APSC 261 - Technology and Society I

An Investigation into Fuelstock Production in the UBC Farm to Create Energy and Reduce Greenhouse Gas (GHG) Emissions

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ABSTRACT

The project is to investigate the best plant as fuelstock that can be grown in UBC Farm, which is a 24 hectare farm on the southern end of the University of British Columbia (UBC). The Triple Bottom Line method is implemented during the entire investigation.

Since several fuelstock options can be grown in UBC farm, the best candidate should chosen based on economical, ecological and social indicators. The result is derived by estimation since all data are collected from other papers and online resources. The economic indicators include input costs and profit generated by trading *Miscanthus* with the Bioenergy Research Demonstration Facility (BRDF). The ecological indicators applied are reusability of existing space and materials, improvement in environmental condition, protection from environmental degradation and increase in sustainable practice. Also, the social indicators consist of potential job increases, improvement of relations across sectors and providing educational opportunities. The result shows that *Miscanthus* is the best option and is highly recommended.

Although the UBC farm may not provide the enough land to grow *Miscanthus* and supply the entire operation of BRDF, the pattern and model can be transferred to other parts of British Columbia (BC) and be implemented. In short terms, there is money input to the project, however, from long run perspectives, society and ecology environment will benefit of low greenhouse gas(GHG) emissions.

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GLOSSARY

C4 Plant - a plant in which the CO_2 is first fixed into a compound containing four carbon atoms before entering the Calvin cycle of photosynthesis" ("C4 Plant,", n.d.)

LIST OF ABBREVIATIONS

UBC - University of British Columbia

BRDF - Bioenergy Research Demonstration Facility

GHG - Greenhouse Gas

CO2 - Carbon Dioxide

1.0 INTRODUCTION

The UBC Farm is a 24 hectare farm and forest system, which is located in the south of the University of British Columbia (UBC) campus ("About", n.d.). To commit UBC as a global leader in sustainability, UBC Farm plays a key role of enhancing UBC becoming a carbon neutral community through food production and agricultural management ("Centre for Sustainable Food Systems", n.d.). Therefore, UBC Farm is currently interested in the GHG mitigation potential of biofuels and considering the possibility of growing woody biomass as fuelstock within farm margin area, which is not being used for food production (Richer et al., n.d.).

The Bioenergy Research and Demonstration Facility (BRDF) is a power and heat system on UBC campus that replies on biomass fuels instead of fossil fuels such as natural gas or coal. This helps to reduce the GHG emissions while providing power and heat to the UBC campus in Vancouver ("Bioenergy Research and Demonstration Facility", n.d.). Therefore, with BRDF, fuelstock produced from the UBC Farm could be potentially converted into clean energy. One of the primary focuses of this project are the economical, ecological and social implications of fuelstock production.

2.0 INVESTIGATION

2.1 LAND EXPLORATION

Within existing hedgerows and along UBC Farm margins, there is a roughly one-hectare land area not being used for food production. The hedgerows, established to reduce GHG emissions, enhances biodiversity and habitat for wildlife in this area (Keery et al., 2009). Moreover, with improved soil quality and well maintenance, the land is in a good condition ("Farm Features"; "Hedgerows," 2013).

2.2 BRDF SPECIFICATION

BRDF stands for *Bioenergy Research & Demonstration Facility.* It is the first world community-scale power and heat system supplied by biofuel (UBC, 2013). The system is located in UBC and aimed to provide clean energy using biofuel. The fuel stock investigated in this project will be used in BRDF. The detailed specification can be found below.

Expected System Performance

Electricity Production	15 million kWh/yr
Annual Gas Displacement	25 million kWt-hrs/yr
Avoided CO_2 Emissions	5,000 tonnes yr
Avoided CO_2 Emissions (Car Equivalent)	1,000 cars/yr
Wood Fuel Required	12,500 bone dry tonnes/yr

Figure 1: BRDF Specification ("Bioenergy Research and Demonstration Facility", n.d.)

2.3 FUELSTOCK OPTIONS

To determine what type of fuelstock would be best suited for production, *Miscanthus*, *Willow* and *Corn* are listed below with analyses.

2.3.1 *Miscanthus*

Miscanthus, which is also known as Elephant Grass, is a high yielding energy crop that grows over three meters tall and produces 10 to 15 tons of dry matter per acre (Pennington, 2012). It grows fast even on marginal land that contains sand or clay. It requires minimal labor and very few inputs.

2.3.2 *Willow*

Similar to *Miscanthus*, *Willow* is a high energy crop and requires few inputs. It is mainly grown in cold and wet areas, such as Britain. The best production for *Willow* is 5 tons of dry matter per acre. ("The willow biomass", n.d.)

2.3.3 *Corn*

As a first-generation biofuel, *Corn* is widely used as a biomass to produce ethanol in the United States, and corn-based ethanol fuels are mainly utilized in gasoline. However, corn ethanol contributes to rise in food prices due to the debate about whether *Corn* should be mainly grown as biofuel for cars or as food for people (Grooms, 2008, p. 40). The high cost of making corn-based ethanol is influencing a high cost, and the large quantity of fossil energy required to produce ethanol from *Corn* makes the process unsustainable (Patzek, 2004, p. 519).

After doing the primary investigation, we decided to do a further research on *Miscanthus,* since it requires low input and produce high yield, using the Triple bottom line method as seen in the following.

3.0 ECONOMIC ASPECT

Miscanthus is a high yield non-invasive plant that grows wherever it is being planted, even on marginal land with poor soil properties. It is a perennial crop that does not need to be reseeded each spring and with an expected life of 20 years. *Miscanthus* is a warm season crop but it can also be grown at relatively low temperatures but with a smaller yield. The yield goes down as temperature decreases. According to a research done by the Iowa State University in 2010, *Miscanthus* production is eight tons of dry matter in average in Europe, where it is 13 tons of dry matter in average in the United States, an increase of 40% over Europe ("Giant miscanthus for biomass production," 2010).

Miscanthus is one of the potential fuelstocks that can be planted at the UBC Farm. Since it does not have to be grown on farm land, it can be planted on the farm marginal area. In order to have a better approximation on the land area that can be used to plant *Miscanthus*, our group visited the UBC Farm on October 15 and we estimate that there is 1 hectare, which is equivalent to 2.47 acre, of farm margin available for producing *Miscanthus*. Since *Miscanthus* is a perennial crop, it has a very extensive and strong root system that is very efficient when taking up nutrients. As it grows, it uses only a very small amount of nutrients and it stores any excess nutrients in its rhizome. Thus, it does not need much care once it has been established. *Miscanthus* requires minimal labor and very few inputs. It can be grown with very little application of fertilizers and thus reduce the labor cost (Pennington, 2012). In addition, since it grows back yearly and does not need to be replanted, its labor input costs are further minimized. Therefore, the UBC Farm does not have to hire extra worker to take care of the crop(Heaton, 2012).

Costs ($/ton)	Corn/Soybean[1] Rotation			Miscanthus[2] Energy Crop			
	Corn	Soy	10 years[3]	1st year	2nd year	3rd-10th years	10 years
Fertilizer	53	19	251	25	24	9	98
Pesticides	31	32	211	6	0	0	6
Seed	34	19	180	128	0	0	128
Crop drying	7	2	31	0	0	0	0
Machinery repair, fuel, hire	27	24	171	18	41	38	257
Labor	36	34	235	34	33	31	228
TOTAL VARIABLE COSTS	188	130	1076	211	98	79	717
Machinery, overhead, housing	0	0	0	0	0	0	0
Depreciation, non-land interest	104	80	621	9	23	22	146
Land	151	151	1011	151	147	138	1011
TOTAL OTHER COSTS	255	231	1631	160	170	160	1156
TOTAL ALL COSTS	443	361	2707	371	268	239	1873
Yield (tons/acre)	4	1	0	0	0	0	0
Yield (dry tons/acre)	0	0	0	0	7	14	0
Value ($/ton)	98	195		40	39	38	
GROSS REVENUE ($/acre)	413	276	2341	0	268	538	3047
NET PROFIT[4] ($/acre)	-30	-85	-366	-371	0	299	1174

Table 1: Annual cost and profit of two cropping systems over 10 years (Heaton, 2012)

Table 1 above shows the estimated production cost for Miscantus and two other crops. In average, the initial cost, including planting material cost and basic planting expenses, is $ 1,000 per acre and may vary depending on the source. Considering over the lifespan of 20 years, the initial cost are a lot less than other annual crops. According to Table 1, it shows that the variable costs for *Miscanthus* are less than that for *Corn* and *Soybean*. Moreover, it has a higher net profit compared to the annual crops as well. Except for the first two years, *Miscanthus* earns $299 per acre in average and may earn up to $1174 per acre after 10 years of planting (Kristensen, n.d.).

Miscanthus is a tall high yielding fuelstock that grows over 3 meters tall. Its yield depends on temperature and amount of sunshine and rainfall. In general, it produces 10 tons of dry matter per acre and reaches its maximum potential production rate after three to four years (Heaton, 2012). As we estimated, the UBC Farm has around 2.5 acre of marginal land area available for producing *Miscanthus*. Based on the assumption we made, the UBC Farm can produce 2.5 acre × 10 tons of dry matter per acre which is equivalent to 25 tons of dry matter every year. After harvesting, the UBC Farm transports the dry matter to the BRDF on campus where *Miscanthus* is being converted into energy there. Currently, BRDF is paying $62 per ton of fuelstock, including *Miscanthus*. In other words, the UBC‘s gross revenue, excluding input cost and variable cost, from the BRDF will be $1550 per year. Since *Miscanthus* does not need to be replanted every year and requires very few fertilizers, its variable costs are relatively low compare to other annual crops due to its low maintenance fee. Therefore, it is not necessary for the UBC Farm to hire extra workers, where the existing labors are good enough to take care of it. However, during the harvesting, the UBC Farm may have to hire two to three part-time labors. Miscanthus can be harvested using a variety of silage equipment or conventional hay that the UBC Farm already has as well. Since the labors do not have to be professional in this area, it will cost the UBC Farm $2400 to hire three labors with $20 per hour for one week. After it is being harvested, it can be transported to the BRDF simply using a trailer and tractor that the farm already has and thus will cost only a few dollars in fuel. As a result, the cost per year is estimated to be around $2500, where the income from BRDF is only $1550 per year.

Considering the $2470 initial cost for 2.47 acre land area and the labor cost of $2400 per year, the UBC Farm can get the cost balance after planting *Miscanthus* for 30 years, while its expected lifespan is only around 20 years. Although Miscanthus is a high yielding and low input perennial, it is not profitable due to the limited land area at the UBC Farm and thus has insufficient production. Although planting *Miscanthus* is not profitable overall and does not have significant economic impact to UBC, it has environmental and social benefits that we will discuss in the following.

4.0 ECOLOGICAL ASPECT

4.1 REUSABILITY OF EXISTING SPACE AND MATERIALS

The existing hedgerows and farm margins are characterized as an agricultural land of the UBC Farm. By referring to Ecological Evaluation of Land for Planning Purposes (1971), the relative value of an agricultural zone can be determined through features shown on Figure 1. Based on the criteria, the site is evaluated and considered as Category III (See Table 1). This indicates the land has the average rarity and species-diversity of habitats (Tubbs & Blackwood, 1971, p. 169-170).

Grouping of features

1. Permanent grassland;
2. Hedgerows and hedgerow timber;
3. Boundary banks, roadside cuttings and banks, roadside verges;
4. Park timber and orchards other than those in commercial production;
5. Ponds, ditches, streams, and other watercourses;
6. Fragments of other unsown vegetation (including woodland) smaller than the one-half kilometre square size criterion.

Scoring for each group of features

0 = None or virtually none present in zone;
1 = Present (not conspicuous feature of zone);
2 = Numerous (conspicuous feature of zone);
3 = Abundant.

Evaluation of zone

Scoring	*Category*
15–18	II
11–14	III
6–10	IV
0–5	V

Figure 2: Definable features and a subjective scoring system for evaluation of agricultural zone (Tubbs & Blackwood, 1971, p. 170)

Features	**Scores**
Permanent grassland	3 = Abundant

Hedgerows and hedgerow timber	3 = Abundant
Boundary banks, roadside cuttings and banks, roadside verges	0 = None or virtually none present in zone
Park timber and orchards other than those in commercial production	2 = Numerous (conspicuous feature of zone);
Ponds, ditches, streams, and other watercourses	1 = Present (not conspicuous feature of zone)
Fragments of other unsown vegetation (includi woodland) smaller than the one-half kilometr square size criterion	3 = Abundant
Total Score	**12 (Category III: 11-14)**

Table 2: Evaluation of the existing hedgerows and farm margins

Therefore, the site has the potential to provide suitable habitat for migratory or resident species such as *Miscanthus*. Moreover, the site has some already existing improvements. There had been continued stone removal, and changes to the organic matter which improved the soil quality. In addition to these points, cultivation in this location will be able to produce a wide variety of crops throughout the year due to its mild maritime climate. These factors indicate that the land has been well maintained ("Farm Features"; "Hedgerows," 2013).

4.2 IMPROVEMENTS IN ENVIRONMENTAL CONDITION

Miscanthus is a warm-season grass, but it is also cold-tolerant so that it can still maintain a high carbon dioxide assimilation at temperatures below 15 degree Celsius (Heaton, 2011). Therefore, *Miscanthus* would be suitable for establishment and distribution within existing hedgerows and along farm margins due to its remarkable adaptability and tolerance to different environments. Also, as a perennial plant, *Miscanthus* offers better environmental profits compared to annual plants. The environmental impact of *Miscanthus* can be determined due to its fertilizer and pesticide demands, water and nutrient use efficiency, soil carbon storage, GHG mitigation, and biodiversity (Uffe, 2011, p. 24-25).

4.2.1 Low Input Requirements

As a perennial crop, *Miscanthus* usually has high productivity associated with low input requirements such as fertilizer and pesticide. *Miscanthus* only requires herbicides for the establishment years. Fertilizers may enhance weed growth to compete with young *Miscanthus* if there are sufficient nutrients present in the soil. Once plants mature, chemical fertilizer and pesticide use is not recommended (Caslin, Finnan, & Easson, 2011, p. 35). Furthermore, low fertilizer and pesticide demands of *Miscanthus* reduce nitrate pollution because it reveals low level of nitrate leaching, which is comparable to other forms of unfertilized grass such as forests and natural areas. Table 2 shows the loss of nitrate significantly becoming lower after planting *Miscanthus* in 1994 (Jones & Waish, 2000, p. 175; Uffe, 2011, p. 26).

Year	Leaching losses (Kg N ha^{-1})		
	Nitrogen fertiliser rates(Kg ha^{-1} yr^{-1})		
	0	60	120
1993–4	154	187	228
1994–5	8	24	87
1995–6	3	11	20

Table 3: Nitrate loss on unfertilized and fertilized Miscanthus plots (Jones & Waish, 2000, p. 175)

4.2.2 High Water and Nutrient Use Efficiency

As a C4 plant[1], *Miscanthus* is a very efficient user of water, and it also has low nutrient requirements compared to other bioenergy crops. *Miscanthus* develops deep and extensive rhizomes and roots to take up nutrients very efficiently and utilizes the nutrients to grow other plant parts. By referring to Table 3, it shows that nutrient uptakes through rhizome account for a large proportion of *Miscanthus* nutrient requirements. This also explains the low fertilizer requirement of *Miscanthus*. With high nutrient use efficiency, *Miscanthus* has the potential to turn small amount of nutrients into large amount of biomass (Caslin et al., 2011, p. 17; Pennington, 2012).

	At planting	After 1 year	After 2 years	After 3 years
Rhizome fresh weight (t/ha)	0.5	8	25	35
Total N in rhizomes (kg/ha)	2	25	80	115
Total P in rhizomes (kg/ha)	0.2	4	11	16
Total K in rhizomes (kg/ha)	3	40	130	180

Table 4: Rhizome Development and Nutrient Content over the First 3 Seasons of Growth (Caslin et al., 2011, p. 17)

4.3 PROTECTION FROM ENVIRONMENTAL DEGRADATION

4.3.1 Soil Carbon Sequestration

Miscanthus also offers a good solution to the harmful effects of bioenergy productions. The carbon emissions resulted from soil disturbance and vegetation loss can be mitigated by *Miscanthus* growth. By sequestering carbon into soil, *Miscanthus* can transfer carbon dioxide from and prevent its release into the atmosphere (Zimmermann, Dauber, & Jones, 2012, p. 453). In addition, *Miscanthus* also stores carbon in its rhizomes and roots. According to *Miscanthus* Best Practice Guidelines (Caslin et al., 2011, p. 17), "*Miscanthus* can store 8.8 tonnes of carbon per hectare in its roots and rhizomes

[1] C4 plant is "a plant in which the CO2 is first fixed into a compound containing four carbon atoms before entering the Calvin cycle of photosynthesis" ("C4 Plant,", n.d.).

12 years into its life." Soil carbon sequestration helps not only mitigates carbon emissions from fossil fuel combustion but also promote soil quality and long-term agronomic productivity (Sundermeier, Reeder, & Lal, n.d.).

4.3.2 GHG Mitigation

Growing *Miscanthus* as a renewable source of clean energy allows the conservation of fossil fuel such as oil and coal (Jones & Waish, 2000, p. 172). *Miscanthus* is capable of growing over 12 feet tall and producing a range of 10 to 15 tons of dry matter per acre. With recent advancements can now produce 25 tons ("Freedom Giant *Miscanthus* Fact Sheet", 2010; Heaton, 2011). One tonne of *Miscanthus* is roughly equivalent to 0.6 tonnes of coal while 30 tonnes of coal contains the same energy content as 12,000 litres of oil (Jones & Waish, 2000, p. 172). Also, 1.8 MW of electricity could be produced through 1 tonne of *Miscanthus* ("*Miscanthus* Overview", n.d.), which means growing *Miscanthus* as a fuel is very energy efficient. Although the dry matter yield of *Miscanthus* is typically insufficient to produce energy in the establishment year, the yield will keep increased every year, and the maximum may be reached in the third or fourth year (See Figure 2) (Heaton, 2011).

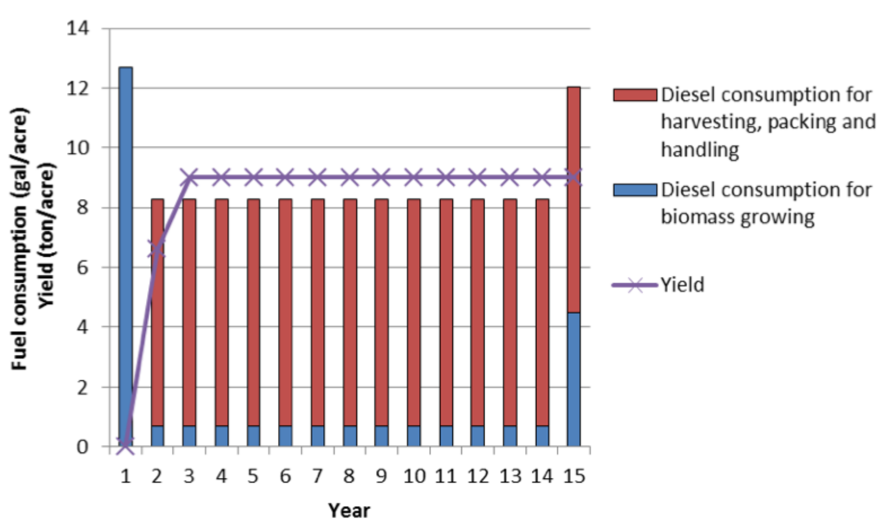

Figure 3: Year-to-year yield and fuel consumption for Miscanthus production excluding fertilizer production and transportation (Wang, Dunn, & Wan, 2012)

Table 4 summarizes the net avoided fossil energy when *Miscanthus* replaces it as an energy source. The amount of net avoided fossil energy can be affected due to variations in cultivation method, biomass yield, electricity generating technology and so on. However, the amount of net avoided fossil fuel still reveals the high net energy balance of *Miscanthus* compared to other bioenergy crops (Jones & Waish, 2000, p. 172-173). By referring the data in Table 4, when using *Miscanthus* to produce renewable energy in the UBC farm, it is predicted to avoid 148 GJ ($\frac{153+134+99+240+102+160}{6} = 148$) fossil energy per year.

Net avoided fossil energy (GJ ha^{-1})	Conversion route	Reference
153	gasification/CHP	Bijl (1996)
134	gasification	Bijl (1996)
99	co-firing	Bijl (1996)
240	not known	Hartmann (1995a)
102	not known	Jørgensen and Jørgensen (1996)
160	not known	Kaltschmitt *et al.* (1996)

Table 5: Net avoided fossil fuel energy (GJ ha^{-1}) when Miscanthus is used for energy production (Jones & Waish, 2000, p. 172).

Using *Miscanthus* as a source energy avoids emissions resulting from the combustion of fossil fuels, which is the main cause of GHG effect. Furthermore, *Miscanthus* is a carbon dioxide neutral fuel; therefore, carbon dioxide released from the combustion of *Miscanthus* is as much as it takes up. In other words, no net increase of carbon dioxide released into the atmosphere while *Miscanthus* is used as an energy source because the plant has absorbed carbon dioxide released during photosynthesis. According to *Miscanthus* for Energy and Fibre (2000), "the quantity of avoided GHG emissions arising when fossil fuels are replaced by biomass for energy production is equivalent to the sum of the GHG emissions which would be produced if the substituted fossil fuel were used for energy production." Therefore, the reduced amount of GHG emission when using *Miscanthus* as a fuel can be the sum of avoided CO_2, and Table 5 can be referred to see the reduction of CO_2 emissions resulted from *Miscanthus* combustion (Caslin et al., 2011, p. 35-36; Jones & Waish, 2000, p. 173-174). By referring the data in Table 5, when using *Miscanthus* as a biofuel in the UBC Farm, it is predicted to reduce 11.5 tonne CO_2 per year ($\frac{10.7+10.3+7.8+17.2+8.8+11.5}{6} = 11.5$), which is only around 0.019% of total GHG emissions for UBC's Vancouver campus buildings in 2012 ($\frac{11.5}{60,715} = 0.019\%$) ("GHG Inventory", n.d.).

Net CO_2 equivalent reduction (t ha^{-1})	Conversion route	Reference
10.7	gasification/CHP	Bijl (1996)
10.3	gasification	Bijl (1996)
7.8	co-firing	Bijl (1996)
17.2	not known	Hartmann (1995a)
8.8	not known	Jørgensen and Jørgensen (1996)
11.5	not known	Kaltschmitt *et al.* (1996)

Table 6: Net avoided GHG emissions (t ha^{-1}) when Miscanthus is used as a fuel for energy production (Jones & Waish, 2000, p. 173).

4.4 INCREASE IN SUSTAINABLE PRACTICES

As a biofuel, *Miscanthus* can be considered as a technology to reduce GHG emissions. The adoption is due to the closed biofuel life cycle shown in Figure 3. Growing plants recycles the carbon dioxide from the combustion of biofuel to prevent its release into the atmosphere, and later the plants are converted into biofuel ("The Clean Burning Alternative Fuel", n.d.). In other words, growing *Miscanthus* as a fuel would not have a net increase in carbon dioxide in the atmosphere. This points out that producing *Miscanthus* to create energy could be a good chance to start the sustainability.

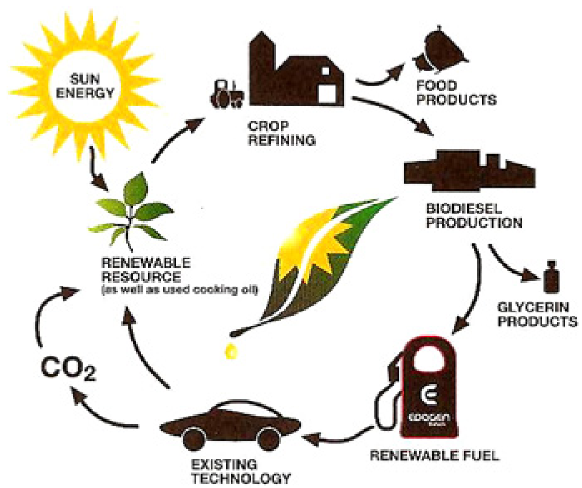

Figure 3: Biodiesel life cycle helps mitigate global warming ("The Clean Burning Alternative Fuel", n.d.)

5.0 SOCIAL ASPECT

Social impact analysis is one of the most important ideas used in Triple Bottom Lines method. There are four indicators used in this project to assess the social impact of the initiative:

- Increase in job opportunities
- Improve relationship across sectors and industries
- Enhance local ownership
- Provide educational opportunities

The four indicators show that the candidate plant *Miscanthus* has very positive impacts on the society and again *Miscanthus* should be used as primary biofuel grown in the UBC Farm.

Although *Miscanthus* requires minimal labor during planting comparing to other candidate plants, it probably requires some extra labor than the farm currently has. The main labor inputs are in planting, harvesting and storage stages. According to a study in the UK ("Policy for Energy Crops Scheme", 2013), planting *Miscanthus* in the estimated area on the UBC Farm requires human labor to first spray appropriate herbicide on the farm, prepare *Miscanthus* seeds and propagate the plants. Those processes are one-time investment ideally, and requires about two to three people to finish in two to three weeks. During the harvest seasons, more labor are needed to harvest and bale the *Miscanthus*. Since Vancouver, BC does not have extreme winter like Denmark (Erik, 2013), the exact chopping and pelleting on the farm may not be necessary. Therefore labor are saved and roughly two to three people may be able to handle it during the busy harvest seasons using appropriate machines.

Comparing to other biofuel candidates such as *Willow* and *Corn*, *Miscanthus* requires few inputs and care during the growth. Also after harvest, there are only a few work to process and handle the *Miscanthus* to be ready to use in BRDF, whereas *Corn* and *Willow* need much more work to dry and chop to be used in BRDF, and the parts like *Corn* meat need to be specifically taken care of to be use as other purposes. There is no labor wasted to handle other parts of the plants: all the harvested *Miscanthus* can be used to burn in BRDF and be part of energy conversion process. All in all, two to three job opportunities can be created during the busy seasons and very few labor are needed during the growth as *Miscanthus* requires few inputs.

Harvested *Miscanthus* bales should be stored like dried draws before they are used in BRDF ("UBC", 2013). This may potentially require the UBC Farm to deal with other departments or business owners to provide appropriate storage space. Since Vancouver, BC are wet and rainy during the winter, an indoor dried environment is recommended. UBC does have several dried storage warehouses provided on campus, and it is a good opportunity to contact those departments and seek any cooperations and this will enhance the relationship across departments.

The BRDF now purchases biofuels from WA, USA and BC Canada. Since *Miscanthus* is very suitable to grow on the UBC Farm as reasoned above, growing *Miscanthus* on the UBC Farm and supply BRDF can make BC own the entire chain and avoid dependencies of other states. As land exploration made above, the UBC Farm is able to provide the enough arable land to grow *Miscanthus* to meet the need of BRDF. On the other hand, the weather in Vancouver, BC may make *Miscanthus* much easier to grow and more likely contribute to more harvest(Erik, 2013). All the evidences and investigations lead to a conclusion that UBC is compatible to start the entire idea and is able to implement the whole chain independent of other states or countries. This improves local ownership which is one of the most important social indicators used in this project.

Nowadays, reducing GHG emissions has become a more and more important task. Many major countries like USA and EU encourage domestic reduction of GHG emissions(Mark & John, 2013). As posted months ago, President Obama declaring that ‘Americans across the country are already paying the price of inaction’ and American citizens now should take actions to cut GHG. The project is a very promising and convincing example for USA, the neighbour to learn: UBC is a living lab and shows a successfully story to Americans or even the world that reducing GHG is not only just words but also can be instantiated by actual starting on similar projects. The American can borrow the idea and copy what UBC has been done to reduce GHG. Since USA has much more arable land to grow biofuels, they can build same pattern on their own land and contribute to the world environment by reducing GHG emissions.

There are even more transferable opportunities for the project to be modeled in Europe as most European countries have similar latitude. The weather, political and economic systems and markets are even more similar to Canada. So this idea of using biofuel to reduce GHG are more likely to be educational in EU as well.

In summary, *Miscanthus* is more likely to be social friendly candidate as investigation above. There are four social indicators used to evaluate *Miscanthus* as well as other candidate plants. All of the social indicators show that *Miscanthus* can create some job opportunities, improve relationship across sectors and departments, enhance BC local ownership and provide a very sound educational opportunities to other provinces, USA and other countries.

6.0 CONCLUSION AND RECOMMENDATIONS

As a high yielding and low input perennial, *Miscanthus* would not have a any significant economic impact to the UBC Farm if growing it as fuelstock to create energy. On the other hand, in the ecological aspect, although *Miscanthus* could enhance the environmental condition and reusability of existing spaces and material in the UBC Farm, the quantity of GHG mitigation would be insignificant when fossil fuels are replaced by *Miscanthus* for energy production. In addition, considering social benefits, such as leading educational opportunities to other provinces and countries and a few job opportunities, planting Miscanthus at the UBC Farm would not be worthwhile in overall. Therefore, to conclude, the marginal land of the UBC Farm might be not capable of producing enough amount of *Miscanthus*, as a biofuel for energy production, to BRDF per year. However, the idea could still be highly transferable to other farms with bigger land scale and the benefits would be more significant. Moreover, in a long run, the economic, environmental and social benefits could be resulted from implementing such a low GHG emission project.

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