 2. The fraction of offal coming from ruminants is expected to range from 73 to 77% of the waste stream, whereas hogs are expected to account for 7% and birds for 16 to 20%.

Table 1. Quantity of offal produced per head of various types of livestock

Waste per head		
Cattle	90.91	kg
Lambs	7.73	kg
Hogs	23.13	kg
Chicken	0.62	kg
Turkey	2.07	kg
Duck	0.62	kg

Table 2. Total quantities of offal produced per year, for years 1, 3 and 5

	Year 1			Year 3			Year 5		
	# head	waste		# head	waste		# head	waste	
Cattle	30	2727	kg	42	3818	kg	54	4909	kg
Lambs	750	5795	kg	1050	8114	kg	1500	11591	kg
Hogs	30	694	kg	45	1041	kg	60	1388	kg
Chicken	3000	1855	kg	3700	2287	kg	4400	272	kg
Turkey	200	413	kg	250	516	kg	300	620	kg
Duck	100	62	kg	125	77	kg	150	93	kg
	Total	11546	kg	Total	15853	kg	Total	18872	kg

From the quantities presented in Table 2, a waste treatment facility should be designed to be capable of treating 20 tonnes of offal per year. In addition, the operation of the slaughterhouse will be somewhat seasonal, and may shut down for up to two months at a time (Thomson 2012), so the facility would ideally have minimal requirements for shut down and start up.

Any biological treatment technology should be over-sized as a safety factor, and also for periods where a lot of waste is produced in a short period of time. In the case of anaerobic digestion, a good option is the two-stage digestion model, where initial decomposition (hydrolysis and acidogenesis) place in one tank and biogas production (methanogenesis) takes place in a separate, secondary tank. That means that the first tank, defined as the “feedstock tank”, can act as a buffer tank to receive large amounts of waste when it is produced, and then pump feed material into the biogas reactor (second tank) at a constant rate. In this case, the biogas reactor can be sized for the maximum average waste flow (perhaps over 4 months) and the mixing tank can buffer sudden increases or decreases in waste production.

One option for improving the flexibility of the system is to use modular feed & biogas tanks. That means an extra tank may be added to increase capacity if that is necessary in the future.

Thus important parameters for system design include:

- 20 tonnes per annum offal
- 10 tonnes maximum per 4 month period

For the purposes of this investigation, these numbers will be used, with the expectation that no increase in capacity will then be required for the first 5 years of operation.

1.4. Small Scale Anaerobic Digestion

Small scale Anaerobic Digestion or "AD" is not common in the industrialized world. On the other hand small scale AD is very common in the warm developing world. For example millions of biogas systems exist on small farms in India, Southern China, Bolivia and many African countries. A review completed by the Community Composting Network of the UK in 2008 concluded that the main reason for that is the relationship between the cost of resources and the cost of labour; in BC, human labour is expensive while conventional energy, fertilizer and waste treatment are cheap. In India, that relationship is reversed. Still, pioneers of small AD systems in the industrialized world are developing automated systems that require minimal labour, and in some cases can be economically beneficial. This technology is extremely rare in Canada and the US, and most biogas consultants consider the minimum scale for an "economical" anaerobic digestion to be in the order of 10,000 tonnes per annum. Here we are looking at 20 tonnes per annum.

Yet small systems do exist, especially in the Netherlands and in the UK, and Off-grid Gas & Fertilizers Ltd. is currently constructing several such systems on Vancouver Island and Salt Spring Island. For many years proponents of sustainable waste treatment and resource recovery have promoted the idea of small and decentralized AD systems (Lettinga 2008, Radcliff 2012), but this technology is still in its infancy in the western world, even in Europe. As a result, such systems always involve some research and development. Several companies can provide inexpensive micro-scale biogas reactors that may be used to test a given waste stream, and provide data on gas production and quality of effluent produced.

There could be benefit to mixing offal with other waste streams such as food waste, sewage sludge, animal manure or green waste for anaerobic (co-)digestion on Salt Spring Island. Large co-digestion plants are used in Northern Europe to produce vehicle fuel (CNG) from huge amounts of organic waste. On the other hand these kinds of large centralized waste treatment facilities mean increased transportation, and higher susceptibility to contamination and system failure. These large systems are also expensive and take a long time to conceive. The question of "What scale and method of organic waste recycling is suitable for other organic waste streams Salt Spring Island?" will have influence on the benefits of a dedicating a facility to SSI abattoir waste.

The following section will consider some details and design parameters for an anaerobic digester dedicated to offal from the SSI abattoir.

2. An On-site Anaerobic Digestion System

2.1. System Components

Based on the quantity of waste, the quality of waste, and the treatment requirements (section 1) a biogas system has been detailed.

Grinder,

Reduces the particle size to less than 12 mm. (Eg. A restaurant garborator)

Pasteurizer, 600 L

Pasteurizers often use a batch process, this is the simplest way to ensure all material reaches the temperature-time requirement. In Europe, the input and the output of the pasteurizer must be separated into a clean area and a dirty area. The size of the pasteurizer depends on how often batches are processed (pasteurized). Factors to consider when deciding on size include (1) the labour associated with pasteurizing and/or testing batches, (2) how much and for how long "dirty" material is on site, (3) the capital costs associated with a larger pasteurizer system and (4) energy efficiency. At the maximum flow rate of offal (10 tonnes per 4 months), a 600 L pasteurizer would not have to be used more than once per week. 300L minimum size for the pasteurizer is suggested to accommodate the offal from one large cow in one batch.

Feedstock tank, 15,000 L

The design requirement is a capacity of 10 tonnes of feedstock material.

Biogas digester, 4,200 L

The design requirement is being able to treat 10 tonnes in 4 months, therefore an average feed rate of 83 kg per day. A safe hydraulic retention time will be 50 days for this kind of material (assuming a plug-flow series of completely mixed tanks) therefore the reactor must be 4200 L.

Digestate storage, 15,000 L

The size of the digestate storage will depend on how often material is picked up for spreading on land. Having a capacity of 15,000 L will allow for at least 4 months between pickups. Further treatment of digestate such as solids composting or drying of separated fibre can happen on the site where the dry soil amendment will be applied. Similarly tanks of liquid digestate fertilizer may be filtered on the site where they will be applied.

Gas handling

Gas production will be in the order of 21 kWh per day, higher heating value, or 28 GJ per year, worth $1000 as propane, $336 as Fortis Renewable Natural Gas, or $230 as electricity (at 10 cents per kWh) after being burned in a small generator with no heat recovery (30% efficiency). Gas can be stored in propane tanks or compressed natural gas (CNG) tanks (3000 psi of pressure), which are currently used on several City of Victoria vehicles. Gas scrubbing, drying and compressing should be done according to the CSA code on digester and landfill gas and registered with the BC Safety Authority.

Boiler system, 12kW

A 12 kW boiler and hydronic heating system would complete a 600 L pasteurization cycle in 6 hours, and would use only 35% of the biogas produced by the that quantity of waste. A further 15% of biogas will go towards keeping the digester warm, and the remaining gas with energy value of 10 kWh per day higher heating value (energy capable of boiling an additional 120 L of water per day) – can be used or stored according to hot water requirements onsite.

Electrical control & Monitoring

The AD system must be automated and well-monitored. Internet based monitoring is highly recommended so that performance data is continually assessed for signs of problems. The automation can be achieved with timers, mechanical float switches, and thermostats that control pumps, mixers, compressors and valves. Instead of traditional timers and thermostats, a computer may be used to control relays.

2.2. Suppliers & Capital Costs

Table 3 estimates the capital costs for design work, equipment, materials, and installation for an anaerobic digester (AD) installation of this scale. Accurate quotes will need to be verified by the Dutch and British biogas companies mentioned below and all estimates are subject to change based on more detailed specification.

Table 3. Estimates of capital costs

Restaurant In-sink-erator	$4,000
Milk Pasteurizer	$10,000
Feedstock tank, mixers, pump	$14,000
Biogas Digester	
British Methanogen UK Ltd system	$30,000
Dutch DeSaH BV Ltd system	$45,000
Gas Handling System	
Off-grid Gas & Fertilizers Ltd system	$10,000
Digestate tank, mixer, pump	$14,000
Hydronic Heating System	$10,000
Electrical system control & monitoring	$10,000
Total capital cost	**$109,500**

Before this system is designed in detail, it is recommended that a small pilot reactor be operated, in order to assess the benefits of AD for this waste stream. The next section makes an estimate of the value of the operational benefits produced by AD.

2.3. Operational Costs & Benefits

Operational Costs

The cost of a contracted operation and maintenance package for a digester of this scale might be in the order of $2000 per year in monitoring, biological risk testing and routine maintenance. The cost of electricity is expected to be less than $100 per year and the energy in the biogas produced is expected to exceed the heating loads of the digester and the pasteurizer.

The digester system proposed would be completely automated and would include web-based monitoring, so monitoring costs can be very low once the system is operating smoothly. On the other hand, if the system is over-loaded, the anaerobic digestion process can become acid or "crash". In that case, it takes several weeks to restart a stable operation. Because the feedstock tank has the capacity to hold 4 months of waste material, this scenario will not incur other waste disposal costs, however it will cost expert time to restart the reactor. Ideally, a monitoring and maintenance package can be established which gives the responsibility of process control to an AD expert.

Revenue & Benefits

$70,000 will be spent on waste and wastewater disposal during years 1 – 5, according to the abattoir business plan. Treating offal onsite may save a large fraction of this expense, which by year five will be $19,000 per year.

$1000 is expected in revenue from biogas energy production, per year plus another $600 in BC carbon credits per year.

Fertilizer sales or spreading costs will depend on the demand, and regulators. Market research is required, ideally based on samples of finished soil amendment products made from abattoir waste.

3. Recommendation

The local value of the finished product(s) will control the economics of recycling abattoir waste on Salt Spring Island. Thus in order to assess whether an anaerobic digestion (AD) system makes sense for this waste stream, the finished soil amendment products must be investigated.

It is recommended that once the abattoir is running, samples of the offal waste be digested in a micro-scale AD trial (pilot system). Such a system would include a pasteurizer, an AD system, and a digestate separator. Samples of separated fibre and fertilizer liquid would be tested both for safety and effectiveness in agriculture.

Such a trial would reveal not only the value of the fertilizer products but would reveal also many process parameters which would allow for a full scale system to be designed accurately. An automated 400L micro-AD pilot reactor might cost $8000, or could be rented.

More information on micro-AD pilot systems is available from Off-grid Gas & Fertilizers Ltd, and anyone from the SSIAA is invited to visit to one of the 400L micro-AD reactors running in Duncan and on Salt Spring during the summer of 2012. During July 2012, Henri Spanjers, senior expert in anaerobic treatment and professor at Delft University in the Netherlands will visit Duncan and Salt Spring Island to look at AD projects. He and several other European experts are keen to collaborate and advise on AD projects here in the BC islands.

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