Industrial Ecology

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Orit Ofri • Business Administration

Jennifer Howard-Grenville • Assistant Professor • Management

UNIVERSITY OF OREGON

SCI
Sustainable Cities Initiative

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About SCI

The Sustainable Cities Initiative (SCI) is a cross-disciplinary organization at the University of Oregon that seeks to promote education, service, public outreach, and research on the design and development of sustainable cities. We are redefining higher education for the public good and catalyzing community change toward sustainability. Our work addresses sustainability at multiple scales and emerges from the conviction that creating the sustainable city cannot happen within any single discipline. SCI is grounded in cross-disciplinary engagement as the key strategy for solving community sustainability issues. We serve as a catalyst for expanded research and teaching, and market this expertise to scholars, policymakers, community leaders, and project partners. Our work connects student energy, faculty experience, and community needs to produce innovative, tangible solutions for the creation of a sustainable society.

About SCY

The Sustainable City Year (SCY) program is a year-long partnership between SCI and one city in Oregon, in which students and faculty in courses from across the university collaborate with the partner city on sustainability and livability projects. SCY faculty and students work in collaboration with staff from the partner city through a variety of studio projects and service-learning courses to provide students with real-world projects to investigate. Students bring energy, enthusiasm, and innovative approaches to difficult, persistent problems. SCY's primary value derives from collaborations resulting in on-the-ground impact and forward movement for a community ready to transition to a more sustainable and livable future. SCY 2010-11 includes courses in Architecture; Arts and Administration; Business Management; Interior Architecture; Journalism; Landscape Architecture; Law; Planning, Public Policy, and Management; Product Design; and Civil Engineering (at Portland State University).

About Salem, Oregon

Salem, the capital city of Oregon and its third largest city (population 157,000, with 383,000 residents in the metropolitan area), lies in the center of the lush Willamette River valley, 47 miles from Portland. Salem is located an hour from the Cascade mountains to the east and ocean beaches to the west. Thriving businesses abound in Salem and benefit from economic diversity. The downtown has been recognized as one of the region's most vital retail centers for a community of its size. Salem has retained its vital core and continues to be supported by strong and vibrant historic neighborhoods, the campus-like Capitol Mall, Salem Regional Hospital, and Willamette University. Salem offers a wide array of restaurants, hotels, and tourist attractions, ranging from historic sites and museums to events that appeal to a wide variety of interests. 1,869 acres of park land invite residents and visitors alike to enjoy the outdoors.

Course Participants

Amanda Rhodes, Business Graduate
Amy McCann, Business Graduate
Brad Puglio, Business Graduate
Brett Ratchford, Business Graduate
Brian Rajotte, Business Graduate
Brie Becker, Business Graduate
Dan Simon, Business Graduate
Douglass Anderson, Business Graduate
Erika Penner, Business Graduate
Erin Malone, Business Graduate
Greg Carlson, Business Graduate
Hendrik Van Hemert, Business Graduate
Jaxon Love, Business Graduate
Jia Hu, Business Graduate
JJ O'Connell, Business Graduate
John Rumin, Business Graduate
Katie Brennan, Business Graduate
Kelly McKeag, Business Graduate
Laura Lu, Business Graduate
Lauren Schwartz, Business Graduate
Orit Ofri, Business Graduate
Paul Clark, Business Graduate
Sara Hoversten, Business Graduate
Sergio Ibarra Bolaño, Business Graduates
Tom Cramer, Business Graduate
Tracy Sagal, Business Graduate
Walther Bueckle rs, Business Graduate

SCI Directors and Staff

Robert Liberty, Executive Director

Nico Larco, SCI Associate Director, and Assistant Professor of Architecture

Marc Schlossberg, SCI Associate Director, and Associate Professor of Planning, Public Policy, and Management

Chris Jones, SCI Program Manager

Amy Hause, SCI Program Manager

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Executive Summary

This report summarizes the work done by students in the Industrial Ecology class at the University of Oregon during fall term 2010. The students explored industrial ecology concepts to evaluate opportunities in two business cases in the Salem area: the City of Salem's Willow Lake Water Pollution Control Facility (Willow Lake) and NORPAC Foods, Inc. (NORPAC). The students worked on the two cases through five separate projects – three for Willow Lake and two for NORPAC.

At Willow Lake, the objective was to evaluate the feasibility of transforming waste to energy and reclaiming water generated by the facility.

- **Project #1** investigated the feasibility of adopting a fuel cell that would replace the current generator to generate energy from the methane produced by the current digester at the facility.

  The students recommended that Willow Lake continue with traditional cogeneration technology and deploy an 848 kW replacement engine. Included with the students' project report was an Excel financial model for Willow Lake to examine and use to further refine understanding of the likely effects of each replacement alternative.

- **Project #2** assessed the feasibility of a symbiotic partnership between SeQuential-Pacific Biodiesel (SeQuential) and Willow Lake through an evaluation of the environmental and financial implications of biodigestion of grease trap waste. Students found that, at the level of accuracy currently available, a partnership between Willow Lake and SeQuential has environmental and financial benefits. They recommend that SeQuential and Willow Lake continue to investigate the methane production potential of this waste to determine an appropriate tipping fee (a charge levied by a waste treatment facility to accept waste).

- **Project #3** identified opportunities for Willow Lake to secure a long-term water supply and reduce wastewater discharge impacts through water reclamation. The case studies and cost analysis show that the use of reclaimed water in the region under the current system is not cost effective. However, future water supply and discharge limitations indicate the need to start considering multiple reclamation alternatives now.

At NORPAC, the objective was to evaluate opportunities to reuse, recycle, or compost waste generated from facilities in Brooks, Stayton, and Salem.

- **Project #4** proposed a viable strategy for NORPAC to achieve its goal of conserving and recycling nutrients in its facilities by discovering opportunities to reuse, recycle, or compost the waste generated by operations. While each has its own benefits and challenges, the alternative with the highest revenue potential and environmental benefits to NORPAC is vermicomposting. Specifically, NORPAC could create a partnership with

Oregon Soil Corporation to develop a vermicomposting (worm composting) operation.

- **Project #5** assessed the current disposal solution for defective cans and evaluated three potential strategies for a more sustainable disposal process. The students recommended NORPAC take a two-pronged approach to restructure its current disposal process. In the short term (0-6 months), NORPAC could centralize can collection at the Madrona (Salem) facility and recycle 100% of its defective cans internally. In the long run (6 months and longer), NORPAC could partner with Recology to establish an ongoing waste disposal program, integrating other local canneries into this waste disposal program.

Introduction

Overview

This report summarizes the work done by students in the Industrial Ecology class at the University of Oregon during fall term 2010. The students in the class were Masters of Business Administration students.

Industrial Ecology Concepts and Class Objectives

Industrial ecology represents a systems approach to the design and manufacture of products (and delivery of services) with minimized ecological impact. It breaks from traditional corporate environmental management approaches by looking beyond the boundaries of individual facilities and firms to consider the industrial metabolism within supply chains, industrial clusters, and geographic regions.

Students in this course learned about the key principles related to industrial ecology:

1. A systems perspective that encompasses attention to the life cycle of products, processes, and facilities.

2. A focus on multiple levels of activity – facility, firm, region, supply chain, consumption – and their interactions.

3. A multidisciplinary approach that places the analysis of industrial metabolism within a social, political, and technological context.

Case Studies

The students explored industrial ecology concepts to evaluate opportunities in two business cases in the Salem area.

Case Study 1: Willow Lake Water Pollution Control Facility

The Willow Lake Water Pollution Control Facility (Willow Lake) is operated by the City of Salem's Public Works Department. It is responsible for treating the wastewater generated by the citizens of Salem, Keizer, Turner, and other unincorporated areas of Marion County served by the sewer collection system. The current service population is approximately 229,000 people. The treated effluent (liquid waste) is piped to the Willamette River, and the biosolids are spread on area farms.

Students evaluated the feasibility of transforming waste to energy and reclaiming water generated by Willow Lake through three separate projects.

Case Study 2: NORPAC Foods, Inc.

In operation since 1924, NORPAC Foods, Inc. (NORPAC) grows, processes, and packages premium quality vegetables and fruit products at facilities in Brooks, Stayton, and Salem, Oregon. Farmers in NORPAC's cooperative grow 600,000 pounds of produce annually. NORPAC has made a strong commitment to sustainability, as evidenced by obtaining EarthWISE certification for its facilities and participating in the Food Alliance certification program.

Students evaluated opportunities to reuse, recycle, or compost waste generated from facilities in Brooks, Stayton, and Salem through two separate projects.

Process

The students explored the connecting points between projects implementing the concepts of industrial ecology. For example, in both the SeQuential-Pacific Biodiesel project and in the NORPAC Can Recycling Analysis the students explored collaboration with Willow Lake.

In almost every project, the students expanded the scope of the project beyond the original definition. As an example, students working to evaluate the deployment of a fuel cell at Willow Lake were given a set of scenarios to evaluate; they expanded their project to define and evaluate additional scenarios. The students created an Excel financial and environmental model that will allow Willow Lake to evaluate scenarios as circumstances change, and the students conducted phone interviews with experts and technical staff at other facilities who had information beneficial to Willow Lake.

Willow Lake Water Pollution Control Facility Case Study

About Willow Lake

Willow Lake is responsible for treating the wastewater generated by the citizens of Salem, Keizer, Turner, and other unincorporated areas of Marion County served by the sewer collection system. The current service population is approximately 229,000 people. The treated effluent is piped to the Willamette River and the biosolids are spread on area farms.

Figure 1: Willow Lake Water Pollution Control Facility

Willow Lake uses anaerobic digestion, which is the oxygen-free process of breaking down biodegradable material to manage waste and release energy. Biogas production using an anaerobic digester reduces odor, produces energy, and improves the storage and handling of waste, usually manure, thereby reducing the emissions of landfill gas into the atmosphere (Penn State University). This process produces methane gas (biogas, a renewable energy source) and odor-reduced but nutrient-rich biosolids that can be used as fertilizer.

SCI Projects' Focus for Willow Lake

Willow Lake projects evaluated the feasibility of transforming waste to energy and reclaiming water generated by Willow Lake through three separate projects:

Project #1: Fuel Cell Feasibility Study at Willow Lake

Building from a previous feasibility study, this project investigates the feasibility of adopting a fuel cell to generate energy from the methane produced by the current digester at Willow Lake's facility. The fuel cell would replace the current generator.

Project #2: SeQuential-Pacific Biodiesel Process Effluent Fed to Willow Lake's Digester

This project assesses the feasibility of developing a relationship between SeQuential-Pacific Biodiesel (SeQuential) and Willow Lake in which effluent from SeQuential's biodiesel production process would be fed into Willow Lake's digester in order to take advantage of the digester's excess capacity. Currently, the process effluent is shipped to Portland, dehydrated, and spread on land.

Project #3: Willow Lake Wastewater Reclamation

This project explores potential opportunities for other facilities and organizations to use reclaimed water from Willow Lake for application in non-potable water uses (e.g. cement mixers, quarries, irrigation). It identifies potential recipients of the water and evaluates the quantity of demand and associated logistics.

Project #1: Fuel Cell Feasibility Study at Willow Lake

Overview

General

This project compares alternatives for converting gas into electricity and process heat. In addition to an analysis of the alternatives, this project assesses industry best practices in wastewater cogeneration and reviews additional possibilities. Finally, this project provides a financial modeling tool that will enable Willow Lake to perform sensitivity analyses under various scenarios.

This project provides Willow Lake with a quantitative and qualitative analysis that will supplement the work performed by Carollo Engineering in its March 2009 Cogeneration Feasibility Study (Carollo Engineering Company, 2009). This assessment utilizes some of the information contained in that study. However, the results of this report differ in both the alternatives analyzed and data compiled.

Current Situation Analysis

Currently, Willow Lake uses an engine cogeneration system to convert digester gas into electricity and process heat. Confronted with escalating operational and maintenance costs, Willow Lake seeks to replace its current generation technology. In order to best understand the available alternatives, in March 2009 Willow Lake consulted Carollo Engineering, which produced a study assessing six distinct alternatives. Ultimately, the study endorsed the adoption of a 1400 kW fuel cell that would enhance the facility's current methane processing capacity and reduce its CO_2 emissions.

Per Willow Lake's request, the following report will independently assess the Carollo study's findings. Through an evaluation of three replacement alternatives alongside thorough industry research, this report recommends that Willow Lake reject the adoption of the 1400 kW fuel cell and instead adopts an 848 kW engine in its stead, for both financial and technological reasons.

Alternatives

This project evaluates three replacement alternatives based on consideration of technical, regulatory, and economic aspects coupled with a best practices overview:

- 848 kW Engine Replacement: This is alternative 5 in the Carollo study.
- 1400 kW Fuel Cell: This is alternative 6 in the Carollo study.
- 1148 kW Hybrid of 848 kW Engine and 300 kW Fuel Cell: This alternative

is being introduced after examining various case studies and reexamining findings in the Carollo study.

Methodology

To come up with an economic estimate of the different alternatives, the students first calculated the associated annual cost and revenue streams for the year 2011. The 2011 estimate was then used in the summary section, where the students estimated the same cost/revenue streams for an additional 19 years to calculate the Life Cycle Cost (LCC) analysis and compare the alternatives.

The method used to come up with the technical and economic calculation is explained in further detail for the first alternative and later applied for the other two alternatives. Appendix 1 shows the assumptions used in the calculations.

Key Findings from Technical and Economic Analysis

Baseline Scenario

Willow Lake requires process heat at a rate of 2.8 MMBtu/hr on average, with a peak heat demand of 4.4 MMBtu/hr. Electricity demand averages 2,045 kW. There are seasonal variations in both process heat and electricity demand, but a detailed analysis of energy demand trends was outside the scope of this project.

Willow Lake produces a daily average of 317,000 standard cubic feet (scf) of digester gas comprised of 60% methane (190,200 scf of methane per day) as a byproduct of the sewage treatment process. This methane can then be used by a cogeneration system.

At present, Willow Lake operates an aging 600 kW cogeneration engine to convert digester methane into energy for use on site. Average annual cogeneration power rating, including downtime for maintenance, was 570 kW between 2007 and 2008. Based on students' calculations, the engine produces roughly one fourth of Willow Lake's electricity requirement and two thirds of its average process heat requirement.

The engine was built in 1987 and installed at the facility in the 1990s. Willow Lake has indicated that continued operation and maintenance of the engine is not a viable long-term alternative. For this reason, students did not consider this alternative in their analysis.

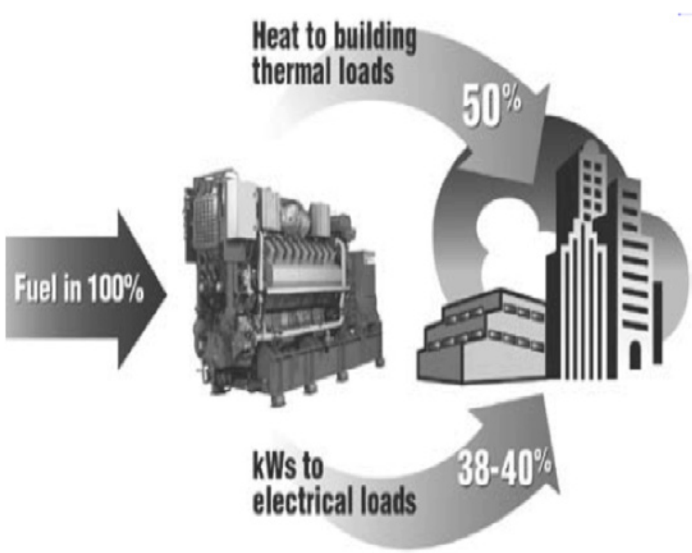


Figure 2: Cogeneration Engine

Alternative 1: 848 kW Engine Replacement

The first alternative for replacement of the existing engine cogeneration system is the installation of a new engine. In evaluating this alternative, students used the 848 kW engine proposed in the Carollo study.

Alternative 1: Electrical and Thermal Output

The electric power rating for this replacement engine is derived from the Carollo study (Carollo Engineering Company, 2009) and is estimated at 848 kW. Students used the following methodology to arrive at estimates for the heat production and methane input requirement of this engine:

- Divide the given maximal electrical power output by the electrical efficiency (both taken directly from the Carollo study) to derive the equivalent electrical power input required to achieve maximal output.
- Multiply that input by the thermal efficiency (also taken directly from the Carollo study) to arrive at the thermal power output equivalent.

The following table presents the technical specifications for the 848 kW engine.

Maximal Electrical Power Output	848 kW
Electrical Efficiency	0.34
Equivalent Electrical Power Input	2,494 kW
Thermal Efficiency	0.42
Thermal Power Output (Equivalent)	1,048 kW

With these values, students calculated annual electricity costs, annual natural gas costs, and annual excess methane for the year 2011. These values will later be used to compare the Net Present Value (NPV) of the different alternatives.

Alternative 1: Annual Costs for Year 2011

The following table summarizes the annual costs for year 2011 associated with the 848 kW engine alternative.

Annual Electrical Energy Cost	$ 910,370
Annual Heat Deficit Cost	$ 0
Total O&M Costs	$ 177,320
Total Annual Costs	$ 1,087,690

Among the three alternatives considered, Alternative 1 has by far the lowest Operating and Maintenance (O&M) costs. More importantly, this differential in O&M costs remains constant over twenty years and therefore significantly impacts the project's LCC.

Detailed calculations for the three alternatives considered are shown in Appendix 2.

Alternative 1: Capital Expenditure
The capital expenditure required to purchase the new 848 kW engine is also the smallest relative to the two other alternatives; students' calculations demonstrate that this alternative's net costs are less than $7 million.

Total Gross Cost	$ 10,168,500
Tax Credits/Grants	33.50%
Capital Expenditure	$ 6,762,053

In addition – these values were drawn out of the Carollo study – students' conversations with engineers at other wastewater facilities (discussed in the Case Studies section below) suggest that capital costs are lower today than they were when the Carollo study was written.

Alternative 2: 1400 kW Fuel Cell

At present, Willow Lake is considering installing a 1400 kW fuel cell at its facility. Such technology, it is proposed, will allow the facility to (1) generate more electricity, reducing its current electricity bill, (2) generate more heat, reducing its need for additional process heat, and (3) reduce its carbon emissions.

Figure 3: Fuel Cell (DFC)

Alternative 2: Electrical and Thermal Output
The electric power rating for the 1400 kW fuel cell is derived from the Carollo Study and is estimated at 1400 kW. The calculations were preformed using the methodology used for the first alternative, to arrive at estimates for the heat production and methane input requirement of this engine.

The following table presents the technical specifications for the 1400 kW fuel cell:

Maximal Electrical Power Output	1400 kW
Electrical Efficiency	0.47
Equivalent Electrical Power Input	2,979 kW
Thermal Efficiency	0.22
Thermal Power Output (Equivalent)	655 kW

Alternative 2: Annual Costs for Year 2011

The following table summarizes the annual costs for the year 2011 associated with the 1400 kW fuel cell alternative.

Annual Electrical Energy Cost	$ 490,550
Annual Heat Deficit Cost	$ 60,016
Total O&M Costs	$ 548,959
Total Annual Costs	$ 1,099,525

Among the alternatives considered, Alternative 2 has by far the highest O&M costs. More importantly, this differential in O&M costs remains constant over twenty years and therefore significantly affects the project's LCC.

Detailed calculations for the three alternatives considered are shown in Appendix 2.

Alternative 2: Capital Expenditure

The capital expenditure required to purchase the 1400 kW fuel cell falls between the two other alternatives; the calculations demonstrate that Alternative 2's net costs are just over $7 million.

Total Gross Cost	$ 10,758,406
Tax Credits/Grants	33.50%
Capital Expenditure	$ 7,154,340

Alternative 3: 1148 kW Hybrid of 848 kW Engine and 300 kW Fuel Cell

Due to the operational challenges associated with the 1400 kW fuel cell, students identified a hybrid approach that would reap the economic and environmental benefits associated with the use of a fuel cell while avoiding the 1400 kW fuel cell's significant costs. The following analysis assesses the operational and economic implications of combining a small 300 kW fuel cell with a new 848 kW engine.

Alternative 3: Electrical and Thermal Output
The electric power rating for a small 300 kW fuel cell combined with a replacement 848 kW engine is derived from the Carollo study and is estimated at 1148 kW. Students made separate calculations for the fuel cell and for the engine using the methodology discussed above; the two were combined to arrive at estimates for the heat production and methane input requirements of this engine.

The following table presents the technical specifications for the 1148 kW Hybrid alternative:

	848 kW Engine	**300 kW Fuel Cell**	**1148 kW Hybrid**
Maximal Electrical Power Output	848 kW	300 kW	1148 kW
Electrical Efficiency	0.34	0.47	0.37
Equivalent Electrical Power Input	2,494 kW	638 kW	3,132 kW
Thermal Efficiency	0.42	0.22	0.37
Thermal Power Output (Equivalent)	1,048 kW	140 kW	1,188 kW

Alternative 3: Annual Costs for Year 2011
The following table summarizes the annual costs for the year 2011 associated with 1148 kW Hybrid alternative.

Annual Electrical Energy Cost	$ 667,906
Annual Heat Deficit Cost	$ 0
Total O&M Costs	$ 279,752
Total Annual Costs	$ 947,658

Perhaps the largest benefit afforded by this hybrid alternative over the 1400 kW fuel cell lies in the potential reduction in O&M costs. More importantly, this differential in O&M costs remains constant over twenty years. Over a twenty-year life span, such reductions in annual O&M costs become a significant source of savings which significantly affect the project's LCC.

Detailed calculations for the three alternatives considered are shown in Appendix 2.

Alternative 3: Capital Expenditure
The capital expenditure required to purchase both a new 848 kW engine and a small fuel cell far exceeds that associated with the 1400 kW fuel cell. The calculations demonstrate that this alternative's net costs exceed $12 million.

Gross Cost for 848 kW Engine	$ 8,867,820
Gross Cost for 300 kW Fuel Cell	$ 10,168,500
Total Gross Cost for Hybrid	$ 19,036,320
Tax Credits/Grants	33.50%
Capital Expenditure for Hybrid	$ 12,659,153

Therefore, similar to the large fuel cell alternative, Willow Lake decision makers will need to weigh the significant upfront costs associated with this alternative and identify a feasible means of financing the project before proceeding with the project.

Life Cycle Cost Analysis: Comparing the Alternatives

The Life Cycle Cost (LCC) of each alternative is the total discounted cost of acquiring, operating and maintaining an alternative over 20 years at the stated discount rate.

Assumptions for LCC Calculation

The following growth rate variables were used to come up with financial estimates for 20 years.

Discount Rate	5.00%
O&M - Fuel Treatment Escalator	3.00%
O&M - Engine Escalator	3.00%
O&M - Engine Escalator	3.00%
Electricity Cost Escalator	7.00%
Gas Cost Escalator	5.00%
REC Revenue Escalator	0.00%
Methane Revenue Escalator	0.00%

LCC Estimates Summary

With the above assumptions regarding discount rates, O&M price escalations, and increases in the price of gas and electricity, this report performed discounted cash flow analyses in an attempt to determine which alternative presents the lowest LCC to Willow Lake.

The following is a summary of the LCC for the three alternatives considered in this project:

- 848 kW Engine: This alternative netted an LCC of $31,067,734 when assuming that the generator will operate at gas levels currently available at the facility. However, at full capacity, the engine actually achieves a reduced LCC of $30,460,587. It is able to achieve a lesser cost because it is able to fully use gas at the facility, thereby reducing Willow Lake's electrical and gas bills. Other key considerations include escalating utility costs over the project's twenty-year life span. Finally, capital expenditures are significant, but lower than the alternatives.
- 1400 kW Fuel Cell: This is the most controversial project. Interestingly, it has a relatively attractive LCC when operating at full capacity. Due to reductions in energy and heating costs, its LCC totals $28,305,990, a total which would be even lower were it not for significant capital expenditures and, more importantly, very high O&M costs. However, unless Willow Lake can significantly increase its sources of gas for use in the fuel cell, the LCC

increases significantly; at current gas supply levels, it would total more than $34 million, making it the most expensive of the six scenarios considered.

- 1148 kW Hybrid: The hybrid alternative, because it combines equipment costs for both a new 848 kW engine and a 300 kW fuel cell, requires the greatest upfront costs, nearly $12.5 million. This alone contributes significantly to the project's LCC. Compounding the costs of the project is the fact that this combination requires significant O&M costs. However, because this combination is less efficient, it still incurs high costs of electricity. The sum of these three major factors account for an LCC that totals $32,763,002 when utilizing its full capacity and $33,651,554 under current plant conditions.

Regulatory Aspects

The current analysis does not account for the cost of carbon, given its speculative nature and given its minimal effect on the project's LCC. For example, the 848 kW Engine is estimated to account for more than 1,000 tons of CO_2 per year when compared with the 1400 kW fuel cell; as such the 848 kW generator slightly increases the project's LCC. However, given that the cost of one ton of carbon is about $15, such differences are minimal, accounting for less than $17,000 per year. Any future cost differentials will provide the 1400 kW fuel cell (Alternative 2) with relatively small cost advantages. Such savings are dependent upon the implementation of carbon pricing schemes. As such, decision-makers must determine the likelihood of carbon pricing when assessing the attractiveness of the large fuel cell alternative.

From a strictly regulatory standpoint, Willow Lake may realize benefits from reductions in CO_2 levels not captured in the proposed economic analysis. Currently, Willow Lake and similar wastewater facilities are not subject to the Environmental Protection Agency's (EPA's) guidelines regarding emissions, as made clear by EPA 40 CFR Part 98. However, given the current uncertainty surrounding climate legislation, it is possible that in future years Willow Lake will be subject to carbon emission regulations, in which case the large fuel cell would become a much more attractive alternative. Given that there is no indication that legislation will soon change, however, Willow Lake is advised to not consider carbon legislation as a determining factor in its decision-making process.

Financial incentives for clean energy generation projects have been difficult to predict in recent years. Primarily for this reason, independent assessment of these incentives were not included in the analysis. It should be noted that Oregon's Business Energy Tax Credit (BETC) rules are permanent as of November 23, 2010 (Oregon Department of Energy, 2009).

The appendix in the Carollo study has a thorough list of federal and state grants and tax incentives that apply to renewable technology but are dependent on the type and size of the project. Once a long-term renewable energy technology is selected and an estimated timeline of installation is established, it is recommended that Willow Lake submit the project to a consultant for indepth LCC analysis. This strategy will give Willow Lake transparency in the financing requirements and applicable incentives for the best renewable energy production method.

Sensitivity Analysis

When conducting the economic analysis, this report made several key assumptions which affected the results found in the economic analysis. These assumptions included:

- Discount rate: The Carollo study listed the discount rate at 5%, so this report's LCC calculations used that same value. However, any changes in the discount rate will significantly alter the final LCC of the proposed project.
- A second critical factor is the price of electricity. Given electricity's price volatility, any rate increases will also increase the plant's operating costs, which would in turn make the large fuel cell a more attractive alternative.
- Capital expenditures: Current adjustments to capital expenditures leave great room for interpretation. In all three alternatives, these costs have been reduced to reflect 33.5% in tax credits. Should this amount decrease, a distinct likelihood in the current economic environment, each project's capital costs would rise accordingly.
- Operating and Maintenance costs account for significant portions of both fuel cells' costs. With improvements in technology, these costs may decrease, making their future purchase more viable. It is recommended that staff at Willow Lake run their own sensitivity analyses to make adjustments to the LCC model as they see fit.

Project #1: Key Findings from the Case Studies

Students researched best practices at two nearby wastewater treatment facilities to qualitatively assess fuel cells vs. cogeneration engines:

- The Columbia Boulevard Wastewater Treatment Plant (CBWPT) in Portland is the largest wastewater treatment plant in Oregon. The facility handles approximately 82 million gallons of wastewater per day (US Department of Energy and Environmental Services, City of Portland, 1999).
- The South Treatment Plant (STP) in Renton, Washington was the location of the first molten carbonate fuel cell demonstration from 2004 to 2006 (Bloomquist, 2006).

The following is a summary of the findings.

Fuel Cell Technology

The CBWTP installed a fuel cell in 1999 and stopped using it in 2005. It was the first installation in the western United States of a fuel cell running on wastewater digester gas and only the third such system in the nation. The STP installed a 1 MW molten carbonate fuel cell in 2004 and stopped using it in 2006.

Both facility engineers decommissioned the fuel cells at these facilities and did not recommend installation of new fuel cells at other wastewater facilities. Instead, the engineers recommended reciprocating cogeneration engines rather than fuel cells for the following reasons:

- The fuel cell developed a leak allowing water to infiltrate the core and ruin it. A replacement core cost $300,000 to install. With this model of fuel cell, the core needed to be replaced every five years as part of routine maintenance.
- The maintenance of the cells was expensive. Maintenance costs averaged 2 cents per kWh annually and required keeping highly skilled staff at the facility. Maintenance could not be performed by lower level workers.
- Heat recovery with the fuel cell was a problem. The fuel cell did not produce the heat needed to warm the digesters during the winter, so natural gas had to be purchased at extra expense for this purpose.
- Overall qualitative assessment from the engineers was that the fuel cell did not have a great track record for ease of operation and maintenance.

Replacement of Decommissioned Fuel Cells

The CBWTP replaced its 300 kW fuel cell with two 848 kW engines in 2008. STP's replacement generation method was not determined by the authors of this report. In addition to related quantitative factors, the choice to abandon fuel cells in favor of cogeneration engines was informed by a number of qualitative factors. Traditional generation engines are a proven technology. Operation and maintenance costs are relatively lower and more predictable. The higher heat output from engines is a particular advantage to wastewater treatment facilities because of the significant need for process heat on site.

Conclusions, Recommendations, and Open Issues

Financial analysis used information available in the Carollo study to estimate the energy output and LCC of three alternatives to replace the existing 600 kW engine.

The LCC analysis provides a valid economic tool by which decision makers can objectively assess the three alternatives. As the above calculations reveal, the large fuel cell can, at times, achieve the most favorable LCC figure. However, such a scenario requires a large number of assumptions, the most serious of which include hoping for decreased O&M costs coupled with the possibility that Willow Lake can obtain adequate amounts of gas to feed to the fuel cell. Due to such uncertainties, it is more economically advisable to heed the LCC analysis and consider the less variable alternative, namely the 848 kW engine.

While the results presented here are limited by the input assumptions of the financial model, the model was constructed in such a way that any assumption can be modified to adjust the output results. As Willow Lake moves forward with the planned engine replacement, the financial model can be adjusted to forecast the viability of alternate scenarios.

Students investigated the experience of other wastewater treatment facilities that have implemented fuel cells in the past. The two facilities interviewed indicated that the equipment they had installed was no longer in operation and had been decommissioned after a few years of operation. Their experience with fuel cells, as well as information available from the US Department of Energy (DOE), suggests that fuel cells remain a demonstration technology characterized by high operation and maintenance costs as well as uncertain power output performance (US Department of Energy, 2009).

In addition to the quantitative and qualitative analysis of cogeneration replacement alternatives, students conducted preliminary research to determine the feasibility of methane storage and sale. While the students did not make any conclusive determinations regarding the viability of storing methane, they determined that the possibility exists to generate supplemental revenue from the sale of biogas that is currently sent to a waste burner. Further analysis should be performed to determine the cost and benefit associated with abandonment of cogeneration in favor of storing and selling all of the methane produced at Willow Lake.

Based on the quantitative and qualitative investigation, students recommend that Willow Lake:

- Continue with Traditional Cogeneration Technology: Students believe that Willow Lake would be best served by the 848 kW replacement engine alternative. The estimates suggest limited, if any, lifecycle cost savings from fuel cell cogeneration at Willow Lake. Furthermore, fuel cell technology does not yet appear to be ready for commercial deployment.
- Customize the Financial Model: Included with the students' project report was an Excel financial model for Willow Lake to examine and use (see Appendix 3). The model can be adjusted to customize input assumptions and further refine understanding of the likely effects of each replacement alternative.
- Examine Feasibility of Methane Storage and Sale: While Appendix 3 provides only a high-level discussion of methane storage technologies, research suggests that capture and sale of biogas may be a viable revenue stream. This could involve capture of gas in excess of cogeneration requirement only, or abandonment of cogeneration all together. Students suggest deeper technical and economic evaluation of these alternatives.

Project #2: SeQuential-Pacific Biodiesel Effluent Fed to Willow Lake's Digester

Overview

General

This project assesses the feasibility of a symbiotic partnership between SeQuential-Pacific Biodiesel (SeQuential) and Willow Lake Water Pollution Control Facility (Willow Lake). In order to determine if a symbiotic relationship exists, the project evaluates the environmental and financial implications of the co-digestion of grease trap waste.

Current Situation Analysis

SeQuential currently collects grease trap waste for processing into biodiesel, which is its final product.

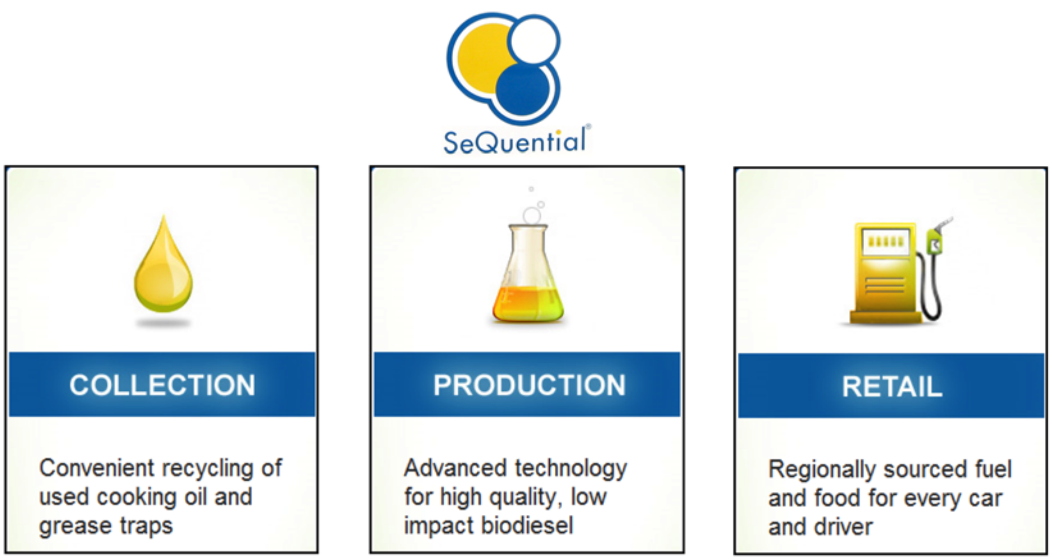


Figure 4: SeQuential's Business Model

Only a portion of the grease trap waste is usable; the rest is Wastewater Grease Trap (WWGT) waste that must be disposed of. This report focuses on the disposal of the WWGT waste, the more grease-laden component of SeQuential's process effluent, which is proposed to be taken to Willow Lake and processed through its anaerobic digester. Currently, the WWGT waste is shipped to Portland, dehydrated, and spread on land.

Figure 5: SeQuential Grease Trap Disposal Process

Methodology

To come up with a recommendation, students worked on this project in three stages:

- Case study examples of co-digestion: Students looked at a range of scenarios where food and grease wastes were processed through a wastewater treatment plant's anaerobic digester. Each case had varied results depending on the composition of the food or grease waste processed, the proportion of wastewater to solids, and the preparation of the waste before it was added to the digester.
- The students examined the following cases: D.C. Water, the wastewater treatment authority for Washington D.C. (Washington D.C.), Clearwater Road Wastewater treatment plant (Hershey, PA), the City of Gresham (Gresham, OR), and East Bay Municipal Utility District (San Francisco, CA).
- Environmental analysis: Students focused on greenhouse gas (GHG) emissions resulting from, or abated by, each disposal alternative. They identified the key emissions activities as transportation, processing and land filling of the waste, or digesting the waste to produce usable methane.
- Financial model analysis: Students considered the incremental differences for SeQuential to dispose of its grease trap waste at Willow Lake rather than the current method of disposal. This involved an evaluation of the transportation and tipping fees.

Key Findings

Case Study Examples of Co-digestion

In all the cases the students examined, the addition of food and grease waste increased the production of methane per pound of solids fed into the digester, although the level of increase varied greatly. The research revealed that each type of grease waste is distinct in its chemical composition. None of the case studies looked at the energy value of the grease waste after being processed for biodiesel. Because of this, the students were able to make estimations of the potential value of the waste; however, calculation of exact numbers will require on an additional chemical study of the waste's composition.

See Appendix 4 for further details on the findings from these examples as well as results from relevant experiments.

Environmental Analysis

SeQuential's current waste management practices affect the environment in the following ways:

- Transportation: Fuel is used to transport unprocessed WWGT waste and wastewater process water.
- Dehydration: Energy is used to dehydrate the WWGT waste before land spreading.
- Land filling: Land spreading the dehydrated WWGT waste releases greenhouse gases (e.g. CH_4, CO_2) into the atmosphere.

Among these three practices, land spreading has the largest effect on the environment.

The following provides an estimate of the environmental impact of the switching from current disposal methods to cooperation with Willow Lake, with a primary focus on the carbon footprint:

- Transportation: Due to the proximity of Willow Lake, a monthly reduction of 0.64 tons of CO_2 from decreased transportation.
- Dehydration: SeQuential takes the WWGT waste to a processing facility that dehydrates and disposes of it. The carbon footprint of this process is difficult to estimate due to insufficient information. Yet, it is clear that by eliminating this step from the disposal process, these resulting emissions are also eliminated.
- Land spreading: The students used the first order model from the Intergovernmental Panel on Climate Change (IPCC) to estimate the methane potential from land spreading the dehydrated WWGT. The total methane emissions from the current levels of WWGT land-spread waste are about four tons per month. This converts to around 92 tons of CO_2 emitted each month.

Financial Model Analysis

Because Willow Lake is closer than the current disposal location, transportation costs are lower. Thus, the question lies in the tipping fees that Willow Lake must charge in order to cover its costs and whether these fees offer a reduction in costs for SeQuential.

SeQuential's current method of WWGT waste disposal costs $0.15 per gallon. The truck used for waste transportation has a carrying capacity of 7,200 gallons per load and costs $0.03 per gallon of WWGT waste to travel to and from Portland. Thus, the total cost for transportation and disposal is $1,296 per truckload, or $6,480 per month.

Separating out the costs shows where the partnership with Willow Lake could have the most impact. The total transportation cost is $216 per truckload, or $1080 per month. Because the total mileage would be reduced by 75%, these costs would be reduced, however not proportionately with the mileage, as other employee and maintenance costs are involved. The remaining $1,080 per truckload or $5,400 per month is directly for disposal. Based on the price ranges found in other wastewater treatment plants' co-digestion projects, the following table provides a calculation of the savings for SeQuential resulting from different pricing.

Cost	*Baseline*	*Scenarios*			
$/g	0.15	0.05	0.08	0.10	0.12
Truckload	1080	360	576	720	864
Month	5400	1800	2880	3600	4320
Baseline	5400	5400	5400	5400	5400
Savings	**$0**	**$3,600**	**$2,520**	**$1,800**	**$1,080**

Modifications Needed at Willow Lake

The analysis of wastewater treatment plants that process fat, oil, and grease (FOG) revealed the possible need for modifications of the Willow Lake digester in order to accept SeQuential's WWGT waste.

- Mixing the sludge in the digester: Some digesters are not equipped with enough mixing blades to distribute the FOG throughout the chamber. Adequate mixing is essential for the FOG to properly break down in the digester.
- Consistency of the grease waste: The waste coming from SeQuential has already been passed through a ½ inch filter, so most large solid chunks should be removed. This size may be small enough to avoid the addition of a chopper pump to the digester. Some wastewater treatment plants that have started to accept FOG have had to add chopper pumps to ensure the added waste is fine enough.

- The effect of the addition FOG on the pH level of the digester: Some wastewater treatment plants have needed to add chemical pretreatment alternatives to ensure the FOG does not alter the pH of the digester.

While these three areas could result in capital outlays for Willow Lake, the avoided electricity costs and revenue from tipping fees would help offset these costs.

Tipping Fees

A tipping fee is a charge levied upon waste accepted by a waste treatment facility. Digesters that are equipped to accept FOG as a feedstock typically charge a tipping fee for processing FOG waste. Tipping fees for FOG range widely across the country. Current tipping fees for FOG waste in the Portland metro area range from $0.06 to $0.15 per gallon. Gresham's preliminary report of the biodigestion of FOG recommends an initial drop-off fee of $0.03 per gallon to incentivize grease haulers to consider the wastewater treatment plant as an option over the current method of land spreading (CH2MHILL, 2009). However, the CH2MHILL report notes that the wastewater treatment plant could increase the tipping fee over time as it deems necessary. The report also mentions that the wastewater treatment plants could forge relationships with the grease haulers to stabilize the quantity of waste being received.

Methane Production

The potential methane production of this new synergistic relationship could help Willow Lake reduce its energy costs. Using the literature to predict the potential methane production of the processed grease is difficult to accomplish with any measure of accuracy due to the variability of the WWGT waste and the unknown effect of removing yellow grease on the chemical composition of the WWGT waste. Although the literature was inconsistent, the most widely reported result was an increase of methane production (7-30%) with the addition of WWGT waste (Davidsson, 2008) (CH2MHILL, 2009). A 30% increase in methane production from Willow Lake's reported current production rate of 6-9 cubic feet of gas per pound of total solids fed to the digesters, results in a potential 7.8-11.7 cubic feet of methane per pound of total solids. Further chemical testing of the SeQuential WWGT waste will indicate whether Willow Lake can expect a similar increased rate of production.

Conclusions, Recommendations, and Open Issues

Students found that, at the level of accuracy currently available, a partnership between Willow Lake and SeQuential has environmental and financial benefits. They recommend that SeQuential and Willow Lake continue to investigate the methane production potential of this waste to determine an appropriate tipping fee.

The carbon emissions that this partnership will avoid, compared to the baseline process of WWGT waste disposal, are a significant portion of the process's total emissions. Transportation emissions will be reduced by 74% and the emissions resulting from dehydrating and land spreading the waste will be avoided.

Figure 6: Advantages: Less CO_2, and Productive Methane

Financially, the partnership also makes sense. SeQuential will pay less for transportation and any price below $0.15 per gallon results in disposal savings. Based on the research, Willow Lake should be able to charge an even lower price, making SeQuential's savings greater.

These pricing details need further analysis of costs and potential benefits of the WWGT waste. The students recommend a chemical analysis of the WWGT waste to determine its methane production potential. This will help determine a tipping fee for Willow Lake such that both parties benefit. A second analysis will need to be completed to determine what modifications will be necessary for the Willow Lake digester to accept the WWGT waste.

Project #3: Willow Lake Wastewater Reclamation

Figure 7: Willow Lake Wastewater Reclamation

Overview

General

Each day, Willow Lake treats millions of gallons of wastewater and returns it to the environment. All of Willow Lake's activities adhere to guidelines of the federal Clean Water Act. At this time, there is not a concern about the availability of clean water or the ability to discharge wastewater in Salem; however, future shifts in the economic, regulatory, or environmental conditions may provide a strong rationale for water reclamation.

The purpose of this project is to identify opportunities for Willow Lake to secure long-term water reclamation opportunities and reduce wastewater discharge impacts. In order to achieve this goal, Willow Lake must grow institutional knowledge, develop infrastructure capabilities, and foster relationships with local businesses, neighbors, and community members.

Current Situation

Following processing, the treated effluent is currently piped to the Willamette River and the biosolids are spread on area farms.

Methodology

To develop final recommendations, students worked on this project in three stages:

- Situation Analysis: This stage included economic analysis, environmental analysis, and an analysis of the practices used by the City of Salem.
- Case study examples: Students reviewed case studies and economic trends and contacted water reclamation experts in the northwest. Interviews with local business owners in the cement production, agricultural, and recreation industries revealed barriers and opportunities for future water reclamation projects in Salem.
- Cost analysis: To further understand the barriers and opportunities of reclaimed water for Willow Lake, and solidify case study findings, a distribution cost analysis was performed. It was determined that the delivery of reclaimed water from Willow Lake to a potential costumer would result in significant economic costs.

Key Findings from Situation Analysis

Economic Analysis

The opportunities for cost-effective wastewater reclamation are location specific and almost entirely dependent on two characteristics: wastewater discharge limits and water supply constraints.

- Wastewater discharge limits can force cities to implement building moratoriums. Meeting discharge limits often means expensive upgrades to treatment facilities. As a result, reclamation is often seen as a cost-effective alternative.
- Constrained water supply from filtration systems and from the purchase of water rights creates demand for reclaimed water, but the marginal cost of reclaimed water must be cost-competitive with the traditional water supply source. In contrast, the presence of easily accessible, low-cost water supplies significantly undermines the economics of reclamation and is likely to result in short-lived projects.

Environmental Analysis

Reclaimed water efforts are emerging across the country in response to increased water shortages and the push for sustainable development. Increased population projections and warmer temperatures are significantly depleting global water sources. A 2010 study completed by the Natural Resources Defense Council found that over one third of U.S. counties will face water shortages by mid-century. The same study found that 18 Oregon counties will face medium to high water shortages by 2050, including Polk, Benton, Marion, and Yamhill counties. The U.S. currently reclaims only 7.4% of its water, signifying a huge potential for growth in this market.

Although the environmental need and market potential for reclaimed water is evident, there are many barriers. Known barriers to implementing water reclamation projects include the need for innovative technologies, technology transfer, and novel applications; the need for public education and increased public acceptance; better documentation of the benefits of water reuse; the lack of available funding for water reuse projects; working with the media; and the need for support by regulators and politicians.

One of the main barriers to implementing a water reclamation system is overcoming the social stigma. Public health concerns have emerged, fearing that the sewer water could be mistreated and pose serious health risks. Although reclaimed water is highly regulated, people's mistrust has limited the market, affecting successful implementation and use by businesses. Studies have shown that transparency of governance and regulatory institutions are essential for public acceptance of reclaimed water. The more information people are given about the safety and uses of reclaimed water, the more the concept will be accepted. Reclaimed water projects are more likely to be successfully implemented in regions of higher income and education where regulatory agencies are providing extra information on the advantages and safety implications of using reclaimed water.

Despite the social stigma against water reclamation, many of the fruits and vegetables consumed in the United States are produced using reclaimed water. Specifically, California producers use almost only reclaimed water in production. The state provides specific water quality standards for types of crops and stages prior to human consumption. Further, Californian growers face significant environmental and climate risks that could significantly decrease crop production. Although Oregon is less vulnerable than California due to plentiful water supplies, there are projected water shortages for the state, with resulting opportunities for successful wastewater reclamation.

City of Salem Practices Analysis

The City of Salem has launched a number of sustainability initiatives, including energy efficiency programs, an environmental action plan, watershed preservation and protection programs, and a water conservation program. The water conservation program includes a "one-inch-per week" lawn watering program and a state-mandated water conservation plan. The city's water conservation plan focuses mainly on affecting the residential customer class by reducing water consumption during peak hours. In the past, the city provided small grants to businesses exploring water conservation projects. Due to budget cuts, those funds are currently unavailable.

Although there are currently no water shortages, policies, or regulations driving the City of Salem to develop a more robust water reclamation system, the city does anticipate that this will change. With impending state and nationwide water shortages, the city would like to position itself for changing conditions. Moreover, the city sees water reclamation as a potential economic development strategy. In line with Business Oregon's 2009 Strategic Plan, Salem hopes to attract the renewable energy/clean technology and metal manufacturing industries. These industries are known for using huge amounts of water. Being able to provide cheap non-potable water to incoming industries will make Salem more appealing. The City of Salem, in partnership with the Sustainable Cities Initiative, will be conducting a target industries assessment plan in early 2011 to help position itself to attract these industries.

Key Findings from the Case Studies

Wastewater reclamation projects can take a variety of forms. Although certain system-dependent aspects can be generalized, issues surrounding cost structures, infrastructure and usage requirements, social perceptions, and overall feasibility occur on a case-by-case basis.

A look at the issue as it pertains to specific cases provides detailed explanations of potential benefits and constraints. Students' analysis of successful projects worldwide and local industrial water usage rates determined that the most theoretically suitable industries to consider partnering with Willow Lake were concrete production, agriculture operations, and recreation, including golf courses, driving ranges, and public parks.

A search of relevant businesses in the geographic area, within a radius of approximately 11 miles, was performed, and interviews with business operators were conducted. The operators were presented with questions regarding their potable and non-potable water usage amounts, cost structure, and opinions about using reclaimed water in their operations.

Findings from the following cases can be expanded and used as a reference for the future application of reclaimed wastewater in a variety of industries, and have been used as the basis for final recommendations:

- Concrete Case Study: With approximately 10 concrete production companies located within 11 miles of Willow Lake, there is potential for the development of symbiotic water reclamation relationships. The concrete companies contacted are operating with closed-loop non-potable water systems. Water is pumped from on-site ponds/quarries to satisfy all wash-out requirements, and is recycled back after use. Wash-out areas often feed into filter dirt which is used by other companies as mineral-rich top soil. Through this self-contained system, the facilities avoid the large costs associated with high-volume fresh water use, separate potable/non-potable pipe infrastructure, and trucking water.
- Agriculture Case Study: The agriculture industry consumes a large amount of groundwater and surface water, accounting for 80% of total water used in the U.S. Given this trend, and the large agricultural base in the Willamette Valley, there is a strong incentive to utilize reclaimed water in the agricultural and food processing industries in Salem. However, although water usage is high, the social stigma around reclaimed water in food products is a significant barrier to implementation. To further understand business perceptions, barriers, and opportunities in the agricultural sector, students contacted food processing operations and nurseries.
- Recreation Case Study: Because golf courses are major users of water in the recreation industry, they have emerged as excellent partners for water reclamation facilities around the world. This trend applies to the Pacific Northwest as well. The communities of Bandon, Bend, and Newberg in Oregon, and several more in Washington, provide reclaimed water to nearby golf courses. The students examined two cases: a golf course partnership with Willow Lake that did not last and another from Snoqualmie, Washington that has been a primary driver for reclamation. Success at Snoqualmie required more than just infrastructure improvements. Public education efforts were critical to long-term acceptance. Contrasting the experiences of Snoqualmie and Willow Lake further emphasize the role external drivers play in the feasibility of reclaimed water.

Further details on the case studies are shown in Appendix 5.

Key Findings from Cost Analysis

The two primary delivery methods are a subterranean pipe system and tanker trucks. This section identifies the costs associated with delivery of reclaimed water from Willow Lake to its potential customers.

- Subterranean pipe system: The most recent bid for a water line replacement project in the City of Salem closed on November 2, 2010. That project encompassed 1.3 miles of excavation and replacement over three roads;

Crestview Drive, Neelon Drive, and Garlock Avenue. Estimates ranged from $516,000 to $767,000 to complete the project. While costs per mile of water line will fluctuate based on a number of factors, a conservative estimate of $590,000 per mile of water line can be derived from the high bidder ($767,000 / 1.3 miles). According to a 2004 study conducted by HDR, Inc. for the City of Salem, the city would need approximately 44 miles of 8-inch pipe to establish a delivery system network for reclaimed water. The estimated costs were $24.1 million “for pump station modifications and reuse water distribution system associated with first 1.0 mgd” (million gallons per day) and $7.6 million for each additional mgd (City of Salem, 2004).

- Tanker trucks: Trucking reclaimed water to a specific location is an expensive proposition. A 2,000 gallon tank truck costs around $200,000. The truck requires regular maintenance and staff to operate. Additionally, the life span of a truck is finite, with engines being rebuilt or replaced every 1 million miles on average. The largest operating expense is fuel. Large diesel engines get 6 to 8 miles per gallon depending on a number of factors. Current diesel fuel prices in the Salem area range from $3.30 to $3.50 per gallon. In addition to the capital expenditure for the truck, maintenance, and labor, trucking water to a location 10 miles away would have a fuel cost of approximately $12 per round trip, or $0.006 per gallon of water.

An Example of a Wastewater Transportation Cost Comparison: Oregon Cherry Growers

Oregon Cherry Growers, Inc. consumes over 500,000 gallons of water annually and is 6.1 miles away from Willow Lake. Using the costs associated with a per mile water line replacement, the cost of installing a pipe from Willow Lake to Oregon Cherry Growers Inc. is $3.6 million. Assuming the lifespan of the water

Assumptions Table

Pipe System			Truck			City		
Cap Ex	$ 590,000	per mile	Cap Ex	$ 200,000		Agricultural	$ 3.31	per 100 cf
Flow Rate	500	gpm	Mn + Labor	$ 200,000	annual	Industrial	$ 2.12	per 100 cf
Lifespan	75	years	Lifespan	1,000,000	miles			
			Tank Size	2,000	gallons		7.48	cf / gal
			Use	50,000	miles / year			
			Fuel	$ 3.50	per gallon			
			Efficiency	6	mpg			

Results Table

			Price per Gallon		
Organization	Distance (m)	Water Use (gpy)	Pipe	Truck	City
Oregon Cherry Growers	6.1	500000	$ 0.0960	$ 0.0164	$ 0.0044
Norpac	11	440000	$ 0.1967	$ 0.0295	$ 0.0044
River Bend Sand and Gravel	10.8	200000	$ 0.4248	$ 0.0290	$ 0.0028
Cemex	11.4	300000	$ 0.2989	$ 0.0306	$ 0.0028

These calculations are not discounted to reflect the time value of money

Figure 8: Cost of Delivery of Reclaimed Wastewater in Salem through Current Transportation Alternatives

line is 75 years, that all 500,000 gallons could be replaced with reclaimed water, and that pumping costs are negligible, the cost to deliver reclaimed water via pipe is $0.096 per gallon. These calculations are not discounted to reflect the time value of money. Using some broad assumptions about allocating expenses associated with owning and operating a truck, students calculated the per gallon price for water delivery by truck to Oregon Cherry Growers. Figure 8 on the previous page depicts the same calculations for other local businesses.

As the results show, the delivery of reclaimed wastewater in Salem through current transportation alternatives is highly cost ineffective. Major alterations, such as alternative delivery methods, need to occur before the use of reclaimed water becomes a more attractive option.

Conclusions, Recommendations, and Open Issues

The case studies and cost analysis show that the use of reclaimed water in the region under the current system is not cost effective. However, future water supply and discharge limitations indicate the need to start considering multiple reclamation alternatives now.

Strong social and environmental arguments can be made for the use of reclaimed wastewater in non-potable water applications, especially in cities facing water shortages. As illustrated in the above case studies, though, the use of reclaimed wastewater in the Salem area is currently not cost effective nor is it a pressing issue. However, long-term water supply constraints, water discharge limits, and possible regulations suggest there are future risks that Willow Lake should be prepared to mitigate. To prepare for future water shortages and impending regulations, Willow Lake should understand the long-term risks to water supply in the region and begin laying the groundwork to expand wastewater reclamation opportunities in the future. This long-term water supply resilience will be a result of having the institutional knowledge and physical capacity to reclaim wastewater when necessary. Willow Lake must remain at the forefront of technology, applications, and business models for reclamation systems. This capacity may not be cost effective today, but imposing environmental and economic trends suggest value in beginning to build it immediately. This organizational shift, along with the strategies described below, could help Willow Lake achieve its environmental and economic goals over the long term.

The following recommendations were identified for Willow Lake and the City of Salem to foster relationships and grow institutional capabilities that will provide long-term water security:

- Expand Pre-treatment Program: Strengthen Willow Lake's capabilities to provide greater levels of technical assistance to local small-scale water reclamation projects.
- Mini Reclamation: Explore opportunities to add capacity through satellite reclamation facilities serving specific locations with reclaimed water tailored

to local demand.

- Economic Development: Partner with the City of Salem Economic Development Division to link business attraction initiatives to water reclamation projects and infrastructure.
- Laying Purple Pipe (see Appendix 6): Invest now in the infrastructure required to support a system-wide reclamation system.

The development of outreach programs to residents, business owners, and institutions can help educate people on the uses and safety of reclaimed water and begin to lay the foundation for regional water supply resilience.

Appendix 6 shows details on the recommended strategies, including an explanation of "purple pipe."

As the above recommendations commence, education and outreach initiatives become increasingly more important. In order to increase community support and grow relationships with other businesses and organizations, both of which are critical for water reclamation to be successful, Willow Lake must begin to develop education and outreach activities. There are many examples of wastewater treatment facilities that use interactive stations and dioramas to communicate with audiences on site. Additionally, Willow Lake could include brochures in its paper monthly billing cards.

All of the water reclamation strategies outlined above – expanding the pre-treatment program, mini-reclamation, economic development, and laying purple pipe – require relationships with and buy-in from neighbors and members of the service area. Willow Lake's Salem Demonstration Project Natural Reclamation System is a good start to engaging the public. At this point, Willow Lake could engage community members, current business owners, and future business owners in understanding the benefits of system wide water reclamation and begin to lay the groundwork for long-term water supply resilience.

NORPAC Case Study

About NORPAC

NORPAC was founded in 1924 as a grower cooperative by a group of farmers to develop a market for the central Willamette Valley's fruit and vegetable crops. Today, NORPAC is a nationally recognized farmer cooperative and processor of vegetable and fruit products with over 240 farmer-members who manage 45,000 acres and produce over 600 million pounds of produce per year. As a leader in innovation, NORPAC's values form the basis of their mission: To be Stewards of the Environment (NORPAC).

In 2010, NORPAC partnered with Sustainable City Year students to assess current waste disposal solutions. NORPAC's motivation for this project is to find a more sustainable solution for the disposal of over 1,400 tons per year of unmarketable canned goods (Steele, 2010).

Figure 9: NORPAC

SCI Projects' Focus for NORPAC

NORPAC projects evaluated opportunities to reuse, recycle, or compost waste generated from facilities in Stayton, Salem, and Brooks through two separate projects.

Project #4: NORPAC Repack

This project identifies alternative uses for mixed food waste from NORPAC's repack facility; this waste includes some meat, and therefore cannot be used in cattle feed. Previously, this waste was used as pig feed and it currently is being land spread as fertilizer. Hauling costs are the largest cost in delivering the waste to farmers. Students explored whether there are other viable alternatives for this waste that are both cost effective and environmentally favorable to the current approach.

Project #5: NORPAC Can Recycling Analysis

This project explores whether an economically and operationally attractive opportunity exists to recycle materials currently being landfilled by NORPAC. This material includes filled canned vegetables that are used for quality testing or otherwise not sold on the market (approximately 300 tons per year). Students considered whether there is a way, within NORPAC's current operational footprint, to separate the cans from the vegetable matter, recycling the former and composting the latter.

Project #4: NORPAC Repack

Overview

General
This project creates a viable strategy for NORPAC to achieve its goal of conserving and recycling nutrients in its facilities by discovering opportunities to reuse, recycle, or compost the waste generated by operations.

Current Situation Analysis
There is approximately 1,100 tons of waste generated per year from NORPAC's operations. Traditionally, this waste has been used as pig feed, but currently it is being spread on land as fertilizer.

Alternatives
Through extensive research, the following three alternatives were identified as possible solutions:

- Biogas Generation: converting the waste to biogas
- Composting: converting the waste to compost
- Vermicomposting: converting the waste to a higher-end compost

While each alternative has its own benefits and challenges to NORPAC, the alternative that is seen as most viable to NORPAC is the last one – vermicomposting, or worm composting.

Methodology

To asses the NORPAC's alternatives the students studied the general application of each alternative as well as the specific implications for NORPAC. The students then analyzed the main considerations for each alternative (e.g. regulations, budget) and provided recommendation and next steps for each alternative.

Considerations affecting the viability of possible alternatives included:

- Cost to implement and maintain
- Benefits to environment and sustainability measures
- Organizational "fit" with current company operations

The students used the assessment of each alternative to recommend the alternative that is best suited for NORPAC.

Key Findings

Alternative 1: Biogas Generation
This alternative entails converting the food waste to biogas through anaerobic digestion, a process by which microorganisms break down organic material and convert the waste into methane and carbon dioxide; the methane can be used to generate electricity. This process is a fairly common option for recycling food

processing and crop waste in Europe, and is becoming more common in the United States.

Students investigated:

- Other anaerobic digesters
- Viable waste inputs for anaerobic digestion
- Food manufacturers within a 10 miles radius
- Food growers within a 10 miles radius

The students found that there is more than enough available material to support the infrastructure for an anaerobic digester. See Appendix 7 for maps of relevant locations.

It is less common to see the use of anaerobic digesters at food processing facilities. Students found this surprising, given the number of economic and environmental incentives for food processors to consider them. For example, Stahlbush Farm, located in Corvallis, recently installed an anaerobic digester to break down food processing waste to turn it into electricity for its facilities. This digester has the capacity to digest about 55,000 tons of food processing waste per year, and provides double the amount of electricity required to power the farm's entire plant. All additional electricity generated from the digester is then sold back to a utility company. As an added bonus, the farm received a number of grants and credits to help finance the cost of its digester (oregonlive.com). This is one of many cases in which food processors have improved their financial situations through the installation of anaerobic digesters.

Anaerobic digesters are not limited to processing one type of waste at a time. In California, a wastewater treatment plant currently combines biosolids from its operations with food wastes collected from local restaurants and food processors to create biofuel through anaerobic digestion.

NORPAC can consider the following alternatives for anaerobic digestion:

- Partnering with Willow Lake to deliver NORPAC's food processing waste to Willow Lake's existing digester.
- Creating a regional digester facility through partnership with other food processors, growers, or businesses including SeQuential.
- Building a digester for waste from NORPAC's multiple facilities. The Repack Facility produces only about 1,500 tons of waste per year. Consolidating waste from all facilities would amount to about 143,000 tons, which would make this alternative much more feasible.

Relevant considerations for this alternative include: energy contracts, digester type (wet vs. dry), local regulations and programs, budget, collection, waste hauling, and carbon footprint analysis. See Appendix 8 for more details on these considerations.

If considering NORPAC only, the environmental and economic benefits for implementing the anaerobic digestion alternative would be too small to support the purchase of the system. If partnerships and synergies in and around Oregon can be created, this alternative becomes much more viable.

To make this alternative viable, NORPAC could look to create partnerships with local businesses to collect enough waste volume to capitalize on the benefits of anaerobic digestion.

Alternative 2: Composting

Composting is the natural process of rotting, or decomposition, of organic matter by microorganisms under controlled conditions. Raw organic materials such as crop residues, animal waste, food garbage, and some municipal waste can be used in creating compost as a fertilizing resource.

Figure 10: Compost

There are two main types of composting: anaerobic and aerobic. In anaerobic composting, decomposition occurs where oxygen is absent or in limited supply. Anaerobic microorganisms decompose the matter and produce several byproducts that include methane, organic acids, and hydrogen sulfide (FAO).

Aerobic composting takes place in the presence of an ample supply of oxygen. The byproducts produced by the organisms in this process include carbon dioxide, ammonia, water, heat, and humus. Although this process can produce organic acids, they are broken down further than in anaerobic composting, which greatly reduces the toxicity. The high heat involved in aerobic composting allows for matter to break down much more quickly, which reduces the total processing time.

Because NORPAC's Repack Facility handles waste that includes meat, special treatment and regulations would apply to the composting process. Meat, or carcass, composting must be broken down into three specific types. Because of the additional processing required, meat-waste composting can take as long as 120-180 days to complete (Solutions to Crook County Disposal).

NORPAC can consider the following models for composting:

- The composting company owns the contributing waste; NORPAC would be able to charge a raw material fee for delivery of the the waste product.
- NORPAC controls the ownership of the waste product, the composting companies can charge a fee for the composting process, and then NORPAC can provide (or sell) the fertilizer to its own farmers or sell it on the market.
- A third party processor handles the transport of waste to and grinding of waste at the composting facilities. This model will have fees from both the third party and the composting facility, but NORPAC would be able to use

the fertilizer or resell it with a much quicker turnaround time due to the streamlined process.

- NORPAC would build its own composting facility; however, careful consideration has to be placed on the costs of regulation and equipment investment necessary to run a successful composting operation. With meat in the waste, it becomes economically unattractive to build a facility to treat this waste.

Relevant considerations for this alternative include: regulation, required infrastructure, and environmental impact. See Appendix 8 for more details on these considerations.

If considering the alternative of NORPAC building and owning its own composting facility, the economic benefits are too small and capital outlay is too high to be feasible. If considering partnerships or outsourcing of the waste for composting, it is unclear whether or not the economic benefits support this alternative. However, both alternatives do make sense environmentally, due to a large reduction in greenhouse gas emissions.

To make this alternative viable, NORPAC must search to build a partnership with one of the 12 local composters for which certification to handle meat waste can be obtained. Creative solutions and profit sharing can make the incentives large enough for one of these composters to become certified.

Figure 11: Composting Overview

Alternative 3: Vermicomposting

Vermicomposting, commonly known as worm composting, is the process of utilizing various species of worms to decompose vegetable or food waste, bedding materials, and vermicast. Once complete, the process ends with high-end compost, which can be used as fertilizer or sold on the market at a premium. Vermicomposting offers a unique opportunity to deal with food waste in an environmentally beneficial way.

Figure 12: Vermicomposting

Two options to implementing the vermicomposting alternative were analyzed:

Option 1: Partnership between NORPAC and Oregon Soil Corporation (OSC)

NORPAC may be able to partner with a local vermicomposting operation to lower their operational costs and reduce its overall carbon footprint. This diversion strategy would involve shipping the estimated 1,100 annual tons of the waste to a vermicomposting facility.

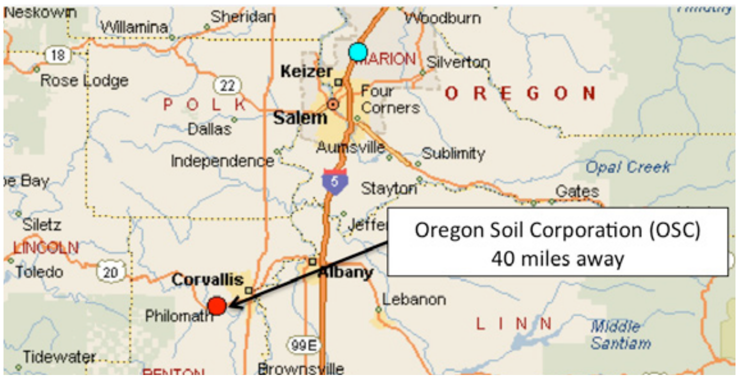


Figure 13: Vermicomposting - Partnering with the Oregon Soil Corporation

The Oregon Soil Corporation (OSC) facility is approximately 40 miles from the Salem area, in the town of Philomath, Oregon. Since 1988, OSC has been an influential industry leader in vermicomposting, providing both installation consulting and state of the art vermicomposting equipment.

One of the key operational requirements for a vermicomposting facility is consistency in feedstock. The worms need consistent feeding in order to maintain healthy populations and composting conversion. A partnership with NORPAC would help OSC maintain that important consistency of feedstock.

The meat component within NORPAC's waste may be a concern for OSC. If it is an issue, the waste would first have to be aerobically composted, taking advantage of the high composting temperature to sterilize the waste by killing pathogens associated with meat in the waste.

The key to making this option a success, at least financially, is to ensure the partnership includes revenue sharing with the sale of the worm castings. As the data indicates, there is very little environmental benefit, in terms of total greenhouse gas reductions.

Option 2: NORPAC On-site Vermicomposting Facility

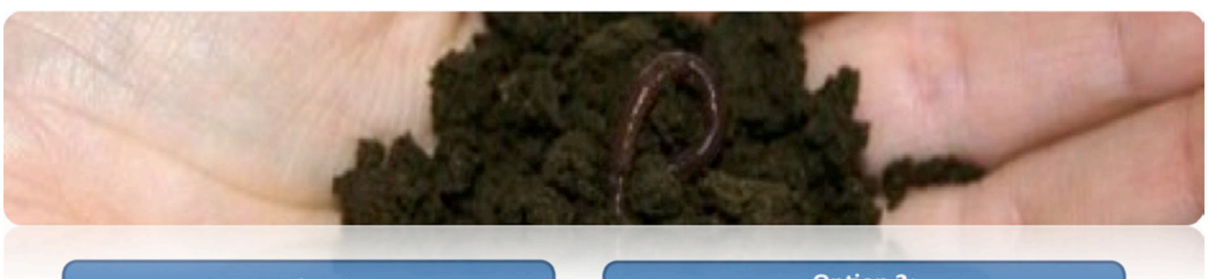
As an alternative option to shipping the waste, NORPAC could investigate constructing an on-site vermicomposting facility. This facility would provide additional reductions in greenhouse gases, as well as a saleable by-product – worm castings, a high-nutrient fertilizer.

Given the consistency and amount of vegetable waste available from NORPAC's operations, there is reason to believe that it may be feasible to operate a vermicomposting facility on-site. Research into existing vermicomposting operations suggests a minimum daily input of 0.5 tons per day of feedstock (food waste) (Holcomb, 2010). NORPAC is currently producing an average of 3 tons per day. This large amount of potential feedstock suggests that NORPAC has sufficient waste to operate a vermicomposting facility.

It is important to note that a vermicomposting facility is similar to any other operation that cares for livestock, in that the worm population will require consistent input of feedstock to maintain its health. If a facility cannot insure a consistent amount of feedstock, it is recommended that backup or supplemental sources are planned for. This could include manure from local dairy farms, poultry houses, or hog farms (Yelm Earthworm and Castings Farm, 2010).

The vermicomposting process converts the input feed stock to half its weight, therefore with an input of 1100 tons annually, it is estimated to result in 550 tons of worm castings. The castings are a highly prized soil amendment, sought by landscapers, gardeners, and horticulturists. Studies of nutrient-rich work castings have proven their preferred value over ordinary compost and synthetic fertilizers. The castings have excellent soil structure, porosity, aeration, and water retention capabilities (Bogdanov).

This high performing fertilizer is sold for approximately $1 per pound (Organic and Mechanic); therefore a 550-ton output has an estimated annual retail value of $1.1 million. The estimated capital cost for a large-scale facility processing approximately 10 tons/day (2,500 to 3,000 tons/yr) of food and yard waste is approximately $30,000 to $40,000 for a basic reactor system, not including land costs. Operational costs are estimated at approximately $40-60 per ton; the capital and installation costs would require further exploration (Vermicomposting). Further financial analysis is required to fully evaluate this business opportunity, but initial review suggests high potential for profitability.



Option 1:
NORPAC & OSC Partnership

Advantage: 30% reduction in shipping costs.

Disadvantage: Minimal greenhouse gas reductions.

Option 2:
NORPAC On-site Vermicomposting Facility

Advantage: Additional income stream from the sale of worm castings.

Disadvantage: New operational requirements to facility.

Figure 14: Vermicomposting Overview

Students evaluated the following considerations:

- Expertise of Personnel: Vermicomposting is a delicate process and must be monitored closely by an experienced professional, which will require additional staffing expertise outside of the normal business operations of NORPAC.
- Regulations: As mentioned previously, the meat content will require composting prior to being fed into the vermicomposting reactor. There may also be other regulatory and permitting issues that will be specific to the Salem area. NORPAC would need to research and anticipate possible barriers to successfully implementing a vermicomposting operation.
- Environmental Impact: By installing a vermicomposting facility, NORPAC would reduce the carbon footprint associated with the current transportation of the waste to the local field. This would reduce the GHG emissions by 0.5 tons annually.

The following next steps are recommended for NORPAC:

- Explore partnership options between NORPAC and OSC to determine if there is mutual benefit and strategy fit. This would include detailed discussions of tipping fees, if applicable, and other logistical issues related to delivery and frequency.
- Determine feasibility of relationship. If feasible, proceed with formal contract agreements.
- Complete a financial analysis of the option to install and operate a vermicomposting operation on a NORPAC site. Compare this option with other alternatives examined in this report.

Conclusions, Recommendations and Open Issues

The following chart summarizes the three alternatives that were discussed for this project, which include converting waste to bio-gas, converting waste to compost, and converting waste to higher end composting (vermicomposting).

		Micro	Macro
Bio-Gas	ECO	No. Too small.	Yes. Volume large enough.
	ENV	No. Too small.	Yes. Volume large enough.
Composting	ECO	Permit /EQU Too high.	Maybe/who owns the compost.
	ENV	Yes. GHG reductions.	Yes. GHG reductions.
Vermicomposting	ECO	Yes. 1.5M revenue.	No. Too big.
	ENV	Yes. GHG reductions.	No. Too complicated.

Figure 15: NORPAC Repack: Summary of Alternatives

While each has its own benefits and challenges, the alternative with the highest revenue potential and environmental benefits to NORPAC is the vermicomposting alternative. Specifically, NORPAC should look to create a partnership with OSC to develop a vermicomposting operation.

Project #5: NORPAC Can Recycling Analysis

Overview

General

With four plant locations that run canning production lines, and landfill costs averaging $16,800 annually, NORPAC has an economical and an environmental interest in evaluating sustainable canning solutions. Students assessed the current disposal solution, evaluated three potential strategies for a more sustainable disposal process, and made final recommendations to NORPAC.

Figure 16: Green Growth

The canning process is simplified in the figure below, identifying the waste produced at each step. At this time, NORPAC employs waste reduction strategies during the first three steps. The last step, packaging, has not been evaluated for sustainable improvements or waste reduction. The team focused its research and recommendations on this last step of the canning process.

Figure 17: Current Operations at NORPAC

The following figure details four of the nine sustaining principles developed by the NORPAC board of directors and the Stewardship Planning Committee that directly relate to canning operations. These principles encourage further

Sustainable Principles	**Course of Action**	**Impact on Canning Operation**
Continually Improve Practices	Seek out new and innovative business practices	Innovation is the key driver to improving canning operations
Conserving and Recycling Nutrients	Converting Organic waste into productive uses	Currently, organic material inside discarded cans is landfilled
Quality Fruits and Vegetables	Critical control monitoring	Implementing sustainable strategies
Protecting and Conserving Water Resources	Increasing water efficiency	Water used for canning consistently monitored

innovation and form the basis of the short-term and long-term recommendations for sustainable canning operations (NORPAC Stewardship).

In addition to these internal principles, as an innovator NORPAC may choose to incorporate the principles of industrial ecology. By doing this, NORPAC can increase efficiencies, reduce costs, and continue toward the goal of environmental stewardship.

Current Situation Analysis

NORPAC has three facilities whose four-year average of canned produce is 19,000 tons per year. 300 tons of defective cans are being landfilled annually.

Currently, there are two basic approaches to dealing with canned waste at NORPAC:

- When labor is available, plants try to effectively recycle all components, the organic matter as well as the steel. The cans are first opened by hand and the contents are used for either cattle feed or fertilizer. The steel cans are recycled.
- When labor is not available, the defective cans are simply landfilled together with the rest of the waste from the plant operations.

Overall, the current disposal methods are inconsistent across the plants and depend on the labor capacity available within the plant to manually open cans. As such, there is an opportunity to standardize the waste management in a way that not only benefits NORPAC operations in terms of cost and efficiency, but also is consistent with their corporate sustainability principles.

Environmental implications:

- Methane emissions from landfill: The EPA has reported that methane from landfills account for 34% of all national methane emissions (Humboldt Waste Management Authority, City of Eureka, City of Arcata, Pacific Gas and Electric Company, 2010). Furthermore, methane is about 20 times more damaging than carbon dioxide, in terms of global warming potential (National Sustainable Agriculture Information Service).
- Potential risk to water systems from leaching: Reducing food waste in landfills is a critical component in reducing greenhouse gases, because food waste usually has high moisture content, so when it decomposes, it leaches metals, contaminating water sources.
- Greenhouse gas emissions from transportation of defective cans.
- Depleting sources of steel: According to the Steel Recycling Institute, all steel products, including food cans, are recyclable. Currently, more than 65% of the steel produced in the United States is recycled. “By recycling your steel cans, you not only provide the steel industry with a much-needed resource, you also divert material from the landfill, help save energy, and preserve precious domestic natural resources” (Steel Recycling Institute).

While the total amount of cans sent to landfills by NORPAC each year is small within the grand scheme of operations, there is an opportunity to find more environmentally friendly ways to manage this waste. As a leader in innovation, NORPAC is in the ideal position to lead efforts in creating an organization that encourages sustainable waste management. This coalition could lead the efforts for further partnership efforts in achieving industrial symbiosis.

Strategies

Students evaluated three strategies:

- Recycle 100% of Cans: Each plant currently employs a different disposal method for defective cans as the result of a decentralized operational infrastructure. A significant amount of autonomy is given to each plant manager, and plant operations differ significantly. The issue lies within the operational capacity of NORPAC. When a plant's canning operations increase, so does the number of defective cans. As these cans are loaded into the plant's designated municipal recycling bins, the bins eventually become full and the remaining cans are sent to landfill.
- Partner with Recology: This strategy uses collaboration from within and outside the industry to salvage as many faulty cans and food waste from going to landfills as possible. In addition, more operational efficiency can be achieved through this plan due to its reliance on existing parts of the supply chain, playing on the strengths of collaborators, and collecting the waste stream from other canneries in the area. Through a shared investment made by all waste contributors, environmental responsibilities can be handled through a third party while allowing NORPAC to establish itself as a community leader and innovator in environmental stewardship.
- Investigate Digester Opportunities: taking advantage of an existing element at a nearby location, or considering the possibility of building one on-site at the Madrona plant in Salem. If executed successfully, the biogas production process can become fully sustainable, by using the output (methane) to heat or cool parts of the chain, or by converting the gas to electricity to run the operations.

Figure 18: Approach, Stakeholders, and Constraints Used to Evaluate Strategies

Methodology

The figure on the previous page displays the approach (sources of information), the stakeholders (those affected by NORPAC's business), and the constraints (NORPAC's available resources) that the team used to evaluate the three strategies for NORPAC. All were considered when making the final recommendation.

Key Findings

Strategy 1: Recycle 100% of Cans

Overview

There are many steps leading up to NORPAC's final disposal of can waste to the landfill. NORPAC has four plants involved in the production of canned goods: Brooks, Madrona, Salem, and Stayton (both the "Madrona" and "Salem" plants are located in Salem). Each plant currently employs a different disposal method for defective cans as a result of a decentralized operational infrastructure. A significant amount of autonomy is given to each plant manager, and plant operations differ significantly.

Both the Brooks and Salem plants have very small canning operations, which allows recycling to be more manageable. By delegating employees to recycling duties during 'down' time, these plants are able to manually open the majority of their defective cans and distribute them to municipal recycling bins. The canning operations at Stayton are significantly larger. The higher level of production leads to a larger number of defective cans for recycling, while the plant's capacity remains equivalent to the smaller plants. Therefore, Stayton only has the capacity to recycle about 50% of its can waste. Madrona is NORPAC's labeling plant and represents the final level of quality assurance. As a result, Madrona produces nearly 65% of NORPAC's total defective cans; it recycles none of them (Steele, 2010).

The issue lies within the operational capacity of NORPAC. When a plant's canning operations increase, so does the number of defective cans. As these cans are loaded into the plant's designated municipal recycling bins, the bins will eventually become full and the remaining cans will be sent to a landfill.

A systems analysis reveals that NORPAC has the capacity to recycle while production is low, but a decreasing capacity to do so with increasing disposal demand. The company faces a clear capacity issue; by reorganizing its current processes to better meet this demand, NORPAC may be able to close the loop on its current landfill waste stream in a relatively short period of time.

Implementation

The following chart lays out a step-by-step implementation plan to assist NORPAC in achieving this goal:

Step 1- Centralized Collection of Defective Cans

- Leave defective cans intact and transport all of them to Madrona
- Utilize current shipping routes

Step 2- Opening

- Relocate current can openers (Edlund 625A models) to Madrona
- Direct employees to manually open cans during down time or implement a schedule that delegates opening duties to employees during historical down time
- Divide metal scrap and food waste into two bins

Step 3- Sell & Recycle Scrap Steel

- Sell cans to current scrap metal partner and receive 40% of the proceeds
- Utilize partner's regular pickup schedule

Step 3A- Spreading

- Continue to spread food waste on nearby fields for fee($.10/lb of weight gain in cattle)

Step 3B- Composting

- Transport the food waste to Recology for $30/ton

Figure 19: Step-by-step Implementation Plan to Achieve Zero Waste Now

Benefits

This strategy takes advantage of pre-existing shipping routes and can openers at no added cost. It also utilizes employee down time and adds value and efficiency through employee specialization. By centralizing can opening duties to one plant, employees can benefit from a faster learning curve. As they become more familiar with the can openers, both their operational skills and efficiency will improve. This will minimize safety risk to employees and damage

COST TYPE	ACTIVITY
Transportation	Defect cans are transported to Madrona on current shipping routes
Transportation	Utilizing pre-existing partnership and pickup routes
Capital	NORPAC already owns can openers
Labor	Reducing labor required to manually open cans; a conservative estimate of this demand requires that cans be opened for 5hrs/day, 5days/wk, 52 wks/yr

Figure 20: Benefits for NORPAC Can Recycling Strategy #1

to machines. Moreover, it creates a simple, consistent process for the entire company to follow.

As an environmental leader, NORPAC should regularly assess its operations and identify opportunities to increase the efficiency of processes and to ‘close the loop’ on certain waste streams or emissions. Food waste accounts for 20% of municipal solid waste today. By changing the disposal model to discontinue landfilling, NORPAC will greatly reduce the amount of total food waste going to the Marion County landfill. This will reduce local methane and leachate pollution. Moreover, both spreading and composting increase carbon sequestration, soil water retention, and crop quality, according to the EPA.

By establishing more environmentally conscious methods of disposal, NORPAC will not only realize economic savings from avoided landfill costs, but will also further its mission to become an environmental leader within the industry. NORPAC has a clear opportunity to achieve zero waste within its canning operations right now. By reorganizing the current disposal process, NORPAC can increase its operational efficiency and successfully achieve zero waste within its canning function.

Strategy 2: Partner with Recology

Overview

This strategy uses collaboration from within and outside the industry to divert as many faulty cans and as much food waste from landfills as possible. In addition, more operational efficiency can be achieved through this plan by relying on existing parts of the supply chain, playing on the strengths of collaborators, and collecting the waste stream from other canneries in the area. Through a shared investment made by all waste contributors, environmental responsibilities can be handled while allowing NORPAC to establish itself as a community leader and innovator in environmental stewardship.

Partnering with Recology Oregon Material Recovery (Recology) requires NORPAC to take the lead in developing a joint initiative between internal locations in Salem as well as four other nearby canneries. The goal is to accumulate all faulty cans and then transfer them to Recology to be recovered for compost material and steel. This waste stream will be made possible through investment in a commercial can opener funded proportionally by each cannery. The financial incentive for NORPAC and the other canneries will be reduced tipping fees, reduced transportation costs associated with recycling the cans and their contents, and improved efficiency in waste programs. NORPAC will also benefit through goodwill. By following through with advocated sustainable principles, NORPAC will strengthen relationships with stakeholders and its reputation in the community by establishing itself as a leader in environmental stewardship. Recology benefits from this plan through streamlining the collection of the cans, developing a new revenue stream, and goodwill through an expanded presence within the community.

The resources that would be required to initiate this program include necessary equipment expense as well as some major logistical planning. To identify the possible scale of this program, students first identified the probable partners. As Salem is an agricultural cluster, there are several other canning operations that stand to benefit from this opportunity. The four most likely partners and their contribution to the waste stream are as follows:

Company	Cans Processed	Recyclable Cans/Yr*	Recycling?
Truitt Brothers	72 Million	36, 000	Yes
Calyx Fruit Company	3 Million**	1, 500	Yes
Oregon Fruit Products Company	7 Million	3, 500	Yes
NORPAC	22 Million	11, 000	Yes
Total	**104 Million**	**52, 000**	

* Assumed .05% Faulty Can Rate

** Could not be contacted, assumption based upon # of employees and estimate from Kurt Alameda, Oregon Fruit Co.

Figure 22: Summary of the Four Most Likely Partners and Their Contribution to the Waste Stream

The companies identified for the collaboration were chosen based upon the amount of cans that would enter the waste stream, as well as their location relative to NORPAC and Recology. In the case of Truitt Brothers, the large amount of cans contributed was beneficial, but their operational capacity to assist in transporting the cans was also a primary factor. All companies are located in Salem, and the shortest route from the farthest company to Recology is only 15 miles.

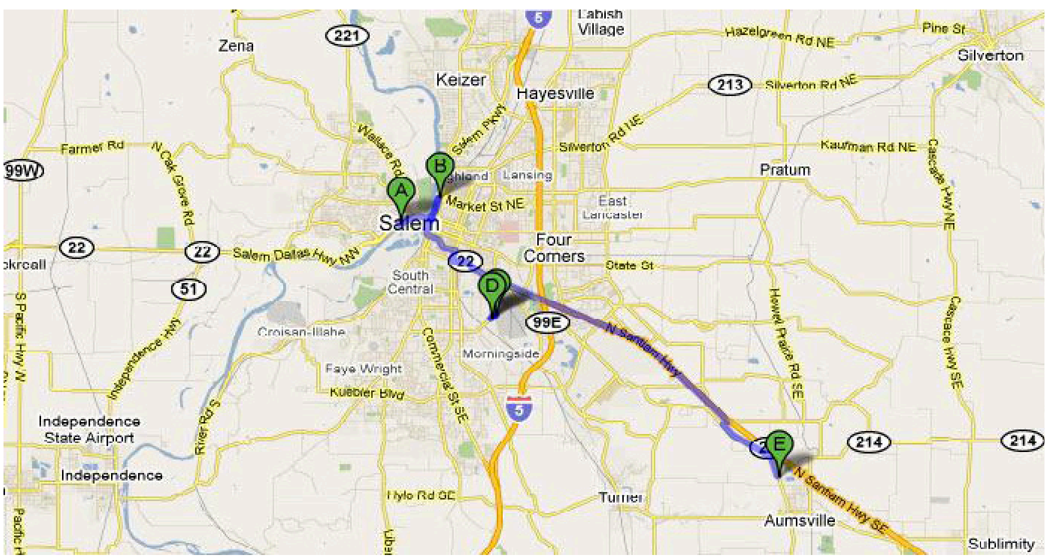


Figure 23: (A) Oregon Fruit Products Co. (B) Truitt Brothers (C) Calyx Fruit Co. (D) NORPAC (E) Recology

There are many commercial can openers available; however, the best alternative would allow for minimum involvement of manual labor due to liability and cost concern. The alternative presented by Mark Steele, CEO of NORPAC, fulfilled these requirements. Therefore, the calculations and investments used in this recommendation are based on the purchase of the Edlund 925 commercial can opener.

Since Recology is the only regional organization that has the capacity to handle the number of cans estimated, it is necessary to evaluate its competencies to determine if they are a viable partner. Recology now operates in Aumsville, formerly the Compost Oregon site, acquired by Recology in December 2008 (Recycle Oregon). Recology has a 15-year history serving the area with a strong reputation for its quality product. Recology has a history of developing partnerships with local governments and commercial entities to focus on unresolved solid waste issues as well as community education and participation. Currently, the Jackson County Recycling Partnership (JCRP) and accompanying Master Recycler program is the best comparison to date (Jackson Country Recycling Partnership). As Recology develops a stronger presence in Oregon, these partnerships will eventually be created within the Salem area, giving NORPAC an opportunity to implement this recommendation (Friesen, 2010). Currently, Recology is waiting for a new class of food waste permit which was required once they were acquired, and is expected to take between one and six months.

Benefits

The benefits of this recommendation make the most economic sense for Recology as they will be receiving higher revenues from metal scrapping and composting than they are from their current waste practices. However, the methods by which the cans and food waste are reincorporated into the industrial cycle are also a direct benefit to NORPAC. By creating compost from the waste instead of cattle feed, farm soil will maintain a much higher quality as non-synthetic nitrates are replenished. This will eventually lead to higher-grade produce for canning, allowing NORPAC to provide a higher quality product. By salvaging the steel from the defective cans, NORPAC is decreasing the energy expended and lowers the emissions of can manufacturing, as less material is needed.

Lastly, although the reduced CO_2 emissions and energy expense of transporting the accumulated cans is negligible, all members involved benefit from the operational efficiencies of the saved labor and operating expense compared to standard practices.

Implementation

Developing this new system using a gradual introduction of waste contributors will increase the chance for success as time is allowed for correcting operational missteps. Figure 24 on the following page lays out a step-by-step implementation plan to assist NORPAC in achieving this goal and to account for the logistical implications of taking on this opportunity.

Step 1- Initiate conversation with collaborators

- Truitt Brothers, Calyx Fruit Co., Oregon Fruit Products Co.
- Determine collection route among members

Step 2- Purchase commercial can opener and install at Recology site

- Divide the cost for the can opener between the 4 canneries (proportional to operations size or current landfill cost)
- Develop operating agreement with Recology to determine liability, cost and revenue sharing issues

Step 3- Determine transportation logistics

- Centralize all defect cans at Madrona site
- Accumulated defect cans from other 3 Norpac sites at Madrona and combine with aggregate defect cans from other members
- Transport all cans to Recology in Aumsville

Process waste

- Recology to prepare food waste for composting and can for scrap metal
- Disperse revenues among members based upon proportion added to waste stream or develop alternate method for returning revenue to members (i.e. lower tipping fees, extra services)

Figure 24: Step-by-step Implementation Plan for Partnering with Recology

Strategy 3: Investigate Digester Opportunities

Overview

Opportunities for using a digester to process NORPAC's food waste could include taking advantage of an existing element at a nearby location, or considering the possibility of building one on site at the Madrona plant. If executed well, the biogas production process could become fully sustainable, by using the output (methane) to heat or cool parts of the food processing system, or by converting the gas to electricity to run the operations.

Implementation

There are three possible ways that NORPAC could choose to use digesters:

- Leverage the Existing Digester Capacity at Willow Lake: Willow Lake's on-site digester transforms waste into electricity and heat used by the facility. There is an open question whether a fuel cell will be purchased to replace the current generator, thereby adding capacity to absorb additional waste (see Project 1 above). The alternative of NORPAC's food waste being used in the Willow Lake digester would first be contingent on the overall recommendation regarding the can recycling solution. While Willow Lake would presumably absorb the food waste, there is no indication that they would do the can opening themselves, hence it should be assumed that NORPAC would have to provide organic waste product separately and deliver it to the Willow Lake facility directly. Although the total volume from the NORPAC canning operations would be small enough to be absorbed by Willow Lake, it is expected that NORPAC would be charged a tipping fee (estimated around $0.12/gallon based on the fee for SeQuential) and would not benefit from any of the outputs of the digestion process.

- Investigate the Capabilities of other Farms: Since one of the farmers from the co-operative is investigating the possibility of getting a digester on their farm, this could be an alternative for processing of NORPAC's food waste. While this is an alternative for the future, this would probably be more in tune with NORPAC's operating principles in terms of supporting their community. There is little understanding of the financial implications of giving the food waste to this group, but it is safe to assume that there would be no direct benefit to NORPAC from the output of the digester. Alternatively, NORPAC could choose to partner with a farmer outside of the local community who already has a digester. Additionally, NORPAC could also choose to partner with another wastewater facility other than Willow Lake. Overall, there are a significant number of partnership opportunities available given the rise of digesters on farms and at wastewater plants in particular. This is partly due to more stringent government regulations related to waste disposal in landfills, but also because digesters provide important opportunities for farmers (especially those with livestock) to greatly reduce the environmental impact of their own farming operations.

- Build a Digester at NORPAC's Madrona facility: The main advantage of having an on-site digester at NORPAC facilities is that the company would be able to benefit directly from the output of the digester, which it would not if it used another company's digester. However, there are significant financial implications to setting up and operating a digester, so the first step would be for NORPAC to understand whether there is enough waste material volume as input to justify the purchase, given expected financial returns. Nevertheless, there would be great benefits from having a centralized community digester, since most individual farmers would be unable to build and maintain their own digesters due to high costs and a limited amount of materials to use as feedstock for the digester. Setup cost of a new digester is quoted to be between $250,000 and $1 million. While the total setup cost would depend on the size of the digester and volume of input, it should be expected that costs will be high, so NORPAC should devote significant effort at investigating the possibility of getting government subsidies to pay for the cost of the digester. Similarly, there would be costs to adapt current systems to use the new energy source, as well as operating and labor costs.

Environmental Benefits of a Digester
NORPAC

- Provides a renewable energy source (heat and electricity) that can allow the company to reduce its energy costs, use of fossil fuels, and overall energy footprint.
- Provides output that can be used in current operations, such as a "sludge" that can be used as fertilizer and a "solids" base that can be used as a supplement for cattle feed, thereby reducing the cost of buying these two ingredients for NORPAC. There is also the opportunity for NORPAC to sell the excess to the co-operative members.
- Improves storage and handling of waste.
- Maintains consistency with NORPAC sustainability principles and long-term commitment to reducing waste. Specifically, it (1) continues to use the process water on the land, further increasing water efficiencies; (2) is consistent with the principle of returning nutrients to the soil through process water and through vegetable matter that cannot be fed to animals; (3) demonstrates NORPAC's commitment to continually improving their practices and highlights their commitment to energy efficiencies.
- Preempts regulation from the EPA, which is expected to become more stringent with regard to landfill, greenhouse gas emissions, and general farming and food processing activities.

Community

- Reduces negatives of decomposing food waste by reducing odor and methane emissions.
- Eliminates reliance on landfills for waste disposal, thereby reducing landfill gas emissions and leaching.
- Creates jobs in the community linked to the installation of a new digester, because it will require an independent team to manage it. Given the complexity of the process, it requires dedicated resources.

Best Practices

Stahlbush Island Farms in Corvallis, Oregon (Stahlbush Island Farms) currently operates a state-of-the-art biogas plant. It produces electricity using fruit and vegetable byproduct from the Stahlbush operations. They expect to produce enough electricity for 1,100 houses, the equivalent of twice as much as what the entire farm and food processing plant requires. Although the plant took 14 months to complete and cost about $10 million, it reduces Stahlbush's carbon footprint significantly and allows it to gain energy independence through a renewable energy source on site.

The EPA has made a showcase out of California's East Bay Municipal Utility District, which obtained great results from their use of post-consumer food waste (EPA). The digester in that case was funded through a grant, which reduces the financial burden.

Conclusions

Using a digester to process the waste from canning operations would be a great intervention for NORPAC in terms of impact on the local community – environmentally, economically, and socially. The benefits from using a digester are clear, and there are some important outputs that could be used in the farming operations immediately. Furthermore, this alternative would bring to life the concepts of industrial ecology by creating connections between the different local entities: NORPAC and co-operative farmers, NORPAC and Willow Lake.

Nevertheless, the setup and operating costs are significant, and without a clear understanding of the volume of waste to be processed, this alternative is not financially viable for NORPAC today. However, if NORPAC were awarded a government grant for the purchase of a digester, the economic and environmental benefits would greatly outweigh the financial costs in the long term.

Financial Analysis

The students calculated the volume of imperfect cans that were produced at the NORPAC facilities per minute to determine the feasibility of an on-site automatic can opener. The automatic opener would open cans at a rate of 25 per minute. NORPAC's facilities produce 0.7 imperfect cans per operational minute. Therefore, students considered the issue of scale when identifying feasible solutions.

After developing the strategies, students conducted a financial analysis of the feasibility of each possible solution. The goal was to cost-effectively create a process that eliminated the need to landfill the 300 tons of defective cans per year. NORPAC explained that the current cost of landfilling these cans is $16,800 annually. This analysis assumes landfill costs are going to rise 5% annually. The forecasted cost to NORPAC to landfill was the baseline upon which students judged the financial performance of each alternative. In order to quantify the implications of undertaking each strategy, the team identified the additional costs that NORPAC would have to incur to implement each solution presented. Depending on the strategy, NORPAC would have to spend on additional labor, transportation, tipping fees and continued operational costs. In most instances, the assumption was that these costs would grow 3% per year. In other instances, certain efficiencies were assumed to develop over time as NORPAC refined the new processes that each solution required.

Other considerations were beneficial to NORPAC's revenue stream. Scrap steel proceeds were included, as well as depreciation of capital expenditures on equipment. In the Recology partnership solution, NORPAC's share of revenues from compost sales and scrap metal proceeds were measured. Grants were also taken into consideration. A grant, such as one from the Marion County Solid Waste Division, would help mitigate the upfront costs of Strategy 2 and make the purchase of the commercial can opener more feasible. Electricity produced was considered positive cash flow and is specific to the on-site digester recommendation.

In order to calculate the financial impact of each of these strategies, there were many assumptions that had to be made about both present and future costs. The assumptions were based on conservative judgment. The Excel spreadsheet delivered to NORPAC was designed for these estimates to be easily adjusted based on the availability of salient information.

Conclusions, Recommendations, and Open Issues

The students recommend NORPAC take a two-pronged approach to restructure its current disposal process for defective cans. In the short term (0-6 months), NORPAC should centralize can collection at Madrona and recycle 100% of its defective cans internally. In the long run (6 months and longer), NORPAC should partner with Recology to establish an ongoing waste disposal program, integrating other local canneries into this program.

In addition to a consistent process for can disposal and increased operational efficiency within the canning department, this recommendation best resonates with the internal culture and values of NORPAC. It supports its leadership in innovation and commitment to environmentally sound practices. Furthermore, and perhaps more importantly, this plan encourages NORPAC to foster collaboration within and between industries. NORPAC has and should continue to position itself as a leader in the sustainable development of the central Oregon agricultural community.

The costs in the short term will include the time and effort needed for logistical coordination and labor management. The costs for the long-term approach will include time and effort needed to develop key relationships, and a monetary investment in the Edlund 925 can opener.

At this time, NORPAC should collect defective cans at the Madrona sight and bring existing Edlund can openers to this location. NORPAC should then allocate labor to opening the cans and separating the organic content for composting at Recology. In addition, NORPAC should apply for the Marion County Solid Waste Grant and begin to develop relationships with key stakeholders including Recology and other local canneries that may be interested in a sustainable waste management program.

Conclusion

Industrial ecology principles call for a holistic approach to overcome environmental challenges. The benefits of using this approach were exposed through the work of the students on the five projects. The students proposed partnerships between businesses in the Salem area to support mutual growth and cost savings, while at the same time creating a cleaner environment by reducing emissions of greenhouse gases and eliminating waste.

The recommendations made by the students come from a thorough investigation of the situations, exploring not only the financial outcomes of each strategy but also the social, political, and technological context, bringing forward strategies to solve broader problems, create additional opportunities, and produce long-term benefits.

The concept of symbiosis between businesses in the same region came forward in all of the projects, from recommending knowledge sharing on best practices for the use of fuel cells to establishing strategic partnerships to build water treatment facilities.

The students created analytic tools and frameworks to allow the City of Salem and local businesses to reexamine situations as circumstances change in the coming years. With these tools, the businesses and the city will be able to make strategic decisions that are based on industrial ecology principles.

Through their work on the projects the students got to see how the theory of sustainable business practices could be applied in the real world.

Appendices

Appendix 1: Assumptions Used in Project #1 Analysis

Technical Analysis Assumptions

Determining the technical and economic characteristics of the replacement alternatives presented in the project required some assumptions of power output and efficiency as well as the conversion of power and energy units for gas and electricity.

Students derived estimates of power output and efficiency from the Carollo study, which indicated that engine cogenerators have electric efficiency of 34% and heat efficiency of 42%. Fuel cells are rated at 47% electric efficiency and 22% heat efficiency.

The following table highlights the energy conversion factors used to calculate the estimates for energy input requirements of the replacement alternatives (Conversion Factors). Starting from the assumed energy output rating, students calculated backward to arrive at the energy input requirement of each alternative.

Starting Units	Ending Units	Conversion Factor
kWh	BTU	3413
BTU	kWh	0.000293
Scfd	BTU	1030
BTU	Scfd	0.0097
kW	kWh/yr	8760
kW	MMBTU/hr	0.00341
MMBTU/hr	MMBTU/yr	8760

8,760 is the number of hours per year. Note that the Carollo study uses different amounts of hours per year when calculating power generation by different cogeneration methods to account for utilization. Students did not use this method in their calculations.

Economic Assumptions

The following table summarizes energy price estimations for 2011 that were used in calculations.

Electricity Price ($/kWh)	$ 0.0868	Carollo Study at 2011
Natural Gas Price ($/MMBtu)	$ 12.16	Carollo Study at 2011
Methane Gas Price ($/MMBtu)	$ 06.08	Half of Natural Gas Price (Portland Case)
Business Energy Tax Credits	33.5%	Carollo Study at 2011

Methane Assumptions

For all the alternatives considered, there was not enough methane gas produced by the digesters to allow operation at maximal power. The following is the calculation of the annual methane deficit for all three alternatives:

	848 kW Engine	1400 kW FC	1148 kW Hybrid
Available Methane from digesters/day	190,200 scf	190,200 scf	190,200 scf
Equivalent Electrical Power Input	2494 kW	2,979 kW	3,132 kW
Required Input to operate at full power/day	198,346 scf	236,884	249,107 scf

This deficit will cause the facility to operate in lower capacity than the maximal electric and thermal power or it would cause the purchase of natural gas. Increased on-site production can also provide the extra methane. The deficit was taken in consideration in the final NPV calculation.

Appendix 2: Annual Cost Estimates for Year 2011 Used in Project #1 Analysis

Alternative 1: 848 kW Engine Replacement

- Electricity: The following table summarizes the calculation to arrive at the estimated annual cost of electricity for 2011 of the 848 kW engine.

Electrical Power Demand (average)	2045 kW
Electrical Power Output (at max input level)	848 kW
Electrical Power Deficit	1197 kW
Annual Electrical Energy Deficit	10,485,720 kWh
Annual Electrical Energy Cost	$ 910,370

- Natural Gas: The following table summarizes the calculation to arrive at the estimated annual cost of natural gas for 2011 of the 848 kW engine.

Heat Demand (average)	2.80 MMBTU/hr
Thermal Power Output (at max input level, equivalent)	1048 kW
Heat Output (at max input level)	3.58 MMBTU/hr
Heat Demand Deficit	0 MMBTU/hr
Annual Heat Deficit	0 MMBTU
Annual Heat Deficit Cost	$ 0

- Operation and Maintenance (O&M): The following table summarizes the calculation to arrive at the estimated annual cost for O&M for 2011 of the 848 kW engine.

O&M – Fuel Treatment	$ 70,928
O&M – Engine	$ 106,392
Total O&M Costs	$ 177,320

Alternative 2: 1400 kW Fuel Cell

- Electricity: The following table summarizes the calculation to arrive at the estimated annual cost of electricity for 2011 of the 1400 kW fuel cell.

Electrical Power Demand (average)	2045 kW
Electrical Power Output (at max input level)	1400 kW
Electrical Power Deficit	645 kW
Annual Electrical Energy Deficit	5,650,200 kWh
Annual Electrical Energy Cost	$ 490,550

- Natural Gas: The following table summarizes the calculation to arrive at the estimated annual cost of natural gas for 2011 of the 1400 kW fuel cell.

Heat Demand (average)	2.80 MMBTU/hr
Thermal Power Output (at max input level, equivalent)	655 kW
Heat Output (at max input level)	2.24 MMBTU/hr
Heat Demand Deficit	0.56 MMBTU/hr
Annual Heat Deficit	4936 MMBTU
Annual Heat Deficit Cost	$ 60,016

- Operation and Maintenance (O&M): The following table summarizes the calculation to arrive at the estimated annual cost for O&M for 2011 of the1400 kW fuel cell.

O&M – Fuel Treatment	$ 119,339
O&M – Engine	$ 429,620
Total O&M Costs	$ 548,959

Alternative 3: 1148 kW Hybrid

- Electricity: The following table summarizes the calculation to arrive at the estimated annual cost of electricity for 2011 of the 1148 kW Hybrid.

Electrical Power Demand (average)	2045 kW
Electrical Power Output (at max input level)	1148 kW
Electrical Power Deficit	897 kW
Annual Electrical Energy Deficit	7,857,720 kWh
Annual Electrical Energy Cost	$ 667,906

- Natural Gas: The following table summarizes the calculation to arrive at the estimated annual cost of natural gas for 2011 of the 1148 kW Hybrid.

Heat Demand (average)	2.80 MMBTU/hr
Thermal Power Output (at max input level, equivalent)	1188 kW
Heat Output (at max input level)	4.05 MMBTU/hr
Heat Demand Deficit	0 MMBTU/hr
Annual Heat Deficit	0 MMBTU
Annual Heat Deficit Cost	$ 0

- Operation and Maintenance (O&M): The following table summarizes the calculation to arrive at the estimated annual cost for O&M for 2011 of the 1148 kW Hybrid.

O&M – Fuel Treatment	$ 74,998
O&M – Fuel Cell	$ 98,362
O&M – Engine	$ 106,392
Total O&M Costs	$ 279,752

Appendix 3: Methane Storage and Sale Considerations for Willow Lake (Project #1)

In the baseline scenario, digester gas (which is 60% methane) not used by the cogeneration system or by the boilers is flared in the gas burner. From 11/2008 to 10/2010 Willow Lake sent an average of 50,374 cubic feet per day of methane to the waste gas burner. All the alternatives analyzed in Project #1 have methane deficit and thus this would no longer be an issue.

Willow Lake could abandon cogeneration completely and instead invest in a storage facility for methane and sell the generated methane. This will entail buying all energy for heat and electricity and also some low operation and management costs. If demand for methane was guaranteed this would have been a viable alternative as the annual costs are similar to the other alternatives after the additional revenues have been taken into account.

There is a great difference between storing relatively small quantities of methane at low pressure and storing large quantities at high pressure. Learning from the Riverside case – the costs to install a 250,000-cubic foot high-pressure gasholder dome are around $5 million while a 10,000-cubic foot Gasholder Installation is about $1.5 million. The higher volume storage system also generates annual operating costs of $25,000 to $75,000 per year.

The following two examples are solutions for methane storage that have been around for over twenty years:

- Covered Anaerobic Lagoon: A low cost, simple solution that could be used over water waiting for treatment. Once the lagoon has been formed and lined the provision of a “floating cover” is a simple matter and an inflating floating cover will provide a simple means of methane storage. When considering this alternative the risk of an explosion or flashover has to be addressed as well as the risk of a leak. This method is in use by the City of Portland, where they have one customer and get about half market rate of natural gas.
- A Dome to Hold Digester Gas: Dystor® system from Siemens Water Technologies is a digester gas holder that uses a dome-shaped, engineered membrane system to store methane gas, provide for sludge storage and prevent odors. There is a simplified version for the Dystor® which is employed when only gas storage is desired and which is substantially less costly than a high pressure gas storage sphere and does not require the use of compressors where a separate gas storage unit is mounted directly on a concrete foundation ring.

As technology advances and as fuel cells are in more prevalent use, energy-storage systems are introduced. As Willow Lake considers future upgrades (after the current one addressed by this report), it should keep an eye for such technology leaps, which can generate more revenue streams. University of California San Diego, for example, received incentives of about $11 million from California's Self-Generation Incentive Program for the installation of an innovative fuel cell energy generation and storage system that allows it to store the generated energy for future use.

Appendix 4: Existing Domain Research Reviewed in Project #2

Since the 1990s, the use of FOG (fat, oil, and grease) in co-digestion facilities has greatly expanded (Co-Digestion). Wastewater treatment plants have noted grease wastes are a valuable feedstock for their digesters. The results of their efforts to integrate WWGT waste into their waste inputs have produced a body of research that can inform the potential SeQuential and Willow Lake collaboration.

D.C. Water (Washington D.C.)

D.C. Water, the wastewater treatment authority for the Washington D.C. metro area, conducted a preliminary assessment for its Blue Plains Advanced Wastewater Treatment Plant to determine if adding FOG to its digester would make economic sense. The report evaluates whether an adequate amount of FOG was available in the service area to support a grease-to-gas-to-energy project. This study calculated the projected increase in methane production with the addition of "brown grease," the waste collected from grease traps after food waste enters the wastewater stream, to the digester. (Brown grease waste is different in make-up and properties from "yellow grease," also known as "fryer oil," which can more easily be processed into biodiesel.) The D.C. Water report determined that adding 5% of brown grease to the digester's overall load would yield an increase in methane production of 13% (Schafer).

Clearwater Road Wastewater Treatment Facility (Hershey, PA)

This project in Hershey, PA, highlights how FOG may need pre-treatment before it can be readily broken down by the digester. Initially, the wastewater treatment plants added the FOG material directly into the digester, but this method did not yield any noticeable increase in biogas production. Once a pretreatment regimen was added, including processing through chopper pumps, pH adjustment with magnesium hydroxide, and an injection of bacteria into the feedstock, the production of biogas improved dramatically. Unfortunately, the report did not quantify the impact of FOG on the wastewater treatment plant's methane production. It also noted that "because of the all the variables involved in the digestion of sludge," a quantitative relationship between grease received and methane produced is difficult to establish, though "clearly a relationship exists" (Schutz).

City of Gresham, Oregon

In 2009, the City of Gresham assessed the economic feasibility of developing an electrical co-generation system using FOG at its wastewater treatment plant. The Gresham report is useful for Willow Lake because it looks at taking advantage of Oregon-specific tax credits and energy incentives. This report recommended that Gresham first investigate the energy potential of its FOG supply in its continued investigation of co-generation. Knowing the energy potential of the waste stream will determine how much additional methane the wastewater facility could create. This, in turn, reduces overhead through forgoing the purchase of electricity equaling the energy provided by produced methane (CH2MHILL, 2009).

East Bay Municipal Utility District (San Francisco, CA)

In 2006, the EPA awarded the East Bay Municipal Utility District a $50,000 grant to conduct a study on the benefits and limitations of co-digestion of food waste in a wastewater digester (Co-Digestion). The food waste used in the study is typical of that found in restaurants, grocery stores, and cafeterias in California and across the US. The study found that under the same conditions, food waste was more completely consumed by the anaerobic digester than municipal wastewater solids (Gray, 2008) and produced digester gas with higher energy value. This is attributed to the fact that food waste has a higher specific energy content than municipal wastewater solids. Food waste also has a higher volatile solids (digestible matter) to total solids ratio: 86-90% compared to 70-80%. Additionally, the study found that adding food waste to the wastewater solids allowed for faster digestion, reducing the processing time from 15 to 10 days. This reduced digestion time can result in lower necessary capacity and therefore lower capital costs as well as higher overall methane gas production.

Relevant Experiments

Experiments in Mikkeli, Finland

Increased biogas production at wastewater treatment plants through co-digestion of sewage sludge with grease trap sludge from a meat processing plant.

This experiment examined the co-digestion of grease trap sludge from a meat-processing plant with digested sewage sludge from a wastewater treatment plant in Mikkeli, Finland that treats both residential and small to medium industries producing 36,400 m^3 (1,290,000 ft^3) sewage sludge per year. The testing was conducted in both small tube batches and large 4-liter temperature-controlled reactors. The reactor experiments most closely mimic that of the digester conditions at Willow Lake with a larger volume, controlled temperature, mixture ratios, and constant mixing. The maximum reactor yield came from a mixture in which 46% of the total volatile solids were from grease trap sludge. Higher percentages of grease trap sludge resulted in decreased methane production due to a build up of methanogenic bacteria (Luostarinen, 2009).

Experiments at Gresham, Oregon

The methods used to arrive at the estimate presented in this study are not specified, but it reports three scenarios for methane production from grease trap waste as presented in the table below.

Scenario	Gallons FOG	% Solids	VS/VT	Removal %	SCF/lb VS Removed	Methane Produced ft3/day
1	6,000	6.7%	90%	80%	24	58,000
2	11,000	6.7%	90%	80%	24	106,000
3	11,000	2.74%	90%	80%	24	43,400

The composition of the grease waste is demonstrated to have a huge impact on the total methane produced. The total methane production per gallon of FOG input was 9.67, 9.6, and 3.95 ft3/day in scenarios 1, 2, and 3 respectively, the largest differing factor being the composition of the FOG input.

Co-digestion of grease trap sludge and sewage sludge

This study conducted a 4-6 month pilot-scale digestion, which is the most robust replicate of the SeQuential and Willow Lake case. The study concluded that when grease trap sludge is added to digesting sewage sludge, methane production increases by 9-27%. The peak yield was produced by a mixture of 70% (by volume) wastewater sludge and 30% (by volume) grease trap sludge (Davidsson, 2008).

Appendix 5: Existing Domain Research Reviewed in Project #3

Concrete

The concrete industry currently consumes 264 billion gallons of water worldwide annually (Metha, 2001). Although there can be exceptions, potable water is generally used as mixing water for concrete, as this ensures impurities will not affect the setting time and strength. Non-potable water that meets American Society for Testing and Materials (ASTM) standards is used in large volumes for a variety of the wash-out purposes.

River Bend Sand & Gravel Company
4105 Lancaster Dr. SE Salem, OR

Salem area provider of ready-mix concrete, crushed rock, sand, gravel, and asphalt.

Distance from Willow Lake: **10.8 miles**
Amount of water used annually: **unknown**
Amount paid on water in 2009: **unknown**

CEMEX – Lancaster Ready Mix Plant
2425 Lancaster Dr. SE Salem, OR

Worldwide producer of cement, ready-mix concrete and aggregate

Distance from Willow Lake: **6.2 miles**
Amount of water used annually: **unknown**
Amount paid on water in 2009: **unknown**

Salem Mobile Mix
4000 Riverbend Rd. NW Salem, OR

Salem onsite concrete delivery system.

Distance from Willow Lake: **8.1 miles**
Amount of water used annually: **unknown**
Amount paid on water in 2009: **unknown**

With approximately 10 concrete production companies located within 11 miles of Willow Lake, there is potential for the development of symbiotic water reclamation relationships.

The interviews proved there are no strong preferences against the use of reclaimed wastewater in all wash-out applications, provided the water meets ASTM standards. The source of water utilized to clean transit-mixing cement trucks and rinse sand or gravel is not subject to the high level of customer scrutiny as some water-intensive operations. If cost savings could be realized or water scarcity was an issue, concrete production facilities would be ideal candidates for wastewater reclamation partnerships. However, there is simply no current need for the water in this region.

The concrete companies contacted are operating with closed-loop non-potable water systems. Water is pumped from on-site ponds/quarries to satisfy all wash-out requirements, and is recycled back after use. Wash-out areas often feed into filter dirt which is used by other companies as mineral-rich top soil.

A Case of Industrial Symbiosis

Salem MobileMix extracts rocks from an on-site quarry to manufacture concrete. During the winter, the quarry is filled with rain and ground water forming a non-potable water source used by the company for different applications. Excess water is pumped directly from the pond and used on the crops of the neighboring farm. Come summer and peak crop irrigating time, the pond is emptied to provide easy access to rocks and water is again utilized by the farm next door.

City pipelines or wells provide the potable water for concrete mixing. Estimations of potable water use could be extracted from utility bills, but non-potable volumes were more difficult to determine. There is little concern for tracking the exact usage amounts when the water is pumped from and returned to the same source. A reason (i.e. cost) to calculate and record non-potable water use has yet to present itself in these local operations.

Through this self-contained system, the facilities avoid the large costs associated with high volume fresh water use, separate potable/non-potable pipe infrastructure, and trucking water.

Agriculture

The agricultural industry consumes a large amount of ground and surface water, accounting for 80% of total water used in the U.S. (Irrigation and Water Use). Given this trend, and the large agricultural base in the Willamette Valley, there is a strong incentive to utilize reclaimed water in the agricultural and food processing industries in Salem. However, although water usage is high, the social stigma around reclaimed water in food products is a significant barrier to implementation. To further understand business perceptions, barriers, and opportunities in the agricultural sector, food processing operations and nurseries were contacted.

Oregon Cherry Growers
1520 Woodrow Street NE Salem, OR

Distance from Willow Lake: **6.1 miles**
Amount of Water Used Annually: **66,338 cubic feet**
Amount paid on water in 2009: **$87,543**

NORPAC Plant #7
4755 Brooklake Road NE Salem, OR

Distance from Willow Lake: **11.1 miles**
Amount of Water Used Annually: **56,394 cubic feet**
Amount paid on water in 2009: **$74,589**

Willow Lake Nursery
5655 Windsor Island Road North Keizer, OR

Distance from Willow Lake: ***.4 miles via Windsor Island Road, adjacent to Willow Lake***
Amount of Water Used Annually: ***unknown***
Amount paid on water in 2009: ***unknown***

Iseli Nursery located in Sandy, Oregon
30590 Southeast Kelso Road Sandy, OR

Distance from Willow Lake: **not relevant, but is a successful example of reclamation in Oregon**
Amount of Water Used Annually: **unknown**
Amount paid on water in 2009: **unknown**

Food Processing

Oregon Cherry Growers is one of the largest producers of maraschino cherries in the world. The company used 66,338 cubic feet of water in 2009, making it the tenth largest water consumer in Salem. Given its large consumption of water year round, Oregon Cherry Growers was contacted to understand its perceptions regarding the potential use of reclaimed water.

Oregon Cherry Growers currently reuses 15-20% of its own water on site. In the maraschino cherry-making process, the brine is rinsed out of the cherries repeatedly. Cherry Growers is able to reuse the cleanest water to rinse the cherries in one of the earlier rinse cycles. When asked if non-potable water could be used in any part of their process, Steve Travis, VP of Operations, said that they could possibly use it for sanitation purposes, but there is not much buy-in for it from Cherry Growers or customers. Without a shortage of water, he explained, there is really no need. There could be an opportunity to reuse more of its water on site; however, they would need monetary incentive to build the needed infrastructure.

NORPAC was also contacted due to its large water usage. NORPAC is a food processing company with three warehouse and processing plants in the Salem region. The plant on Madrona Avenue alone used 56,394 cubic feet of water in 2009, making this plant the 13th largest water consumer in Salem.

Mark Steele of NORPAC noted that public perception is the most pressing issue when considering the use of reclaimed water in food processing. A number of years ago, Steele attended a meeting in Portland where the city proposed to put its reclaimed water on farm land. NORPAC's major competitor settled the decision by stating that if NORPAC put reclaimed water on its crops, the competittor would differentiate itself by stating that they were the company that did not use "sewer water" on its crops. Although some water on site is recycled from spray coolers back to washing incoming product, USDA and FDA regulations and public perception are prohibiting them from recycling more of their water. Steele asks, "would you rather have potable water or recycled water put on the food you eat?"

Nurseries

Commercial nurseries offer an ideal alternative for agriculture-based businesses to use reclaimed non-potable water. The final non-edible agriculture product is less likely to be impacted by misconceptions of dirtiness of lower grade water, which means the issue of customer perception is less of an issue.

Willow Lake Nursery is located on the southwest border adjacent to Willow Lake. At this point, the nursery harvests walnuts and hazelnuts, and serves as a wedding venue, holding 42 events this past year. Although Willow Lake Nursery does not require large amounts of water to run its operations, the owner's perspective as a local business owner is valuable to understanding the relationship between Willow Lake and nearby agriculture based businesses or neighbors.

Willow Lake Nursery claims that the area east of the Willamette River is above a low aquifer shelf. The Willow Lake Nursery well is only 26 feet deep, which means two things: the initial cost to drill the well is inexpensive, and the ongoing cost to power the well is low. The owner reported that the land located west of the Willamette River was drastically different: the water table is located between 400 and 600 feet below ground, which means that unlike on the east side of the river, the initial cost to drill the well and to power it are significant. Farmers raise crops based on the availability and cost of water, with the majority of row crop growers located on the east side of the river, and grains and wheat growers on the west side of the river. Farmers grow high-water-use crops where water is abundant and low-water-use crops when it is not. It is unclear whether or not access to cheap water would change the types of crops the farmers grow on either side of the Willamette River.

Community perceptions are also a challenge to any new and potentially expensive projects. Community members expressed concerns regarding the ability of Willow Lake to follow through on such large scale projects.

Recent political movements that emphasize reduced government spending may constrain Willow Lake's ability to borrow funds for reclaimed water infrastructure. Building strong relationships in the community will be critical to successful reclamation system developments.

Case Study of Successful Reclamation in Oregon

The City of Sandy, Oregon, located southeast of Portland on the edge of the Mt. Hood National Forest, currently has a relationship with a local agriculture-based business to transfer non-potable water for on-site use. Roughly ten years ago, the City of Sandy held a number of community meetings to discuss building a water pipe from its wastewater treatment facility to the Sandy River. Iseli Nursery, located between the wastewater treatment facility and the Sandy river, proposed that the city should build a shorter, less expensive pipe to the company property. The City of Sandy opted to build the pipe directly to Iseli Nursery and signed a ten year contract to provide non-potable water.

Iseli Nursery is a $15 - $20 million company that uses large amounts of water each year to raise its crops. Iseli Nursery has numerous on-site wells that supplied water from 300 - 800 feet below ground and required significant energy. The company saw an opportunity to collaborate with the City of Sandy by diverting the reclaimed water to agricultural usage while adding significant volume and supply to meet its operational demands. This relationship results in lower energy costs for Iseli Nursery and less treated water being pumped into the Sandy River. The nursery receives secondary, tertiary, and chlorine treated water from the city wastewater treatment facility via a pipe. Iseli Nursery also filters all non-potable water before using it in operations. The contract is now in year six and both parties have already agreed on an extension. Iseli Nursery continues to source a limited amount of water from its on-site wells (Holbert, 2010).

Recreation

As major users of water in the recreation industry, golf courses have emerged as excellent partners for water reclamation facilities around the world. This trend applies to the Pacific Northwest as well. The communities of Bandon, Bend, and Newberg in Oregon, and several more in Washington provide reclaimed water to nearby golf courses. There are several key reasons why golf courses are excellent users of reclaimed water:

- Access to sufficient water represents a major operating cost and long-term risk for golf courses
- Golf courses tend to be located outside the city center and are therefore more likely to be near treatment facilities
- Golf courses do not face the same stigma regarding reclaimed water as agriculture users

Willow Lake Golf Center & Driving Range
6020 Windsor Island Road North, Keizer, OR

Distance from Willow Lake: **Adjacent**
Amount of water used annually: **unknown**
Amount paid on water in 2009: **unknown**

- Water features on golf courses provide water storage opportunities
- New housing developments around golf courses can provide the economic benefit necessary to justify investments in water reclamation infrastructure

This section examines two case studies: a golf course partnership with Willow Lake that did not last, and another from Snoqualmie, Washington that has been a primary driver for reclamation.

In 2006, Willow Lake completed an expansion of its treatment facility to produce a maximum of 1 million gallons a day of Class A reclaimed water. This project was granted $950,000 of funding by the Bureau of Reclamation (BOR) (CRS Report for Congress). The funding stipulated that Willow Lake would produce reclaimed water to be used by a nearby facility for at least two years. This was achieved by leasing land to be used as a driving range. The lease stipulated that irrigation water would be provided for free for the length of the lease (10 years) (Eisner, 2010). Unfortunately, after the two years required by BOR were up, Willow Lake moved from providing reclaimed water to using on-site wells to pump water for irrigation. This decision was driven by budget constraints and reflected the marginally higher cost of chemicals for the treatment of reclaimed water relative to the cost of electricity to run the on-site wells.

The driving range experiment failed because the alternative to reclaimed water at the driving range was an existing well. However, had there been discharge limits, Willow Lake may have been more willing to subsidize the slightly higher cost of providing reclaimed water. Alternatively, had well water been more expensive (i.e. from a deeper, less pure water table) then the cost of well water would exceed the cost of reclamation. The absence of either of these drivers signaled the end for reclaimed water use at the driving range.

An example of a successful long-term public-private partnership can be found in Snoqualmie, a community of approximately 4,000 in Washington state. Snoqualmie was chosen as a possible location for a PGA golf course and resort complex. However, the town owned limited water rights and faced regulatory risks related to violations of their discharge permit. Together, these factors put the golf course project – and the economic benefit to the town – at risk. A partnership between the developer (Weyerhaeuser Development Corporation)

Case Study - Snoqualmie, WA

- 2 million gallons per day maximum of class A reclaimed water (summer flows are closer to 1 million gallons)
- Price to users of reclaimed water is same as price of tap water
- Annual operations costs equal $240,000
- Upfront cost of $18 million was paid by Weyerhaeuser Development Corp. in 1998
- Snoqualmie currently has more customer demand than available reclaimed water during the summer irrigation season

and the city solved both the water and wastewater concerns. The golf course required one million gallons of water per day and the treatment facility was upgraded to produce up to 2 million gallons per day (Cupps, 2005).

Success required more than just infrastructure improvements. Public education efforts were critical to long-term acceptance. Homeowners in the new development were provided with information about the reclaimed water system. The weekly city newsletter included articles about reclaimed water, and the city also provided information online. Engaging the public around the project has built local knowledge and support for reclaimed water. Community members recognize the economic and environmental benefits and are well informed about the strict management of the system which minimizes risk to humans.

The project has had so much success that Snoqualmie plans to meet future water needs through additional reclaimed water projects. Alternatives include adding capacity at the current facility, building a new facility to serve historic Snoqualmie (satellite facility), or adding storage facilities to allow water reclaimed in the winter to be stored until peak summer use periods.

Contrasting the experiences of Snoqualmie and Willow Lake further emphasizes the role external drivers play on the feasibility of reclaimed water. Willow Lake lacked the external drivers necessary to justify reclamation. However, in the future, as water resources become increasingly scarce and wastewater regulations tighten, Willow Lake should revisit its relationship with the nearby driving range and other golf courses in the near vicinity. As Snoqualmie has proven, golf courses are excellent partners for reclaimed water, and public-private partnerships can serve to protect water resources while also driving economic development in the region.

Appendix 6: Details on Recommended Strategies for Project #3

Expand Pre-Treatment Program

Treating Wastewater at the Source

Water reclamation is often thought of as a linear process of transforming wastewater at the treatment facility into usable reclaimed water, which is then pumped back to end users. However, taking a systems level approach (with the end goal of reducing wastewater outflow and minimizing impact on water sources) suggests Willow Lake could serve as a consultant to large water users and wastewater generators. The model is similar to city-owned electric utilities investing in energy efficiency as the lowest cost source of energy. Willow Lake has already laid the foundation for this model through its consulting and advisory services. However, allowing Willow Lake to make investments in recommended on-site reclamation projects would better align systems level benefits with project financial models. Through this expanded service and resource provider role, Willow Lake stands to garner goodwill in the community and better position Salem's infrastructure to meet the demands of the future.

Potential partners for Willow Lake in this endeavor include:

- Water Supply Department
- Water Conservation Efforts
- State Entities
- Water Resource Strategy Board

This would require integration with the water supply department as well as water conservation efforts. An example includes using Willow Lake's expertise to help users build gray water systems or water reuse infrastructure. Oregon Cherry Growers has expressed interest in expanding its water reclamation infrastructure, however there is insufficient economic incentive to build this capacity. With financial assistance from Willow Lake, projects such as the Oregon Cherry Growers will be financially feasible and will reduce the burden on Willow Lake's systems.

Mini-Reclamation

Right Size Water Reclamation Efforts

A growing trend in sustainable economic development strategies is the district scale provision of services. District energy systems go back hundreds of years. Initiatives like Portland's Eco-Districts and successful district scale systems in British Columbia are re-energizing the concept and expanding beyond energy to also tackle water and wastewater (Cole, 2010).

Approaching wastewater reclamation issues from a district scale perspective raises the idea of distributed reclamation. There are several advantages to distributed reclamation:

- Reduce infrastructure costs of moving reclaimed water from treatment facility to end user
- Increase viability of reclamation by serving clusters of similar water users
- Reduce treatment costs by treating water only to quality required at that location
- Establish district level thinking and policy frameworks to tackle shared long-term risks
- Enhance recruitment of large water users by cost-effectively meeting their needs without placing undue strain on local water supplies
- Increase resilience by building several facilities that serve a similar purpose (if Willow Lake faces a significant shut-down, wastewater services can be provided at satellite sites)

Maximizing district level efficiencies opens new opportunities for water reclamation by spreading infrastructure costs among several users and creating a local framework for symbiotic relationships to emerge. Additionally, targeted satellite water reclamation can tailor the reclamation quantity and quality to district demand. This avoids the common problem of over-building infrastructure. For example, having one reclamation process at the treatment plant and one distribution system for that reclaimed water forces the facility to treat to the highest possible end use. For Willow Lake that means producing only Class A reclaimed water. From the traditional water treatment facility model, this makes sense, however, when framing the issue from a district scale it is clear that some users may only need Class C water, and if these users are clustered, then serving them with a mini-reclamation facility may reduce costs.

The inefficiencies of one central facility are contrasted with the inefficiencies of individual facility reclamation or reuse projects. Finding the right-sized, district scale opportunities, reduces inefficiencies from too large central facilities and too customized building facilities.

To pull source water, satellite reclamation sites can either tap into sewer mains or they can tap into the outflow from large wastewater producers. If tapping into the wastewater of a specific facility, incentives can be created to ensure a certain quality and quantity of wastewater is produced. For example, facilities with large cooling demands produce large quantities of relatively high quality water (from cooling towers). These facilities could be paid for that wastewater because it could serve as the foundation for a mini-reclamation

"At the fundamental level, an eco-district is a framing strategy for a district or neighborhood scale community to get behind environmental performance improvements that will bring them greater community benefit and economic returns."

-Naomi Cole

site and provide value to nearby facilities. Based on the end user of the water, distributed reclamation can take several forms:

- Urban: In an urban environment, reclamation may take the form of gray water treatment at a neighborhood or city block scale. There are achievable infrastructure and operations costs savings from combining several small gray water filtration systems into a large system. Dockside Green, a luxury housing development in Victoria, BC is an excellent example. Gray water from several buildings is filtered and re-distributed from one district scale facility and then sent back to individual buildings for re-use.
- Industrial: Centralized reclamation requires reclaiming to the highest class used in the entire system. Distributed reclamation can allow for clusters of lower class water users to be served at a lower cost. New industrial parks could benefit from the provision of potable and non-potable water to each site. If the primary uses of water at a park are for cooling then it may be cost-effective to tap into the sewer and reclaim to a lower standard (Class C) than Willow Lake currently reclaims to and provide that water as cooling water to large industrial facilities in the park.
- Mini-reclamation can also be used to provide water to critical ecosystems. These mini-reclamation plants may actually mimic natural water filtration systems and be incorporated as a part of the ecosystem. The LOTT Clean Water Alliance in Olympia, Washington is an excellent example – water is being reclaimed at a satellite facility and then used to enhance a local wetland area and city park.

Together, all these strategies combine to reduce the load on the central treatment facility and increase the resilience of the water supply by reducing point source demand for water. Distributed reclamation may be cost-effective in certain situations and should be explored as a potential long-term strategy for water reclamation.

Economic Development

Attracting Clusters

The City of Salem is working to increase its GDP by actively pursuing target industries in the trade sector market. In the winter of 2011, the Community Planning Workshop at the University of Oregon will be conducting a target industries analysis. Based on Business Oregon's strategic plan and clusters identified by the Oregon Business Council (Oregon Business Plan), the City of Salem has identified renewable energy and metal manufacturing as two target industries.

To ensure that Salem has the competitive advantage to attract these national and global industries, it is imperative that water rates are low with a secure water source. The metal manufacturing and renewable energy industries are large consumers of water. For example, according to the U.S. Department of Energy's National Renewable Energy Laboratory, solar generating plants that use conventional cooling techniques to manufacture solar panels use 2-3 times the amount of water as coal-fired plants (Schneider, 2010). If Salem is able to guarantee non-potable water at a set and affordable price over the long term, it will be in a good position to attract metal manufacturing and renewable energy industries.

The City of Salem's Mill Creek Corporate Center and Energy and Technology Center have a combined 900 acres of "permit ready" land (Salem Renewable Technology Center). To ensure that clean-tech and manufacturing companies locating on these sites have affordable and secure water supplies, the City of Salem could choose one of two alternatives: provide tax credits to companies that install closed loop systems to maximize on-site water recycling, or build a distributed reclamation systems on site. For example, a distributed reclamation system could be installed at the Mill Creek Corporate Center that would treat water on site and transport it back to the industries in whatever class is needed (A, B, C, or D). Although there would be considerable upfront costs, building the distributed reclamation plant could be beneficial. Over the long term, it may be cheaper for the city to establish this on-site system instead of building the miles of piping that would be required to transport non-potable water from the Willow Lake Water Treatment plant to the Mill Creek Corporate Center. The cost of the on-site system would be outweighed by the benefit of the tax-base and jobs that these industries could potentially bring to Salem.

Alternatively, the city also has an opportunity to position the land around Willow Lake for industrial development. To utilize Willow Lake's reclaimed water that is currently being dumped into the Willamette River, the City of Salem should assemble property in the industrially zoned land north of the plant. Although developers have considered this in the past for a natural gas plant, nothing has happened to move this project forward (Eisner, 2010). The city, in partnership with the Strategic Economic Development Corporation and Marion County, should take the lead on this project, assemble the land for development, and market it to potential businesses. As mentioned earlier in the report, piping from Willow Lake to this site already exists based on a pilot project that was done in 2006. Therefore, the benefit to the potential companies would outweigh the cost to the city.

Incenting and promoting reclaimed water systems goes hand-in-hand with the type of businesses that the city is trying to attract as part of its long-term economic development strategy. Given projected water shortages in Oregon, it is in the city's best interest to help secure long-term water supplies for incoming metal manufacturing and renewable energy industries. Salem will also benefit from positive publicity; by offering incentives to ensure long-term business success, the city will appear to be open and supportive to business, in addition to being conscious of the industries' environmental impact.

Laying Purple Pipe

Upgrading Reclaimed Water Infrastructure

Another solution Willow Lake should explore is to build the reclaimed water infrastructure in anticipation of future changes in water supply or discharge constraints. In the industry, this is referred to as "laying purple pipe," so named for the purple hue of the reclaimed water pipes. This approach allows Salem to build the reclaimed water infrastructure in a targeted and cost effective manner.

The first step would be to identify a zone within the city for this infrastructure development. Zones for commercial and mixed use within a given radius of Willow Lake are ideal. Once the city has targeted the area for purple pipe development, the next step is to establish regulations that require reclaimed pipes be laid with any potable water pipe replacement that takes place. Purple pipes should be installed either when pipes are replaced or when infrastructure is built for new development.

Figure 25: Laying Purple Pipe

Using the Crestview Drive bids as a basis for an incremental cost calculation, it is determined that the cost of the pipes accounts for less than 30% of the total costs ($224K / $767K) (City of Eugene, 2010). The other 70% is spent on labor, traffic safety and control, erosion control measures, excavation and backfill, foundation stabilization, asphalt and concrete removal and replacement, as well as restoration and cleanup. Salem can begin to build the infrastructure of a reclaimed water delivery system by spending 30% more when replacing existing faulty pipes or laying new potable water pipes. When it becomes economically feasible or necessary to implement the reclaimed water distribution system, having these pieces in place at a lower incremental cost will lower the required investment and reduce the time to operation.

Appendix 7: Maps Used in Analysis of Biogas Generation Project #4

Local Digesters in Oregon

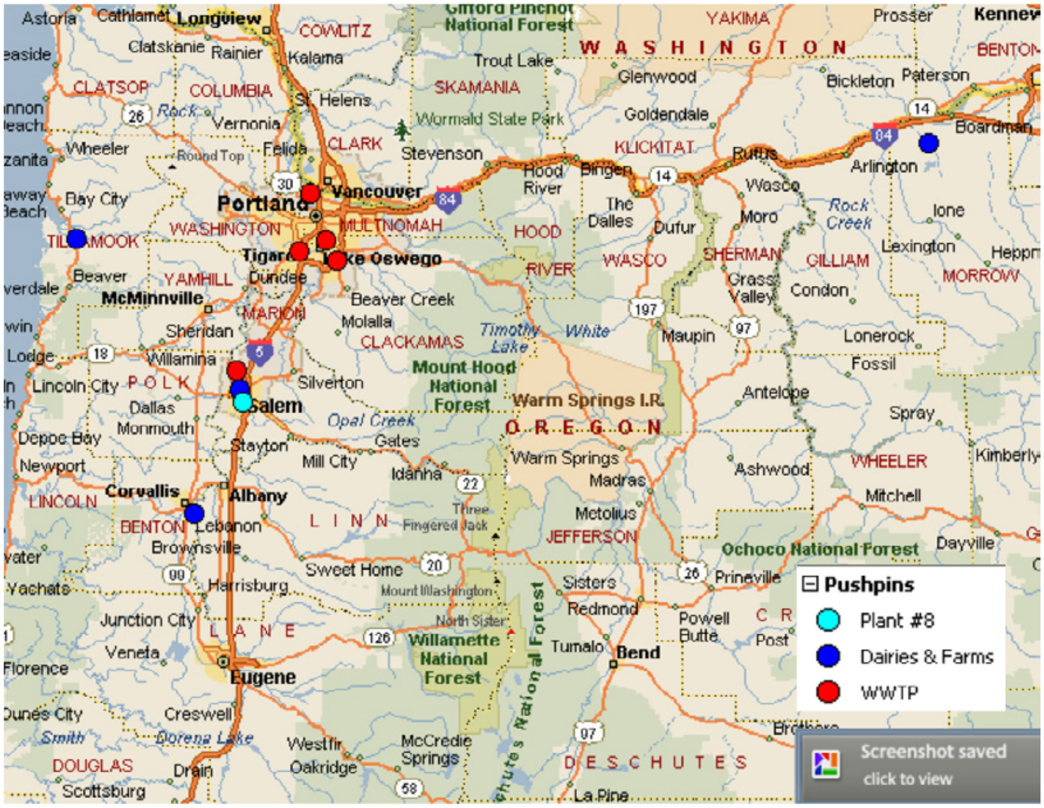


Figure 26: Map of Local Digesters in Oregon

Composting Infrastructure

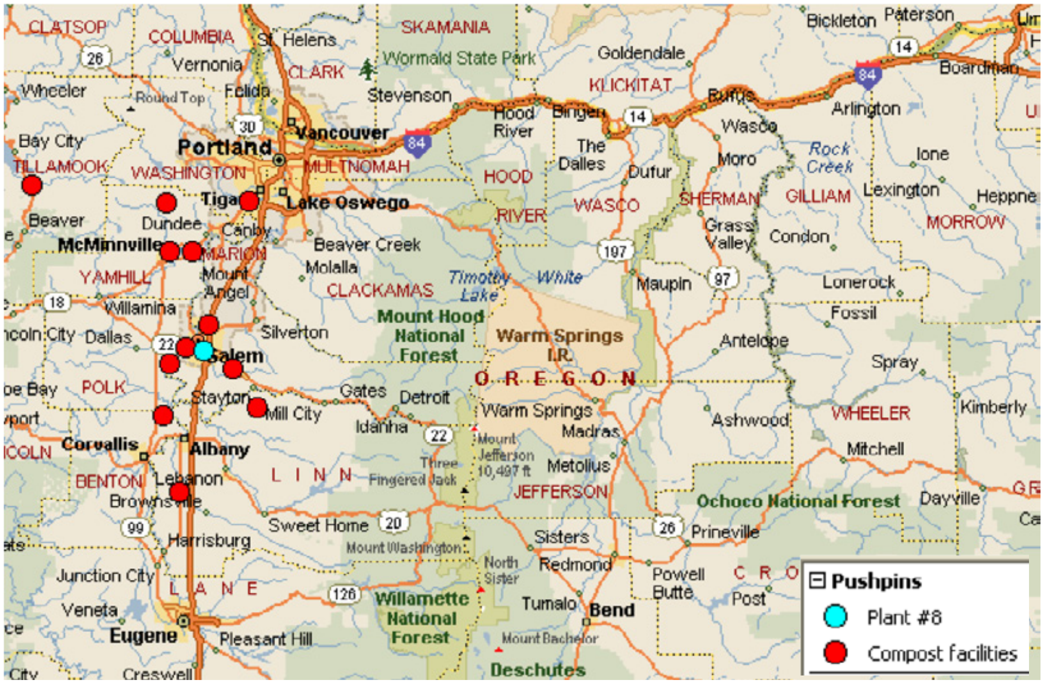


Figure 27: Map of Composting Infrastructure

Local Food Growers and Processors

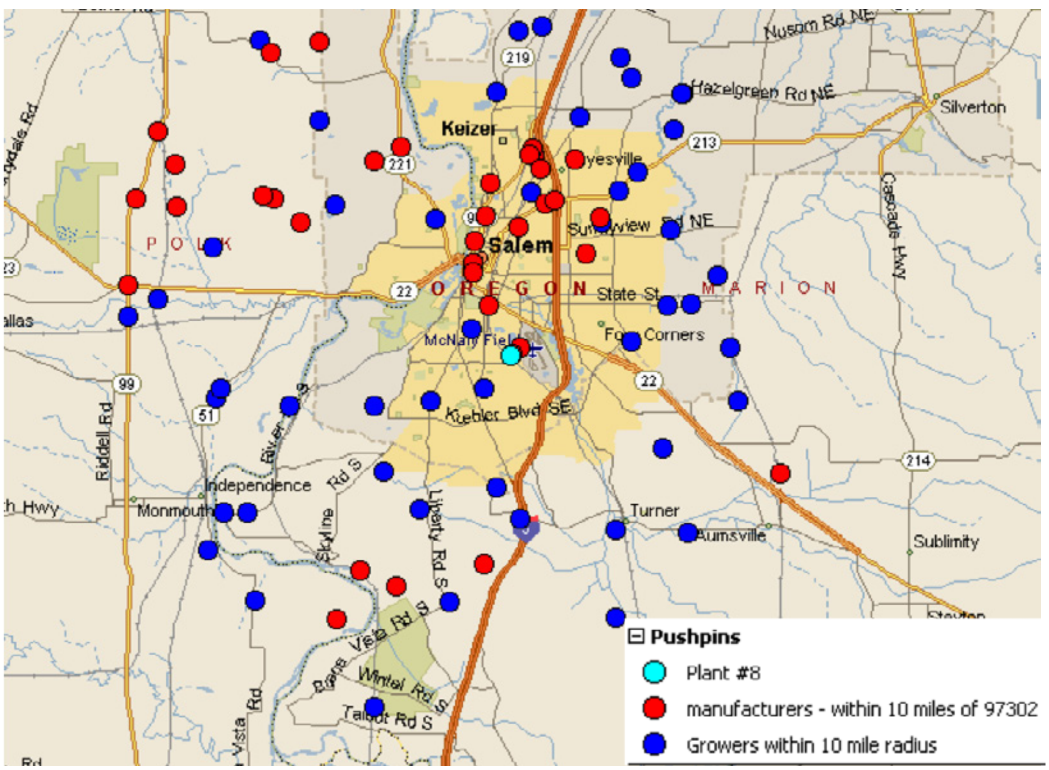


Figure 28: Map of Local Food Growers and Processors

Appendix 8: Consideration for Application of Alternatives in Project #4

Considerations for Alternative 1: Biogas Generation

Energy Contracts

Depending on the alternative, it must be decided which party will own the energy produced by digestion. Additionally, it is important to consider how the energy will be used. Some alternatives include selling the excess energy back to utility companies for profit or storing the energy for future use. It can be difficult to reach agreement on these issues, so every scenario should be considered before entering into any anaerobic digester energy contract.

Digester Type

There are currently two types of digesters, wet and dry. Both types of digesters can operate in either a multistage or continuous feed fashion. The entire dry digestion process takes approximately 35 days (Fact sheet Anaerobic Digestion). Wet digesters allow for the processing of bio-waste that is less refined, which takes considerably less time than dry digestion. However, wet anaerobic digesters often yield less biogas per ton and can be up to 50% more energy intensive than dry digestion. It is important for NORPAC to consider the tradeoffs between the two types of digesters before making any purchasing decisions.

Local Regulations and Programs

The major regulatory agency that oversees biogas conversion is the Environmental Protection Agency (EPA), while the legal authority that regulates the digestion process is the federal Clean Air Act (CAA). In addition, the federal Clean Water Act (CWA) regulates the storage of biosolids. The State of Oregon's Department of Environmental Quality enforces regulations on a state level (Summary of the Clean Water Act). It is important to understand how these agencies work together to regulate digester processes, and to anticipate any roadblocks that may come as NORPAC further considers anaerobic digestion.

Many programs currently exist to assist companies in the purchase of anaerobic digesters for the purpose of improving environmental impacts. Currently, two major governmental agencies work on biogas conversion, including the USDA's Natural Resource Conservation Service (NRCS) and Rural Development Agency. The NRCS will assist companies in developing and funding the creation of the infrastructure required for storing bio-waste. In addition, research is currently being performed to help develop biogas programs and promote the use of biogas technologies (Biogas: Benefits to the Farm, Rural America, Environment and Economy, 2009). NORPAC should consider all of the available support alternatives available to help make anaerobic digestion more viable and affordable.

Budget
The cost of anaerobic digesters can vary based on style, size, capacity, and intended purpose. Covered low-tech lagoon-style systems that can accommodate waste for approximately 150 livestock can cost as little as $25,000. Conversely, high-tech lagoon-style systems that accommodate waste for up to 5,000 livestock can cost as much as $1.3 million. It can be assumed that NORPAC's anaerobic project would cost an estimated $10 million in total, which is similar to that of the Stahlbush Farm project that was previously mentioned. It is important to consider purchase costs along with potential opportunities for future revenue generation. Possible incoming revenue streams can come from electricity generation, sale of digested fibers as compost, and reduced cost for natural gas and propane (John Balsam, 2006).

The AgStar program conducted a cost-benefit analysis of seven anaerobic digesters that were installed in the US in 1997. The scope of the study included digesters in the states of Oregon, Connecticut, Iowa, Virginia, North Carolina, Illinois, and New York. Analyzing initial outlay and costs, as well as the revenue generated from a sample of four of the digesters, reveals that an in-house anaerobic digester may not be feasible for the NORPAC Repack facility alone. In order to consider the alternative of owning its own digester, NORPAC could explore the alternatives that include consolidation of its company-wide waste or local partnerships.

Collection and Hauling of Waste
The collection and hauling of waste is often the most costly and environmentally intensive aspect of anaerobic digestion. Considerable regulatory concerns must also be taken into account. NORPAC can take advantage of various alternatives to reduce these environmental impacts, including investment in fuel-efficient vehicles and optimization of waste pickup routes and schedules. The more central the anaerobic digestion facility is to its contributing sources, the less environmentally intensive the process becomes.

Carbon Footprint Analysis
Because sustainability is an overarching theme to the operations of NORPAC, an environmental analysis is essential to evaluate the viability of the anaerobic digester alternative.

NORPAC currently takes its 1,100 tons of toted vegetables to a local farm, where it is used as fertilizer. In terms of carbon footprint, all of the anaerobic digesters (with the exception of Meduri, based on distance) are more beneficial for the environment. In terms of financial cost, however, this may not be true. Because NORPAC is a cooperative, the farmers will always be burdened with the cost of the anaerobic digestion model.

Considerations for Alternative 2: Composting

Regulations

To be able to operate a composting site, NORPAC would need to be accredited by the State of Oregon Department of Economic Quality (DEQ). Under state law, composting facilities must pass a rigorous environmental screening test to evaluate the potential of a composting facility to adversely impact surface water and groundwater, as well its ability to control unacceptable off-site odors (Instructions: Permit Application for Composting Facility Environmental Risk Screening). In addition, the screening survey evaluates operations and physical attributes of the plant. Composting sites that accept meat, however, are much more difficult to certify. Currently, the State of Oregon has only one composting facility certified to accept meat-waste, which is the Crook County Landfill. There are no regulations specifically aimed at the transportation of food waste to composting facilities.

It is important for NORPAC to consider the regulatory climate surrounding the operation of a composting facility, especially when considering the time and capital required up front to receive certification for a meat-waste facility.

Composting Infrastructure

There are currently 47 accredited composting facilities in the State of Oregon, twelve of which are located within a 48-mile radius of the NORPAC Brooks Plant. The following table details each facility and its distance from the NORPAC plant.

Facility Name	City	County	Distance from Norpac	Environtmental Impact*
Brown's Island Compost Facility	Salem	Marion	13 mi	783 CO2E
Compost Oregon (was Woodwaste Reclamation)	Salem	Marion	17 mi	784 CO2E
Rod Mclellan Company	Independence	Polk	20 mi	785 CO2E
Alderman Farm	Dayton	Yamhill	24 mi	786 CO2E
Gordon Farm	Dayton	Yamhill	26 mi	786 CO2E
Grimm's Fuel Co.	Tualatin	Washington	28 mi	786 CO2E
NW Greenlands Landscape And Supply	Mcminnville	Yamhill	32 mi	787 CO2E
Yamhill County Mushrooms, Inc.	Yamhill	Yamhill	39 mi	789 CO2E
Processing & Recovery Center	Monmouth	Benton	41 mi	789 CO2E
Ground-Up Soils Compost Facility	Scio	Linn	42 mi	789 CO2E
Stalford Seed Farms	Shedd	Linn	48 mi	790 CO2E
Willamette Landscape Supply Compost Facility	Salem	Marion	5 mi	782 CO2E
Dairy Compost, Inc.	**Tillamook**	**Tillamook**	**56 mi**	**792 CO2E**

***Assumptions:** Truck Efficiency 6mi/g; 22.3lb of CO2E per gallon of diesel combusted; 25 ton payload size; 1 ton of compost off-gasses 0.71 tons of CO2E

Figure 29:Accredited Composting Facilities within a 48-mile Radius of the NORPAC Brooks Plant

From a brief survey of these, it appears as though any one of them could shoulder the Brooks Plant waste output of 1,500 tons per year. However, the NORPAC waste cannot be shipped to any of these facilities due to the meat-waste regulations. The Crook County Landfill, which could accept this meat-waste, is more than 154 miles away.

NORPAC must consider the economic and environmental impact of shipping waste to the Crook County Landfill when considering the composting option.

Environmental Impacts

NORPAC should first concentrate its energy on making its waste free of animal byproducts. If achieved, NORPAC could then consider an aerobic composting solution. This process makes both business and environmental sense. First, total turnaround time is shorter than anaerobic composting and produces less methane. Additionally, weed seeds and pathogens are destroyed during the process. A related issue to consider is the environmental impact from transporting the waste. With a large waste output, hauling the material over large distances can have a significant impact. For example, 60 round trips to accommodate the 1,100 annual ton output to Tillamook produces approximately 792 tons of CO_2E. (The waste is not going to Tillamook; it is going to a local field, less than five miles away.)

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