Hybrid Willow – Does it Pay?

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1. Introduction

- There has been increasing interest in using short-rotation woody crops (SRWC) as a source of biomass energy in Canada

- This interest has largely emerged from growing concerns over:
  - Energy security
  - Volatility of fossil fuel prices
  - Global CO_2 emissions
  - Need to revitalize rural economies

- **Hybrid willow** is one SRWC that has been identified as having outstanding potential to serve as a dedicated feedstock for the production of renewable energy and other products

  - It can provide a long-term, sustainable, carbon neutral replacement for fossil fuels, promote rural development & environmental co-benefits (water/wildlife)

Hybrid Willow Trials:

- Many hybrid willow experiments have been conducted in Canada over the past 30 years, most recently through the Canadian Biomass Innovation Network and the ecoENERGY Technology Initiative.
  - The focus of the experiments have been on examining growth & yield performance, and quantifying carbon and associated environmental co-benefits.
- In PEI, a number of landowners have been participating in a recent SRWC program called the Bioeconomy Crop Initiative.
  - Offered by the PEI Dept. of Agriculture through the Agricultural Flexibility Fund, a cost-sharing agreement between the Government of Canada and the Province.

Hybrid Willow Economics:

- The economics of hybrid willow crops has been studied in many regions of the world including Europe, the United States, and Canada.
  - Study findings often tend to support willow production as a competitive source of energy compared to other fossil fuels.

- **Examples:**
  - **Buchholz and Volk (2011)** examined benefits/costs of producing willow biomass for <u>off-farm</u> energy-use (10 hectare, 3-year rotation, 22-year horizon), upstate NY.
    - Findings: internal rate of return (IRR) = 5.5%.
  - **McKenney et al. (2011)** examined benefits/costs of producing willow biomass for <u>on-farm</u> greenhouse heat source (144-1430 ha, 3-year rotation, 20-year horizon), ONT.
    - Findings: IRR for displacing heating oil = 11% to 14%.
    - Findings: IRR for displacing natural gas = -1% to 4%.

The Issue:

- What is the relative economic attractiveness of producing hybrid willow crops on traditional farms (i.e., crop and livestock producers) for use as an <u>on-farm</u> vs. <u>off-farm</u> energy source?
  - To-date there has been no systematic comparison of these investment opportunities.
  - Need to conduct this analysis in the context of planting the crop on different types of land:
    - Marginal (high-sloped)
    - Productive (in-field)
    - Environmentally sensitive (non-legislated riparian)
  - Such analysis would shed light on possible opportunities for traditional farms to play a role in:
    - Revitalizing rural economies
    - Increasing energy security / Reducing reliance on fossil fuel prices
    - Contributing to global CO_2 emission reductions.

Study Objective:

- The purpose of this study was to conduct a financial benefit-cost analysis (BCA) of producing hybrid willow biomass on riparian, in-field, and high-sloped agricultural land in PEI for use as <u>on-farm</u> or <u>off-farm</u> renewable energy source.
  - Ancillary research questions to be explored include:

    (i) Under what conditions is hybrid willow production a feasible source of renewable energy for an average size farm on PEI?

    (ii) Can the use of fertilizer be justified on economic grounds?

    (iii) What would be the acreage requirement be to heat typical farm buildings on PEI?

2. Methods and Data

- Benefit-cost analysis included comparison of benefits & costs for a hybrid willow cropping system in PEI for <u>on-farm</u> and <u>off-farm</u> uses considering:
  - Project sizes of 3, 6, and 9 hectares
  - Yields on riparian, in-field, and high-sloped land (with/without fertilizer)

(a) <u>Off-farm</u> Use Scenario:

- Plant willow over the entire project size in the initial year
- Harvest and chip in year 4, and transport/sell chips in year 5 to PEI Energy Systems in Charlottetown.
- Subsequent harvests/transport/sales occurred every 3 years thereafter, for 7 rotations, followed by stump removal (a 23-year project).

(b) On-farm Use Scenario:

- Plant willow over 1/3 of the entire project size annually for the first 3 years
- Harvest and chip annually 1/3 of project size starting in year 4, and for use in a biomas boiler that would offset heating oil and other costs on the farm.
- Continue annual harvests for 7 rotations, followed by final harvest and stump removal (a 25-year project).

Illustration of a Biomass Boiler

Cost = $21,000

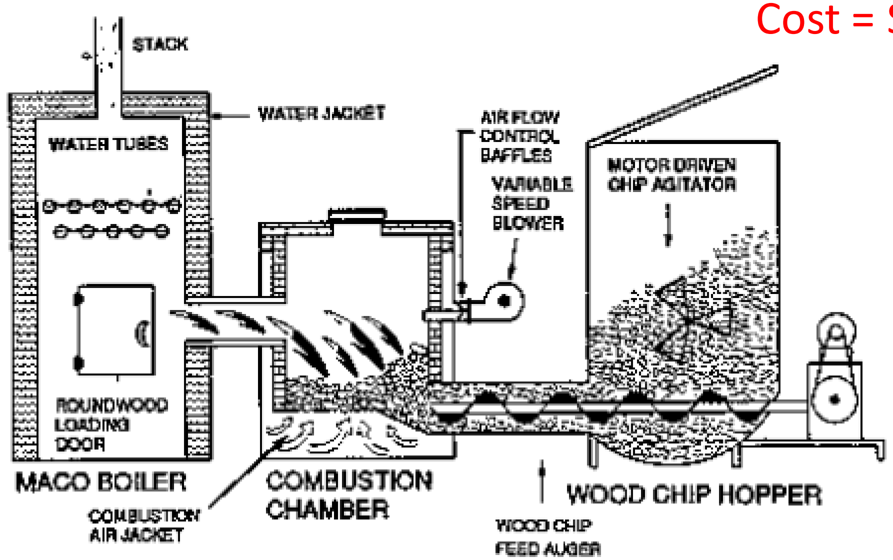

Figure 1. - Woodchip combustion system, courtesy of Island Bioenergy Newsletter

Range of willow yields from selected trials in Eastern Canada

Source	Location	Plot Characteristics		Productivity
		Age (yr)	Density (cuttings/ha)	ODT/ha/yr
Labrecque and Teodorescu (2005; 2003; 2001)	Quebec	4	18,000	6.2-16.9
		3	20,000	7.4-23.5
		3	20,000	4.9-15.1
Labrecque et al. (1993)	Quebec	3	27,000	11.2-13.6
Girouard et al. (1999)	Quebec	5	10,000	7.5-8.9
Schroeder (2012)	PEI (Riparian trials)	3	6,666	4.5-23.4 (average = 16)
Pharo (2012)	PEI (In-field trials)	3	6,666	7.0-19.6 (average = 13)
Wright (2012)	PEI (High-sloped trials)	3-4	6,666	2.5-3.7[a] (average = 3.1)

[a] Yields for the PEI high-sloped trials were atypically low due to significant mortality in the initial planting season.

Typical yields would be expected to be in the range of 8+ ODT/ha/yr , especially if fertilizer was used.

Basic hybrid willow cropping system costs per ha

Activity	Unit Cost (2012 CDN $/ha)	Year(s) Occurring
Plow (deep tillage)	$60	1
Disks (level and loosen)	$40	1
Cuttings	$1,000	1
Plastic mulch planting	$1,948	1
Broadcast grass seed	$70	1
Mechanical weed control	$70	1
Manual coppice	$531	1
Opportunity cost of land use	$185/$100	annually
Harvesting	$500	4, 7, 10, 13, 16, 19, 22
Stock removal	$400	22

Scenario Assumptions for off-farm use

Inputs	Unit	Value[a]	Year(s) Occurring
Project Size	ha	3/6/9	1-23
Project lifetime	years	23	1-23
Willow Yield	ODT/ha	16/14/12/10/8	annually
Planting area	ha	3/6/9	1
Site prep., planting, and maintenance costs	$/ha	$3,719	1
Fertilizer cost	$/ha	$60	1 (when applicable)
Harvesting area	ha	3/6/9	4, 7, 10, 13, 16, 19, 22
Harvesting cost	$/ha	$500	4, 7, 10, 13, 16, 19, 22
Transportation	$/ha	$456/$399/$342/ $285/$228	5, 8, 11, 14, 17, 20, 23
Harvest revenue	$/ha	$2,400/$2,100/ $1,800/$1,500/ $1,200	5, 8, 11, 14, 17, 20, 23
Stock removal	$/ha	$400	22
Discount rate	%	6	annually

[a] Multiple values separated with '/' indicate multiple scenarios.

Scenario Assumptions for <u>on-farm</u> use

Inputs	Unit	Value[a]	Year(s) Occurring
Project Size	ha	3/6/9	1-23
Project lifetime	years	23	1-23
Willow Yield	ODT/ha	16/14/12/10/8	annually
Planting area	ha	1/2/3	1, 2, 3
Site prep, planting, and maintenance costs	$/ha	$3,719	1, 2, 3
Fertilizer cost	$/ha	$60	1, 2, 3 (when applicable)
Harvesting area	ha	1/2/3	annually, in yr 4-24
Harvesting cost	$/ha	$500	annually, in yr 4-24
Biomass boiler financing cost	$	$1,785	annually, in yr 5-25
Cost savings (i.e., benefits) from displacing heating oil	$/ha	$18,035/ $15,781/ $13,526/ $11,272/ $9,018	annually, in yr 5-25
Stock removal	$/ha	$400	22, 23, 24
Discount rate	%	6	annually

[a] Multiple values separated with '/' indicate multiple scenarios.

3. Results

Benefit-cost analysis of willow production for off-farm use [a]
- Riparian land -

	Project Size		
	3 hectares	6 hectares	9 hectares
	No Fertilizer (16 ODT/ha/yr)		
Benefits ($)	50,400	100,800	151,200
Costs ($)	44,643	89,286	133,929
Net benefit ($)	5,757	11,514	17,271
Net present value ($)[b]	-3,806	-7,612	-11,419
Benefit- cost ratio ($/$)[b]	0.87	0.87	0.87
Internal rate of return (%)	2.90%	2.90%	2.90%
Payback Period (years)	16	16	16

[a] Assuming chips sold to PEI Energy Systems Waste Plant (at $50/ODT) over a 23-yr period.

[b] 6% discount rate.

Benefit-cost analysis of willow production for off-farm use [a]
- In-field Land -

	Project Size					
	3 hectares		6 hectares		9 hectares	
	Fertilizer (14 ODT/ha/y)	No Fertilizer (12 ODT/ha/y)	Fertilizer (14 ODT/ha/y)	No Fertilizer (12 ODT/ha/y)	Fertilizer (14 ODT/ha/y)	No Fertilizer (12 ODT/ha/y)
Benefits ($)	44,100	37,800	88,200	75,600	132,300	113,400
Costs ($)	43,626	42,249	87,252	84,498	130,878	126,747
NB ($)	474	-4,449	948	-8,898	1,422	-13,347
NPV ($)[b]	-6,528	-8,889	-13,055	-17,778	-19,583	-26,667
BCR ($/$)[b]	0.77	0.68	0.77	0.68	0.77	0.68
IRR (%)	0.26%	-2.85%	0.26%	-2.85%	0.26%	-2.85%
PP (years)	22	>23	22	>23	22	>23

[a] Assuming chips sold to PEI Energy Systems Waste Plant (at $50/ODT) over a 23-yr period.

[b] 6% discount rate.

Benefit-cost analysis of willow production for off-farm use [a]
- Steep-Sloped Land -

	Project Size					
	3 hectares		6 hectares		9 hectares	
	Fertilizer (10 ODT/ha/y)	No Fertilizer (8 ODT/ha/y)	Fertilizer (10 ODT/ha/y)	No Fertilizer (8 ODT/ha/y)	Fertilizer (10 ODT/ha/y)	No Fertilizer (8 ODT/ha/y)
Benefits ($)	$31,500	$25,200	$63,000	$50,400	$94,500	$75,600
Costs ($)	$35,622	$34,245	$71,244	$68,490	$106,866	$102,735
NB ($)	-$4,122	-$9,045	-$8,244	-$18,090	-$12,366	-$27,135
NPV ($)[b]	-$8,355	-$10,717	-$16,711	-$21,433	-$25,066	-$32,150
BCR ($/$)[b]	0.65	0.54	0.65	0.54	0.65	0.54
IRR (%)	-2.85%	-8.13%	-2.85%	-8.13%	-2.85%	-8.13%
PP (years)	>23	>23	>23	>23	>23	>23

[a] Assuming chips sold to PEI Energy Systems Waste Plant (at $50/ODT) over a 23-yr period.

[b] 6% discount rate.

Benefit-cost analysis of willow production for on-farm use [a]
- Riparian land -

	Project Size		
	3 hectares	6 hectares	9 hectares
	No Fertilizer (16 ODT/ha/yr)		
Benefits ($)	378,741	757,482	1,136,224
Costs ($)	64,784	92,081	119,378
Net benefit ($)	313,957	665,401	1,016,846
Net present value ($)[b]	141,942	301,516	461,090
Benefit- cost ratio ($/$)[b]	4.92	6.51	7.29
Internal rate of return (%)	52.58%	54.26%	54.81%
Payback Period (years)	4	4	4

[a] Assuming chips, with energy content of 13.8 GJ/ODT, and biomass boiler replace fuel oil (at $1.04/L) for heating typical farm buildings on PEI over a 25-year period.

[b] Assuming a 6% discount rate.

Benefit-cost analysis of willow production for on-farm use [a]
- In-field Land -

	Project Size					
	3 hectares		**6 hectares**		**9 hectares**	
	Fertilizer (14 ODT/ha/y)	No Fertilizer (12 ODT/ha/y)	Fertilizer (14 ODT/ha/y)	No Fertilizer (12 ODT/ha/y)	Fertilizer (14 ODT/ha/y)	No Fertilizer (12 ODT/ha/y)
Benefits ($)	331,399	284,056	662,797	568,112	994,196	852,168
Costs ($)	64,964	64,784	92,441	92,081	119,918	119,378
NB ($)	266,435	219,272	570,356	476,031	874,278	732,790
NPV ($)[b]	119,504	97,407	256,641	212,446	393,777	327,484
BCR ($/$)[b]	4.29	3.69	5.66	4.88	6.33	5.47
IRR (%)	47.64%	43.03%	49.47%	45.09%	50.07%	45.75%
PP (years)	4	5	4	5	4	5

[a] Assuming chips, with energy content of 13.8 GJ/ODT, and biomass boiler replace fuel oil (at $1.04/L) for heating typical farm buildings on PEI over a 25-year period.

[b] Assuming a 6% discount rate.

Benefit-cost analysis of willow production for on-farm use [a]
- Steep-Sloped Land -

	Project Size					
	3 hectares		6 hectares		9 hectares	
	Fertilizer (10 ODT/ha/y)	No Fertilizer (8 ODT/ha/y)	Fertilizer (10 ODT/ha/y)	No Fertilizer (8 ODT/ha/y)	Fertilizer (10 ODT/ha/y)	No Fertilizer (8 ODT/ha/y)
Benefits ($)	236,713	189,371	473,427	378,741	710,140	568,112
Costs ($)	62,924	62,744	88,361	88,001	113,798	113,258
NB ($)	173,789	126,627	385,066	290,740	596,342	454,854
NPV ($)[b]	76,100	54,002	169,832	125,637	263,564	197,271
BCR ($/$)[b]	3.16	2.54	4.21	3.39	4.74	3.82
IRR (%)	37.82%	31.57%	40.15%	34.32%	40.90%	35.20%
PP (years)	5	5	5	5	5	5

[a] Assuming chips, with energy content of 13.8 GJ/ODT, and biomass boiler replace fuel oil (at $1.04/L) for heating typical farm buildings on PEI over a 25-year period.

[b] Assuming a 6% discount rate.

Break-even biomass price ($/ODT) for off-farm use scenarios [a]

Project size	Riparian land		In-field land			High-sloped land	
	Fertilizer (16 ODT/ha/y)		Fertilizer (14 ODT/ha/y)	No Fertilizer (12 ODT/ha/y)		Fertilizer (10 ODT/ha/y)	No Fertilizer (8 ODT/ha/y)
3 hectares	$57.60		$64.90	$73.70		$76.70	$92.70
6 hectares	$57.60		$64.90	$73.70		$76.70	$92.70
9 hectares	$57.60		$64.90	$73.70		$76.70	$92.70

[a] These prices reflect the lowest biomass price that could support the hybrid willow project investment on economic grounds (current price = $50/ODT).

Break-even heating oil price ($/litre) for on-farm use scenarios [a]

Project size	Riparian land	In-field land		High-sloped land	
	Fertilizer (16 ODT/ha/y)	Fertilizer (14 ODT/ha/y)	No Fertilizer (12 ODT/ha/y)	Fertilizer (10 ODT/ha/y)	No Fertilizer (8 ODT/ha/y)
3 hectares	$0.21	$0.24	$0.28	$0.33	$0.41
6 hectares	$0.16	$0.18	$0.21	$0.25	$0.31
9 hectares	$0.14	$0.17	$0.19	$0.22	$0.27

[a] These prices reflect the lowest heating oil price that could support the hybrid willow project investment on economic grounds (current price = $1.04/L).

4. Summary

- **Off-farm use**:
  - At a current price of $50 per oven dried tonne (ODT) sold to PEI Energy Systems, willow is not an attractive investment opportunity for farmers.
  - Biomass prices would have to increase to the range of $58-$93/ODT before such an investment would be profitable.

- **On-farm use**:
  - At a current price of $1.04/L for fuel oil to heat farm buildings, willow is a very attractive investment opportunity for farmers.
  - Heat replacement costs of $39-$124/ODT to implement the system and biomass boiler vs. cost savings of $375/ODT from displacing heating oil

    … net savings = $336-$251/ODT.
  - Using this system would reduce heating costs on the farm in the range of 67%-90%.
  - Fuel oil prices would have to decrease to the range of $0.14-$0.41/L before such an investment would be unprofitable.

5. Limitations

- There are a number of issues and assumptions that need to be further investigated in order to instill confidence in these estimates.

- **Yield uncertainty**: yields vary substantially by test site and clones. Studies have shown that field-scale yields are sometimes lower than test sites

- **Fertilizer impact uncertainty**: relatively little is known empirically about the impacts of fertilizer on willow yields, especially in the PEI region

- **Unit cost uncertainty**: little is known about local input costs for willow production. We've estimated average PEI farm cost estimates using the expert opinion and data from a recent willow study in Ontario.
  - These estimates could vary considerably by farm and, as such, future efforts should be made to verify the costs with farmers.

- **Additional costs and benefits**: these may include unaccounted-for costs (opportunity, administration, maintenance, etc.), potential ALUS payments, carbon credit payments , and other environmental service benefits (e.g., water quality; wildlife habitat; aesthetics; etc.).