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Attachment A

13043

ALTERNATIVE USES
AND MARKET OPPORTUNITIES FOR BIOSOLIDS

April 2009

King County

A report to the King County Council
by the
Wastewater Treatment Division
King County Department of Natural Resources and Parks

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Alternative Uses and Market Opportunities for Biosolids

Purpose

This document provides the Wastewater Treatment Division's (WTD) response to the budget proviso on the division's operating budget for 2009, which reads as follows:

> *Of this appropriation, $100,000 shall not be expended or encumbered until the wastewater treatment division of the department of natural resources and parks, transmits to the council for review and approval by motion a report on (1) the status of the work program for the biosolids program; (2) an analysis of alternative uses of biosolids being considered including, but not limited to those proposed via a Request for Information ("RFI") in 2008, with the analysis including attributes, risk and reliability, flexibility, community support, cost and benefits; (3) recommendations for next steps; and (4) a schedule of potential implementation of biosolids alternatives utilization.*

This report responds to each element of the proviso. The document begins by providing brief background information on the current biosolids program, item (1) of the proviso. Next, the report summarizes and analyzes in detail alternative uses of biosolids as informed by the Request for Information (RFI) in 2008, item (2) of the proviso. Finally, the report provides recommendations for next steps (item 3), as informed by this analysis, and a general timeframe for the recommended next steps (item 4).

Background

Treating wastewater yields three products: clean water, biogas, and biosolids. Biosolids have not always been recognized as a valuable commodity but King County (previously Metro) was one of the early advocates of biosolids as an important resource. Since the early 1970s, King County has been striving to reuse biosolids in a manner that is beneficial to society, cost-effective for its ratepayers, and publicly acceptable.

In 1999, through its Regional Wastewater Services Plan (RWSP), the county articulated its biosolids policies, intended to guide future uses of biosolids. These policies, contained in K.C.C. 28.86.090, are flexible enough to accommodate a variety of future options that strive to achieve beneficial use. For example, the county's policy is to recognize a beneficial use as any that proves to be environmentally safe, economically sound, and utilizes the advantageous qualities of the material. The county also considers new and innovative technologies brought forward by public or private interests. In recognition of biosolids as a valuable commodity, the county established the policy of using marketability as the basis for future decisions about technology, transportation and distribution.

The status of the current biosolids program—primarily forest and agricultural land application and composting—is robust and follows these RWSP policies. In particular, the current program implements the direction to maintain a diverse program with reserve capacity and to work cooperatively with statewide organizations, using local sponsors whenever biosolids are used outside King County. Table 1 provides an overview of the current biosolids program.

As Table 1 indicates, the largest market for biosolids is in Douglas and Yakima counties, where farmer-owned companies receive and manage the application of biosolids on their own crops and the fields and crops of their neighbors.[1] In these counties, there is more demand for biosolids fertilizer than can be supplied by King County and other generators. These projects are unique in the amount of local involvement and control. These projects have proven to be stable and reliable for more than fifteen years. However, the location of this market requires that biosolids be trucked across mountain passes year-round. Rising fuel costs and temporary closures of mountain passes can impact the program. The county's biosolids are also land applied to commercial forests in King County, and a relatively small amount is used to produce compost.

Table 1. Average Current Distribution of King County Biosolids

Project Name	Uses/Crops	Customers	Location	Average Annual Use (wet tons)	% of Total Annual Production
Boulder Park	Dryland wheat	Farmers	Douglas	65,000	57%
Natural Selection Farms	Canola, hops, misc. crops	Farmers	Yakima	15,000	13%
Hancock - Snoqualmie Forest	Commercial forests	Forest management company	King	25,000	22%
State Department of Natural Resources (WA DNR)	Commercial forests	State forest management agency	King	5,000	4%
GroCo	Compost product (Class A, Exceptional Quality biosolids product)	Landscapers and general public	King	5,000	4%
		Total Annual Production		115,000	

In July 2008, the county issued a Request for Information (RFI) because it was interested in learning about market options available for supplementing, strengthening or diversifying its existing biosolids program. The county is occasionally approached with other potential uses of biosolids, such as for an alternative energy source or land reclamation, and was interested in

[1] Figures are approximate; annual tonnage and distribution vary slightly based on annual production and market conditions.

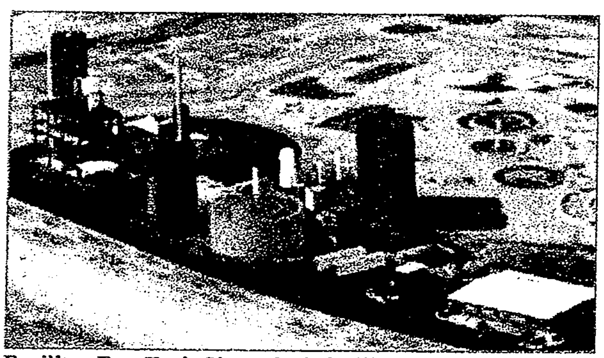
learning more about and comparing various options. The county was especially interested in options that (1) avoid or manage the impacts of winter weather on biosolids transportation; or (2) reduce the amount of diesel fuel used for transportation; or (3) use biosolids as a tool to reduce emissions of greenhouse gases, (i.e., through substitution of biosolids directly for fossil fuels, as a replacement for fertilizers made with fossil fuels, by composting, by direct carbon sequestration, or other methods).

Eleven responses to the RFI were received, and county staff have been evaluating these proposals over the past few months. Four responses were from vendors that currently contract with the county for biosolids management; seven were new proposals. While the proposals vary, they can be grouped into three major categories:

- **Energy** (biosolids as a fuel) proposals were received from Polaris Renewable Energy (Polaris) and EnerTech Environmental (EnerTech);
- **Composting** (biosolids as a compost feedstock) proposals were received from GroCo, Cedar Grove, and Ekotek Bio-Technologies;
- **Land application** (biosolids as a fertilizer and soil builder in agricultural, forestry, and reclamation activities) proposals were received from Boulder Park, Inc.; Natural Selection Farms; Cascade Materials; Ramco, Inc., and Sylvis Environmental.

The next sections of this report summarize the proposals and highlight their advantages and disadvantages in respect to a variety of success criteria listed in Exhibit A: reliability, year-round availability and access, flexibility, local sponsorship, community support, storage capacity, additional program diversity, demonstration of multiple benefits, quality control, social justice/equity, innovation, and risk. Using information gathered from the proposals and follow-up interviews, a separate section describes a particular emerging area of interest—greenhouse gas benefits, and another section provides information on the relative cost of alternative management scenarios involving these proposals.

ENERGY OPTIONS



Facility: EnerTech SlurryCarb facility, Rialto, CA
Source: http://www.enertech.com/facilities/sitedevelopments/rcrf.html

Product: dried pellets, similar to EnerTech E-fuel
Source: http://www.tpomag.com/editorial/1248/2009/01

Two respondents to the RFI—EnerTech Environmental, Inc and Polaris Renewable Energy—proposed processes to convert biosolids to a renewable biofuel. Each vendor proposed to sell the dried biosolids to local industries, such as cement manufacturers, for co-combustion with coal. In a cement kiln, dried biosolids can be a coal supplement, replacing 10-15 percent of the crushed coal fuel.

EnerTech Environmental, Inc., a company headquartered in Atlanta, Georgia, is just completing its first operational facility in Rialto, California. This facility has a capacity of 883 wet tons per day (for comparison, King County produces about 315 wet tons per day) and has long-term (25-year) contracts to take biosolids from five southern California municipalities, including Orange County Sanitation District and Los Angeles County Sanitation District. Using the patented SlurryCarb™ process, the biosolids are subjected to heat and pressure, resulting in a dried product called "E-fuel." EnerTech will be marketing its E-fuel to cement kilns in southern California. No specific location was proposed for a Washington facility.

Polaris Renewable Energy has offices in Seattle and Portland, but has no operating biosolids project at this time. They propose to locate a facility locally, perhaps in Snohomish County, which will harness waste heat from a landfill to dry biosolids. An Andritz belt dryer, in use in numerous locations in Europe, can dry the biosolids using this type of heat, or using natural gas if needed. The dried biosolids would be sold to industrial users of solid fuel, such as cement or steel manufacturers or coal-fired power plants.

Findings. The energy proposers provided processing fees between $55 and $95 per wet ton, not including transportation. While costs are discussed later in this report, by comparison, land application fees average about $12-14 per wet ton, not including transportation. However, depending upon the location of the facility, these energy options could reduce transportation costs, reduce capital costs, and could require less county staff than currently needed to manage the current land-based program. EnerTech costs would be dependent on location of a facility; a facility located at one of the county's treatment plants (so that the process leachate could be treated by the plant) would cost less.

The energy options are considered higher risk than the other options for these reasons:

- They require the majority of the county's biosolids to implement their technology, reducing program diversity.
- They are difficult to back up with land-based projects, which are not viable on standby.
- Only one of the energy proposers has operating or processing experience and project management experience with biosolids.
- In the U.S. biosolids industry, there is a significant history of risks associated with first-time implementation of drying and other technologies.
- One of the energy proposers provides limited equipment redundancy and relies heavily on third-party operations for both the heat source and the product combustion. This creates risk of both short and long-term process downtime and diminished reliability.

Advantages of these proposals are:

- Biosolids could be recycled locally, unaffected by weather, reducing transportation costs and fuel consumption.
- Facilities would include one to two weeks of storage for unprocessed biosolids.

- A few local, large coal-burning industries could have access to a renewable fuel source that can mitigate a portion of their air emissions.
- Long-term (20-25 year) contracting, with no capital costs to King County.
- Likely to generate verifiable, tradable carbon credits for the county, based primarily on the offsetting of emissions from coal burning. At current U.S. market prices for voluntary credits, the value of these credits (assuming all King County biosolids co-combusted) on the Chicago Climate Exchange would be approximately $45,000, possibly more in other markets. See section on carbon and greenhouse gas impacts later in this report and also Exhibits C and D for more information on carbon accounting.

COMPOSTING OPTIONS

Facility: Cedar Grove compost facility, Everett, WA
Source: http://www.cedar-grove.com/about/environment.asp

Product: compost
Source: http://www.cedar-grove.com/

Four responses were received that proposed composting services: GroCo, Inc., Cedar Grove, Ekotek Bio-Technologies, and Cascade Materials. Composting is an end use that generates carbon benefits and gives the general public access to high-quality Class A biosolids products for their lawns and gardens. Composting sites generally have the ability to store large quantities of biosolids on-site while awaiting or following processing. For this reason, composters located west of the Cascade mountains are thought to represent secure and reliable sites for the county in that they can be accessed year-round with few exceptions.

GroCo, Inc. has composted the county's biosolids for approximately 30 years. Their manufacturing facility is in Kent, with a retail outlet in Seattle. They have served as the severe weather site for biosolids deliveries when other sites were not accessible. On many occasions, they have taken the entire biosolids production of King County for consecutive days. In addition to this emergency service, they also act as the backup site when other local projects are temporarily down or on hold. GroCo has strong local support with a brand name sought after in the home landscaping market. Recently, GroCo has had some difficulty sourcing the sawdust bulking agent they prefer for their mix and this has caused an increase in the price—from $30 to $64 per wet ton—that they charge their biosolids suppliers.

Cedar Grove is a well-known composter with facilities in Maple Valley and Everett. Cedar Grove has operated compost facilities in this region since 1980; they currently have an environmental management system (EMS) that meets ISO 14001 standards. They proposed three different options to the county: (1) the county could purchase their Gore Cover system for a new county operation; (2) they could provide "turn-key" operation of a composting facility that the county would locate and build; (3) they could provide some winter composting capacity for biosolids at their Everett composting facility for an estimated $40 per wet ton. Because of their strong brand recognition, they could provide marketing expertise for a biosolids-based compost.

Ekotek Bio-Technologies is a compost development company that does not currently operate any facilities. Ekotek's lead scientist, Dr. Joe Horvath, previously designed several successful compost facilities in Idaho, Montana, and eastern Washington. They propose to produce a high quality, enhanced compost with additional nutrients, as well as a national marketing program. Specifically, their proposal is to site and permit a large facility (about 250 acres) in eastern Washington to manage all of the county's biosolids production, along with biosolids from other generators. They also propose to manage the transportation of the biosolids by rail car. Additionally, they would like to have the county's municipal waste and yard waste and scale the facility to be able to accept similar throughput from many agencies. They envision the project with a capacity of 400,000 to 1,000,000 wet tons per year of various organic materials (as such, the county's total biosolids would represent 10-20 percent of the total). They estimate a project of this scale would require from two to seven years to become fully operational. The estimated processing fee they would charge the county would be $55 per wet ton, including rail haul. Ekotek also proposes to fund university research and provide a rebate of up to 20 percent to King County.

Cascade Materials in Snohomish, Washington, has proposed that their agricultural operation could provide biosolids composting services in the future, combining biosolids, yard waste, and horse bedding to produce a Class A product. They have experience composting manures, but have no experience composting biosolids and would need to secure a permit and more fully develop the on-farm site where they have composted manure. They offer a site in southern Snohomish County, near Brightwater, with storage out of the flood plain for those severe weather events when transport to other sites is impossible. Cascade's proposal to the county includes both land application and composting. They did not propose specific tons or a price for their composting services.

Findings. The composting proposers provided a range of $40 to $64 per wet ton for a processing fee, not including transportation. Ekotek's estimated fee of $55 per wet ton does include rail haul, and they also proposed a potential rebate of up to 20 percent of this price. In general, the fee associated with composting is higher than regular land application but lower than high-tech options such as drying and combustion.

GroCo and Cedar Grove composting options are considered low risk for the county:

- Their composting methods are proven, successful technologies for creating customer-friendly products.
- Both have name recognition and established reputations in the Puget Sound area. Cedar Grove is a popular consumer product; GroCo's market has been more focused on landscape companies.
- They do not require large amounts of the county's biosolids in order to produce their products.

- They rate highly in reliability, flexibility, year-round availability, environmental benefits, community support, storage capacity, quality control, and program diversity.

Ekotek and Cascade Materials represent higher risk. Ekotek requests a commitment of all the county's biosolids, reducing program diversity and backup options. Cascade Materials is new to biosolids composting, and its proposed site is currently not permitted for biosolids composting and would need upgrading for access and compost process management.

In general, advantages of composting proposals are:

- Biosolids could be recycled unaffected by weather, reducing transportation costs and fuel consumption.
- Composting sites provide storage during inclement weather and backup capacity when other sites are temporarily on hold.
- Composting facilities usually have a high degree of flexibility in the amount of biosolids they can accept.
- Environmental benefits of compost are numerous and would be spread among all users of the products.
- No capital costs to King County.
- Composting has a positive carbon value: transportation debits are minimal, greenhouse gas emissions from composting are minimal, and soil carbon storage is high. See section on carbon and greenhouse gas impacts later in this report and also Exhibits C and D for more information on carbon accounting.
- Composters produce a user-friendly product that the general public (rate payers) can use themselves, which is valuable in establishing public understanding and support for biosolids reuse.

In general, disadvantages of composting proposals are:

- Uncertainty about the size and continuing strength of the market for compost in this region.
- Higher cost than direct land application of biosolids.

LAND APPLICATION OPTIONS

Agriculture


Wheat crop at Boulder Park, Douglas County


Canola at Natural Selection Farms, Yakima County

Three of the respondents provide agricultural land application services: Boulder Park, Inc. in Douglas County; Natural Selection Farms in Yakima County; and Cascade Materials in Snohomish County. The first two vendors have had existing contracts with the county since the early 1990s. They have proven to be reliable contractors with good year-round access except for the occasional short-term winter pass closure. They each have credible, articulate, local sponsors who are well known in their communities. Both eastern Washington projects enjoy strong community and local agency support. They both have the ability to store a large volume of biosolids on their sites prior to application. Given their history of performance, both are considered low risk.

Boulder Park, Inc. (BPI) is farmer-owned and contracts directly with King County to receive and apply biosolids to thousands of acres of wheat ground in Douglas County in the vicinity of the towns of Mansfield and Waterville. More than 100 farmers are signed up to receive biosolids under the project. Although BPI receives the majority of the county's biosolids (about 50-60 percent), not all farmers receive biosolids each year. Biosolids production is not sufficient to meet demand, and underused capacity can be valuable. In some previous years, in time periods when other projects have been temporarily on hold, Boulder Park farmers have been able to receive and use large quantities of biosolids.

Natural Selection Farms (NSF) is farmer-owned and contracts directly with King County to receive and apply biosolids to hops, fruit, corn, grapes, wheat and range land. Originally permitted only in Yakima County, the project has grown to include thousands of acres permitted in Yakima, Benton, Kittitas, and Klickitat counties. As in Douglas County, the supply of biosolids is not sufficient to satisfy demand. Growth of this project has expanded on an annual basis as biosolids becomes available. NSF worked with the University of Washington to develop its "Biosolids to Biodiesel" program, in which biosolids are used to fertilize canola, and the oil seeds are crushed in an on-farm facility and the raw oil sold to biodiesel producers.

Because of the local demand for biosolids, both Boulder Park and Natural Selection Farms receive biosolids from generators in addition to King County. Many smaller towns and cities work with BPI and NSF, usually depending on which facility is closer. Natural Selection Farms is classified under state biosolids regulations as a Beneficial Use Facility, and they are now receiving biosolids from 17 municipalities.

Cascade Materials is a relatively new entry into biosolids management. They have worked successfully with the City of Everett, Washington, applying their biosolids to agricultural land in Snohomish County. They are associated with French Creek Farms (a dairy and farming operation) owned by the Bartelheimer family. Approximately 625 acres of feed crops—field corn, canola, grass and hay—would be available for biosolids fertilization. Neighboring farms could provide another 600 acres. In addition to agricultural land application, they also proposed under-cover storage capacity during the winter months. Based on their work for the City of Everett, it appears they would operate a reliable site with year-round storage capacity. A particular advantage of this facility is that they are located on the west side of the Cascade Mountains, which would add to overall program diversity. Their sites are located about nine miles from Brightwater.

Findings. Application fees associated with agricultural proposals average $12-14 per wet ton, not including transportation. They represent the lowest fee, although for eastern Washington projects, the additional transportation cost is higher than for local uses. The options also require staff to oversee and maintain programs and contracts, and involve capital costs associated with application equipment.

BPI and NSF are considered to be low risk for the county because:

- They are proven, successful options with outstanding environmental records.
- They have systems in place for quality control, being an integral part of the county's certified environmental management system (EMS).
- Both have grown to include more customers and more suppliers of biosolids.
- They rate highly in almost all the project success criteria: reliability, flexibility, multiple environmental benefits, competitive cost, community support, local sponsors/spokespersons, storage capacity, quality control, social justice/equity. NSF also rated highly in innovation for its "Biosolids to Biodiesel" project.

Cascade Materials represents a higher risk for the county. Although they are located closer to WTD's treatment plants (only nine miles from Brightwater), the fields are close to the town of Snohomish and biosolids projects are not a long established, well-understood practice in that locale, despite interest by local farmers in using the product. Developing a new site requires small beginning projects with open houses and considerable work with the public by credible local spokespersons. Another concern with this location is that most of the proposed fields are in the flood plain, which is a practice that King County has avoided in the past.

In general, advantages of these agricultural proposals include:

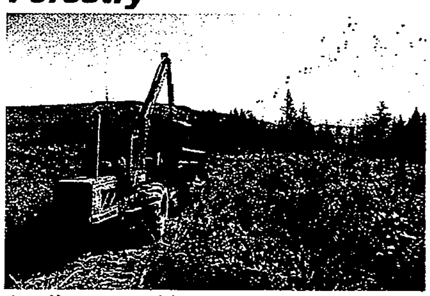
- A proven record of reliable year-in, year-out management of biosolids for more than 15 years.
- Community understanding and support as well as strong market demand.
- Local project management and control; many local spokespersons.
- Numerous and well-dispersed environmental benefits, such as fertilization with multiple nutrients, addition of organic matter to soil, carbon storage, reduction of wind erosion, increase in soil tilth, increase in crop yields, increase in crop residue for animal feed and return to soil, increase in water-holding capacity, and reduction of use of chemical fertilizers and herbicides.
- BPI and NSF projects promote good will for King County in eastern Washington.

- Low operating and capital costs.
- Large storage capacities.
- Use of biosolids in agriculture has a positive carbon value: transportation debits (emissions from fuel use) are minimal compared to credits for replacement of chemical fertilizer and soil storage. See section on carbon and greenhouse gas impacts later in this report and also Exhibits C and D for more information on carbon accounting.

Disadvantages:

- BPI and NSF represent the county's strongest markets, but they are about 200 miles from the treatment plants. This requires the use of a significant amount of diesel and biodiesel annually, which leaves the program budget vulnerable to increases in fuel prices.
- Much of the county's reserve capacity is at Boulder Park, which is 200 miles away.
- These projects require some capital expenditures. King County owns the tractors, manure spreaders, and other miscellaneous equipment used by BPI.

Forestry



Applicator working at Tiger Mountain State Forest

One proposal for forestland application was received from Ramco, Inc., the county's existing contractor for this end use. The county has contracted with Ramco since 1993 to apply biosolids on the Snoqualmie Forest, owned by Hancock (formerly owned by the Weyerhaeuser Company) and on state forests in the county, owned and managed by the state Department of Natural Resources.

Forestry was the county's first beneficial use of biosolids, pioneered and researched by the University of Washington since 1973. The first contract for commercial application of biosolids to forests was in 1985 with the Weyerhaeuser Company. In 1995, the Mountains to Sound Greenway Trust, a local environmental/conservation organization, put together a multi-party program to use biosolids on local public and private forests and to promote the purchase of forestlands in the county for forest management in perpetuity. This gave WTD's biosolids program a 50-year contract to apply biosolids fertilizer to local state forests owned by Washington State Department of Natural Resources. The Greenway Trust became an important local spokesperson for biosolids use in forests and now manages an environmental education program for local schools that includes lessons on sustainability and environmental enhancement from biosolids use.

Because of this history, King County is known worldwide for its forestry biosolids program; representatives from other countries have come here to learn about biosolids forestry and have returned to establish similar programs in their home countries.

Findings. The Ramco forestry proposal is about $13 per wet ton, not including transportation. Transportation costs are relatively low, since these projects are located in eastern King County rather than eastern Washington.

Forestry is considered low risk for the county because:

- These projects are proven technologies with a long successful history, including more than twenty years of environmental monitoring data.
- They do not require large amounts of the county's biosolids annually. To maintain project viability and availability of a contractor, only about 25,000 to 30,000 wet tons per year (about 30 percent of the county's total) need to be allocated to forestry.
- Forestry applications rate highly in reliability, flexibility, year-round availability, environmental benefits, community support, quality control, and program diversity.

In general, advantages of the forestry option are:

- Forestry adds an important local element to the program and provides valuable diversity.
- Biosolids can be applied nearly year-round, reducing transportation costs and fuel consumption.
- Forestry applications provide several environmental benefits, including addition of nutrients and organic matter, soil building, and improvement of wildlife forage and habitat.
- Biosolids application improves forest yields, helping to maintain commercial forestry as a viable industry.
- Forestry has a positive carbon value: transportation debits are minimal, soil carbon storage is high and there can be long-term carbon storage in wood products. See section on carbon and greenhouse gas impacts later in this report and also Exhibits C and D for more information on carbon accounting.

Disadvantages of the forestry option are:

- These projects contribute no storage capacity to the program; the contractor applies the daily deliveries and no significant daily carryover is practiced. This is due to the lack of covered storage, which is necessary for extended storage in the wet west side climate.
- Capital costs to support this project are higher than the agricultural projects. Capital funds support construction of equipment trails through the forest and the purchase and replacement of specialized application equipment.

Reclamation

Reclamation mix growing on copper mine tailings, Kamloops, British Columbia
Source: http://www.ualberta.ca/~anaeth/recent_grads.htm

Two responses proposed using biosolids to reclaim and restore lands damaged through past activities such as mining of sand, gravel, or minerals. Such lands have no topsoil and cannot sustain vegetative cover. This type of biosolids use involves combining biosolids with a carbon-rich material such as woody waste to make a soil replacement mix that can restore and sustain normal vegetation with a one-time application.

Ramco, Inc., the current forestland application contractor, submitted a proposal to apply a biosolids mix in the reclamation of gravel pits. Sylvis Environmental, a Canadian company, proposed to develop options for using biosolids mixes in landfill closure, as a biocover to trap methane emissions at landfills and for reclamation of mined lands. Both companies have experience with projects of this type and have demonstrated excellent performance in previous work.

Neither company has offered a site for their project. These proposals need further development and evaluation; however, some general advantages and disadvantages to these types of projects can be identified.

In general, advantages of the reclamation options are:

- These projects have proven to be successful in many parts of the country, including Washington and British Columbia.
- They do not require large amounts of the county's biosolids annually. The amount needed would depend on the availability of sites to be restored. Several smaller pits might use 5,000 tons per year. A large restoration project might use 15,000 tons per year for a few years.
- Reclamation projects rate highly in multiple environmental benefits (including carbon storage), community support, year-round availability, low cost and program diversity.
- By focusing on reclamation sites in and near King County, transportation costs would be low.

In general, disadvantages of the reclamation option are:

- These projects do not provide daily reliability of a long-term program. They represent discrete opportunities, with projects identified and then completed.

CARBON AND GREENHOUSE GAS IMPACTS

The county's RFI evaluation team calculated the potential greenhouse gas (GHG) credits and debits for each proposal by using values in the peer reviewed literature, data collected from sites that had received King County biosolids applications, and default values from the Intergovernmental Panel on Climate Change (IPCC). In the RFI, King County asked questions about practices that would provide information to calculate GHG credits and debits. Although two of the respondents said that their program would result in GHG credits, no quantifiable information was provided. The review team opted to use the same basis for evaluation for all of the proposals received. (In this carbon accounting exercise, the use of the word "credit" is a generic term used to assign a value to a reduction or offset of greenhouse gas emissions. The term "tradable credits" will be used to refer to a carbon dioxide emission displacement credit certified by the Chicago Climate Exchange or other similar body).

Carbon credits were calculated for:

- Replacing synthetic fertilizers
- Accumulating soil carbon
- Replacing fossil fuels
- Displacing traditional materials in cement manufacturing

Carbon debits were calculated for:

- Burning diesel to transport biosolids from treatment plant to end use
- Burning diesel to land apply biosolids
- Using energy to dry biosolids
- Emitting nitrous oxide (N_2O) gas

No debits were taken for methane emissions for any end use options. The likelihood of methane emissions from land application or composting sites is minimal whenever anaerobic conditions are avoided. We also assumed that no net change in nitrous oxide emissions would result from using biosolids in lieu of synthetic fertilizer so no debits or credits were taken for this substitution. A survey of the literature generally showed that N_2O from land application of biosolids was generally significantly lower than emissions from equivalent rates of nitrogen fertilizers.

No data was provided by the proposers for NOx or N_2O emissions from any biosolids combustion. Although it is likely that temperatures in kilns would be high enough to minimize N_2O emissions, NOx emissions are likely to increase as a result of elevated temperatures. In addition, the most quantitative study on N_2O emissions from combustion of biosolids showed that the CO_2 equivalent of N_2O emissions from fluidized bed combustion facilities ranged from 0.44 to 1.9 Mg CO_2 per dry Mg biosolids. Based on the absence of data and high values in the published literature we felt that it was conservative to use the IPCC default value of 0.9 kg N_2O per dry Mg biosolids.

Findings. All proposals showed a positive carbon balance, reinforcing the point that all proposals represent beneficial uses. Forest application had the highest carbon value and drying using natural gas was the lowest. The analysis also found that debits for transportation of biosolids, even to sites that were 200 miles distant, were minimal when compared to credits for fertilizer replacement and soil carbon storage.

See Table C-1 in Exhibit C for a summary of the carbon values for each proposal. For background and more detailed information on carbon accounting for biosolids, see Exhibit C for the methodology used and Exhibit D for the background paper *Climate Change, Carbon Accounting and Biosolids – An Overview* by Dr. S. Brown, University of Washington.

RELATIVE COSTS OF OPTIONS

The proposals received in response to King County's RFI varied in the amount of biosolids tonnage they could manage or process. Therefore the division created a set of alternative program scenarios for biosolids management, organized by different policy objectives, in order to facilitate a rational cost comparison. Each scenario would handle the full amount of the county's biosolids, but distributes tonnage to different entities. One scenario is the current program, or the baseline, and reflects the approximate 2008 distribution of biosolids by end use. Other scenarios include those with the objective of minimizing cost, maximizing energy production, maximizing market strength, maximizing reliability, maximizing carbon sequestration, and maximizing diversity of uses on the west side of the Cascades.

Several points about this approach merit mention. Several scenarios–notably those that maximized energy production–involved only one major user of biosolids. Those proposers indicated a preference for receiving the full amount of biosolids tonnage, likely because of economies of scale. Also, it should be noted that each scenario, except the least cost option, included a small amount of tonnage going to GroCo compost as an emergency backup. Finally, it should be emphasized that the scenarios vary in implementation feasibility or schedule–some scenarios can be implemented relatively soon, whereas others may require siting, permitting, construction or other factors that may impact costs and schedule.

In analyzing costs of each option, the division first assembled the actual 2008 costs (and revenues) for the biosolids program, and divided that by total wet tons to arrive at a baseline cost of $59 per ton. This included operating costs such as haul and application, as well as average annual capital costs to support the current program,[2] less any revenues received by the program. The division then estimated how its costs and revenues would change for each option–for example, several options might result in lower transportation, staffing, and capital costs. An important element of this analysis was how land application or processing fees would change, using fee estimates provided by the different proposers. Some scenarios reduce capital costs, but involve higher fees than the county currently pays in its operating program. The total costs of the scenario are then divided by the total wet tons to arrive at an average per ton cost.

Table 2 provides the results of this analysis. The table illustrates the distribution of tonnage across the different scenarios, how the project team assessed each scenario for various evaluation criteria, as well as the estimated per ton cost. Also included is a column assessing implementation feasibility and schedule. The table allows a comparison of each scenario to the baseline of the current program. Assumptions used for each scenario–and how they would affect the division's operating costs, capital costs, and revenues–are summarized below.

[2] Average annual cost estimates were used for capital since they have historically been within a fairly consistent range.

An additional note as to the reliability of this cost comparison is that proposal respondents provided varying levels of details regarding their costs, perhaps in part because they were responding to an RFI rather than to a request for a specific project proposal. We have attempted to present the data we received as accurately as possible and in the fairest light possible to all proposers.

Table 2. Program Scenarios and Estimated Net Cost

Scenario	Description	Provides 150 % Capacity ?	Boulder Park Inc.	Natural Selection Farms	Cascade Materials	Ramco Inc.	GroCo	Cedar Grove	Ekotek	Enertech	Polaris	Ramco Inc.	Sylvis	Success Criteria						Implementation Feasibility	Cost per Ton	Total Cost	Variance From Current Program
			Agriculture			*Forestry*	*Compost*			*Drying & combustion*	*Drying & combustion*	*Land Reclamation*		*Reliability*	*Year-Round Access*	*Flexibility*	*Community Support*	*Storage Capacity*	*Low Risk*		*$/Wet-Ton*	*x$1000*	*Total $ (x$1,000)*
Current Program	2008 distribution	Yes	65	15		30	5							+	+	+	+	+	+	+	$59	$6,785	$0
Max Energy	Alternative A: Enertech Slurry-Carb	No					5			110				0	+	-	0	+	-	-	$96	$11,040	$4,255
	Alternative B: Polaris @ $55/wt Tip Fee	No					5				110			0	+	-	+	+	-	-	$72	$8,280	$1,495
Max Market Strength	Strongest customer demand + backup	Yes	85	25			5							+	+	+	+	+	+	+	$54	$6,210	($575)
Max Reliability	End-uses with proven reliability or storage	Yes	50	20	10	30	5							+	+	+	+	+	+	+	$61	$7,015	$230
Max Carbon Sequestration	Uses with highest carbon sequestration	No			35	30	5	35				5	5	+	+	+	0	+	+	0	$60	$6,900	$115
Westside max diversity	Mix of westside sites	No			30	30	5	40				5	5	+	+	+	0	+	+	0	$61	$7,015	$230
All Compost No Diversity	Single Composter - Eastside with Rail Haul	No							115					0	+	-	0	+	-	-	$60	$6,900	$115

Success Criteria	
+	Positive rating - Response met or exceeded criterion
-	Negative rating - Response did not meet criterion
0	Neutral - Not enough information to rate response

Implementation Feasibility	
+	Operable within 2 years
-	Requires > 2 years for siting, construction, permitting
0	Some elements of these scenrios may be operable within 2 years

Each program scenario assumes annual production of 115,000 wet tons.

Tons shown by project = x1000 wet tons. For example "65" = 65,000 wet tons.

OVERALL FINDINGS

The best biosolids management options are those that fit local conditions and circumstances, provide beneficial uses (including greenhouse gas reduction), and meet a range of success criteria such as risk, reliability, community support, and cost. An overall analysis of the options suggests that the current program, emphasizing land application, should be continued at this time. Washington state is fortunate to have a well-established regulatory program and an effective network of universities, municipalities, and communities that support and benefit from land-based uses of biosolids. The current program is reliable, minimizes risk, and provides compelling benefits in carbon reduction. Moreover, the current program appears to be less expensive than other options, and King County and its sewer utility ratepayers currently benefit from these lower cost programs.

The analysis suggests that other options, particularly drying and combustion, do not appear to meet the range of criteria as well as does the current program at this time. While these approaches provide beneficial uses, they appear to have more risks, be less reliable, have greater overall costs, and do not provide greater carbon benefits.

A major finding from the RFI is that technologies and practices are available to capture all the many benefits that biosolids can provide, including:

- An energy source and replacement for fossil fuels;
- A fertilizer and soil-builder for crops;
- A tool to restore disturbed or devastated sites; and
- A tool to reduce carbon dioxide and other greenhouse gases in the atmosphere.

Currently, the county's wastewater treatment and biosolids management processes take advantage of all four of these benefits when the entire program is considered. The division captures a significant amount of energy in the wastewater treatment process by producing biogas in anaerobic digesters at the treatment plants. Both West Point and South Plant treatment facilities employ waste-to-energy operations that use biogas to reduce energy needs. The county's biosolids program focuses on land application and composting that provide fertilizer and soil building benefits, as well as carbon reduction by storing (or sequestering) carbon in the soil.

There were several findings from this RFI that are likely to affect the biosolids program in the future. One finding is that the county has not fully developed local opportunities for reclaiming disturbed sites. While this use may not replace the full scope of the program, such uses can provide local benefits and should be explored further. Another finding was that there may be additional agricultural and composting options on the west side of the Cascades that may be cost-competitive. These options should be explored further as a way to improve program diversity and/or further reduce costs and risks.

Finally, the report yielded a substantial and increased interest in biosolids as a resource. The volume and variety of responses attested to the developing interest in maximizing the beneficial use of this product. This is consistent with local, state, and national interest in pursuing innovative, environmentally beneficial, and economic activities. It will be important for the county to continually evaluate its biosolids program to ensure its program maximizes the overall benefits to citizens and the environment.

The overall assessment yielded several findings:

- Beneficial use of biosolids provides multiple environmental benefits, even more benefits than were realized 10 years ago. A program of diverse uses will allow the county to extract the maximum value from this resource.
- Since WTD lacks significant storage for biosolids on the west side of the Cascades, reliability, year-round availability, and flexibility in deliveries are program priorities.
- Although biosolids can be marketed and sold as a commodity, they must be managed carefully to ensure community support. Vendors who have little experience in handling biosolids and representing them to the public can be considered higher risk for the county.
- The current biosolids program does not impose negative impacts on disadvantaged communities. In fact, the current eastern Washington agricultural projects have had a positive financial impact on local towns and families there.
- Energy and biofuel options are innovative technologies that may be ideal solutions for cities without land-based options. They are relatively expensive and require significant amounts of biosolids daily, making them potential regional options.
- Trucking emissions/***debits*** are very small (-0.15 metric tons of carbon per dry ton of biosolids) compared to ***credits*** from land application (+1.1 metric tons of carbon per dry ton of biosolids).
- Energy/biofuel alternatives have smaller carbon benefits than land-based alternatives.
- Tradable carbon credits (approved by Chicago Climate Exchange) are not a significant cost offset with current market prices.
- All land application-based scenarios were similar in total program cost per wet ton, of about $60 per wet ton for a total program cost. Energy/biofuel scenarios have higher overall program costs, because of higher processing fees associated with their use. Given the higher cost and need to keep sewer rates as stable as possible, these options are not desirable at this time. They also added an element of risk associated with the loss of program diversity and backup.

RECOMMENDED NEXT STEPS

As this report has indicated, there are a variety of options for managing biosolids to provide multiple environmental benefits. Biosolids have value as an energy source, as a fertilizer and soil builder, and as a tool to store carbon and reduce greenhouse gas emissions. The county has a program in place to capture all these values from biosolids at a reasonable and competitive cost, but there are opportunities to enhance the current program.

While this land-based program may be stable and economically attractive, many factors can affect the marketplace and doing strategic planning now can provide options for changing conditions as well as enable the county to take advantage of emerging opportunities. WTD will move ahead with strategic planning. This will involve consultation with internal and external stakeholders, further evaluation of markets and technologies, and development of strategies to meet future market conditions.

As a result of this analysis, the division suggests the following next steps:

- Design and conduct a thorough strategic plan for biosolids management to be completed within two years.

- Continue the existing program (with minor modifications, as described below) until strategic planning is completed. These additions to the program would be implemented while the strategic plan is being developed:
  - Establish a new composting contract for maximum 3,000 wet tons per month during winter season, if it results in lower costs to ratepayers. This would provide more program reliability during the winter months.
  - Plan and implement a reclamation pilot project and other research and demonstration projects. These projects will provide an opportunity to test carbon sequestration methodology, will support existing agreements for gravel mine reclamation, and will inform the strategic plan.

EXHIBIT A
Success Criteria for Biosolids Projects

King County uses a number of criteria to evaluate current and potential projects. Listed below are project characteristics that have proven to be indicative of long-term success for biosolids projects. These are drawn from the county's experience of the last 30 years of producing and providing biosolids to a variety of markets. This list was included in the 2008 Request for Information (RFI) to encourage respondents to demonstrate how well their proposed projects could meet the needs of the county as itemized in this list. The RFI review team considered these factors for each proposal, using information from the proposals, and from site visits and meetings with the respondents.

Reliability. The ability of a project site to receive biosolids consistently as scheduled by county staff and to operate dependably, with minimal downtime.

Year-round availability and access. Some projects have seasonal restrictions, such as sites or roads that will withstand traffic only from July through September. Projects that can accept biosolids throughout the year are especially valuable for managing daily production flow of biosolids from the county's plants.

Flexibility in tonnage accepted on a daily and seasonal basis. Projects that have "expandable" receiving capacity, in order to accommodate variability in production of biosolids. There are two primary types of variability in the county's daily biosolids operations: (1) the number of truckloads will vary at times as a result of process and equipment adjustments. For example, at South Plant in 2007, the annual average was six loads per day, but number of daily loads varied from zero to ten over the course of the year; (2) During the winter, mountain pass closures will result in all truckloads being rerouted to local Westside project sites. To manage this variability, the county's biosolids program works with multiple beneficial use sites and needs sites that are flexible in their ability to take varying daily amounts of biosolids.

Competitive cost. The cost of new recycling options for biosolids will be considered in the context of existing rates and the total suite of benefits derived from the new use.

Presence of a local sponsor/spokesperson. Projects that have local sponsors—residents and/or businesses who have credibility and respect in the local community are the most effective advocates for biosolids and the type of beneficial use occurring in, or proposed for, their community. Local spokespersons are essential for providing factual information about a project and improving public perceptions.

Community support and local agency support. Projects that provide visible benefits to many members of a community lead to broad community support of the project. Projects that have respected local sponsors, widespread benefits and community support/approval have a greater chance of long-term sustainability.

Storage capacity to manage peak deliveries. Projects that can provide on-site temporary storage. Storage provides benefits for both the biosolids generator and the user. For example, stored biosolids gives the user the ability to apply or use biosolids efficiently, without delivery delays or to maintain a consistent operation even on days when biosolids are not being delivered. For the generator, biosolids storage provides a delivery site that can accommodate peak periods—days when number of loads of biosolids being produced by the plant is higher than normal.

Additional program diversity (location, contractor, type of use). The county seeks to maximize program reliability and minimize risk by maintaining diversity in its program. A project that differs from the current program by county and by type of use may add diversity to the program. It may also reduce overall program diversity if it impacts existing markets significantly.

Demonstrable & multiple benefits. County policy does not support disposal options for biosolids; we are seeking projects that use the beneficial aspects of biosolids (such as energy value, nutrients, or organic material) and produce environmental benefits (that may include reduced greenhouse gas emissions, energy, improved soil fertility, increased water-holding capacity, higher crop yields decreased wind erosion, carbon storage in soil and crops).

Emphasis on quality control. The county and its biosolids contractors operate under an Environmental Management System (EMS) that provides quality control and encourages continual improvement. All projects need to have established standard operating procedures, accurate recordkeeping and when necessary, corrective actions to maintain high standards of operation.

Social justice/equity. The county strives to eliminate inequity and discrimination in all its programs. For biosolids management, this commonly means that any negative impacts of biosolids processing and management should not occur disproportionately in disadvantaged communities such as communities of color or low income.

Innovation. The county is interested in learning about new and creative beneficial uses that will provide markets and customers for biosolids into the future.

Low risk. The county seeks projects that have a proven record of safety, reliability, environmental protection and benefits, public acceptance and financial stability.

EXHIBIT B
Program Scenarios and Estimated Costs

This exhibit describes the cost analysis of responses to the Request for Information (RFI). As indicated in the report, the basic approach was to combine the proposals in various alternate program scenarios, and then to estimate how the Wastewater Treatment Division's (WTD) costs would change with each scenario compared to the current baseline program. It was necessary to do this because the RFI proposals differed substantially in terms of amount of tonnage they could manage or process. Moreover, several proposals, if implemented, would represent a significant change in overall program direction.

This analysis draws from technical descriptions of proposed technologies and project concepts as contained in RFI proposals. In some cases, additional information was obtained from post-proposal discussions with potential vendors. While the division's analysis primarily focused on estimating how its costs would change, the division did rely on estimates of application or service fees from potential vendors. It should be noted that information on fees submitted with RFI responses was often limited based on the absence of specifics regarding such factors as period of performance and available tonnage. In cases where proposers provided a range of fees, the midpoint was used.

The description of the division's baseline program's costs and revenues is first provided below. Following this, each alternative scenario is briefly described, along with assumptions about how they affected the division's costs and revenues.

Description of Baseline Program – Costs and Revenues

In order to understand the potential budget impact of the scenarios, it is necessary to examine operating costs, capital costs, and program revenues. It is important to understand all of these, as each alternative scenario could affect any of these components.

A. Operating Costs

Biosolids program operating costs include staff labor, supplies and support services, a biosolids hauling contract, and several application contracts. Major components of operating costs include:

Staff Labor

Seven full time staff are dedicated to various biosolids program activities: a supervisor, a lead planner, and five project managers.

Supplies and Services

Supplies consist of general office supplies and other project-related consumables. Biosolids services are costs associated with various projects. Examples are permit fees; county import fees; membership fees and research funds to the Northwest Biosolids Management Association and participating universities; road use fees to forestry landowners; rental for a truck maintenance facility and contributions to the King County Fleet Administration Revolving Fund for trucks and other equipment supporting the program.

Haul Contract

The biosolids haul contract consists of a fixed price contract with a single vendor who was selected on the basis of lowest cost. This vendor operates and maintains a fleet of King County-owned truck and trailer combinations under the direction of county staff. Contract payments consist of fixed costs (that do not vary with tonnage or miles traveled) and variable costs that do vary based on tonnage or mileage. Fixed costs consist of a monthly service fee, which covers management, a maintenance facility, and insurance premiums. Variable cost is paid on the basis of a mileage rate times tons hauled based on predetermined mileage to each of several hundred discrete application sites identified by biosolids staff.

Diesel Fuel

King County contracts with PetroCard to provide diesel fuel for the truck fleet at key card facilities located throughout the state. The basis of the WTD's cost for diesel is a fluctuating market cost plus a negotiated profit per gallon of fuel.

Application Costs

King County has four current biosolids application contractors:

- Boulder Park, Inc. (BPI) located in Douglas County, applies biosolids to dryland wheat fields. In addition to application of the biosolids, BPI staff maintain county-owned equipment used on the project. BPI has the lowest application rate of all the county's application contractors, but has a higher haul cost due to distances traveled.

- Ramco, Inc. is the application contractor for forestry projects in eastern King County and applies biosolids using county-owned equipment under the direction of WTD staff.

- Natural Selection Farms (NSF) is located in Sunnyside, Yakima County, and applies biosolids to a variety of crops and pastureland. NSF provides all its own equipment.

- GroCo is a composting contractor with a manufacturing facility in Kent and a wholesale/retail outlet in south Seattle. Scarcity of bulking materials in recent times has driven cost higher, and GroCo is currently used primarily during inclement weather when mountain pass closures may shut down agriculture and forestry projects.

B. Capital Costs

The Biosolids Management Program involves some capital projects. Site Development funds support forestry applications, and consist of contractor labor for application unit design, and trail construction and reconstruction. Forestry Equipment and Agriculture Equipment are other stand-alone capital projects. Capital costs vary from year to year, based on a planning schedule. For the purposes of this analysis, an average total cost by project covering the period 2004 – 2014 (past and projected) was used. This was divided by total 2008 tonnage to develop an estimated capital cost per ton of $4.58.

C. Program Revenues[3]

The division currently receives revenue from agriculture projects based on the fertilizer value of biosolids delivered. Formulae for calculation are specific to the contracts and calculated slightly differently for the two current agricultural operations, BPI and NSF. For the purposes of this analysis, the sum of fertilizer revenue from each contractor is divided by the total biosolids tonnage for 2008 to create an overall program revenue of $1.22 per wet ton.

Total Baseline Cost

The 2008 total operating cost of King County's biosolids program per the financial reports was $6,468,413. The division produced 115,926 wet tons of biosolids in 2008 (note that 300 tons temporarily stored at the City of Everett treatment plant in late December due to pass closures are excluded from calculations, as the cost for applying these tons will be incurred in 2009).

In sum,
Cost per wet ton = $55.80 (operating cost) + $4.58 (capital cost) – $1.22 (revenue) = **$59.16** per wet ton

Alternative Scenarios

This section describes alternative scenarios and the assumptions of how they affected division costs that were used in the analysis. The scenarios were named for easy reference with regard to the primary objective they might be designed to achieve. Each alternative, except the all compost-no diversity scenario, assumes 5,000 wet tons of backup or inclement weather capacity at the GroCo composting facility.

There were two alternatives that would maximize energy production from biosolids.

Maximum Energy Alternative A Scenario

This scenario consists of 110,926 wet tons delivered to EnerTech, who proposes a SlurryCarb™ drying facility, with sale of the E-fuel product to cement manufacturers. Assumes 5,000 tons to GroCo for backup capacity. EnerTech estimated a processing fee of between $65 and $90 per wet ton; this analysis assumed $80, near the midpoint. The scenario would affect the division's operating costs, capital costs, and program revenues. The cost analysis assumes the following changes to baseline:

Operating Costs:

- Staff Labor – Reduce staff labor to 3 FTEs. This alternative eliminates forestry and agriculture projects.
- Supplies and Services – Supplies are reduced on a pro rata basis with FTE reduction. Eliminate all services associated with forestry and agriculture. Reduce fleet equipment rental expense, assuming 50 percent reduction in hauling fleet.
- Haul Contract – Reduce insurance expense 50 percent based on fleet reduction. Assuming similar haul distance/rate as GroCo, reduce diesel fuel usage by 80 percent.

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[3] This analysis does not include a revenue estimate for any carbon or other marketable credits for any of the alternatives. The extent to which the division can capture revenues from carbon reduction or greenhouse gas benefits is unclear, though it is possible that this could be significant source of revenue in the future. Analysis of the carbon benefits of the alternatives is discussed elsewhere in this report.

- Application Costs – Assume $80 per wet ton processing fee, which is near the mid point of range identified by vendor.

Capital Costs – Eliminate all capital cost due to elimination of forestry and agriculture.

Revenue – Eliminate all revenue due to elimination of agriculture.

Overall Cost per wet ton = $95.55 (operating cost) + $0 (capital cost) - $0 revenue + .29 loss of sales tax exemption on polymer purchases = **$95.84** per wet ton

Maximum Energy Alternative B Scenario

This scenario consists of 110,926 wet tons delivered to Polaris, who proposes a drying/reclaimed energy facility, with sale of the biosolids-derived-fuel product to cement manufacturers and others. Assumes 5,000 tons to GroCo for backup capacity.

Operating Costs:

- Staff Labor – Reduce staff labor to three FTEs. This alternative eliminates forestry and agriculture projects.
- Supplies and Services – Supplies are reduced on a pro rata basis with FTE reduction. Eliminate all services associated with forestry and agriculture. Reduce fleet rental expense assuming 50 percent reduction in hauling fleet.
- Haul Contract – Reduce insurance expense 50 percent based on fleet reduction. Assuming similar haul distance/rate as GroCo, reduce diesel fuel usage by 80 percent.
- Application Costs – Based on discussion with vendor, assume $55 per wet ton processing fee.

Capital Costs – Eliminate all capital cost due to elimination of forestry and agriculture.

Revenue – Eliminate all revenue due to elimination of agriculture.

Overall cost per wet ton = $71.62 + 0 capital - 0 revenue + .29 loss of sales tax exemption on polymer purchases = **$71.91 per wet ton**

Note: This vendor indicated in its proposal that it can reduce current program cost by "10 percent, less cost of hauling". Based on a detailed analysis of how its costs would change under this scenario, WTD staff believes vendor may have misinterpreted data from the KC WTD website. Our analysis of division costs suggests the vendor would have to offer a processing fee of about $33.50 per wet ton to enable the division to reduce the costs of its biosolids program by 10 percent. WTD staff will follow up with the vendor.

Maximum Market Strength Scenario

This scenario would provide biosolids to the areas where market demand for the material is currently the greatest: agricultural operations in eastern Washington. This alternative eliminates the forestry projects, and distributes 85,926 wet tons to BPI, 25,000 wet tons to NSF, and 5,000 wet tons to GroCo. Application service fees for this scenario are those in the proposals, varying from $6-11 per wet ton. The following changes to baseline are assumed:

Operating Costs:

- Staff Labor – Reduce staff labor to six FTEs. This alternative eliminates forestry projects.
- Supplies and Services – Supplies are reduced on a pro rata basis with FTE reduction. Eliminate all services associated with forestry.
- Haul Contract – No change from baseline.
- Application Costs – Assume current contract application rates.

Capital Costs – Eliminate forestry related capital.

Revenue – Revenues from agriculture would increase and are calculated based on weighted average distribution.

Overall cost per wet ton = $54.97 (operating costs) + $.57 (capital costs) – $1.64 revenue = **$53.90** per wet ton

Maximum Reliability Scenario

This scenario maintains existing projects and adds Cascade Materials for agricultural application. It would add reliability because it would add another location for biosolids storage on the west side of the Cascades. Biosolids distribution in this scenario assumes 30,000 wet tons forestry, 50,926 to BPI, 20,000 to NSF, 5,000 to GroCo, and 10,000 to Cascade Materials. The following changes to baseline are assumed:

Operating Costs:

- Staff Labor – No change from baseline.
- Supplies and Services – No change from baseline.
- Haul Contract – No change from baseline. Assume Cascade Materials at same haul rate as forestry.
- Application Costs – Assume current contract application rates. Assume Cascade Materials at $14.40 based on vendor proposal.

Capital Costs – No change from baseline.

Revenue – Recalculated based on weighted average distribution.

Overall Cost per wet ton = $57.15 (operating) + $4.58 (capital) – $1.06 (revenue) = **$60.67** per wet ton

Maximum Carbon Sequestration Scenario

This scenario would result in the highest incorporation of carbon materials into the soil among the various alternatives. This scenario would eliminate agriculture applications, maintain forestry and GroCo, add composters Cascade Materials and Cedar Grove, add gravel pit restoration (Ramco Alt 1), and Sylvis land reclamation. Distribution assumes 30,926 wet tons to forestry, 5,000 to GroCo, 35,000 to Cascade Materials, 35,000 to Cedar Grove, 5,000 to Ramco Alt 1, and 5,000 to Sylvis. The following changes to baseline are assumed:

Operating Costs:

- Staff Labor – Reduce staff labor to 6 FTEs. This alternative eliminates agriculture projects.
- Supplies and Services – Reduce supplies based on FTE reduction. Eliminate agriculture-related services. Reduce fleet equipment rental due to eliminating agriculture hauls.
- Haul Contract – Assume Cascade Materials, Cedar Grove, Ramco Alt 1 and Sylvis at same haul rate as forestry. Reduce insurance and fuel costs for closer hauls.
- Application Costs – Assume current contract application rates. Assume: Cascade Materials at $14.40, Cedar Grove at $50.00, Ramco Alt 1 at $7.60, Sylvis at $7.60 per wet ton.

Capital Costs – Eliminate agriculture capital.

Revenue – Eliminate fertilizer revenues.

Overall Cost per wet ton = $55.70 (operating cost) + $4.02 (capital cost) – $0 (revenue) = **$59.72** per wet ton

Westside Maximum Diversity Scenario

This scenario would maximize the number of uses of biosolids in the west side of the Cascades. The alternative would eliminate agriculture projects, maintain forestry and GroCo, add composters Cascade Materials and Cedar Grove, adds gravel pit restoration (Ramco Alt 1), and Sylvis land reclamation. The tonnage distribution assumes 30,926 wet tons to forestry, 5,000 wet tons to GroCo, 40,000 to Cascade Materials, 30,000 to Cedar Grove, 5,000 to Ramco Alt 1, and 5,000 to Sylvis. The following changes to baseline are assumed:

Operating Costs:

- Staff Labor – Reduce staff labor to six FTEs. This alternative eliminates agricultural projects.
- Supplies and Services – Reduce supplies based on FTE reduction. Eliminate agriculture-related services.
- Haul Contract – No change from baseline. Assume Cascade Materials, Cedar Grove, Ramco Alt 1 and Sylvis at same haul rate as forestry. Reduce insurance and fuel costs for closer hauls.
- Application Costs – Assume current contract application rates. Assume Cascade Materials at $14.40, Cedar Grove at $50.00, Ramco Alt 1 at $7.60, Sylvis at $7.60.

Note: Cedar Grove high volume rate is higher than low volume rate due to construction requirements at higher levels.

Capital Costs – Eliminate agriculture capital.

Revenue – Eliminate fertilizer revenues.

Cost per wet ton = $57.24 (operating cost) + $4.02 (capital cost) – $0 (revenue) = **$61.26** per wet ton

All Compost – No Diversity Scenario

This scenario would devote all the division's tonnage to one composting facility, assumed to be on the west side of the Cascades. It corresponds to a proposal by Ekotek Bio-Technologies, Inc. The following changes to the baseline are assumed:

Operating Costs:

- Staff Labor – Reduce staff labor to three FTEs. This alternative eliminates forestry and agriculture projects.
- Supplies and Services – Supplies are reduced on a pro rata basis with FTE reduction. Eliminate all services associated with forestry and agriculture. Reduce fleet equipment rental expense assuming 50 percent reduction in hauling fleet.
- Haul Contract – Reduce insurance expense 50 percent based on fleet reduction. Assuming similar haul distance/rate as GroCo, reduce diesel fuel usage by 80 percent.
- Application Costs – Assume 100 percent biosolids production at $44.00 ($55 – 20 percent rebate) based on discussions with vendor.

Capital Costs – Eliminate all capital cost due to elimination of forestry and agriculture.

Revenue – Eliminate all revenue due to elimination of agriculture.

Overall cost per wet ton = $60.18 (operating cost) + $0 (capital cost) – $0 revenue = **$60.18** per wet ton

EXHIBIT C

Methodology for Carbon Accounting

By Sally Brown, University of Washington

The RFI evaluation team calculated the potential greenhouse gas (GHG) credits and debits for each proposal by using values in the peer reviewed literature, data collected from sites that had received King County biosolids applications, and default values from the Intergovernmental Panel on Climate Change (IPCC). In the RFI, King County asked questions specific to GHG credits and debits. Although two of the respondents said that their program would result in GHG credits, no quantifiable information was provided. Instead, the review team opted to use the same basis for evaluation for all of the proposals received. In our quantification of debits and credits associated with each proposal, all values are reported on the basis of one dry metric ton (1000 kg or 1 Mg) of biosolids (see Table C-1).

Credits

Fertilizer credits

Fertilizer credits were given for all end uses that included land application. For composting, we considered that the total nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) per dry Mg (metric ton or 1000 kg) of biosolids used as compost feedstock would remain constant during the composting process. It should be noted that there is potential for credits for the micronutrients in the biosolids. By discounting (not calculating) these potential credits, we have effectively used more conservative values for credits. We used kg CO_2 equivalents for replacement of N, P, K, and S from a previous study that developed a life cycle analysis for composting operations (Recycled Organics Unit, 2007). Average nutrient concentrations for South Plant and West Point were used to determine credits.

Soil carbon

Soil carbon (C) accumulation or accumulation credits were calculated based on data collected from sites with a history of biosolids applications. Changes in soil C (percent) were converted to Mg CO_2eq using a mass of 2000 Mg of soil per 0-15 cm. Data are shown for replicated field plots set up by Washington State University (WSU) and sampled in fall 2008. For compost-amended sites, data were from hops, cherry and grape fields in Sunnyside, Washington, that were sampled in the fall of 2008. For restoration, data collected from the Highland Valley Copper mine site in British Columbia were used. Biosolids from MetroVancouver were used to restore this site. These data were collected by University of Washington (UW) in the summer of 2008. Soil carbon research and results used in this analysis were funded by a grant from the Washington State Department of Ecology to WSU and UW.

Energy

Energy credits from combustion of biosolids would depend on the Btu (British thermal unit) content of the feedstocks as well as the energy required to dry the biosolids. As the biosolids from King County are anaerobically digested prior to combustion, a lower end value for the Btu content is likely to be appropriate, such as the 11,000 Btu per dry kg used by Metcalf and Eddy (2002) or the 7,500 Btu per dry kg digested biosolids used by Murray et al. (2008). We calculated a possible range of fuel displacement values, with the low end represented by Murray et al. values and the high end represented by values submitted by the proposers. Polaris suggested a value of 17,380 Btu per dry kg, which represents a test value from dried biosolids from the Chamber Creek Wastewater Treatment Plant in Pierce County. EnerTech stated that their E-fuel ranged from 14,300 Btu/dry kg to 17,600 Btu/dry kg. Neither proposer provided information on the number of samples or the standard variation in this value. We used 17,380 Btus in our calculations for the upper end of the range.

For the Polaris proposal, waste heat for drying was assumed, so no energy costs for removing water were considered. For the EnerTech proposal we used the energy required to evaporate 1 kg of water from Metcalf and Eddy (2002) and natural gas as the energy source. The EnerTech proposal did request access to the gas produced during digestion. As this gas is currently beneficially used, energy to dry the biosolids prior to combustion was factored into this estimate.

It should be noted that Murray et al. (2008) calculated a significantly lower net energy for combustion, which we used to calculate the low end of the range in this analysis. The authors of this paper are from the Civil Engineering department at the University of California at Berkeley and the results were based on values from the East Bay Municipal Utility District treatment facility and the Central Contra Costa biosolids combustion facility. Their study involved a life cycle analysis of different biosolids management practices. A range of options was considered in this study including combustion and use of ash for cement manufacture. Default values for energy credits were 0.147 Mg CO_2 where waste heat was included and 0 where a source of energy for drying was not identified. It should be noted that the IPCC advocates use of biosolids as an energy source when it displaces traditional fuels and when it would otherwise be landfilled or incinerated without energy capture.

Cement production

Here we used values from Murray et al. (2008) for displacement of traditional materials by biosolids ash for cement manufacture. This credit (0.0055 Mg CO_2) was given to both proposals that included use of ash for cement manufacture.

Debits

Transportation

All of the proposals require transport of biosolids from the treatment plant. For all proposals that had west side end uses, we used a default value of 60 miles round trip for a haul distance. It is possible that a closer processing site could be identified. However, prior difficulties in siting processing sites suggest that this may not be simple to accomplish. In addition, the GHG emissions associated with transport are minimal in comparison to other GHG impacts. Altering a haul distance to 40 miles round trip would have no impact on the final balance. For east side end use sites, a default value of 400 miles round trip was used. For each case, we considered a transport vehicle that could carry 30 wet tons of biosolids with a moisture content of 80 percent. Diesel mileage used for the calculations was 5 mpg. Emissions for west side sites were 0.018 Mg CO_2 per dry Mg biosolids. For east side sites, this increased to 0.12 Mg CO_2 per dry Mg biosolids.

Application

Fuel required for land application was provided by some of the respondents. From this information, we calculated the GHG emissions for application of materials. These ranged from 0.0032 to 0.015 Mg CO_2 per dry Mg biosolids.

Methane emissions

No debits were taken for methane (CH_4) emissions for any end use options. The likelihood of CH_4 emissions from land application sites is minimal as all end uses are to aerobic soils. Some studies have reported detectible CH_4 emissions during composting (Brown et al., 2008). However, these are generally associated with high moisture compost piles where odors are also a problem. A recently developed Chicago Climate Exchange protocol does not give any debits for fugitive GHG emissions during composting. In addition, the U.S. Environmental Protection Agency does not consider fugitive GHG emissions during composting and the Recycled Organics Unit (2008) did not consider GHG emissions during windrow composting.

Nitrous Oxide emissions

There is a great deal of uncertainty regarding nitrous oxide (N_2O) emissions from agricultural soils. The IPCC uses a default value of 1 percent of total N applied as synthetic fertilizer converted to N_2O. The same value is used for biosolids and composts whereas manure slurries have default emissions set at 2 percent total N. The IPCC also recommend use of organic sources of fertilizer including biosolids and manures. Specific reductions in N_2O emissions from use of organic fertilizers are not provided. The scientific literature shows higher N_2O emissions from poorly drained soils under wetter conditions. High rates of fertilizer addition, both as synthetic N as well as organic N, result in greater emissions than lower rates of fertilizer addition. Because of the uncertainties associated with agricultural N_2O emissions, we decided that emissions from biosolids-amended soils would be similar to synthetic fertilizer. We assumed that no net change in N_2O emissions would result from using biosolids in lieu of synthetic fertilizer so no debits or credits were taken for this substitution.

There is also uncertainty regarding N_2O emissions from biosolids combustion. Literature suggests that higher burn temperatures reduce N_2O emissions. The IPCC provides default values for N_2O emissions from combustion of biosolids. The factors provided are 900 g of N_2O per wet Mg and 990 g N_2O per dry Mg. This would give a range in N_2O associated emissions factors from biosolids combustion from 0.24 – 1.18 Mg CO_2 per dry Mg biosolids. A research paper (Suzuki et al., 2003) measured N2O from fluidized bed combustion facilities in Japan and found emissions ranging from 0.44 to 1.9 Mg CO2 equivalent per dry ton of biosolids combusted.

The IPCC emissions from coal (lignite) combustion include 1.5 (range of 0.5-5) kg CO_2 per TJ (terra joule of energy combusted) for N_2O-related emissions, 1 (range of 0.3 to 3) for CH4 related emissions, and 101,000 (range of 90,900 to 115,000) kg for CO_2 related emissions. The heat content of lignite coal ranges from 9 to 17 million Btu per ton on a moist, mineral free matter basis. A terra joule is 1,000,000,000,000 therms and a therm is 100,000 Btus. This suggests that the N_2O-related emissions for coal combustion are minimal.

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Table C-1. Results of carbon accounting for RFI proposals

			Carbon Credits Per Dry-Ton				Carbon Debits Per Dry-Ton					
			Replacement Of Synthetic Fertilizer	Accumulation Of Carbon In Soil	Displacement Of Fossil Fuels	Displace Material In Cement Manufacture	Energy Required to Dry	Diesel Burned to Transport Biosolids to End-Use Site		Diesel Burned For Application Of Biosolids	Emission Of Nitrous Oxide	Credit Per Dry-Ton
Vendor	Technology	Basis for Values	Metric tons (Mt) CO2	Mt CO2	Mt CO2	Mt CO2		Distance (miles)	Emissions Mt CO2	Emissions Mt CO2	Emissions Mt CO2	Metric tons (Mt) CO2
Boulder Park	Agriculture - Dryland grain crops, reduced till	UW/WSU data from KC field site	0.29	2.00	0.00	0.0		400	(0.120)	(0.015)	0.000	2.16
GroCo	Compost - Aerated static pile	UW/WSU data from KC field site	0.29	0.78	0.00	0.0		60	(0.018)	0.000	0.000	1.05
Natural Selection Farms	Agriculture - Agronomic crops, hops, and rangeland	UW/WSU data from KC field site	0.29	2.00	0.00	0.0		400	(0.120)	(0.015)	0.000	2.16
Ramco	Forest application	UW/WSU data from KC field site	0.32	2.00	0.00	0.0		60	(0.018)	(0.015)	0.000	2.29
Cascade Materials	Agriculture, Compost	UW/WSU data from KC field site	0.29	2.00	0.00	0.0		60	(0.018)	(0.015)	0.000	2.26
Cedar Grove	Compost - Windrows with Gore cover for heat and odor containment	UW/WSU data from KC field site	0.29	0.78	0.00	0.0		60	(0.018)	0.000	0.000	1.05
Ekotek	Regional organics composting, including rail transport of biosolids	UW/WSU data from KC field site	0.29	0.78	0.00	0.0		400	(0.120)	0.000	0.000	0.95
EnerTech	Renewable Biofuel - SlurryCarb process to co-combustion with coal	Murray et al 2008, Metcalf & Eddy, Suzuki et al 2003, Werther & Ogada 1999	0.00	0.00	0.6239 - 1.4457	0.0055	(0.65)	60	(0.018)	0.000	(0.293)	(0.33) - 0.49
Polaris	Renewable Biofuel - Waste heat biosolids drying to co-combustion with coal	Murray et al 2008, Metcalf & Eddy, Suzuki et al 2003, Werther & Ogada 1999	0.00	0.00	0.6239 - 1.4457	0.0055	0.00	60	(0.018)	0.000	(0.293)	0.32 - 1.14
Ramco	Gravel Pit Restoration/Reclamation	UW data from MetroVancouver field site	0.29	1.00	0.00	0.0		60	(0.018)	(0.003)	0.000	1.27
Sylvis	Land Reclamation - Landfill cover and mine reclamation	UW data from MetroVancouver field site	0.29	1.00	0.00	0.0		60	(0.018)	(0.003)	0.000	1.27

☐ = Existing Contractor

The values for Polaris and EnerTech are not based on actual data from their facilities; such data were not available. Estimates for the energy options were made using values supplied by the proposers and from published sources.

Notes for EnerTech:

- Assumes drying 25% solids to 100% solids, using Metcalf & Eddy values for energy required to dry (4,750 Btus/kg) and using natural gas, which has 55% emissions equivalent to coal.
- Proposer supplied a range for heat value of their E-fuel of 14,300 to 17,600 Btu per dry kg, which represents the high end of the range. 100% combustion efficiency was also assumed for the high end of the range. Murray et al. found 7,500 Btu per dry kg and efficiency of 75% and Metcalf and Eddy found 11,000 Btu per dry kg. Murray et al. was used for the low end of the range.
- For nitrous oxide emissions, published values range from 0.44-1.89 Mg CO_2 per dry metric ton (Mg) biosolids; based on the absence of data from proposers and the high values in the published literature, the IPCC default of 0.9kg N_2O per dry Mg biosolids was used.

Notes for Polaris:

- Assumes drying to 100% solids with waste gas; however, Werther and Ogada report difficulties in drying at 40-60% due to "sticky phase." Murray et al. assumes drying to 43% solids prior to combustion using waste gas.
- Assumes drying 25% solids to 100% solids, using waste heat.
- Proposer supplied data for heat value of 17,380 Btu per dry kg based upon testing of dried biosolids from Chambers Creek Treatment Plant (Pierce County), which represents the high end of the range. 100% combustion efficiency was also assumed for the high end of the range. Murray et al. found 7,500 Btu per dry kg and combustion efficiency of 75% and Metcalf and Eddy found 11,000 Btu per dry kg. Murray et al. was used for the low end of the range.
- For nitrous oxide emissions, published values range from 0.44-1.89 Mg CO_2 per dry metric ton (Mg) biosolids; based on the absence of data from proposers and the high values in the published literature, the IPCC default of 0.9kg N_2O per dry Mg biosolids was used.

EXHIBIT D
Background Information on Carbon Accounting

College of Forest Resources
UNIVERSITY *of* WASHINGTON

Climate Change, Carbon Accounting and Biosolids – An Overview

Background information for King County's Request for Information (RFI)
for Biosolids Management Services

Sally Brown, Research Associate Professor
February 2009

About the author:
Sally Brown is a research associate professor at the University of Washington College of Forest Resources. She has an MS and PhD in soil science/agronomy from the University of Maryland. Dr. Brown was one of the first scientists to assess the greenhouse gas implications for biosolids management, with a series of articles in *Biocycle* magazine in 2005. She has also published on greenhouse gas balances for composting operations in the Journal of Environmental Quality (2008).

She is involved in a number of climate-related efforts throughout the country:

- Leads the organics subcommittee of the Washington Climate Action Team
- Member of the US National Academy of Science Standing Committee on Soil Science;
- Member of the Chicago Climate Exchange subcommittee for development of methane avoidance for landfill diversion of organics/composting including food waste, biosolids, and yard waste
- Working with the Metropolitan Wastewater District of Greater Chicago on carbon accounting for their biosolids program;
- Preparing a Life Cycle Analysis of organic residuals for the Integrated Waste Management Board in California;
- Writes a monthly column for Biocycle Magazine on greenhouse implications of different organic waste management practices.
- Developing a modeling tool for Canadian Council of Ministers for the Environment that will predict GHG emissions from a range of biosolids treatment and end use options.

In 2008, Dr. Brown won a first-place National Clean Water Recognition Award from the U.S. EPA for exemplary research and innovation in the field of biosolids management.

Climate Change, Carbon Accounting and Biosolids – An Overview

Background information for King County's Request for Information (RFI) for Biosolids Management Services

Sally Brown, Ph.D.
Research Associate Professor
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In 2008, the Wastewater Treatment Division of King County, Washington, issued a *Request for Information* for new market opportunities for recycling its biosolids. All the responses received were evaluated for a variety of criteria that the county considered important for successful biosolids projects. One of the evaluation criteria was the greenhouse gas (GHG) balance for each proposed end use option. In determining the GHG impact of each proposal, the evaluation group (including this author) considered both potential emissions as well as the potential for carbon credits from carbon sequestration or GHG avoidance. To help readers understand the calculations and assumptions that the group made in the proposal review process, this document will describe the basic principles of carbon accounting. The basic concepts of emissions and sequestration will be discussed. Different biosolids management options will be evaluated in terms of these basic processes. The extent of existing knowledge and associated levels of uncertainty will also be presented.

Causes of climate change

Climate change is occurring because the concentration of gases that can trap heat from the sun in the atmosphere is increasing. The majority of gases in the atmosphere—nitrogen and oxygen--are structurally symmetrical and so cannot absorb energy from the sun. Nitrogen gas makes up about 77% of the atmosphere with O_2 gas comprising approximately 18% of the atmosphere.

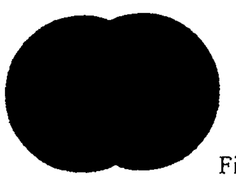


Figure 1. Representation of a nitrogen gas molecule illustrating its two nitrogen atoms and structural symmetry. Source: http://www.globalwarmingart.com/wiki/Gallery_of_Greenhouse_Gas_Molecules)

However, other types of gases can absorb the energy radiating off the surface of the earth. These gases hold onto the energy and only gradually release it, re-radiating it back in all directions. As a result of this, the energy does not leave the earth's atmosphere. A large portion of the heat energy remains in the lower region of the atmosphere, making it warmer. In addition, less heat reaches the upper portion of the atmosphere, leaving it cooler. These gases are responsible for changes in how the earth's climate is regulated and are referred to as greenhouse gases. These gases are increasing in concentration in the atmosphere primarily as a result of anthropogenic (human) activities Carbon dioxide (CO_2) is the benchmark greenhouse gas (GHG). Its ability to trap heat is used as the basis for comparison for all other GHGs. Regulations and studies on climate change use CO_2 as the basis for comparison and standardized unit for all other GHGs.

Figure 2. Left to right: Nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4) molecules, the three most significant greenhouse gases. Source: http://www.globalwarmingart.com/wiki/Gallery_of_Greenhouse_Gas_Molecules)

Some gases are more efficient at absorption than others. These pose more of a threat to global warming than CO_2. For example one molecule of methane (CH_4) is 23 times (23x) more effective at absorbing heat over a 100-year time frame and therefore 23x more of a concern than the equivalent weight of CO_2. Table 1 shows a list of gases pertinent to biosolids management, their pre and post-industrial atmospheric concentrations, persistence time in the atmosphere, and their CO_2 equivalence.

	Carbon Dioxide	**Methane**	**Nitrous Oxide**
	CO_2	**CH_4**	**N_2O**
Atmospheric concentration	ppm	ppb	ppb
Pre Industrial	280	700	270
Current	370	1745	314
Atmospheric lifetime (years)	5-200	12	114
CO_2 equivalent (per 100 year time frame)	1	23	296

Table 1. Relative Significance of Greenhouse Gases

As the table above illustrates, carbon dioxide, methane and nitrous oxide were all present in the atmosphere prior to the industrial age. Their presence is not responsible for the greenhouse gas effect. It is only their increasing concentrations that are disrupting our normal climate patterns. It is also clear from the table that methane is a very potent GHG. Its lifetime in the atmosphere is 12 years, yet over a 100 year span it is 23x more potent a GHG than CO_2. Reductions in CH_4 emissions over a short time frame can have a dramatic effect on climate change. It is also clear that N_2O is a potent GHG with 296x the global warming potential of CO_2. Very small quantities of N_2O can have a large impact on global warming.

Short and long-term carbon cycles

Long-term carbon includes carbon that is stored in the soil as organic matter, in forests, and underground as coal or fossil fuels. Until the 1970s, the largest source of carbon release to the atmosphere was from soils. Increased tillage and deforestation resulted in release of fixed carbon to the atmosphere as CO_2. This type of release is taken into account when greenhouse gas balances are tabulated.

Every year plants absorb carbon from the atmosphere and convert it into organic matter. This organic matter is what supports life on earth. The fixation and decomposition of this organic matter forms the basis for what is called the short-term carbon cycle.

Figure 3. A Seattle garden fertilized with biosolids. Both the plants growing in the garden and the biosolids used to fertilize the garden are part of the short-term carbon cycle.

Biosolids, as they are made up of newly fixed carbon, are part of the short-term carbon cycle. This cycle of carbon fixation and rapid decomposition is not considered as part of the carbon accounting process. This is an important concept that affects the carbon calculations for all biosolids management options. This cycle can also be seen from the perspective of atmospheric nitrogen. Nitrogen gas is converted into organic nitrogen by soil and aquatic organisms and lightning. It is used by plants and animals as part of their growth cycle. As these die and decompose, the N is converted back to mineral forms. Denitrification is the process by which mineral nitrogen is returned to the atmosphere as N_2 gas. If denitrification results in the production of N_2O (nitrous oxide) rather than N_2, this short-term cycle process results in a GHG debit. It is only when there are disruptions in this cycle that biosolids or other short- term carbon can impact the carbon cycle.

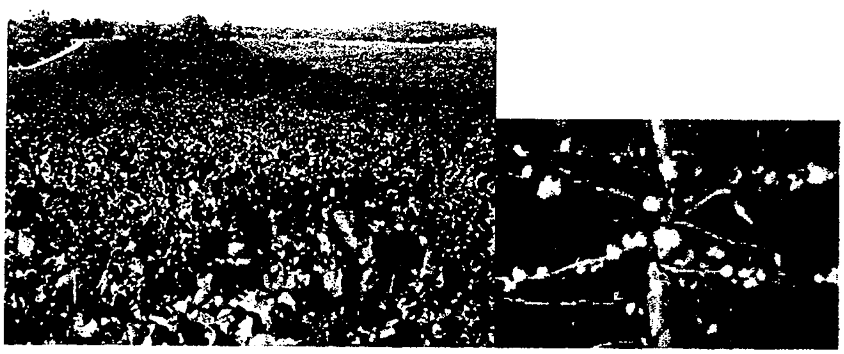


Figure 4. Crimson clover (pictured on left) is a legume; legumes form symbiotic relationships with soil bacteria called rhizobia. The rhizobia inoculate the roots of legumes and form nodules (picture on right). They supply plants with usable nitrogen that they "fix" or convert from atmospheric nitrogen. In return, the plants supply the microbes with carbohydrates, proteins and oxygen. Historically, the primary sources of nitrogen for agriculture were manures and this fixation.

As part of the short-term carbon cycle, the decomposition of the organic matter in biosolids and subsequent production of CO_2 does not alter the global carbon cycle. Biosolids management can, however, impact the carbon cycle when the decomposition of biosolids results in the release of gases other than CO_2. For example, if the nitrogen in the biosolids is released to the atmosphere as N_2O rather than N_2, this decomposition process will count as a greenhouse gas debit. A positive example of how biosolids can impact the carbon cycle is when biosolids are used to supply the N needs of a crop as a replacement for synthetic fertilizer. The production of synthetic fertilizers is a highly energy intensive process. When organic sources of fertilizer are used as a substitute, there is a potential GHG credit for the averted emissions associated with fertilizer production.

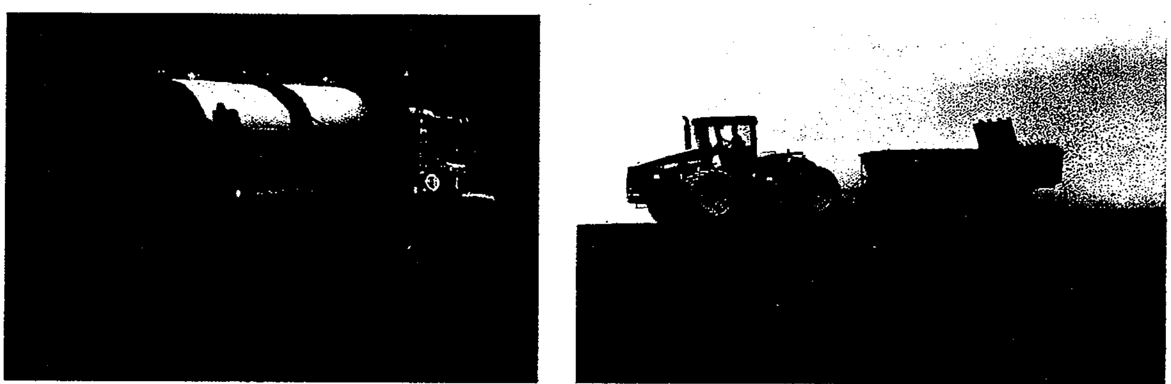


Figure 5. An application vehicle applying liquid biosolids to farmland (left) and a tractor-spreader combination applying dewatered biosolids (right).

Regulatory framework

As scientists have realized the potential impact of increased atmospheric concentrations of GHGs, efforts have begun to limit and reduce emissions of these gases. These efforts are occurring on international, national, and local levels. The primary international organization working to understand the ramifications of climate change and quantify the practices responsible for it is the Intergovernmental Panel on Climate Change (IPCC, http://www.ipcc.ch/). The IPCC was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environmental Program (UNEP) to provide decision-makers in all nations with an objective source of information about climate change. Members of the IPCC include scientists and engineers from around the world including members from the United States. The IPCC has authored a number of documents on climate change in which the impact of different practices on carbon emissions are quantified. These are the primary tools used by nations to quantify their GHG emissions and to develop GHG inventories.

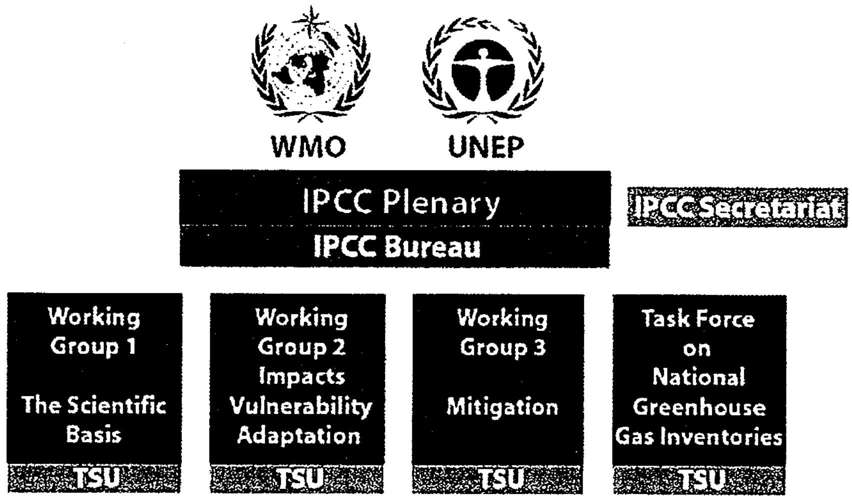
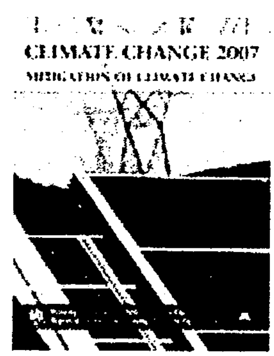


Figure 6. Organization of the IPCC into working groups and task forces.

The IPCC provides basic guidance on carbon emissions as well as carbon sequestration associated with different practices. These guidance documents are meant for use by all nations. The IPCC *2006 Guidelines* lay out the boundaries for any GHG inventory, such as the definition of what constitutes "anthropogenic" (human-caused) GHGs and must be included in the scope of an inventory. IPCC has divided activities with GHG impacts into separate sectors of the economy for accounting purposes. These sectors are :

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste
- Other (e.g., indirect emissions from nitrogen deposition from non-agriculture sources)

Each sector includes individual categories (e.g., transport) and sub-categories (e.g., cars) (IPCC, 2006). The sections of these guidelines that pertain to biosolids include assessment reports on Agriculture and Waste (Doorn et al., 2006; Sabin et al., 2006; Smith et al., 2007).



In 2007, Working Group III released "Mitigation of Climate Change," which provided an in-depth analysis of the costs, policies, and technologies that could be used to limit or prevent emissions of greenhouse gases. The authors advocated a portfolio of actions, both adaptation and mitigation, to combat climate change. They recognized biosolids as a potential tool for reducing GHG emissions and increasing soil carbon storage in croplands, pasture lands and in restoring degraded lands. Composting and anaerobic digestion were recognized as processes that could reduce GHG emissions and provide useful products. Thermal processes (incineration, co-combustion, and waste-to-energy) using biosolids as a fossil fuel replacement were noted as costly, but providing GHG reduction compared to landfilling.

Carbon accounting is mandatory for nations that have signed onto the Kyoto Protocol. Industrialized countries that have signed on as participants in the Kyoto agreements are required to reduce their collective CO_2 emissions to below 1990 levels by the end of the first commitment period (2008-2012). Although there are a number of regulatory structures for carbon accounting, the IPCC is the primary international organization that is recognized for setting standards on accounting methods. A goal of the IPCC (2006) has been to develop an international standard through a consensus process. While other organizations have developed other standards, a few of the standards are becoming recognized as "gold standards" for GHG emission accounting, and these share approaches, assumptions, and protocols. Examples of organizations that have frameworks for carbon accounting include the Greenhouse Gas Protocol, ISO, the California Climate Action Registry (CCAR), the Climate Registry (TCR), and the Chicago Climate Exchange. King County is a registered member of the Chicago Climate Exchange.

The IPCC *Guidelines* provide methods for estimating GHG emissions: "the most common approach is to combine information on the extent to which a human activity takes place (called *activity data* or *AD*) with coefficients which quantify the emissions or removals per unit activity. These are called *emission factors (EF)*. The basic equation is therefore: *Emissions = AD • EF"* (IPCC, 2006). This basic equation is adequate for establishing a baseline or "snapshot" of GHG emissions for a nation, company, agency or a biosolids program.

Another component of GHG emissions involves determining which emissions are the direct consequence of a particular activity, which are indirect, and which are sufficiently indirect to a particular activity to be excluded from that inventory and included in a separate inventory. These are divided by the IPCC into Scope 1 (direct), Scope 2 (indirect), and Scope 3 (indirect and part of a separate inventory) emissions. For wastewater treatment, Scope 1 emissions would include CH_4 or N_2O released during secondary treatment. Scope 2 emissions would include the power used to provide aeration for secondary treatment. Scope 3 emissions would include energy use for polymer manufacture.

The emissions or carbon credits associated with a particular practice are based on the level of knowledge both about the practice in general and the specific characteristics of the local environment. For example, there are general default values provided for N_2O emissions from soils related to use of fertilizers. These can be used for all climates and soils around the world. These are the Tier 1 values. Tier 1 is meant for use by all nations. The default values for greenhouse gas debits and credits in the Tier 1 guidelines are the most conservative. Tier II and III values are increasingly based on national or local data. An example of Tier III values would be specific emissions factors for land application of biosolids at agronomic rates for particular types of soils in Washington State where N_2O emissions rates have been documented in scientific studies. The IPCC encourages use of Tier II or III values as these are likely to provide more precise values for debits and credits.

Carbon credits

Projects that sequester carbon require protocols (sets of rules) to quantify sequestration or emissions reductions. The most extensive number of projects to reduce emissions and sequester carbon has been assembled by the Clean Development Mechanism (CDM, http://cdm.unfccc.int/index.html). Like the IPCC, the CDM was instigated by the Kyoto Protocol. The stated goal of the CDM was to develop projects for certified emission reductions (CER) or sequestration in developing countries. These 'offsets' can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol. The basic unit for trading on carbon markets is a metric ton (1000 kg) of CO_2. The CDM has developed a number of protocols that are currently being used to generate carbon credits. These credits are being traded on carbon markets. Since 2006, more than 1000 projects have been registered and 2.7 billion tons of CO_{2eq} are expected to be produced for the first commitment period of the Kyoto Protocol.

In the US, carbon credits are being traded at the Chicago Climate Exchange (CCX) (www.chicagoclimatex.com). The CCX has both public and private members (King County is one of only 3 US county members). Members are legally obligated to meet set emissions reductions within a specified time frame. As part of this process, the CCX also recognizes carbon offset projects and develops protocols for additional projects. It is also a place where nations that have signed on to Kyoto can invest in programs or businesses that accrue carbon credits.

The Chicago Climate Exchange currently recognizes all CDM protocols for carbon offset projects. In addition to CDM protocols, it is possible to develop protocols for carbon offsets on the CCX. Protocols are developed by committees. Committee members generally include a mixture of academics, industry and government. The committee for a particular protocol will develop a draft that is then presented to the offset committee for changes or approval. Once a protocol is approved, it can be used for different projects that will generate carbon credits that are then sold on the exchange. For the credits to be valid, they must comply with the rules in the protocol. Independent auditors are used to verify the validity of the projects.

As the market for carbon offset projects is very young, there are currently a limited number of protocols. The protocols that have the potential to generate a large number of credits at a relatively low cost per credit are the most likely to be developed. Over time as the market becomes more mature it is likely that a wider range of protocols will be approved with increasing levels of sophistication. The development of protocols is also driven in part by the trading value of CO_2. At low prices per Mg of CO_2, more sophisticated protocols won't make financial sense. So for example, there is a current protocol for covering animal manure storage lagoons to prevent release of methane into the atmosphere. However, there is no existing protocol for deep well injection of super critical CO_2.

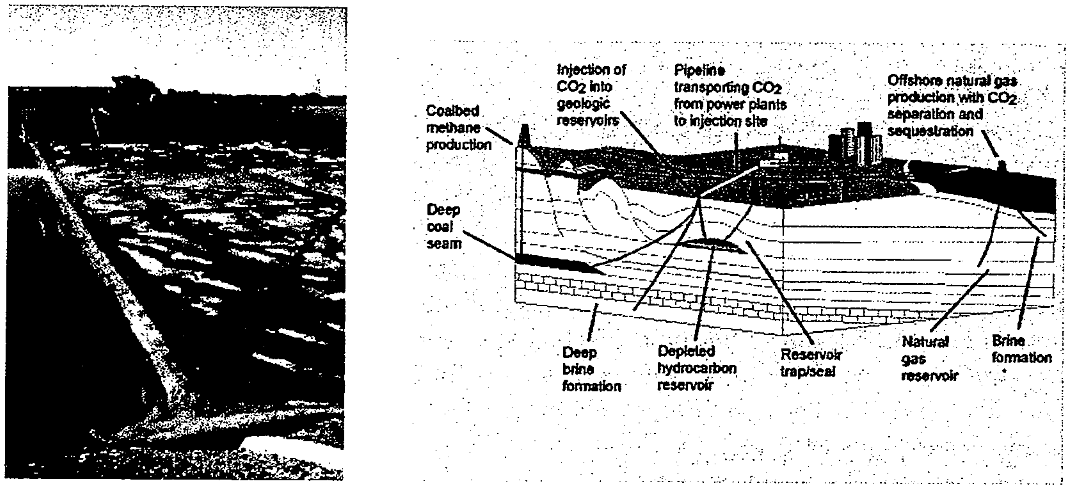


Figure 7. A manure lagoon cover (left) and a schematic of deep well CO_2 injection (right). The lagoon cover is a much simpler means to produce carbon credits and already has an accepted protocol for quantifying its emission reduction benefits.

Carbon credits for diverting putrescible organics to compost facilities and away from landfills is one example of a protocol that has been adopted by the CDM and provisionally adopted by the CCX. The protocol gives carbon credits for yard waste, biosolids and food scraps in cases where these materials have traditionally been landfilled. Aerobic decomposition of these materials eliminates methane release. The basis for the credits is the methane avoided as a result of composting these organics instead of landfilling them.

The CDM protocol includes an equation for calculating the quantity of methane avoided. It has been adopted for the CCX protocol. Basically, the quantity of methane avoided depends on the degradable organic carbon in the material, the time the material would reside in the landfill, and the rate of decay of the waste. The total methane produced is then multiplied by an uncertainty factor as well as a factor to correct for the % of methane that would be oxidized by the cover material in the landfill. For the CDM protocol, different decay rates are given for different climates and the time frame for credits is not restricted. For the CCX version of the protocol, single decay rates are used as the vast majority of landfills in the US are sanitary landfills. In these landfills, the heat produced by the decomposition of the waste sets the climate of the landfill independently of the ambient temperature. In addition, in the CCX version of the protocol, the time frame for collecting credits is limited to the period before a gas collection system is in place and operating for the cell where the waste would have been deposited.

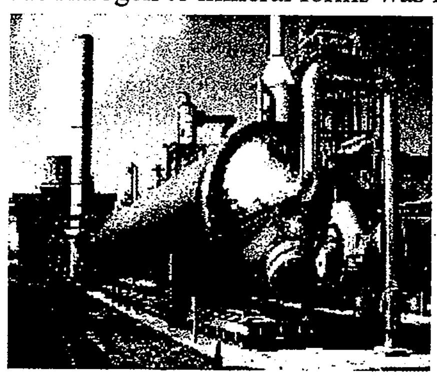
For a compost facility to qualify for credits using this protocol, the facility must meet US EPA time and temperature requirements for biosolids to kill pathogens. This is a way to assure aerobic decomposition that will limit the release of fugitive gases during composting. Most importantly, the material that is composted must have been landfilled prior to the compost operation. In order for the practice to be considered new and innovative, the switch from landfilling to composting must have occurred after the year 2000. This may seem counter intuitive if an agency is doing something beneficial for the GHG balance and has been doing so for an extended period. However, the goal of the Kyoto protocol is to reduce CO_2 emissions to pre-1990 levels. In other words, even if a practice is environmentally sound, if it was part of the balance sheet of carbon emissions from 10 years ago, it will not count towards reducing emissions.

Values used in the RFI evaluation

I. GHG Credits from biosolids

Nutrients

Biosolids are generally applied to soil to meet the nutrient needs of a crop. Nitrogen demand is the factor that determines application rate. Biosolids also contain phosphorus in high concentrations, potassium in small amounts and the full range of required plant macro and micronutrients including Mn, Mg, Ca, Fe, Zn, Cu, Ni, B, Mo, and S (manganese, magnesium, calcium, iron, zinc, copper, nickel, boron, molybdenum and sulfur). Farmers have traditionally used synthetic fertilizers in lieu of organic fertilizers such as biosolids, composts and manures. Production of synthetic fertilizers is highly energy intensive. For example, in order to produce nitrogen fertilizer, nitrogen gas is converted to mineral nitrogen. This is a reduction reaction, which means that electrons are added to the N_2 gas to form NH_3. Any reaction that involves reduction is energy intensive. The ability to convert gaseous nitrogen to mineral forms was first developed by German scientists in World War I as a way to make explosives. The Haber-Bosch process is still used today to manufacture N fertilizers. In order to add electrons to the gas, large quantities of energy are required.



Using an organic source of nitrogen like biosolids means that the energy that would have been spent to manufacture synthetic nitrogen fertilizers will be conserved. As this energy is almost exclusively from long-term carbon cycle sources, using the biosolids results in a credit in carbon accounting. At this point there is an approved CDM protocol for use of legumes to supply nitrogen in place of synthetic fertilizers. It is likely that a protocol for credits related to use of organic sources of nitrogen will also be developed.

In addition to the energy required to synthesize N, energy is also required to manufacture the other fertilizers. There are published values for the energy required to produce P and K. It is more difficult to find values for production of the different micronutrient fertilizers. Of all of the necessary plant nutrients, biosolids will have the highest concentration of N and P. By considering the total N and P as plant available, it is likely that the differences in nutrient availability will compensate for the exclusion of values for energy required to produce micronutrient fertilizers. As our understanding of the GHG impact of different processes becomes more sophisticated, it is likely that we will be able to better quantify the nutrient value of biosolids.

Soil carbon
Biosolids contain high concentration of carbon. Carbon is the basis for soil organic matter. High intensity agriculture along with conventional tillage and use of synthetic fertilizers have degraded soils and resulted in a loss of soil organic matter (Lal, 2007). By using biosolids to supply nutrients for a crop, one is also adding organic matter back to the soil. It has been suggested that not only will this result in increased soil organic matter concentrations, it will also improve soil tilth and soil health (Recycled Organics Unit, 2006; Spargo et al., 2008; Tien et al., 2009; Wallace et al., 2009).

An important aspect of carbon sequestration is the length of time that sequestered carbon will remain in organic forms in the soil. For example, the proponents of the production of biochar (charcoal from a range of carbon-based residuals) argue that char is sufficiently inert that it will remain in the soil for hundreds of years. On the other hand, the organic matter added to soils with biosolids is much more reactive. This reactivity implies several things. It suggests that the carbon will be potentially available for microbial decomposition. It also suggests that the carbon will be more reactive in soils resulting in significant changes in soil properties. Long-term studies have shown that application of biosolids to agricultural soils increases soil carbon concentrations for decades following biosolids application. This suggests that the addition of active organic matter to the soils is potentially altering the baseline carbon concentrations in soils to higher levels. The values for increased soil carbon as a result of biosolids application that have been used to evaluate the different proposals for the RFI are based on soil samples collected from a range of biosolids and compost application sites. This soil sampling effort is being funded by King County and the Washington State Department of Ecology and is being conducted jointly by researchers from the University of Washington and Washington State University. This type of data would fall under the Tier III IPCC guidelines.

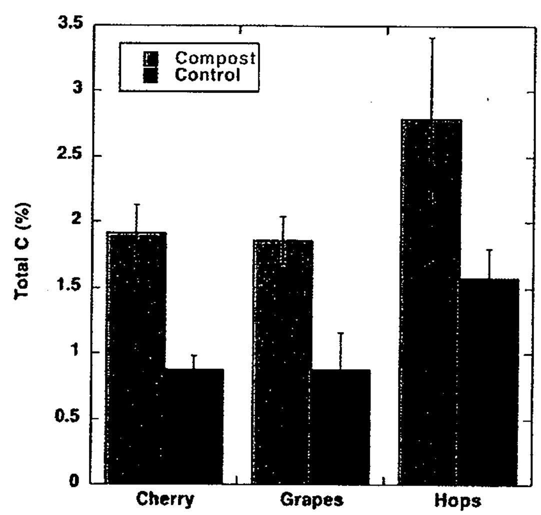


Figure 8. Soil sampling in a biosolids compost-amended hop field in Sunnyside, WA. Initial results showing soil carbon is higher in compost-amended soils than in control (non-amended) soils at this site.

Restoration

Biosolids can also be used as part of a soil amendment for restoration. For disturbed sites such as hard rock mining sites or sand and gravel pits, the organic matter in the surface soil horizon has been removed during mining operations. Without a healthy surface soil, vegetation on these sites is sparse. When organic amendments like biosolids are used to restore these sites, there are rapid increases in both soil and above-ground carbon stocks. High rates of organic mixtures (generally biosolids mixed with a high carbon material like woody debris) are required to restart plant growth and soil formation. There is not enough data to precisely quantify the rate of carbon accumulation on these sites, but it is highly likely that carbon accumulation will be greater than on conventional agricultural sites.

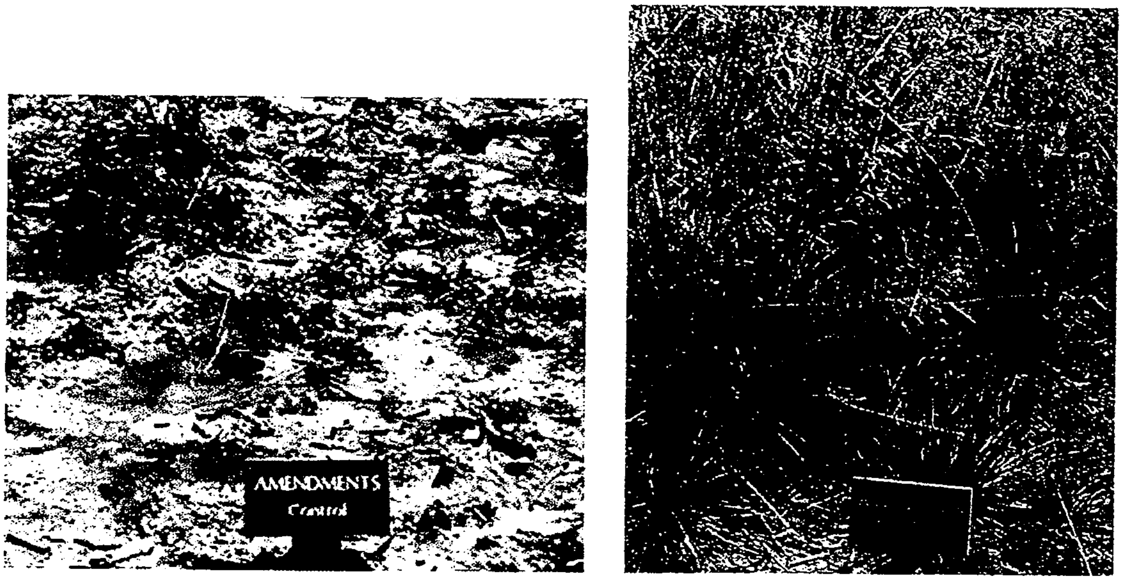


Figure 9. Replicated field plots in Leadville, Colorado, show the effect of biosolids addition on plant growth. Increased above-ground and below-ground carbon accumulation were clearly seen in 2005, 7 years after amendment addition (photo on right).

Energy

The carbon in biosolids can also be considered as a source of green energy. As the carbon in biosolids is from the short-term carbon cycle, using the biosolids for energy production will offset use of energy sources from the long-term carbon cycle. It is common practice in the wastewater industry in the Pacific Northwest to use anaerobic digestion as a way to decrease the volatile solids content, reduce pathogen concentration and extract energy from biosolids. When raw wastewater solids are biologically digested, methane gas (often referred to as biogas) is produced. This gas can be scrubbed and sold to natural gas utilities, or it can be used on-site to supply some of the energy needs of the treatment plant.

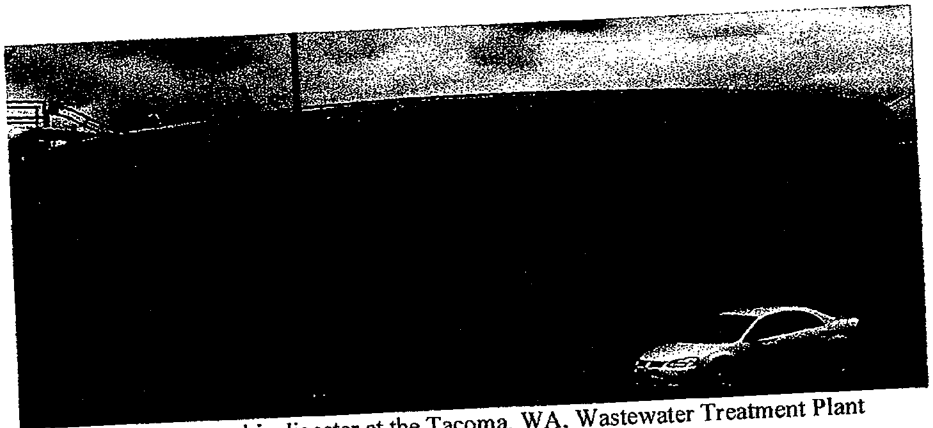


Figure 10. An anaerobic digester at the Tacoma, WA, Wastewater Treatment Plant

Recently, the focus on green energy from biosolids has been on energy from combustion rather than anaerobic digestion. For any combustion process, the energy value of biosolids will vary based on the level of solids treatment. With increasing treatment (for example from raw solids to digested), the energy value of the biosolids will decrease.

Another factor to consider in extracting energy from biosolids via combustion is the high moisture content of the biosolids. In order for biosolids to burn, it is necessary to dry the material. There is quantitative data on energy required to dry biosolids. The specific heat of water and energy for evaporation are standard measures and very well understood. In general, an average energy value for 1 kg of anaerobically digested biosolids is 11,000 British thermal units (Btus) while the energy required to evaporate 1 kg of water is 4750 Btus (Metcalf and Eddy, 2002). In order for combustion of biosolids to produce rather than consume energy, it must be demonstrated that there is an energy- neutral means to dry the material. Once this has been demonstrated, a next step is to look at the energy that the biosolids would replace. If the energy is derived from fossil fuel sources, then the energy from biosolids would result in emissions avoidance. On the other hand, if the energy from combustion replaces wind, solar or hydro power, there would be no associated GHG credits.

Cement production

It has also been proposed that the ash from biosolids combustion can be used as a component of cement manufacture. Cement manufacture is one of the most GHG-intensive industrial processes. Carbonaceous materials are used to make cement and in the production process much of the fixed carbon is released as CO_2. For each ton of cement produced, one ton of CO_2 is released into the atmosphere (Ferreira et al., 2003). Biosolids ash tends to be similar to cement with the exception of an elevated silicon (Si) content and reduced calcium (Ca) concentration. Because of this, only a portion of the cement mixture (generally <10%) can be comprised of biosolids ash if the cement is to be certified as Portland cement.

	Cement	Sludge ash
	Weight % (dry)	
SiO_2	21-24	30-49
Al_2O_3	4-6	8-15
Fe_2O_3	3-4	5-23
CaO	64-66	9-22
MgO	1-2	0.5-1

Table 2. Values for the GHG credits associated with use of biosolids ash as a substitute for cement (Murray et al., 2008).

II. GHG debits associated with use of biosolids

Transport

When biosolids are transported to a land application site, a compost facility, or a combustion facility, the trucks that carry the biosolids use fuel. If this fuel is from a traditional source such as diesel, there are clear, well quantified GHG debits associated with fuel combustion. Fuel is used for processing biosolids into compost or to spread biosolids on fields. In general, the GHG debits for fuel use in transporting and handling biosolids are minimal in comparison to other debits or credits associated with the use of biosolids. Even when biosolids are hauled a distance of 200 miles (as with King County's biosolids), the greenhouse gas debits for fuel combustion are minimal compared with the credits associated with soil carbon storage and replacement of chemical fertilizers.

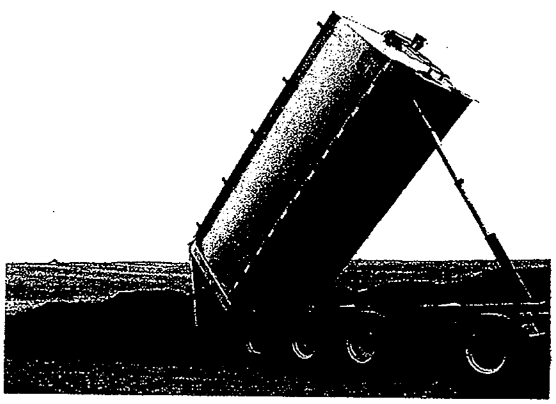


Figure 11. Biosolids from King County's treatment plants being unloaded onto dryland fields in eastern Washington.

N_2O emissions: Land application

There is a potential for N_2O emissions from both land application and combustion of biosolids. Nitrous oxide is formed as mineral nitrogen cycles back to nitrogen gas. Nitrogen in biosolids is initially present as organic nitrogen. As microbes degrade the organic matter in biosolids, a portion of the nitrogen is transformed into ammonia (NH_3). The ammonia is then converted into nitrate (NO_3^-) by soil microorganisms. Plants are generally able to utilize nitrogen in soil either as NH_3 or NO_3^- Under anaerobic conditions, soil microbes will use the NO_3^- instead of oxygen when they oxidize carbon for energy. After nitrogen converts to a series of intermediate nitrogen oxides, nitrogen gas N_2 is released to the atmosphere. This process is known as denitrification.

One of the primary environmental benefits of wetlands is the denitrification that occurs as wetland microbes reduce undesirable concentrations of nitrogen in water.

Although soils are aerobic, there can be small areas (microsites) of anaerobic conditions within a soil. The availability of a carbon source (like organic matter) in combination with excess N will result in denitrification. Nitrous oxide, as an intermediate in the denitrification process can evolve from soils (DeKlein et al., 2006; Rochette et al., 2000; 2008). Nitrous oxide emissions are more likely to occur in poorly drained soils, soils with excess N and soils with a readily available carbon source. Poorly drained soils are not good candidates to receive biosolids.

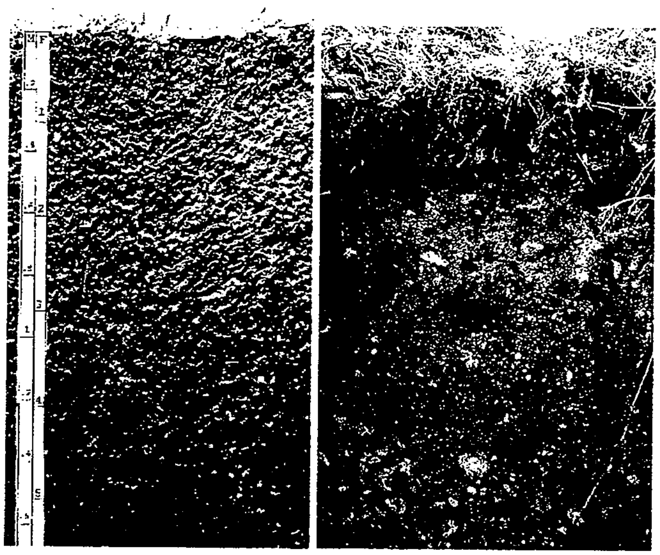


Figure 12. A high clay soil (left) and a well drained soil (right). The potential to produce N_2O is greater in the high clay soil due to poor drainage and anaerobic conditions in waterlogged parts of the soil. The well drained soil is a good candidate for biosolids application.

The IPCC has default values for N_2O emissions from different types of fertilizers. The default value for biosolids, 1% of total N applied, is the same as the value for synthetic fertilizers and composts. The value for certain animal manures is 2% of total N applied. High urea concentration in the manures increases the potential for N_2O emissions. It is likely that additional studies will show differences among fertilizers. There is also the potential for materials to behave differently based on loading rate, soil type, climate factors and specific crops.

One study suggests potential differences due to source of nitrogen. Ball et al. (2004) tested N_2O emissions from fields amended with pelletized biosolids, composted biosolids and digested liquid biosolids in a study that also included standard and slow release synthetic N and cattle slurry. The amendments were added to an imperfectly drained clay loam in Scotland. Total emissions after five amendment applications were (in kg N ha^{-1}):

NPK fertilizer	26.4±1.29
Cattle slurry	15.3± 1.31
Biosolids - compost	10.0 ± 0.67
Biosolids – digested liquid	10.3 ± 2.12
Biosolids - dried pellets	8.0± 1.91

Due to the high level of uncertainty about N_2O emissions, and the current Tier I default, biosolids were not considered to be a greater or lesser source of N_2O than synthetic N fertilizers.

N_2O emissions: Combustion

Biosolids combustion is also a source of N_2O emissions. There is very little specific data on N_2O emissions from different types of biosolids combustion facilities. Currently, the two accepted technologies for combustion of biosolids are multiple hearth furnaces and fluidized bed combustion. There is a growing interest in combustion of biosolids as an option that includes provisions for energy capture. Pyrolysis, combustion under high pressure and temperature with limited oxygen, or modifications of this process are receiving attention as potential alternatives to the standard combustion technologies. As there are no operating facilities at this time, actual N_2O emissions from biosolids combustion using these technologies is not known. As a result we are basing emissions factors for this option only on proven technologies currently in use.

The IPCC provides default factors for N_2O emissions for combustion of biosolids. These are: 900 g of N_2O per wet Mg biosolids combusted and 990 g of N_2O per dry Mg biosolids combusted. No values are provided for % solids for wet or dry materials. For incinerators that operate fairly continuously, emissions of CH_4 are minimal. As most biosolids combustion facilities operate for extended periods, no CH_4 emissions are considered here.

There are a limited number of publications concerning N_2O emissions from combustion of biosolids. However, there is general agreement that emissions from mono-combustion of biosolids are high as a result of the high N content of the biosolids. The factors that will affect the quantity of N_2O formed include

- Combustion temperature (temperatures > 920 C° are associated with low emissions)
- Emissions control systems. If selective noncatalytic reduction (SNCR) based on urea (not ammonia) for emissions control is used, emissions are higher.
- Different moisture content with the highest rates observed for wet biosolids. Svoboda et al (2006) define wet as moisture > 76%, semi-dried as moisture content of 68 % and dry as moisture content < 13%.

In the literature the relative amounts of N_2O produced ranged from 200 pg (N_2O, dry basis)/mg m^3) for dry biosolids, 325 for semi-dry biosolids, and 600 for wet biosolids. These relative emissions are not provided for in terms of Mg of biosolids. Svoboda et al. (2006) also argues that increased oxygen content in the combustion chamber will also increase N_2O concentration, however, the data shown does not clearly follow this pattern.

Co-combustion of biosolids with coal also shows high N_2O emissions. From the data given in Svoboda et al (2006) it is not clear that co-combustion of coal and biosolids should be treated differently from mono-combustion of biosolids in net emissions of N_2O Emissions reduction technology can increase or decrease N_2O emissions. Use of selective non-catalytic reduction (SNCR) using urea as a catalyst can be a significant source of additional N_2O. Use of SCR or SNCR with ammonia is a much less significant source of N_2O; however, no details on emissions increase with urea based SNCR are provided. Some data from mono-combustion facilities in Japan and Canada suggests that the IPCC default values are too low (Marc Hérbert, Environment Canada).

Based on a high level of uncertainty about N_2O emissions from the combustion of biosolids, it is appropriate to use the default IPCC emissions for N_2O for mono- or co- combustion if the furnace temperature is < 920° C.

N2O emissions: Composting

There is also the potential for fugitive GHG emissions from biosolids composting operations (Brown et al., 2008). In general, a compost operation that is well aerated will have minimal emissions of both N_2O and CH_4. The Chicago Climate Exchange, in their recent compost protocol, requires that compost facilities meet US EPA time and temperature requirements for pathogen destruction as a means to assure aerobic conditions in the composting process.

Summary

Concerns about global climate change caused by greenhouse gas emissions have led to the development of models to measure and track these emissions. Wastewater utilities have become interested in these models because they produce organic materials (biosolids) that have a potential to either emit greenhouse gases such as methane or nitrous oxide or to be used as a tool to avoid GHG emissions.

Biosolids contain significant amounts of carbon, which is part of the actively cycling or short-term carbon cycle. Carbon that is actively cycling through plants, animals, and humans has no net impact on overall long-term levels of carbon (CO_2) in the atmosphere and is not added to GHG emissions calculations. In a carbon accounting model, credits from biosolids management can be accrued by:

- Using biosolids to replace chemical fertilizers that require the use of long-term carbon for their manufacture;
- Using biosolids to store carbon in the soil, either through regular fertilization and soil amendment or through the use of biosolids-woody mixes for land reclamation;
- Anaerobically digesting biosolids to produce biogas that can substitute for natural gas;
- Combusting biosolids as a biofuel to substitute for fossil fuels;
- Using biosolids ash in a cement kiln to replace materials that would release CO_2.

Debits from biosolids management accrue primarily due to the burning of diesel fuels while transporting biosolids. Nitrous oxide may also be released if biosolids are used in anaerobic conditions or are combusted at temperatures less than 920°C.

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