Biodigester Development in Saskatchewan

By: Shawn Halter

CSALE Occasional Paper # 11

Table of Contents

Biodigesters are a technology that has been applied in equatorial and temperate regions of the world for manure management and energy production. A positive externality is created from the use of biodigesters when volatile gasses that would otherwise enter the atmosphere as "greenhouse gasses" are captured. The capture of greenhouse gasses suggests that biodigesters are a potential technology for earning greenhouse gas credits given the existence of a carbon credit trading market involving the exchange of emission permits analogous to that of any other commodity.

This report uses SaskPower, the monopsony provider of electricity in the Province of Saskatchewan, as a case study for describing the potential benefits / difficulties faced in cogeneration agreements. Similar arguments apply to other electricity generating companies that use coal as their primary source of power (for example TransAlta).

1 Introduction

1.1 Background

For more than two decades members of the scientific community have been voicing concerns about the impact of human activity on climate change (Leskiw, 1997). During the 1980s, climate change, specifically global warming, became a topic of widespread domestic and international concern. Given the trans-boundary nature of the issue and potential solutions, governments entered into multilateral discussions on a wider range of climate related issues. One set of negotiations was undertaken to formulate policy initiatives whereby governments around the world would agree to reduce anthropomorphic [1] emissions. Efforts by the international community culminated in the 1992 Earth Summit in Rio where 36 countries, including Canada, committed to a voluntary agreement to reduce greenhouse gas emissions (GHG) to 1990 levels by 2000.

Greenhouse gasses absorb and re-emit heat within the atmosphere. The most commonly cited greenhouse gasses are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Although the parties to this agreement may have been well intentioned, the majority of the 36 signatories did not reduce their emissions over the specified time period. Rather, from 1990 to 1995, GHG emissions for most countries increased (Leskiw, 1997).

In 1995, the Intergovernmental Panel on Climate Change (IPCC) concluded that there is a discernable human influence on global climate and that this influence represents an important stress on the global ecosystem (IPCC, 1995). Concern over this assertion and the apparent difficulties countries have in finding the political will to enforce GHG reductions led to the December 1997 United Nations Framework Convention on Climate Change (FCCC) meeting in Kyoto, Japan. This convention resulted in the drafting of the Kyoto Protocol as a showcase for how, despite past failings, governments could affect GHG output. Canada committed to a six percent reduction of GHGs from 1990 levels by 2012. Since Canadian emissions have been steadily increasing since 1990, a six percent reduction from 1990 requires drastic policy changes to reduce emissions by an estimated 25% from the business as usual scenario (Edwards, 1999).

---

[1] Anthropomorphic greenhouse gas emissions are those that originate from human activities such as burning of fossil fuel.

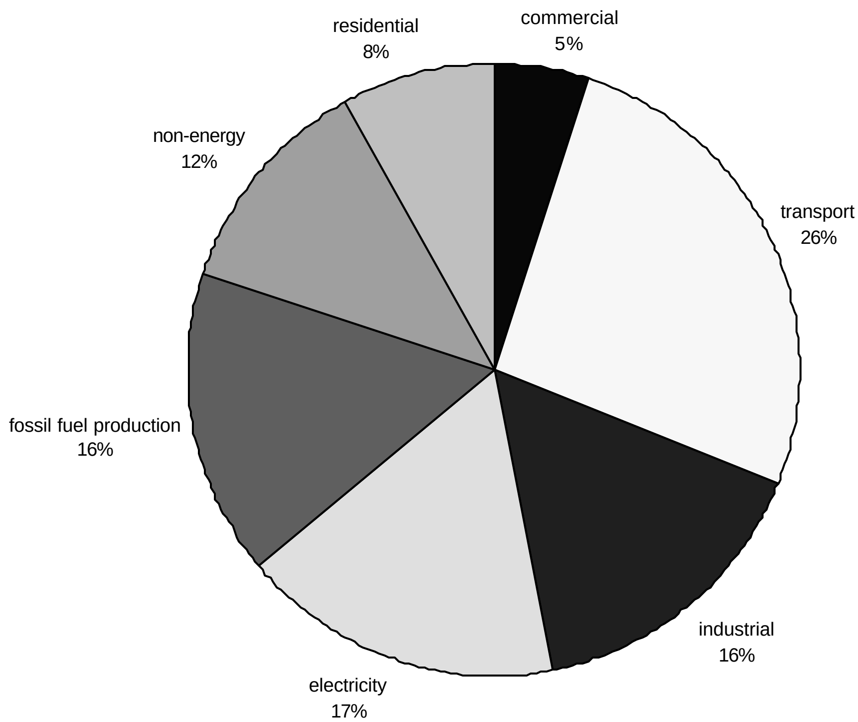


Figure 1.1 Canada's GHG Emissions by Sector, 1995

Source: adapted from Natural Resources Canada (1997)

The Bush government's refusal, in 2001, to ratify The Kyoto Protocol has cast doubt on how, or if, the Canadian government intends to realize GHG reductions. Nevertheless, it is accepted that if policies were enacted for Canada to meet its reduction commitments, it would have profound implications for energy intensive industries such as electrical utilities. A breakdown of emissions by sector is presented in Figure 1.1.

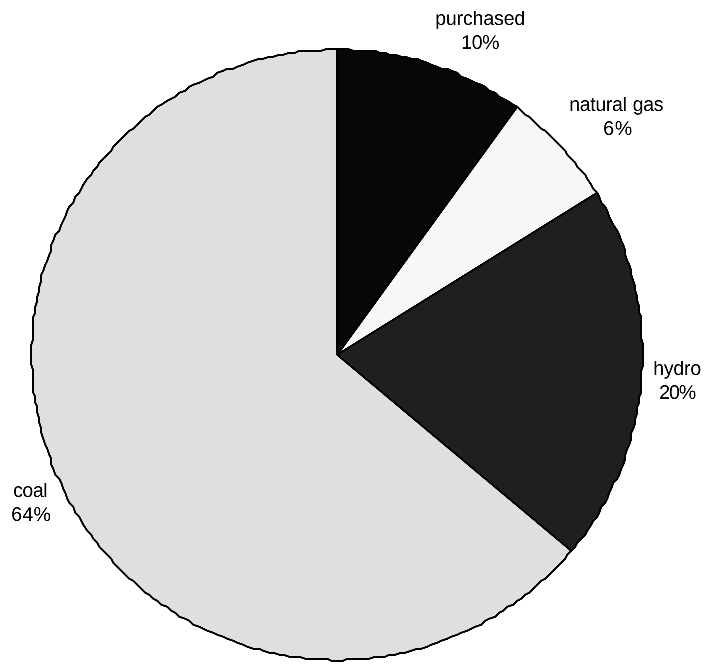


Figure 1.2 Saskatchewan's Sources of Electricity in 1995

Source: adapted from SaskPower 1999 Annual Report.

The status of the Federal government's intentions regarding its Kyoto commitments has generated uncertainty for SaskPower, the crown corporation with the responsibility for generating electricity in the province of Saskatchewan, since the thermal generation of electricity is a major contributor of GHGs. Sixty four percent of the electricity generated in Saskatchewan is from coal fired thermo-electric facilities. The sources of electric power in Saskatchewan are indicated in Figure 1.2.

Emissions of GHGs from coal fired electricity generation are 67% higher (1.2 kg of CO_2 per kWh) than those from combined cycle[2] natural gas (0.4 kg per kWh). If, in the future, stronger GHG regulations are put in place SaskPower, as an electrical utility, potentially faces penalties due to its emissions of GHGs. Hence, SaskPower may have an incentive to change its generation process. In response to this uncertainty SaskPower has chosen to review options for reducing or offsetting its GHG output.

1.2 Biodigesters

One approach SaskPower has chosen to focus upon is manure biodigester facilities (biodigesters) juxtaposed to hog operations as a means of electrical generation and GHG reduction. This entails a fundamental departure from the existing business relationship between SaskPower and its customers. Given biodigester technology, SaskPower has the potential to divest itself of part of its generating capacity and supplanting it with microturbine district energy provision (DE)3.

The processing of hog barn manure via biodigesters is believed to enable SaskPower to offset some of its coal-fired capacity. This is achieved by diverting the GHGs emitted from hog production into the consumer stream in the form of electricity and fertilizer. These processes transform GHG emissions from hog production to a more benign form, hence potentially earning carbon credits for the owner of the biodigester.

It should be noted that a comprehensive study of biodigesters entails a situation of multiple transactions including, GHG offsets, electricity, and the flow of manure between barn and biodigester. This complicates the analysis and requires a close examination of the transactions and their related costs. This process should assist in identifying a superior institutional structure to govern the multiple transactions or to layout exactly the tradeoffs among institutional forms if there is no clearly superior form.

1.3 Scope of Study

The objective of this research are to review how biodigesters can be used to potentially reduce SaskPower's GHG output.

This project will deal exclusively with the application of biodigesters in Saskatchewan. This entails environmental, climatic and market features specific to this province. The boundaries of evaluating the application of biodigesters are defined by the limit of SaskPower's electrical jurisdiction. However, the study could be used as a template for future studies of bio-digestion application in other jurisdictions.

[2] Waste heat in the exhaust gas of the gas turbine is captured in the form of steam in a heat recovery steam generator. The steam is then used in a steam turbine generator to produce even more electricity. The efficiency of a combined cycle plant is in the range of 45-50%, or 1/3 to 1/2 more useful energy from the same fuel as a simple cycle plant.

[3] Micro-turbine district energy is defined as small generating facilities at close proximity to customer demand.

2 Background of Electricity and Hog Production

2.1 Introduction

This chapter is an overview of the industries that are central to the biodigester technology presented in Chapter One. The first section of this chapter outlines the Saskatchewan electrical system, its history, market organization and district energy provision (section 2.1). The second section outlines the development of hog production in Saskatchewan and its potential for district energy provision (section 2.2). The third section of this chapter (section 2.3) highlights uncertainty and the hog market.

2.2 History of Electricity in Saskatchewan

SaskPower has not always been the sole provider of electricity and electrical transmission facilities in Saskatchewan. Electrical services have been available in parts of Saskatchewan since the latter part of the nineteenth century but these services were limited in scale, scope and potential. In 1927, the Provincial government formed the Saskatchewan Power Resource Commission to study the widespread electrification of the province. Unfortunately, this Commission was put in place less than two years before the onset of the Great Depression, followed by World War II. These events combined to further delay reform of the electricity industry in Saskatchewan. Thus, until the early 1960s, most farms in Saskatchewan remained without electricity, while towns and urban centers were powered by stand-alone facilities that were dispersed, isolated and non-integrated. This electrical supply market has been described as an "economic waste spanning over thirty-five years, a time when citizens of the province… utilized energy produced at unnecessarily excessive cost" (White, 1976:49).

The excessive cost can be attributed to the absence of economies of scale typical of electricity provision during that period. Since there were no high voltage transmission wires to transmit electricity throughout the province, power plants were built close to population centers. These plants had to have enough excess generating capacity to maintain consistent service even if their largest generator was out of commission during peak demand (stand-by capacity). If the latter were not the case, then electricity would no longer be "uninterrupted" and there would be blackouts. Hence, power plants had to be completely self-contained since there was no other source of electricity for a given market. This excess capacity was expensive to build, maintain and required a lot of labour to operate. Although it may currently be possible to have an integrated system which includes small generating facilities, there are large "hook up" costs associated with linking small power plants into high voltage grids.

In 1965, Saskatchewan achieved a fully integrated electrical system. This integrated electrical system involves a small number of large generating facilities joined by high voltage power lines. High voltage lines are important due to the physics of electricity. Higher voltages mean that there is less energy "lost" due to resistance of the conductive materials used in the transmission lines. Although it is possible to have an integrated system of small facilities, economies of scale for high voltage lines has tended to be better supported by large generating facilities. Hence, the operations of all plants are synchronized such that they feed a high-voltage network that, in-turn, feed a low voltage grid from which consumers draw their power.

Although Saskatchewan's integration occurred later than many other areas of the continent, the scenario of an electrical system being integrated from a collection of small isolated systems was common. Throughout North America, as it became technically and economically feasible, isolated systems were replaced with integrated ones and important economies of scale resulted. Electricity provision from a small number of large plants has lower operating and capital costs relative to a large number of smaller plants.

This is due to several reasons:

? Larger facilities are located at more favorable locations, i.e. near coal or natural gas reserves. This is because it tends to be cheaper to transport electricity, via high voltage lines, relative to the cost of transporting coal via train or natural gas via pipelines.
? To provide consistent service, an isolated system must have enough spare generating capacity to handle peak demand while having its largest unit generating out of service. This is to maintain continuous service given breakdowns, repairs or spikes in demand.
? Within an integrated system, "stand-by" capacity in any plant is part of the available reserve for all plants in the system. Thus, less total capacity is required and capital costs are subsequently reduced and reliability is ensured since all plants in the system can assist others experiencing difficulty.
? Labour requirements for a small number of large power plants are less than many smaller plants due to labour saving technologies associated with economies of scale.
? Generating units can be brought into or out of service on the basis of their operating costs. The most economical units can be used to supply the "base load", or minimum continuous power, needed for the system. Units with higher operating costs only need be engaged for peak load times (White, 1976).

These factors culminate in a powerful economic argument in favor of integrated systems. Nevertheless, it is helpful, for this report, to look at the electricity industry within the context of its components: generation, transmission and distribution.

2.2.1 Market Components for Electricity

The electricity market can be divided into three components:

? Generation: Electricity is produced using internal combustion engines, steam turbines powered with steam produced by fossil fuels, nuclear fuels, and various renewable fuels, water or wind driven turbines and photo-voltaic technologies.

? Transmission: Transportation of high voltage electricity across great distances via wires. When high voltage is used there is less electricity "lost" due to resistance in the conductive material.

? Distribution and retailing: With the use of transformers, the high voltage electricity from the transmission lines is "transformed" into lower voltages which can be used by residential appliances and industrial machinery. This segment also entails making arrangements for supplies of power from generators, metering, billing and various demand management services.

These components of the electricity market are technically separable. Hence, there are transactions that must take place between these separate market components. According to Hobbs (1996), vertical coordination is necessary when any production or distribution takes place.

Until recently the means of vertical coordination between generation, transmission and distribution was almost exclusively vertical integration. Vertical integration has meant the elimination of potential opportunism between market components. Stranded assets typify all of the market components. For example, once a coal-fired power plant is built it is immobile and has no alternative uses (the same applies to transmission and distribution systems). Hence, investments, like power plants, are considered "stranded" since they have a very low salvage value.

Thus there is a:

> …mutual dependency between seller and buyer for each of these transactions. While it is technically possible to have competing

> transmission systems that could eliminate dependency, the high costs of such duplication prevent it from being considered as a serious option. The dependency between seller and buyer leaves the door open for opportunism (Hulleman and Kerr, 1998:242).

To coordinate all the market components involved in the seamless provision of electricity, incentives for opportunism must be limited. Therefore, this supply chain may be thought of as a quintessential example that warrants vertical integration.

As vertical integration of the electricity industry precludes normal market competition, monopolization (either via a regulated monopoly or government ownership) of all three components has been the common industrial structure. Some electrical jurisdictions represent exceptions to the monopoly held / vertically integrated electricity market. In these cases, the components may have different owners but the jurisdiction's government regulates the pricing and service interruptions between components. However, since Saskatchewan is currently a monopoly structure, it is the organizational form assumed to be prevalent for this report.

2.3 Electricity: Monopoly and Market Reform

The demand and provision of electricity is distinct from most other commodities. Both residential and industrial consumers make their lifestyle and production decisions based upon the assumption of instantaneous gratification of their electricity demands when they flip a switch. When electricity is no longer wanted the switch is turned off and that specific transaction is terminated. The consumer realizes the transaction's initiation and termination at the end of the month as a charge for the amount of electricity consumed while the switch is on. There is no negotiation of prices and, so long as the bill is paid on time, no legal wrangling.

The market for electricity throughout North America developed as monopolies subject to either government regulation or government ownership. Retail customers have purchased their electricity from their regulated monopoly supplier with the legally entrenched right and obligation to supply. This form of market organization has proven adequate to provide consumers with dependable low-cost electricity. However, the advent of new technologies for generation and distribution as well as the political push from industrial customers, independent power producers and new electricity marketers to impose greater efficiency on the system has resulted in some deregulation of the market. This has brought to the fore two forms of market coordination: transmission access and wheeling.

2.3.1 Transmission Access and Wheeling

Transmission access is a form of regulation that is designed to overcome problems associated with stranded assets:

> …the right or opportunity of electricity generation entities to use transmission facilities owned by others.
> (National Energy Board, 1992)

Wheeling is another form of regulation designed to overcome the stranded asset problem for generators and to remove monopoly power of transmission firms for distributors or final consumers:

> …the authorized use of the transmission facilities of an intermediate entity by two other entities whose transmission facilities are not directly connected.
> (National Energy Board, 1992)

2.3.2 Saskatchewan Electrical Market Paradigm

The current market in Saskatchewan most closely resembles that of *transmission access*. SaskPower is the only seller of electricity in the province and most electricity that is consumed within the Saskatchewan Provincial jurisdiction is generated, transmitted and distributed by SaskPower. However, given trends toward market reforms in other electrical jurisdictions as well as technological developments and potential climate change legislation, there are new incentives for SaskPower to change its market paradigm. This entails expanded interests in IPPs[4] (and district energy production) and to allow these generators to use SaskPower transmission facilities.

2.3.3 IPPs and District Energy

Independent Power Producers (IPPs) tend to be either co-generators or small gas fired units with smaller generating capacities than SaskPower's base load generators. For example, SaskPower operates coal fired facilities with greater than 300 MW capacity while IPPs often have less than 500 kW capacity. Historically, economies of scale have dictated that larger power plants can more cheaply provide electricity than many smaller plants. However, the advent of new natural gas fired turbines steadily reduced the capital and operating costs for small-scale facilities. This has allowed smaller companies to enter into the electricity market. The lower start up costs, and lower need to locate near fuel sources, has given IPPs a new market advantage for district electricity provision.

District energy consists of industries producing some or all of their electricity needs as part of their normal operations. The advantage of this to a utility like SaskPower is to divest itself of some of the demand on its existing and future generating capacity. In the case of hog barns, large amounts of heating and electricity are needed to maintain normal operations. Since SaskPower is already facing steadily increasing demand for electricity, self-provision of power by biodigesters may offer an opportunity to reduce its climate change impact yet continue to provide electricity to the province.

2.3.4 Current SaskPower Policies toward IPPs

The monopoly and monopsony position of SaskPower allows it to dictate the terms of the agreement it has with any IPP in the province. SaskPower has divided IPPs into two broad categories. Small power producers who have capacities up to 100 kW and large power producers with capacities greater than 100kW.

SaskPower has defined rules for purchases from Small Producers as:

> All electricity supplied will be bought at \$0.02 per kWh regardless of when it is provided.
> (SaskPower Annual Report, 1999)

Small power producers must pay for all interconnecting costs including two-way metering to measure the amount of electricity flowing into the grid from the small producer and vice versa.

Each purchase agreement is updated annually to ensure that the small IPP meets all requirements for safety, power quality and grid system security. This is to ensure that no complications from unmaintained small producer facilities threaten SaskPower's obligation to serve.

Agreements for large IPPs are negotiated on an individual basis. For example, the 215 MW Husky Oil – TransAlta Meridian Co-generation plant in Lloydminster has a 25-year agreement stipulating the details of service and purchase obligations to transact 210 MW of electrical capacity annually. This capacity is sufficient to generate enough electricity for a city the size of Saskatoon.

---

[4] IPP refers to independent power producers and is described in detail in section 2.2.3.

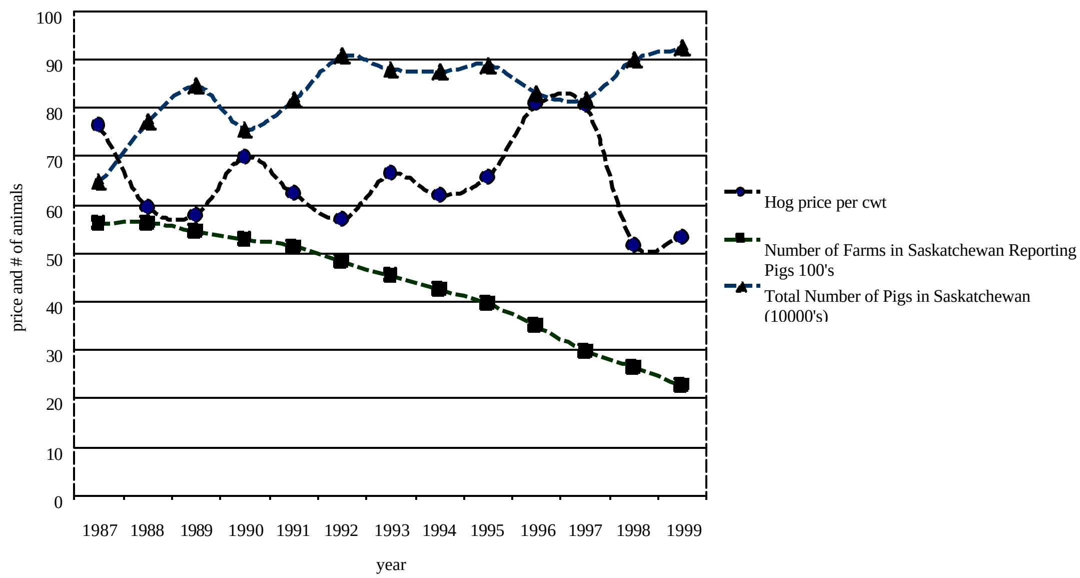
2.4 Saskatchewan Hog Production

The development of biodigester technology in Saskatchewan depends upon a source of livestock manure. Thus, it is dependent upon the continuation of structural trends, occurring in the province, for hog production. During the 1990s there was a small but steady increase in the number of hogs in the province and a significant concentration of production into large-scale (more intensive) operations.

Table 2.1 Numbers of Hogs in Saskatchewan

Year	Average Number of Pigs Per Saskatchewan Farm	Number of Farms in Saskatchewan Reporting Pigs	Total Number of Pigs in Saskatchewan
1987	115	5,620	646,300
1988	137	5,620	769,940
1989	155	5,450	844,750
1990	143	5,290	756,470
1991	159	5,130	815,670
1992	188	4,820	906,160
1993	194	4,530	878,820
1994	206	4,240	873,440
1995	225	3,950	888,750
1996	238	3,490	830,620
1997	275	2,975	818,125
1998	339	2,650	898,350
1999	410	2,250	922,500
2000	540	1,780	961,200

Source: Banks, (2000)



Graph 2.1 Saskatchewan Hog Production from 1987 to 1999

Source: Banks, (2000)

As is indicated by the statistics in Table 2.1, Saskatchewan hog production has shifted from an industry typified by many small and probably unspecialized producers to a specialized industry. The industry has adopted large-scale production units with large demand for heating, electricity and specialized manure management systems to handle waste. Such changes in hog production open an opportunity for district energy provision. This entails the hog barn providing a portion, or all, of its electricity requirements. Much of the previous material has supported the case for integrated electricity provision; however, pressures from new climate change legislation and regulatory developments provide a potential symbiosis between SaskPower and large hog operations. Such a relationship may mitigate SaskPower's obligation to increase its generating capacity and allow it to accrue carbon offsets. This will be discussed in further detail in Chapter Three.

2.5 Uncertainty and the Hog Market

The primary goals of SaskPower, in its plans for biodigesters, have been assumed to be the generation of carbon credits and the production of electricity. In either case, the production of these outputs relies on the supply of manure from the hog barn and is, hence, directly dependent on the supply of hogs. For example, if a barn experiences financial difficulty due to a depressed hog market, the logical recourse might be closure. This action would terminate the flow of manure to any adjacent biodigester. The biodigester would be unable to function without this flow of manure and transportation of manure from other barns would likely be prohibitively expensive.

Currently, the majority of SaskPower's generating capacity depends on fossil fuels (coal and natural gas) as its fuel source. SaskPower's experience is in making contracts with suppliers of these inputs has entailed specific asset investments by various parties of the agreement.

The markets for coal and natural gas are subject to price fluctuations. This is accounted for within SaskPower's purchase agreements. The natural gas industry in Saskatchewan is characterized by many gas wells supplying the TransGas pipeline infrastructure. Thus, SaskPower enters into supply arrangements between gas producers and TransGas. Supply or demand disputes are handled by an established arbitration system that is supported by the Canadian legal system.

For the supply of energy from hog barns linked to biodigesters, there is no arbitration or legal mechanism currently existing. Given that there would be many hog barn / biodigester systems supplying electricity, it would be difficult to negotiate arrangements for the consistent supply of energy needed by SaskPower to satisfy its obligation to serve. To depend on hogs to maintain its service capacity (via either GHG credits or as an electricity source), SaskPower would be subject to the price fluctuations of the hog market.

2.6 Uncertainty and SaskPower

The role of uncertainty for SaskPower cannot be overstated. Currently, SaskPower operates in a monopolistic market with little uncertainty. However, by relying on biodigesters to provide either electricity or carbon credits, SaskPower would be depending on a market characterized by far more uncertainty and variability than is the case with its current monopoly status. Despite these challenges, biodigesters are an option being considered by SaskPower. Therefore, further economic analysis is appropriate.

3 Biodigesters as a Means of Achieving Kyoto Commitments

3.1 Introduction

This chapter describes how biodigesters can contribute to the achievement of Kyoto levels of GHG emissions. The emphasis is upon GHG emissions associated with both electricity and hog production in Saskatchewan. Current practices will be contrasted with those using biodigesters as a means of reducing GHG emissions.

This Section begins with explanations of the rationale behind researching biodigesters, how biodigesters work and the end products of the processes. The following section presents how biodigesters would be combined with hog-operations as a means of economic development in Canada. Subsequently, Section 3.3 will focus upon how biodigesters can be used as a value-added method of manure management with particular emphasis on GHG reduction. Section 3.4 describes how biodigesters can be used for GHG reduction.

3.2 Biodigesters

Biodigester technology for converting manure into methane for fuel is neither new nor uncommon. In many parts of Asia, Central America and Europe, biodigester use is widespread. Biodigesters are applied in these areas in response to organic waste (manure) disposal problems and/or high-energy costs. At this point in time, Saskatchewan faces neither of these problems. In fact, Saskatchewan is characterized by relatively low energy prices and it has a vast agricultural land base upon which to apply manure. However, given the possibility of future climate change legislation, the cost of GHG emitting activities like coal fired electrical generation and manure spreading will likely increase. Thus, the incentive for researching bio-digestion, as a means of energy production and waste disposal, is to ultimately achieve reductions in GHG output without undue increases in the cost of electricity.

3.2.1 The Process Inside Biodigesters

The process of bio-digestion is the collection of organic material into a containment body, which is isolated from the external environment. Within this body a microenvironment optimal for methanogenic bacteria (methanogens[5]) is provided. These methanogens digest organic material (in this case manure) and emit CH_4 gas and NPK slurry[6] (NPK concentrate[7] and grey water[8]). This process greatly reduces the emission of volatiles[9] normally associated with manure and converts the solids into a more uniform sterilized product. Carbon that normally would be released in the form of gaseous hydrocarbons, CO_2 and CH_4, is contained and burnt as fuel to heat the barn and biodigester. If the gaseous hydrocarbons are burnt in a microturbine[10], then electricity to power the barn and biodigester facilities can also be generated. The residual heat from the microturbine is available to maintain a consistent climate within both barn and biodigester (see Figure 3.1)

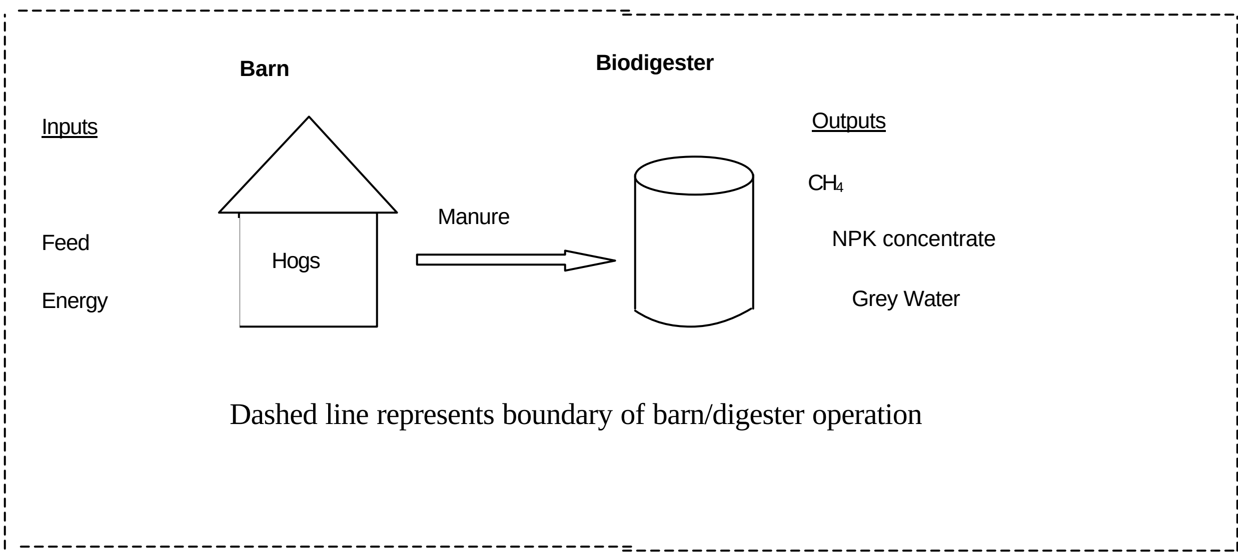


Figure 3-1 Biodigester Schematic

[5] Methanogens are anaerobic bacteria, which digest organic material and release methane as a byproduct.
[6] NPK slurry refers to the liquid material that has passed through the biodigester. It is a mixture which, when separated, constitutes NPK concentrate and grey water.
[7] For this report NPK concentrate is not intended to mean the final commercial product, rather it refers to a product that can be used as input for the production of a commercial product like compost.
[8] Grey water is the water that is removed from the NPK slurry. This water might be purified to potable standards, however, this has yet to be verified by independent study.
[9] For this report volatiles are gaseous substances like NH_3, CH_4, CO_2, or N_2O which are emitted from manure.
[10] Microtubine: For this report shall refer to a small, portable gas-fired electricity generating plant of 75kW capacity.

3.2.2 Emissions from Current Saskatchewan Hog Production

Hog production in Saskatchewan is increasingly done in large intensive operations that house over 500 sows. Emissions of GHGs from hog production occur in the three main stages of the manure handling process; in the barn; in the lagoon; when manure is applied to agriculture land (as illustrated in Figure 3.2).

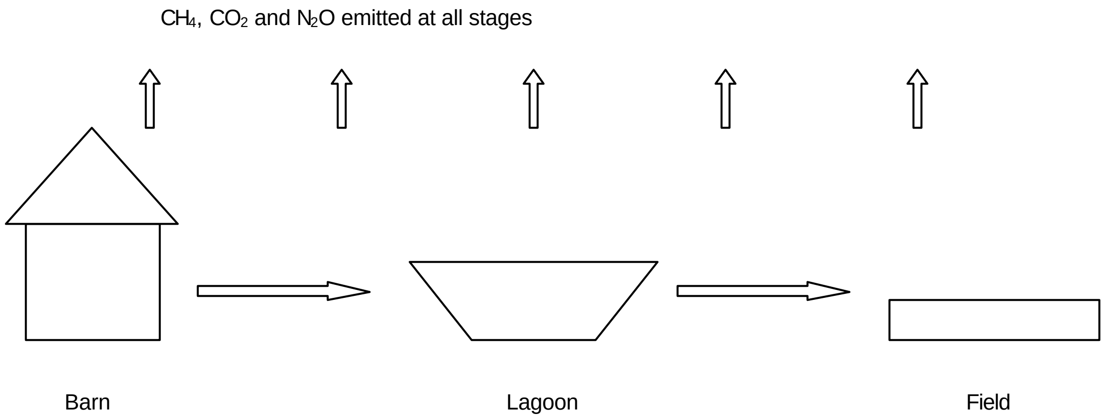


Figure 3-1 Emissions Schematic

The amount of GHGs emitted at each stage is a function of temperature, exposure to air and time spent at each stage, and the initial chemical properties of the manure.

Exposure to air: Both aerobic and anaerobic bacteria emit different relative amounts of CH_4 and CO_2, respectively, while they decompose manure. This pertains to all three stages of the manure management system, however, is most relevant during lagoon storage. Since lagoons are deep and manure does not circulate well, most of the manure is not exposed to air; thus, anaerobic bacterial processes are predominant. Since relative emissions of CH_4 are much higher for anaerobic bacteria, the GHG impact from these processes will be higher.

Temperature: For biodigesters, methanogenic microbial growth (hence, activity) takes place between 10^0C and 45^0C and optimal growth takes place between 30^0C and 35^0C (Coxworth 2000). Within these temperature ranges emissions vary greatly. Thus, external temperature changes, diurnally[11] or annually, can seriously affect the amount of CH_4 produced.

Time: The amount of time spent at each manure management stage affects the amount of GHGs released by the bacteria. For example, if manure sits in a lagoon for many months then anaerobic bacteria will emit a great deal of CH_4. However, if manure is applied to fields, without prolonged lagoon storage, much of the organic hydrocarbon compounds will be incorporated in the soil.

Manure Properties: The constituent properties of the manure are affected by the feeding regime[12] for the animals. This, in turn, affects bacterial activity and the manure GHG potential

Variability of emissions throughout the manure handling process introduces a great deal of complexity when formulating a GHG reduction strategy. To provide a mutually acceptable reduction

[11] Diurnally, to occur over the period of a day.
[12] Feeding regime: the amount of elements such as nitrogen in the feed is reflected in the manure. Similarly, if the animals are treated with antibiotics this will be reflected in the manure and, hence, the health of the digesting bacteria.

value, to whatever governing body[13] is responsible for monitoring reductions, a baseline[14] value is necessary. From the baseline, removal or abatement of the GHG emitting process is treated as the GHG reduction. However, given the potential variation in GHG emissions owing to the variety of possible temperatures, feeding regimes or the quantity of time the manure is at any stage of the manure management process, a mutually acceptable baseline is not easily definable.

3.2.3 Energy Balance

The energy balance for biodigesters is the ability of the biodigester system to produce enough energy to have excess energy for sale, to be self-sufficient or to require energy from an outside source. As was discussed in the previous section, there are several factors affecting the biodigester's ability to operate effectively. Since biodigesters have yet to be proven as an appropriate technology for Saskatchewan, it is difficult to speculate if these systems will be able to provide surplus energy throughout the year or if they will require supplemental energy during some times of the year.

3.2.4 Hypothetical Hog-Barn and Biodigester Enterprise

Application of bio-digestion to Saskatchewan hog operations entails on-site self-provision of energy. This energy is produced via digestion of the manure into CH_4 gas. The burning of CH_4 provides heat and/or electricity for the barn/biodigester (as illustrated in Figure 3.3).

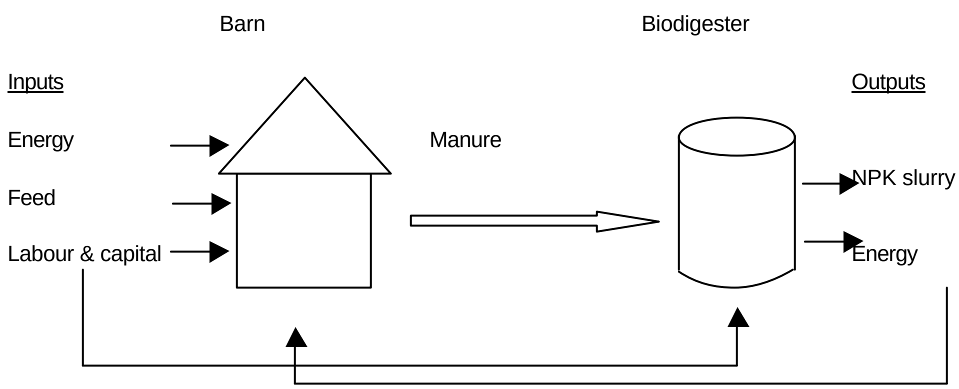


Figure 3-1 Hypothetical Biodigester

3.3 Biodigesters as a means of Economic Development

The Saskatchewan economy may experience economic hardship given higher production costs arising from climate change legislation. Saskatchewan is a capital-intensive resource based economy that relies on inexpensive energy as an input for agriculture, mining and fertilizer production. Bio-digestion could help mitigate increased energy costs by reducing demand on electricity and natural gas resources.

As illustrated in Figure 3.3, biodigesters produce heat and electricity, which enable expansion in the hog industry without placing further demands on existing natural gas or electricity resources. Also, biodigesters produce a consistent NPK fertilizer product, which may be used in either agriculture

[13] Governing body: an organization, public or private, which monitors and approves GHG reductions and offsets.
[14] Baseline: a GHG emission value, which is treated by the governing body as the accepted industry standard.

or landscaping. Currently, undigested manure is injected[15] into fields in its raw liquid form. Clearly this raw manure is a valuable resource; however, its value can be augmented via digestion.

3.3.1 Hog Manure as Fertilizer

The transformation of prairie swine production from many small, non-specialized producers to large scale operations dominating the production landscape has led to problems associated with the concentration of manure in areas surrounding intensive hog barns. Although the prairies have extensive agricultural land resources requiring fertilizer, the high weight to nutrient ratio of manure slurry precludes transportation for any significant distance.

3.3.2 Water and Air Quality

Intensive hog operations continually receive complaints regarding the quality of air and water proximate to the barn. Such concerns have been heightened since the Walkerton Ontario case of e-coli contamination of the local water supply in May 2000, which resulted in the deaths of 6 people. Although intensive livestock operations have not been positively linked to the contamination, concerns over livestock manure management have become more pronounced. The possibility of similar incidents occurring in the future may press federal, provincial or municipal governments to implement stronger livestock manure management legislation. Hence, it is conceivable that new taxes or environmental charges would be implemented based upon output and management of livestock manure.

3.4 Biodigesters as a Value Adding Means of Manure Management

Biodigesters have been suggested as a way to alleviate pollution concerns as well as offering new revenue opportunities. These opportunities are realized via the fertilizer market, the energy market and GHG credits.

3.4.1 Fertilizer

One product of bio-digestion is the conversion of raw manure slurry into enriched NPK fertilizer. Relative to raw manure, the enriched NPK concentrate has more available nutrients, is relatively odourless, is free of disease, germs, weeds, seeds and is less prone to cause water contamination (Hazeltine and Bull, 1999). Hence, the digested product is characterized by greater consistency and minimizes offensive odours. In effect, a biodigester is an environment that transforms carbon and hydrogen in the raw slurry[16] into gaseous CH_4 for combustion. The remaining liquid mixture is sterilized and rendered into a consistent NPK concentrate via bacterial activity. The liquid NPK fertilizer can then be de-watered to become NPK concentrate. The latter process adds significant value since water is heavy and expensive to transport. When water is removed only the nutrient rich solids remain and can be transported longer distances at less cost. The residual “grey” water can possibly be used to flush manure from the barns into the biodigester.

These factors combine to alleviate the problem of excessive fertilization close to the hog barns and opens opportunities for hog manure in the higher value residential compost market.

---

[15] Injection is a method of manure application that uses apparatus similar to an air seeder to place manure below the surface.

[16] Raw slurry is unprocessed liquid manure.

3.4.2 Energy

Energy from biodigesters is realized by burning the CH_4 from the biodigester to fire microturbine electrical generators and/or furnaces. This heat and electricity is subsequently used to power hog barn and biodigester operations and residual electricity can be fed into the existing grid.

Estimated generating capacity for biodigesters is in a range between 75kW per 750 hogs (0.1 kW per animal) (Kline,[17] 2000) to those from Ben Voss of BDI (Saskatoon engineering firm) of 250kW to 2MW per 1200 animals (0.21kW to 1.67 kW per animal). The latter number, from BDI, is 17 times that of the initial estimate from Kline. This implies that the latter estimate is somewhat optimistic. Thus, the estimate from Kline and the pessimistic estimates from Kline and Voss would require between 29 million and 14 million hogs, respectively, to generate the equivalent of SaskPower's current generating capacity. Recall from Chapter 2 that there were less than one million hogs in Saskatchewan in 2000. Therefore, it is unlikely that SaskPower is considering offsetting much of its generating capacity via hog barn biodigesters

Given that hog barn biodigester facilities have estimated generating capacities ranging from 75kW per 750 animals (0.1 kW per animal) (Kline, 2000) to 250kW per 1200 animals (0.2kW per animal) (Voss, 2000), self-provision of energy seems plausible. However, this may represent net self-provision. The ability of the biodigester to make methane could vary greatly depending on the temperature of the external environment. Thus, it may produce an excess of methane during the summer but may require outside energy inputs during the winter. Storage of the methane may be an alternative to balance these annual variations.

There have been suggestions that electricity from the biodigester could be fed into the consumer stream via the existing electricity grid. Although this is technically possible, many hurdles exist. In Saskatchewan, SaskPower retains monopoly and monopsony power over all purchases and sales of electricity. SaskPower's Small Producer Program purchases any, or all, electricity from IPPs with less than 100kW capacity for $0.02 per kWh. The contractual arrangement for purchases from small producers is renewed annually subject to SaskPower's discretion.

Another consideration is the cost of hook up to the main grid. The electrical voltage that is usable by domestic and industrial appliances (lights, fans, etc) is not the same voltage as that which travels in transmission or distribution lines. As a result, transformers are used to convert the electricity from transmission voltage to domestic (industrial) voltages. Thus, any electricity produced by the biodigester facility must be converted via a transformer and the biodigester must pay the expense. This demonstrates that the generating capacity of a single, or even a group of barns, is very small so it is unlikely to factor prominently in SaskPower's operating decisions.

At first glance the Small Producer Program may seem like an unrealistic impediment to IPPs. However, SaskPower has an existing generating capacity of 2889 MW (SaskPower Annual Report, 1999) and the generating capacity from individual biodigester systems is very small by comparison. Thus, it would seem unlikely that SaskPower would want to put into question their mandate to provide uninterrupted service by relying on unproven technology, like biodigesters, when there are many other forms of alternative energy generation (i.e. wind or industrial co-generation).

SaskPower would have to maintain enough reserve capacity to provide uninterrupted service with or without the contribution of the hog barn biodigesters. Therefore, prudence dictates that bio-digestion would be better looked upon firstly as a means of energy self provision and it is probably unrealistic to think of them as suppliers of electricity to the main grid.

---

[17] Mr. Kline is the president of a Calgary based electricity firm, Mercury Electric, which is interested in developing biomass electricity generation.

3.5 Bio-digestion for GHG Reduction

This report was prompted by the need for energy producers to reduce their GHG emissions. The Kyoto Protocol used 1990 as the base line for GHG reductions. During the time period 1990 to 2000, SaskPower realized a 37% increase in GHG emissions (measured in CO_2 equivalents). Much of this increase has been due to SaskPower bringing the Shand Power Station online in 1992. Building of this 300 MW facility was started in 1988 and although it is a very modern facility with relatively low emissions, the timing of commissioning was unfortunate since the baseline selected by the Kyoto round was 1990.

Table 3.1 Total SaskPower CO_2 Emissions

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Emissions	10.6	10.8	12.3	13.2	13.9	13.8	14.4	14.5	14.8	15	14.5

Source: SaskPower Climate Change Action Plan 1998/99 Update (in Megatonnes)

It remains uncertain if the Federal government intends to realize its Kyoto Protocol commitments by mandating a 6% GHG emissions reduction from 1990 levels on all emitting firms. Nevertheless, application of a 6% GHG reduction by 2012 would mean that SaskPower GHG output would be reduced to 10 Mt.

$$\text{1990 emissions} = 10.6\text{Mt } CO_2 \quad (3.1)$$

$$\text{Emissions 6\% below 1990} = (10.6\text{ Mt} * 0.94) = 9.96\text{ Mt} \quad (3.2)$$

There are three means by which bio-digestion may be viewed as a carbon reduction mechanism:

? By reducing demand on the existing SaskPower generating facilities;

? Supplanting fossil natural gas, which would have been burnt to heat barns;

? By transforming the manure management style currently used in Saskatchewan into one with fewer GHG emissions (bio-digestion), then taking the difference of the two management styles as a GHG emission reduction.

3.5.1 Reducing Demand on the SaskPower Grid

Electricity for hog barns is currently drawn from the power grid. However, if hog barns were able to provide some, or all, of their electricity needs via bio-digestion, then less pressure would be placed upon the existing coal fired electrical plants.

By assuming that biodigesters are feasible, then they could reduce the demand on conventional coal or natural gas fired generating capacity that would translate into a reduction in GHG output.

In the event that SaskPower would face taxes or have to purchase carbon credits, the cost of producing electricity would increase. Thus, if hog barns choose to juxtapose biodigesters to their operations then SaskPower would not have to incur capital costs of retrofitting for natural gas generation or incur penalties for emitting GHGs for the energy used by hog barns.

3.5.2 Reducing Demand on Fossil Natural Gas

Methane produced from bio-digestion of hog manure could be used to offset fossil natural gas used for heating the hog barn. This reduction in fossil fuel may be considered a GHG reduction by taking the difference between business-as-usual natural gas consumption (BAU_{ng}) and consumption after application of biodigester technology (BA_{ng}).

$$\text{Reduction} = (BAU_{ng}) - (BA_{ng}) \quad (3.3)$$

However, this would have to be approved as a reduction by an empowered climate change governing body.

3.5.3 Biodigesters as an Offset Mechanism

The current manure management system utilized by prairie hog producers emits GHGs (CH_4, CO_2, and N_2O) in the barn, during lagoon storage and after it is applied to agriculture land. Bio-digestion offers a means of converting carbon in the manure into gaseous CH_4 for burning and stabilizing the constituent elements in the previously volatile slurry. Thus, if biodigesters were seen as a manure management system, which diverts otherwise emitted GHGs into CH_4 and NPK fertilizer, it would be seen as a GHG reduction.

The IPCC criteria[18] that CH_4 emissions from conventional swine production in North America are 10 kg/head/year for a cool climate[19]. The values for CH_4 are presented in Table 3.2 and their CO_2 equivalents are presented in Table 3.3.

Table 3.2 Manure Management Emission Factors for Swine

Regional Characteristics	Livestock Type	Emissions of CH_4 (kg/head/year) by Climate Region		
		Cool	Temperate	Warm
North America: Liquid manure based systems are commonly used for Swine.	Swine	10	14	18

Source: IPCC Technical Support Unit, (1999)

[18] These IPCC criteria are estimates based upon industry averages.
[19] Cool climate is defined in IPCC guidelines as having an annual average temperature bellow 15°C. The average annual temperature in Saskatoon is –1°C.

Table 3-3 Relative Global Warming Potential

(CO_2 equivalents per unit mass of GHG)

Gas	Time Horizon 20 year	100 year	500 year
CO_2	1	1	1
CH_4	56	21	6.5
N_2O	280	310	170

Source: Adapted from R.L. Desjardins, AAFC, (1988)

The accepted value for converting GHG global warming potential is the 100-year time horizon[20]. Hence, one unit of CH_4 is treated as being the equivalent of 21 units of CO_2.

Table 3-4 CO_2 Equivalent Manure Management Emission Factors for Swine

Regional Characteristics	Livestock Type	CO_2 Equivalent (kg/head/year) by Climate Region		
		Cool	Temperate	Warm
North America: Liquid manure based systems are commonly used for Swine.	Swine	210	294	378

Source: Adapted from IPCC Technical Support Unit, (1999)

The GHG reduction is calculated by taking the difference between the business-as-usual (BAU) emissions and the emissions given the application of biodigesters.

3.5.4 Calculation of Emission Reduction

To calculate emission reduction the starting point is the balanced chemical equation:

$$CH_4 + 2O_2 ? \quad CO_2 + 2H_2O \tag{3.8}$$

Where the result of this combustive reaction is kJ of energy.

[20] The potential for this GHG to absorb and remit energy, relative to CO_2, over a time period of 100 years.

The mass of CO_2 from the combustion of CH_4 is determined from the stoichiometric[21] law at the accepted temperature of 25^0C (298.15K) and one atmosphere (1 atm.).

If the 10-kg of CH_4 had been released into the atmosphere it would have a global warming capacity of 210 kg of CO_2. However, combusting that amount of CH_4 releases only 27 kg of CO_2. This is a 7.8 fold improvement in emissions and is a GHG reduction of 183 kg of CO_2 per animal.

$$\begin{aligned} \text{mols } CH_4 &= (10000\text{g } CH_4)\left(\frac{1 \text{ mol } CH_4}{16.04\text{g } CH_4}\right) \\ &= 623 \text{ mols } CH_4 \end{aligned} \tag{3.9}$$

$$\begin{aligned} \text{mols } CO_2 \text{ produced} &= (623 \text{ mols } CH_4)\left(\frac{1 \text{ mol } CO_2}{1 \text{ mol } CH_4}\right) \\ &= 623 \text{ mols } CO_2 \end{aligned} \tag{3.10}$$

$$\begin{aligned} \text{mass of } CO_2 \text{ produced} &= (623 \text{ mols } CO_2)\left(\frac{44.01\text{g } CO_2}{1 \text{ mol } CO_2}\right) \\ &= 27438\text{g of } CO_2 \end{aligned} \tag{3.11}$$

3.6 Conclusion

This Paper has described how biodigesters can be used to reduce GHG emissions. Biodigesters may offer a means by which SaskPower can earn GHG offsets and reduce demand on its current generating capacity. However, the technology is characterized by uncertainty and further research into the technical hurdles would yield more information on this matter.

[21] Stoichiometry refers to the mass relationships among reactants (CH_4 and O_2) and products (CO_2 and H_2O) in chemical reactions.