Building the Biocarbon Economy: How the Northwest Can Lead

Recycling Carbon: Bioeconomic Development

Building biocarbon through creating new jobs producing bioproducts and bioenergy

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TRANSFORMING WASTE INTO VALUE

From farms and forests come streams of carbon-based matter on which all human life and civilization depend: food, fiber, feed and fuels. **Along the way from field and forest to the consumer, at each step of the production process, much biomass is discarded or inefficiently used.** Ultimately, even many useful products at the end of their lives wind up in waste streams, sent to landfills or treatment plants.

Making more efficient use of biomass streams, transforming them into valuable products, represents two key biocarbon opportunities:

- ***Replacing fossil fuel-based energy and materials with lower emission, bio-based products***
- ***Creating new products that directly return carbon and other nutrients to farm and forest soils.***

This "bioeconomic development" holds great potential to:

- ***Create new business sectors, companies and non-exportable, well paid jobs***
- ***Transform costly disposal and pollution challenges into profitable revenue steams***

Adding what are now wastes back to the carbon cycle has "huge potential," says Chad Kruger, a scientist with Washington State University's Climate-Friendly Farming Project (CFF). In particular, he notes, soil amendments based on organic residues promote high levels of soil carbon sequestration, and "bring their own nitrogen with them," reducing artificial fertilizer use.

Cycling biomass materials through the economy multiple times pays economic dividends. Burying organic residues in landfills amounts to throwing away money**.** The practice itself should be consigned to "the ash heap of history." **All organic waste streams represent economic potential** realized by creating "industrial ecosystems" that convert organic residues into feedstocks for products. Though landfill gas today generates some energy, strategies that sort and direct organic streams have far higher economic returns. Closing carbon loops tightens economic loops. **When local biomass is used to replace fossil fuel-based products imported from beyond the region, it spells more money re-circulating in the local economy**

The scale of the opportunity is massive, as studies of biomass streams have shown. An Oak Ridge National Laboratory (ORNL) assessment conducted in 1999 found that each year Northwest states generate these amounts of waste biomass deliverable at various price points:[1]

	<$20/dry ton	< $30/dry ton	< $40/dry ton	< $50/dry ton
Idaho	204,265	2,572,162	4,117,282	7,165,782
Montana	69,060	1,421,766	2,159,358	3,983,058
Oregon	192,532	3,341,220	4,126,075	9,809,975
Washington	297,432	3,979,387	5,938,641	9,920,241

In 2005 Washington State University and the Washington Department of Ecology (WDOE) released the most comprehensive biomass inventory done for any state. At 16.4 million dry tons annually, the assessment revealed significantly greater potential in Washington state than the ORNL study. The Washington study looked at a wider range of sources.

"This shows the significance of doing a more specific state inventory instead of relying on a nationwide report that struggles to identify the uniqueness of each state," the researchers wrote.[2]

David Sjoding with Washington State University Energy Extension Program, who works extensively on state biomass activities, said a further inventory revision is in the works. Adding new information on categories such as biosolids, the study will show that the state generates at least 20 million dry tons of residues each year, Sjoding says.

The 2005 study shows biomass shares by sector:

- **Forestry – 49 percent**
- **Agriculture – 26 percent**
- **Municipal – 24 percent**[3]

Of the total, 85 percent is woody material. Assuming all material was collectable and could be used for electrical generation via combustion and biodigestion, it would generate 15.5 billion kilowatt hours annually, equal to 49 percent of state residential

[1] Marie E. Walsh, Biomass Feedstock Availability in the United States: 1999 State Level Analysis, Oak Ridge National Laboratory, Jan. 2000. The study also assessed energy crops and at 1999 stage of development found potential only in Montana adding 2,778,386 dry tons annually to the <$50 column.

[2] Craig Frear et al, Biomass Inventory and Bioenergy Assessment: An Evaluation of Organic Material Resources for Bioenergy Production in Washington State," Washington State University, Washington Department of Ecology, Dec. 2005, p.17 The 16.4 MT figure cited is a later adjustment of this study. .

[3] Ibid

power use.[4] If converted into liquid fuels, it could generate 20-30 percent of state transportation fuels.[5] Residue streams could also replace natural gas-based nitrogen fertilizer.

"We concluded that there is sufficient bio-nitrogen in the 16.4 million tons of waste material to substitute for all 176,000 tons of synthetic nitrogen fertilizer purchased each year by Washington farmers," Kruger says. "We need to adequately value the nutrients contained in the biomass. There may be a bigger greenhouse gas (GHG) bump from processing the biomass for nutrient recovery than for energy, but the two are not mutually exclusive."

DOING BIOMASS RIGHT

These numbers come with important caveats that reduce the actually available biomass. They affect the approximately 4.5 million annual dry tons WSU found potentially available from farm field and forest residues (not including mill waste).

Collection and delivery of widely dispersed and bulky biomass sources represents difficult and expensive challenges. A generally accepted guideline is that transportation of raw biomass to processing sites is economically infeasible beyond 50 miles. Reduction of biomass by mobile processing units on site, for example at forest thinning operations, is viewed as a potential solution.

Inappropriate removal of biomass from farm fields and forest floors could deprive soils of nutrients needed for fertility. CFF researchers found that costs for restoring carbon and other nutrients could well exceed benefits of selling residues.

". . . we believe it is essential to recognize the important agronomic role of crop residues; these are not 'wastes' available for energy production. Further analysis shows that removal of wheat straw residues for biofuel production exports valuable nutrients from the field, and may leave inadequate residues to build or even maintain soil organic matter . . . uniform residue removal for bioenergy applied across a field will have vastly different impacts in different parts of the field."[6]

"We are not arguing to eliminate residues from use, but rather to understand that there is a trade-off," Kruger says. "If you do choose to use them, ensure that you limit where you take them from in the field and potentially mitigate the reduction with something returned." Based on the cost of inputs needed to replace nutrients, "We have argued that the cost-recovery mechanism to farmers as specified in various U.S. Department of Energy studies is not a good deal for farmers."

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[4] Frear, p.16
[5] *Vision for Washington's Bioeconomy*, Washington State University, Pacific Northwest National Laboratory.
[6] *Climate-Friendly Farming Project Summary,* CSANR Research Report 2010-001, Washington State University, p.33

Even if no field or forest residue were used, that would still leave at least 12 billion annual dry tons already concentrated at food processing plants, sawmills, municipal waste transfer stations and livestock barns.

There are other important caveats regarding biomass use.

FIRST, Fossil energy will be involved to some degree in generating biomass products, so full lifecycle assessment is needed. Biomass cannot be automatically counted as GHG neutral. Transporting biomass, for instance, will require fossil diesel fuel until it is replaced. GHG emissions involved in activities to make waste streams economically valuable must be taken into account.

SECOND, Biomass resources, though abundant, are still limited, so demand and supply must be carefully matched, and the most efficient uses targeted. Composting and timber mill energy plants are already creating competitive demand for woody residues. Proposed new compost and biomass power facilities would increase demand. A wave of applications for biomass power plants is now sweeping the Northwest. Some may be appropriately scaled to available supplies of mill residues or thinning materials. But others might create incentives for new logging, raising issues around land use and GHG balance.

Product mix is a concern. **Some proposed facilities would generate only electricity, missing large opportunities to generate co-products** including heat used in co-located operations, biochar, bio-oil and biogas (these are discussed below). Biopower may preempt use of biomass for liquid fuels, for which there are fewer non-fossil alternatives than electricity. Even though liquid fuels can potentially generate significantly greater revenues, biopower technologies are established while advanced biofuel technologies are in earlier stages. Of course, when fuels technologies become mature, the lifecycle effects of increasing biomass demand in this area must also be considered.

BIOECONOMY PUBLIC SECTOR LEADERS

In 2008, Washington diverted 45 percent of waste streams to recycling and reduced waste going to landfills by six percent compared to 2007.[7] But the state has far more ambitious goals. Washington has mounted one of the nation's most advanced state efforts to realize biomass potentials. **In 2002 the Washington Department of Ecology (WDOE) revved up Beyond Waste, a 30-year effort to "eliminate wastes and toxics whenever we can and use the remaining wastes as resources,"** the agency says. "This will contribute to economic, social, and environmental health."[8]

A top program goal is to close organic waste loops and from them generate compost, energy and other products. One important milepost of progress is yard waste collection

[7] Washington Department of Ecology, "Washington recycling more; generating less waste," press release, Nov. 16, 2009

[8] Washington Department of Ecology, Beyond Waste page, http://www.ecy.wa.gov/beyondwaste/, viewed May 6, 2010

which "grew from almost nothing in 1988 to 818,000 tons in 2007. Government focus on waste diversion and procurement of recycled products drives this rapid growth," WDOE reports.

The agency notes important climate and energy contributions. "Keeping organics out of the landfill reduces greenhouse gas emissions by decreasing methane, a potent greenhouse gas that's released during decomposition. **Turning organics into compost, bioenergy, biofuels and other products promotes economic vitality in growing industries, and protects the environment**."[9]

BIOECONOMY BUSINESS INNOVATORS

The Northwest's traditional natural resource industries are seeking new opportunities in bioenergy and bioproducts, as the DNR announcement shows. New entrepreneurial businesses are also moving to realize bioeconomy opportunities. The range is far beyond the capacity of this series to do justice. This section offers several exemplars.

A number of companies are exploring innovative bioproducts that use natural processes to reduce pollution.

Fungi Perfecti of Olympia, Washington offers a system to grow backyard medicinal and gourmet mushrooms, as well as fungi-based products to improve plant growth. A new product called the Life Box is commercial packaging stocked with tree seeds and fungi. The box can be planted after use. The company is also demonstrating the advantages of using fungi-based products combined with wood chips to restore old logging road soils, thus promoting forest growth.[10] Fungi Perfecti has staged a field demonstration of the process, known as mycofiltration, on a road section at DNR's Tahuya State Forest on the Kitsap Peninsula. Company founder Paul Stamets has successfully tested a similar mix in a "mycoberm" for purifying waters from manure holding ponds.[11]

Bio-Reaction Industries of Sherwood, Oregon produces a bio-filter that employs soil microbes to clean pollutants from the air. The company just announced a deal with Toyota to use the technology in its Vancouver, B.C. wheel-casting plant. It replaces a thermal system that eliminates volatile organic compounds from painting operations. By reducing the demand for natural gas energy the process cuts GHG emissions 90 percent.

Companies are also working to create industrial ecosystems that convert waste streams to high-value products.

Barr-Tech is creating the Barr Regional Bio-Industrial Park in Lincoln County near Sprague, Washington to open new opportunities for organic waste recycling in the state's

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[9] *Beyond Waste Plan 2009 Update*, Washington Department of Ecology, p.25

[10] Paul Stamets and Sumerlin, David, "Mycofiltration: A Novel Approach for the Bio-transformation of Abandoned Logging Roads," Fungi Perfecti

[11] Paul Stamets, "A Novel Approach to Farm Waste Management," Fungi Perfecti

northeast corner. The 40-acre site 22 miles west of downtown Spokane will receive yard clippings, food waste, municipal biosolids, wood residues and other construction remains. An anaerobic biodigester will produce biogas to generate two megawatts of power, as well as recover nitrogen and phosphorous nutrients. It will also provide heat and CO_2 for greenhouses producing fruits, vegetables and algae. The latter is a prospective feedstock for liquid fuels. High grade compost is another product. The regional bio-industrial park will welcome businesses that wish to co-locate biomass recovery and reuse facilities for other products.

AprèsVin of Prosser, Washington took a mounting waste problem of the burgeoning Washington wine industry, piles of grape seed waste, and realized the opportunity to produce high-nutrition cooking oils and gluten-free flours. These products have very high anti-oxidant value, says Erik Leber, company founder. The AprèsVin motto is "More Goodness from the Grape." The company is exploring a number of other products including pigments, paper, anti-bacterials, fuel additives, lubricants and energy pellets.[12] Allied company Fruit Smart is gasifying the pellets to produce energy in a demonstration project.

Summit Natural Energy is a pioneer in turning what were food processing wastes into ethanol fuel. With locations in Cornelius and North Plains, the Willamette Valley company produces more than two million gallons a year from abundant Willamette Valley food industry residues. This avoids competition between food and fuel markets, and generates some of the lowest net carbon fuels available.

Algae AquaCulture Technologies of Whitefish, Montana is developing integrating bioprocessing systems. A prototype at F.H. Stoltze Land and Lumber Co. in nearby Columbia Falls employs heat to gasify wood waste, producing biochar and CO_2 used to grow algae. That is combined with wood waste and run through a biodigester, also driven by the heat process. The products are energy-generating biogas and compost which is mixed with biochar to provide organic fertilizer.

HM3 Energy of Gresham, Oregon is developing a technology known as torrefaction which converts biomass to a concentrated energy material that can replace coal while dramatically reducing pollution including net CO_2 emissions. The company's T-Wood product is being tested in conjunction with Portland General Electric for possible coal replacement at its Boardman plant. A 50-50 mixture with coal was successfully tested in February 2010. HM3 aims for commercial production by May 2011.

BioChar Products Biochar Products is working toward building a mobile pyrolysis unit at the former Ellingson Lumber mill site in Halfway, Oregon. The plant will be mobile so it can be moved to forest thinning sites. The aim is a plant processing 10 tons of biomass daily to produce 300,000-400,000 gallons of bio-oil and 700 tons of biochar annually. The operation is expected to generate 12-14 full-time and 8-10 seasonal family wage jobs.

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[12]Eric Lieber, "Recovering Value from Organic Waste Materials – Winecycling," AprèsVin and Fruit Smart

BIODIGESTION: A KEY OPPORTUNITY

Biodigestion processes organic wastes in a controlled environment, using heat and microbial organisms to generate biogas and compost. In the process it reduces methane that emits from uncontained manures. Methane is a GHG 30 times more powerful than CO_2, so biodigestion has advantages for the climate. The technology has been used widely on a small-scale in nations such as China, as well as on dairy farms and livestock operations across Europe and the U.S. Wastewater treatment plants have treated biosolids in digesters for many years (though potentials are not fully realized.) But for facilities such as farm biodigesters without a public funding base**, economic hurdles are steep. Northern locations in the U.S have seen failure rates in the 50-percent range,** David Sjoding notes. Washington state is moving to solve these problems.

"We knew we needed to roll up our sleeves to get this fixed," says Sjoding. "We are far down the road in doing this. This puts us in a national leadership position."

The vehicle is a partnership between the WSU Climate Friendly Farming Project and VanderHaak Dairy in Lynden, the state's first commercial-scale biodigester and only the third operating in the Northwest when it opened in 2004. CFF supported creation of the biodigester and uses it as a research program to test technologies and economics. Key to the effort is development of multiple revenue streams.

"Single purpose bioenergy projects (biopower or biofuels) in the Pacific Northwest rarely make business or economic sense on a stand-alone basis," WSU researchers explain. **"Multiple products with multiple revenue streams (including cost offsets) are the key to business and economic success in our region.** In this setting, the development of bioproducts assumes major importance."[13]

The VanderHaak project builds biodigester economics by developing and exploring nine product streams:

1. Processing manure from 700 cows enables shutdown of a dairy lagoon, resulting in reduced methane emissions that can be marketed for **carbon credits**.
2. The biodigester produces biogas fed into an engine that sends **electricity** to Puget Sound Energy customers.
3. Electricity gains a **green power premium**.
4. Engine **heat for greenhouses** is a prospect now being examined.
5. The biodigester is the first in Washington to **co-digest commercial food waste**, dramatically improving performance and reducing disposal costs.
6. Undigested fiber, which can be marketed as animal bedding, can also make **a peat moss substitute.** WSU is now staging greenhouse test runs.
7. **Nitrogen fertilizers** can be derived from biodigester liquids.
8. Liquids also generate a **phosphorus** soil amendment
9. **Sweet nutrients** remaining in liquids can be applied to local farms, replacing fertilizer purchases.

[13] Craig Frear et al, Bioenergy and Bioproducts Fact Sheet: VanderHaak Dairy Anaerobic Digester, Washington State University

The primary reason dairy operators install biodigesters is to control air and water pollution from manures, factors that can limit herd size. Around the U.S., 36 percent of dairy farms have a nitrogen overload, and 55 percent have too much phosphorus.[14] Biodigesters potentially allow livestock operations the opportunity to expand herds. Nutrient-rich biodigester liquids are hard to transport, so still represent an on-site nutrient management challenge. At VanderHaak, WSU is piloting a technology to turn liquids into solid nitrogen and phosphorus products that can be marketed over distances

As of spring 2010, 11 Northwest biodigesters are operating or announced, while others are in the works. They will process wastes from 40,000 cows and generate 15 megawatts.[15] But potentials are far greater. Washington State alone has around 600 dairies and 250,000 cows.[16] Idaho's dairy industry is even larger, ranking fourth in the Based on the performance of the VanderHaak biodigester, CFF estimates that **GHG reduction per cow with biodigestion is 15.24 metric tons of carbon dioxide equivalent annually** ($MTCO_2e$/year). Installing biodigesters at the 40 largest Washington dairy farms would process manures from 70,000 cows, cutting annual GHGs by 1.07 million $MTCO_2e$/year. Biofertilizers that displace fossil fuel-based products would cut out another 17,100 $MTCO_2$/year, and peat substitutes 19,000 $MTCO_2e$/year.[17] Approximately 20-25 percent of Washington agriculture demand for nitrogen and phosphorous could be met by installing VanderHaak-type biodigesters at Washington's largest 135 dairies.[18]

Biodigestion "can, in fact, turn a dairy from a net source to net sink for GHG emissions," CFF researchers write.[19]

Says CFF, biodigestion "will likely represent a win-win strategy that will improve nutrient management, dairy economics, and reduce landfill methane emissions (by using food wastes) in addition to mitigating agricultural GHG emissions."[20]

BIOCHAR FOR LONG-TERM BIOCARBON SEQUESTRATION

Over the past few years an ancient agricultural technology that might solve 21st century problems has been stirring tremendous interest and enthusiasm. **The practice of building soil carbon with charred biomass – biochar – has drawn attention as a tool for soaking CO_2 out of the atmosphere while generating bioenergy and improving soil quality.**

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[14] Climate-Friendly Farming Project Summary, p.15
[15] C. Kruger and Frear, C., "Lessons Learned About Anaerobic Digestion," Climate-Friendly Farming, Ch. 12, Washington State University, CSANR Research Report 2010-001
[16] Craig Frear
[17] Climate-Friendly Farming Project Summary, p.4-5
[18] Personal communication, Chad Kruger
[19] C. Kruger and Frear, C., p.4-5
[20] Climate-Friendly Farming Project Summary, p.5

Biochar has come to light as a result of research into *terra preta*, the black soils of Amazonia, apparently deliberately built by the inhabitants to overcome the poor soil fertility of the region. Compared to similar soils where organic matter might plunge a half-meter below the surface, *terra preta* soils can sustain a two-meter thick layer. The result is 250 metric tons of carbon per hectare, or about 2-1/2 times greater than comparable soils.[21]

Biochar opens up new potentials to actively capture atmospheric CO_2 via plant growth and then process it into a long-lasting solid form, at the same time displacing fossil fuel demand with bioenergy. For these reasons, **it is a very promising biocarbon technology.**

Early studies indicate superior carbon performance of systems that mesh production of biochar and bioenergy. One study showed they reduced GHGs 2-5 times more than if biomass was used to generate energy alone, and yielded 2-7 times the amount of energy used.[22]

Jeff Schahczenski, an agriculture expert at the Missoula, Montana-based National Center for Appropriate Technology, notes, "When plants die they sequester that embodied carbon into the soil, but most of that is rather quickly released back into the atmosphere as CO_2 through plant respiration and soil microbiological activity . . . the natural process is interrupted by capturing part of the biomass before it reaches the soil . . .and using part for the production of bioenergy and part for the production of biochar."

Notes Schahczenski, ". . . **most research to date demonstrates that biochar applied to soil releases carbon back into the environment at a very slow rate that is in excess of several hundreds if not thousands of years**."[23]

A WSU study of five different Washington soils found, "All biochars on all soil types did increase soil C with increasing rates, and the C appears stable." **A metric ton of biochar applied to soil removes 2.93 metric tons of CO_2 from the atmosphere**. [24]

Peter Winsley, a forestry and biochar expert, and strategy lead for the New Zealand Forestry Ministry, notes, ". . . biochar is a highly stable and long-term form of carbon storage, because charcoal is inert and resistant to biochemical breakdown." He notes that biochar is 70-80 percent carbon, compared to wood at 50 percent.[25]

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[21] Peter Winsley, Biochar and bioenergy production for climate change mitigation," *New Zealand Science Review* Vol. 64 (1) 2007, p.5
[22] Jeff Schahczenski, *Biochar and Sustainable Agriculture*, ATTRA-National Sustainable Agriculture Information Service, 2010
[23] Schahczenski
[24] David Granatstein et al, Use of Biochar from the Pyrolysis of Waste Organic Material as a Soil Amendment, Ecology Publication Number 09-07-963, Washington Department of Ecology and Washington State University, July 2009, p.vi, vii
[25] Winsley, p.6

Biochar is viewed by many as an ideal process to handle thinnings from Northwest forests. The WECHAR Bill introduced by Sen. Harry Reid and supported by Montana Senators Max Baucus and Jon Tester targets insect-killed trees in the intermountain west as a biochar feedstock, and so could spur activity in the interior Northwest. Biochar could add to the carbon performance of thinning operations. As noted in the *Reinventing Forestry* briefing, thinning in the short term releases more carbon than leaving forests untouched. But thinning is driven by other needs including fire hazard reduction and improved wildlife habitat. By locking thinning material in biochar and replanting it at the site, some of the carbon loss could be regained.

While the Amazonian origins of biochar are likely associated with charcoal production and kilns for firing clay pottery**, current technology for biochar is based on a process known as pyrolysis.** The biomass is baked in an oxygen-deprived environment to produce the solid char along with bio-oil and syngas, a hydrogen-carbon monoxide mixture once known as "town gas." From these three basic products a wide range of other products can be made. Syngas can be chemically converted into petroleum substitutes or burned directly for electricity and heat. Bio-oil is a feedstock for high-value products including chemicals, fertilizers, resins, acetic acid and food flavorings. Technologies that transform bio-oil to petroleum substitutes are in development.

Charcoals are used as filters because of porous surfaces and extraordinarily high surface area on which reactions can take place. Biochar soil benefits are based on this property. The biochar-held carbon is not available for plants, but biochar helps to aggregate mineral soils creating soil structure through which water and air may enter. Research indicates this structure provides abundant spaces in which nutrient-supplying microorganisms grow, and moisture and nitrogen are retained. The latter reduces nitrous oxide emissions into the air and nitrate leaching into water. The prospect of cutting fertilizer and water applications is economically and environmentally valuable. Biochar also reduces acidity and absorbs pollutants.

Biochar activity is growing exponentially, and the Northwest is a globally-significant hotbed of activity. Besides the new biochar business ventures reported above, citizens, public agencies and researchers are also engaging:

- WSU, USDA Agricultural Research Service and Pacific Northwest National Laboratory are providing lead research work on biochar use and production through pyrolysis.
- An informal network of biochar advocates and researchers, the Pacific Northwest Biochar Initiative, shares information across the region.
- The U.S. Biochar Initiative's lead organizer is Gloria Flora, a Helena, Montana-based sustainability consultant and former supervisor of a national forest in Nevada.
- The International Biochar Initiative's communications efforts are led by Kelpie Wilson, a long-term forest advocate based in Cave Junction, Oregon.
- The Seattle Biochar Working Group is testing biochar performance in garden plots at South Seattle Community College.

- The Umpqua National Forest in Oregon has demonstrated production of biochar, bio-oil and syngas from forest thinnings.

"The Pacific Northwest is one of the most sophisticated regions," Flora says. "But a lot of others are racing to catch up."

John Miedema, one of the organizers of the Pacific Northwest Biochar Initiative (PNBI), says it started as a way to draw together "diverse groups to talk about the potentials and to develop the technology." Miedema himself is working to develop a bioenergy-biochar Operation at Thompson Timber in Philomath, Oregon. "The Northwest has a great braintrust."

OVERCOMING BIOCHAR CHALLENGES

As with any other emerging technology, biochar must overcome economic and environmental hurdles before it reaches mass scale.

Ensuring that biomass feedstocks are produced in an environmentally sustainable manner is on the radar of biochar advocates

Some environmental activists have even raised concerns about mass replacement of natural forests with plantations dedicates to biochar production. This is decisively not the scenario envisioned by Northwest biochar advocates. Sustainability is in the forefront of their concerns.

"To have the ability to remove and use the biomass to make biochar, we have to make sure we do it sustainably," Flora affirms. "We need to leave a sufficient amount to replenish the soil, ensure wildlife habitat and water quality. If we cannot do these things we are not going to get permission to operate."

Among other potential environmental challenges, Schahczenski notes, are emissions from pyrolysis units, carbon dust pollution, potential runoff from highly erodible fields and heavy metal content depending on feedstock. "While none of these issues are beyond solution they will all have to be investigated . . . ."[26]

PNBI is leading development of sustainability protocols for the Northwest that call for lifecycle GHG analysis as well as attentiveness to land use impacts, food security and local economic benefits. PNBI is working in parallel with broader protocol efforts mounted by the International Biochar Initiative.

Biochar also faces economic, technological and scientific challenges.

Technologies are in development, but still considered not fully mature.

[26] Schahczenski

“I am frustrated by the lack of access for equipment and technology because I have people lined up for a unit,” Flora says.

“There is not enough biochar now because of the technology barrier,” Miedema notes. “The first thing we need is technology research.”

A number of pyrolysis technologies are in development. Biochars can be derived from fast pyrolysis which rapidly apply heat to biomass. These units favor bio-oil production, converting around 75 percent to bio-oil and splitting the remainder between biochar and syngas. Gasification technologies can also provide char. But biochar experts point to slow pyrolysis as the technology of choice. By applying lower heats for longer times, it roughly evens the shares of the three products.[27]

Economically, biochar has an uphill climb. WSU modeled four different production facilities, including mobile, stationary, transportable and relocatable. Without carbon pricing, researchers found a positive bottom line only at the large-scale stationary facility, while labor costs tip the scales against smaller mobile units.

“Using fast pyrolysis, a stationary unit with the material hauled to a central site (where transportation costs are covered by existing activities, such as sawmills), had the lowest breakeven cost of about $87 per ton of biochar. The few businesses with biochar have mentioned possible pricing of $200 per ton.”[28] If producers have to bear that cost, the stationary unit breakeven is $191/ton.[29] Adding carbon payments based on replacing lime-based soil amendments with biochar, the breakeven point is

- Relocatable - $1.05/metric ton
- Transportable - $3.39/metric ton
- Mobile - $16.44/metric ton.[30]

Diverse product streams including electricity and heat can also “change economics considerably,” David Sjoding notes.

Chad Kruger notes that WSU research is “focusing on designer chars and site-specific uses of the char – to try to both add value to the char and reduce the per acre cost of getting a benefit.”

“Anything we can do to create markets would be helpful,” says Kelpie Wilson. “Viable demonstration projects are really important.”

Scientifically, biochar still requires extensive field research. Biochar varies by feedstock and production process, and so will behave differently in various soil types and

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[27] Winsley, p.6
[28] Granatstein, p.iii-iv
[29] Granatstein, p.94
[30] Granatstein, p.116. Because is produced in a CO_2 intensive process, replacing lime could gain carbon credits.

locations. "Different pyrolysis produces different chars with huge initial impacts on crop yields, so we need to find the right soil-char combinations," notes Jim Ammonette, a PNNL scientist active in PNBI.

"Funding is needed for universities to experiment with material on the ground," says Max DeRungs, another PNBI organizer. "The point is to really get it in the ground in the Northwest."

Characterizing the qualities of different chars is vital to making biochar a commercial product. "Such characterization can ultimately 'protect' the buyer of biochars so that the final product has the attributes which the buyer expects," Schahczenski notes.[31]

"There is still a lot of technical basic biochar research to be addressed," Wilson says.

ADVANCING THE BIOECONOMY

Driving the bioeconomy forward will continue to require research and development in new ways for collecting, delivering and processing biomass streams, as well as new products and markets. All Northwest public universities are doing work in the area. Several notable efforts are:

- **Washington State University** has extensive efforts at several locations. At the Pullman campus, departments of Biological Systems Engineering, Chemical Engineering, Crops and Soils, and Agricultural Economics have joined together in a major bioenergy research effort. It covers areas including biodigestion, algae and pyrolysis for fuels, biochar production and chemical products. The ***Climate-Friendly Farming Project*** is extensively engaged. WSU is also regional lead for the ***Pacific Regional Biomass Energy Partnership,*** one of five U.S. Department of Energy regional biomass promotion efforts. [32]
- The ***Bioproducts, Sciences and Engineering Laboratory*** is a collaboration of WSU Center for Bioproducts and Energy and Pacific Northwest National Laboratory. This Richland, Washington center is researching advanced biomass technologies to produce energy, chemicals and high-value nutritional products. In addition, PNNL conducts research into applications of biochar to sequester carbon in soils.
- **Oregon Built Environment and Sustainable Technologies Center** is a collaboration of Oregon public universities aimed at propelling state leadership in a range of clean technologies. Among current research areas are transformation of waste into products, making chemicals with solar energy, and promoting on-farm biodiesel production.

[31] Schahczenski
[32] An extensive list of WSU research activities is available in *Bioenergy and Bioproduct Research and Outreach at Washington State University*

- **Montana State University** has two centers. The ***Northern Bio-Energy Center*** in Havre has facilities to do a broad range of analysis and testing for petroleum and bio-based fuels, oils, and additives, and runs its own biodiesel plant. The ***BioBased Institute*** in Bozeman is doing extensive research on camelina oilseed crops for a range of uses including fuels, and looking into other bioproducts such as de-icers and lubricants

Northwest biomass experts point to a Midwest state as the model for advancing the bioeconomy. Iowa, a center of first-generation biofuels, aims to lead the nation in bioeconomy development. In 2001, to found that effort, the state convened the Iowa Industries of the Future/Agriculture project to create a roadmap for building new bioenergy and bioproducts industries. Supported by federal and state agencies, the roadmapping brought together farmers, commodity groups, industry, researchers, environmental advocates, state government and financiers.

Their 2002 report***, Biobased Products and Bioenergy Vision and Roadmap for Iowa*****, set out ambitious goals for 2020:**

- gain three percent of U.S. chemical and liquid motor fuel sales and 15 percent by 2050
- grow production of bio-based materials 20 times
- power biorefineries completely with self-produced renewable energy
- rank first among states in farm soil carbon sequestration.

To achieve those goals, the roadmap sets an agenda for research, market development, capital investment, public policies, standards, incentives, education and outreach.[33]

Based on the roadmap, **Iowa State University created the Bioeconomy Institute to coordinate R&D work.** Though Iowa's land-grant university has engaged this field for many years, ". . . single objective, single investigator approaches to problems in this field have stymied progress toward commercialization of biobased technologies," the university explains. "The BEI was established to provide cohesion among the diverse efforts in bio-renewable resources on campus and to encourage collaboration among departments, colleges, and research units." The university claims 160 researchers across 29 departments and seven campuses who have cumulatively gained $51 million in federal and industry-sponsored research funding. [34]

"Iowa has a huge juggernaut going," David Sjoding comments. **"They have a deeply integrated grand scheme."** Parallel work in the Northwest has been more in "bits and pieces."

Northwest biomass experts envision a bioeconomy roadmap spanning the four Northwest states.

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[33] Available at http://www.ciras.iastate.edu/publications/IABioVisionRoadmap.pdf, viewed May 13, 2010
[34] Iowa State University Bioeconomy Institute, Who We Are, http://www.biorenew.iastate.edu/who-we-are.html, viewed May 13, 2010

"We have a unique opportunity now," notes Peter Moulton, Washington Department of Commerce bioenergy coordinator. "Process technology is starting to firm. We are starting to see results from the several-billion-dollar investment made by the federal government in biorefineries."

But, says Moulton, "We don't have a shared vision. We don't know which process technologies to stimulate for which feedstock." **A Northwest bioeconomy roadmap would "draw everything together – feedstocks, technologies, coherent incentives."**

A roadmap would stimulate public and private investment by filling in knowledge gaps. It would address critical questions such as those raised earlier about correctly matching feedstock supplies to their best uses, and ensuring they will be sufficiently available and produced sustainably. Key roadmapping areas are:

- Creating common standards and definitions for technologies and feedstocks
- Coordinating investment priorities for technologies
- Refining feedstock inventories to identify economical locations for processing facilities

Bioeconomy strategies need to address the right scale at which to develop businesses. They should map development of **local businesses and local jobs that cannot be shipped out of the region.** New business sectors and technologies will likely not be fully competitive on a unit-cost of production basis. They will require public support based on the full range of local economic development benefits. Those include targeted job creation, greater economic activity from keeping dollars circulating locally and a larger tax base for local and state governments

Another key need is updated laws and rules that acknowledge new biomass industries and technologies. New bioeconomy businesses must jump a number of regulatory hoops to win approval. A broad range of state and local agencies regulate how waste streams are handled, as well as emissions into air, land and water. So businesses must seek multiple permits, often from agencies unfamiliar with new processes. This causes delays and increases costs. **Needed is more streamlined permitting that maintains environmental quality while providing more straightforward pathways for new bioeconomy businesses.**

Though Midwest states such as Iowa and Minnesota are acknowledged leaders in building the bioeconomy, the Northwest has an advantage not possessed by the Midwest.

"The Northwest can take a strong leadership position because we don't represent the Midwest model of one or two products. We're not just corn and soybeans," Mark Fuchs of WDOE's Beyond Waste program notes. "We have a variety of feedstocks from different areas. **We've got a head start over many other states because we have to optimize across a bunch of feedstocks."**

The region "has abundant and diverse biomass resources due to our climate, physiography, and population," Fuchs adds. **"We have numerous resources to tap**

from municipal, forest, and agricultural sectors. From these diverse sources we can develop many fuels and agricultural nutrients, as well as numerous high-value food, health and chemical products, all while sequestering carbon along the way."