Building the Biocarbon Economy: How the Northwest Can Lead

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7.1.2010

Posted at:
http://climatesolutions.org/solutions/reports/biocarbon-briefs/

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ACHIEVING A GLOBAL TURNAROUND

Carbon dioxide, the major greenhouse gas increasing the capacity of the atmosphere to trap solar heat, is also the primary food source for plants. Meanwhile, plant materials can replace fossil fuels – ancient plant carbon whose rapid release into the atmosphere is the primary source of human-caused global warming.

These fortunate conjunctions together make up **the biocarbon paradigm,** which fundamentally aims at **leveraging plant growth and rich soils to halt the accumulation of carbon dioxide in the atmosphere and then to achieve a global turnaround.** By making nature a climate ally humanity can actually begin to draw down carbon dioxide toward levels that prevailed before we began massively consuming fossil fuels.

Over the past 250 years atmospheric concentrations of the powerful greenhouse gas have increased by one-third. Scientists increasingly call for reduction of carbon dioxide (CO_2) levels to 350 parts per million (ppm) and below. That contrasts with the current 387 ppm concentration now growing around 20 ppm a decade and rising at an accelerating rate. **CO_2 must be stabilized and reduced to avert massive polar ice melt, accompanying sea level rise and catastrophic release of natural carbon sinks** dwarfing humanity's annual emissions.

Such climate feedbacks, where global warming begins to feed itself, would intensify its effects ranging from intensifying storms and droughts, to increased disease in human populations. Feedbacks could well drive climate change beyond the capacities of human response. Therefore, **biocarbon can and must be mobilized in a concerted fashion if we are to meet the climate challenge.**

This is the introduction to a series of briefings on biocarbon, specially focused on how the Pacific Northwest can mount regional initiatives to accelerate biocarbon progress:

- ***The Biocarbon Imperative: Reaching Target 350*** **–** The science of emerging climate feedbacks driving the urgent need for atmospheric carbon reductions
- ***Reinventing Forestry: Growing Ecosystem Services*** **–** Diversifying forestry by growing carbon, water services, wildlife habitat and high-value wood products
- ***Re-grounding Agriculture: Restoring the Soil*** – Farm practices to build soil carbon, fertility and moisture while cutting fuel and fertilizer costs
- ***Working Lands Toolbox: Building Biocarbon*** **–** Supporting biocarbon-building practice changes by farm and forest landowners

- ***Re-greening Cities: The Carbon Landscape*** **–** Greenspaces and green infrastructure to build biocarbon and climate resiliency while saving energy and tax dollars
- ***Recycling Carbon: Bioeconomic Development*** – Building biocarbon through creating new jobs producing bioproducts and bioenergy

BUILDING THE BIOCARBON ECONOMY

The biocarbon paradigm points to economic transformation of land use practices in forestry, agriculture and urban/suburban development, accompanied by much greater efficiency in the use of biomass that comes from the land. At root this is an economic proposition. **Meeting the imposing challenges of climate requires a massive biocarbon scale-up that will happen only if grounded in economic viability. We must build a biocarbon economy.**

The biocarbon economy:

- ***Creates new value propositions for farming and forestry*** based on producing high-quality products and economically-valued ecosystem services
- ***Builds cities and settlements with high quality of life*** grounded in green features that also provide economical alternatives to high-cost hard infrastructure
- ***Generates new " bioeconomic" industries and jobs*** by transforming waste streams and sustainably produced biomass into bioproducts and bioenergy.

To have any chance of reaching the 350 ppm target, in the coming decades the world must accomplish two tasks:

- ***Vastly reduce fossil fuel emissions, with priority on closing coal-fired power plants that do not capture and store their emissions***
- ***Begin the decades- and centuries-long process of bringing down CO_2 concentrations by pulling the gas from the atmosphere to store it in healthier ecosystems and soils.***

The biocarbon economy contributes to accomplishing both by mobilizing nature's power to capture CO_2 in plants and soils through improved land use practices, while offering fossil fuel alternatives through sustainable employment of biomass.

BIOCARBON FOR ECONOMY AND ENVIRONMENT

Fortunately, practices that build biocarbon can synergistically generate other benefits that meet a host of needs. These co-benefits provide powerful economic and environmental incentives to implement new practices in farming, forestry and urban/suburban development. This opens great opportunities to build policies and economic tools that promote biocarbon while building prosperity and overall healthier environments. These co-benefits are detailed throughout this series.

Forest practices that accumulate carbon also generally build their ability to deliver other vital ecological services including water supply, flood control, wildlife habitat and recreation.

In forestry the greatest accumulations in carbon are gained by minimizing disturbances to forests. This translates into preserving old growth and transitioning working lands forestry to longer rotations and selective cutting. With new management practices lands can be managed for timber while actually increasing carbon stocks. These lands also have superior capacity to hold water, support biodiversity and buffer against projected climate change impacts. Forests that are more mature stand up better against intensified storms and longer dry spells with accompanying wildfire dangers. Meanwhile, commercial forests that harvest on longer rotations provide higher-quality wood products that gain premium value in the market. New revenue streams for carbon and other ecological services also improve economic viability.

Farm practices that stock up carbon in soils improve fertility and can reduce costly inputs subject to wild price swings including fuels, fertilizers and chemicals.

A prime agricultural practice to build soil carbon is conservation tillage that either reduces or eliminates plowing. The resulting buildup of organic matter in and on soils adds carbon, reduces erosion and retains more water than conventional tillage. This prepares farming for increased drought stresses expected under global warming. With improved soil fertility, the need for costly inputs such as fossil-fuel-based fertilizers decreases. Conservation tillage also saves significant amounts of fuel and labor because it requires fewer tractor passes. Other practices that build soil fertility and carbon include new crop rotations and addition of organic fertilizers, which also replace artificial products. Such “climate-friendly” farming can generate valuable new products including bioenergy and higher-quality foods. Benefits for society as a whole include reduced air and water pollution and improved wildlife habitat. New ecological services markets can add to the economic sustainability of farms.

Urban and suburban communities that incorporate greenspaces and green neighborhood features into growth and development strategies will experience improved quality of life while building biocarbon and climate resiliency.

Adding and preserving green features such as wetlands, greenspaces and green roofs to the urban/suburban fabric builds local biocarbon stocks. This “green infrastructure” also acts as a replacement for hard pipe and drain infrastructure in capturing and controlling rainwater flows. Buildings with green features can even generate their own water supplies. Typically “greenfrastructure” provides more economical solutions, saving taxpayer dollars. These features also cool the urban heat island effect, saving on energy bills. Greener cities will be better prepared to handle extremes of heat and precipitation. At the same time, maintaining greenspace reserves around cities preserves carbon in forests and fields. New development can be directed in ways that preserve natural carbon.

Recycling carbon by eliminating organic waste streams to generate valuable products builds new jobs, industries and biocarbon.

Organic residue streams from farms, forests and municipalities that currently are wasted or underutilized can generate bioproducts and bioenergy. All organic residues are prospective feedstocks for valuable products, and should be diverted from landfills to new production processes. This "bioeconomic development" opens tremendous prospects for creating new jobs and business sectors. It also closes carbon loops by replacing fossil fuel products and generating new products such as biochar and organic fertilizers that return carbon and other nutrients to the land. Biomass crops grown and harvested with sustainability criteria can also play on this stage.

SETTING A HIGH BAR FOR BIOCARBON

In building the biocarbon economy, it is crucial to be clear on how the biocarbon paradigm intersects with three controversial areas:

- ***Biofuels*** substitution for fossil fuels has raised many questions over whether carbon emissions are genuinely reduced, or in fact increased.
- ***Offsetting*** schemes to encourage carbon sequestration in forests and farms have come in for scrutiny, with many concerns over their effectiveness.
- ***Geoengineering*** proposals have included controversial "green-up" ideas such as seeding oceans with iron to encourage carbon absorption in plankton.

The biocarbon paradigm sets a high bar for the biocarbon economy – actions must stabilize and then reduce carbon dioxide, and take into account other potential consequences. Employing those criteria:

- ***All products employing bio-feedstocks must undergo analysis of full production lifecycles to determine overall carbon profiles.*** This is an important field for research that should be well supported. In particular, much more effort is needed to understand global land use changes spurred by generating new demand for biomass.
- ***Offsetting contracts must meet requirements that verify actual carbon reductions, and tools beyond offsetting will still be required.*** Offsetting only addresses new emissions, and the balance between incentives for offsetting and developing low-carbon energy sources must be taken into account. Meeting the 350 ppm target will require removing emissions accumulated over the past century or more. This will require additional tools that go beyond offsetting.
- ***Geoengineering plans hold huge potential for unintended consequences and require intensive research before any mass application.*** Whether or not geoengineering research should take place is beyond the scope of this series. The practices explored in this series build on a solid base of science. They apply procedures proven to build ecological and economic sustainability in uses of the land and its products, while adding to biological carbon stocks.

This series provides insights on issues surrounding offsetting and biomass sustainability.

A PACIFIC NORTHWEST INITIATIVE FOR BIOCARBON

The Pacific Northwest's forests are among Earth's greatest carbon accumulators, its farm soils are some of the world's most productive, and its cities are in the forefront of protecting and creating greenspaces. These **rich resources position the Northwest to mount a pacesetting regional biocarbon initiative that builds the biocarbon economy and innovates models for cooperation.** Such an initiative has strong potential to inspire and inform biocarbon efforts around the world.

The prospects for biocarbon are great, both to cool global warming and to improve economic and environmental sustainability. But there are practical challenges in changing land use management and economic frameworks. Overcoming them requires larger initiatives. Needed are new policies and economic tools that enable farmers, foresters, municipalities and bioeconomy entrepreneurs to make the leap to new practices. **By developing new tools and policies, the Pacific Northwest possesses a tremendous opportunity to drive forward biocarbon and realize its many benefits**.

Because biocarbon potential is inherently ecosystem-specific, building collaborative understanding at the regional scale is a logical angle of approach. The Northwest has massive biocarbon storage potential in an almost unparalleled range of forest, farm and metropolitan landscapes, spanning wet and dry climates. So knowledge and practicum can be developed in a diversity of areas. The region also possesses a world-class array of biocarbon innovators, researchers and policy experts ranging across the relevant sectors. By bringing all these assets to bear in a coordinated regional initiative, **the Northwest will develop practices, policies and tools that can be emulated around the nation and world.**

The Northwest starts with a competitive edge. The region's **natural resources** and entrepreneurial spirit have spurred **biocarbon innovations across the landscape** that are featured throughout this series. These assets provide a foundation of knowledge, experience and systems upon which far more extensive efforts can be built:

- Leading nonprofit groups and timber lands owners are **working to reinvent forestry** by exploring value streams for carbon storage, water management and wildlife habitat, as well as higher-quality wood products markets that complement those services.
- A nationally leading cluster of groups and agencies is **developing ecosystem services science, protocols and markets** that engage a range of forest and farm landowners.
- Northwest agricultural scientists and innovative farmers are at the cutting edge in **developing science, technologies and practices for climate-friendly farming.**
- Regional researchers and public agencies are national leaders in **understanding biomass residue streams** from forests, farms, mills, food processors and municipalities, and **developing technologies** and markets to transform residues into valuable products.

- A range of business and nonprofit entrepreneurs are also **pushing forward advanced biomass business models** to make and market bioenergy and bioproducts such as biochar, a soil amendment with great carbon storage potential.
- Northwest municipalities are long-term leaders in **preserving carbon-storing greenspaces through growth management**, and are on the cutting edge of **developing green infrastructure**.
- Urban research centers at Northwest universities are **doing leading-edge science on carbon accumulation across metropolitan landscapes.**

These assets make the Northwest a natural laboratory for biocarbon research, development, demonstration and deployment. And a laboratory is what is needed now. Each area of biocarbon opportunity carries much complexity and significant need for developing new knowledge and practices. **The Northwest can pioneer in building the biocarbon economy by:**

- ***Refining best land use practices*** for agriculture, forestry and urban/suburban development
- ***Developing biomass technologies and markets*** to generate bioproducts and bioenergy
- ***Creating new business models*** that credit ecosystem services and build markets for high-quality farm and forest products.

These are large and complex areas. Full development is a process of decades**. Now is the time to start with research efforts and model projects that develop best practices, policies, economic tools and markets.**

The Northwest has emerged as a national and global climate leader. State and local governments are in the forefront of climate policy and action planning. Strong business clusters are growing in clean technology fields including wind, solar, smart grid and green buildings. **Biocarbon can and should be the Northwest's next leadership initiative.** This series of briefings is meant to inform that effort.

The Pacific Northwest grew from **a base of natural resources** – forests and farms that still play an economically important role. The region has built **cities that lead in technology and quality of life**. These are assets from which substantial biocarbon innovations are growing and on which a coordinated regional biocarbon initiative can be built. **Growing the biocarbon economy is a process of decades. The time to start is now, and the place to start is the Pacific Northwest.**

The Biocarbon Imperative: Reaching Target 350

The science of emerging climate feedbacks driving the urgent need for atmospheric carbon reductions

UPSETTING THE CARBON BALANCE

Carbon is at the center of the community of life, one of its three basic constituents along with hydrogen and oxygen. Life first appeared in the oceans and its carbon remains accumulated on the seabed, where it was drawn into the Earth as tectonic plates slid under one another. When that carbon was pushed into the atmosphere by volcanic eruptions, it thickened the atmosphere sufficiently to trap the solar heat that made life on land possible.

Atmospheric carbon levels have varied greatly over millions of years and with them, global temperatures. But over the long-term, natural biological and geological processes have absorbed carbon dioxide (CO_2) from the air. **Fossil fuels – coal, oil and natural gas – are in essence fossilized photosynthesis.** The CO_2 that pours out vehicle tailpipes and power station smokestacks today was drawn out of the atmosphere millions of years ago by hungry plants. They combined $C0_2$ with water and sunlight to grow and nourish themselves. Natural forces buried plant biomass, and then it was refined by Earth's heat and pressure into fossil fuels. **Now humanity has upset the balance by digging and pumping the carbon stored in fossil fuels and returning it to the atmosphere in a geological eye blink.**

Before the industrial revolution when humanity began to drive civilization on massive fossil fuel burning, carbon dioxide in the air ranged between 180-300 parts per million for around 2.1 million years.[1] We know this by analyzing ice cores,which trap bubbles of the atmosphere as new layers of ice are frozen, and fossil shells in ocean sediments, which contain chemical signals of CO_2 levels from the time they were formed.[2] These CO_2 concentrations may seem tiny, but their small variations signaled the difference between ice ages and warmer periods. **In 2009 CO_2 concentrations reached 390 ppm, up nearly two ppm from 2008, and growing at an accelerating rate.**[3]

CO_2 and other greenhouse gases such as methane and nitrous oxide trap heat from sunlight as it reflects from the planet's surface. While greenhouse gases (GHGs) exist only in trace amounts, they make all the difference. In past eras when greenhouse gas concentrations were low, much of Earth was frozen. When they were high, tropical conditions existed in the Arctic. In the 10,000 or so years since ice age conditions faded from Earth, the capacity of GHGs to trap solar radiation has made possible the growth of agriculture and civilization.

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[1] Intergovernmental Panel on Climate Change Working Group I, *Summary for Policymakers*, 2007

[2] *Science Daily*, Carbon Dioxide Higher Today than Last 2.1 Million Years, June 21, 2009

[3] Atmosphere Monthly, Feb. 2010

But that fragile balance have been overturned by humanity's GHG emissions. **The Earth has warmed around one degree Fahrenheit over the past century, and the rate of warming has accelerated over recent decades.** Strong scientific agreement exists that most of this warming is traceable to the effect growing GHG concentrations have in thickening the heat-trapping blanket around the Earth.[4]

The greater part of the global warming challenge is about dumping ancient carbon into the atmosphere faster than nature can reabsorb it. So it remains in the air for extended periods accumulating more solar energy. Significantly, the second greatest source of GHGs is release from natural carbon sinks through deforestation and agricultural development. But even so, **plant growth is still absorbing a net of one billion metric tons (MT) of the 8.5 billion MT in fossil carbon that human activities release annually**.[5]

Another three billion MT are entering oceans. **Increasing ocean acidification as a result of direct chemical absorption of CO_2 into seawater is a global impact of fossil fuel burning only beginning to be addressed.** In 2010 The National Research Council reported that average pH of ocean surface waters has decreased by 0.1 to 8.1 over the past 250 years. Increasing acidity is already reducing the ability of corals, plankton and shellfish to build shells and skeletons. Corals are the center of ocean biodiversity, plankton are a critical link in biological absorption of CO_2 in oceans, and shellfish are an economically valuable product in many regions including the Northwest. Oceans are projected to drop in pH another 0.2-0.3 units this century. **The rate of change exceeds any known to have occurred in at least 800,000 years**, NRC reports.[6]

Working with nature to increase carbon storage through plant growth reduces ocean acidification and atmospheric warming.

TARGET 350 TO STABILIZE POLAR ICE AND SEA LEVELS

A few years ago, scientists and policymakers targeted a doubling of CO_2 to around 550 ppm as the limit to halt dangerous climate change. As knowledge about how Earth's ecosystems behaved under different CO_2 concentrations in the past grew, that target was refined downwards to 450 ppm. But **now a number of leading scientists are recommending a target of 350 ppm and below.**

The most prominent of those scientists is James Hansen of NASA Goddard Institute of Space Studies. In 2008 Hansen and a team of leading climate scientists published an article which changed the entire climate change dialogue: "Target Atmospheric CO_2:

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[4] Intergovernmental Panel on Climate Change.
[5] James Hansen, *Storms of My Grandchildren: The Truth About the Coming Climate Catastrophe and Our Last Chance to Save Humanity*, Bloomsbury USA, New York, 2009, p.118-120
[6] National Research Council, Ocean Studies Board. *Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean*, National Academies Press, 2010

Where Should Humanity Aim?" [7] The scientists made a compelling case based on the state of the planet **in past geologic eras when GHG concentrations were similar to today's. The geologic record shows much higher sea levels based on massive polar ice melt.** They concluded that unless humanity dials back atmospheric CO_2 concentrations to 350 ppm, a similar fate will befall our era. Their work now sets the goalpost for much of the movement to stabilize the climate.

Writes the Hansen team, **"If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted**, paleoclimate evidence and ongoing climate change suggest that **CO_2 will need to be reduced from its current 385 ppm to at most 350 ppm."[8]**

The 350 ppm goal was also supported in a groundbreaking 2009 scientific paper. It brought together 29 scientists to answer the question, **"**What are the non-negotiable planetary preconditions that humanity needs to respect in order to avoid the risk of deleterious or even catastrophic environmental change at continental to global scales?"

Scientists conclude that ". . . **humanity has already transgressed" the climate boundary, and pointed to 350 ppm as the target to restore a "safe operating space for humanity."**[9]

Hansen and other scientists analyzed data from the time when the planet cooled enough to allow ice sheets to appear in Antarctica around 34 million years ago. Prior to that CO_2 concentrations were higher than today, but they slowly declined as nature absorbed the carbon. Hansen and his fellow scientists concluded that **Antarctic glaciers most likely appeared when CO_2 concentrations declined to 450 ppm.**

Another study published in *Science* in 2009 looked at a period between around 14-20 million years ago when the Earth's temperature was 3-6° C hotter and ocean levels were 80-130 feet higher than today. Using natural markers in tiny fossil shelled organisms, scientists found they were around 400 ppm.[10] At the current rate that level will be reached this decade.

"What we have shown is that **in the last period when CO_2 levels were sustained at levels close to where they are today, there was no icecap on Antarctica and sea levels were 25-40 (meters) higher**," lead researcher Aradhna Tripati told the BBC. The UCLA scientist added, "At CO_2 levels that are sustained at or near modern day values, you don't need to have a major change in CO_2 levels to get major changes in ice sheets." [11]

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[7] James Hansen, "Target Atmospheric CO2: Where Should Humanity Aim?," *Open Atmos. Sci. J.* (2008), vol. 2, pp. 217-231

[8] Hansen et al, p.1

[9] Johan Rockstrom et al, "Planetary Boundaries: Exploring the Safe Operating Space for Humanity," *Ecology and Society* 13(2): 32

[10] Aradhna K. Tripati et al**,** "Coupling of CO_2 and Ice Sheet Stability Over Major Climate Transitions of the Last 20 Million Years," *Science***,** Dec. 4 2009, Vol. 326. no. 5958, pp. 1394 - 1397

[11] Richard Black, 'Scary' climate message from past," BBC News website **,** 10 October 2009

Such studies strongly suggest that the tipping point which sets the course toward an ice-free planet, where sea levels are around 250 feet higher than today, is not far. The process, once started, will not be easy to stop because it feeds itself. Water from melting ice eats down into the ice and melts more, while meltwater also takes in solar heat more effectively than ice. **Where reflective white ice is replaced by heat-soaking blue ocean, far more solar energy is absorbed.** This is known as ice-albedo feedback.

In October 2009, at the end of the summer melt season, Arctic sea ice coverage reached the third lowest level since satellite observations began in 1979 -- 25 percent below the 30-year average. The lowest was in 2007 and second lowest in 2008.[12] In May 2010 the extent of Arctic ice decreased at the fastest May melt rate in the satellite record.[13]

One of the strongest indications that ice-albedo feedback is already feeding global warming came in an Australian study published in *Nature* in April 2010. Increased temperatures during spring and summer are lengthening the melt season, so more sea ice is being melted. Researchers found that **declining sea ice is opening up wide areas of dark ocean, so more heat is being absorbed.**[14]

"The findings reinforce suggestions that strong positive ice-temperature feedbacks have emerged in the Arctic, increasing the changes of further rapid warming and sea ice loss," conclude researchers James Screen and Ian Simmonds of the University of Melbourne.

Abnormally high melt rates are also being observed across regions drained by Greenland's three major glaciers: Kangerlussuaq and Helheim on the east coast, and Jakobshavn on the west, as well as ice sheets at the island's northern end. At the vital ocean outlets where ice accumulations over water slow glacier flow, around 350 square miles were lost from the 34 widest glaciers.[15]

"Ice sheet contributions to sea level rise today are small, but **accelerating ice mass loss observed on Greenland and Antarctica make dubious any assumption that the ice sheets would survive for centuries**" if GHG concentrations remain at current levels, the Hansen team writes.[16] They note that the geologic record shows less powerful global warming events have brought on sea level changes of several meters per century.[17]

RELEASING NATURAL CARBON – FEEDBACK DANGERS

Release of natural carbon storehouses which dwarf humanity's annual emissions represent another grave concern. This could create climate feedback loops that evade any

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[12] http://www.arctic.noaa.gov/reportcard/seaice.html
[13] National Snow and Ice Data Center, "Arctic sea ice extent declines rapidly in May," June 8, 2010, http://nsidc.org/arcticseaicenews/ viewed June 24, 2010
[14] Lauren Morello, "Ice loss accelerates warming in the Arctic – study," Energy & Environment Climate Wire, April 29,2010
[15] http://www.arctic.noaa.gov/reportcard/greenland.html
[16] Hansen et al, p.14
[17] Hansen et al, p.5

possibility of human control. **Carbon stores in rapidly warming northern regions are already releasing GHGs, setting up potential for runaway global warming.**[18]

A dramatic warming event that took place 55 million years ago was caused by the release of around 3,000 billion MT of methane hydrates from the ocean floor, scientists believe. Methane is a GHG 30 times more powerful than CO_2. Today that storage of methane in ice form has rebuilt to 5,000 billion MT.[19] **Researchers are discovering methane hydrate deposits are already releasing their carbon.**

In late 2009 scientists reported, "More than 250 plumes of gas bubbles have been discovered emanating from the seabed of the West Spitsbergen continental margin, in a depth range of 150–400 m(492-1,312 feet) . . ." The emissions, mostly methane, came from depths where hydrates are normally stable. "**Warming of the northward-flowing West Spitzbergen current by 1°C over the last thirty years is likely to have increased the release of methane from the seabed. . .** "[20]

More recently, scientists have discovered that hydrates on the continental shelf off eastern Siberia are perforated and leaking seven MT of methane from 100 hot spots.

"The amount of methane currently coming out of the East Siberian Arctic Shelf is comparable to the amount coming out of the entire world's oceans," said lead researcher Natalia Shakhova of the University of Alaska. **"Our concern is that the subsea permafrost has been showing signs of destabilization already."**[21]

"The release to the atmosphere of only one percent of the methane assumed to be stored in shallow hydrate deposits might alter the current atmospheric burden of methane up to three to four times," Shakhova said. "The climatic consequences of this are hard to predict."

"**Release of even a fraction of the methane stored in the shelf could trigger abrupt climate warming," said the National Science Foundation.**

Land-based Arctic permafrost is another worrisome feedback threat. New research doubles the estimate of carbon stored there to 1.5 billion MT.

Study co-author Pep Canadell of CSIRO, Australia, notes. **"All evidence to date shows that carbon in permafrost is likely to play a significant role in the 21st century climate** given the large carbon deposits, the readiness of its organic matter to release

[18] Fred Pearce, *With Speed and Violence: Why Scientists Fear Tipping Points in Climate Change*, Beacon Press, Boston, 2007, p.77-85

[19] Hansen, *Storms*, p.161-3

[20] Graham K. Westbrook et al, "Escape of methane gas from the seabed along the West Spitsbergen continental margin," Geophysical Research Letters, Vol. 36, L15608, 5 Pp., 2009

[21] National Science Foundation, "Methane Releases From Arctic Shelf May Be Much Larger and Faster Than Anticipated," Press Release 10-036, March 4, 2010

greenhouse gases when thawed, and the fact that high latitudes will experience the largest increase in air temperature of all regions."[22]

Radioactive carbon dating already shows **most of the CO_2 escaping from thawing Alaska permafrost was stored thousands of years ago.** This "demonstrates how easily carbon decomposes when soils thaw under warmer conditions," said Professor Ted Schuur, University of Florida and co-author of the study.[23]

Though humans generally do not plan centuries or even many decades ahead, the important point is that **we have already crossed the danger line. The longer we wait to respond, the more difficult it will become to restore a planetary "safe space."**

"Humanity's task of moderating human-caused climate change is urgent," the Hansen team concludes. **"It is likely that the level of atmospheric greenhouse gases capable of causing undesirable, even catastrophic effects, has already been passed."**[24]

PULLING BACK FROM THE BRINK

There is still time to pull back. The situation might be compared to red-lining a manual transmission automobile. You can rev the engine beyond the red line on the RPM dial for a bit, but the longer you stay above the line the higher the risk you will burn out the engine.

The problem is energy imbalance. Human-made greenhouse gases have increased energy retained by the Earth by .0.5-1 watts per square meter per year, or the equivalent of one Christmas tree bulb for every one or two square meters of the planet. Multiplied across the Earth's surface, that adds up. By comparison, orbital cycles cause ice ages by reducing incoming energy by less than 0.25 watts per square meter.

But humanity can reduce CO_2 concentrations to 300-350 ppm and correct the energy imbalance by reducing the heat-trapping capacity of the atmosphere. **The critical issue is how long CO_2 remains higher than 350 ppm**. The longer it does, the more time the energy imbalance is extended and the greater the risk of catastrophic consequences such as irreversible disintegration of polar ice and natural carbon sinks.

If humanity begins now to deeply reduce fossil fuel emissions, and at the same time mobilizes the resources of the plant world to absorb CO_2 through photosynthesis, the odds are we will avoid burning out our planet. **The first requirement is a shutdown of coal-fired power plants that release CO_2 into the air.** The Hansen team calculates that **phasing out coal emissions by 2025 in developed nations and 2030 worldwide would halt CO_2 growth to no more than 425 ppm** (this assumes that oil production will reach

[22] *Science Daily*, "Super-Size Deposits of Frozen Carbon In Arctic Could Worsen Climate Change, July 6, 2009
[23] Ibid
[24] Hansen et al, p.15

a peak due to resource limitations, and unconventional substitutes such as tar sands, oil shales and coal-to-liquids will not grow). Capturing and sequestering carbon from gas-fired power plants could halt CO_2 growth at 400 ppm.

The gap of 50-75 ppm reductions in CO_2 concentrations needed to reach target 350 must be filled by the power of nature in the form of photosynthetic process. Just as plants are the origin of fossil fuels, so must they be mobilized to soak fossil carbon out of the atmosphere. Forests, agricultural soils, even vegetation and soils in developed areas, all have a vital role to play. Bringing the power of photosynthesis to bear fully upon the climate challenge will take changes in land management practices, as well as far more efficient use of biomass to replace fossil carbon and cycle carbon back to the land. **This will require new public policies as well as development of new economic instruments, markets and technologies**. Those are detailed in other installments of this series.

Reinventing Forestry: Growing Ecosystem Services

Diversifying forestry by growing carbon, water services, wildlife habitat and high-value wood products

A WORLD-CLASS CARBON RESOURCE

The iconic forests of the Pacific Northwest represent the region's greatest carbon storage opportunity, and one that ranks at world-class scale. Westside forests ranging from the coast to just east of the Cascade crest "are capable of sequestering more carbon on some sites than any other terrestrial ecosystem," notes veteran University of Washington forest scientist Jerry Franklin.

A U.S. Forest Service study found **that forests in Oregon, Washington and California store 20.5 billion metric tons of carbon.** That is **39 percent of total forest carbon in the U.S. and close to two percent of carbon stored in world forests**.[25]

Another study places the potential upper bound for carbon storage in westside forests at 671 metric tons CO_2 equivalent ($MTCO_2e$) per acre compared to a current average 330 $MTCO_2e$/acre.[26] **While it is unrealistic to expect that the old forests will be fully restored, it is conceivable to envision far greater carbon storage.**

"We could really do a lot with Northwest forests in the next 50 years to take CO_2 out of the air," Franklin says. "We've drawn down the carbon stocks. There's general agreement that **only 20-25 percent of aboveground carbon remains in coastal forests compared to the amount before European settlement.** That means you have a lot of capacity you could theoretically fulfill."

"We could probably double the store, if that is the only objective," Oregon State University forest scientist Mark Harmon says. "**I'm sure we could easily increase it by 50 percent."**

Building up biocarbon in forests involves a set of practice changes centered on one "fairly simple" rule, Harmon says**. "The less frequently you disturb a forest, the more carbon it's going to store."**

"What we could do to really increase carbon sequestration is much longer rotations on managed lands," Franklin says. "We tend to cut at a time when forests are really beginning to sock away a lot of carbon, at 40 years. Douglas fir forests tend to accumulate biomass through the second century."

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[25] Richard A. Birdsley, *Carbon Storage and Accumulation in United States Forest Ecosystems,* USDA Forest Service General Technical Report Wo-59, 1992, p. 3

[26] Erica A.H. Smithwick et al, "Potential Upper Bounds of Carbon Storage in Forests of the Pacific Northwest," *Ecological Applications*, 12(5), 2002, 9.1315

After a disturbance, whether cutting, disease or fire, **forests accumulate carbon on a steep curve over the first 150 years and do not reach a stable carbon level until around 200 years**.[27] In older forests, carbon gain and loss tend to balance out.

Carbon releases continue years after clearcutting due to decomposition of organic material. Even at 80 years, regenerating forest stands store approximately half the tree carbon of nearby old-growth forests averaging around 500 years in age, "indicating that **conversion of old-growth forests to younger managed forests results in a significant net release of C (carbon) to the atmosphere."**[28]

Not everyone agrees that longer rotations are the prescription for gaining the most carbon storage from forests. Some scientists and forest industry representatives maintain that short-rotation cutting locks large amounts of carbon in wood products. Most forest advocates as well as leading scientists dismiss that argument.

One study found that only 23 percent of carbon in Oregon and Washington wood products harvested from 1900-92 was stored, including 74 percent in structures and 20 percent in landfills. Most carbon is released to the atmosphere during the production phase, 45-60 percent depending on the year.[29] Meanwhile, a trend toward shorter rotations is generating lower-quality wood products that tend to deteriorate more quickly. The thickly grained wood of older trees provides longer-lasting products.

However, the argument that short rotations based on carbon stored in wood products is still influential with both the timber industry and some policymakers. Thus **research must continue on the dynamics of carbon in wood products** with different forest management practices and production practices. **Results and their implications need to be communicated to the public and policymakers** in order to ensure that an accurate picture informs public policy.

Besides longer rotations, **another forest management option that yields high biocarbon performance is selective cutting.** Harmon says cutting 20 percent of a forest every 20 years can equal maintaining the whole forest to 200 years. Selective cutting leaves an overall healthier forest better capable of sustaining tree re-growth. Targeting larger, older trees opens spaces for younger trees to grow faster.

"**Frequent partial harvest of forest stands can store as much C in the entire forest system as long intervals between complete harvests** of trees in a stand," writes Harmon and other scientists. "This occurs because with partial harvest in a stand, the live C store

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[27] Ibid

[28] J.E. Janisch and Harmon, M.E., "Successional changes in live and dead wood carbon stores: implications for net ecosystem productivity," *Tree Physiology*, 22, p77-89. 2002.

[29] Mark E. Harmon et al, "Modeling Carbon Stores in Oregon and Washington Forest Products: 1900-1992," *Climatic Change* 33: 521-550, 1996

is not reduced to zero . . . . With complete harvest of the trees in a stand, the live C store has to accumulate from zero stores."[30]

OPTIMIZING FOR MULTIPLE ECOSYSTEM SERVICES

In general, practices that improve carbon storage in forests tend to enhance other ecosystem services**. Healthy westside forests capture water, beneficial during both droughts and drenching storms, and sustain high levels of biodiversity.** So improving their biocarbon performance not only tamps down global warming – it improves regional capabilities for adapting to the intensified heat and water cycles of global warming.

But there are cases where ecosystem forest carbon storage needs to be balanced with other objectives including wildlife habitat and fire management.

For example, forest researchers and advocates are reaching agreement that careful thinning is needed to improve habitat in some westside forests thickly replanted as tree farms after clearcutting. East of the Cascades forests typically have one-third to one-half the carbon storage of their coastal cousins. In contrast to westside forests where fire is rare, on the eastside light forest fires are key to ecological functions. But a century or so of fire suppression has thickened the forest with overgrowth, threatening genuine old growth trees with stand-replacing fires. So some level of thinning there is also widely regarded as a necessity.

Thinning to improve habitat and reduce fire dangers is not expected to maximize short-term carbon storage. But it will but will prepare forests to better withstand the extremes of climate change, and to build up carbon stocks over the long term.
Thinning to improve habitat and reduce fire dangers is not expected to maximize short-term carbon storage, but it will but will prepare forests to better withstand the extremes of climate change, and to build up carbon stocks over the long term.

"Treating these dense monocultures through variable-density thinning (with stops and gaps in trees to create structural diversity) is likely to help facilitate onset of older forest characteristics," notes Dominick DellaSala, chief scientist for the National Center on Conservation Science and Policy.[31]

A bill introduced by Oregon Sen. Ron Wyden in December 2009 reflects an emerging consensus between a wide range of forest advocates and the forest industry on the issue. The *Oregon Eastside Forests Restoration, Old Growth Protection and Jobs Act* would set the stage for thinning on six national forests, while prohibiting logging larger trees. The

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[30] Mark E. Harmon et al, "effects of Partial Harvest on the Carbon Stores in Douglas-fir/Western Hemlock Forests: A Simulation Study," *Ecosystems* (2009) 12: p789

[31] Testimony of Dominick A. DellaSala, Ph.D., Chief Scientist, National Center for Conservation Science & Policy, and President Elect, Society for Conservation Biology, North America Section, House Subcommittee on National Parks, Forests & Public Lands, Committee on Natural Resources, March 3, 2009 Hearing, :"The Role of Federal Lands In Combating Climate Change"

bill would allocate $50 million to ramp up the effort, and set up a science advisory committee to guide it.

"We need the timber industry to help restore eastside forests. It's no longer zero-sum," comments Andy Kerr, a veteran forest advocate who helped negotiate the deal between the industry and advocates including Oregon Wild and Defenders of Wildlife.

Much Northwest commercial timber land is also planted thickly as industrial tree farms with trees 30-40 years old. From the ecosystem services standpoint, the worst action owners can take apart from clearcutting those lands is to do nothing at all, says Ian Hanna of the Forest Stewardship Council U.S.

"For optimal growth the best thing they can do is thin," Hanna says. "The younger the forest the truer is this notion."

PROVIDING ECOSYSTEM SERVICES ON FEDERAL FORESTS

Northwest federal forest lands represent carbon stores of the first order, a Wilderness Society study found:

- U.S. Forest Service lands store an average of 500 $MTCO_2e$ per acre, and account for nine of the top 10 carbon-storing national forests in the U.S. (the other is the Tongass in the neighboring biome of Southeast Alaska).
- Oregon and Washington national parks store 644 $MTCO_2e$/acre.
- Bureau of Land Management forests in the region average 460 $MTCO_2e$/acre.
- By comparison, tropical rainforests hold 360-460 $MTCO_2e$/acre.[32]

The Wilderness Society notes that "our national forests and other public lands might add carbon storage to the set of multiple uses they provide as a public service to the nation, through practices that accumulate carbon in old-growth forests, large woody debris, and forest soils."[33]

Explicitly **re-purposing federal forests as providers of ecosystem services – climate, water, biodiversity, recreation – is a goal supported by many forest advocates.** This would also ensure that federal forests are available to buffer against climate change.

"Federal lands often contain large blocks of intact and functional ecosystems with viable fish and wildlife populations most capable of adapting to rapid climate change in the coming decades," Dominick DellaSala testified before Congress. "Therefore in an era of increasing climate disruptions, federal lands are our best hope for conserving the ecosystem services upon which society depends. Managing for the restoration and conservation of those ecological systems must become the clear and primary goal of federal agencies." DellaSala asked that the Secretaries of Agriculture

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[32] Ann Ingerson and Anderson, Mike, Top Ten Carbon Storing National Forests in America, Wilderness Society, March 2010

[33] Ann Ingerson, *U.S. Forest Carbon and Climate Change: Controversies and Win-Win Approaches*, The Wilderness Society, 2007, p.9

and Interior be required "to develop a connected system of lands and waters as a climate change refuge." [34]

For westside old-growth forests, almost all on federal public lands, the clear imperative is preservation of a globally-significant carbon sink. It will take at least 250 years after cutting down an old-growth stand to re-grow the carbon store.[35] Since the forest struggles in the 1980s and 1990s, the trend has been toward preservation. While the Northwest Forest Plan adopted in the mid-'90s allowed cutting some older trees, in effect very little old growth has been cut. But permanent preservation has not yet been enshrined into law. Many forest advocates believe this is a logical step.

Meanwhile restoration forestry will grow young forests into mature and old growth stands. Actions such as thinning and road closings are needed on forests that have been managed for timber harvest. The Wilderness Society estimates that one-third of the Forest Service's 375,000-mile road system could be retired and reseeded for $601 million to $1.26 billion. That would sequester at least 40 million metric tons for CO_2 nationally, half in Northwest and Northern Rockies forests.[36]

Since the "timber wars," the trend in the U.S. Forest Service has been toward forestry oriented to ecosystem services.

"Most timber harvesting we do now has a restoration focus – fire, wildlife, forest health – typically in an integrated approach where timber production is an outcome," notes U.S. Forest Service Region Six Director of Natural Resources Jose Linnares.

An innovative Forest Service research project on the Deschutes National Forest in Oregon aims to describe and quantify the value of ecosystem services provided by the forest including carbon, water, recreation and habitat. These new analytical tools will be used as a framework for forest stewardship, with an initial analysis of trade-offs between thinning to reduce fire dangers and other ecosystem services.

Some make the argument that carbon offset markets could be used to fund reforestation and improved forest management projects on federal lands. Projects on federal lands could potentially be much cheaper to implement than private land projects Federal agencies often do not require the same financial returns as private landowners. But this concerns opponents, among whom number many public lands advocacy groups and many who work in the private lands offset market. The large extent of federal lands raises worries that the market could be flooded by cheap offsets that dampens other markets. **Lands advocates maintain that a basic function of federal public lands should be to provide ecosystem services such as carbon accumulation**.

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[34] Testimony of Dominick A. DellaSala

[35] Mark E. Harmon; Ferrell, William K., and Franklin, Jerry F., "Effects on Carbon Storage of Conversion of Old-Growth Forests to Young Forests," *Science*, Feb. 9, 1990, p.669-702

[36] Joe Kerkvliet et al, "Carbon Sequestered When Unneeded National Forest Roads are Revegetated," The Wilderness Society, Feb. 2012

So this should not be a marketable, private commodity, but a function supported by public budgets, they argue.

Forest advocates in British Columbia are moving strongly toward climate-based preservation of BC Forest lands, providing a model for work in the U.S. Northwest. Seven BC environmental NGOs have formed Working Group on Biodiversity, Forests and Climate. The group commissioned a scientific study by veteran ecologist Jim Pojar. The report calls for an interconnected climate conservation network managed for carbon and biodiversity covering 50 percent of the provincial landscape. That compares to 15 percent that is now in parks and protected areas. BC groups are working to have one or more climate conservation areas designated in the next four years and for science-based mapping of priority areas around the province.

"Intact, functional, natural ecosystems could be more resilient to climate change than are ecosystems that are fragmented, simplified or degraded by human activities," Pojar writes. These ecosystems contain microclimates that buffer climate change, and make it easier for species to migrate in response to warmer temperatures. "Natural forests in particular play a major role in protecting the quality and quantity of water by buffering the impacts of storms, floods, erosion, drought and rising temperatures."

At the same time, **"There is a strong link between ecosystem conservation and carbon stewardship."** BC forests average 311 $MTCO_2e$/acre, while **BC forests hold an estimated 18 billion metric tons of carbon**.[37]

On the U.S. side **the Sierra Club is assembling the scientific base for climate-based conservation efforts in the Puget Sound and Olympic Peninsula region**. The club's emphasis on climate and energy issues is cross-fertilizing with its traditional focus on lands issues.

"We realized we needed to look through a different lens, resilient habitat," explains Cascade Chapter Public Lands Organizer Benjamin Greuel. The effort is still shaping, and will require a broader alignment, he adds. "To tackle something like this, no one can do it alone."

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REINVENTING FORESTRY ON WORKING LANDS

Working forest lands under private, state and tribal ownership forest lands represent a different set of challenges, as well as a far larger portion of U.S. forested lands.

"With 63 percent of our nation's forests privately owned . . . carbon-friendly management of public forestland will not be enough," the Wilderness Society points out."[38]

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[37] Jim Pojar, *A New Climate for Conservation,* Working Group on Biodiversity, Forests and Climate, Jan. 2010.

[38] Ingerson, *U.S. Forest Carbon and Climate Change: Controversies and Win-Win Approaches,* p.9

The biocarbon challenge on working forest lands is to make an economic proposition out of longer rotation harvesting and selective cutting. That entails building bridges to new markets for ecological services and higher quality wood products.

For two decades efforts have been underway to build new economic models for working lands forestry that create value for ecosystem services including wildlife habitat, clean water and carbon storage. Through voluntary efforts and early carbon cap-and-trade programs, small but significant markets for ecosystem services have been created (an extensive discussion on carbon offsetting and ecosystem services markets is carried in the *Working Lands Toolbox* briefing). Much of this work has focused on preventing conversion of working forests to development.

West Coast states have been a global innovation center in economically valuing ecosystem services as a forest product. Work to develop credible forest accounting protocols for increased forest carbon sequestration in California has evolved into the ***Climate Action Reserve.*** Paula Swedeen describes it as "the most rigorous carbon accounting protocol in existence."

Over 50,000 acres of working forest in California, Oregon and Washington have been conserved through the ***Pacific Forest Trust*** since its inception in 1993. That represents $160 million worth of land. Conservation easements (also covered in *Tools & Policies*) cover 38,000 acres of that land. PFT now shares its knowledge nationally, consulting with operations managing more than five million acres of working forests.

One exemplar forest owner with which PFT has worked is the Fred M. Van Eck Foundation in the redwood region of Northern California. The foundation is using carbon money and the sale of a conservation easement to restore second growth forest to its former structurally and functionally complex form through selective harvest. Income to the landowner is coming from sustainable timber harvest – 50 percent of growth per decade – and carbon credits registered by the Climate Action Reserve.

Carbon stocks will be significantly higher on this 2,200-acre property in 100 years than it was when the project started. The land also provides a home to a pair of spotted owls. The permanent conservation easement ensures that the restored forest will continue to provide ecosystem services for a very long time. Such arrangements provide income that can be crucial to allowing forestland owners to make a transition to longer rotations.

Small, non-industrial forest ownerships offer fertile biocarbon potential. In Washington State, 90,000 landowners hold five million acres mostly in blocks of a few hundred acres or less, notes Mitch Friedman, executive director of Conservation Northwest. Around half of landowners are not managing for timber. "Of those that do, most do so on significantly longer rotations than the 35-45 years now common on industrial lands. The Hamma Tree Farm aims for 77 years on its 3,000 acres; Cowlitz Ridge aims for 80 years on its 1,200 acres."

Court Stanley, president, of Port Blakely Tree Farms, explains the challenges facing timber operators in making the transition to new forestry practices. Once management decisions have been made to harvest at a certain age, companies are financially locked in to that plan.

"Once you reduce a rotation age, it is hard to get back," Stanley says. "It becomes impossible for a company to do, based on cash flow."
"It is hard to make the leap based on the old paradigm," Hanna agrees. "A diversity of income streams is the ultimate solution"

Ecological services payments are an important element of that diversity. They can come from a multiplicity of sources, including private land trusts; ecosystem services markets for water, carbon and biodiversity; and local, state and federal programs. For example a number of USDA conservation programs now support forestry improvements including the Conservation Reserve Program, Wildlife Habitat Incentives Program and Environmental Quality Incentives Program. USDA programs and other ecosystem services supports are covered in the *Working Lands Toolbox* briefing.

"If there were financial incentives to increase rotation age, companies would do it," Stanley says.

BUILDING MARKETS FOR HIGH-QUALITY WOOD PRODUCTS

Port Blakely itself has rotation ages around 60 years, around 20 years longer than on typical Northwest commercial forest lands. The company's model works because it has developed markets for higher-quality logs in Asia. This hearkens to an older strategy which may also map the future for the Northwest timber industry.

The Northwest formerly could achieve market differentiation with high-quality wood products from older trees. One ironic consequence of the Northwest's forest struggles has been to push the industry toward shorter rotations that result in harvesting younger trees. Ecotrust, a group in the lead of developing new models for Northwest forestry, describes the consequences:

"As harvests shifted to smaller trees, the manufacturing technology has adapted. **The region now produces commodity lumber from commodity trees,** much as is done in Canada, the US South, New Zealand, Australia, Brazil, Chile, Russia, the rest of Europe using low-cost Russian logs, and, soon, Uruguay.

"**The difficulty with a commodity log and lumber strategy for Pacific Northwest firms is that competing regions have lower log and labor costs**, and access to the same manufacturing technology as is available elsewhere in the world . . . . One can imagine a 'race to the bottom' as falling costs and expanding market share from lower-cost competitors drive down lumber prices in the US, and eventually timber prices."[39]

While current timber prices in the US might average around $100/cubic meter, competitors in the southern hemisphere and Russia can supply wood at around a fifth of that. "It is difficult to see how a cost-minimization commodity focus will be successful in a world where there is abundant commodity timber available from lower-cost competitors."[40]

So **the Northwest timber industry should build markets for longer rotation forestry producing premium wood products**, Ecotrust says. The region's proximity to the U.S. Southwest and Asia provides additional advantage as energy and transport costs rise: "Japan with its traditional markets for high quality softwood continues to buy high-end products from the region. And the most rapidly growing market in the world – China – is readily accessible . . . ."

Making this model work requires ensuring that the infrastructure to harvest, process and market larger trees will be available at the end of longer rotations.

"To make long-rotation forestry feasible, we need to assure to the satisfaction of thousands of individual landowners that there will be a future market for the big trees, as well as the means – loggers, haulers, mills, people who want to buy the products from big logs – for processing big logs," Mitch Friedman says. "That means we need to sustain enough of an economy in big logs now to keep those things around."

That is going to require policy decisions to make larger trees in the 80-120-year age range available from state and federal lands while stands grow to maturity on private lands, Friedman adds.

Stanley cites another market-building tool for longer rotations: changing LEED green building standards that favor concrete and steel over wood. Current standards eliminate wood products from many government building contracts where LEED standards are required.

"A push on the benefits of wood would help keep forestry as a viable business on the landscape," Stanley comments.

Conversion of forest lands to development represents a serious threat for releases of forest carbon, and is fed by financial trends.

"The timber industry is in upheaval," Friedman notes. "**Tax and investment policy and trends have driven transformation of the private industrial forest ownership** away

[39] Clark S. Binkley et al, *An Ecosystem-Based Forestry Investment Strategy for the Coastal Temperate Rainforests of North America*, Ecotrust, April 7, 2006, p.9-10
[40] Binkley, p.3

from the large vertically-integrated companies that at least pretended to have long-term commitments to forestry, and **toward fractured ownerships** by timber investment management organizations and real estate investment trusts that seek short term profits."

"In short," adds Friedman, "**we can't assume that today's industrial timberlands won't be tomorrow's strip malls.** The closer to town, the higher the risk to those forests and the water, recreation, views, carbon storage and other ecosystem services they provide local communities."

MODELING ECOSYSTEM-BASED FORESTRY MANAGEMENT

Ecotrust is developing a new model for ecosystem-based forestry management that draws together the key elements in reinventing the industry.

The model is based on regular light thinnings aimed at promoting growth of larger, more valuable trees to 60-70 years and beyond. Older trees supply high-quality, high-strength fiber that earns higher prices and is thus more economical to harvest per unit. The model provides steady timber revenues that tend to rise over the life of the rotation. **Revenues from ecosystem services, including carbon payments and conservation easements, provide a bridge in early years when timber revenues are lower.**

Underscoring the vital role of tax policy, **Ecotrust has made creative use of the federal New Markets Tax Credits aimed at promoting economic development in depressed areas.** Most Northwest timber-oriented communities fall in this category. Credits are given to Community Development Enterprises (CDEs), which use them to improve the business case for investments. Winning $50 million in credits, Ecotrust's for-profit CDE, Ecotrust Forest Management, purchased four blocks of timberland on the Olympic Peninsula and Oregon coast. Ecotrust is using those lands to test and refine new forestry models.

"We are trying to look at how ecosystem services can help us move to longer rotations," Ecotrust Forest Carbon Program Manager Steve Dettman says. "In the board market the U.S. is going to be outcompeted by many areas of the world. What can we do in the region that provides competitive advantage? We have forests that sequester more carbon than anyplace else in the world."

"Probably no other region has as much potential to store high quality carbon, while providing other services such as water, biodiversity, scenic resources, recreation and climate adaptation," says Ecotrust Forest Management CEO Bettina von Hagen. "This is a hugely significant strategy for the Pacific Northwest and the world."

FILLING IN KNOWLEDGE GAPS

While much is known about carbon accumulation in Northwest forests there are still gaps in knowledge that must be filled to realize biocarbon potentials.

"We don't have a good handle on carbon fluxes in many different ages and conditions," Jerry Franklin says. The University of Washington scientist did seminal research on carbon accumulation in old growth forests, but he says less is known about mature forests in the 80-200-year age range. While extensive modeling work has been accomplished, "We have very little field-oriented research looking at carbon. **The most important topics we need to address are productivity and carbon fluxes in mature forests, and the impact of timber harvests on mature stands."**

The region does have a first-class old growth research station at the Wind River experimental forest in the southern Washington Cascades, where carbon flux instruments mounted on a crane provide real-world data. It will be the Northwest core observatory for an unprecedented National Science Foundation (NSF) network of around 20 such centers in the U.S., National Ecological Observatory Network. Franklin had hoped NEON could help fill the mature forests gap, but funding stresses eliminated that option.

Franklin scales the research effort needed to understand mature forests at $200,000-$500,000.

"Most traditional funds for research are drying up," Franklin says. "It is very hard to compete for NSF grants to do the work we're thinking about. The Forest Service Pacific Northwest Research Station doesn't have money. It is even difficult to keep the crane work going."

Mark Harmon cites other research needs.

"We still need to investigate through modeling and field studies which practices are going to pay off the most," the Oregon State University forest scientist says. "It is more complicated than people are portraying."

Harmon adds that **the region could also use more real-time data about forest conditions that could be generated with remote sensing technology.** Matched with understanding of various practices being applied on specific plots, the information could build detailed knowledge on best practices for biocarbon. This would enable better prediction of performance, which could help reduce costs for carbon offset contracts and other ecosystem services payments.

Large-scale data gathering that analyzes carbon performance across the entire landscape would be highly valuable to forest managers as they make decisions, Steve Dettman says.

"Funding would allow agencies to share information, bring in serious data analysis and build a compelling case for best practices, showing where we are doing well and where we are not," he notes. "The data is out there. It is a matter of sharing it and committing time to do analysis."

Such knowledge on forest behavior and practices could have applications beyond the Northwest, and demand will only increase, Dettman says. **"We can be the people to whom everyone turns to provide answers. Getting ahead of the curve would be a smart move for all of us."**

Re-grounding Agriculture: Restoring the Soil

Farm practices to build soil carbon, fertility and moisture while cutting fuel and fertilizer costs

ADVANCING CLIMATE-FRIENDLY FARMING

From the Willamette Valley to the Columbia and Snake River Basins to the high plains of Montana, the Northwest possesses some of the nation's most productive agricultural areas. **To regional mainstays such as potatoes, wheat and dairy, pioneering farmers and researchers envision adding new ecosystem services products that reduce greenhouse gas emissions and concentrations**.

One indication of regional potentials came in a report from the Agriculture Sector Carbon Market Workgroup, a group created by the Washington Legislature. In 2008 the group reported that state agricultural lands could sequester 6.96 million metric tons of carbon dioxide and equivalents ($MTCO_2e$) yearly. The estimate based on available data was described as conservative and covered only the most promising potentials.[41]

Many Northwest farmers are being economically driven to practices that save soils, improve water use, and reduce inputs of costly fertilizers, fuels and chemicals, all subject to volatile price swings over recent years. These new practices build soil health and fertility while soaking carbon at the same time.

Though some areas of the Northwest still retain a rich soil endowment despite generations of loss, other areas are reaching critical thresholds for loss of soil fertility.

"We've been really hard on our soils for a long time," says Chad Kruger, one of the lead scientists at Washington State University's Climate-Friendly Farming Project. . **The long-term consequence is increased input costs**. "A lot of producers are looking at how all these issues are packaged together. It starts with soil management."

David Sjoding, a WSU Energy Extension Program agriculture and biomass expert, quotes an Eastern Washington wheat grower. **"I've been mining the carbon out of my soil for 40 years. I used to get 100 bushels to the acre. Now I get 60."**

"There is a ferment going on, driven by the shock of the price of nitrogen fertilizer and diesel a couple of years back," Sjoding says. **"We're coming up on an opportunity to totally overhaul how we do agriculture in the Northwest.** If we do it right it is a very big deal, and incredibly helpful in the carbon sequestration side of the equation."

The Climate-Friendly Farming Project (CFF) is one of the nation's most ambitious efforts to understand the connection between agriculture and climate change. The project has three practical goals: reduce farming greenhouse gas (GHG) emissions,

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[41] *Recommendations for the Development of Agricultural Sector Carbon Offsets in Washington State*, Agriculture Sector Carbon Market Workgroup, October 2008, p.4

improve carbon sequestration, and replace fossil fuels with farm-based products. The project's national leadership was recognized in October 2009 with a USDA Cooperative State Research, Extension and Education (now the National Institutes for Food and Agriculture) Partnership Award for Innovative Program Models.

Kicked off in 2003 with $3.75 million in research funding from the Paul G. Allen Family Foundation, the project has since drawn around $11 million from other sources. This has given the region a strong base on which to mount larger biocarbon efforts in agriculture. Thus this briefing focuses heavily on the project's work and findings.

Agriculture is a major climate player – a significant source of GHGs including CO_2, methane and nitrogen. The Intergovernmental Panel on Climate Change says direct agriculture emissions account for 10-12 percent of human GHG releases. Taking into account other emissions, including fuel use, production of chemicals and fertilizers, and carbon released by opening new cropland, agricultural emissions can reach 26-35 percent of total human GHGs, the World Bank calculates.[42] So opportunities to GHGs in agriculture are huge.

CFF has developed the most comprehensive information to date on Northwest farm GHGs for key regions and crops including dryland wheat and irrigated potatoes. The project has modeled the results of different tillage systems in rainfed and irrigated regions. The project also supported development of Washington state's first commercial dairy manure biodigester, a critical contribution in a state and region with a major dairy industry.

The WSU research team overviewed a number of carbon-reducing practices and technologies and found several ready for use now or in the near future:

- **Conservation tillage**
- **Precision agriculture**
- **Improved cropping systems**
- **Anaerobic digestion**

The first three will be covered below. Because anaerobic digestion is a biomass processing technology it will be covered in the *Recycling Carbon* briefing.

CONSERVATION TILLAGE: ACCUMULATING SOIL CARBON

Soils hold an estimated 2,250-2,500 billion metric tons of carbon, more than three times the amount in the atmosphere. Converting natural lands to agriculture has released between 40 and 100 billion metric tons. Recapturing that carbon with adoption of farm practices that sequester carbon in soils would remove the equivalent of 29-47 parts per million (ppm) CO_2 from the atmosphere.[43]

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[42] *Climate-Friendly Farming Project Summary, ,* CSANR Research Report 2010-001, Washington State University, p.1

[43] T.T. Brown and Huggins, D.R., "Dryland Agriculture's Impact on Soil Carbon Sequestration in the Pacific Northwest, " CSANR Research Report 2010-001, Washington State University, Ch. 14, p.4; 1 part

Conservation tillage is widely viewed as one of the most promising carbon soaking and reducing strategies. The practice is based on the general rule that the less soils are disturbed, the more carbon builds up in their surface layers. Conservation tillage (CT) either reduces or replaces tillage that turns over soils by directly planting seeds in soils. These practices are respectively known as reduced tillage and no-till. **By one estimate, converting all U.S. cropland to no-till could soak 47 million MTCO$_2$e annually**.[44]

"Tillage-intensive agriculture of the past century has caused severe soil erosion and has depleted more than 50 percent of the native soil carbon in the dryland grain cropping region of the PNW (Pacific Northwest)," CFF notes. "Conservation tillage . . . reverses this trend; it reduces direct emissions of CO2 from decreased on-farm fuel use, reduces *direct* emissions of CO_2 to the atmosphere caused by oxidation of soil carbon, and can increase carbon accumulation in soils . . . While our drier climate leads us to expect more modest potential for sequestering soil C (carbon) than reported for the U.S. Midwest, widespread deployment of conservation tillage to protect the region's fragile soil resource (and the remaining C sink) is still an essential goal for future sustainability." [45]

"Many GHG emissions management strategies provide significant environmental and/or economic benefits to farmers, which will encourage their adoption," CFF notes.[46]

The prime drivers moving farmers toward CT are reduced erosion, improved water retention and lower costs. CT builds organic matter in and on farm soils, soaking water like a sponge and protecting soil from winds. Cutting tractor passes from the usual seven or more to four or less reduces fuel use 50-80 percent and labor 30-50 percent. Encouraged by USDA conservation programs, no-till adoption grew more than three times from 1990-2004 to 22 percent of U.S. cropland. This and CT in general had much to do with a 43 percent reduction in wind- and water-caused erosion of U.S. cropland from 1988-2003.[47]

"I don't think within 20 to 25 years there will be a whole lot of conventional tillage systems here (in the Northwest) due to factors such as fuel costs," Chad Kruger says. "Farmers are going to have to makes changes in order to stay in business. No-till has become more and more successful as time goes on, enabling them to mange more acres. If we can do something to shift the switch to five to 10 years, which I think is realistic, we can gain 15 years head start with the carbon."

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per million = 2.12 billion metric tons from James Hansen, *Storms of My Grandchildren: The Truth About the Coming Climate Catastrophe and Our Last Chance to Save Humanity*, Bloomsbury USA, New York, 2009 p.117

[44] T.T. Brown, p.5

[45] *Climate-Friendly Farming Executive Summary*, Washington State University "CSANR Research Report 2010-001

[46] *Climate-Friendly Farming Project Summary,* p.14

[47] Huggins and Reganold

CT provides ecosystem services beyond carbon. Reducing erosion improves air and water quality, while keeping residues on soils improves nesting conditions for birds. An Iowa study found 12 species living in no-till lands -- four times more than those conventionally farmed.[48] This is a prime illustration of a practice change enhancing several different ecosystem services at once, underscoring a key understanding needed to advance CT in the Northwest. **The practices that accumulate carbon serve other vital ends, so policies and economic tools to drive CT will be most effective when they recognize and reward multiple benefits**.

Means to support ecosystem services provided by agricultural lands, including USDA conservation programs, are covered in the *Working Lands Toolbox* briefing.

NORTHWEST CONSERVATION TILLAGE PERFORMANCE

CFF modeled soil and residue carbon accumulations at four eastern Washington locations, one irrigated and three dryland with varying annual precipitation. Over a 12-year period, CT improved sequestration in all locations – no-till more than reduced tillage. Results covered a wide span from near zero to 0.33 $MTCO_2e$/acre/year. Results averaged 0.22 for no-till and 0.07 for reduced tillage.[49] At that rate, converting one million dryland acres to no-till would absorb about 700,000 $MTCO_2e$ annually.[50] Dryland farming covers approximately nine million acres in Oregon, Washington and Idaho.[51]

Though these figures are substantial, they tend toward the lower bound of estimates for U.S. farm soil carbon accumulation. So **per-ton carbon payments alone are not likely to provide incentives for a shift.** In three of the four modeled locations, credits of $67-$123 per acre would be required, CFF estimates, adding these levels are “unlikely to occur in near future.”[52] But crediting a fuller range of ecosystem services benefits could tip the balance. For example, USDA estimates that off-site erosion damages inflict costs of $37.6 billion on the nation annually.[53]

Widely varying modeling results carry two important messages about CT.

First, notes CFF, “. . . **not all research reports carbon benefits for all forms of conservation tillage**.”[54] In some low-rainfall areas reduced tillage along with other cropping and fertilizer strategies can make more sense. They are covered below in a section on other climate-friendly farming practices.

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[48] David R. Huggins and Reganold, John P, “No-Till: the Quiet Revolution,” *Scientific American*, July 2008., p.70-77
[49] K. Painter, “An Economic Analysis of the Potential for Carbon Credits to Improve Profitability of Conservation Tillage Systems Across Washington State,” Washington State University, CSANR Research Report 2010-001, Chapter 24, p.16
[50] *Recommendations for the Development of Agricultural Sector Carbon Offsets in Washington State*, Agriculture Sector Carbon Market Workgroup, October 2008, p.37
[51] T.T. Brown, p.1
[52] K. Painter, p.19
[53] *Climate-Friendly Farming Project Summary*, p.19
[54] *Climate-Friendly Farming Project Summary*, p. 6

Second, **high variability in soil carbon levels "makes it difficult to develop reliable carbon sequestration data for carbon markets,"[55]** CFF says. This points to the importance of continued research to develop better databases by soil, climate and cropping.

Another key insight is that **soil reaches a new carbon equilibrium**. The first 5-10 years of no-till yield the top carbon performance. Soils reach stable carbon levels after 20-50 years. Some studies show no-till sequesters carbon in top layers while regular tillage pushes carbon deeper. Other studies suggest that no-till with intermittent light tilling buries surface carbon and resets the surface accumulation process.

"Basically the situation in many continuous no-till scenarios, particularly when starting with degraded soils, is that carbon is stratified at the soil surface over time, not tilled in as with plowing," explains David Huggins, a USDA Agriculture Research Service soil scientist. "This can result in greater carbon in surface three to six inches or so, but sometimes less from six to 10 inches as this depth is not receiving as much carbon input as with tillage. Periodic tillage, once every 5-10 years, may lead to greater soil carbon storage as this transports carbon-rich material to deeper depths and starts the accumulation at the surface over again."[56]

An important no-till angle is pesticide use.

"No-till can, in some cases, result in an increase in the total amount of herbicide used over conventional, though not necessarily, particularly during the transition phase," Chad Kruger notes. "But the more important questions than the total amount of chemicals used are the eco-toxicity, fate and transport of chemicals used in no-till versus conventional tillage. Existing data indicates that **the total toxicity of chemicals used in conventional production systems may be higher** due to the type of chemicals used even though less total product is used. Also, **chemicals used in a no-till system are far more likely to stay where they are sprayed** rather than run-off due to the fact that soil erosion is dramatically reduced."

Research indicates that the more advanced a cropping system is, the more likely it is that total herbicide use can be reduced, Kruger adds.

ADVANCING NO-TILL IN THE NORTHWEST

Northwest land grant colleges and growers associations have long worked collaboratively to advance no-till in the Northwest. In 1975, they came together as ***STEEP, Solutions To Environmental and Economic Problems***, to form "an innovative interdisciplinary research/education program focusing on developing profitable cropping

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[55] *Climate-Friendly Farming Project Summary*, p. 27
[56] T.J. Purakayastha; Huggins, D.R..; Smith, J.L., "Carbon Sequestration in Native Prairie, Perennial Grass, No-Till, and Cultivates Palouse Silt Loam," *Soil & Water Management and Conservation*, Vol.72, (2), March-April 2008, p.534-40

systems technologies for controlling cropland soil erosion and protecting environmental quality." Joining in the effort were Oregon State University, University of Idaho, Washington State University, USDA-Agricultural Research Service, and the wheat growers associations of the three states. STEEP continues to refine conservation tillage for the Northwest and educate farmers in best practices.[57]

The first contract for farm soil carbon accumulation in North America, and one of the world's first, came to Northwest no-till farmers in 2002. A voluntary offset was purchased by southern utility Entergy from the Pacific Northwest Direct Seed Association. The utility paid $75,000 to soak 30,000 tons of CO_2 into 6,470 acres owned by 77 grower members of PNDSA.[58] That translated into 0.15 tons of carbon per acre each year over 10 years, delivering to farmers modest returns of around $1.10 per acre after administrative fees were deducted.[59]

"It isn't the money," a PNDSA presentation wryly noted.[60] Instead, the association's goal was to build a base of knowledge on the carbon performance of no-till farming in the interior Northwest. With this farmers could potentially find larger and more profitable markets for farm soil carbon accumulations.

"The carbon sequestration of no-till will someday have value," notes Russ Zenner, founding president of PNDSA.

Though the Northwest pioneered the no-till carbon market, adoption rates are actually lower than the national average. Among reasons given are costs of buying needed equipment – a no-till seed drill can cost $100,000 – and the challenges of a steep learning curve. No-till represents a sharp break with conventional practices. The Northwest saw no-till failures in the 1980s and '90s because a need for altered crop rotations was not understood as it is today. Farmers also have concerns about yield loss despite significant research and experience that indicates it can be overcome.

A CFF analysis shows that no-till is already more profitable in the Palouse around Pullman, increasing annual per acre profits by $5 to $37 for a winter-wheat-spring barley-pea rotation. But no-till adoption is still relatively low, indicating that simple profitability does not alone drive adoption.

"Farmers may be resistant to change from something that has proven profitable," CFF says. "These rich deep soils appeared to be endlessly fertile, but estimations of soil erosion suggest that the region has lost about 35-45 percent of its topsoil from erosion over the years."[61]

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[57] http://pnwsteep.wsu.edu/ viewed June 15, 2010
[58] PNDSA Soil Carbon Sequestration Lease History, http://www.directseed.org/carbonhistory.html#carbonhistory viewed April 23, 2010
[59] Carbon Sequestration Fact Sheet: PNDSA and Entergy, Pacific Northwest Direct Seed Association, Sept. 12, 2002
[60] Ibid
[61] *Climate-Friendly Farming Project Summary,* p. 20

In other dryland areas with different conditions CFF finds a profitability gap of $13-15/acre/year between conventional- and no-till, assuming equal yields, largely due to greater herbicide costs. But 10 percent yield gains bring no-till nearly even with conventional tillage. "This result is not implausible, as **large yield increases have been achieved under NT** in the ongoing Direct Seed Mentoring project, in which direct seed farmers plant land for conventional farmers who are interested in no-till systems."[62] The mentoring project, run by Spokane Conservation District, University of Idaho and WSU Extension, demonstrated 50 percent higher spring wheat yields due to moisture retention.[63]

Such **mentoring efforts are one of the keys to unlock no-till potential**. Successfully employed in the Midwest, they join experienced no-till farmers with those using conventional tillage. The no-tiller generally plants several hundred acres on the conventional farmer's land, whose direct costs are limited to supplies.

Bill Warren, a Columbia County, Washington no-tiller, notes that conservation districts and county extension services have played a crucial role driving very high adoption rates in his county and Wasco County, Oregon. "It comes down to the people to pioneers and leadership." **Once farmers understand no-till advantages they will "never look back."**

"No-till spreads neighbor to neighbor," says David Brown, soil scientist and terrestrial lead for Big Sky Sequestration Partnership.

Pioneering farmers "are very important to show success and share experience with neighbors," Zenner says.

MANAGING CARBON INPUTS

Conservation tillage prevents soil carbon releases. Taking active steps to reduce carbon losses and add carbon to the soil through changed cropping and land management practices is a natural complement. In many cases these practices can actually generate more carbon accumulation than changes in tillage. A number of land management practices that lock carbon in soils are covered in this section.

Adding organic amendments to the soil

Organic amendments including barnyard manures, compost and biochar also have potential to cut fossil fuel-based fertilizer inputs and have been shown to dramatically increase soil carbon sequestration. In one Northwest dryland farming location where municipal biosolids from waste treatment plants have been applied for 14 years, carbon has accumulated at rates as high as 1.4 $MTCO_2e$/acre/year. That compares to an 0.1 $MTCO_2e$/acre/year rate for conservation tillage at a similar location. So, in fact, organic

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[62] *Climate-Friendly Farming Project Summary,* p. 19
[63] K. Painter, p.3

amendments could become even more important that tillage changes for accumulating biocarbon.

Biosolids have long been applied to Northwest farms on a commercial basis. They improve soil quality, cut costs for fossil-fuel-based fertilizers, and reduce public waste disposal costs. Fossil fertilizers represent significant GHG emissions, as will be discussed in the nitrogen use efficiency section below. So reducing fertilizers with crops or amendments is a double-win for climate. WSU researchers are exploring other new organic crop amendments beyond biosolids. The huge potential to generate organic amendments from biomass streams is covered in the *Bioeconomy* briefing.

Rotating "green-manure" crops

Nitrogen-fixing crops such as alfalfa and sweetclover provide a cover crop benefit and reduce use of fertilizers. Though some studied cases show a carbon loss of as much as 1.79 $MTCO_2e$/acre/year, most results are positive, ranging up to 1.60 $MTCO_2e$/acre/year. "Rotations that include green manures, as compared with rotations that did not include a green manure crop, generally shows increases in SOC (soil organic carbon). . ." in the eastern Palouse, CFF reports.[64]

Reducing field burning

Some farmers burn fields to manage crop residues. Besides raising air pollution concerns this practice also releases soil carbon. Studies show Northwest farm losses ranging from 0.25-1.22 $MTCO_2e$/acre/year.[65] "Burning generally accelerates SOC (soil organic carbon) losses beyond that from cropland management practices that did not use burning for residue management," CFF finds.[66] Systems which leave residues in place, such as no-till, or forms of CT which harrow residues into the soil, provide superior performance.

Replacing fallow with cover crops

Leaving fields fallow exposes soils to oxidation. Studies show Northwest fallow carbon losses range from 0.13-1.01 $MTCO_2e$/acre/year.[67] Cover crops protect the soil and legume cover crops can be a source of fertility. Oilseed crops such as camelina, canola and mustard provide additional benefits by adding a crop rotation and supplying biofuels feedstocks. At the same time, biofuel markets can provide an incentive to add this agronomically valuable rotation that does not exist now.

Growing perennial crops

Crops which grow year to year reduce soil disturbances to a minimum. Many Northwest farmers operate mixed perennial-annual systems using crops such as wheatgrass and

[64] T.T. Brown, p.26
[65] T.T. Brown, p.45
[66] T.T. Brown, p.25
[67] T.T. Brown, p. 44-45

alfalfa to restore soil fertility. CFF conservatively estimates such systems add an average of 0.82 $MTCO_2e$/acre/year in the eastern Palouse region [68] A full perennial switchgrass system field tested by USDA Agricultural Research Service in the irrigated Columbia Basin found carbon increases of 1.6 $MTCO_2e$/acre/year.[69] Demonstrating higher productivity than in other regions, Northwest switchgrass is a potential bioenergy crop.

Active grazing management

Continuous livestock grazing which turns animals loose over large pastures tends to erode soils and trample grasses. Active grazing management is a set of practices that rotate livestock around more frequently in order to reduce impacts on any one plot of turf. Pastures divided by fences are subjected to short, high-intensity grazing and then allowed to recover, maximizing plant growth and carbon storage in roots. Introducing active management on grazing lands could add 0.3-.0.7 $MTCO_2e$/acre/year. Washington Department of Natural Resources leased grazing lands hold potential to sequester 2.3 million $MTCO_2e$/year.[70]

IMPROVING NITROGEN USE EFFICIENCY

CFF cautions that **practices which bring new carbon to the soil involve inputs such as fertilizer which have the potential to wipe out the carbon benefits**. "Further evaluation of the life-cycle impacts of such practices is needed in order to more fully understand their impact on net GHG emissions."[71]

Carbon gains could be cancelled by one practice alone, overuse of nitrogen fertilizers. They release nitrous oxide, N_20. Commonly known as "laughing gas," and used as a dental anesthetic before more sophisticated drugs, N_2O impacts on the atmosphere are no joke. Each pound of N_2O is the equal of 296 pounds of CO_2 in terms of its potential to warm the atmosphere. So small reductions in N_2O have a big climate impact.

U.S. N_2O emissions come mostly from the farm sector. In 2008 U.S. N_2O emissions were 300 million $MTCO_2e$. The agriculture share was 218 – 76 percent was from nitrogen fertilizer and 24 percent from animal waste. Since 1990, farm N_2O emissions have grown nine percent.[72]

No-till and reduced tillage release approximately the same N_2O as conventional tillage – around 0.1-0.2 $MTCO_2e$/acre/year – as far as can be measured by current technology.[73] But the shift to no-till offers a prime opportunity to implement a series of agricultural

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[68] *Climate-Friendly Farming Project Summary,* p.13
[69] *Climate-Friendly Farming Project Summary*, p.32
[70] Ibid
[71] *Climate-Friendly Farming Executive Summary,* p.2
[72]U.S. Energy Information Administration, Emissions of Greenhouse Gases Report, http://www.eia.doe.gov/oiaf/1605/ggrpt/nitrous.html (viewed April 29, 2010)
[73] *Climate Friendly Farming Project Summary*, p.10

practices known as precision farming. GPS-based soils mapping and sensors tailor timing and amount of fertilizer applications to specific crop needs and conditions. **Precision nitrogen management increases efficiency and minimizes leakage into the atmosphere and waterways** where overabundance of nutrients endangers fish.

CFF conducted the first rigorous field tests of precision nitrogen application on Northwest dryland wheat. **Scientists found 18 percent reduction possible on winter wheat crops without impacts on yield or protein content**.[74]

Precisely managing irrigation water applications through techniques such as drip irrigation and center-pivot irrigation also controls N_2O emissions. These allow cuts in nitrogen application, while controlling moisture reduces emissions from fertilizers that are applied.

AGRICULTURAL RESEARCH NEEDS

Though this briefing has focused heavily on WSU's Climate Friendly Farming Project, other **Northwest universities also have significant agricultural research programs in related areas**. For example:

- **Oregon State University** is the western regional center coordinating nine states for Sun Grant, a national partnership focused on advanced bioenergy and bioproducts.
- **University of Idaho** is researching rotational oilseed crops such as canola and mustard that improve soil conditions while providing biofuel feedstocks.
- **Montana State University** research on camelina has generated a new industry focused on sustainable biofuels from the drought-resistant oilseed crop grown in rotation with wheat. In December 2009, 14 airlines signed an agreement with AltAir, a new company in Seattle, to deliver camelina-based jet fuel at Sea-Tac International Airport. Montana is expected to be a major source.

Other regional research assets include the **USDA Agricultural Research Service**, which does significant work across all four states, and two U.S. Department of Energy national biomass research centers: **Pacific Northwest National Laboratory** for processing, and **Idaho National Laboratory** collection and delivery. The universities and federal institutions already collaborate extensively, and are well positioned to usefully employ increased resources for biocarbon-related research and development. This is needed in a number of areas:

Irrigated agriculture – "We don't have the extensive research and experimental basis with irrigated that we have for dryland. We're getting a much later start on conservation in these systems and the industry is leading the way," Chad Kruger says. Improved cropping along with residue and nutrient management will play important roles. "We need more research that can validate grower experiences and we are starting to see it fairly significant change happening."

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[74] *Climate-Friendly Farming Project Summary*, p.5

Grazing lands – There are strong indications and some early experience to indicate active management of livestock herds improves grass growth and carbon storage. Credits for these practices have already been sold on the Chicago Climate Exchange. But, says Kruger, "We don't have defensible datasets yet." Monitoring and measurement is needed to understand carbon performance in different sub-regions.

Orchards – Practices such as growing nitrogen-fixing crops between tree rows could reduce fertilizer use and costs. Innovative orchardists are beginning to experiment with such creative cropping, but more systemic research efforts are needed.

Nitrogen management – While CFF has done important research on nitrous oxide, more monitoring and field work needs to be done to minimize emissions of this powerful GHG from farm fields

No-till – "The next step is to enhance the inherent nutrient cycling of the soil," Russ Zenner says. This is accomplished through cropping practices discussed in the carbon inputs section above. "The ultimate would be organic no-till." Publicly-funded agricultural research has been losing out to research driven by chemical manufacturers over the past 10-15 years, so a new emphasis on soils research is crucial, Zenner says.

Working Lands Toolbox: Building Biocarbon

Supporting biocarbon-building practice changes by farm and forest landowners

EXPLORING NEW WAYS TO SUPPORT BIOCARBON

This briefing looks at tools and policies to promote new land use practices, both existing and potential, including ecosystem services markets, land conservation efforts and sustainable products marketing.

To this point innovative financing of biological carbon sequestration has mostly been associated with carbon offset markets. In these markets, farm and forest landowners change practices to improve carbon accumulation and reduce greenhouse gas (GHG) emissions. They require funding by a carbon emitter, such as a utility operating coal-fired power plants, that either wishes or is required to mitigate its emissions**.** By creating a balance between new emissions and emissions reductions, offsets are designed to stabilize overall GHG releases.

But actually reducing historic CO_2 concentrations to 350 ppm will require funding tools that support biocarbon storage as an independent objective. Since offsetting inherently trades off against current emissions, it does not address the buildup of CO_2 concentrations since humanity began massive fossil fuel burning around 250 years ago. New tools to reduce the historic buildup of CO_2 can form a parallel and complementary track to offset markets.

A keystone understanding is that **practices which build carbon storage generally synch well with provision of other ecosystem services** such as clean water, flood control, clean air, wildlife, biodiversity, beauty and recreation, to name just a few. Carbon-enhancing practices sequester carbon in biomass above and below ground. This increased vegetation and soil organic matter also retains water, buffering extremes of drying and drenching. Ecosystems rich in carbon also tend to provide good habitat for wildlife and diverse species, and often offer greater aesthetic assets and recreational opportunities.

A wide array of potential options builds biocarbon while improving other ecosystem services and economic viability. This represents tremendous opportunities. Focusing on biocarbon alone might not provide the incentives for needed practice changes in many situations. But **supporting biocarbon as part of a broader portfolio of ecosystem services could tip the balance and spur changes.** Targeting the increase in any single ecosystem service is less important than supporting practice changes which build overall healthy ecosystems. This opens many options for improved biocarbon performance even if that is not necessarily the prime objective.

It is important to note that these are difficult areas in terms both of complexity and resource requirements. As the old saying goes, if it were easy we would have done it by now. **Building new tools and policies to support biocarbon calls for collaborative**

exploration that cuts across sectors, including private landowners, public agencies, environmental NGOs and ecosystem markets organizations. This discussion in this briefing is intended to spur those discussions on a regional level in the Northwest, an acknowledged leader in developing support for ecosystem services. The "whole" that is produced should be greater than the sum of the "parts" outlined here, and even bring some new "parts" to the table.

VALUING NATURE'S SERVICES

An old saying goes, "The best things in life are free." But free things are often taken for granted, and abused as a result. There is no set of things for which that is more true than ecosystem services where another common saying might be more fitting, "You don't know what you have 'till it's gone."

"Historically, these services have been available for free as landowners do not receive payments for the value they provide through sustainable management. Typically, they were noticed only when reduced or eliminated," the Oregon State University Institute for Natural Resources notes. "Perceiving their loss as a failure of a market economy to provide for the common good, **environmental economists advocated for payments for ecosystem services as a way to align economic interests with land and water stewardship.** The creation of tradable credits for the development or preservation of ecosystem services has emerged as a method to provide such payments."[75]

While ecosystem services provide real benefits, they are not quantified or rewarded so economic incentives tip toward products that have a defined market. Part of the gap is met through direct regulation and public action. For example, state growth management laws preserve farm and forest land, while state forest practices rules set minimum standards for logging operations. Clean air and water rules set boundaries for pollution and runoff. Regulation is an appropriate means to achieve ends of broad social benefit. **A complementary means to ensure provision of ecosystem services is to create economic values and markets that provide incentives and efficient tools to achieve regulatory goals**.

Ecosystem services markets are emerging for carbon, water quality, wildlife, wetlands and flood protection. For example, a water quality market is in development for the Chesapeake Bay watershed, driven by regulatory requirements to cap runoff into the bay. New York City pays forest owners to do low-impact logging to protect its upstate water supplies. Advanced efforts in Oregon are covered below.

With increased growth pressures, society will "increasingly need to find the least costly and most effective ways to mitigate for the environmental impacts," notes Don Stuart, Pacific Northwest Director for the American Farmland Trust. ". . . **our farm and forest**

[75] Ray Hartwell et al, *Ecosystem Service Market Development: The Role and Opportunity for Finance*, Oregon State University Institute for Natural Resources, Jan. 2010, p.iii

lands (are) where environmental gains can be accomplished at moderate cost… farmers can typically continue to farm while enhancing these environmental values for much less than it would cost to ignore, prevent or offset them elsewhere."

Adds Stuart, "An agriculture industry broadly engaged in selling ecosystem services will ultimately become as enthusiastic about, and as effective at producing clean water, clean air and wildlife habitat as they are today about growing wheat and carrots."[76]

But overall progress toward ecosystem services markets has been slow. The Institute for Natural Resources points out that "a paucity of transactions in the early stages of market development is a challenge." A lack of markets translates to unwillingness by landowners to take on the complex tasks of developing marketable ecosystem services products. This "in turn, leaves potential buyers discouraged. This broad chicken-and-egg dynamic has meant that **the potential to harness credit markets to meet environmental goals has been largely unrealized**."[77]

OREGON: AN ECOSYSTEM SERVICES INNOVATOR

Oregon institutions are seeking to overcome these hurdles, making Oregon a national leader in developing ecosystem services markets.

Oregon's leadership in developing carbon markets dates to 1997 when the state created the nation's first institution to buy carbon offsets. That institution was ***The Climate Trust (TCT)***, a nonprofit commissioned to develop offsets for a mandated portion of emissions from new natural gas power plants. This was the first law in the U.S. setting a carbon limit. Since its first offset purchase in 2001, TCT has channeled $10.5 million to 18 projects ranging from Portland low-income energy efficiency retrofits to a Mt. Vernon, Washington dairy biodigester. Methane emissions eliminated by the biodigester are the basis of an effort with NW Natural; it is the first U.S. natural gas utility offering customers an option to offset emissions by supporting Northwest methane capture projects. Two forest projects in the Northwest and one in Ecuador directly support biocarbon sequestration.

TCT's work now extends far beyond Oregon. The group advised the Northeast states Regional Greenhouse Gas Initiative carbon cap-and-trade system on offsets, and recruits projects and manages funds for the Colorado Carbon Fund. In 2007 TCT led creation of the Offset Quality Initiative and serves on the steering committee for the Voluntary Carbon Standard, a global effort to ensure offset performance.

From the start with TCT Oregon has generated a cluster of organizations and activities in the ecosystem service area. ***Bonneville Environmental Foundation*** creates voluntary markets to support habitat restoration, water conservation and renewable energy**.** ***Portland General Electric*** includes a habitat restoration option in its

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[76] Don Stuart, *How Ecosystem Services Markets Can Transform Agriculture and Protect the Environment*, American Farmland Trust

[77] Hartwell, p.iii

voluntary green power program. The Portland area has also generated a number of consultancies in the ecosystem services and credits arena.

Experience in developing offsetting deals and protocols will help push biocarbon forward generally. Financing and project management provides a knowledge base of incentives and assistance needed to propel land practice changes. This is true whether the ecosystem services support is provided by offsetting or other tools discussed later in this briefing. **The carbon credits cluster that has developed in Oregon gives the region a leg up.**

An emerging Oregon ecosystem services leadership initiative is the Willamette Partnership. An alignment of public agencies, environmental groups and industry, the partnership is developing the Willamette Ecosystem Marketplace to support a range of services. Those include clean water, fish and wildlife and carbon. The partnership was formed in 2004 as a follow-on to the Willamette Basin Study, which identified land use changes to restore salmon and other species. In 2005 , the partnership began creating the marketplace with a $779,000 grant from the U.S. Environmental Protection Agency. The group also received a conservation innovation grant from the USDA Natural Resources Conservation Service.

The Partnership is pioneering a first-of-its-kind Ecosystem Credit Accounting System to standardize values for several ecosystem services. It has regulator approval on a standard crediting process for "currencies" in four areas – wetlands, salmon habitat, upland prairie habitat and water temperature. The group is working with the ***Freshwater Trust*** on a currency for water quality and stream flow. It is also partnering with ***Defenders of Wildlife*** on voluntary market currencies for biodiversity and habitats including oak, sagebrush and bottomland hardwood. A carbon currency is planned.

The effort has generated a level of agreement among stakeholders that may be unparalleled in the nation. Twenty-five organizations have agreed to pilot accounting system protocols for the initial four currencies during 2010-11. All environmental regulatory agencies operating in Oregon are on board, as well as key environmental groups, local governments, and lands and water agencies. Data is being collected and methodology tested at sites around the Willamette.

The Partnership's currencies system aims to solve a critical problem with ecosystem services contracting: how to credit multiple benefits from improved management. Systems to date have only credited one benefit to avoid "double-dipping." While avoiding such double counting is important to maintain the integrity of the projects, creative solutions must be found to provide sufficient incentives for change. So the accounting system sets up standardized means to quantify and credit multiple services generated by an action. Restoration projects are divided into ecologically distinct map-units. Landowners can then seek the best deals for map-units among ecosystem credit markets.

The Willamette Ecosystem Marketplace has opened with a nation-leading stream temperature trading program led by Clean Water Services in the Tualatin River Basin. Overly warm water in the Tualatin basin endangers fish, so temperatures of water discharges into the river are regulated. However, improving streamside vegetation and shade cover can more economically cool stream temperatures than refrigeration equipment at treatment plants. The marketplace provides a way to shift investments from industrial plants to green plants. By spring 2010 those funds generated 35 miles of streamside restoration and native planting.

The Tualatin project is an example of a "fee in-lieu" system that provides a hybrid market-regulatory model. The regulation provides the driver for participation. The public regulatory agency provides a market option to meet the regulation by collecting fees in lieu of direct action at the participant's site. The aggregated funds then drive the marketplace, attracting offerings by landowners to supply ecosystem services needed to realize the overall regulatory goal.

"In a fee in-lieu program a very conscious, scientific effort is made to establish fees that will generate the right amount of revenue needed to address the problems being caused by the mitigated behavior," Don Stuart says.

THE ROLE OF CARBON OFFSETS

In carbon offset markets, polluters pay for carbon reductions in order to balance out their own emissions. To date much of the market has been voluntary. But in systems that place a mandatory cap on carbon emissions, offsets allow emitters an alternative to meeting the cap on their own by purchasing carbon reductions outside of capped sectors. For example, utilities which are capped buy offsets from agriculture and forestry which are not. Such emitters can also buy emissions allowances from others within a capped sector who are exceeding requirements.

The Offset Quality Initiative[78] provides this definition of the practice:

"Offsets are used in lieu of an emissions reduction, removal or avoidance that would have otherwise been required to occur within the boundaries of the emissions cap. In other words, provided that the project meets the established eligibility criteria, the purchasing firm is allowed to use offset credits to meet its compliance obligation as though the firm had made the reduction itself. The essential promise of an offset is the achievement of a real and verifiable reduction in global GHG emission levels beyond what would have otherwise occurred that is equally effective as on-site emission reductions by regulated entities."

By giving regulated emitters more options for finding and financing emission reduction projects, **offsets lower the costs associated with complying with climate legislation.** Carbon offset projects can provide lower cost options while new, more economical technologies are developed.

[78] http://www.offsetqualityinitiative.org/ viewed June 18, 2010

Don Stuart makes the case, “When you can address an environmental problem like carbon emissions less expensively than with an on-site technological fix or a reduction in operations, it frees up resources making it easier to deal with more of the problem.”

Many offset projects provide multiple environmental or social benefits beyond their climate mitigation value. **Offsets provide incentives for innovation, investment and deployment in unregulated sectors like agriculture and forestry.** They give a cap-and-trade system the flexibility to quickly funnel capital from capped sectors into new practices and technologies outside of the cap.

But the cost advantage of offsets has a flipside**. By opening reduction opportunities outside of capped sectors, offsets can reduce the incentive for clean technology innovation, investment and deployment in capped sectors.** For instance, a utility might meet a requirement to reduce emissions from its coal-fired plants by buying an offset that preserves forests instead of investing in wind and solar power. To respond to this concern, limits on the use of offsets have been proposed in many climate policy initiatives.

“The key point is that energy-related emissions – which account for the vast majority of heat-trapping pollution -- must be reduced in order to reach climate stabilization objectives. Energy technology transformation and biocarbon storage must be complementary and additive – not competing initiatives.” says Climate Solutions Policy Director K.C. Golden.

COMPLEXITIES OF CARBON OFFSETTING

Offset deals face complex requirements to assure they will really reduce carbon emissions in the amount and for the time that is claimed

“Additionality” is one of the many challenges faced by offsets. This means that for an offset to be credible, it must represent added carbon storage that would not have taken place without the offset purchase. For example, if a forester was already preparing to manage their lands in ways that would store more carbon, that action does not qualify as a high-quality project. The additionality requirement can prove thorny. Proving what a farmer, forester or other offset provider would or would not do if the offset contract were absent can be highly speculative and subject to manipulation.

The Offset Quality Initiative sets out these guidelines for additionality: “Because offsets are used to compensate for emission reductions that an entity operating under an emissions cap would otherwise have to make itself, the reductions resulting from offset projects must be shown to be ‘in addition to’ reductions that would have occurred without the incentive provided by offset credits. The revenue from selling the project’s emission reductions should be reasonably expected to have incentivized the project’s implementation for an offset project to be considered additional.”

The amount of carbon that would have been stored or not emitted if the offset had not been purchased is known as the "baseline." Here is how the Offset Quality Initiative defines the baseline: "A baseline represents forecasted emission levels in the absence of the offset project; this is sometimes referred to as the baseline scenario, or the 'without project' case. The difference between the baseline and the actual emissions after the offset project is implemented represents the reductions achieved by the project, and this amount is credited as an offset. Offsets are only as credible as their baselines."

The Northwest has taken a leadership position in sorting out the additionality issue with the first forest methodology approved under the Voluntary Carbon Standard. The work was led by Ecotrust, a Portland-based effort missioned to build a conservation-based economy in the Northwest. With the protocol, forest owners will more readily be able to market offsets.[79]

Another requirement is **the quantity of carbon stored as a result of an offset purchase must be monitored, measured and verified**. This involves establishing the baseline and using technically acceptable means to track carbon additions. For example, farm soil tests are employed to measure carbon accumulations. If they do not meet contract specifications the farmer may receive a lower performance-based incentive payment because carbon delivery was lower than anticipated.

Landowners are also required to guarantee that carbon will be stored for a particular amount of time, commonly 100 years. Known as "permanence," this obligation is tied to the property and becomes a condition in any sale.

Finally, **offset deals must ensure against "leakage."** This is when instituting a carbon accumulating practice in one place merely shifts carbon emissions elsewhere. For example, if a contract for longer rotations in one forest resulted in a shift of timber demand to other forests, that would be leakage.

LIMITATIONS OF CARBON OFFSETS

The complexities of offsetting spur skepticism about their effectiveness, and ammunition in efforts to limit the role of offsetting in carbon caps. Such concerns have undermined voluntary offsetting efforts. For example, In early 2010, Nike abandoned its offsetting program.[80]

Meanwhile, **meeting requirements can prove costly and complex, creating disincentives to participate in offset markets.** The risks are too great and the revenues they provide are too small or uncertain be worth the hassle for many landowners, **especially smaller land owners**. Because the transaction costs associated with

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[79] Ecotrust, "Breakthrough Ecotrust Tool Advances Carbon Markets," May 20, 2010

[80] "Nike Makes Environmental Strides and Abandons Carbon Offsets," *New York Times Green Inc.*, Feb. 2, 2010

implementing, monitoring and verifying a project are relatively fixed regardless of the size of the project, **projects that are capable of storing large amounts of carbon are favored over smaller projects**. Current domestic offset markets, with low carbon prices due to lingering uncertainty about regional and federal cap-and-trade programs, in many cases simply do not currently provide the funding to make practice changes. If policies created a more certain and robust price signal, then many project types would become viable.

The complexities of offsetting raise questions about how many farmers and foresters will actually participate in markets.

For farming, carbon offset markets as they are envisioned will only provide limited incentives for change, says Chad Kruger, an agricultural scientist with Washington State University's Climate-Friendly Farming Project.

"By and large our group thought offsetting would not be a very effective strategy. Overall it's too complicated," Kruger says. However, he adds, making offset deals simpler and development of new technology for monitoring performance could help overcome obstacles.

The project has extensively analyzed the economics of offsets for dryland farming areas of the Northwest, where practice changes such as conservation tillage would curb soil erosion and runoff into streams while increasing soil carbon. But in some dryland areas relying on carbon credits alone to drive the change would take $67-$123 acre/year per metric ton of carbon dioxide equivalent, levels "unlikely to occur in near future."[81]

"We have a substantial public benefit that could be achieved by making changes, but individual incentives are low," Kruger says. "The changes farmers need to make to stay in farming for the long term are likely to provide a carbon benefit." But carbon credits alone will not provide the incentive to make the practice change in many cases, he adds. **"We need a more comprehensive plan to promote widespread adoption of new practices. The goal of policy is to accelerate the inevitable."**

In the forest sector, "It is hard for landowners to wrap their heads around offsetting requirements," notes Paula Swedeen, director of ecosystem service programs at the Pacific Forest Trust, a group which works with forest landowners to promote sustainable practices. **"I don't think there's going to be massive participation in markets. People are thinking about alternatives to offsets.** We need more straightforward rules."

Ecotrust Forest Management CEO Bettina von Hagen comments**, "It is mind-boggling how much brain space is involved in offsetting. So doing these deals is hugely expensive.** The current tool is hopelessly complex and needs to be greatly simplified. "

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[81] K. Painter, *An Economic Analysis of the Potential for Carbon Credits to Improve Profitability of Conservation Tillage Systems Across Washington State*, , CSANR Research Report 2010-001, Washington State University, Chapter 24, p..16-17, 19.

Ecotrust is engaged in a project to aggregate offset offerings from smaller landowners, who alone could not handle the complexities and costs.

"If we did not see offsets as part of a larger project of incentivizing better land use practices, we would not be engaged," von Hagen says**. "I think many forest owners would be receptive to other tools."**

OPTIONS IN CONSERVATION AND MARKETING

A number of tools that promote land conservation and sustainable products already support biocarbon.

One land conservation tool that builds biocarbon is purchase of lands or development rights. Under the latter, landowners sell conservation easements which guarantees land will be left in forestry and agriculture and not developed. Rights are sold to developers in other areas. For example, developers may be allowed to build buildings in cities taller than standard zoning would allow. Groups such as ***The Nature Conservancy*** and ***Trust for Public Lands*** have secured large swathes of land to serve conservation goals, in effect creating carbon reserves. The ***Cascade Land Conservancy (CLC)*** works to preserve working forest lands around Puget Sound through leveraging development rights. CLC has partnered with King County, Washington to secure development rights on working forest lands in the old Weyerhaeuser Snoqualmie tree farm. Proposed federal legislation would allow non-profits to sell up to $3 billion in tax-exempt Community Forestry Bonds to secure conservation lands.

Creating new marketing tools that build demand for sustainable products also builds biocarbon.

For example, forest products sustainability certification offered by groups such as the ***Forest Stewardship Council*** (FSC) look to improve wildlife habitat and water management. By requiring increased tree retention and longer rotations, certification criteria also build forest carbon. The ***Northwest Natural Resources Group*** (NNRC***)*** builds on FSC certification to gain carbon credits for smaller landowners in the region. Currently its Northwest Certified Forestry program includes 146 members managing 65,000 acres. NNRG Policy Analyst Stewart Matthiesen says FSC criteria can result in up to 50 metric tons of additional carbon storage per forest acre.
Similarly, farm products with superior nutritional value gain premium market prices through targeted marketing. For example, Palouse wheat grown by the ***Shepherd's Grain*** cooperative targets improved farmer revenues and erosion prevention. The higher quality wheat is grown in a conservation tillage system that also adds carbon to farm soils.

BUILDING BIOCARBON THROUGH USDA PROGRAMS

USDA land conservation programs aimed at reducing soil erosion and water pollution promote practice changes on farms and forests. Programs help share the costs of practice changes with landowners, and pay for setting aside conservation lands. These programs constitute ecosystem services payments by government to farm and forest landowners to promote broader public interests. Though increased carbon storage is not the goal, they provide a carbon benefit.[82]

Financial and technical assistance

The ***Environmental Quality Incentive Program*** (EQIP) shares up to half the costs farm and forest operators incur implementing new practices and buying equipment to improve environmental performance. The program provides financial and technical assistance. In the 2008 fiscal year, EQIP provided $1.2 billion in cost-shares, including $80 million to Northwest farmers [83] ***The Conservation Security Program*** (CSP) provides similar support, and can support existing practices as well as changes. Northwest states in 2008 drew a $60 million share of the $300 million national program. The ***Wildlife Habitat Incentives Program*** shares costs for practice changes to improve habitat. Chad Kruger says ***cost-shares are "probably #1 for general change in practice***. When money comes on the table that gets people thinking."

Land Conservation

The ***Conservation Reserve Program*** (CRP) pays farm and forest owners to place highly erodible farmland in grasses and trees. One study found that CRP lands gain on average 0.27 metric tons of CO_2 equivalent per acre each year over a 4.5-5.5-year period.[84] However, there is evidence that this carbon boost is short-term as the system rapidly reaches a new equilibrium in the absence of active management. All Washington farm lands set aside under USDA conservation programs sequester 1.13 million $MTCO_2e$ annually, the Washington Department of Agriculture estimates. However, contracts on around 40 percent of those lands will expire by 2010, with the threat of significant carbon losses.[85]

The ***Conservation Reserve Enhancement Program*** (CREP) pays to set aside riparian areas. Another conservation program that does not retire land but allows managed grazing is the ***Grasslands Reserve Program***. The ***Forest Legacy Program*** administered by the U.S. Forest Service helps states buy conservation easements on forest land threatened by development

Outside of USDA, the National Oceanic and Atmospheric Agency, a branch of the Department of Commerce, offers help to state and local governments in securing coastal area conservation easements through the ***Coastal and Estuarine Land Conservation***

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[82] For a fuller discussion of programs, see *Federal Resources for Sustainable Farming*, ATTRA – National Sustainable Agriculture Information Service

[83] http://www.nrcs.usda.gov/programs/2008_Allocations/pdfs/FY_2008_final_eqip_state_allocations_footnoted.pdf Viewed May 4, 2010

[84] *Climate-Friendly Farming Project Summary,* CSANR Research Report 2010-001, Washington State University, p.13

[85] *Recommendations for the Development of Agricultural Sector Carbon Offsets in Washington State*, Agriculture Sector Carbon Market Workgroup, October 2008, p.19

Program. The ***Land and Water Conservation Fund administered by the Department of Interior*** acquires land for parks, wildlife and open space directly and through matching grants with states.

FOCUSING BIOCARBON IN THE 2012 FARM BILL

Large opportunities to promote biocarbon are presented by the next Farm Bill revision slated for a vote in 2012.

USDA land conservation programs originated with one of the regular Farm Bill revisions passed in the mid-1980s. They grew substantially with passage of the 2002 Farm Bill. That revision was also noted for the first Farm Bill Energy Title, which now funds renewable energy production and energy efficiency in agriculture. The Section 2007 *Renewable Energy for America Program* enacted in the 2008 bill dedicates $255 million to farm energy over a four-year period.

The 2008 bill was passed over the veto of President George Bush, who wanted to cut commodity subsidies. Farm groups representing corn, wheat and other subsidized commodity crops strongly objected, and Congress voted overwhelmingly against the cuts. **Hearings have now commenced toward the 2012 revision.** In an era of tighter budgets, debate over the farm program's future could well be fierce.

At the same time, the debate could open the way to discuss new options for biocarbon. **Devoting a greater share of Farm Bill funding to land conservation and farm energy programs would serve biocarbon goals.** To this point, Farm Bill conservation and energy programs have not been tied to carbon objectives. **Setting explicit carbon goals would help focus efforts on actions that produce the greatest carbon reductions**. For example, setting carbon goals for conservation lands could promote more active management to increase long-term carbon storage.

Oregon is setting a precedent for bringing carbon goals to USDA programs. In April 2010 USDA announced the nation's first Natural Resources Conservation Service (NRCS) state program to explicitly include GHG reduction and carbon sequestration. NRCS is the USDA's largest conservation funder. This was the product of an initiative by the Oregon Department of Agriculture and Oregon Environmental Council, which led a multi-partner effort to advocate the change.

A vulnerability in current farm programs is pointed out by Environmental Law and Policy Center (ELPC), a Chicago-based group that has extensively working on Farm Bill and on-farm energy production. **Commodity subsidies could be ruled an illegal barrier to trade by the World Trade Organization**. WTO has already ruled against U.S. cotton subsidies in a case brought by Brazil. ELPC recommends shifting supports to farm programs which provide environmental benefits. These "green box programs" have greater leeway under WTO rules.

"We continue to think **it's an excellent reason to justify farm energy and conservation programs,"** ELPC Senior Attorney John Moore says. In any event, the goal should be to "start putting a carbon filter on Farm Bill and Department of Energy programs."

Russ Zenner, a Genesee, Idaho wheat grower and climate-friendly farming pioneer, says the long-term interests of farmers, consumers or the land would be served by a new approach to federal farm supports.

"We need changes in the farm program from the crop concept**. Instead of taxpayer support for a handful of crops, agriculture and rural communities would be better served by providing incentives for sustainable resources** – growing systems providing healthy, nutritious food. The current farm program is curbing cropping diversity."

Zenner says farm programs should focus on building healthy soils to grow diversified, high-value crops, with benefits ranging from reduced health care costs to a smaller carbon footprint. Farmers themselves are going to have to realize the need for Farm Bill change and move for change in their own commodity groups. **"It's probably going to have to come up through the commodity groups**," the wheat farmer comments.

NEW WAYS TO SUPPORT ECOSYSTEM SERVICES

New ways to structure and shape ecosystem services markets could make them more effective and economical to operate while spurring broader participation.

One example is **contracting with landowners to implement practice changes rather than to deliver a specific performance level.** This briefing has covered the challenges of carbon offsetting, such as the requirement to monitor and verify carbon accumulation on each project. This adds significant costs, which would be reduced by paying for practices known to accumulate carbon rather than for proving specific results on each piece of land. This format can be applied to other ecosystem services as well.

Moving to practice-based options will require improved scientific understanding of how specific changes promote carbon accumulation and other ecosystem services in specific landscapes. With that knowledge payments can be made on an expectation that overall goals will be met across the landscape. Some sites may under-perform while others exceed expectations, but there will be confidence an overall average will be maintained. All that must be verified at each site is that the practice change has been implemented and is in use.

"Practice-based transactions are a way to efficiently get to scale. They are very attractive," says David Primozich, former executive director of the Willamette Partnership. "A really interesting idea is contracts based on whole-landscape practice change. If a broad level of agreement were reached, there would be an ability to move to scale more quickly than with current markets."

Changing the manner in which funds are delivered could also broaden participation. For example, USDA conservation efforts are structured as programs to which farmers and forester must apply for funding. As noted above, the most they can receive for cost-share programs is half their expenses. This limits participation. An alternative model is provided by in-lieu funding such as the Tualatin water temperature market under development in Oregon.

Building on this model, **federal, state and local land conservation efforts could be structured as markets.** Large funding blocks tied to overall ecosystem services goals would create a marketplace. Landowners would bid into the market to supply services. Instead of a cost-share that requires them to spend money, they would have access to a market in which they might actually make money. Systems which set a market value for changes will reach a far broader swathe of landowners.

Don Stuart maintains, "**The first key change would need to be instituted would be to pay the full cost plus profit – an actual market rate for what the farmer is being asked to do**. If we're going to solve any real-world problem by paying for this stuff, we've got to be prepared to cover what it is worth. Until we stop relying on farmer charity we're never going to be able to accomplish the density and intensity of change needed to actually solve major problems."

Finding ways to **credit multiple ecosystem services provided by a project rather than just one,** as the Willamette Partnership is doing in Oregon, would also bring more funding to the table.

"We need to integrate carbon storage with other benefits," comments Kirk Cook, the Washington Department of Agriculture's Natural Resources Section supervisor.

DIRECTING CARBON REVENUES TO BIOCARBON

Existing tools and policies provide a groundwork for a broader agenda to build the role of biocarbon in climate stabilization. Important models and experience are provided by carbon and other ecosystem services markets, land conservation payments, practice change cost support and sustainable products marketing**. But achieving CO_2 reductions to 350 parts per million in the atmosphere, vital to stabilize the climate, will require far more extensive efforts. Adoption of new carbon-accumulating land use practices must be massively ramped up.** Current tools and policies must be adopted to new challenges. New tools and policies must be developed. New resources must be brought to the table.

Ultimately, creating the widespread change in practices needed to achieve the 350 ppm goal entails a significant increase in funding. **A logical source is revenues generated through carbon regulation,** whether taxes on emissions or auction revenues from purchase of carbon credits in a cap-and-trade system.

Carbon revenues could support a number of biocarbon-building efforts:

- **Multiply funding for land conservation programs** and other federal, state and nonprofit efforts to preserve working and conservation lands.
- **Develop new markets**, **business models and mechanisms** for delivering ecosystem services and verifying performance.
- **Support building new markets and businesses** in high-quality wood and food products, bioproducts and bioenergy.
- **Provide federal public lands agencies with new resources** for actions to improve forest health and carbon storage such as road closures and restoration forestry.
- **Build knowledge and experience of carbon-accumulating practices and technologies** through greatly increased research, development and demonstration efforts.

New income streams in addition to offsets are being envisioned in federal climate legislation. The Kerry-Boxer and now Kerry-Lieberman bills include language that would direct funding from the sale of emission allowances to pay private landowners to sequester more carbon. This would be done through direct contracts outside the offset market. Vehicles such as USDA conservation programs could be used to funnel this money through existing federal infrastructure, but the source of funding would be entirely new through the sale of carbon emission allowances.

"This approach has the advantage of using forest-based carbon sequestration as a complement to, rather than a substitute for, reductions of emissions within the fossil fuel sector," says Paula Swedeen. "In addition, money from the climate bill is directed to fund more voluntary conservation easements, which are a crucial source of income to assist with transitioning to new ecologically-based forestry models, and to prevent the loss of sequestration potential in the first place."

Federal climate framework legislation that sets a price on carbon emissions must be passed. Employing carbon revenues to directly support new biocarbon-building practices in farming and forestry is a vital step to reach target 350. The investment will also yield many other economic and environmental benefits for those sectors, the nation and the world.

Re-Greening Cities: The Carbon Landscape

Greenspaces and green infrastructure to build biocarbon and climate resiliency while saving energy and tax dollars

URBAN AND URBANIZING – THE BIOCARBON DIMENSION

Urban and suburban areas represent under three percent of the U.S. land base, around 60 million acres. That is relatively small compared to the 442 million acres of cropland, 587 million of grazing land, and 651 million of forest.[86] Nonetheless, **developed and developing areas represent biocarbon opportunities that deserve a focus for several reasons.**

FIRST, urbanization is absorbing more land. **Urbanized American land has more than doubled since 1960** when U.S. Census measurements showed urban areas occupying 25.5 million acres.[87] It is critical to control urban growth and guide toward development patterns that preserve forest cover and other carbon stocks within and around urban/suburban areas. Constraining sprawl and preserving greenspaces in urban and suburban areas are the needs.

"If recent trends continue, the expansion of urban areas will markedly outpace the growth in urban populations . . . making urban carbon dynamics very important within the global carbon cycle," write a team of urban ecologists in a study of Seattle area carbon accumulations.[88]

SECOND, enlightened city governments are already taking a lead on climate action. As of June 2010, over 1,000 U.S. cities signed on to the U.S. Mayors Climate Protection Agreement committing to efforts to meet Kyoto climate treaty goals within city boundaries. Initiated by then Seattle Mayor Greg Nickels, the agreement has grown to span the largest cities in the U.S. including New York City, Chicago and Los Angeles. Dozens of Northwest cities have signed on, including Portland, Spokane, Tacoma and Boise.[89]

Actions to build and leverage biocarbon resources synch well with city efforts to control sprawl, create and preserve urban greenspaces, and replace fossil fuels with biomass waste streams. And the opportunity to directly engage citizens in climate preserving activities, discussed later in this briefing, has implications beyond the amount

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[86] Ruben M. Lubowski et al, *Major Uses of Land in the United States 2002*, USDA Economic Research Service.

[87] Land Use, Value, and Management: Urbanization and Agricultural Land, USDA Economic Research Service, http://www.ers.usda.gov/Briefing/LandUse/urbanchapter.htm viewed June 3 2010

[88] Hutyra, L. Yoon, B. and M. Alberti. 2010, "Terrestrial carbon stocks across a gradient of urbanization: A study of the Seattle, WA region," *Global Change Biology*, forthcoming

[89] United States Conference of Mayors Climate Protection Center, http://www.usmayors.org/climateprotection/revised/ , Map of cities at http://www.usmayors.org/climateprotection/ClimateChange.asp viewed June 3, 2010

of carbon that can be stored. (The opportunity to transform municipal waste streams into valuable products is covered in the *Recycling Carbon* briefing.)

Greener cities will also be better prepared to buffer the heat and extremes of drought and storms that will come with global warming. Local governments are already taking this into account. For example, ***Portland and Multnomah County, Oregon*** have included greenspace-oriented climate adaptation in their climate action plans. ***Seattle Public Utilities*** is one of a group of eight large city water systems that is building climate adaptation into its strategies. This includes green features as well as other strategies to harvest rainwater. ***King County,*** working with University of Washington Climate Impacts Group at the University of Washington, and ICLEI-Local Governments for Sustainability, has developed a publication to guide adaptation work around the U.S. *Preparing for Climate Change: A Guidebook for Local, Regional and State Governments*.[90]

THIRD, carbon storage potentials within developed areas are not small, as innovative research emerging from Northwest cities is demonstrating. The Seattle study noted above looked at carbon at 154 sites ranging from the city center to lots 58 kilometers distant. The study found that:

- Central Puget Sound lands store an average of 89 metric tons of live biomass carbon above ground per hectare (MTC/ha) and another 12 MTC/ha in woody debris.
- Forested areas within the region average 140 MTC/ha and hold 89 percent of live biomass carbon, while urbanized lands average 18 MTC/ha.
- Forest canopy covers 57 percent of the Central Puget Sound region.

Full results are contained in the chart below.[91]

	Impervious Surface	Live Biomass	Woody Debris
Heavy Urban	+80%	2	0.6
Medium Urban	50-80%	13	0.2
Low Urban	20-50%	38	2.6
Mixed Forest	-	98	12.7
Conifer Forest	-	182	27.1
Weighted mean		89	11.8

"Within most carbon studies, urban and urbanizing areas have only been considered as a source for emissions . . .," the researchers write. "The vegetation within urban areas has been largely ignored or assumed to be negligible within the carbon cycle . . . In this study, we have found that **the Seattle urbanizing region . . . has very significant carbon stores within its terrestrial vegetation, which do play an important role in**

90 Available at www.cses.washington.edu/cig/fpt/planning/guidebook.shtml
91 Hutrya

the terrestrial carbon cycle through a combination of carbon storage, carbon uptake, and urban land development activities."

The researchers add, **"Both the total carbon stocks and mean vegetated canopy were surprisingly high, even within the heavily urbanized areas**, well exceeding observations within other urbanizing areas and the average U.S. forested carbon stocks." Earlier studies found urban forests averaging 25 MTC/ha and U.S. forests in general at 53.5 MTC/ha.

"We were pretty astonished at how much carbon stock is out there," comments Marina Alberti, a member of the research team and director of the University of Washington Urban Ecology Research Laboratory.

"The remarkable magnitude of observed carbon stocks in the rapidly urbanizing Seattle region is particularly clear when compared to the biomass stored in Amazonian rainforests," researchers note. Central Puget Sound conifer forests at 182 MTC/ha compare favorably with the 197 MTC/ha found in a heavily studied Amazonian rainforest tract.

The Seattle region lost 40 percent of its forest cover in the last 100 years, and is projected to lose another 20 percent as metropolitan population grows 32 percent to 4.3 million by 2030. These "patterns of urbanization and sprawl . . . are not atypical for Western U.S. cities."

The Seattle region results send a broader message summed by the Seattle study team: **Pay attention to vegetation "as urban land covers and populations continue to rapidly increase around the globe."**[92]

THE NORTHWEST'S GROWTH MANAGEMENT HERITAGE

Northwest states are among the nation's leaders in growth management strategies to constrain sprawl and preserve natural greenspaces, with substantial biocarbon benefits. Oregon, the nation's original leader in state land use planning and growth management, began implementing its system in the 1970s. Washington followed in 1990 with its Growth Management Act. Today, both states require growth boundaries around cities and metropolitan areas, and have enacted policies to concentrate development in city and town centers. Growth management has preserved carbon-rich greenspaces in and around cities, even though carbon storage has not been a prime goal.

"**In the Portland metropolitan region 2040 Growth Management Plan, one of our most important efforts is ensuring there is nature in the city,"** notes Mike Houck, director of the Urban Greenspaces Institute and a veteran Portland areas greenspaces advocate. "Carbon sequestration has not been an explicit reason for doing so, at least not until recently. Regardless of the lack of explicit connection, we are doing it. **Now it's**

[92] Ibid

time to formalize the link between sound land use planning, carbon sequestration and climate change adaptation."

The value of bringing climate into the picture "is huge," Houck says**. "**Many public officials are more dialed in on climate than other aspects of green infrastructure. **Climate brings in new people and strengthens our existing alliances**."

Growth management already generates unusual alliances. The original 1970s Oregon land use legislation was a product of coalitions between farmers and civic groups. That pattern is repeated in current efforts to set aside large rural reserves beyond the Portland Urban Growth Boundary for at least 40 years, "close as possible to a permanent UGB," Houck says. "We believe that within the existing UGB land can be used more efficiently." The Agriculture and Natural Resources Coalition backing expanded rural reserves includes groups ranging from ***1000 Friends of Oregon*** to the ***Washington County Farm Bureau*** and ***Oregon Association of Nurseries***.

Advancing beyond current policies, new strategies for development hold promise for biocarbon.

"The way we develop may actually influence the amount of carbon that can be stored," Alberti says.

For example, research indicates that **larger patches of greenspace could provide more effective carbon storage than dispersed vegetation, the urban forest versus street trees.**

"We can do something about protecting carbon stocks in urban areas, perhaps by cluster development that maintains a larger portion of the forest," Alberti says. "We haven't lost the battle in urban areas."

"At the urban fringe we find a lot of viability, depending on whether we develop very compact buildings or sprawl," the urban ecologist adds. "In a place with more density in terms of people and height of buildings, you have the ability to maintain more carbon stocks."

Cascade Land Conservancy is advancing the concept of "conservation villages", which cluster new rural development in a manner resembling older towns rather than spreading it out in conventional suburban fashion. That would allow greenspace blocks surrounding the village to be preserved.

"Even in the core area you still find quite a bit of carbon, primarily in small parks**,"** Alberti adds. **There is an issue of how many trees you can keep together in developed areas. It is important to think about development practice.** The question is what rules and building codes and practices are in place for one type of urban development or another."

Refining development policies will require more site-specific research, Alberti says. "Right now we have a general understanding. But **we will not be able to provide rules until we have better understanding of urban carbon storage**."

She adds that another area in need of research is how growth boundaries cause spillover patterns such as low development in rural areas.

"Urbanization extends very much beyond what we call urban," Alberti says. "It's a big mistake if we don't pay attention to this. Depending on how we develop we will impose different resource patterns. We need to find out how much."

MOVING FROM GREY TO GREEN INFRASTRUCTURE

Moving to incorporate more green features in developed and developing areas has benefits beyond climate. **Increasingly, municipal jurisdictions are finding that economic benefits make a powerful case for greening cities and suburban areas**. Impervious street and building surfaces intensify stormwater runoff and urban heat that were absorbed by vegetation and soils before development.

Rich options to "move from grey to green" are coming to the fore in cities around the U.S. They are finding ways to create green features such as pocket wetlands, green roofs and walls, rain gardens, swales and vegetated buffers that hold water and cool the air. A U.S. Environmental Protection Agency study contrasted development strategies employing green features and conventional "hard" infrastructure. In most cases **savings of "greenfrastructure" are substantial, ranging from 15-80 percent, with reduced costs on the one-quarter to one-third range common**.[93]

Northwest municipalities are leaders in moving "from grey to green." Portland already requires that new and redeveloped buildings manage stormwater. By disconnecting 45,000 drain spouts, one billion gallons of water that would have gone down municipal pipes now stays on site. **In Southeast Portland's Brooklyn Creek Basin green infrastructure has cut city costs for stormwater control by $63 million.** Portland's Bureau of Environmental Services has convened an expert panel to quantify a broad range of ecosystem services derived from the city's greening efforts.
Seattle is also adding green to its streets and has installed a green roof on its new city hall. King County gathers water for toilets and irrigation at its King Street Center. The new Bill and Melinda Gates Foundation headquarters includes rainwater harvesting tanks. **A 30-year goal set by Seattle to increase urban forest cover** to 30 percent from the current 18 percent is **projected to increase annual economic benefits** including stormwater management, cleaner air and carbon storage **by $15 million** to $44.6 million.

Greening cities generates many other benefits. **Chicago's extensive green roof program, buffering the urban heat island effect, is saving residents $100 million**

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[93] Dominique Lueckenhoff, U.S. Environmental Protection Agency, Green Infrastructure: *Saving Money & Water, Creating Jobs and a Sustainable Future*, Mayors Innovation Project Annual Meeting, Washington, D.C., Jan. 23, 2010. All statistics in this section drawn from presentation.

annually in energy bills. The city hall roof alone, reducing temperatures 10-15° Fbelow a nearby tar roof, saves city taxpayers up to $3,600 on annual energy bills. If Los Angeles greened 15 percent of its roofs, a study shows, it would reduce urban temperatures by 5-9° F and save from 500-1,000 megawatts in peak power annually.

Creating green infrastructure is a source of green jobs. **A Washington, D.C., study estimates that a major green roof effort there would create 1,769 full-time jobs for 10 years.** A 10-percent tree canopy increase is estimated to reduce energy costs 5-10 percent by providing shading and windbreaks.

Green features even seem to reduce crime. **A University of Illinois study compared similar neighborhoods and found 52 percent less crime in greener areas.**

ENGAGING CITIZENS IN BUILDING BIOCARBON KNOWLEDGE

Urban and suburban areas represent by far most of the population, offering civic engagement potential with implications for climate beyond the amount of carbon that can be stored.

Grappling with climate change is tough and often overwhelming for ordinary citizens. It is a huge issue seemingly beyond the power of any one person to affect. **Biocarbon offers a literally grassroots way for citizens to engage in climate in their own backyards.** In World War II citizens were encouraged to grow "Victory Gardens." In the climate struggle, **citizens might grow "Climate Victory Gardens" through gaining understanding of how to manage their properties.** Providing a means to make a direct contribution can translate into a sense of empowerment and broader involvement with the climate issue.

Indeed, the lawn plays a more important role in land use than most people recognize. Turf grass including lawns, parks, golf courses and sports fields covers 1.9 percent of U.S. land (this includes urban and rural locations). Consuming 75 percent of the nation's household water**, turf grass covers three times more area than irrigated corn, the largest irrigated U.S. crop, and the area is growing**.

The study which developed those numbers also concluded that **"well-watered and fertilized turf grasses act as a carbon sink." But too much water, nitrogen-based fertilizer or pesticides could eliminate positive carbon balance**.[94] Another more focused study of four parks near Irvine, California concluded that greenhouse gas emissions could actually increase. CO_2 gains in grass were equaled or exceeded by fertilizer emissions of nitrous oxide, a powerful GHG, and fossil fuel emissions to pump water and run maintenance equipment.

[94] Cristina Milesi at al, "Mapping and Modeling the Biogeochemical Cycling of Turf Grasses in the United States," *Environmental Management*, Vol. 36, No. 3, p.426-38

"Green spaces may be good to have," said lead researcher Amy Townsend-Small. "But they shouldn't automatically be counted as sequestering carbon."[95]

Replacing standard lawns with native vegetation reduces the need for water, chemicals, fertilizers and energy, all lowering greenhouse emissions. In the Northwest, with its typically dry summers, water use to maintain lawns and pumping energy to deliver water are significant. So are emissions from lawn mowers. Native vegetation adapted to the climate requires much less water, chemicals, fertilizers and yard care in general. This suggests great potential for civic engagement efforts by local governments and nonprofits to drive a major shift toward native plantings. It could include education, as well as civic science work, to measure carbon accumulations and overall emissions performance of various landscaping strategies.

Engaging neighborhood groups and residents in civic science efforts will build understanding of best practices to manage urban lands for biocarbon. Portland State University is laying the foundation for such work

PSU researchers have been undertaking studies similar to those in Seattle, The PSU team is marrying remote sensing data from satellites with ground surveys by students working with residents. PSU is undertaking an exploratory analysis of urban carbon below-ground carbon stocks while the Seattle study looked at above-ground vegetation.

Neighborhood interest is "extraordinary. Receptivity is there," says Vivek Shandas, a professor at PSU's College of Urban and Public Affairs. "We want to engage citizens around the urban environment. **Without having citizens engaged much of this is not going to go far politically or scientifically."**

Civic science engaging citizens will provide "a more nuanced characterization of soil carbon in different land uses and vegetation**,"** Shandas says**. "It could lead to a better and more refined model for urban soil carbon sequestration. We could make Portland into a living laboratory."**

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[95] *Los Angeles Times*, "Urban parks: a global warming downer?" Feb. 10, 2010

Recycling Carbon: Bioeconomic Development

Building biocarbon through creating new jobs producing bioproducts and bioenergy

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:[96]

	<$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.[97]

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**[98]

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 power use.[99] If converted into liquid fuels, it could generate 20-30 percent of state transportation fuels.[100] Residue streams could also replace natural gas-based nitrogen fertilizer.

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[96]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.
[97] 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. .
[98] Ibid
[99]Frear, p.16
[100] *Vision for Washington's Bioeconomy*, Washington State University, Pacific Northwest National Laboratory.

“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.”[101]

“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.”

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.

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[101] *Climate-Friendly Farming Project Summary,* CSANR Research Report 2010-001, Washington State University, p.33

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.[102] 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."[103]

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 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.

[102] Washington Department of Ecology, "Washington recycling more; generating less waste," press release, Nov. 16, 2009
[103] Washington Department of Ecology, Beyond Waste page, http://www.ecy.wa.gov/beyondwaste/, viewed May 6, 2010

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**."[104]

Another Washington agency taking a leading role in biomass is the Department of Natural Resources. In 2009, the state legislature authorized DNR to stage a Forest Biomass Initiative employing materials from state lands. In January 2010, four projects were announced for first-phase review:

- **Parametrix** will develop a mobile pyrolysis unit to process forest thinnings into liquid fuels, and biochar to demonstrate the technology (pyrolysis and biochar are discussed in a section below). The project will be based at partner firm SDS Lumber in Bingen.
- **Borgford Bioenergy** will gasify biomass from forest thinning operations to produce 14,000 pounds of syngas and 2,000 gallons of bio-oil daily, while operating two power plants that will also supply 8.2 megawatts of power as well as heat and steam to the Kulzer BioEnergy Park and Springdale Lumber in Stevens County.
- **Atlas Pellets** will install equipment at its Omak mill to enable pellet manufacture from forest biomass, expanding feedstocks for the energy product from sawdust the company has been using.
- **Nippon Paper** will expand the biomass boiler at the company's Port Angeles paper mill, generating a 20-megawatt power surplus to be sold to the local utility while preserving the plant's financial viability and hundreds of jobs.

DNR is mounting a statewide forest biomass supply and accessibility study to verify that the projects can move forward sustainably. That extends an Olympia Peninsula inventory done by the University of Washington for the agency. The new study is to be completed in 2011.

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.

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

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.[105] 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.[106]

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 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.[107] 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.

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

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

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

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.

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."[108]

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.

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.[109] 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.[110] But potentials are far greater. Washington State alone has around 600 dairies and 250,000 cows.[111] 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.[112]

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[108] Craig Frear et al, Bioenergy and Bioproducts Fact Sheet: VanderHaak Dairy Anaerobic Digester, Washington State University
[109] Climate-Friendly Farming Project Summary, p.15
[110] C. Kruger and Frear, C., "Lessons Learned About Anaerobic Digestion," Climate-Friendly Farming, Ch. 12, Washington State University, CSANR Research Report 2010-001
[111] Craig Frear
[112] Climate-Friendly Farming Project Summary, p.4-5

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.[113]

Biodigestion "can, in fact, turn a dairy from a net source to net sink for GHG emissions," CFF researchers write.[114]

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."[115]

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.**

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.[116]

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.[117]

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

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[113] Personal communication, Chad Kruger
[114] C. Kruger and Frear, C., p.4-5
[115] Climate-Friendly Farming Project Summary, p.5
[116] Peter Winsley, Biochar and bioenergy production for climate change mitigation," *New Zealand Science Review* Vol. 64 (1) 2007, p.5
[117] Jeff Schahczenski, *Biochar and Sustainable Agriculture*, ATTRA-National Sustainable Agriculture Information Service, 2010

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**."[118]

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**. [119]

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.[120]

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.

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[118] Schahczenski
[119] 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
[120] Winsley, p.6

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 . . . ."[121]

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.

"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.[122]

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."[123] If producers have to bear that cost, the

[121] Schahczenski
[122] Winsley, p.6
[123] Granatstein, p.iii-iv

stationary unit breakeven is $191/ton.[124] 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.[125]

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 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.[126]

"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

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[124] Granatstein, p.94
[125] Granatstein, p.116. Because is produced in a CO2 intensive process, replacing lime could gain carbon credits.
[126] Schahczenski

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. [127]

- 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.
- **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.[128]

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

[128] Available at http://www.ciras.iastate.edu/publications/IABioVisionRoadmap.pdf, viewed May 13, 2010

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. [129]

"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.

"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

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[129] Iowa State University Bioeconomy Institute, Who We Are, http://www.biorenew.iastate.edu/who-we-are.html, viewed May 13, 2010

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."**