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Industrial and Market *Development of Biochar* in British Columbia

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EXECUTIVE SUMMARY

Biochar is a form of black carbon created from biomass. It holds great potential for reducing greenhouse gas (GHG) emissions in British Columbia (BC), and in the longer term, for diversifying into higher value products and markets. The BC government considers biochar a renewable, low-carbon fuel because rather than introducing more carbon to the atmosphere (as burning fossil fuels does), it simply releases carbon that would have been emitted if the biological feedstock naturally biodegrades. Substituting biochar for coal or natural gas as a fuel could help reduce the province's GHG emissions by up to 22 per cent, which is a big step towards BC's emissions reduction goal of at least 33 per cent below 2007 levels by 2020. Biochar can also be used for air or water filtration, as a soil amendment, and as a method for sequestering carbon. It offers additional potential to create higher value products such as carbon electrodes or synthetic graphite.

Biochar shares chemical and physical properties with graphite, charcoal, and biocoal (roasted biomass). It is produced from organic material (feedstock) such as wood waste, mill residue straw, or manure through a high-temperature process called pyrolysis. Currently, 12 BC-based companies are known to be producing or planning to produce biochar and a related product, biocoal. The largest step towards developing a biochar industry in BC was a 2012 coal offset proposal advanced through the province's crown corporation at the time, the Pacific Carbon Trust. Additionally, the incremental, revenue-neutral BC Carbon Tax, introduced in 2008, has helped put a price on GHGs associated with fossil fuels, making renewable low-carbon fuels like biochar more competitive.

In terms of legislation, the 2008 BC Bioenergy Strategy helped BC establish a diverse bioenergy market. Since then, however, there has been a lack of government planning around BC's bioenergy industry, including biochar. Additionally, there has been no planning or analysis as to how applications of available biomass resources could most benefit BC's greenhouse gas reduction goals or which bioenergy sectors can be expected to dominate in the future. Without proper planning, future competition for, and increased costs of, waste feedstock for bioenergy could reduce the economic viability for the wider sector, which includes wood-pellet and electricity producers as well as production of second-generation biofuels and low-revenue biochar products.

In BC, excess available biomass waste feedstocks are around 10 million tonnes per year, mainly from forest operations and mills. If this was converted at a 50 per cent yield, five million tonnes of biochar could be produced. If all of this were to be used for coal substitution, for example, it would account for 270 per cent of BC's internal coal usage, including cement production and industrial steam generation. In relation to GHG reductions, if BC were to also substitute a portion of all stationary combustion of fossil fuels with biochar, this could reduce provincial emissions by 22 per cent.

Biochar environmental policies need clarification if BC is to develop a world-class industry. Fortunately, many international agencies have already developed guidelines for producing and using biochar. These cover sustainable production, energy and carbon management, and environmental regulations, and can help guide development of a robust BC biochar industry.

As a fuel, biochar cannot currently compete with conventional fossil fuels on cost alone. However, its environmental benefit has the potential to take BC more than half the way to its GHG reduction goals for 2020. And in the long term, the BC biochar market could evolve into a value-added carbon products industry. The economic viability of biochar would also improve significantly if it becomes tradable as a carbon offset (as it is in Australia) and if the BC Carbon Tax continues to rise, thereby making fossil fuels more expensive by comparison.

This report offers six recommendations designed to move British Columbia toward optimizing the value of its biomass resources:

1. A roundtable should be formed to establish an updated bioenergy strategy. Members should include forestry, agricultural and bioenergy stakeholders, government, carbon auditors, and academia. The roundtable should be charged with developing a biomass strategy and recommending policies that will make best use of limited resources.

2. In the near term, the Climate Action Secretariat should pursue carbon offsets through non-combustion applications of biochar as well as encourage its use as a fuel to displace coal combustion. Over the long term, development of biochar could focus on exploring potential markets where no other renewable alternatives exist (such as the metallurgy industry) or in producing potential higher-value products like synthetic graphite, carbon electrodes, or activated charcoal.

3. Research supported by the province should be conducted by both industry and academia to reduce uncertainty around the efficacy of biochar soil applications, plant growth enhancements, and net emissions reductions.

4. A significant increase in the BC Carbon Tax is recommended. This will improve the cost competitiveness of biochar with coal and natural gas combustion in BC.

5. Application of biochar and ash from combustion of wood products should be clarified as a soil amendment within the Code of Practice for Soil Amendments in BC.

6. Regulations for biochar production, transportation and use should be clarified and require no smoke production and very low emissions of particulate matter such as black carbon.

1. INTRODUCTION

1.1 Description of biochar

Bioenergy is renewable energy created from biologically derived products including ethanol, synthetic natural gas, and a charcoal-like product known as biochar, which can be used to make electricity and heat. The British Columbia (BC) bioenergy industry has developed greatly in recent years. Industrial-scale electricity and heating projects have been built around the province, including novel systems such as a wood to synthetic gas district-heating system at the University of Northern British Columbia in Prince George.

Biochar is similar to the blackened charcoal found at the bottom of extinguished fires. It is made on an industrial scale through a process called pyrolysis, which is the splitting of organic matter in high-temperature, oxygen-limited environments. Biochar is produced in kilns or other closed vessels with either a single batch or continuous flow through process. The facilities for making biochar can vary in size and can be mobile on the back of a 40-foot truck or stationary within a building.

Biochar may be produced from high-fibre organic substances such as nutshells, straw or manure, but wood wastes are the most common starting material. Many of these resources are referred to as biomass and are also a resource feedstock for many other bioenergy processes. The name biochar has, until recently, usually applied to a product destined for use in soil. However this term has begun to be more broadly adopted into the bioenergy and carbon industries as its potential as a versatile product has grown.

Other products along the same charred-carbon spectrum as biochar are blackened carbon, activated charcoal, biocoal, and charcoal. These products are made with different methods and are intended for different purposes. The encompassing term of 'biochar' will be used in this document, however, as it refers to char made from biological sources.

Graphite, another form of carbon, is either mined or made in a similar process at much higher temperatures, around 2500°C. While uses do not overlap at this time, current production of synthetic graphite could help guide research on potential uses of biochar in the future.

At least 12 BC companies are known to be planning to produce or are currently producing biochar and biochar-like products (Table 1). Some BC companies, such as Dynamotive Energy Systems, have focused on co-products of biochar, such as pyrolysis oil. Others, such as Out of Ashes, are focused on producing biochar as a soil amendment. Companies producing biocoal are included in the overview here because the biocoal production process, known as torrefaction, takes place at the low end of the temperature range in which pyrolysis occurs, around 200°C to 300°C.

Table 1. List of biochar and biocoal companies based in BC.

Company	Headquarters	Known or Planned Facility
Biochar/pyrolysis-oil/syngas		
Alterna Biocarbon	Prince George	McBride
BC Biocarbon	Prince George	Prince George
Canadian Agrichar	Grand Forks	Grand Forks
Canadian Biocoal	Vancouver	Prince George
Clean Energy Consulting	Vancouver	Prince George
Diacarbon Energy	Burnaby	Chilliwack
Dynamotive Energy Systems	Richmond	Guelph and West Lorne, ON
Out of Ashes Bioenergy	Quesnel	Prince George
Poncho Wilcox	Prince George	Prince George
Pytrade Canada	Vancouver	Prince George
Biocoal (torrefied wood)		
Global Biocoal Energy	Vancouver	70 Mile House
Nations Energy Corporation	Vancouver	Kamloops

The diverse opportunities and potential for growth in the biochar market indicate the need for planning, especially since biochar may need to compete with other applications for biomass. This white paper is therefore intended to assist policymakers in assessing the bioenergy industry and developing policies that will see BC make the best of its biomass resources.

1.2 BC green economy and emissions-reduction targets

i Background

The BC green economy is one of the province's fastest growing economic sectors. Through the Greenhouse Gas (GHG) Reduction Targets Act of 2007, BC aims to reduce its GHG emissions by at least 33 per cent below 2007 levels by 2020 and 80 per cent below 2007 levels by 2050, in all sectors. To help reach these targets BC introduced the BC Carbon Tax in 2008. The tax is revenue-neutral: all returns to the treasury derived from the tax on carbon emissions are used to reduce provincial corporate and personal income taxes. In addition to setting emissions reductions targets, the Greenhouse Gas Reduction Targets Act required the provincial government, including provincial ministries and agencies, schools, colleges, universities, health authorities and Crown corporations, to become carbon neutral by 2010. That requirement was met in part through the purchase of carbon offsets, wherein businesses and organizations, including the government, buy offsets that pay for the economic cost difference of carbon reduction activities. Until recently offsets in BC were purchased through a crown corporation, the Pacific Carbon Trust (PCT), at $25 per tonne CO_2 equivalent.[2] In November 2013[3] it was announced that the Pacific Carbon Trust would be transitioned, and its operations moved (by April 2014), into the Climate Action Secretariat[3], an office within the BC Ministry of Environment that coordinates climate action activities with various stakeholders.

ii The role of biochar

Biochar can help BC meet its emissions-reduction targets. The BC government classifies biochar as low-carbon product because when burned as a fuel or stored in the ground, instead of emitting additional carbon dioxide that hasn't previously been part of the modern global carbon cycle, biochar emits carbon that would have been released if the original biological feedstock had naturally biodegraded.

In 2010 and across all sectors, BC's CO_2-equivalent (CO_2e) emissions totaled 62 million tonnes, with 19 million tonnes from stationary sources. If BC substituted potentially available low-cost biochar for a portion of all stationary combustion of fossil fuels, such as burning coal or natural gas for industrial heat (discussed in the 'Biomass supply and costs' section below), overall emissions could be reduced by 13.4 million tonnes, or 22 per cent of BC's total emissions. This is two-thirds of the way to BC's legislated 2020 reductions target.

Biochar can also be used as a soil additive. As well as providing nutrients for soil, the carbon remains 'locked up' in the particles (unlike decaying organic matter or manure) and is released into the atmosphere very slowly (on the order of about 25 per cent loss over 100 years, as discussed below. Thus, the application of biochar to soils offers mitigation gains. In fact, its use as a soil amendment can result in net carbon sequestration that can equal to, or in some cases, exceed the reduction in carbon emissions achieved by using biochar as a substitute for coal.

2. BIOCHAR PRODUCTION AND ASSOCIATED PRODUCTS

2.1. Biochar (solid)

Figure 1 shows various images of biochar at different scales. At a molecular level, biochar (c) is a highly complex structure of crystalline carbon rings. Biochar is not a uniform product, as various properties can be achieved by modifying the production process.[4,5] Variations can be made to peak heating temperature, heating period, level of oxygen, pressure, and feedstock. This can vary properties of biochar such as porosity, water-holding capacity, and carbon, oxygen, and hydrogen content. Ultimately, biochar should be viewed as one of a host of cellulose (wood)-based products such lumber, paper, torrefied wood siding, and wood pellets.

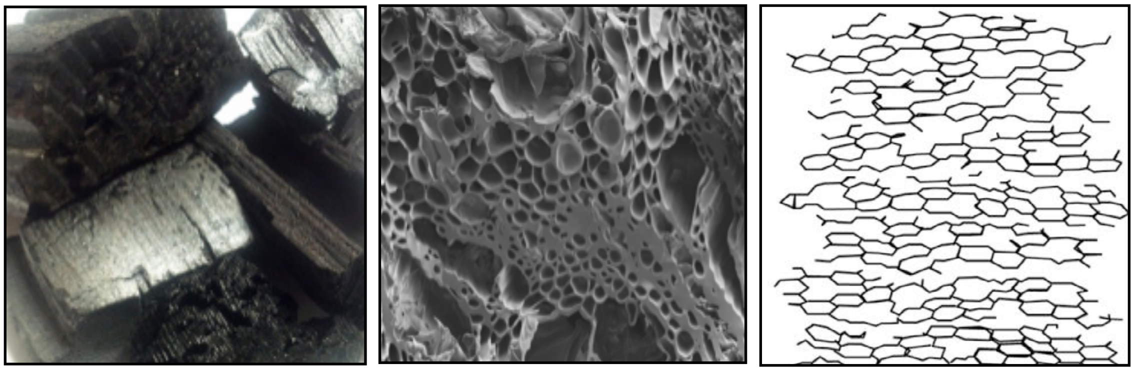

Figure 1. Images of biochar a)-macro-scale (author's image), b)-micro-scale (public domain), and c)-molecular-scale showing relatively organized and crystalline carbon-ring (turbostratic) structure.[6]

Gas and liquid are also produced when biochar is made. The proportion of feedstock converted to biochar, gas or liquid can vary greatly, depending on the type of feedstock and whether fast or slow pyrolysis is used. Table 2 shows the average proportion of primary products obtained from various methods.[7] Average levels of recovered biochar range from 10-35 per cent.[4]

Table 2. Typical product yields from dry wood obtained by different methods of wood pyrolysis.[7]

Pyrolysis type	Conditions	Biochar (solid)	Producer gas/sygas (Gas)	Pyrolysis oil (Liquid)
Fast	Moderate temperature, around 500°C, short hot exposure time ~ 1 second	12%	13%	75%
Intermediate	Moderate temperature, around 500°C, moderate hot exposure time ~ 10-20 seconds	20%	30%	50%
Slow	Low temperature, around 400°C, very long solids exposure time	35%	35%	30%
Gasification	High temperature, around 800°C, long exposure time	10%	85%	5%

2.2. Producer gas/syngas (gas)

A common co-product obtained through biochar production is a non-condensable gas known as producer gas or 'syngas'. The gas is called non-condensable because it will not form a liquid without significant cooling. The main constituents are carbon monoxide, hydrogen gas, and carbon dioxide. Carbon monoxide and hydrogen are combustible and are commonly used to run the pyrolysis process. Syngas can be used as a fuel, for heat and electricity production, or a feedstock for other chemical processes.

2.3. Pyrolysis oil (bio-oil) (liquid)

Pyrolysis oil, also known as bio-oil, is a co-product of pyrolysis; however it may also be the primary and targeted product. Pyrolysis oil contains relatively high levels of water and oxygen and can be used as a heating fuel or as a feedstock for making other fuels or chemical syntheses.

2.4. Heat

Heat is a byproduct from the pyrolysis of biochar. Due to its high temperature, there is large potential for recovery and reuse. Waste heat can preheat or dry feedstocks, and can supply external heating needs.

3. USES OF BIOCHAR

3.1 Energy uses

Biochar has the approximate energy density of coal and can be used as its direct substitute in electricity or heat production plants, with only minor retrofits needed. This displaces GHG emissions from coal. In comparison, wood pellets can only substitute for up to 20 per cent of the coal without retrofitting a power plant's boilers.

Biochar can also be used as a feedstock for chemical conversion to liquid transportation fuels, although this process is inefficient. And it can also be used in industrial applications involving both electricity and heat, for example heating commercial greenhouses or producing industrial steam. Finally, it can be exported as biochar or biocoal pellets.

The production of biochar itself offers another opportunity for energy generation. During production, 50 to 70 per cent of the original potential energy of the feedstock is retained in the biochar. The remainder is expressed in the byproducts of heat and gases. This energy could be usefully captured by coupling biochar production with electricity generation or heat generation. For example, in remote areas, off-grid diesel electricity generators can be replaced with a biochar producing facility, with the byproduct gases being used to run the generator instead of diesel. The resultant biochar could then be used as a local heating fuel or exported for added value.

3.2 Soil uses

Biochar can be added to soil for many purposes. It increases water-holding capacity, a benefit that is well understood and could be used to help mitigate drying during periods of drought. Parameters like soil type, plant type, climate, biochar application rate and properties and use of fertilizers all influence the efficacy of biochar in soil applications[5]. Additionally, soil applications may reduce net GHG emissions because the biochar sequesters carbon, keeping it out of the atmosphere, as discussed below. However, while considerable research has been conducted on the optimal use of biochar to increase soil productivity, results are not consistent. There remains a clear need to conduct additional research, particularly in a province like British Columbia where soil types and environmental conditions span a very wide spectrum.

3.3 Other uses of biochar

Biochar products typically have high surface area and chemically activated surfaces for binding other molecules[5], which make biochar a good raw material for activated carbon applications such as air and water filtration.[8] Biochar could be used for example to recover nutrients from wastewater treatment plants. The enriched material could then be applied to soil to fertilize crops, with the added benefit of reducing the nutrient load released into the wider environment from effluent.

There is also the potential for biochar to be converted into high-value carbon products. Applications could include manufacturing of synthetic graphite, which can be used in some types of batteries and fuel cells, and carbon electrodes in electric arc furnaces for aluminum production and metal recycling. Carbon electrodes in these industries are valuable, selling for $1500 to $5000 per tonne.[9]

4. CHALLENGES OF BIOCHAR USE IN BC

4.1 Environmental considerations

The biochar industry offers many potential environmental benefits but also impacts. Limiting the latter will be key to the industry's success. Environmental considerations discussed in this section are GHG emissions, environmental value of feedstock, smoke production, ash recovery and use, and potential toxicity.

i Non-combustion impacts on GHG emissions

Burning biomass for energy generation can result in significant air pollution. Of particular concern is black carbon particulate emissions (smoke). Dark-coloured surfaces absorb more sunlight and therefore anywhere black carbon particles settle can experience warming, or even increased melting if the particles settle on snow or ice. Simple charcoal production makes large amounts of smoke and black carbon. Thus, modern biochar production should strive to be 'smokeless' by adopting processing systems that capture the carbon particulates before they are emitted as smoke.

As a carbon sequestration mechanism, biochar is relatively predictable and quantifiable, and could be adopted by the carbon-offset industry. Although stable as a form of carbon, biochar does lose carbon slowly when applied to soils. The amount and rate of decomposition depend on many factors: the feedstock used; how the biochar was produced; and general environmental conditions.[5] One study[10] analyzed CO_2 released during the decomposition of biochar derived from various feedstocks (oak, pine, cedar, bubinga, grass, and sugar cane) over one year. Extrapolated carbon losses ranged from 3 to 26 per cent over a 100-year period, with overall half-life (time required for half the biochar to be lost) typically ranging from 100 to 10,000,000 years. Most of the estimated decomposition is projected to occur in the first century. Over longer time periods, decomposition eventually stabilizes. Table 3 summarizes results for three types of wood found in BC: oak, pine, and cedar. These results are based on 32°C temperatures, much higher than average temperatures in the province. Half-lives in British Columbian soils can therefore be expected to be considerably longer, as decomposition rates are temperature dependent.

Table 3. Modeled biochar degradation for half-life and per cent loss in 100 years.[10] Per cent loss of carbon in the first 100 years is shown with '100 year Clost'. Temperatures represent the peak heating temperature during pyrolysis.

	250 °C		400 °C		525 °C		650 °C
Feedstock	Half-life	100 year C_{lost}	Half-life	100 year C_{lost}	Half-life	100 year C_{lost}	Half-life
Oak	840 years	20%	1,020 years	18%	9,590 years	7%	96,200 years
Pine	Could not calc.	7%	990 years	14%	6,790 years	8%	17,000 years
Cedar	730 years	16%	23,800 years	7%	12,800 years	7%	20 million years

Research suggests that emissions from soils of nitrous oxide and methane (N_2O and CH_4, both greenhouse gases) are suppressed following biochar application.[11-20] However, no data exist for this suppression over a period longer than one year, and thus there is an information gap. Mechanisms that can account for such inhibition are not fully understood: microbial influences, altered soil properties and possible increases in soil aeration may explain the observed reductions in N_2O and CH_4 releases to the atmosphere.

ii Other environmental concerns for biochar production

Coarse woody debris left after logging operations plays an important role in ecosystem biodiversity and helps to reduce soil erosion and runoff. Extensive harvesting of such debris for bioenergy production could therefore become a concern in the future.

If biochar is to be applied to soils it will be important to understand its potential toxic and erosive impacts, as well as effects on soil microorganisms, the nitrogen cycle, and water retention. A particular concern is that biochar may be produced with low levels of associated toxic compounds that can be found in pyrolysis oils and syngas. At least in the short-term, such toxins can be harmful to soil microbes and plants, however they may be limited through specific biochar production methods.

If biomass or biochar is burned along with coal, application of the resulting ash to soil may be restricted due to heavy metal and other contaminants derived from the coal. However, clean ash generated from burning biomass or biochar is less problematic and should be directly usable for application to soils. As such ash is also slightly alkaline, it can be used as a mild liming agent.

4.2 Economic factors in biochar production

i Biomass supply and costs

Feedstock supply is a significant influence in determining the economic viability of biochar, as there is competition with other bioenergy uses. Biomass is currently used in British Columbia for wood pellet production and burned to generate industrial heat and electricity. Availability of feedstock supply depends on many factors including the price of carbon, production of crops dedicated to energy applications, and the development of a supply chain.

Low cost biomass available for biochar feedstock is limited in BC. The lowest-cost feedstocks – about $20 per tonne – are mill residues which account for about 20 per cent of harvested roundwood. These include sawdust, shavings, and hog fuel, primarily bark. These residues have ideal characteristics for the biomass industry: low moisture content, small particle size, typically low transportation distances, and low cost. But the amount of such residues available in BC has been decreasing due to reduced sawmill activity, technological improvements in milling that reduce sawdust production, and increasing bioenergy use, which can raise prices. More expensive bioenergy feedstocks include forestry residues from logging operations, crops grown specifically for bioenergy use, municipal solid waste and standing timber. With that said, forestry residues from logging operations, commonly called slash piles, are mainly burned on site at cost to both the logging company and to air quality. Therefore, using biomass in slash piles to produce biochar offers an environmental positive and, depending on location, possible economic returns. Table 4 lists several different estimates of how much biomass is available for use as a feedstock from these sources in BC.

Table 4. Summary of several recent estimates of biomass supplies in BC. Values in million dry tonnes/year.

	Estimate of resource at less than $100/ODT[21]	BC Hydro estimate of available resource[22]	Estimate based on forest model[23]	Estimate for poplar plantations[24]	BIOCAP estimate[25]	Approx. average
Mill residues	8.40					8.40
Forest residues	**8.70[a]**	**3 – 4**	**7.8[b]**		**14.4[c]**	**10**
Energy crops (wood)	0.14			6.3	4	3.5
Energy crops					2.6[d]	2.6
Standing timber		6 – 18			8.7	10
Municipal solid waste	0.67				0.95	0.81

a – based on 16 per cent of roundwood production, cost estimate of 30–55 $/ODT based on grinding & transportation

b – assumes 50 per cent of clearcut residues are available for harvest

c – based on 20 per cent of roundwood production, includes 2.4 million tonnes from increased harvesting of mountain pine beetle-affected trees

d – assumes a yield of 10 tonnes/hectare/year

In 2010, a total of 28 million tonnes of biomass was harvested in BC. Ten million tonnes were used for bioenergy, and one million were exported as pellets. These two uses consumed all of the available mill residues and pulp and paper energy byproducts, known as liquors. Table 4 shows that the remaining biomass, available at a price of less than $100 per tonne (primarily accessible from forestry residues, as well as energy crops and municipal solid waste), is conservatively likely to be only 10 million tonnes per year. Thus, feedstock supply limitations could become a concern if biochar and other bioenergy uses increase.

Conversion at a 50 per cent yield of the 10 million tonnes of known BC feedstocks, recoverable annually at less than $100 per tonne, would produce five millions tons of biochar, condensable oils and tars. To put that number in context, it is equal to 270 per cent of the coal burned in BC to produce industrial steam and manufacture cement.[26] Thus, on a sustainable and theoretical basis there is more than sufficient potential biochar capacity to displace all of the coal currently combusted annually in British Columbia.

Cost would be an issue however. Biochar producers would need to sell their product for approximately two to three times the cost of the original biomass to be profitable, because during pyrolysis only approximately a half to a third of the original biomass is transformable into saleable biochar during pyrolysis. Moreover, while biochar can directly substitute for coal in a cement kiln with only minor retrofits, significant retrofitting would be required for it to substitute for other fossil fuels such as natural gas.

A more tractable and immediate use could be use of biochar in energy production in remote off-grid communities in BC that currently rely on expensive diesel-powered generation. Regional production of biomass from sustainable forest harvesting or local mills would reduce the cost of transporting the raw material, while combusting energy-dense biochar at local facilities would eliminate additional transportation costs.

ii Carbon offsets and pricing

The economic viability of biochar rests in part on its potential value as a carbon offset. However, the BC carbon offset market does not currently include credits for biochar, unlike the case in Australia, which has established a public market for biochar offsets through a program called the Carbon Farming Initiative.[27] Farmers there may add biochar to their soils as an amendment to enhance productivity, with the added benefit of carbon sequestration. The program stipulates that the carbon must be stored in the soil for at least 100 years. Offsets sales began in 2012/2013 at a fixed price of $23 AUD per tonne; buyers purchase carbon credits from farmers at that price to offset their own emissions. This system will shift to a flexible cap-and-trade price in 2015/2016 assuming the program continues under the new Australian government.

Biochar used for soil amendment should qualify as a carbon offset in BC. However, the companies that make biochar individually produce low volumes and this constrains their ability to provide sufficient offset capacity to create market interest. To remove this constraint, carbon offset aggregators or the biochar producers themselves through aggregation co-operatives should collectively pool and sell their offsets from carbon sequestration. Launching an initiative in BC like the Australian Carbon Farming program would require recognition from the Climate Action Secretariat that biochar used to amend soils qualifies formally for carbon offsets.

5. POLICY DEVELOPMENT OF THE BC BIOCHAR MARKET

5.1 BC carbon market

The BC Carbon Tax has helped renewable and low carbon fuels become more cost competitive relative to fossil fuels. Biochar could displace coal, coke, and natural gas used to generate heat; however such use depends heavily on access to low-cost biomass (Figure 2). As indicated in the figure, at a CO_2 emissions tax rate of $30 per tonne, biomass must cost less than $70 per tonne to compete with natural gas, and about $48 per tonne to compete with coke. Clearly, by pushing up the price of fossil fuels, increases in the BC Carbon Tax would improve the cost competitiveness of biochar. Other factors such as improvements in technology, economies of scale, growth of end product uses, and evolution of low-cost feedstocks with high-volumes will also influence the marketability of biochar. Exploiting these will require continued research and development.

At present, there are no known private carbon offset companies in BC that sell biochar credits for either carbon sequestration or fuel replacement. At the public level, the Pacific Carbon Trust (PCT) requested proposals in 2012 for the sale of offsets by organizations willing to switch from burning coal to burning BC biochar ("biocoal" in the PCT request).[28] This coal-offset program would fund the current price difference between biochar/biocoal and coal. Although the PCT's operations are being subsumed into the Climate Action Secretariat, negotiations with biochar producers to promote the coal-to-biochar switch are continuing. This pathway will provide the primary mechanism to facilitate the sale of biochar or biocoal for fossil fuel energy offsets in BC. With the potential to access carbon offsets through the PCT at approximately \$15/tonne CO_2, and with the BC Carbon Tax at \$30/tonne CO_2, companies and organizations have a double layered \$45/tonne incentive to reduce fossil fuel use.

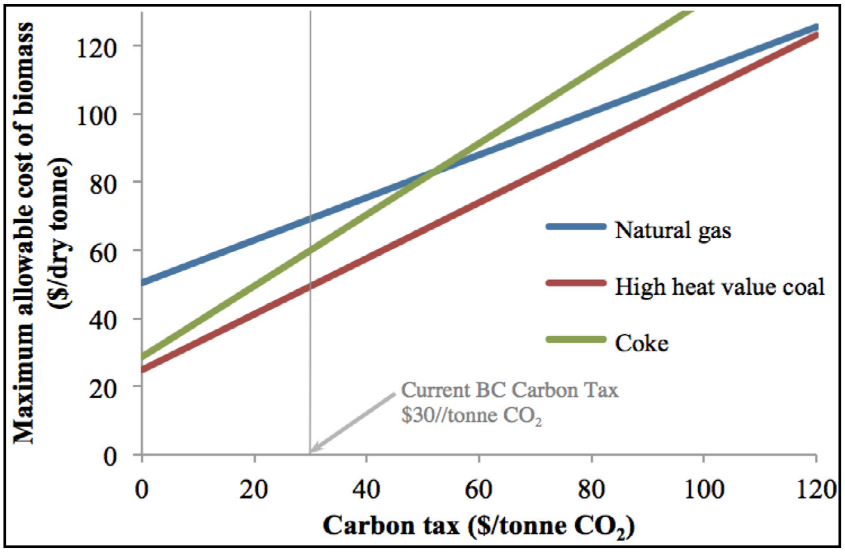

Figure 2. Estimated maximum economical cost of biomass for biochar production compared to the price of carbon emissions. Increases to the carbon tax will allow higher cost biomass to be recoverable or biochar to be produced with higher resale value.

i Comparing biochar to other biomass options to mitigate climate change

Currently, BC's biomass resources are being used in bioenergy applications that are displacing fossil fuels and yielding varying amounts of carbon reductions. Figure 3 shows conceptually various uses of BC's biomass resources and their GHG emissions reductions as well as their revenue-generating potential. Use of biomass to produce biochar and high-carbon products is most effective at reducing GHGs and also optimizing long-term revenue. In contrast, biomass burned directly to generate electricity has relatively low GHG reduction potential depending on the location and fossil fuel intensity of the electricity grid. Such combustion would be a poor choice in BC where almost all electricity is generated from hydroelectricity; it would be a better choice in Alberta, for example, where power is generated primarily via coal and natural gas combustion.

Biomass can also be burned to offset natural gas, with medium GHG reduction potential, and/or be exported as wood pellets, primarily to Europe, with medium to high GHG reduction potential. Note that the net reduction in emissions from exporting biomass is lower than if the materials were consumed locally because fossil fuels are burned in shipping pellets offshore.

Finally, because biochar can directly replace coal with very little retrofitting required in BC or Alberta plants, it offers significant GHG emission reductions, especially if produced and used locally, which keeps transportation costs and emissions to a minimum.

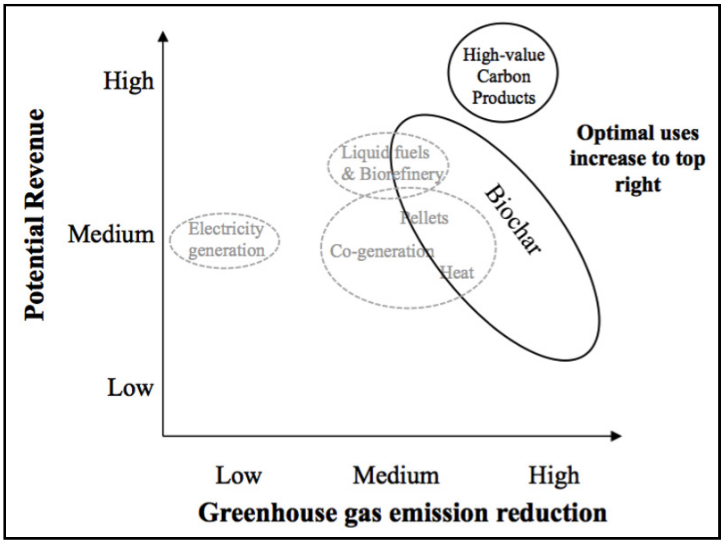

Figure 3. Conceptual comparison of potential revenue and greenhouse gas reductions for biochar (labeled black outlines) relative to other forms of biomass uses (labeled grey outlines).

5.2 Existing biochar guidelines, standards, and programs

Many international agencies have developed guidelines and standards for biochar use, including the International Biochar Initiative (biochar-international.org), the European Biochar Foundation (european-biochar.org/en), and various universities and colleges. The guidelines and standards cover sustainable production techniques and certification[29-31], energy and carbon management[32, 33], and industry standardization[34], and will serve as a resource for British Columbia should biochar policies be drafted here. Japan and most recently Switzerland[35] now allow regulated application of biochar for agricultural enhancement, but adoption of standards and policies on the global scale is moving slowly. The federal US WECHAR Act (Water Efficiency Via Carbon Harvesting and Restoration)[36], was sent to committee in 2009 but did not progress further. This initiative aimed to provide loan guarantees for biochar technology demonstrations using waste biomass. Biochar has been proposed for inclusion within the United Nations Clean Development Mechanism, but no major policies have been announced. Closer to home, Alberta's Lakeland College received $900,000 from Western Economic Diversification Canada and $450,000 from Alberta Innovates Technology Futures in 2012 to study biochar for carbon sequestration and land remediation.[37] This is at present Canada's most significant research program for biochar research and market-ability.

5.3 Biochar environmental policy in BC

i. Air emissions

Production and combustion of biochar in BC needs to meet the existing particulate and air quality emission targets specified by the Environmental Management Act, described for industrial applications in the BC Smoke Management Framework[38]. However, the regulations should be expanded to mandate low dust and black carbon emissions, since it has become recognized in recent years that black carbon is a significant climate-warming agent.

ii. Soil applications

Under the Code of Practice for Soil Amendments in BC[39], regulations for the application of biochar to soil are ambiguous, and require updating. Two soil amendment definitions relate to biochar: "(a) fly ash derived from the burning of wood, other than wood that has been immersed in marine waters", and "(e) industrial residue of wood that has not been treated with glue, paint, a preservative or another substance harmful to humans, animals or plants".

For definition (a), when biochar is combusted there may be a larger quantity of bottom ash (captured in grate) produced versus fly ash (captured from combustion gas stream). Bottom ash often contains lower concentrations of environmentally sensitive metals than fly ash. Regulators should consider modifying the current Code of Practice for Soil Amendments to include bottom ash as a soil amendment.

In the absence of updated regulations, definition (e) may apply to biochar, but further clarification may be required. Including biochar specifically in the BC Soil Amendment Code of Practice (or the BC Organic Matter Recycling Regulation) would simplify potential use of this material in amending soils in BC.

6. CONCLUSION AND RECOMMENDATIONS

The emerging biochar industry in British Columbia has a healthy future, offering considerable environmental value to the province. Developing the industry and realizing that value will require coordination and attention from the policy domain, particularly in areas of supply and cost structures. The recommendations below provide key steps that, when taken, will move British Columbia closer to optimizing the value of its significant biomass resources.

1. An important first step in planning a BC biochar market is establishment of a provincial bioenergy roundtable with a mandate to update the BC Bioenergy Strategy. More specifically, the roundtable should be charged with developing a biomass strategy and recommending policies that will make best use of limited resources. Issues for consideration by the roundtable should include revenue potential, carbon emissions reduction potential, future or current technological feasibility, social and environmental benefits, and/or employment generation. Key participants should include the biochar and other bioenergy industries, agricultural stakeholders, government and non-government organizations, carbon auditors, and academics. Many credible organizations, such as the International Biochar Initiative, have years of expertise from which to draw in the development of policy.

2. In the short term, and in response to BC's legislated GHG reduction targets, the Climate Action Secretariat should pursue carbon offsets through non-combustion applications of biochar as well as encouraging its use as a fuel to displace coal combustion. Taking such steps will diversify the options available to producers and help kick-start other opportunities in the biochar industry. Over the longer term, development of biochar could explore entering markets where no other renewable alternatives exist (such as the metallurgy industry) or investigate the potential of biochar as a substrate for production of higher value products such as synthetic graphite, carbon electrodes, and activated charcoal.

3. Given that there is uncertainty around the efficacy of biochar soil applications and plant growth enhancements, the provincial government should consider funding research by both industry and academia. This will be a key to expanding potential future biochar uses, in addition to clarifying the net carbon sequestration and productivity-enhancement benefits of biochar applications to soils in the widely-varying geographic regions of British Columbia.

4. A significant increase in the BC Carbon Tax is recommended. This will improve the cost competitiveness of biochar relative to coal and natural gas combustion in BC and spur the development of a biochar market.

5. Application of biochar and ash from all wood products should be clarified as a soil amendment within Code of Practice for Soil Amendments in BC. This will help to address ash waste disposal and close the nutrient cycle of the bioenergy industry.

6. Regulations for biochar production, transportation and use should be clarified and include no smoke production and very low particulate matter emissions, such as black carbon.

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