2009-279

Attachment A

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.

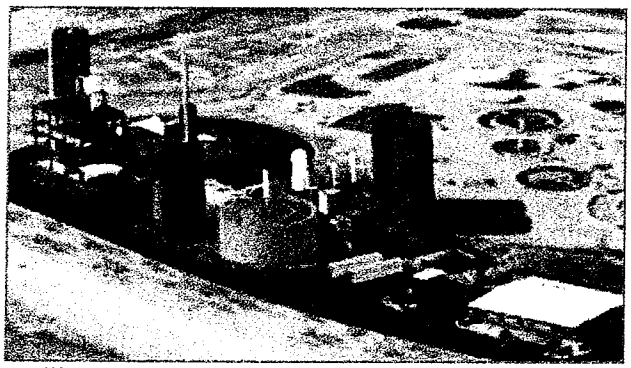
learning more about and comparing various options. The county was especially interested in options that (1) avoid or manage the impacts of winter weather on biosolids transportation; or (2) reduce the amount of diesel fuel used for transportation; or (3) use biosolids as a tool to reduce emissions of 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:

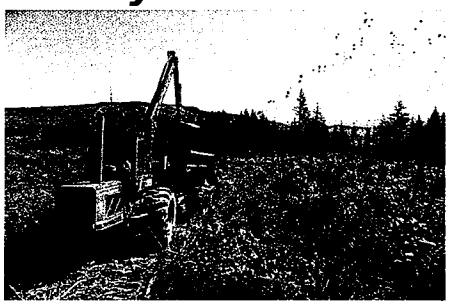
- A proven record of reliable year-in, year-out management of biosolids for more than 15 years.
- Community understanding and support as well as strong market demand.
- Local project management and control; many local spokespersons.
- Numerous and well-dispersed environmental benefits, such as fertilization 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.