University of Nevada
Cooperative Extension

Fact Sheet-14-04

Summary of a Biochar Demonstration and Its Potential Application in Nevada

Frederick Steinmann, Extension Educator/Assistant Professor
Rodney Davis, Extension Educator/Associate Professor
Seth Urbanowitz, Extension Educator/Assistant Professor

Introduction

On Aug. 13 and 14, 2013, University of Nevada Cooperative Extension faculty attended a rotary reactor pyrolysis process demonstration hosted by Amaron Energy (a Utah-based company) in Ely, Nev. The rotary reactor produces three primary byproducts: biochar, biogas and bio-oil. The main byproduct, biochar, is currently being studied for its application as an agricultural soil amendment. A wide variety of benefits have been illustrated, including increased soil moisture retention, increased microfauna reproduction, improved germination of native plants and increased nutrient availability.

This fact sheet summarizes the results of the Amaron Energy rotary reactor pyrolysis demonstration and the potential for the application of biochar, and possibly biogas and bio-oil, in Nevada.

Potential of Biochar, Biogas and Bio-oil Application

According to Palma, et al. (2011), "Pyrolysis is a process that converts agricultural residues and any other carbon materials into bioenergy through intense heat in the absence of oxygen. Pyrolysis produces: 1) a bio-oil similar to crude oil, though not as refined; additional processing is required to generate an equivalent crude oil product, 2) a synthesis gas (biogas) that can be used as fuel for heating or to produce electricity, and 3) a bio-charcoal (biochar) substance that can be incorporated back into the soil to improve soil properties, or processed for other potential uses."

Moller (2013), Page-Dumroese (2013), and Ippolito (2013) each have examined the potential use of biochar in the amending of soils located in Nevada and throughout the United States. Moller (2013) identifies five primary markets for biochar in Nevada, including: (1) broadacre (large-scale) agriculture, (2) forest and rangeland management, (3) mine reclamation, (4) urban forests, and (5) gardening. Citing studies completed by Iowa State University, Moller (2013) claims that because Nevada is one of the driest states in the United States, "…biochar's water efficiency is an attractrive product characteristic…" for Nevada's agricultural producers, growers and irrigators.

Page-Dumroese (2013) summarized 10 existing studies of biochar as a soil amendment designed to enhance and test: (1) hardwood and softwood production, (2) wildlife forage, (3) soil enzymes, (4) lab incubation of native forest plants and the potential impact biochar may have on arresting the leaching of key nutrients from forest soils, (5) road decommissioning, (6) belowground biological changes, (7) water repellency, (8) seed germination (through biochar coating), (9) post-fire vegetation responses, and (10) the use of biochar in forest nurseries. Each of these ten application trials and studies are currently at different stages of implementation, and the long-term results of biochar's impact as an amendement has yet to be fully understood and documented. However, Page-Dumroese (2013) has concluded that biochar has not adversely impacted forest growth, and preliminiary results suggest that wildlife forage and soil enzymes were both improved as a result of the biochar application.

Additional studies currently being conducted indicate that biochar has a wide range of agricultural uses, as well as forest and rangeland restoration potential. Page-Dumroese (2013) also identified future studies including the development of several large-scale plot studies, designed to determine the long-term effects of biochar on soil chemistry and other physical and biological properties. They have also proposed mine reclamation studies, designed to evaluate whether or not biochar can provide needed organic matter to soil.

Ippololito (2013) examined the application of pinyon pine (Pinus monophylla) and juniper (Juniperus osteosperma) biochar in four eastern Nevada soils. After allowing the application of pinyon pine and juniper (PJ) biochar to incubate over a four-month period, Ippolito (2013) concluded that, "Soil salts tended to decrease with increasing biochar application possibly due to biochar acting as a sink and absorbing excess salts from the soil solution." Ippolito (2013) also found that, "A significant positive relationship was found, suggesting that increases in soil moisture due to increasing biochar application may be tied directly to increases in alfalfa germination success."

Although there is a strong potential for the application of biochar in agricultural processes and forest and rangeland management and restoration in Nevada, other studies suggest that the production of biochar, biogas and bio-oil might not produce enough of an economic return in order to be economically viable, even when each of the three byproducts are developed and analyzed together. Palma, et al. (2011), using a transportation logistics costs optimization model with geographic information system (GIS) data, conclude that, "The results indicated that there is a low probability of a positive Net Present Value (NPV) with current economic conditions. In general, the NPV was highest with a stationary scenario and it decreased with additional moving times." As a measure of potential economic success, NPV analysis compares the value of a dollar today to the value of that same dollar in the future while taking inflation and potential returns on investment into account. Typically, a positive and large NPV indicates that the project or investment should be undertaken. If the NPV is relatively low or negative, then the project or investment should not be undertaken. In order to enhance the probability of the economic success of a combined biochar, biogas and bio-oil production process, Palma, et al. (2011) conclude, using a sensitivity analysis, that the following conditions must first be met:

1. If feedstock (biomass) costs were reduced to $16.9 per ton, an expected 90 percent probability of a positive NPV is feasible. According to Palma, Richardson, Ribera, Outlaw, and Munster (2011), given existing technology, the feedsock (biomass) cost was estimated at $67.5 per ton in 2011. According to the U.S. Energy Information Administration (2014), feedstock (biomass) costs have ranged

between $50.0 per ton and $60.0 per ton over a 12-month period between Jan. 1, 2013 and Dec. 31, 2013.

2. If mean crude oil prices are greater than $139 per barrel (measured in 2011 dollars) over a 10-year planning horizon, an expected 90 percent probability of a positive NPV is feasible.

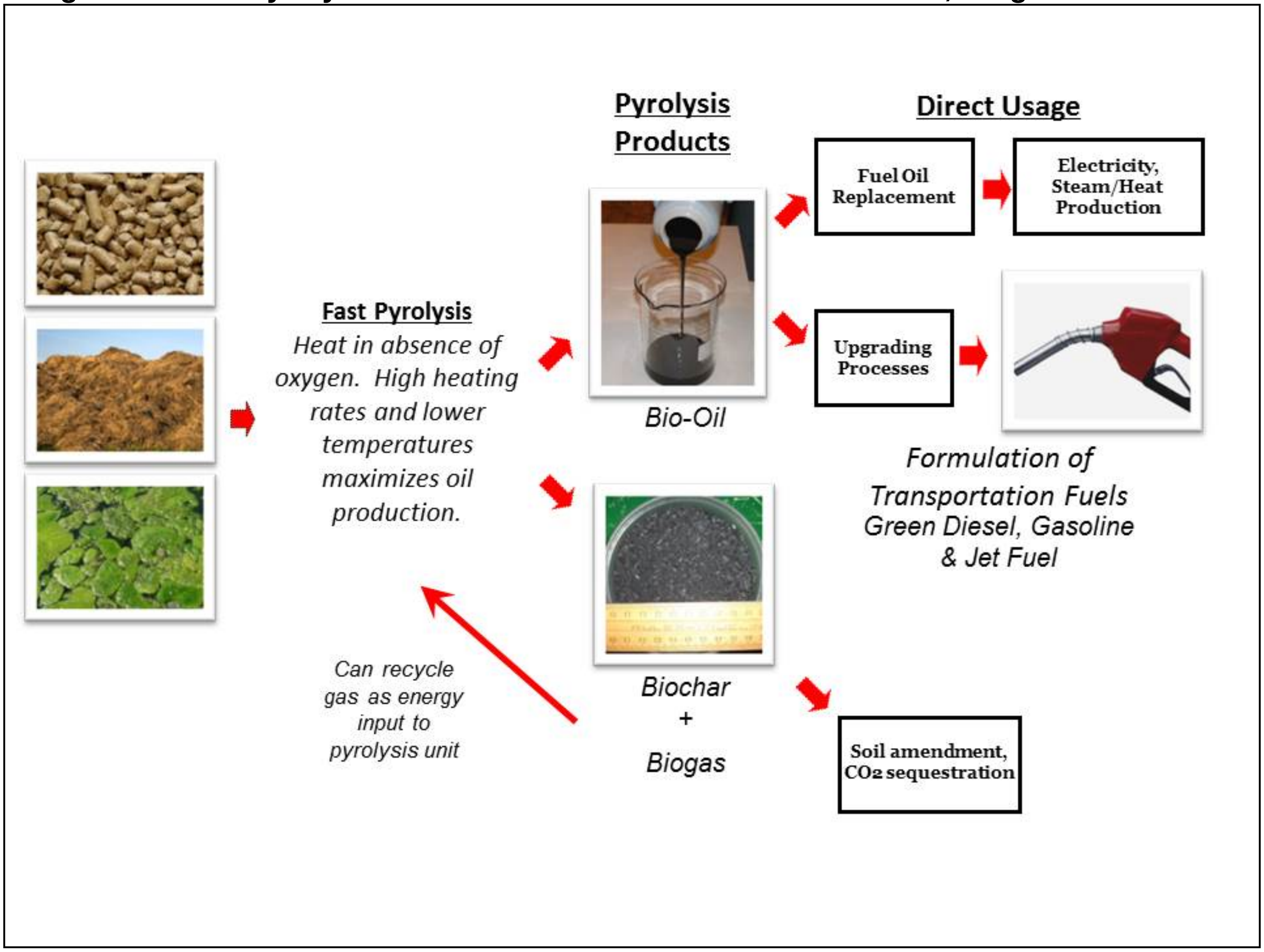
3. If the conversion efficiency of feedstock to bio-oil is increased to 70 to 90 gallons of bio-oil per ton of feedstock, then the probability of success and a positive NPV is higher than 99 percent.

While there is potential for the use of biochar as a soil amendment in agricultural systems and in the restoration of forest and rangeland soils, there is notable concern regarding the economic feasibility of its use. Also, much of the application of biochar is still experimental and the long-term impacts of large-scale applications of biochar are still unknown.

The Pyrolysis Process and the Amaron Energy August 2013 Demonstration

Amaron Energy has developed a prototype rotary pyrolysis reactor capable of producing varying levels of biochar, biogas and bio-oil. Figure 1 illustrates the pyrolysis process and the potential uses of biochar, biogas and bio-oil.

Figure 1 – The Pyrolysis Process and Potential Uses of Biochar, Biogas and Bio-Oil



Source: Coates, et al. (2013).

The pyrolysis process begins with the collection and input of biomass. The rotary reactor can accept different types of biomass, including biomass in pelletized or chipped and sifted forms. The biomass is then baked in a high heat, usually 400 to 600 degrees Celsius, rotary reactor or furnace. Once properly prepared, the biomass is converted into three primary byproducts including biochar, biogas and bio-oil. According to Amaron Energy (2013), the biochar byproduct of the pyrolysis process can be used as a soil amendment or for carbon dioxide (CO_2) sequestration. According to the USDA Forest Service (2014), carbon sequestration is a climate change mitigation strategy. Carbon sequestration is a process in which atmospheric CO_2 is taken up by trees, grasses and other plants through photosynthesis and is stored as carbon in biomass (trunks, branches, foliage and roots) and soils. Sinking carbon, using different approaches such as the production of biochar and its addition to soils, helps offset other sources of CO_2 in the atmosphere, such as deforestation, forest fires and fossil fuel emissions.

The bio-oil byproduct can be either directly used as a fuel oil replacement or used in the production of electricity, steam or heat. Current experimentation also suggests that the bio-oil byproduct can be further refined through upgrading processes in the development and manufacturing of alternative petroleum-based fuels. The biogas byproduct can also be used as an energy input used to fuel the rotary reactor pyrolysis unit.

Amaron Energy has developed a rotary pyrolysis reactor with assistance from the University of Utah and Utah State University. Amaron Energy's mobile demonstration reactor is designed to demonstrate the potential for biochar, biogas and bio-oil production, and serve as a proof-of-concept demonstration model. Amaron Energy received a patent for its rotary pyrolysis reactor technology, U.S. patent number US8298406B2, on Oct. 30, 2012 and a patent application for thier biomass pyrolysis, patent number US20120063965, on March 15, 2012.

Figure 2 – The Amaron Energy Rotary Pyrolysis Reactor

The current Amaron Energy rotary pyrolysis reactor (Figure 2) was demonstrated in Ely, Nev., on Aug. 13 and 14, 2013. Construction of this laboratory-scale rotary pyrolysis reactor began in 2009. According to Amaron Energy, a biomass processing capacity of 0.5 tons per day was demonstrated using a 6-inch diameter rotary reactor. Throughout 2012, Amaron Energy completed over 700 hours of test operations using 14 different raw materials. Using a 10kW generator to power the reactor, the laboratory-scale rotary pyrolysis reactor was installed in a 20-foot shipping container and mounted on wheels.

The laboratory-scale rotary reactor pyrolysis begins with the production of woody pinyon and juniper biomass and is processed using a wood chipper to produce a biomass capable of being placed in the rotary reactor (Figure 3). The laboratory-scale rotary reactor currently does not have an attached chipper for processing the collected pinyon and juniper biomass. The 20-inch diameter rotary pyrolysis reactor currently being developed by Amaron Energy would also not have an attached wood chipper. Field trials of Amaron Energy's rotary reactor pyrolysis unit, either the current laboratory-scale unit or the 20-inch diameter reactor, would require the purchase or lease of a wood chipper sufficient to produce enough chipped pinyon and juniper biomass to maintain regular operation of the unit.

Figure 3 – Processed and Chipped Pinyon and Juniper Biomass

Once processed and chipped, the pinyon and juniper biomass is then hand-sifted (Figure 4) so that smaller particles are separated out and the larger remaining pinyon and juniper biomass chips are collected. In Figure 3, the pinyon and juniper biomass chips on the far left is the resultant material from the collected pinyon and juniper biomass being processed and chipped.

Once hand-sifted, two categories of materials are produced. The materials in the center of Figure 4 are disposed of and not used in the rotary pyrolysis reactor. The final materials on the far right of Figure 4 are collected and then used in the rotary pyrolysis unit and are converted into the three main byproducts of biochar, biogas and bio-oil.

Figure 4 – Hand-Sifted Processed and Chipped Pinyon and Juniper Biomass

Note: the processed and chipped pinyon and juniper biomass (far left), hand-sifted smaller particles disposed of (middle), and the remaining hand-sifted pieces used in the reactor (far right).

Once hand-sifted, the material collected for use in the rotary pyrolysis reactor is then fed, by hand, into a hopper at the top of the laboratory-scale rotary reactor. After sufficient processing of the processed and chipped pinyon and juniper biomass, the biochar and bio-oil byproducts are collected. During the Aug. 13 and 14, 2013 demonstration of the laboratory-scale rotary reactor, the biogas byproduct was just vented and not collected for use. The 20-inch diameter reactor currently being developed by Amaron Energy will collect the biogas byproduct for use in fueling the rotary pyrolysis reactor.

Amaron Energy is currently working on a 20-inch diameter rotary pyrolysis reactor capable of processing up to 10 tons of biomass per day. Tables 1 and 2 contain reactor temperature and yields data and an analysis of the pinyon and juniper wood and biochar byproduct provided by Amaron Energy on reactor temperature and yields for this laboratory-scale rotary pyrolysis reactor.

Table 1 – Reactor Temperature and Yields

	Pyrolysis[1]	**Torrefaction**[2]	**Pyrolysis of Torrefied Wood**
Reactor Temperature (Celcius)	425	315	425
C1 Temperature (Celcius)	71	82	76
Torrefied Wood		69%	
C1 Liquid	28%		27%
C2 Liquid	16%	18%	27%
Total Liquid	49%	26%	54%
Gas	23%	5%	19%

Source: Amaron Energy, "Pinyon-Juniper Pyrolysis" as presented in Ely, Nev. in 2013.

[1] Pyrolysis: Decomposition of biomass brought about by high temptures; a thermochemical treatment of biomass carried out under atmospheric pressure in the absence of oxygen.

[2] Torrefaction: A milder form of pyrolysis; a thermochemical treatment of biomass carried out under atomospheric pressure in the absence of oxygen.

Table 2 – Ultimate Analysis of Pinyon and Juniper Wood, Biochar

Analysis of the Pinyon and Juniper Wood			**Analysis of the Pinyon and Juniper Biochar**	
	As Received	**Dry**		**As Received**
Moisture	14.89%	0.00%	Moisture	0.98%
Carbon	45.13%	53.02%	Carbon	72.97%
Hydrogen	5.10%	5.99%	Hydrogen	3.87%
Oxygen	33.15%	38.95%	Oxygen	16.65%
Nitrogen	0.29%	0.34%	Nitrogen	0.64%
Sulfar	0.03%	0.04%	Sulfur	0.02%
Ash	1.41%	1.66%	Ash	4.87%
Total	**100.00%**	**100.00%**	**Total**	**100.00%**

Source: Amaron Energy, "Pinyon-Juniper Pyrolysis" as presented in Ely, Nev. in 2013.

Further Study and Application

The Eureka County Natural Resources Department and the University of Nevada Cooperative Extension Eureka County office are currently working on a collaborative effort to test the applicability and economic feasibility of biochar in the treatment and reclamation of mine tailing piles. Trial applications of biochar will likely begin in early 2014 at the Ruby Hill mine site currently owned and managed by the Barrick Gold Corporation. Results of these trials will be published through University of Nevada Cooperative Extension in partnership with faculty and staff from the USDA-ARS; the University of Nevada, Reno; Biochar Solutions; the United States Forest Service; the Nevada Division of Wildlife; the Eastern Nevada Landscape

Coalition; and the Rocky Mountain Research Station.

Conclusion

Much of the research on biochar and its application as a soil amendment for either agricultural uses, or forest and rangeland restoration as summarized in this fact sheet is based on small-scale trials. However, there is sufficient evidence to suggest that there is potential in developing and using biochar in agricultural systems and forest and rangeland management and restoration in Nevada. Nevertheless, serious concerns remain regarding the economic return from applications and the long-term impacts of soils amended with biochar. Amaron Energy's rotary reactor pyrolysis unit, as demonstrated in Ely, Nev. in Aug. 2013, showed the process of producing biochar, along with the additional byproducts of biogas and bio-oil, and the required inputs needed. Future research will include the trial application of biochar in the reclamation of mine tailing piles in Eureka County, Nev.

References

Amaron Energy. 2013. *Demonstration of a Pyrolisis Reactor*. Ely, NV.

Coates, R., E. Eddings, and B. Coates. 2013. *Presentation Meeting*. Amaron Energy. 2013.

Ippolito, J. 2013. *Biochar Research*. USDA-ARS NW Irrigation and Soils Research Laboratry: Kimberly, ID.

Moller, E. D. 2013. *Biochar – A Soil Restorative – Useful in Agriculture and Forestry*. University of Nevada, Reno: Reno, NV.

Page-Dumroese, D. 2013. *Summary of Biochar Studies*. USDA Forest Service, Rocky Mountain Research Station: Moscow, ID.

Palma, M. A., J. W. Richards, B. E. Roberson, L. A. Ribera, J. Outlaw, and C. Munster. 2011. Economic Feasibility of a Mobile Fast Pyrolysis System for Sustainable Bio-crude Oil Production. *International Food and Agribusiness Management Review*. 14 (3): 1-16.

U.S. Energy Information Administration. 2014. *Monthly Energy Review*. http://www.eia.gov/totalenergy/data/monthly/#prices.

U.S. Department of Agriculture, Forest Service. 2014. *Carbon Sequestration*. http://www.fs.fed.us/ecosystemservices/carbon.shtml.