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AN INVESTIGATION INTO PRODUCING BIOENERGY AT THE UBC FARM

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ABSTRACT

This report presents an investigation into the opportunity for the UBC Farm to produce biomass for energy production at the UBC Bioenergy Research and Demonstration Facility (BRDF). The goal of this investigation is to contribute to UBC's effort to reduce greenhouse gas emissions in an economically and socially responsible manner. The stakeholder for the project is Kate Menzies, Agroforesty Coordinator at UBC Farm.

The land considered to be available for use in the presented analysis was 500m^2 of marginal lands and hedgerows at UBC Farm. The extent of this area was measured in person and estimated using maps (Google Maps, 2013). To manage the amount of research required for the project, miscanthus giganteus, switchgrass and hybrid poplar were investigated and compared on several qualitative and quantitative criteria designated by UBC Farm and the BRDF. The result of this evaluation was that miscanthus giganteus is the most beneficial crop to produce. Its expected annual yield will increase over time, achieving a maximum of 1 ton of dry matter after three to four years. At maximum yield rates, it will supply 0.008% of the BRDFs annual biofuel consumption (Nexterra Energy Corp., 2013). Assuming the BRDF is operating in thermal mode at all times, this accounts for 1.6 lbs/hr of steam production and a reduction of 0.4 tons of greenhouse gas (GHG) emissions per year (Nexterra Energy Corp., 2013).

The triple bottom line assessment conducted for growing miscanthus giganteus indicates that UBC Farm will need to invest $460 to begin the project. This project will operate at a net loss of $205 per year afterwards. However, this is a sound investment considering the environmental and social benefits of the project. Environmentally, the project needs to be increased in scale to significantly reduce UBC's GHG emissions, but there are other positives such as reduced soil erosion to consider. Socially, there is the potential for this project to have a significant impact in that it will broaden interest and understanding of the production of bioenergy and create new relationships within UBC's community and beyond. Overall, UBC stands to benefit from this project from an investment point of view, and it is recommended that UBC consider taking action in the near future.

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LIST OF ABBREVIATIONS

BRDF:	Bioenergy Research and Demonstration Facility
Btu:	British Thermal Unit
CHP:	Combined Heat and Power
GHG:	Greenhouse Gases
ppmv:	Parts Per Million By Volume
UBC	University of British Columbia

GLOSSARY

Biodiversity:	The aggregate variety of flora and fauna in a particular ecosystem.
Bioenergy:	Renewable energy produced from organic matter.
Biofuel:	A fuel derived from organic matter.
Biomass:	Organic matter used as biofuel.
Coppice:	Cutting a tree or shrub to ground level regularly to stimulate growth.
Crop density:	Number of crops per unit area of farmland.
Genotype:	The genetic composition of an organism.
Hedgerow:	A mixed hedge of plants, bordering a road or field.
Marginal land:	Land that cannot support agriculture without investments.
Perennial grass:	A plant that has a life cycle of more than two years.
Rhizome:	An underground stem from which plant shoots continuously grow.
Runoff:	The flow of water from precipitation over the land.
Senesce:	The deterioration of a living organism with age.
Sequester:	To store or hide away.
Soil structure:	The constitution of soil particles and pores between them.
Taproot:	A straight root growing vertically downwards from which roots sprout.

1.0 INTRODUCTION

The University of British Columbia (UBC) is aiming to meet strict deadlines to reduce its greenhouse gas (GHG) emissions until its ultimate goal of zero emissions is achieved in 2050 (UBC Sustainability, 2013). UBC's bioenergy research and demonstration facility (BRDF) will play a large role is making this possible. The BRDF has two operating modes, but it is currently running in thermal mode at all times (Menzies, 2013). In this mode of operation, wood residuals are gasified to fuel a boiler for steam production (Nexterra Energy Corp., 2013). When running at full capacity, the BRDF can supply 25% of UBC's steam use (Nexterra Energy Corp., 2013). This significantly reduces the campus' reliance on less sustainable forms of energy production.

Currently, the wood residuals being used as fuel for the BRDF are being trucked in from areas around Vancouver (Menzies, 2013). UBC Farm has expressed interest in contributing to the BRDF's fuel supply by growing biomass on hedgerows and marginal lands. This has the potential to further integrate UBC's sustainability efforts by bringing together UBC Farm and the BRDF. It will also serve as an important demonstration of the use of bioenergy for greater society. This report presents an investigation into which crop is best suited for growth at UBC Farm and energy production at the BRDF. The economic, environmental, and social impacts of implementing such a project will be considered in the form of a triple bottom line analysis.

1.1 CROP SELECTION

In order to simplify this investigation, three types of crops were considered for growth at UBC Farm: miscanthus giganteus, switchgrass, and hybrid poplar. These crops were compared based on various quantitative and qualitative criteria designated by UBC Farm and the BRDF. The checklist shown in Appendix B summarizes the findings of this comparison. It should be noted that a general assumption was made that a wood chipper can be borrowed from UBC Plant Operations to chip all crops to less than three inches in size and that shading can be mitigated with occasional trimming.

The amount of land available for planting was estimated to be 500 square meters, or 0.05 hectares. This statistic was determined by visiting UBC Farm in person and analyzing maps provided by the project stakeholder.

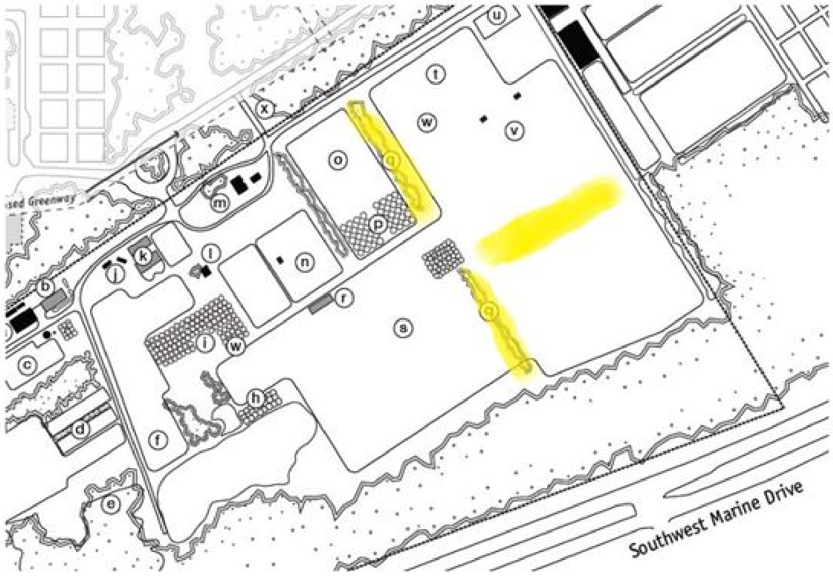

Figure 1: A top view of the UBC Farm, where the highlighted areas are the prospective hedgerows that the miscanthus may be planted on (Menzies, 2013).

1.1.1 MISCANTHUS GIGANTEUS

Miscanthus giganteus is a sterile genotype of the perennial grass, miscanthus. It is propagated by rhizome division, so there is no reason for concern with regard to invasiveness (Kludze et al., 2011). Its low demand for nutrients and water make it well suited for growth at UBC Farm (Kludze et al., 2011). In addition, it can be grown organically without much risk of losing yield. Miscanthus giganteus stands typically last for 15-20 years and require three to four years before reaching a mature yield (Wang et al., 2013). A stand density of 10,000 plants per hectare is considered ideal, with the potential to yield roughly 20 tons of dry matter per hectare (Kludze et al., 2011). It is best to harvest miscanthus giganteus in February or March, as the plants will return nutrients to the soil and dry out, dropping all leafy, green material (Kludze et al., 2011). The timing of harvest may prove to be very important to ensure that miscanthus giganteus meets certain requirements designated by the BRDF. Some data indicates that miscanthus giganteus may have levels of sulfur (S) and chlorine (Cl) slightly in excess of the specifications listed in the ultimate analysis section of the fuel specification sheet provided by the stakeholder and attached as Appendix A (Nexterra Energy Corp., 2007). Excesses of these chemicals may result in unwanted emissions, corrosion, and lowered ash melting temperatures (Kludze et al., 2011). However, these chemical levels decrease when harvesting is delayed, and it is unlikely that there would be long-term harm to the BRDF considering that it would only process 1 ton of dry miscanthus giganteus each year. Nevertheless, it would be prudent to perform an ultimate analysis on miscanthus giganteus grown at UBC Farm prior to introducing it at the BRDF. Miscanthus giganteus has the highest projected yield of the three crops investigated and it also has the highest energy content according to data from proximate analyses (Kludze et al., 2011). Overall, it was judged to have the most potential for successful use for this project, so the triple bottom line assessment will consider the economic, social, and environmental impacts of growing miscanthus giganteus for bioenergy at UBC Farm.

1.1.2 SWITCHGRASS

Switchgrass is also a perennial grass (Kludze et al., 2011). It is planted as a seed and is not known to be invasive, as it can be easily outcompeted by other plants (Kludze et al., 2011). It is similar to miscanthus giganteus with regards to nutrient demand, water demand, and being able to be grown organically, although yields may suffer if it has to compete with weeds (Kludze et al., 2011). Switchgrass typically requires two to three years to reach a mature yield and stands are known to last beyond ten (Wang et al., 2013). Growing 10-32 seedlings per square meter is considered ideal for achieving yields up to 12 tons per hectare, per year (Kludze et al., 2011).

Switchgrass was not considered the ideal crop for this project because its yield is projected to be less than miscanthus giganteus, and it also showed elevated levels of S in its ultimate analysis (Kludze et al., 2011). In addition, switchgrass is about 500Btu/lb short of the BRDF requirement of 8,500Btu/lb (Kludze et al., 2011). All in all, it would likely grow with ease at UBC Farm, but it doesn't appear to be well suited for energy production purposes.

1.1.3 HYBRID POPLAR

Hybrid poplars are considered members of the willow family (Kludze et al., 2011). They are known for their high growth rate and the ability to coppice (Kludze et al., 2011). Hybrid poplar can be expected to grow well at UBC Farm based on its water demand and soil requirements. In fact, trials with hybrid poplar at UBC Farm have already been conducted with encouraging results (Menzies, 2013). Furthermore, hybrid poplar was the only crop considered that did not appear to have any potential issues with its chemical composition, as determined by ultimate analyses (Kludze et al., 2011).

On the other hand, there may still be issues with processing hybrid poplar at the BRDF. Proximate analyses indicate that it averages 7000 to 8000Btu/lb and it may be too high in moisture content, depending on handling (Kludze et al., 2011). In addition, yields are projected to be low relative to growing miscanthus giganteus (Kludze et al., 2011). A disease known as the stem canker is known to further reduce yields in some cases (Kludze et al., 2011).

The main disadvantage with using hybrid poplar for this project is that it sends down a deep taproot, making the plants extremely difficult to remove if they are found to be ineffective for energy production (Kludze et al., 2011). Even if miscanthus giganteus does not perform as idealized, it wouldn't be too difficult to remove it and try something else. In fact, hybrid poplar would likely be the next best option if combustion issues arise with miscanthus giganteus. This is difficult to predict, so there may be some trial and error required with the implementation of this project. With this in mind, it is more prudent to test a plot of miscanthus giganteus before planting hybrid poplar.

2.0 ECONOMIC ASSESSMENT

In the following economic analysis of miscanthus hedgerows at UBC Farm, the primary assessment indicator is the dollar. A yield model for the crop will be introduced, the costs of all inputs will be explained in detail, and the net profit will be calculated over the full life cycle of miscanthus. The final results of this analysis will shed light on the economic viability of miscanthus at the farm.

2.1 YIELD MODEL

As described in Section 1.1.1, miscanthus giganteus is a perennial energy grass that has a crop life of approximately 15 years. This species of miscanthus has a yield of 2 to 3 tonnes per hectare in year 1, 8 tonnes per hectare in year 2, 13 to 15 tonnes in year 3, and more than 20 tonnes per hectare from year 4 onwards as the crop reaches its maximum yield (Kludze et al., 2011). Given the available land area of 500m^2 at UBC Farm, the yield model of miscanthus at UBC Farm is shown below in Table 1.

Year	Miscanthus Yield (tonnes/hectare)	**Yield at UBC Farm (tonnes)**
1	2 to 3	**0.1 to 0.15**
2	8	**0.4**
3	13 to 15	**0.65 to 0.75**
4 to 15	20+	**1+**

Table 1: Yield model for growing miscanthus on 500m^2 of land at the UBC Farm (Kludze et al., 2011)

2.2 COST ANALYSIS

As with most crops, the greatest costs are incurred in the first year, the establishment year. For miscanthus, the cost of rhizomes is responsible for the bulk of this initial investment. Miscanthus giganteus rhizomes, at a cost of $0.24 each, would cost $150 in total to achieve an ideal crop density at UBC Farm (Kludze et al., 2011). Another portion of the start-up investment lies in the agricultural inputs. During the first year, miscanthus requires fertilizer that includes 30-60 kg/hectare of nitrogen, 7 kg/hectare of phosphorus, 100 kg/hectare of potassium, and 2300-4500 kg/hectare of lime (Khanna & Huang, 2010). In post-establishment years, the cost of inputs decreases significantly as the cost of rhizomes is omitted, the amount of nitrogen fertilizer required decreases to 25-50 kg/hectare, and lime is no longer required (Khanna & Huang, 2010). The costs of these fertilizers on average is $300/tonne for nitrogen, $250/tonne for phosphorus, $350/tonne for potassium, and

$30/tonne for lime (Agriculture and Agri-Food Canada, 2012). Miscanthus is best harvested in the spring, between February and March. According to the project stakeholder, labour during this period would be paid at $16/hr (Kludze et al., 2011). During the establishment year, the hours of labour required at the farm is estimated to be 10 hours for planting and 8 hours for harvest. As the yield of the miscanthus crop increases, the time required for harvest will increase to 10 hours in year 2, 12 hours in year 3, and peak at 15 hours from year 4 to the end of the life cycle. Conventional hay equipment can be used to harvest miscanthus, so new infrastructure or equipment will not be required. Regarding transportation, UBC Farm has a trailer available to transfer the miscanthus biomass to the BRDF. The distance between the two locations is 3.1 km, adding up to a 6.2 km round-trip between the two locations, as shown in Figure 2 below (Google Maps, 2013).

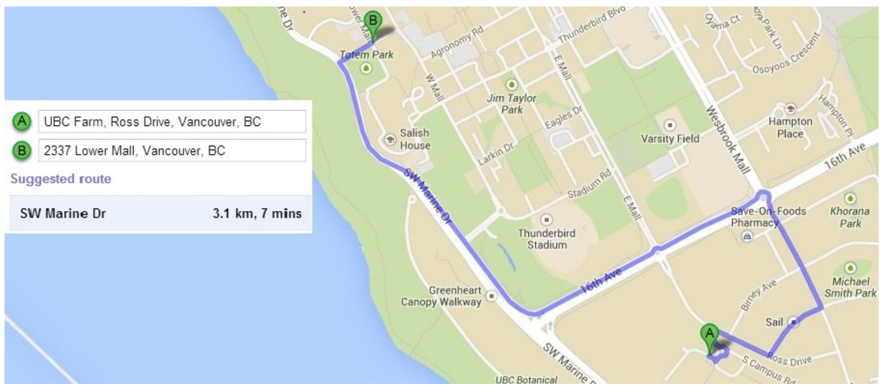

Figure 2: Image of the travel distance between UBC Farm and BRDF, courtesy of Google Maps.

Once the miscanthus giganteus achieves a mature yield, a maximum estimate of 10 round trips of the trailer would amount to 62km of total distance. With an average of 16 miles per gallon, or 6.8 kilometers per litre, the total amount of fuel consumed by the trailer in a maximum yield year amounts to 9.1 litres (US Department of Energy, 2013). Currently, the price of gasoline or diesel fluctuates around $1.50/litre and consequently, the yearly cost of transportation fuel totals to $13.67. In this economic analysis, an upper limit of $15/year for fuel will be taken into account.

All of the variable factors mentioned above are summarized into Table 2, which contains information on the inputs required for each year of the miscanthus life cycle. The overall cost analysis, taking into account all of the yearly inputs, is shown in Table 3 below. The first year requires the greatest investment and each subsequent year has significantly lower costs.

Year	Rhizomes (Yes/No)	Nitrogen (kg)	Phosphorus (kg)	Potassium (kg)	Lime (kg)	Labour (hrs)
1	Yes	30 to 60	7	100	2300 to 4500	18
2	No	25 to 50	7	100	0	10
3	No	25 to 50	7	100	0	12
4 to 15	No	25 to 50	7	100	0	15

Table 2: Summarized amount of variable inputs for each year of the miscanthus life cycle

Year	Rhizomes	Nitrogen ($300/tonne)	Phosphorus ($250/tonne)	Potassium ($350/tonne)	Lime ($30/tonne)	Labour ($16/hr)	Transportation ($15/year)	**Total Costs**
1	$150	$0.45 to $0.90	$0.09	$1.75	$3.45 to $6.75	$288	$15	**$459 to 463**
2	$0	$0.375 to $0.75	$0.09	$1.75	$0	$160	$15	**$177**
3	$0	$0.375 to $0.75	$0.09	$1.75	$0	$192	$15	**$209**
4 to 15	$0	$0.375 to $0.75	$0.09	$1.75	$0	$240	$15	**$257**

Table 3: Detailed costs calculations for each of the inputs per year, indicating yearly total costs

2.3 OVERALL ECONOMIC ANALYSIS

For every dry tonne of biomass, the BRDF will pay $64, generating income for UBC Farm (Menzies, 2013). This figure allows the annual net profit to be calculated by referring to the yield model in Table 1 for yearly revenue, and adding the results to the annual total costs in Table 3 The overall economic summary is shown below in Table 2.3.

Year	Total Costs	Total Revenue (Yield x $64/tonne)	**Net Profit**
1	$459 to $463	$6.4 to $9.6	**-$449.4 to -$456.6**
2	$177	$25.60	**-$151.40**
3	$209	$41.6 to $48	**-$161 to -$167.4**
4 to 15	$257	$64	**-$193**

Table 4: Annual net profit calculations for the 15 year life cycle.

Over the 15-year life cycle of miscanthus at UBC Farm, the total profit amounts to -$3,084.6, indicating a small economic loss that averages to $205/year. From the perspective of UBC as a whole, the total miscanthus biomass produced at the UBC Farm will translate to 1,200 kilowatt-hours produced at the BRDF from year 4 to 15, which in turn reduces the electricity bill for UBC. The statistic for kilowatt-hours is described in detail in Section 3.0 of this paper. Factoring in BC Hydro's "Large General Service" rate of $0.0956/kWh, the money that UBC will save, over the 12 year period, amounts to $114.72 (BC Hydro, 2013). For UBC Farm, this arrangement of planting miscanthus hedgerows does not generate any financial benefits. This holds true for the entire UBC campus, as miscanthus will only offset $1,376.64 of the electricity bill. Including the losses from UBC Farm, the final figure amounts to a net of -$1,708 for UBC as a whole, indicating that miscanthus hedgerows will have a negligible economic impact.

3.0 ENVIRONMENTAL ASSESSMENT

Since the scale of this project is very small, only the local environmental impacts of producing miscanthus giganteus as a bio-fuel crop at UBC Farm will be considered. A brief discussion on the impacts of replicating this project on a larger scale and its consequences will follow. With regard to the triple bottom line, all the benefits to the environment will be compared against the negative impacts to determine whether there is an overall ecological benefit or hindrance.

3.1 LOCAL IMPACTS

Local impacts affect the immediate environment at the UBC Farm and the rest of the UBC campus. At the UBC Farm, the miscanthus will be planted in the hedgerows indicated on Figure 1, which approximately span a total area of $500m^2$. To consider the impact that this will have on the surrounding farm area, it is necessary to discuss the role that hedgerows play in the local ecosystem.

Figure 3: A hedgerow on the UBC Farm, corresponds to the uppermost highlighted section on Figure 1.

Hedgerows provide a plethora of ecological benefits to the farm. The hedges provide organisms with food, breeding sites and shelter (Wolton, 2012). Furthermore, hedgerows filter out polluting fertilizers, pesticides and sediments so that the toxins do not infiltrate the groundwater (Wolton, 2012). Hedgerows also decrease soil erosion by reducing wind speeds and water runoff. This effect is of particular importance to the UBC farm as the hedgerows are located on a slope, which makes the area more vulnerable to erosive processes such as flooding and excessive wind (Menzies, 2013).

By taking into account the importance of the presence of hedgerows and their function, it is imperative that the use of miscanthus does not inhibit any of the hedgerows properties. The research conducted for this investigation indicates that miscanthus not only upholds the environmental benefits of hedgerows, but also is beneficial to the farm in the following ways (Kludze et al., 2011):

- Releases nutrients and moisture back to its roots each year
- Serves as a habitat for farmland bird population
- Can be grown organically
- Sequesters Carbon
- It is a noninvasive species
- Rapid growth (up to 3.5 m in one growing season)
- Consistent annual yield
- High energy output to input ratio
- Releases nutrients and moisture back into its roots as it senesces
- Facilitates water filtration
- Mitigates runoff

Furthermore, if the hedgerows are converted into miscanthus crop, it has the potential to increase the farmland biodiversity significantly. As the investigation by Bellamy et al. (2008) suggests, miscanthus is an ideal habitat for farmland bird populations, providing sufficient shelter in the winter season. During the birds' breeding season, the miscanthus crop plants house a greater number of insects, a food source (see Figure 4). These benefits, however, are likely to diminish with the age of the crop and wildlife management will be required to maintain the ecological benefits that miscanthus has introduced (Bellamy et al., 2008).

Species	Mean density ± SE	
	Miscanthus	Wheat
Birds using fields (birds ha^{-1})		
Game birds	0.81 ± 0.28	0.16 ± 0.05
Granivorous passerines	0.53 ± 0.18	0.10 ± 0.04
Skylark	0.46 ± 0.17	0.46 ± 0.20
Warblers	**0.38 ± 0.11**	**0**
Pigeons	0.22 ± 0.11	0.03 ± 0.02
Crows	0.21 ± 0.12	0.03 ± 0.03
All herbivores	**0.89 ± 0.17**	**0.10 ± 0.05**
All insectivores	**1.5 ± 0.29**	**0.63 ± 0.26**
All omnivores	**0.72 ± 0.21**	**0.15 ± 0.05**
Woodland spp.	**0.16 ± 0.07**	**0.01 ± 0.01**
Farmland spp.	**1.35 ± 0.20**	**0.65 ± 0.25**
All birds	**3.1 ± 0.29**	**0.87 ± 0.22**
Breeding pairs (pairs ha^{-1})		
Pheasant (5,4) *Phasianus colchicus*	0.38 ± 0.19	0.15 ± 0.06
Skylark (4,4) *Alauda arvensis*	0.33 ± 0.12	0.24 ± 0.10
Red-legged partridge (6,1) *Alectoris rufa*	**0.30 ± 0.09**	**0.04 ± 0.04**
Reed bunting (4,3) *Emberiza schoeniclus*	0.18 ± 0.07	0.07 ± 0.04
Reed warbler (5,0) *Acrocephalus scirpaceus*	**0.41 ± 0.14**	**0**
All species	**1.8 ± 0.12**	**0.59 ± 0.12**

Figure 4: Mean breeding abundance of bird species groups and density of individual bird species recorded breeding (territories 50-100 % within the crop) in miscanthus and wheat fields. Figure reprinted from Bellamy et al. (2008)

To quantify miscanthus' beneficial impact towards the environment, it is important to consider the interactions between the UBC Farm and the BRDF as miscanthus transforms from a crop to a fuel. As a biofuel, miscanthus has a very high energy density, which means it is very efficient in being converted into energy (Kludze et al., 2011). This property makes miscanthus an ideal fuel to be used in the BRDF. Moreover, it is important to note that the BRDF has two modes of operation: combined heat and power (CHP) mode and thermal mode, so the miscanthus impact to the environment changes depending on which mode the BRDF is running in. The CHP mode is when the facility is running ideally and produces both electricity, whereas thermal energy and the thermal mode is when the BRDF produces only thermal energy. In the CHP mode of operation, the miscanthus sent from the farm will contribute 1 dry ton of biofuel to the BRDF's annual consumption of 12,500 dry tonnes, which means 0.008% of the BRDF's annual energy production will be produced from the miscanthus. This translates to 1,200 kWh of energy per year, and avoided carbon dioxide emissions of 0.4 tonnes per year Nexterra Energy Corp. (2013). Alternatively, when the BRDF is running in thermal mode (its current configuration), the miscanthus will produce 1.6 lbs/hour of steam. This directly translates to 0.002% of the current campus use of thermal energy. In other words, it displaces 0.002% of the thermal energy (for heating) otherwise received from natural gas. From the above discussion, it is evident that the amount of miscanthus provided by the UBC farm does not have any significant impact in the production of energy at the BRDF. Furthermore, the miscanthus itself does not contribute significantly in the reduction of GHGs.

Environmental Indicator	Growing Phase	Mature Phase	Type of Impact
Biodiversity/ Plants and Animals	-	+	Has a negative impact in the beginning, whilst initially growing (consequences such as shading), due to displacement of existing hedgerows. Overall, it is expected that some species will reap the benefits, while others lose out. Also, a positive impact on biodiversity is the facilitation of a bird habitat.
Water Quality	+	+	Miscanthus acts as a water filter and provides an infiltration system for any toxic material that may be found on the surface. Also minimal fertilizer is required.
Air Quality	+	+	Potential to have a positive impact on air quality due to the low processing required by the UBC Farm and a reduction in allergens in the local ecosystem.
Soil Structure	-	+	May improve soil structure due to miscanthus' deep rooting system, but these effects are only possible for when the crop is relatively mature.
Fossil Fuel	+	+	Positive impact due to some displacement of fossil fuel energy is possible through the use of miscanthus as a biofuel at the BRDF. Impacts increase as the crop matures and yield increases. Note that this impact is overall, not very significant, due to the small scale of the project.
Greenhouse Gas Emissions	+	+	Direct reduction of GHGs through carbon sequestration and indirection reduction of GHGs by way of using less fertilizer and by being used as a biofuel at the BRDF (displacement of energy that would have created more GHGs).

Table 5: Summary of the main points of the ecological assessment, where + indicates a positive impact and - indicates a negative impact.

In the local scope, it is clear that converting the hedgerows to a miscanthus biofuel crop introduces net positive impacts (see Table 5). The surrounding environment benefits by the presence of miscanthus as it provides soil stabilization, water filtration, wildlife shelter, and protection from excessive wind (Heaton, 2010). Due to the low amount of biomass produced over its life cycle, the crop does not make a significant impact in energy production or GHG emission reduction. However, these results do not effect miscanthus' standing in this assessment. Miscanthus is seen as largely beneficial to the local ecological systems at UBC and should be very seriously considered.

3.2 UPSCALE DISCUSSION

The scale at which the UBC Farm has proposed its project is too small to create any dramatic changes in the environment or in the production of energy. However, if it is scaled up to a larger project or replicated to a larger scale, there can be significant impacts to the environment and energy production. A study conducted by Hughes et al. (2010) concludes that large scale use of miscanthus could, by an upper estimate, reduce atmospheric carbon dioxide concentrations by 162 ppmv by the end of the century. This reduction in concentration is extremely significant as the carbon dioxide levels since the pre-industrial era to the present have increased by 100 ppmv. A large scale miscanthus project can effectively remediate this increase (Hughes et al., 2010).

Although the scale of the project is small at the UBC Farm, the project can play a role in demonstrating to other organizations and farms that miscanthus as a hedgerow or farm margin crop is an option to be seriously considered. If enough organizations become involved, the positive ecological impact will grow and eventually become substantial.

4.0 SOCIAL ASSESSMENT

The final criteria of the triple bottom line evaluation is the social impact of growing miscanthus giganteus at UBC Farm. Considering that the cost of the project and its environmental impacts are both very small, the primary indicator of this evaluation will be the social impact. In order to analyze the social impact of the project, the following discussion will consider the social outcomes expected at UBC and abroad from implementing this project.

4.1 LOCAL SCOPE

Some of the immediate social benefits that will result from this project will take place directly at UBC Farm. For example, the volunteers and staff who will come together to plan and manage the growth of miscanthus at UBC Farm will likely develop a sense of camaraderie. Ideally, this project will be a subject of pride for those involved. It should also be inspiring to students, professors, researchers, and visitors at UBC. Energy production is an issue that receives a lot of attention, so it should be encouraging for others to see that UBC is truly putting forth an effort into improving modern practices. For that matter, this project has educational value for students in many faculties. UBC could incorporate information and lessons learned from this project into curriculum and research opportunities. Furthermore, students could have the chance to get involved on a first hand basis through volunteering at UBC Farm.

The operational side of implementing the project will also broaden the relationships between institutions at UBC. The BRDF and UBC Farm are not currently involved with one another, so this will help integrate the campus (Menzies, 2013). Furthermore, UBC Plant Operations may be able to become involved by providing equipment and extra labour, as necessary.

4.2 GREATER COMMUNITY

The vision of UBC Farm is to be *"a world-class academic resource and a central part of UBC's sustainability aspirations, enabling UBC to explore and exemplify new globally significant paradigms for the design and function of sustainable communities and their ecological support systems"* (UBC Farm, 2009). This is a large and important role. The demonstrations that take place at UBC Farm are very influential to others. With this in mind, aspects of the project investigated in this report could encourage other farms to produce bioenergy on scales larger than what is proposed here. This could influence new trends in the agricultural industry and provide a significant amount of support for green energy production. Other universities and municipalities may also take an interest in UBC's efforts and consider taking on small-scale projects of their own to make use of marginal lands. As more groups get involved with developing bioenergy crops, there will be a greater understanding of their potential and projects will increase in their effectiveness.

5.0 CONCLUSION AND RECOMMENDATION

In summary, a preliminary analysis indicated that miscanthus giganteus was the best of three crops to consider producing at UBC Farm (see Appendix B). Its properties were determined to be more promising for energy production than switchgrass, and it is expected to produce a higher yield than hybrid poplar. In addition, miscanthus is fairly easy to remove at the end of its 15-year life cycle, unlike poplar, which produces a large taproot that is extremely difficult to remove. UBC Farm incorporates many educational projects on its property, so the flexibility gained by being able to easily remove miscanthus in the future is very important to consider.

Conducting a triple bottom line assessment brought the investigation to the conclusion that growing miscanthus giganteus at UBC Farm has a net positive impact overall. The economic projections for the project indicate a small financial commitment from UBC Farm, but the project should be considered a worthwhile investment based on the long-term environmental and social benefits. The initiative has potential for growth in scope and it will ideally promote understanding and interest in the use of biomass for energy production.

It is recommended that UBC proceed with planning an effective means of growing miscanthus giganteus on the available land at UBC Farm. Some testing will be required prior to introducing the crop to the BRDF processing circuit to ensure that the final product meets the required specifications for energy production, but this is the only major foreseeable obstacle based on this investigation.

REFERENCES

Agriculture and Agri-Food Canada. (2012, March). *Canadian Farm Fuel and Fertilizer: Prices and Expenses.* Retrieved from http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/crops/crops-market-information-canadian-industry/market-outlook-report/canadian-farm-fuel-and-fertilizerprices-and-expenses-march-2012/?id=1378845446435

BC Hydro. (2013, April). *Business rate prices.* Retrieved from https://www.bchydro.com/accounts-billing/customer-service-business/business-rates-overview/business-rates-prices.html

Bellamy, P., Croxton, P., Heard, M., Hinsley, S., Hulmes, L., Nuttall, P., ... Rothery, P. (2008). The impact of growing miscanthus for biomass on farmland bird populations. *Biomass and Bioenergy*, *33*, 191-199.

Google Maps. (2013). *UBC Farm, Vancouver, British Columbia (Street Map).* Retrieved from https://maps.google.ca/maps?q=google+maps&ie=UTF-8&ei=Yw-UUp3IJMTroAS4pYLAAQ&ved=0CAoQ_AUoAg

Heaton, E. (2010, January). *Giant miscanthus for biomass production.* Retrieved from http://www.extension.iastate.edu/publications/ag201.pdf

Hughes, J. K., Lloyd, A. J., Huntingford, C., Finch, J. W., & Harding, R. J. (2010). The impact of extensive planting of Miscanthus as an energy crop on future CO2 atmospheric concentrations. *GCB Bioenergy*, *2*, 79-88. doi: 10.1111/j.1757-1707.2010.01042.x

Khanna, M., & Huang, H. (2010). The breakeven costs of producing alternative feedstocks for cellulosic biofuels. *Energy, Biosciences Institute*.

Kludze, H., Deen, B., & Dutta, A. (2011). *Report on literature review of agronomic practices for energy crop production under Ontario conditions* (Tech. Rep.). University of Guelph. Retrieved from http://www.ofa.on.ca/uploads/userfiles/files/ofaproject-finalreportjuly04-2011raac.pdf (Manuscript submitted for publication, Department of Agriculture)

Menzies, K. (2013, October 8). *Interview.*

Nexterra Energy Corp. (2007, November 20). *Nexterra typical wood fuel specifications.*

Nexterra Energy Corp. (2013, March). *UBC bioenergy research and demonstration facility.* Retrieved from http://www.nexterra.ca/files/pdf/Project-Profile_UBC-20130321_FINAL_EMAIL.pdf

UBC Farm. (2009). *Vision.* Retrieved from http://ubcfarm.ubc.ca/about/vision/

UBC Sustainability. (2013). *UBC Bioenergy Research and Demonstration Facility.* Retrieved from http://sustain.ubc.ca/research/signature-research-projects/bioenergy-research-and-demonstration-facility

US Department of Energy. (2013). *Most and least efficient trucks.* Retrieved from http://www.fueleconomy.gov/feg/best/bestworstEPAtrucksNF.shtml

Wang, Z., Han, J., & Wang, M. (2013). Material and energy flows into the production of cellulosic feedstocks for biofuels for the greet model. *U.S. Department of Energy, Argonne National Laboratory*.

Wolton, R. (2012, February). *What hedges do for us.* Retrieved from http://www.hedgelink.org.uk/files/What%20hedges%20do%20for%20us,%20V2,%2020%20Mar%202012,%20Rob%20Wolton,%20Hedgelink.pdf

APPENDICES

APPENDIX A

nexterra
a new era of energy security

NEXTERRA TYPICAL WOOD FUEL SPECIFICATIONS

The Nexterra Gasifier System is designed to operate on fuel having the following specifications:

A. Fuel Size
Wood residue must be sized to 3 in. minus in all dimensions. Long fibers or sticks that are longer than 3 in. in length are not acceptable. Residues sized less than 1/4 in. must be limited to 25 percent or less.

B. Fuel Composition
Wood residue must be a clean fresh mix free of substances foreign to natural composi ion of wood such as preserving chemicals, paint, processing chemicals, glues, sulphurous, phosphorous or nitrogenous chemicals that might be classified as hazardous or appear in flue gas or ash. The fuel should be free of nails or other metal strips. The wood fuel should be free of rotten material which evidences a state of decomposition. The wood fuel should be free of leafy greens or needles.

Fuel must be well mixed with a consistent moisture content level. The system will be able to accommodate seasonal fluctuations in moisture content.

C. Ultimate and Proximate Analysis
The proximate and ultimate analysis of the design fuel on a dry weight basis for performance calculations is as follows:

Proximate Analysis	
Component	
Moisture Content (wet basis)	10-55%
Volatile Content	70-85%
Fixed Carbon	15-25%
Ash	<10%
Higher Heating Value (HHV)	> 8500 btu/lb

Ultimate Analysis	
Component	
Carbon	48-52%
Hydrogen	5-6%
Oxygen	36-44%
Nitrogen	<0.300%
Sulphur	<0.025%
Chlorine	<0.025%
Total	**100%**

D. Ash Content
Wood fuel may contain less than 5% dry basis inorganic material including materials that are part of the normal composition of wood as well as materials that are not part of the makeup of natural wood. The initial deformation temperature (IDT) of ash must be greater than 2100 ° F.

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APPENDIX B

	Biomass Checklist		
BRDF Specified	**Miscanthus**	**Switchgrass**	**Poplar**
Fuel Size	Yes	Yes	Yes
Fuel Composition	Yes	Yes	Yes
Ultimate Analysis	Maybe High Cl, S	Maybe High S	Yes
Proximate Analysis (BTU/lb>8500)	Very Close 8,417	Maybe 8,000	Maybe 8,177
Ash Content	Yes	Yes	Yes
Moisture Content	Yes	Yes	Wet
UBF Farm Specified			
Non-Invasive	Yes	Yes	Yes
Water Demand	Yes	Yes	Yes
Soil	Yes	Yes	Yes
Climate	Yes	Yes	Yes
No Pests/Diseases/Organic	Yes	Maybe	Maybe
Off Season Harvest Time	Yes	Yes	Yes
Low Labor Requirement	Medium	Medium	Medium
No Shading	Maybe	Maybe	Maybe
Estimated Yield	Highest	Medium	Low