EVERGREEN

THE EVERGREEN STATE COLLEGE
OLYMPIA, WASHINGTON

Report from:
The Sustainability Council

To:
The Vice-Presidents

The Feasibility of Biomass Gasification as a Carbon Neutral Replacement for Natural Gas in the Campus District Heating System

Summary of Findings and Recommendations

Table of Contents

Abstract

Biomass gasification is assessed as a mechanism to meet The Evergreen State College's goal of carbon neutrality by 2020. Utilization of current technology, including Electrostatic Precipitators and Selective non-Catalytic Reduction (SNCR), would make biomass gasification emissions comparable to or less than natural gas; noise and traffic would have a minimal impact on the campus and surrounding community. However, adequate Forest Sustainability Council (FSC) certified fuel sources are a critical factor in the economic viability of this project. Quantifying carbon impacts is complex, a conservative approach concludes that there would be a carbon benefit to replacing natural gas with biomass, but carbon neutrality would only be achieved if the biomass came from replanted non-forested lands.

Introduction – Scott Morgan, Sustainability Council Chair

Early in 2010, Evergreen's Sustainability Council was directed by the college's vice presidents to evaluate the hypothesis that biomass gasification could be a sustainable renewable energy replacement for the natural gas fueled campus heating system. The Council had been previously tasked to develop Evergreen's plan to achieve carbon neutrality, and the biomass gasification proposal was a substantial feature in that plan because carbon emissions from the use of natural gas for campus heating account for nearly one-third of the college's total emissions.

The Sustainability Council's various community engagement efforts began in the spring of 2010 and were followed with efforts across the summer and fall (e.g. student forums, community forums, West Olympia neighborhood association outreach, media engagement, community dialogue, student orientation and additional outreach efforts).

The study of biomass gasification as an option proved to be controversial from the outset. Since the moment we began the assigned work, the Council found itself spending most of its limited time and energy tending to important political and external public engagement processes regarding biomass concerns. This meant that our focus on the scientific and technical review of biomass gasification implications was deferred until much later.

During that time, we learned from experts within the biomass industry as well as those who have already installed similar biomass gasification facilities regarding the merits of the biomass gasification proposals. We heard from other state agencies who wanted to partner with Evergreen in our shared state level interests to reduce our dependence on fossil fuels. We heard from many of our surrounding community members who articulated their concerns, suggestions and questions that needed further exploration. And we experienced a great deal of political pressure from a small, but passionate group of anti-biomass activists.

From the very first days of the study, we spent a great deal of time listening, following up on key concerns, and tracking down research to clarify the assertions and conclusions that emerged from multiple engagements. It was clear that everyone who came to the table, regardless of their position (pro, con or undecided), had the same shared concerns about maintaining healthy forest systems and air quality in this region. I believe that in the process of acknowledging and understanding these shared concerns, we developed a substantially enhanced framework for evaluation of biomass.

What did we find in the course of our study? After separating the sensational from the factual and the apples from the oranges, we found that biomass gasification could be the most promising solution for Evergreen's specific heating needs, situation, and standards. We found that, by many measures, it is possible to demonstrate a carbon benefit compared to natural gas. We found that the proposed project would have little impact on forests or forest health, but that fuel that meets our high standard for sustainable forest practices could be difficult to come by. We found that air pollution and health impacts would be comparable to or less than natural gas – very similar to what we are already producing by burning fossil fuel.

We also found, as a result of sorting through concerns that did not apply to our specific proposal, that biomass projects can vary substantially. Because of those variances, we must emphasize that our findings are not true of all biomass to energy projects. They are quite specific to Evergreen's project parameters.

This report on our feasibility study begins with the Council's recommendation on biomass gasification as a renewable energy solution for campus heating. I encourage you not to stop with our recommendation, however, but to dig into the details that follow. It was part of the Council's education, during this study, to develop an understanding of the complex relationships and trade-offs attendant upon all of our energy choices.

Along the way we found that many in this community and region share our passion for the environment, and yet differ greatly on their views of how progress can be made to preserve it. Through months of listening, research, and consideration – sorting through and responding to an array of concerns and information related to various kinds of biomass energy, often having little in common with Evergreen's proposal – we honed in on facts and analysis most relevant to Evergreen's specific values and situation. We share those findings and much of the research that contributes to them in this document.

In summary our concluding recommendation is that the biomass gasification technology referenced in this study is a viable central heating option at Evergreen in the future if:

1. The college can identify a reliable supply of FSC-certified fuel from local working forests (so there will be a carbon benefit in comparison to natural gas), or
2. The college can replant non-forested lands with purposely grown fuel (in which case, campus heating could be demonstrably carbon neutral).

Although the capital project cannot proceed at this time, due in part to the Thurston County Commission moratorium that led to the loss of critical grant funding for the project, we don't need to repeat the study should the college decide to advance the project in the future.

In the spirit of shared concern for our environment, and in acknowledgement of our collective thinking that we must find reasonable alternatives to fossil fuels, we hope the research and findings of this study will contribute, at least in a small way, to a more sustainable future and that they will be helpful to other small organizations, municipalities and regional regulatory entities as they consider biomass as an option.

We also hope that the many community members who participated in this process who voiced their concerns and questions to the Council will find value in work that we have done together over the past academic year in examining the complex issues surrounding biomass as an alternative to Evergreen's dependence to fossil fuels.

Scott Morgan
Chair, Evergreen Sustainability Council
April 2012

Sustainability Council Recommendation on Biomass Gasification

In 2010, Evergreen's vice presidents charged the Sustainability Council to coordinate a feasibility study of biomass gasification technology as a local renewable energy model for the college, and to provide the college administration with an assessment of this proposed capital project. This document provides an executive summary of the findings based on that assessment.

The Sustainability Council finds that biomass gasification may be the best local, renewable energy solution for campus heating at Evergreen. The proposal meets most of the operational, environmental and economic criteria established for the project. However, we have a critical concern regarding the predictable quantity and reliability of FSC-certified fuel supply. We've also identified that, while there would be a carbon benefit to switching from natural gas to forest slash for fuel, carbon neutrality would require purposeful afforestation of otherwise un-used land. (No steps have been taken to identify appropriate candidate lands for such purpose.)

The Sustainability Council has completed a substantial body of work related to the feasibility of biomass gasification for Evergreen. Several important questions have been satisfactorily resolved, and the Council is confident that this study will serve as a substantial stepping stone for future work should the college choose to re-consider biomass gasification. As a complex as well as controversial technical, social, environmental, and economic issue, we strongly encourage that this body of work be supported with additional academic studies.

If the college does choose to re-consider this renewable energy option, the Sustainability Council recommends that the college President charge a highly focused, short-term Disappearing Task Force with expertise related to the science of the project and experience with public engagement for environmental projects. The DTF would provide a scientific review of the work accomplished in this year's study, update and clarify any emergent areas of uncertainty, and design a process and schedule of community consultation and engagement with the study findings.

We recommend that the DTF include participants with expertise in forest carbon cycles/ecosystems, forestry practices, facilities district heating system and plant operations, renewable energy technologies, economics and finance, public consultation and engagement, global carbon cycle/greenhouse gases/climate change, and air pollution and human health. The DTF would review current findings, update volumes and sources of fuel, update the project-specific carbon impact study, and establish an effective process for consultation with campus and local communities at an appropriate time.

Project Findings Based on Key Criteria

At the outset of the project, the Sustainability Council established a number of criteria for a renewable energy replacement for natural gas. Overall, the Council found that biomass gasification meets most of our criteria, though fuel supply and carbon neutrality are conditional to specific circumstances. The following summarizes Council conclusions on key project criteria.

Carbon Neutrality

During the study, we found multiple perspectives and means of assessing carbon neutrality. We also found that the science on carbon neutrality continues to evolve and that it is difficult to find a widely supported methodology for determining the carbon neutrality of a specific project. **While carbon neutrality is a complex and controversial subject, we have identified significant research to indicate that Evergreen's project, as modeled, could have a carbon benefit and that carbon neutrality is achievable if fuel were sourced from an afforestation project.**

Access to a dependable and sustainable fuel supply

Choices related to fuel sourcing play a major role in our ability to predict forest impacts. To ensure that our fuel would derive from timberlands managed for forest health and sustainability and to promote economically and environmentally valuable relationships with responsible and ecologically minded forest owners, the Sustainability Council strongly recommends that the fuel for this project should be sourced exclusively from timberlands managed under Forest Stewardship Council (FSC) certification. FSC certification is critical to address concerns about carbon neutrality and long-term sustainability of the forests.

The Council finds that our FSC certification criterion leads to three potentially significant complications:

- the maximum available local fuel supply is substantially reduced (only narrowly exceeding anticipated project demand);
- the distance the fuel must travel is close to this project's maximum economical range; and
- the certainty of year-round fuel availability is low

The Council finds that a dependable fuel supply will likely require a contracted agent capable of reliably adjusting fuel sources (working forests) on a regular basis and/or a large volume storage facility able to provide a buffer of two to three month's worth of fuel. Depending upon the real time slash quantities and accessibility, this need could drive fuel costs higher than currently outlined for the project.

The Council also feels that it would be worthwhile for Evergreen to become engaged with a process that is now getting underway in our state to implement a new certification process developed for the Roundtable for Sustainable Biofuels (RSB). This certification process may provide a future means of validating sustainable biofuel practices.

For Future Reference: Our current understanding is that available FSC-sourced fuel supply only narrowly exceeds the anticipated project demand. Prior to any renewed consideration of this project, actual supply availability must be quantified in detail and evaluated in terms of seasonal availability by timberland. Potential suppliers and contract agents also need to be identified and contract terms established.

Use of a resource and technology compatible with our existing district heating infrastructure

A wood gasification system fits with our existing heating infrastructure and can be fueled by local forest slash.

A durable and reliable solution during our demand season (Oct – June)

The gasification technology and infrastructure is proven and durable. Heat can be produced on demand, as needed, provided the fuel is available. Some flexibility exists with this design to temporarily use natural gas in times of biomass shortages, emergencies, etc. This flexibility may mitigate some issues related to supply, but would also affect the economic and carbon balance equations.

Airborne emissions similar to those that result from burning natural gas

Nexterra's operational gasification plants have demonstrated emissions comparable to natural gas, with the exception of nitrogen oxides. Addition of control equipment (Selective non-Catalytic Reduction - SNCR) to Evergreen's plant would reduce nitrogen oxide levels to be comparable to natural gas.

Minimal impact on the campus and surrounding community (emissions, noise, traffic)

Evaluation of air and waste emissions, water use and runoff, noise and smell, traffic and land use has shown that those impacts will be minimal.

An economically affordable and viable solution

Of all the identified options for Evergreen, wood gasification is the most economically affordable and viable – within certain parameters. It also has active support from other state agencies, the governor's office, and our local legislators. The fuel savings, in comparison to the cost of natural gas, give this project a much higher viability than comparable options that have been considered. However the fuel savings alone will not allow the college to secure funding for the entire project. There is a need for substantial capital resources outside of the funding available by bonding. These additional capital resources are in the $6-$7 million range.

Potential to create an alternative energy learning opportunity

There is significant potential to engage academic programs and student learning experiences with this project in areas such as carbon monitoring and modeling, gasification operations, forestry practices and impacts, and local energy economies. Creating and maintaining that engagement, however, will not happen automatically and will require commitments from the academic side of the college.

Two models that could help support the academic commitments are: 1) long-term financial support for defined student internship positions (perhaps in partnership with DNR) to provide data collection and ecosystem monitoring services; and 2) a financial commitment to a carbon monitoring lab or other physical infrastructure that may be used by existing academic programs such as the Evergreen Ecological Observation Network (EEON).

Findings Focused on Community Concerns

Community concerns brought to light over the course of the project focused on the following three key issues:

Emissions/Health

- While health impacts of particulate and other emissions are a legitimate concern, shared by Evergreen, based on data from other Nexterra facilities and additional fuel/slash testing from Capitol forest, **we have confidence that this facility would have emissions comparable to or less than natural gas, and that health impacts would not be substantially different from the status quo.**
- **Much of the data and information provided to us by those concerned about biomass energy emissions and health impacts varied significantly from the actual parameters of this project.** Upon close reading, emissions and health implications were frequently based on different types of biomass combustion (e.g. direct burn vs. gasification), different/less efficient energy production models (e.g. electricity vs. heat or combined heat and power), different fuel sources (including municipal solid waste/garbage and treated construction waste), different emission sources (e.g. vehicle emissions or smoke from residential woodstoves), and different emissions control measures. **It is, however, important to follow continuing scientific and regulatory developments related to nano-particulate emissions and human health.**

Forest/Ecosystem Impacts

- Given the size, scope, standards and narrowly defined fuel supply, **the proposed project would not encourage negative changes in forest practices** (e.g. clear-cutting of old growth, land conversion, use of whole timber-grade trees for biomass fuel) and may have a small positive influence by supporting responsible forestry and providing a fuel-sourcing model for others to consider.
- Using FSC as the minimum standard, **concerns for forest, soil and ecosystem health are responsibly addressed.** Focused contracting, monitoring and long-term study would ensure continued compliance and accountability to these environmental goals.

Other Alternatives

The Council explored research on a range of alternatives to determine how well they could meet the criteria for this project. **Solar, wind, tidal, kinetic** and **ground source heat pumps** could not meet the criteria for the project (due to technical, geographic and/or financial factors). Based on community input, the college also conducted additional research – including technical consultation from multiple sources and a detailed site visit – to evaluate the potential of **Variable Refrigerant Flow (VRF)** air source heat pumps for campus heating needs. We confirmed from multiple sources – including experts suggested by VRF advocates – that VRF is not suitable as a total substitution for natural gas (for technical and financial reasons – it would not work for all areas of the college and would be significantly more costly). It does, however, show promise for future projects on a smaller scale and should be considered on a project-by-project basis.

Overall Conclusion

Based upon our experiences with assumptions and arguments that equated all biomass to energy projects, despite significant differences in context, technology, and fuel source, we feel it is important to state definitively that this report is **absolutely not a blanket endorsement of all biomass for energy projects**.

The Council finds that the **following parameters are key requirements for a responsible implementation** of biomass energy at Evergreen:

1. **Fuel** must be sourced from FSC certified timberlands.
2. **Processes and policies for monitoring of forest impacts and fuel supply chain of custody must be defined.** College processes should define the desired environmental goals of this project and where the responsibilities lie for ensuring those goals are achieved through vendor selection, contracts and other processes as required.
3. **Processes and policies for carbon accounting must be defined.** College processes should define the desired environmental goals of this project and where the responsibilities lie for monitoring, reporting, and ensuring that the goals are being met.
4. **The environmental goals of the project must be supported with a commitment to internal monitoring processes** through academic engagement plus staff training, process accountability, and plant maintenance to maintain the awareness necessary for long-term positive environmental benefits.
5. **The plant must be planned with provision for future flexibility**, which may include addition of electrical generation for high efficiency **combined heat and power**.
6. **Electrostatic Precipitator (best possible) and Selective non-Catalytic Reduction (or better) emission controls must be included** as planned.
7. The College should continue to explore **diversified renewable energy technologies** and production on campus. For example, it may be possible to address both our Carbon Neutrality and Zero-Waste goals, in part, through the use of energy technologies such as facility scale heat pumps and dry anaerobic digestion. Variable Refrigerant Flow technologies may also have a role to play.

In addition to the Evergreen-specific parameters noted above, the Council's **conclusions** regarding emissions, forest impacts and other considerations are **contingent upon these critical project characteristics and assumptions:**

- Non-commercial, campus only application;
- Heat production;
- Joined to an existing district heat distribution system;
- Forest slash as fuel;
- Fuel only from sustainably managed, FSC certified working forests;
- Small project size (5600 bone dry tons per year);
- Location within 30-50 miles of all short- and long-term fuel supplies;
- Substitution for an existing fossil fuel heat source;
- Gasification using Best Available Control Technology (BACT);
- Electrostatic precipitator to mitigate particulate emissions;
- Selective non-Catalytic Reduction (or better) for mitigation of NOx emissions; and
- Academic efforts to ensure long-term monitoring and follow-up.

Within these specific parameters, it is our view that biomass gasification may be the best currently available, renewable energy alternative to natural gas for campus heating if:

1. **Project conditions for carbon neutrality are met;**
2. **There is a dependable and sustainable fuel supply; and**
3. **Supplementary funding becomes available to augment fuel cost savings and achieve a reasonable payback period for the investment.**

Respectfully submitted by The Evergreen State College Sustainability Council

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Evergreen's Goal and Criteria

Atmospheric levels of carbon dioxide and other greenhouse gases are increasing. Greenhouse gases hold heat in the atmosphere and carbon dioxide is absorbed into the oceans, increasing their acidity. There is now strong evidence to indicate that global warming and ocean acidification are occurring because of increased carbon dioxide and other greenhouse gas emissions from human activities that *could be changed*. (IPCC, Working Group 1, 2007)

Fossil fuels – natural gas, coal, and petroleum – are carbon compounds that were sequestered underground over millennia. Combustion of fossil fuels has dumped an enormous quantity of new carbon dioxide (a by-product of combustion) and other greenhouse gases into our biosphere with no compensatory ways to remove those gases. Consequently, that 'fossil' carbon dioxide is overburdening the natural carbon cycle, and appears to be a primary contributor to the atmospheric and oceanic changes that are occurring. The world has been dumping waste greenhouse gases into the atmosphere for two centuries without even thinking about it. We now know that we cannot blithely dump wastes without an impact; we have learned that about other pollutants and now we know it about carbon dioxide.

It isn't entirely clear what will happen as a result of rising CO_2 and greenhouse gas levels. But, if the levels continue to increase, our global ecosystems are likely to be disrupted, perhaps even catastrophically. We should be concerned, and we should be taking action.

Evergreen made an institutional commitment in 2007 to take action on climate change and to be Carbon Neutral by 2020.

> As part of the updated Strategic Plan, the College has established the ambitious goal of being carbon and waste neutral by the year 2020. This sustainability focus has informed a process that is rethinking campus operations and facilities planning at the College. (The Evergreen State College, 2008)

The college's plan for achieving carbon neutrality was developed in 2009. The strategic choices in the college's Climate Action Plan were based upon a fundamental decision to first make local and real change then pursue carbon sequestration strategies in the form of third party 'offsets'.

Our strategies were defined to:

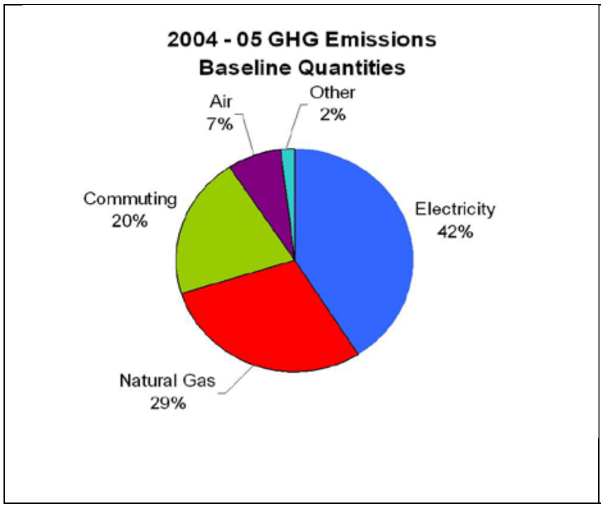
1. **Reduce –** energy & resource use, single occupancy vehicle miles traveled, and waste
2. **Replace –** energy sources, commuting and resource use practices
3. **Offset –** mission critical activity that cannot be otherwise reduced or replaced

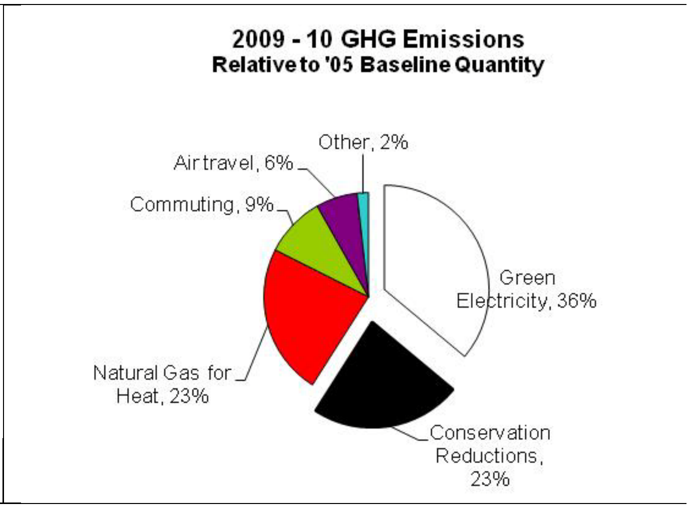
> Carbon neutrality is accessible in a variety of ways, but there are at least two fundamental strategic paths. The first path assumes that carbon neutrality is a cost of doing business and approaches the goal by purchasing carbon offsets to zero out normal operational emissions. This strategy places the responsibility for carbon neutrality solely upon the operational side of an institution. The second path assumes responsibility uniformly throughout the institution. This strategy is possibly more difficult, as it requires an active engagement with and exploration

> of the goal as part of the process. It requires a process of engaging and including key stakeholders, of complementing educational goals, of reaching for widespread campus participation and strategic community partnerships, as well as exploring innovative technical solutions. The second strategy focuses upon reducing overall emissions, throughout the organization, and only then considering offsets for unavoidable greenhouse gas emissions.
>
> Institutions with sufficient budget or endowment may choose to pursue the first path, and legitimately claim impressive reductions in net carbon emissions. Yet, this solution lacks a large part of the learning and local engagement of the second (longer, more challenging, and arguably more substantive) path. Through this Climate Action Plan, Evergreen is committing to the latter course. We are choosing to be active and engaged. (The Evergreen State College, 2009)

The college's first success was in 2005 when the students voted in the clean energy fee to purchase Renewable Energy Credits for 100% of Evergreen's purchased electricity. Since then, Evergreen's Facilities Department has aggressively pursued energy conservation measures throughout the campus (along with many other campus wide conservation measures in purchasing, waste diversion, and transportation). In 2009 – 2010, the college's greenhouse gas emissions due to natural gas were reduced by 20% (from 5658 to 4543 metric tons of carbon dioxide equivalent) over our 2005 baseline emissions. Those reductions, and more to come, are an important part of our overall plan to minimize impacts and use only the energy we need, regardless of where it may come from. Though the college continues to pursue additional conservation measures, it is impossible to save our way to carbon neutrality without significantly impacting the mission of the college. Energy replacement strategies are critical to accomplishing our goal.

Figure 1: Comparison of total college emissions – 2005 to 2010.





The most significant change that can be made to address global warming is to stop burning fossil fuels. The world needs energy solutions that are not adding more to the carbon cycle, but that are either contained within the existing cycle or are non-emitting. Evergreen currently burns natural gas (about 85,000 MMBtu annually) to heat the Olympia campus (1 million sq. ft.) through a centralized district steam heating system. The steam is generated in natural gas fired boilers at our central utility plant and piped around campus to the individual buildings. But combustion of natural gas is adding fossil carbon (that had been stored away for hundreds of thousands of years) to the existing carbon cycle. Evergreen's goal is to minimize and replace fossil carbon emissions.

In winter quarter 2009, graduate students in the class Current Topics in Environmental Studies: Climate Action Planning performed an analysis of existing renewable energy technologies available for campus use. They were tasked to identify:

- renewable energy replacements for natural gas and electricity
- technologies that could be located on-campus and use local resources
- technologies appropriate to meet the college's seasonal and on-demand needs

The group's findings indicated that:

- local solar, wind, and tidal resources are not reliable during our peak demand periods (October through June)
- groundwater source heat pumps may be technically feasible, but the expense of new installation is currently prohibitive; however, geo-thermal systems might be feasible and should be considered for new on-campus construction
- biomass (forestry slash; unmarketable woody debris from forestry operations) is a plentiful local resource currently treated as a waste that is either burned in the forest or left to decompose
- forestry slash could be utilized as fuel in a gasification system (gasification is a process of heating biomass in a very low oxygen atmosphere which keeps it from burning and vaporizes a "synthesis gas" which is pumped into a second chamber where the vapors are burned) that could replace natural gas in our existing heating system

Based on this research, forestry slash and gasification technology appeared to hold the most promise to replace natural gas at Evergreen. All indications were that the available fuel is indeed a local waste stream, the technology fits with the college's heating infrastructure, and that adverse impacts would be minimal.

Why Replace Natural Gas?

According to the Intergovernmental Panel on Climate Change's Fourth Assessment Report, *Climate Change 2007*, greenhouse gas emissions from human activity very likely drive global warming. The IPCC points out that much of those emissions come from fossil fuels, and that properly utilized biofuels have potential to alleviate some of those emissions.

> Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. This is an advance since the [Third Assessment Report's] conclusion that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations". Discernible human influences now extend to other aspects of climate, including ocean

> warming, continental-average temperatures, temperature extremes and wind patterns. (IPCC, Working Group 1, 2007)
>
> The global mean concentration of CO_2 in 2005 was 379 ppm, leading to an RF (radiative forcing) of +1.66 [±0.17] W m^{-2}. Past emissions of fossil fuels and cement production have likely contributed about three-quarters of the current RF, with the remainder caused by land use changes. For the 1995 to 2005 decade, the growth rate of CO_2 in the atmosphere was 1.9 ppm yr^{-1} and the CO_2 RF increased by 20%: this is the largest change observed or inferred for any decade in at least the last 200 years. From 1999 to 2005, global emissions from fossil fuel and cement production increased at a rate of roughly 3% yr^{-1}. (IPCC, Working Group 1, 2007)
>
> If the development of biomass energy can be carried out in ways that effectively address concerns about other environmental issues (e.g., impacts on biodiversity) and competition with other land uses, biomass could make major contributions in both the electricity and fuels markets (SAR II, SPM 4.1.3.2). By and large, renewable sources of energy could offer substantial reductions of GHG emissions compared to the use of fossil fuels (SAR II, 19.2.5), provided their economic performance continues to improve and no siting problems arise. (IPCC, 1996, p. 40)

The pursuit of carbon neutrality will ultimately require that we learn to work within the existing carbon cycle, and stop adding fossil carbon to that cycle.

Criteria for Replacing Natural Gas

Emissions from the extraction and combustion of natural gas add additional burden to the existing carbon cycle and there is no short term cycle that removes that additional carbon back out of the cycle. Replacing natural gas will require a strategy that reduces or eliminates input of geological carbon to the atmosphere, thereby relieving the subsequent overburden.

The college's initial criteria for an effective natural gas replacement included:

- A locally available renewable resource for on-site generation of heat
- A resource and technology compatible with our existing district heating infrastructure
- An economically affordable and viable solution
- A durable and reliable solution during our demand season (Oct – June)

Early in our feasibility study, the Sustainability Council identified additional criteria that alternatives to natural gas should also meet:

- Combustion emissions similar to those that result from burning natural gas, including criteria pollutants such as nitrogen oxides (NOx), volatile organic compounds (VOC), particulate matter (PM), sulfur oxides (SOx), and carbon monoxide (CO).
- Access to a dependable and sustainable fuel supply
- Minimal impact on the campus and surrounding community (emissions, noise, traffic)
- Potential to create an alternative energy learning opportunity

These criteria were the basis for evaluation and judgment as the council explored the feasibility of biomass gasification, and reviewed other renewable energy options.

Replacing the college's heating infrastructure would be a capital project, an investment in support infrastructure with a long life span. As with any capital project, there were also economic criteria that necessarily limited our options even though the project was not being driven by economic return. The Evergreen State College is a public agency and, as such, is not eligible for tax credits or most other economic stimulus funds associated with private energy installations. Evergreen draws funding for capital projects from three possible sources:

- Legislative appropriations – the normal source of funds to support college infrastructure is through designated state appropriations in each biennial budget
- External grants – grants of State or Federal funds are occasionally available for capital projects and are awarded through competitive application processes
- Self funded – Evergreen can self-fund projects through operational savings, the Energy Savings Performance Contracting (ESPC) process managed by General Administration is the self-funding process specifically applicable to this project

The above criteria and economic restrictions effectively restricted our choices as we explored various renewable energy options.

Process Steps

The biomass gasification project was scheduled in the college's Climate Action Plan for the 2013-15 biennium because of the expected lead time required to add a capital project to the budgetary planning processes and acquire funding. However, the college learned early in 2010 that the state would be encouraging biomass energy projects and that competitive grant opportunities would be available for energy projects in higher education. Since the current economic crisis has severely curtailed the state's ability to fund new capital projects, this was recognized as a unique opportunity to successfully fund the biomass gasification project.

Early in 2010, Evergreen procured funds for a professional study of biomass gasification from the college Clean Energy Committee ($125,000), the college reserves ($125,000), and the state Legislature ($125,000). These funds allowed the college to begin a professional feasibility study of the project in the spring of 2010.

Preliminary research had indicated that a biomass gasification plant might show operational cost savings sufficient to self-fund the project, so an Energy Savings Performance Contract seemed to be the most viable path toward funding the project. After confirming with the Washington State Department of General Administration that the college's biomass gasification proposal would qualify as an energy savings project, Evergreen's Energy Savings Contractor (ESCO) McKinstry was asked to lead the feasibility study.

McKinstry works with multiple public agencies around the state to identify and implement facilities energy conservation measures. The Energy Savings Performance Contract process requires that the ESCO (Energy Savings Contractor) must:

First – Perform an audit to identify conservation measures

Second – Provide an advance guarantee of savings that would result from the conservation measures

Third – (if the project proceeds) Design, construct, and implement the defined facilities improvement measures

Fourth – Measure and verify that the guaranteed savings have been met after the improvement measures have been completed (the ESCO must ensure that guaranteed savings are achieved)

McKinstry has been working with Evergreen since 2008 and has successfully identified and implemented multiple energy conservation projects including:

- installation of a 9 kV solar photovoltaic array on the library building roof – estimated to save about 7 tons of CO_2 annually
- repaired and replaced steam traps – estimated savings of 65 tons of CO_2 annually
- installed an insulating pool cover on the college's swimming and diving pools – estimated savings of 325 tons annually
- installed heat recovery system to Lab I Outside Air – estimated saving of 75 tons

In November of 2010, McKinstry reported the pre- and post-survey measurements on the projects listed above and confirmed that all four facility improvement measures are on track to meet or exceed their Guaranteed Energy Savings values (per the ESP contract), an estimated total 8,100 kWh of electricity and 101,158 therms of heating.

Evergreen chose McKinstry for this feasibility study because of our good working relationship, their detailed knowledge of Evergreen's heating infrastructure, and the strength of the Energy Savings Performance Contracting process through General Administration. McKinstry was tasked in April 2010 to:

a) Determine energy and energy cost savings associated with the installation of a biomass gasification plant and associated upgrades to the existing steam plant system
b) Determine the feasibility of whether a biomass gasification plant can contribute significantly to achieving the sustainability goals of The Evergreen State College as articulated in college's Strategic Plan.

In early summer 2010, Evergreen's Vice-Presidents charged the Sustainability Council to coordinate the biomass feasibility study and provide the college administration with a recommendation on the proposed project.

Overview of Communications and Community Outreach

October – November 2009: Clean Energy Committee outreach and student forums regarding funds for the biomass gasification feasibility study.

May 2010: Campus announcements and a table exhibit at Synergy opened a wider dialogue on biomass exploration.

June 2010: Evergreen's biomass gasification FAQ was posted online and publicized; including solicitation of community input on key questions. This posting also included an explanation of plans to seek state and grant funding while simultaneously completing a project feasibility study.

July 2010: Evergreen held an open internal planning meeting scheduled to be accessible to Evergreen faculty which included public comment and discussion. Meeting invitations were issued to some known faculty and students who opposed the project concept because we wanted their input. 30 people attended, including Evergreen staff, faculty, and students, neighboring community members, state agency representatives, No Biomass Burn community activists, and McKinstry project managers.

July/August 2010: Media coverage of Evergreen's study, including goals, criteria, technology, funding approach and process appeared in the Olympian, Tacoma News Tribune, Seattle Times and Works in Progress.

Summer 2010: Multiple community discussions *to inform the shape and content* of our study took place on local email list serves and through extensive staff interaction with, and responses to, individuals and groups interested in the biomass topic (person to person, email, blogs, media outreach, etc.).

August 2010: Local neighborhood associations were invited to campus for a regular campus update meeting, which included an introduction to the biomass project.

September 2010: An informational session was held for new students during orientation week.

October 2010: A community informational meeting was held on campus.

November 2010: Dr. Mark Harmon was brought to campus to speak on Forest Carbon Cycles. His presentation was publicized and open to the general public.

January 2011: A community open house and discussion with the Sustainability Council was held on campus.

February 2011 – The Evergreen student program "Applied Research: Biomass, Energy, and Environmental Justice" (26 students) reported to the Sustainability Council on their research performed during winter quarter, 2011 (Applied Research: Biomass, Energy, and Environmental Justice, 2011).

Community Reactions

Evergreen opened up the college's study and planning process very early by asking for community concerns and questions that could be included in the study. The college's call for questions and concerns was subsequently swamped by a simultaneous community process of anti-biomass activism originally and primarily aimed at the biomass electrical plant proposed for Mason County. As a result, the college's request for questions was rapidly overwhelmed by a large number of pre-formed arguments based mostly on biomass-to-energy models unlike the college's proposal. None the less, Evergreen's Sustainability Council has done their best to sort and qualify the many arguments and address those that are pertinent to this particular project in the study findings.

Evergreen's community engagement approach entailed educational offerings, question and answer sessions, community meetings, solicitation of key questions for further research, web and blog postings, as well as dozens of staff and council member responses to inquiries related to the project, media coverage of the project, and other activities. The primary emphasis was on *community consultation* to refine the shape and focus of the inquiry, including the refinement of key questions that should be answered and concerns that should be addressed. The process, while imperfect, did yield significant input from a range of stakeholders, although mainstream media coverage in Olympia, Seattle, Tacoma and other communities generated very little feedback. The input Evergreen did receive was evaluated for concepts or source information to be explored. Much of the feedback and input generated came from stakeholders with a primary interest in biomass proposals in Mason County, elsewhere in the Northwest or elsewhere in the country.

It became clear at an early stage that Evergreen's project was considered to be nearly identical to the utility scale biomass electrical plant proposed in Shelton. Evergreen's requests for public input, public events, and planning meetings were consistently overwhelmed with accusations and 'evidence' based upon an apparent assumption that there was no difference in the two projects. The college noted that much of the data provided to demonstrate that Evergreen's project should not be pursued was not directly applicable to the proposal being studied. Apples to oranges comparisons – between different fuel types, technologies, economic models, environmental conditions, and organizational motivations – were common. The Council also noted that, while

Evergreen's project is defined by quantitative engineering and economic criteria along with many qualitatively defined environmental and social criteria, much of the input received during our public outreach process reflected singular perspectives with little attempt to balance all the complex criteria involved.

Publicly expressed concerns reflected fears that Evergreen would be providing leadership and tacit approval for all types of biomass to energy installations. The college also heard concerns that biomass is not a sufficient or certain source for 100% of local energy needs and that Evergreen's success with a biomass plant might prohibit any others from doing the same because of a lack of fuel. Other questions and concerns included:

- What other renewable energy alternatives have been considered and to what extent?
- What new study should or could be done to ensure that all alternatives have been researched?
- How does this project fit in with the college's mission; learning laboratory, think creatively, challenge change?
- What is the best science present in or missing from the existing data?
- What fuel sources have been considered?
- What reliability, sustainability, and quality information is available for the fuel?
- Where does a sustained and sustainable source of biomass come from?
- What funding sources are currently being considered, those available now as well as in the future?
- What is the community's engagement with this and how is their input included in the decision making process?
- What energy conservation alternatives can be implemented?
- What are the gasification plant emissions?
- What are the life-cycle emissions and how do they compare with the existing system?
- We should use local, regional, global, short and long term perspectives to qualify our information.
- What is the value of the forests as a carbon sink and how does that compare to harvest for fuel?
- What are the decision-making criteria?
- Who makes the decision?
- Can we hire an opposing opinion consultant or maybe use a peer review process?
- What is the student engagement process?
- Can the past student work be released?
- Can the current study be incorporated into academic programs?
- Can we get real-world information from existing facilities?
- How could this decision affect/transform ourselves and our region? These issues extend beyond technology and bio-systems. We're talking about communities. This is a local vs global issue and it could lead to a radical transformation of the American energy paradigm. The social dynamic is critical and just as important as the technical and biological. We have an opportunity to address the social dynamics and paradigms. We should also include the social dynamics of local sourcing in the study.

All questions and concerns raised by the public were shared among the Sustainability Council, then incorporated and evaluated to the best of our ability during the course of this study. More detailed elaboration of arguments and concerns can be found in the Findings section of this report.

Funding

As per college budgeting processes, the biomass gasification proposal was included in the college's ten-year capital plan that was presented to the college's Board of Trustees in the summer of 2010. This project was also included in the college's list of capital project funding requests that was forwarded to the Higher Education Coordinating Board (HEC Board) and the Governor's office in the fall of 2010.

Though the energy savings associated with the biomass gasification project would allow the college to self-fund a substantial portion of the project, those savings would not be sufficient, by themselves, to fund the project fully. In August 2010, Evergreen applied for a Jobs Act grant through the Department of Commerce, requesting $5 million for the project. This application was turned down, but Evergreen was encouraged to re-apply during the second round of the grant cycle. The college re-applied to Commerce in September of 2010 and on October 15th the college accepted a $3.7 million Community Capital Facilities-Jobs Act for Public K-12 and Higher Education grant from the State Department of Commerce, which was allocated for the purposes of stimulating Washington's economy by creating jobs and creating long-term reductions in the energy costs at the state's public education facilities. This grant provided about a quarter of the financial resources necessary to support the project, as it was scoped at that time.

Thurston County Moratorium

In December of 2010, the Thurston County Commissioners passed an emergency 12-month moratorium (see attachment) on the permitting of any biomass energy projects to allow county staff time to study, clarify, and define any new code requirements. This action was followed by a month of briefings and work sessions then a public hearing on February 9, 2011. (Thurston County, 2011) The information and public comment in support of this moratorium was predominantly aimed at utility scale projects like the Adage project proposed for Mason County, although no projects of that type or scale have been suggested for Thurston County. The county commissioners did not act to lift the moratorium, so it remains in place for 2011 as a barrier to any actual implementation of Evergreen's project proposal.

Evergreen initially requested that the County reconsider its moratorium and provided information to support that request (including information related to emissions, fuel supplies, facilities and expected community impacts). When the moratorium was continued, the college offered to participate in a technical advisory group the County had indicated it would form to examine issues related to biomass. As of this writing (April 2011), the County has not formed such a group and has given no indication that such a group will be formed in the near future.

Review of local renewable energy resources and technologies.

Evergreen reviewed several renewable energy resources and technologies as possible replacements for natural gas. Renewable resources were evaluated in terms of local availability during our critical demand period from October through May and in terms of how well they fit the college's need, infrastructure, and economic capacity. Table 1 summarizes those findings.

Table 1: Evaluation of local renewable resources

Resource	Local Availability	Reliability
Sunshine	Low	Low
Wind	Low	Low
Flowing water	Low	Low
Biomass	High	High
Geothermal (hot water or volcanic heat)	Low	Low

Electrical production technologies were necessarily set aside because a thermal source is required to fit the current steam heating system. Converting the campus infrastructure to purely electrical heat is undesirable due to much lower energy efficiencies. It was also clear that solar photovoltaic, wind, and tidal generators are not only very expensive relative to the amount of energy produced, but that none would be reliable energy sources on campus.

Table 2: Evaluation of Renewable Energy Technologies

Technology	Reliability	Economic Viability
Solar PV	Low	High installation cost, low output, payback about twice the lifetime of the equipment
Wind generators	Low	High installation cost, low output, long payback period
Solar thermal collection	Low	Medium cost, low output, unreliable, not a sole source solution
Ground source heat pump	High	Very high installation cost, low operational savings compared to current costs
Air source heat pump	High	High installation cost, low operational savings compared to current costs
Biomass Gasification	High	High installation cost, high operational savings over current costs

Anaerobic digestion technologies were briefly reviewed, as well. Existing systems depend upon high quantities of animal manure (that would have to be brought to campus), use large volumes of water, and are optimized for a consistent quantity output of gas, rather than the on-demand outputs required for our heating system. 'Dry' anaerobic systems that can use food and organic wastes are in development, but the technology is not yet sufficiently mature to meet the college's needs for reliability and durability.

Heat Pumps

Ground and air source heat pumps were found to be technically feasible but economically infeasible within the criteria for this project. Ground Source Heat Pumps were studied and considered for the college in 2006. They have high installation costs and low operational cost savings which makes this a difficult technology to finance. Air source heat pumps (Variable Refrigerant Flow) are less expensive but still high cost. Our energy services contractor (McKinstry) and other engineers who commonly work with VRF do not recommend it as a ***sole*** campus heating technology. VRF is recommended, however, as a supplement to the college's main heating system. Evergreen's Facilities Department is continuing to consider heat pump technologies for discrete application in new buildings and renovations.

Though heat pumps are not truly 'renewable' technologies, they do benefit from roughly a 2 or 3 to 1 return on the electricity used to run the systems, which grants them very favorable performance efficiencies. However, ground source systems are very expensive to install and the economic benefits of conversion are relative to current heating and cooling costs. The National Renewable Energy Laboratories provides the following assessment guidelines for campus installations. (NREL: National Renewable Energy Laboratory, 2011)

> <u>Suitable Soil Conditions</u>
> The geotechnical conditions and hydrology of the soil must be evaluated for heat transfer at a specific site before a GSHP system is considered. Usually, an installer will drill an exploratory well before estimating the cost to drill a large number of wells for a GHSP field.
>
> <u>Significant Heating and Cooling Needs</u>
> GSHP systems are relatively expensive to install and are most likely to be cost effective with a combination of high winter heating loads and summer cooling loads. This reduces the payback time for the initial investment.
>
> <u>High Fuel Cost</u>
> Ground-source heating and cooling are more likely to be cost effective where fuel and electricity costs are relatively high. This is usually the case where inexpensive natural gas is not available and electricity is used for heating and cooling.
>
> <u>Land Availability</u>
> GSHP systems may require significant open space for wells or ground loops. The land can be used for parking or open space use after the system is installed, but installation may take some time.

Evergreen does not have high winter heating loads and summer cooling loads, nor are our current fuel costs high since Evergreen uses "inexpensive natural gas". Local temperature extremes are quite moderate and Evergreen's current heating and cooling systems have already been optimized to improve operating efficiencies.

Air source heat pumps (Variable Refrigerant Flow) are not recommended by our energy services contractor (McKinstry), the Washington Energy Extension office, or a local distributor of VRF equipment (recommended to us by community members concerned about biomass) as a sole campus heating technology for both economic and operational reasons:

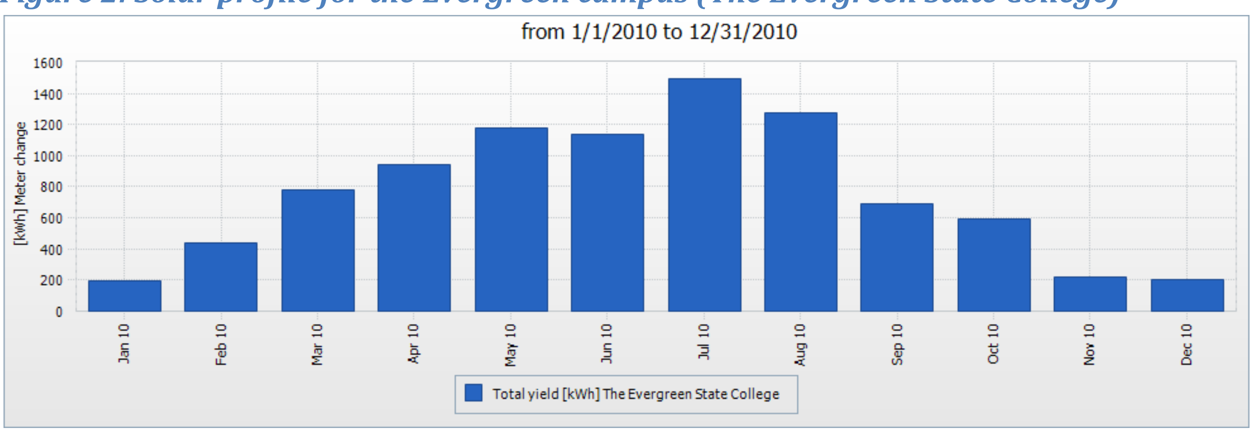
- VRF systems are not likely to be effective for all the buildings on campus, though they could be effective in some. (see attachment VRF Analysis for TESC – additional input from other sources indicated some differences of opinion about which buildings might be suitable but there was a general agreement on cost)
- Though less expensive than ground source systems, VRF installation costs are estimated to begin at $15 per square foot and could be over $20 per square foot, which implies a minimum cost of $15 million to retrofit the entire campus, before taxes, fees, and overages.
- Operational savings are estimated to be insufficient to support an energy savings financing strategy, which would force us to rely solely upon grants or state appropriation funding for the project. Per conversations with a local Mitsubishi VRF representative, given Evergreen's circumstances, total payback period (relying on energy cost savings) could easily extend beyond the projected life of the equipment (20 years).

Finally, both heat pump technologies run on electricity. Though Evergreen is able to purchase 'green' electricity with funds collected from a student fee, we should not assume that electricity is automatically clean and green. Our local electrical mix includes hydropower, coal, nuclear, wind, solar, and biomass. Shifting our energy demand from natural gas to the electrical grid also shifts the responsibility for effective or substantial renewable energy change from us to the energy providers. Deferring responsibility may or may not result in verifiable renewable energy use.

Wind and Solar Resources

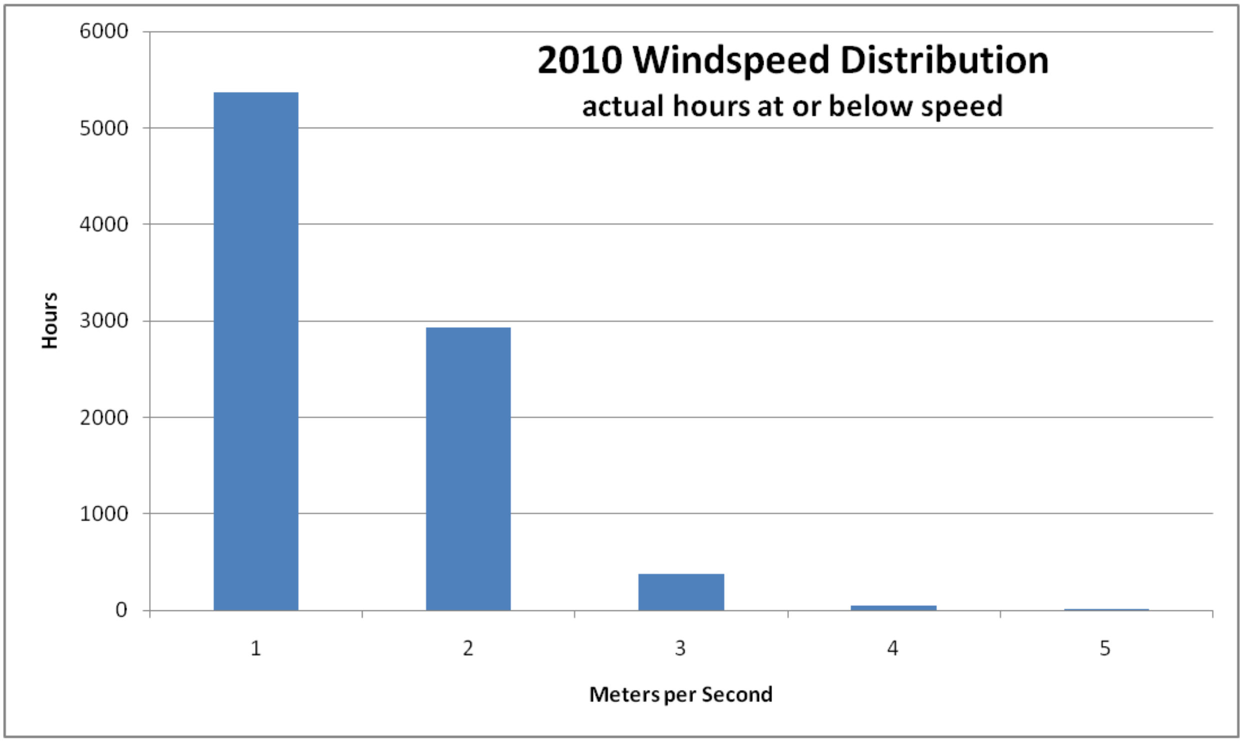
Actual Evergreen solar photovoltaic array output in 2010 (9 kW on the Library roof)

Figure 2: Solar profile for the Evergreen campus (The Evergreen State College)



On-campus measurements from the weather station located by the tennis courts indicate a very low velocity wind profile for campus.

Figure 3: Evergreen campus 2010 wind profile (The Evergreen State College)



Micro-turbine wind generators currently on the market require a minimum of 3.6 m/s (7.9 mph) to generate power and efficient output is rated at 11 to 12 m/s (24.2 – 26.4 mph) wind speeds, which is not a normal wind speed for our location. (1 m/s = 2.2 mph)

Wind speeds are greater above 50 meters, and micro-turbines mounted at or above 50 meters (about 164 ft) might provide a supplemental energy source. However, output is unlikely to be steady or reliable.

Biomass Gasification

Biomass gasification was selected for further detailed investigation as the best fit for our need, criteria, and circumstances. Our initial analysis indicated that biomass gasification could:

- utilize forest slash, a locally plentiful, renewable resource with few other uses (it is commonly burned in the forest or left to decompose), as fuel
- fit with our existing infrastructure since gasification produces a combustible gas similar to natural gas
- meet our need for a reliable heating system
- have emissions comparable to our existing natural gas system

Gasification is a two-step process in which wood chips smolder in a high temperature, low oxygen chamber and give off a flammable gas (synthesis gas) which is combusted in a separate chamber. This process limits fly ash and other particulate matter by products.

Figure 4: Nexterra Gasification Thermal Plant Diagram

Summary of Renewable Energy Alternatives

Overall, few alternative energy strategies, other than biomass gasification, have the potential to be sole source solutions to Evergreen's energy needs. There is potential, however, for discretely purposed installations that may be economic and sufficient to meet our needs for individual buildings. Heat pumps, both ground and air source, will continue to be reviewed for economy and efficacy during building renovations or new construction. Dry anaerobic digestion is another technology that may have potential for on-campus use as we begin addressing our zero-waste goals.

Feasibility Study Findings

Technical and Economic Findings

Evergreen's Energy Services Contractor, McKinstry Essention, was tasked in April 2010 to:

- Determine energy and energy cost savings associated with the installation of a biomass gasification plant and upgrades to the existing steam plant system
- Determine the feasibility of whether a biomass gasification plant can contribute significantly to achieving the sustainability goals of The Evergreen State College as articulated in college's Strategic Plan.

McKinstry's final report was delivered in January 2011. The engineering evaluation and pre-design of this project (based on Evergreen's existing infrastructure, Nexterra's biomass gasification technology, and the college's projected use) verified that:

- A 15 MMBtu (million British Thermal Units) biomass gasification thermal plant (as designed by Nexterra) could effectively replace Evergreen's existing natural gas boiler and would be reliably compatible with Evergreen's district heating infrastructure.
- The guaranteed maximum project allowable cost is $11,578,398. Including sales tax and Engineering & Architectural Services (E&AS) management fees, and before any utility incentives, the final project cost is estimated at $12,675,996.
- The plant could meet all existing regulatory requirements (environmental and emissions).
- McKinstry can *guarantee* that the improvements would produce over $476,000 of annual energy savings (based upon the difference in fuel costs; natural gas is highly valued, slash is not).
- There is substantially more forestry slash available for commercial use within our resource supply area than this project would require on an annual basis.
- The plant will fit within the existing Central Utility Plant (CUP), but an additional 4,900 square foot add-on fuel storage facility would be required.
- An existing utility road would need to be re-purposed to allow for fuel deliveries.

Operating costs include an additional half-time position in the college's Central Utility Plant, as well as fuel purchase costs.

A fuel availability study (LD Jellison, Inc, 2010) included a review of resource competition and indicated that there are seven identified competing large biomass facilities that annually consume an estimated 276,300 BDT of woody biomass within the Study Resource Counties (Cowlitz, Grays Harbor, King, Kitsap, Lewis, Mason, Pierce, and Thurston counties). The draw of these existing facilities upon the Study Resource Area and Study Resource Counties is assumed in their analysis and calculation of commercially available woody biomass. Additional plants may be built in the area, and complicate that picture. However, if a few small scale plants are located around the region, large utility scale plants would be less economical for this region because the fuel will not be cheap and unwanted.

Opposing perspectives: Technical and Economic

The internal rate of return (net annual cash flow as a percentage of the investment over the life of the project) is negative, so the project should not proceed.

This argument is based on an assertion that a positive rate of return is a requirement of projects accepting Jobs Act funding (which Evergreen was awarded in October 2010 and subsequently declined in March 2011). The basis for the argument is taken from Engrossed House Bill 2561, 2010. It is now found in RCW 43.331.040:

> "Cost-effectiveness" means that the present value to higher education institutions and school districts of the energy reasonably expected to be saved or produced by a facility, activity, measure, or piece of equipment over its useful life, including any compensation received from a utility or the Bonneville power administration, is greater than the net present value of the costs of implementing, maintaining, and operating such facility, activity, measure, or piece of equipment over its useful life, when discounted at the cost of public borrowing. (Washington State Legislature)

However, the language referenced above is a *definition* not a criterion as implied. Cost-effectiveness is *not* listed among the criteria for Jobs Act projects, except in reference to the extent that Jobs Act grants may be used to fund preliminary and investment grade audits determined by the "higher education institution's predetermined cost-effectiveness criteria" (Washington State Legislature). Evergreen had no plans to use Jobs Act funds for the preliminary audits, so this criterion does not apply to the proposed college project.

The cost per ton of carbon reduction is too high. Most projects come in under $75 per ton of carbon reduction; Evergreen's project is estimated to cost over $200 per ton.

This argument compared the economic impacts of multiple options and found Evergreen's project lacking in comparison. Evergreen's study, however, necessarily began with an analysis of what local, renewable energy resources are available and what mature technologies would reliably fit our existing infrastructure. It was only after identifying what was truly possible that the college applied economic analyses to determine the solution most likely to be fundable. If all possible carbon mitigation projects were truly viable options, Evergreen's proposal would be very different.

Evergreen should have run a SEPA (State Environmental Protection Act) review prior to creating our Climate Action Plan.

This argument attacks Evergreen's process, implying that a SEPA review should have been a determining factor in the course of defining the college's carbon mitigation strategies. While the SEPA process is critical to determining whether a project should move forward, it cannot precede the fundamental resource, technical, and economic analyses during Evergreen's planning stage that were necessary to define what is actually possible. The SEPA process is commonly run once a project has been defined sufficiently that environmental impacts may be clearly defined, and a preliminary SEPA assessment has been performed as part of McKinstry's Energy Services Proposal. No significant issues have been identified.

McKinstry's recommendations should not be accepted because McKinstry was paid for those recommendations and they'll be paid more if the project proceeds.

Actually, McKinstry has made a ***guarantee***, as required by their Energy Savings Performance Contract with General Administration, that the biomass gasification project will work and will demonstrate the specified savings. If the project does not perform as guaranteed, they must redo the work accordingly and/or compensate the college for the difference in savings. If the project were to proceed, McKinstry would be fairly paid for professional work and guaranteed performance.

Carbon Impacts

There are two key measures of change within a system:

- Pools or stocks are accumulated quantities within the system
- Flows are additions and depletions of a pool and are measured in rates (quantity over time)

  IPCC's guidance (2008, Annex A) defines carbon stock as "the quantity of carbon in a pool." Further, it defines carbon stock changes as: "The carbon stock in a pool can change due to the difference between additions of carbon and losses of carbon. When the losses are larger than the additions, the carbon stock becomes smaller and thus the pool acts as a source to the atmosphere; when the losses are smaller than the additions, the pool acts as a sink to the atmosphere." (Johnson, 2009)

<u>To determine project specific carbon impacts, we must:</u>

1. Define the system(s)
2. Define the system boundaries
3. Define stocks and flows within the systems
4. Measure and account

The carbon impact of a project measures the changes in carbon stocks and/or flows within the system. However, agreement upon just what is being measured to determine carbon impacts is complex and confusing because it's necessary to measure local impacts within a global perspective. Atmospheric greenhouse gas levels are a global issue but Evergreen's project is a small, local installation.

Local impacts are the systemic outputs of the thermal plant. The simplest measure of local impacts is 'at the stack', or the total greenhouse gas emissions flowing from the exhaust stack. A more thorough measure includes lifecycle emissions from all the activities that are directly related to the thermal plant system; i.e. collection, processing, and transport of fuel, as well as any sequestration activities that may be directly associated with plant operations.

The global perspective, however, is concerned with whether the greenhouse gas emissions (relative to the status quo) are additional to the global cycle and/or whether the emissions represent a substantial and undesirable shift of carbon stocks into carbon flows (emissions). The Sustainability Council does agree that fossil fuel emissions are legitimately additional to the global carbon cycle and, in that manner, distinct from biogenic emissions (those already in the carbon cycle of the biosphere). Conversion of biogenic carbon stocks to flows is not necessarily *additional* but is *undesirable* when it leads to a net reduction of carbon stock and a net increase in global emissions.

The Council's research has led us to conclude that there are three fundamental criteria essential to a responsible assessment of greenhouse gas impacts:

- **Carbon source –** Emissions from fossil fuels (fossil carbon) are additional to the natural carbon cycle. (Berner, 2003) While ideal energy sources would not emit any greenhouse

gases, that isn't always possible. Emissions of carbon currently contained within the natural carbon cycle of the biosphere (biogenic carbon) are preferable to additive emissions of geologically sequestered carbon that is not currently part of that cycle.
- **Alternate fates –** The "alternative fates" of the fuels must be considered in any carbon calculations (e.g. what emissions impact would the fuel have anyway if it was not used to generate energy) to help define global scale impacts. Re-purposing non-productive material that would emit greenhouse gases anyway into a productive use that emits similar levels of greenhouse gases with the added benefit of replacing fossil carbon emissions is a key strategy in developing carbon neutral energy solutions. However, re-purposing carbon stocks to create new and additional energy resources could be a substantial and undesirable conversion of stocks to flows. Alternate fates are also critical when energy resources cause competitive impacts on food and agriculture markets or drive undesirable land conversion from forests to agriculture.
- **Lifecycle emissions –** The total project emissions over the lifecycle of activities directly associated with the project provides a more detailed perspective on systemic impacts.

There are also several key variables that define total greenhouse gas (carbon) emissions:
- Fuel type
- Fuel source (what energy goes into maintaining the source and extraction)
- Type of energy being produced and technology used (variations in efficiency)
- Emissions controls
- Geographic/forest stock parameters
- Time frames
- Avoided emissions in replacement scenarios
- Accounting parameters (lifecycle v. stack only, project only and global impacts)

The preponderance of scientific literature we reviewed indicated the possibility of achieving a carbon benefit from the use of biomass in place of fossil fuels. But, there are also clear warnings that biomass to energy systems must be done correctly to realize those benefits.

> These results demonstrate quite clearly that, overall, biomass power provides significant environmental benefits over conventional fossil-based power systems. In particular, biomass systems can significantly reduce the amount of greenhouse gases that are produced, per kWh of electricity generated. Additionally, because the biomass systems use renewable energy instead of non-renewable fossil fuels, they consume very small quantities of natural resources and have a positive net energy balance. (NREL, 2000)
>
> Bioenergy production reduces atmospheric greenhouse-gas levels by enhancing long-term forest-carbon sequestration and by reducing the greenhouse-gas potency of the carbon gases associated with the return of biomass carbon to the atmosphere that is an intrinsic part of the global carbon cycle. These greenhouse-gas benefits are provided in addition to the benefit common to all renewable energy production of avoiding the use of fossil fuels. (Morris G. , 2008)

All of these fates involve displacing fossil fuel use with biomass residue use…The reduction in net GHG emissions for fates that displace fossil fuel is dependent on the amount of energy generated from the woody biomass fate and the emissions intensity of the fossil fuel displaced. (Stockholm Environment Institute, 2010)

Fossil fuel emissions reductions from substituting (untreated, unpainted construction/demolition waste) wood chips for natural gas total 2,100 pounds eCO2 per ton of wood chips. (Morris J. , 2008)

With increasing use of biomass for energy, questions arise about the validity of bioenergy as a means to reduce greenhouse gas emissions and dependence on fossil fuels. Life Cycle Assessment (LCA) is a methodology able to reveal these environmental and energy performances, but results may differ even for apparently similar bioenergy systems. Differences are due to several reasons: type and management of raw materials, conversion technologies, end-use technologies, system boundaries and reference energy system with which the bioenergy chain is compared…Because many key issues are site-specific, and many factors affect the outcome, it is not possible to give exact values for the amount of greenhouse gas emissions and fossil energy consumption saved by a certain bioenergy product, because too many uncertainties are involved. (Cherubinia, Birda, Cowieb, & Jungmeiera, 2009)

If the biomass burned is truly from "waste" wood normally generated in the course of timber harvesting, then these combustion emissions are approximately equivalent to what would occur over the course of natural decomposition, although they are emitted instantaneously instead of over a longer time period as occurs in nature. However, if fuel is obtained by harvesting trees that would not otherwise be cut...then the carbon "payback period" is decades to more than a century, even if the harvested trees are replaced. (Harmon & Searchinger, 2011)

Bioenergy chains which have wastes and residues as raw materials show the best LCA performances, since they avoid both the high impacts of dedicated crop production, and the emissions from waste management. (Cherubinia, Birda, Cowieb, & Jungmeiera, 2009)

Most guidance for carbon footprinting, and most published carbon footprints or LCAs, presume that biomass heating fuels are carbon neutral. However, it is recognised increasingly that this is incorrect: biomass fuels are not always carbon neutral. Indeed, they can in some cases be far more carbon positive than fossil fuels. (Johnson, 2009)

The expression "no free lunch" comes to mind. Everything we take out of the forest prevents the use of the energy and nutrients contained therein by other forest organisms, removes the habitat contributions of those materials, and affects the important hydrological role of organic matter in forests. We know that a

> substantial amount of forest biomass can be harvested periodically without long term negative consequences, but for every ecosystem and every value there will be some frequency of biomass harvest with some intensity of removal beyond which forest ecosystem function and biological diversity will be impaired. (Kimmins, 2008)

Ultimately, the Council has learned that there are too many variables to apply generic calculations to individual biomass-to-energy projects. It is necessary to define a project specific analysis.

Since Evergreen proposes to replace an existing system it is possible to quantify 'business as usual' emissions based upon existing practices and to compare those with the proposed mitigation project emissions. Such a comparison between scenarios is standard practice in climate action plans and carbon mitigation strategies because it helps quantify the global impact of a local project.

Evergreen's two scenarios are:

- Status quo – natural gas combustion. 'Business as usual' forest emissions are not impacted.
- Proposed – forest slash gasification and maintenance level natural gas combustion (natural gas may still be used as a backup fuel during maintenance or other necessary down-times). 'Business as usual' natural gas emissions will be substantially reduced as will emissions from the decomposition of the forest slash that would have been left in piles.

The stocks and flows for these scenarios can be generally defined as:

- Stocks include geologically sequestered carbon (natural gas) and woody biomass (forest debris)
- Flows include greenhouse gas emissions from combustion, decay, transportation, processing, etc and sequestration rates from new plant growth and geological sequestration

The first step to calculating emissions is to clarify the systemic boundaries. These boundaries separate that which is affected by system changes from that which is peripheral or indifferent to system changes.

We can draw the boundaries by clarifying what activities are specifically impacted by the project:

- What would happen anyway, if the project does not happen?
- What new or existing practices/events would be significantly altered?
- What time scale is most relevant for this evaluation?

The Sustainability Council has explored the question of project boundaries and come to the following conclusions:

Geographic boundary – A part of the appeal of biomass for fuel is that the fuel can be re-grown, thereby replenishing the fuel source and re-sequestering the carbon emissions. However, in calculating re-sequestration impacts the question arises around what area of forest should be considered in the calculations?

At a minimum, the project boundary should be consistent with the state level forest management picture as defined and measured by the Washington State Department of Natural Resources:

> Carbon balance is measured on a statewide scale, over time (taking the forest carbon cycle into account). This is the approach supported by Governor Gregoire and Commissioner of Public Lands Peter Goldmark. Neutrality exists so long as a state's forest carbon stocks remain constant or increase over time, as is the case in Washington State. (Washington State Department of Natural Resources, 2011)

The Council's desired project boundary is to be able to report carbon impacts in terms of the specific Forest Stewardship Council (FSC) certified stands that the fuel is sourced from (based upon the project specific model under development). This approach will require development of extensive monitoring and accounting procedures and may take time to realize. This approach is characterized by:

> Carbon balance is measured on the facility supply circle scale, right now (at a single point in time, not fully taking the forest carbon cycle into account). With this approach, a determination of neutrality can be made only if the forests in a facility's supply circle are absorbing at least as much CO2 as is being released from the stack at the point of emission. (Washington State Department of Natural Resources, 2011)

The Council recognizes that it is much more difficult to develop and maintain monitoring at such a level of detail. But, we feel this project should be striving for that goal, should the plant be installed. However, because this particular model is a short time-frame 'snapshot', the Council also recognizes a need to compare such current moment measures against long-term life cycle assessments to ensure a comprehensive perspective.

Local project emissions of Evergreen's current natural gas boiler vs. the proposed biomass gasification boiler can be simply characterized by calculations of the stack emissions.

Table 3: Snapshot – stack only emissions

Local Carbon Impacts; Boiler only annual emissions		
Scenario	**Quantity**	**Metric Tons CO2 Equiv.**
Status Quo (natural gas)	85,000 MMBtu	4,500
Proposed (biomass)	5,600 bdt	10,080

The global impacts of these emissions are characterized by the differences in:

- Sources of the carbon; natural gas emissions are external to the active carbon cycle while biomass emissions are internal to the active carbon cycle.
- Impacts on carbon stocks; natural gas emissions are drawn from long-term geological carbon stocks, biomass emissions are drawn from short-term carbon stock (forest slash).

The global impact is also quantifiable. The carbon impact resulting from a change of fuels is the sum of all emissions directly resulting from the new energy system minus all avoided emissions that will no longer happen as a result of that change. (Net emissions = system emissions – avoided emissions)

Table 4: Snapshot – net project emissions

Emissions	MTCDE	Notes
Biomass gasification	10,080	Inclusive of collection and transport; 5,600 bone dry tons (Stockholm Environment Institute, 2010)
Biomass decomposition (avoided)	(8,960)	Avoided emissions from the most common fate for 5,600 bone dry tons of forest slash (Stockholm Environment Institute, 2010)
Natural gas combustion (avoided)	(4,410)	98% reduction of natural gas combustion in the college's district heating system. Stack only, not inclusive of extraction and transport emissions.
TOTAL	**(3,290)**	A net reduction of total emissions as a result of switching from natural gas to biomass gasification.

From this broader perspective, there appears to be a reduction in total carbon emissions as a result of switching from natural gas to biomass.

We also performed additional research to define the impact of biomass to energy on forest carbon stocks, by itself, absent any substitution or replacement calculations.

We developed a set of models to estimate potential ecosystem Carbon impacts of biomass harvest utilization for energy at the Evergreen State College. The models were developed based on a set of assumptions for forest biomass decay rates in the Pacific Northwest and presume (based on DNR guidelines and economic values) that live bole harvesting will be driven by the high-value timber market and not the low-value biomass/slash market. (These models are ecosystem focused and do not include natural gas replacement effects.)

We considered biomass harvest from Washington Department of Natural Resources (DNR) Forest Stewardship Council (FSC) certified forests first, and then afforestation biomass harvests from poplar plantations on converted cropland where all material was harvested for biomass. For purposes of verification and comparison, we modeled a series of scenarios, ranging from no forest harvest at all to a series of variations upon common forest harvest practices compatible with current DNR biomass harvest options. Some scenarios represented more hypothetical options but provide a clarifying perspective, and may not have been defined or were specifically excluded as fuel sourcing scenarios for the Evergreen project. In all scenarios we also compared 40 and 80 year rotation cycles. We then compared all scenarios over a 240 year time frame to evaluate average carbon impacts of each model. Finally, because our models are dependent on assumptions for within-system carbon decay dynamics, we present a ranked list of carbon impact for five realistic models where slash is treated differently in each model rather than actual values for carbon impacts.

The difference among these models was small, and likely within the error range for each model. At most the greatest and least impactful scenarios differed by ~15% (between 240 and 210 Mg C per ha). Ordered from most to least depletion of forest carbon stores, the scenarios are:

1. Biomass harvest of tops, no other slash treatment
2. Broadcast burning of slash without biomass harvest
3. Pile burning of slash without biomass harvest
4. Broadcasting slash with no burning and no biomass harvest
5. Afforestation with poplar, then whole tree harvest for biomass

Because the fifth scenario resulted in afforestation of former crop land, average landscape Carbon stocks represented a net carbon gain from the status quo. It was surprising that biomass harvest was not a neutral impact on forest carbon storage, even when compared to burning of slash and tree tops, and may in fact reduce carbon storage compared to burning slash and tree tops. We attribute this difference to the fact that though burning reduces volume of material, it does not release all the actual material carbon from the system, whereas biomass harvest for fuel guarantees near-complete loss of carbon from the system.

We estimate the impact of biomass harvest of tree tops could be as much as 5 Mg C ha-1 per harvest (roughly 44 Metric Tons of Carbon Dioxide Equivalent per acre). Our models also show that carbon impacts are higher in more frequent (40 yr) rotations compared to longer (80 yr) rotations. Afforestation scenarios, when commensurate with our assumptions, are carbon positive at the outset, and would provide the best option for the school using biomass as a carbon neutral heat source.

Opposing perspectives: Carbon Impacts

Emissions measured at the stack are greater for wood than for fossil fuels therefore wood cannot be carbon neutral.

This argument attempts to equate biogenic and fossil emissions (based upon the fact that a molecule of carbon dioxide is a molecule of carbon dioxide regardless of source) but ignores the established scientific evidence that fossil fuel emissions are overloading and altering the active (biogenic) carbon cycle; i.e. that fossil fuel greenhouse gases are additive to the current biosphere, whereas biomass gasification emissions (carbon molecules) are already part of the natural cycle and will re-circulate in less than a geologic timescale.

Biomass cannot be carbon neutral because there is a lag time between the moment of combustion and when the wood has re-grown.

The lag time until re-sequestration of fossil carbon is in a rough range of 10,000 to 100,000 times the lag time for biogenic carbon – millennia v. decades (Berner, 2003). Releasing carbon sequestered millions of years ago is *not* better than releasing carbon sequestered in the past few decades. Because biogenic carbon can be re-sequestered within human timescales, lag times are a concern only in terms of the alternative fates of the fuels and if the forests are not being managed for additional growth (Manomet Center for Conservation Sciences, 2010).

Wood waste to energy is one of the least carbon neutral fates for demolition and municipal wood waste. Greater carbon reductions are achievable by land filling wood wastes.

This argument is framed in terms of municipal solid waste management, based on research that finds, in terms of all common uses of municipal waste, that land filling creates the least carbon (and other) emissions while waste combustion for energy commonly creates the most. Land filling is *not* a common fate for forestry slash, nor is it a fate that could provide heat for the Evergreen campus. Although the college could theoretically consider buying slash then shipping it to the landfill, that particular strategy would not create heat for the college nor have we found sufficient justification for the associated economic and land use impacts (the ideal landfills are over 200 miles away).

Biomass is not carbon neutral because of substantial greenhouse gas emissions from land use impacts that result from the cultivation of the biomass.

There is no change of land use associated with this project because it relies upon existing local forestry practices that are unlikely to either increase or decrease as a result of this project.

There isn't enough biomass in the world for it to be the sole energy source for the planet.

This argument actually applies to all energy sources and is not cause to dismiss locally available resources. Renewable energy resources are all geographically defined, and the world's energy solutions are unlikely to be the same everywhere. The world's energy infrastructure is already a diverse patchwork of place-based resources and will likely remain as such or even more so with renewable energy technologies.

Fuel Sustainability and Forest Health Impacts

Evergreen entered this project proposal with three basic presumptions concerning the fuel:

1. That the biomass fuel would come from an existing by-product stream that is produced by unassociated existing logging activity
2. That those by-products would otherwise be treated by open air combustion or decay
3. That no new or additional forestry activity is necessary to support this project

Research has confirmed that significant quantities of slash are still burned in Evergreen's immediate area, but sourcing that specific fuel (slated for burn piles) is not likely to support the Council's desired goal of using slash from FSC certified timberlands.

Table 5: Slash burn permit applications in Thurston and Lewis counties (Grant, 2011)

Total (green) Tonnage of Silvicultural Burn Permit Applications				
County	**2006**	**2007**	**2008**	**2009**
Lewis	24,314	26,565	17,366	9,855
Thurston	2,115	2,585	2,715	598
Annual Total	**26,429**	**29,150**	**20,081**	**10,453**

Table 6: Burn pile fuel tradeoffs (Grant, 2011)

Issues involved with using burn piles for fuel	
Positive	**Negative**
Significant reduction in criteria pollutant airborne emissions; particularly PM & CO.	Burn piles contain dirt, rocks, stumps, and could be difficult to chip and process.
Nearly identical GHG emissions from the slash and a clear benefit from reduction of natural gas emissions.	No restriction on origin of the fuel from FSC certified timber lands.
Economic benefit to forestry companies (not necessarily the landowner).	Potential to create a negative feedback loop encouraging more burn pile intent or behaviors.

The investment grade audit of forest slash fuels prepared by L.D. Jellison, Inc. clearly demonstrates that Evergreen's proposed demand for forest slash is trivial in comparison to the total quantities available within our resource supply area. This study also confirmed that the economic impact of Evergreen's purchases is extremely unlikely to motivate land owners to acquire FSC certification in order to sell slash to the college. The annual income from slash sales would be less than the cost of acquiring and maintaining FSC certification for the timber acreage necessary to provide that slash.

> The percentage of forest lands that are FSC certificated is a relatively small portion of the total available timberlands within the Study Resource Area, and the anticipated TESC annual fuel requirement of 5,500 BDT is relatively insignificant with respect to the total potentially available biomass within the Study Resource Area. It is therefore unlikely that the anticipated fuel demand by TESC for the biomass facility will precipitate additional timberland owners to obtain FSC certification of their forest lands in order to comply with TESC standards if TESC

> chooses to adopt a standard of utilizing only biomass sourced from FSC certified forests. It is likely that TESC would be able to procure biomass on a spot basis for the proposed facility from fuel suppliers utilizing woody biomass sourced from Washington Department of Natural Resources' South Puget HCP Planning Unit, which currently consists of 144,630 acres of FSC certified forests, at prices that are not significantly above market rates. However, such procurement that is limited to biomass sourced from FSC certified forests will be more difficult to manage and obtain and possibly more expensive. (LD Jellison, Inc, 2010)

The Council's criteria for fuel supply explicitly require Forest Stewardship Council certified sources. Investigation into FSC certified lands within the college's resource supply area has revealed that the Washington Department of Natural Resources (145,000 acres) and Joint Base Lewis/McChord (22,000 acres) have the most FSC certified timberlands in our area and are Evergreen's most likely suppliers. Unfortunately, certified timberlands are widely distributed through this resource area, which complicates the transportation costs and coordination aspects of fuel sourcing. Though the annual quantities of slash produced from FSC certified forestry appear to be sufficient and available, there remain uncertainties about month to month fuel availability during our demand season (Oct – May).

It appears that Evergreen's limited buying power is unlikely to affect regional forestry practices as a whole in any measurable manner. The college can, however, support existing FSC certified timberlands through effective contract language, on-going relationships with our suppliers, and pro-active monitoring of our fuel supply through student internships and academic engagement.

The ecological health of working forests ultimately results from responsible forest management practices. Both the state Department of Natural Resources and the Forest Stewardship Council are developing forest practice guidelines pertaining to biomass extraction, and Evergreen recognizes the value of working with both groups to define our fuel procurement expectations. The Council remains intent upon sourcing fuel from lands managed under Forest Stewardship Council (FSC) certification, the most ecologically stringent forest management standard currently available in our region. DNR has the most FSC certified timber acreage within the college's resource supply area.

Table 7: FSC Certified Timber lands (LD Jellison, Inc, 2010)

Local FSC Certified Timber Lands		
Landowner	**Acreage**	**Details**
Joint Base Lewis/McChord	22,000	All slash is removed from the forest, but they may be installing their own biomass facility.
Dept. of Natural Resources	144,630	South Puget Planning Unit
NW Natural Resource Group	9,000	Many small land owners. Available material may change dramatically, year to year, in quantity and location.

FSC Certified Small Forest Lands

> There is definitely interest amongst small woodland owners to sell biomass when economically feasible. Identifying the subset of forest owners, forest types and harvest systems that will yield viable quantities of biomass is the tricky part. Generally speaking we are talking about forest owners with older forests that yield higher volumes of post-logging slash.
>
> The FSC standards require forest owners to maintain approx. 20 tons of debris per acre after harvesting…That's a lot of debris and only older forest stands will have much excess beyond that to yield a "surplus" of biomass that can be exported for alternative uses. (Hanson, 2011)

Focusing on DNR Lands for FSC Certified Fuel Sourcing

DNR's FSC certified lands include some in Capitol Forest, some in the Tahuya, the Tahoma, and the Elbe Hills (see attachment Supply Areas for The Evergreen State College). Some of Capitol Forest is FSC certified, but the forest splits along the watershed (in terms of management responsibilities), so the south-west side of Capitol Forest is not FSC certified. This means that FSC certified trust lands are spread out and are a lesser portion of our local trust lands. Slash sourced solely from DNR managed, FSC certified, public trust lands would necessarily come from multiple locations around the Sound.

Harvesting generally happens during the summer (May to October), although harvests in Capitol Forest may occur year round because of its higher quality roads. The common species mix in DNR forests is about 80% Douglas Fir. The rest is Hemlock and Alder. Slash piles are expected to be removed to free up space for replanting, which begins in January or February. So slash collection should follow harvest cycles and winter time supplies would need to come from a storage depot.

DNR acts as a trust manager on these lands, with a responsibility to maintain a competitive return from harvests. The trust lands we could purchase slash from provide funding to counties and to the common school fund. DNR's long term supply agreements are not yet specifically scoped, but the agency will be bound by the common requirements for competitive and open bidding processes.

Table 8: Advantages and disadvantages of sourcing from DNR FSC certified trust lands

Advantage	Disadvantage
$ spent for energy would support local counties, public schools, and state government.	Solely FSC certified sources are spotty and from a wide geographic area.
Capitol Forest is accessible nearly year round, though that acreage is small.	Dec – Jan through May – June fuel supply is likely to need off-site storage.
DNR can issue slash purchase agreements for 5 years, with potential to renew up to 15 years.	DNR's competitive bid process remains in development.
Slash piles are commonly removed by burning or collection, so purchasing the slash is a small	Most timber land roads are not ideal for fuel haulers.

change to existing practices.	

Standards for Biomass Extraction

Understanding that the dynamics of land use options and climate change pressures are likely to impact local forestland, the college's intent is to be engaged and attentive to the needs of our supply sources so that we may develop a mutually supportive, long-term relationship. Evergreen has the capacity to engage students and faculty with the real world applications of this project to track and assess impacts, and help us proactively adjust to concerns before they become problems.

The council learned in March 2011 of a new certification process developed by the Roundtable for Sustainable Biofuels (Roundtable for Sustainable Biofuels, 2011) that may be directly applicable and advantageous for Evergreen's project. This certification process is specifically designed to verify the social and environmental sustainability of biofuel feed stocks and end use. The Roundtable is currently in discussion with Washington State Department of Natural Resources to evaluate possibilities for coherence between RSB certification and DNR's biomass extraction policies that are under development. RSB certification may also align with FSC certification standards. The council feels that it would be worthwhile for Evergreen to become engaged with this process and to consider RSB certification as a future means of validating sustainable biofuel practices.

The Sustainability Council has identified the following fuel sourcing concerns:
1) Available FSC sourced quantities are not substantial relative to Evergreen's need and are likely to vary significantly from year to year.
2) Reliable sourcing will likely require multiple sources and a large buffering capacity.
3) Sourcing will require the additional expenses of a full-time procurement agent, either on staff or third-party, and an off-site storage facility.

Opposing perspectives: Forest Impacts

Why not use ivy, dandelions, and other urban yard waste for the biomass gasification? It would be a good thing to develop a system to use that which is truly not wanted.

Chippings from municipal tree trimming operations are a potential, though not a major, fuel source. Urban yard waste, however, is predominantly leafy material, will be high in nitrogen and would cause gasification plant emissions to increase unfavorably.

This will increase deforestation rates; the fuel source isn't sustainable over 30 – 40 years.

Evergreen's demand is not large enough to stimulate any additional forestry. The Council has specifically designated FSC certified forests for fuel source because of the long-term ecological management practices required in those forests. The Council has also identified Department of

Natural Resources Trust lands as probable fuel sources. DNR is legally bound to maintain the ecological health and productivity of those lands.

How can you prove that trucks of wood chips didn't come from whole trees?

Again, an additional advantage of FSC certified suppliers is that they use chain of custody practices to verify the source of their wood. Also, the economics of timber values preclude chipping whole timber-grade trees for fuel, which would mean reducing a higher value product to the lowest value timber product on the market.

Human Health Impacts

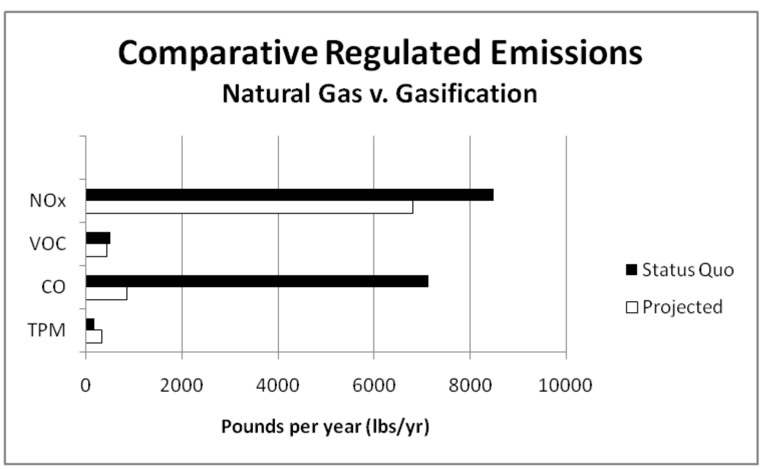
Evergreen chose to look at gasification technology in part because it is inherently cleaner than other biomass to energy options. Most combustion technologies require extensive emissions control equipment to keep air emissions within regulatory boundaries. However, gasification creates a flammable gas that burns cleanly, even without emissions controls. Evergreen's Sustainability Council was concerned about potentially increased emissions from the Central Utility Plant and defined the gasification project to include additional emissions controls (electrostatic precipitator for particulate matter and Selective Non-Catalytic Reduction for nitrogen oxides) in order to keep emissions comparable to what is currently produced by the combustion of natural gas.

Third-party, independent flue gas analyses of Nexterra built gasification plants have confirmed that those plant emissions are comparable to natural gas. Evergreen has supplemented this information with chemical analysis of a local fuel sample (attached) to get a sense of the elemental composition of our fuels. (Nitrogen and sulfur oxide emission levels are dependent upon the levels of nitrogen and sulfur in the fuels, which can vary substantially by region or fuel type.) These varied analyses support our conclusion that a gasification system, using local slash, with the emissions controls specified in the college's plans is very likely to produce airborne emissions comparable to natural gas. Based on our research, Evergreen's current and anticipated emissions would compare similarly. (Gasification emissions are based upon the high end of the anticipated range of operational emissions.)

Table 9: Criteria air pollutant emissions

Comparison of Regulated Emissions		
	Lbs/MMBtu	
	Natural Gas	**Gasification**
Total Particulate Matter (TPM)	0.002	0.004
Carbon Monoxide (CO)	0.084	0.01
Volatile Organic Compounds (VOC)	0.006	0.005
Nitrogen Oxides (NOx) (uncontrolled)	0.1	0.08
Sulfur Oxides (SOx)	0.0006	Trace

Figure 5: Comparative emissions



The following table and chart demonstrate the performance of four Nexterra biomass gasification projects. Because the plants are each in a different air quality jurisdiction only the common tests between the four are shown for purposes of comparison. Unlisted comparison data include sulfur oxides (SOx) and PM 2.5. The emissions below are measured in terms of pounds per million British Thermal Units (lbs/MMbtu), a standard measure in the energy industry.

Figure 6: Nexterra Gasification Plant Emissions

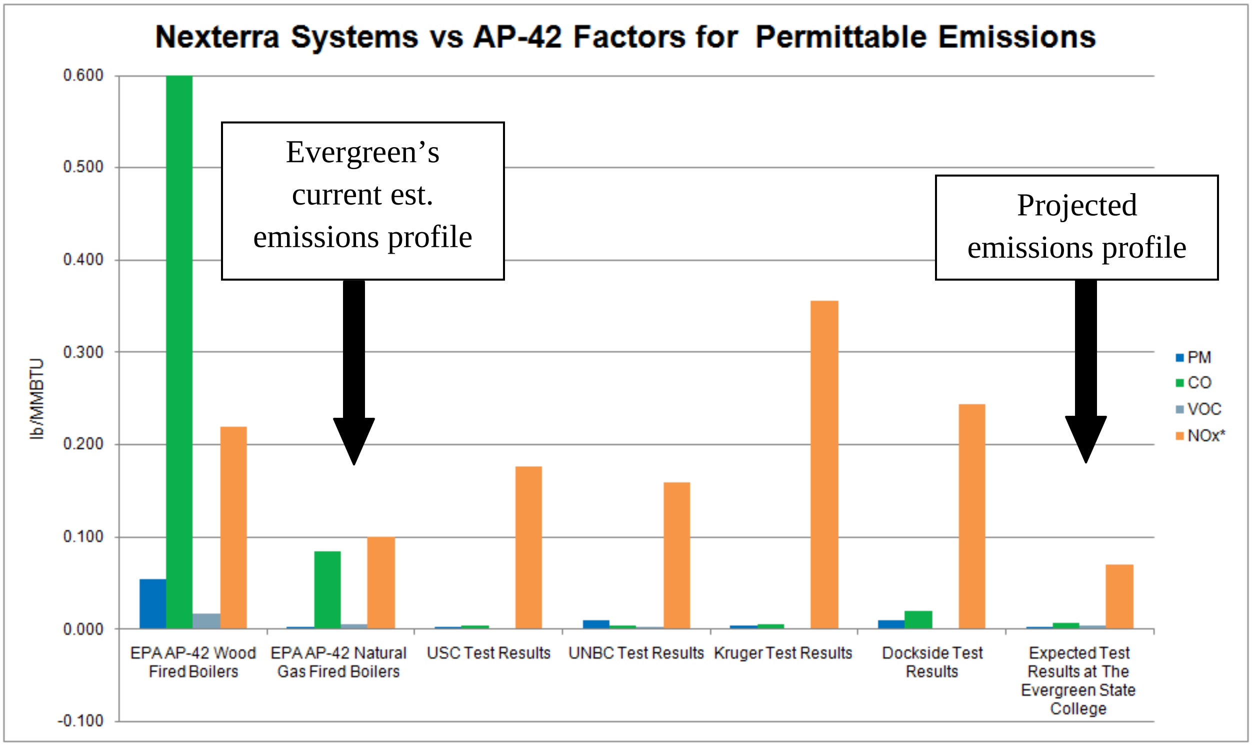


Table 10: Nexterra Gasification Plant Emissions Data

Emission data	EPA AP-42 wood fired boilers (lbs/MMbtu gross input)	EPA AP-42 natural gas fired boilers (lbs/MMbtu gross input)	USC test results (lbs/MMbtu gross input)	UNBC test results (lbs/MMbtu gross input)	Kruger test results (lbs/MMbtu gross input)	Dockside test results (lbs/MMbtu gross input)	Expected test results at The Evergreen State College (lbs/MMbtu gross input)
PM	0.054	0.002	0.002	0.010	0.004	0.010	0.002-0.004
CO	0.600	0.084	0.004	0.004	0.005	0.020	0.005-0.010
VOC	0.017	0.006	0.0004**	0.003	0.0004***	n/a	0.003-0.005
NOx*	0.220	0.100	0.176	0.159	0.356	0.244	0.06-0.08****

* Fuel related emissions: Nox emissions are directly related to the amount of Nitrogen in the wood fuel.
** TOC measured at USC
*** THC measured at Kruger
**** Achievable with Nexterra Selective Non-Catalytic Reactor technology

The third-party verified emissions results for Nexterra systems in operation (table, blue background), from left to right are: 1) the University of South Carolina; 2) the University of Northern British Columbia; 3) the Kruger Products system; and 4) Dockside Green in Victoria, B.C. For convenience, these Nexterra systems are compared against the EPA AP-42 emissions factors for both wood fired systems and natural gas boilers (table, green background). Emissions of oxides of Nitrogen (NOx) depend on the specific fuel, as is illustrated by the variations from site to site. Expected emissions test results for The Evergreen State College project, which reflect the advanced emissions control devices specified by Evergreen for their project, are also included. Oxides of Sulfur are also dependent upon the fuel, and early indications are that Evergreen will only see trace emission levels with our local fuel.

Concerns about excessive and unsafe emissions of nano-particulates (PM 2.5 and below) cannot be answered definitively since most of the jurisdictions with operating plants do not require air quality sampling specifically for PM 2.5 and none require sampling for nano-particulates as a separate category. We have found that the supporting evidence for harmful nano-particulate emissions is primarily based upon vehicular emissions and mixed vehicular/industrial emissions. Consequently, though the potential impact of nano-particulate emissions appears to be a valid concern (Sammons, 2010), there is currently no data on actual PM 2.5 or nano-particulate emissions from a wood gasification system.

The emissions tables and charts below were calculated based upon EPA AP-42 and Nexterra's emissions projections (based on actual emissions and the proximate and ultimate analyses of local fuel). Calculations are based upon Evergreen's 85,000 MMBtu/year heating demand for the district system. 5,600 bone dry tons of woody biomass is the fuel quantity required to meet that heating demand with the projected system design.

Table 11: Status Quo Emissions at Evergreen

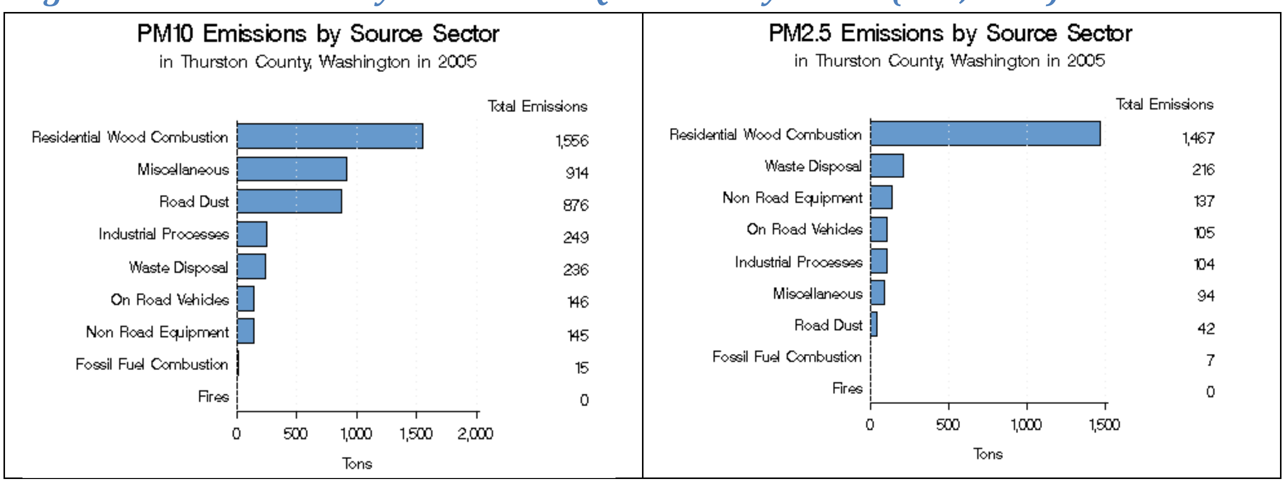
STATUS QUO; Regulated Emissions from Natural Gas at Evergreen		
	Emissions	
	Lbs/MMBtu	**Lbs/year**
Total Particulate Matter (TPM)	0.002	170
Carbon Monoxide (CO)	0.084	7,140
Volatile Organic Compounds (VOC)	0.006	510
Nitrogen Oxides (NOx) (uncontrolled)	0.1	8,500
Sulfur Oxides (SOx)	0.0006	51

Table 12: Projected Emissions at Evergreen

PROJECTED; Regulated Emissions from Gasification at Evergreen		
	Emissions	
	Lbs/MMBtu	**Lbs/year**
Total Particulate Matter (TPM)	0.004	340
Carbon Monoxide (CO)	0.01	850
Volatile Organic Compounds (VOC)	0.005	425
NOx (with Selective non-Catalytic Reduction controls)	0.08	6,800
Sulfur Oxides (SOx)	Trace	

A greater sense of perspective on particulate matter emissions may be gained from an overview of particulate matter emissions in Thurston County. Projected TPM emissions for Evergreen's project are 0.17 tons per year, or roughly 0.8% of the TPM (PM 10 & PM 2.5) emissions from fossil fuel combustion (such as natural gas) in all of Thurston County (which are, themselves, merely 0.3% of all particulate matter emissions). Figure 8 illustrates the magnitude of difference between sources.

Figure 8: Thurston County PM Emission Quantities by Source (EPA, 2005)



Residential wood stoves are very common in Thurston County, and they also have high particulate emissions.

Table 13: EPA AP-42 Wood stove PM 10 emissions (EPA, 1996)

Stove Type	Lbs/ton	Lbs/MMBtu
Conventional	30.6	1.77
Catalytic	20.4	1.18
Pellet (exempt)	8.8	0.51
Pellet (certified)	4.2	0.24

The Nexterra gasifier proposed by Evergreen is expected to produce up to 0.004 lbs/MMBtu which is more than *100 times cleaner* than a certified pellet stove, and over *400 times cleaner* than a conventional residential wood stove, relative to the heat produced.

The Olympic Region Clean Air Agency (ORCAA) is the local agency "responsible for enforcing federal, state and local air pollution standards and governing air pollutant emissions from new and existing sources." (Olympic Region Clean Air Agency, 2011) Evergreen's operational emissions will be monitored by ORCAA. Any emissions sampling required by ORCAA would be performed by third party contractors. ORCAA's regulations are defined by state law and include heavy metals, dioxins/furans/polycyclic aromatic hydrocarbons, and the other various possible substances of concern that have been raised by the public.

Ash/Char

The gasification plant is expected to produce roughly 231 tons of charred wood ash per year (about 19 truckloads per year). The system will produce 55 lb of ash per hour and operates for 8400 hrs per year:

This ash is predominantly elemental in nature and is essentially bio-char, though with a much lower percentage of carbon composition. Bio-char has been demonstrated to be a generally non-reactive, though valuable, soil supplement.

Opposing perspectives: Human Health Impacts

Wood combustion emissions have significant and poorly understood human health impacts.

This argument starts from the assertion that wood combustion technologies are somehow unstudied and uncontrolled.

In fact, the human health impacts of wood combustion emissions are very well understood. There is over a century of research and discovery that informs our knowledge. There is also an extensive technical knowledge base that informs the design and use of emissions control equipment to mitigate wood combustion emissions. The likely emissions and health impacts of wood combustion technologies in combination with specific emissions controls equipment can be clearly defined using existing knowledge bases.

What is not clearly understood is the impact of very small and nano-particulate matter (<PM 2.5) on human health. There is an increasing focus of medical research on the health impacts of PM 2.5 and smaller. However, PM 2.5 emissions result from ***all*** combustion processes so, while it is fair to say that they are a concern in any wood combustion system, the majority of the research around PM 2.5 human health impacts is focused on *vehicular* emissions. This evidence is only indirectly related to wood gasification emissions.

Biomass combustion creates highly toxic Dioxins/Furans and other Polyaromatic Hydrocarbons

There is a historical connection between wood combustion and dioxin contamination throughout the Puget Sound region. At one time, sawmills located on the Sound burned salt water soaked woody debris (which contained a high concentration of sodium chloride/salt – the chlorine portion of which is required for dioxin formation) in direct combustion furnaces with no emission controls. This resulted in dioxin/furan formation and contamination from the soot plumes. Since that time, much has been learned about the formation of these compounds.

- The reaction is kinetically limited and only a small portion of the total chlorine in the fuel is converted. Fuels with high chlorine content are primary producers of dioxins.
- The reaction is temperature dependent. The dioxin precursors form at temperatures above 1000º C.
- Dioxins are associated with particulate matter and one mechanism of formation appears to be dependent upon the catalytic effects of large particulates.

> The principal contributors to the creation of [Dioxins/Furans] are medical waste incineration followed by municipal solid wastes (MSW) incinerators and landfill fires. The production of dioxin in large incinerators is influenced by the furnace type, the operational conditions, and the type and efficiency of air pollution control systems. (Garcia-Perez, 2008)

> Although dioxins can be formed in the range of pyrolysis temperatures…the precursors have to be formed at higher temperatures. This may explain why it was not possible to find any report on the presence of dioxins in bio-oils or chars. The temperature history in pyrolysis reactors is very different to that of incinerators. The formation of dioxins is heavily dependent on this parameter. (Garcia-Perez, 2008)

ORCAA looks for dioxins and other polyaromatic hydrocarbons during their operating permit review. Operating temperatures and particulate matter levels are key components in that review process.

Based upon the research and the proposed technology, it's reasonable to find that dioxins and other polyaromatic toxins are unlikely to be a concern.

Dangerous levels of heavy metals are emitted by the combustion of wood.

The data provided to support this assertion was based upon municipal solid waste (MSW) combustion, which is a very different fuel and combustion technology. Evergreen collected samples of woody debris from a recent logging cut in Capitol Forest and sent that material out for a proximate and ultimate chemical analysis (see attached). The test results indicate very low levels of heavy metals in the sample.

The Learning Laboratory

A part of Evergreen's long-term goal for this project is to incorporate the plant into academic programming and study. The project plan provides for an attached classroom space in the Campus Utility Plant (CUP), as well as a secondary mirror control display in the classroom.

Faculty members have expressed interest in incorporating the local energy model, forest impacts, and carbon accounting into their academic work. Creating and maintaining that engagement, however, will not happen automatically and will require planning and commitments from the academic side of the college.

Two models that could help support the academic commitments are 1) long-term financial support for defined student internship positions (perhaps in partnership with DNR) to provide data collection and ecosystem monitoring services, and 2) a financial commitment to a carbon monitoring lab or other physical infrastructure that may be used by existing academic programs such as The Evergreen Ecological Observation Network (EEON), which is studying the carbon dynamics and forest structure relationships in the Evergreen forest.

Public Input – Objections and Concerns

Evergreen solicited public input on concerns and objections at the front end of the college's feasibility study to inform the direction and details of the study. From the outset, a passionate core of anti-biomass activists freely shared their answers and opinions on the question of biomass for energy. Their stance began from the conviction that biomass is dirtier than coal, the emissions are highly toxic, and biomass is not a carbon neutral fuel. They were also convinced that using biomass for fuel would lead to deforestation and supported heat pump technologies as better alternatives.

Many concerns and objections heard from college and local community members were found to be apples to oranges comparisons between other biomass to energy models and the model that Evergreen was considering.

- Some applied to different fuels such as municipal solid waste or purpose grown crops.
    - Airborne emissions and waste products vary dramatically according to the chemical composition of the fuel. Municipal solid waste emissions are not comparable to forest slash emissions because of the substantial difference in chemical composition of the fuels. It is also clear that purpose grown energy crops will have much greater land use, energy, and water use impacts than will by-products of existing silvicultural activity.

- Some concerns and objections applied to different technological applications such as direct combustion (from utility size down to residential wood stoves) and electrical generation.
    - Each technological application has unique operating characteristics, from thermodynamic efficiencies to fuel demands to emissions. Comparisons across technologies are often not valid. Residential wood stoves, for instance, do not have electrostatic precipitators or selective non-catalytic reduction controls that industrial plants will use. Similarly, direct combustion and gasification technologies produce dramatically different levels of particulate matter and carbon monoxide.
    - Comparisons between applications are similarly invalid. The thermodynamic efficiency of electrical generation is generally half that of district heating applications; therefore calculations based upon emissions by energy produced will vary substantially between the two.

- Some concerns and objections applied to different economic models such as privately owned power plants.
    - Expressed concerns about tax credits and stimulus funding that may apply to a private entity do not apply to a public college. Also, economic comparisons based upon the market value of green electricity have little validity when evaluating a thermal plant.

There were, however, some concerns and objections that do apply to this project which have been addressed in Evergreen's study. Concerns and arguments around economics, carbon neutrality, impacts on our forests, and human health impacts have been juxtaposed with the study findings that are addressed or disputed. Below are several fundamental objections that were commonly presented to the college.

The amount of carbon in the biosphere is fixed.

This is incorrect. The biosphere is defined as the part of the Earth and its atmosphere in which living organisms exist or that is capable of sustaining life; or the living organisms and their environment composing the biosphere. The amount of carbon in the biosphere is increasing, due largely to the release of carbon from fossil fuels previously locked in the earth. That is the underlying issue with climate change.

A carbon molecule is a carbon molecule. (CO_2 is CO_2) The source doesn't matter.

While carbon molecules are the same, the natural carbon cycle can circulate and reabsorb a limited amount of carbon over time. Continuing to add carbon that has not been part of that cycle for millions of years overloads the system. Using carbon already in the system does not add to the total (though it can affect the timing of the cycle).

Biomass is unequivocally not carbon neutral.

Unequivocal means admitting of no doubt or misunderstanding; clear and unambiguous; leading to a single conclusion. Several environmental and research organizations have found that biomass can be a carbon neutral fuel when **properly managed**. At a minimum, biomass energy can be, but isn't automatically, carbon neutral according to:

> Sierra Club, Natural Resources Defense Council, Union of Concerned Scientists, Nature Conservancy of Massachusetts, National Renewable Energy Laboratory, Pacific Institute, and many other sources.

Much of the data used to support this non-carbon neutral assertion is based on electricity generation (not heat or combined heat and power). This data, even if correct for electricity, is not correct for the higher efficiency of heat or CHP. Efficiency matters.

Biomass plants don't just burn forestry "waste" (tops and branches) – they burn whole trees that have been chipped.

Washington State law defines biomass sourced from public lands as:

> (6)(a) "Forest biomass" means the by-products of: Current forest management activities; current forest protection treatments prescribed or permitted under chapter 76.04 RCW; or the by-products of forest health treatment prescribed or permitted under chapter 76.06 RCW.
> (b) "Forest biomass" does not include wood pieces that have been treated with chemical preservatives such as: Creosote, pentachlorophenol, or copper-chrome-arsenic; wood from existing old growth forests; wood required to be left on-site under chapter 76.09 RCW, the state forest practices act; and implementing rules, and other legal and contractual requirements; or municipal solid waste.
> (Washington State Legislature, 2011)

Whole trees removed as a result of natural damage or thinning operations, that *are not marketable* as lumber or pulp may be marketable as biomass. However, the superior market value of timber-grade trees (compared to slash) precludes the use of those whole trees as biomass fuel. It's simply not cost effective. Whole trees are too valuable to sell for biomass energy; land owners can get much more revenue from timber for lumber than from biomass energy for the same trees.

Wood is worse than coal.

This argument is based upon superficial interpretations of the Manomet study (Manomet Center for Conservation Sciences, 2010) of biomass energy in Massachusetts. Manomet has issued a clarifying statement addressing this and other interpretations:

> One commonly used press headline has been 'wood worse than coal' for GHG emissions or for 'the environment.' This is an inaccurate interpretation of our findings, which paint a much more complex picture. While burning wood does emit more GHGs initially than fossil fuels, these emissions are removed from the atmosphere as harvested forests re-grow. As discussed in more detail below, the timing and magnitude of the recovery is a function of forest productivity, land management choices, and technology and fuel characteristics. (Manomet Center for Conservation Sciences, 2010)

A similar argument, 'wood is *dirtier* than coal' has also been made. However, a recent evaluation of particulate matter emissions from 35 coal plants performed by the Pennsylvania Department of Environmental Protection (Parrish, 2010) found that average plant emissions (based on plant type) ranged from 0.022 to 0.106 lbs/MMBtu of Total Particulate Matter. Nexterra's operational gasification plants have measured TPM emissions ranging from 0.002 to 0.010 lbs/MMBtu. Wood is not dirtier than coal when the right technology is used.

Wood has a lower energy density than fossil fuels and, therefore, has greater carbon emissions per equivalent energy output.

This argument disregards the fundamental need to eliminate or replace fossil carbon emissions. Though it points to a fundamental reason why we are so dependent upon fossil fuels in the first place and why many people feel that we should continue to use those fuels, it disregards the significant amount of energy used to extract and transport fossil fuels. Taking all energy inputs into consideration, some studies demonstrate that wood has a net energy density (on a life cycle basis) that is comparable to or greater than fossil fuels.

> Because of the perception that biomass fuels are of lower quality than fossil fuels, it was expected that the external energy ratios for the fossil-based systems would be substantially higher than those of the biomass-based systems. The opposite is true, however, due to the large amount of energy that is consumed in upstream operations in the fossil-based systems.

> The life cycle energy balances of the coal and natural gas systems are significantly lower than those of the biomass systems because of the consumption of non-renewable resources.
>
> Not counting the coal and natural gas consumed at the power plants in these systems, the net energy balance is still lower than that of the biomass systems because of energy used in processes related to flue gas clean-up, transportation, and natural gas extraction and coal mining. (NREL, 2000)

Beyond that, this argument is still good reason to use the highest efficiency possible in any wood fueled energy system. Evergreen's proposed system would operate around 65% efficiency, or better.

Biomass energy markets will stimulate more forest logging and cause our local forests to be over-harvested and significantly harmed.

This argument has commonly been framed by adding all existing markets for forestry products to all potential markets to demonstrate that there will be more demand than our forests can support. In fact, forestry slash is currently an unvalued forestry product that has almost no market (excluding firewood permits). The anticipated values of forestry slash are substantially lower than timber values and are extremely unlikely to be the economic driver in any timber harvesting decision. Also, public sales of biomass are being decoupled from timber sales so that slash sales will not add to the value of a logging contract. Finally, privately owned energy plants are seeking to use the lowest cost fuels which creates natural economic barriers to over saturation of the local biomass energy market, unless that plant is able to dominate and control the market.

It is true that forest management, harvesting, and biomass collection practices may have consequential and harmful impacts on the forests. The Sustainability Council recognized this concern and specified early in the study that we should require the most stringent locally available forest management practices (Forest Stewardship Council) in our fuel procurement agreements.

If Evergreen could actually implement a biomass gasification facility with a clear carbon benefit, no significant increase in other emissions and little or no negative impact on forests and ecosystems, it would still be bad because large energy companies could use Evergreen's example to justify projects that did not hold to the same high standards.

It is unclear how this view is reconciled with the fact that Evergreen is not the first "green" college to build and operate a biomass gasification facility (e.g. many other examples are already available to large power projects if they want to point to an environmentally conscious college or university). In fact, some of these "green" colleges are touted by *environmental organizations* as examples of achievements in climate change mitigation (e.g. Green Mountain College is highlighted by Sierra Magazine in part *because* it has biomass gasification). If private energy companies were to follow Evergreen's lead to developing a clean, efficient, and responsible power plant to **replace** an existing power plant that isn't clean, efficient, and responsible, the college would have had a commendable impact in our world.

Finally, the college has been accused of abandoning "environmentally friendly" natural gas to burn highly toxic wood.

Natural gas is the cleanest burning fossil fuel and, as such, has long been marketed as an environmentally friendly fuel (a relative truth in comparison to coal or fuel oil). Natural gas is, however, a fossil fuel and the extraction and transportation processes have significant environmental impacts. The natural gas supplied to Evergreen by Puget Sound Energy comes from Wyoming and Canada through thousands of miles of pipeline. The impacts of natural gas pipelines include energy for transportation (Jaramillo, Griffin, & Matthews, 2007), extensive forest setbacks where they cut through forested lands, leakage and explosions. The Wyoming gas fields are using hydraulic fracturing extraction methods, which appear to have significant local environmental impacts (Fox, 2010) (Colborn, 2007) (Lustgarten, Natural Gas Drilling: What We Don't Know, 2009) (Lustgarten, Climate Benefits of Natural Gas may be Overstated, 2011). When one adds up the impacts of fossil carbon emissions, drilling and extraction processes, the pipeline infrastructure (and occasional failures) it is very difficult to qualify natural gas as 'environmentally friendly'.

Appendix 1 – Input and Questions from the Community

1) How do other renewable energy options compare to biomass gasification?

- In terms of compatibility, reliability, installation and operating costs, environmental and other impacts.
- What conservation measures have we taken? Can't we just turn off the heat?
- Why aren't we purchasing carbon offsets instead? They are cheaper than a new power system.

2) What is the real carbon balance of this project?

- Inclusive of peripheral fossil fuel use in wood fuel processing and delivery.
- What role could the biochar/ash have in carbon sequestration?
- What would be the criteria for a thorough assessment of inputs (biomass) and outputs (emissions, ash, etc.) of the system?

3) What are the impacts of using forestry residues for fuel?

- What are the long term impacts on the forest growth, health, and ecosystem?
- How do gasification GHG emissions compare to the GHG emissions of current forestry slash handling practices?
- How could the fuel source be maintained and monitored for contamination (fertilizers, pesticides, anthropogenic debris, etc.)?
- Would the gasification plant be competing for a resource that could have better uses?
- How much of the money that this further extraction will provide will be returned to the forest in ways to improve it for the future?
- Why cannot ivy, kudzu, dandelions, etc. be used for the biomass gasification? Perhaps some excess forest waste may be available. However, if a system were developed to use that which is truly not wanted, would that not be a good thing?
- What about urban yard waste?
- Can humans ever improve over the long term on the unattended ecosystem?
- What is the life cycle energy balance of this project?

4) What are the installation and operating costs?

- How does local competition for fuel drive long-term projections?
- What are the long-term waste impacts?
- What are the long-term costs of this project over time, and how does that cost compare to the costs / waste of modernizing and maintaining the existing power generation system?

5) What are the emissions and how do they compare to our existing system?

- What are the amounts and composition of waste products generated by this project?
- What about Dioxins and Furans?
- Is there a Life-cycle assessment of the emissions of this system?
- What's in the ash/char?
- What about nano-particulates?

- Who would be responsible for testing emissions, and how often would that happen?
- What are the safety concerns for the people who would operate the plant? And, of course, those living close by.

6) Where is the learning laboratory?

- How do we incorporate long-term academic engagement?
- Can we establish the structure and support for a long-term academic study of the forestry impacts, carbon neutrality, social impacts, or some other aspect of this project?

Facilities Services
December 29, 2010

Appendix 2 – VRF MEMORANDUM

TO: Paul Smith
Director of Facilities Services

FROM: Richard J. Davis, P.E.
College Engineer

SUBJECT: Applicability of VFR to TESC

There are two key questions regarding Variable Refrigerant Flow (VRF) systems at the college: (1) Are they sustainable from a carbon neutrality standpoint and otherwise, and. (2) are they applicable here.

Sustainability

VRF systems operate on electricity and TESC electricity is green because students purchase renewable energy credits (RECs). On that basis, VRF is sustainable. However, electricity is likely the most precious of our energy sources. If generated with fossil fuel, it comes with considerable waste of heat. If generated at dams on our rivers, it damages our fisheries. If produced at a thermonuclear plant, it generates waste on which we still debate the disposition. It is also a versatile energy source, easily converted to light and heat, powering electronic equipment of all types and providing an essential input into data processing. The college's green electricity is very costly to produce, and suffers from transmission losses because the generating facilities are largely east of the mountains. Also, the U.S. does not have enough green electricity to enable widespread use of VRF (similarly, there is not enough forestland for everyone to embrace biomass).

VRF systems are essentially split system heat pumps with added piping, valves and controls. They require much copper and energy intensive metals to manufacturer. The economic life of heat pumps is approximately 15 years and I assume this is an equally applicable number for VRF. On the other hand, central boilers and chiller systems have a 25-year economic life.

Cost vs. Energy Savings

Net costs per million btu of heating are given in the table below. I used an average cost for electricity at Evergreen that includes the green fee and demand costs. The numbers are not exact, but should assist your evaluation.

The cost of operating VRF neglects the incremental cost of operation during extremely cold exterior temperatures. The cost to operate with natural gas assumes an 80% efficient boiler.

This can be increased to 90 to 95% with condensing boilers. The efficiency of biomass may be in the mid-sixties. I used 60%. My assumptions have probably made VRF appear a little better compared to the other two systems than is justified.

Energy Cost Summary				
Description	**Energy Source**	**Cost to Purchase**	**Efficiency (or SEER, if noted)**	**Net Cost to TESC per mmbtu**
VRF	Electricity (green, includes demand)	$0.08 per kwhr	15 (SEER)	$6
NG Steam Boilers	Natural Gas	$8.00 per mmbtu	0.8	$10
Biomass Steam Boilers	Biofuel	$44 per bdt	0.6	$5.23 (7000 btu per bdt)

Gerry Galvin also mentioned that central control was difficult and costly. My speculation is that VRF systems include sophisticated thermostats that handle the complex control of the indoor units and the outdoor unit. Some manufacturers may allow interface with central controls, but some may not. The biggest market for this equipment is not buildings with central control systems, so I would be cautious in assuming that centrally initiated night set-back is accomplished easily.

<u>Capital Cost</u>

The attached ASHRAE article concludes that VRF is somewhat more costly than a chilled water system in new construction and much more costly than a chilled water system for a retrofit. Their reasoning is that the retrofit of a chilled water system benefits from piping already in place. This is not an applicable argument if heating is the primary reason to install VRF until you consider that the heating system in existing building can be retrofitted without a need to install heating pipes, too.

I believe Gerry Galvin's cost estimate to be more accurate (low twenty dollar per square foot range) than the numbers that you received from the Department of Energy. My reasons are as follows:

- The DOE is not distinguishing between commercial buildings that are often not covered by prevailing wage rules and public buildings that are. VRF is often installed in medium sized privately owned commercial buildings. Not clearly identifying the effect of prevailing wages on cost suggests the estimate is low.
- The State of Washington has been adding requirements to construction contracts, such as apprentice rules and a named insured requirement. This tends to increase construction costs compared to other states and the private sector.

- TESC spaces will require separate designs, referenced by the ASHRAE article and by Marcia, for outside air, heat recovery and other custom designs to function adequately. Maintaining the operating benefit of the college's 100% air economizers will be difficult and costly with VRF.
- Partial installation of VRF will decrease some of the more costly system installation costs. The "cost" of that savings is maintaining the existing boiler system, which substantially maintains its standby losses, increasing the fraction of loss compared to the total output of the boilers, and keeping maintenance and operating costs high. This is not efficient, cost effective or sustainable.
- It is not appropriate to disregard demolition of equipment to be abandoned as a cost of VRF. Demolition of abandoned equipment is a cost that should be reflected as a cost of a new system that is allegedly sustainable, even if that demolition is deferred.
- Mechanical and electrical systems in new buildings often account for 30 to 40% of new construction cost. More than half of those costs are mechanical, which includes plumbing, fire sprinkler and HVAC. Gerry's cost for VRF, in the low twenties of dollars, is about 10% of new construction cost. This seems to be a modest cost for an entirely new HVAC system installed campus-wide.

<u>Fuel Diversity</u>

You aptly cautioned against having essentially one energy source for heating, cooling, lighting and powering equipment. This lack of diversity has several serious consequences for the college:

- The college will be more vulnerable to electric cost increases than it is now. There is some competition in the natural gas market, but none in the electric market. Biomass would increase the number of fuels for heating to three: natural gas, Diesel, and biomass. VRF would change the college to a single energy source for all purposes.
- VRF would move an appreciable natural gas load from the CUP to distributed electrical load on the campus. The additional load would burden existing switchgear in several buildings, making large upgrades necessary.
- VRF would end the college's ability to provide heat to the dormitories during power outages.

<u>Conclusion</u>

Although there could be cost decreases for VRF since the ASHRAE article was written, I believe the conclusions and reasoning contained therein are sound.

Many of the articles and our colleagues suggest considering the use of VRF in situations where:
1. Natural gas is unavailable (this is a purely economic recommendation and is irrelevant if sustainability is the prime criterion).
2. Control in many sub-zones is required.

3. Zones have simultaneous heating and cooling due to varying internal loads occurring over many hours per year.
4. There is a need to measure utility use in tenant space.

I believe the correct application of VRF is as a system choice where some of the conditions above exist.

Appendix 3 – Carbon Emissions Calculations

Biomass carbon emissions were calculated using the nominal values from the Stockholm Environment Institute study recently completed for ORCAA (the Olympic Region Clean Air Authority) (Stockholm Environment Institute, 2010).

These values reflect annual emissions of greenhouse gases in the equivalent metric tons of carbon dioxide and include post-harvest processing and transportation emissions in the gasification scenario.

Calculations are based on Evergreen's 85,000 MMBtu/year heating demand for the district heating system. 5,600 bone dry tons of woody biomass is the fuel quantity required to meet that heating demand with the projected system design.

Emissions Scenario[1] (Post-timber harvest to Grave)	**Annual System Emissions**[2] (Metric tons CO_2e per Bone dry Ton Woody Biomass {CO_2, N_2O, CH_4})
Forest Decomposition	1.6
Forest Combustion	1.8
Gasification	1.8

Green House Gas Emissions (Metric Tons of Carbon Dioxide Equivalency)		
Source	**Lbs/MMBtu**	**MTCDE/Year**
Natural Gas	117	4,500
Decomposition of Forest Slash	232	8,960
Gasification of Forest Slash	261	10,080

Transportation emissions are included in the annual system emissions calculated by SEI (Stockholm Environment Institute, 2010). However, an illustrative estimation may be valuable for a sense of scale. Assuming an average mileage of 10 mpg and a 100 mile roundtrip for the trucks, we get a value of 10 gallons of diesel per trip. Assuming 2 trips per day for 300 days per year we would have 600 trips per year. Estimated diesel usage is then 6000 gallons per year, which would emit about 61 MTCDE of greenhouse gases.

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[1] For existing streams of forest harvest slash only.

[2] Inclusive of "emissions associated with the gathering, processing, transport, use and disposal of the woody biomass residue" as well as "air emissions associated with the manufacture of equipment used to harvest, process and transport the woody biomass."

Appendix 4 – Carbon Offsets

Carbon offset markets are currently voluntary and unregulated in the United States. Evergreen has chosen not to pursue carbon offsets as an immediate solution to carbon neutrality, but rather to use them only as a final solution to offset all mission critical activity that cannot otherwise be reduced or replaced. However, the offset strategy has been raised multiple times as a cheaper and safer alternative to replacing natural gas. So a local and verifiable offset strategy was identified.

Northwest Natural Research Group is offering local offsets that could be physically monitored and verified by Evergreen and that contribute to the economy and preservation of our regional forest lands. These are based upon a voluntary offset market and compliance program currently provided by Northwest Natural Resource Group through their Northwest Neutral program.

Offsets cost **$20/ton/yr**. (This was the 2010 rate, and is expected to hold for 5 years.)

Evergreen's natural gas emissions are roughly 4600 tons per year. The cost to purchase full offsets for natural gas would be about **$92,000 per year**.

Northwest Natural Resource Group (NNRG) is a 501(c)3 non-profit headquartered in Port Townsend. They have established a voluntary program, NW Neutral, in which they assist FSC certified, small woodland owners in establishing protected forestlands as carbon offsets and market the offsets locally. All the current participating lands are in Washington State.

1. Offsets are FSC certified forest lands with an operational FSC management plan.
2. Overall biomass on the land is inventoried by NNRG, and 20% of the total is deducted as a natural change buffer, the remainder is available as offset.
3. The landowner signs a 100 year contract with NNRG that attaches rights to the property deed. Development plans and neighboring property are taken into consideration.
4. The property is monitored and the biomass inventory is re-assessed by NNRG and FSC auditors on 5 year cycles.

These offsets appear to be based upon existing timber lands that would no longer be harvested, so the sequestration impact would be additional. This program could also provide the college with an opportunity to invest in a local carbon economy that can be physically observed by students, faculty, staff, and community members.

Appendix 5 – Modeling Biomass Harvest Impacts on Carbon Neutrality (summary)

Dylan Fischer, Rob Cole, Mark Harmon, and Scott Morgan

We developed a set of models to estimate potential ecosystem Carbon impacts of biomass harvest utilization for energy at the Evergreen State College. The models were developed based on a set of assumptions for forest biomass decay rates in the Pacific Northwest and presume (based on DNR guidelines and economic values) that live bole harvesting will be driven by the high-value timber market and not the low-value biomass/slash market. (These models are ecosystem focused and do not include natural gas replacement effects.)

We considered biomass harvest from Washington Department of Natural Resources (DNR) Forest Stewardship Council (FSC) certified forests first, and then afforestation biomass harvests from poplar plantations on converted cropland where all material was harvested for biomass. For purposes of verification and comparison, we modeled a series of scenarios, ranging from no forest harvest at all to a series of variations upon common forest harvest practices compatible with current DNR biomass harvest options. Some scenarios represented more hypothetical options but provide a clarifying perspective, and may not have been defined or were specifically excluded as fuel sourcing scenarios for the Evergreen project. In all scenarios we also compared 40 and 80 year rotation cycles. We then compared all scenarios over a 240 year time frame to evaluate average carbon impacts of each model. Finally, because our models are dependent on assumptions for within-system carbon decay dynamics, we present a ranked list of carbon impact for five realistic models where slash is treated differently in each model rather than actual values for carbon impacts.

The difference among these models was small, and likely within the error range for each model. At most the greatest and least impactful scenarios differed by ~15% (between 240 and 210 Mg C per ha). Ordered from most to least depletion of forest carbon stores, the scenarios are:

1. Biomass harvest of tops, no other slash treatment
2. Broadcast burning of slash without biomass harvest
3. Pile burning of slash without biomass harvest
4. Broadcasting slash with no burning and no biomass harvest
5. Afforestation with poplar, then whole tree harvest for biomass

Because the fifth scenario resulted in afforestation of former crop land, average landscape Carbon stocks represented a net carbon gain from the status quo. It was surprising that biomass harvest was not a neutral impact on forest carbon storage, even when compared to burning of slash and tree tops, and may in fact reduce carbon storage compared to burning slash and tree tops. We attribute this difference to the fact that though burning reduces volume of material, it does not release all the actual material carbon from the system, whereas biomass harvest for fuel guarantees near-complete loss of carbon from the system.

We estimate the impact of biomass harvest of tree tops could be as much as 5 Mg C ha-1 per harvest (roughly 44 Metric Tons of Carbon Dioxide Equivalent per acre). Our models also show that carbon impacts are higher in more frequent (40 yr) rotations compared to longer (80 yr) rotations. Afforestation scenarios, when commensurate with our assumptions, are carbon positive at the outset, and would provide the best option for the school using biomass as a carbon neutral heat source.

Appendix 6 – Glossary of Terms

AP-42, *Compilation of Air Pollutant Emission Factors*
The primary compilation of EPA's emission factor information. It contains emission factors and process information for more than 200 air pollution source categories. A source category is a specific industry sector or group of similar emitting sources. The emission factors have been developed and compiled from source test data, material balance studies, and engineering estimates. (http://www.epa.gov/ttn/chief/ap42/)

Biogenic
Biological in origin, as opposed to fossil. While at root even fossil fuels have a biological origin, biogenic refers to fuel derived from sources that are cycling through the current and near term biosphere, rather than being mined from past ages (fossil fuels).

Buffering
The capacity to store then provide energy when the generator is not operating. This is particularly important with wind and solar generators that operate intermittently.

Conversion Factors
Global Warming Potentials (GWP; 100-Year Time Horizon)

Greenhouse Gas	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)*	21
Nitrous oxide (N_2O)	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	*1,300*
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

Source: IPCC (1996)

* The CH_4 GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.

Global warming potentials are not provided for CO, NOx, NMVOCs, SO2, and aerosols because there is no agreed-upon method to estimate the contribution of gases that are short-lived in the atmosphere, spatially variable, or have only indirect effects on radiative forcing (IPCC 1996).

Forest Stewardship Council (FSC)
The Forest Stewardship Council was created to change the dialogue about and the practice of sustainable forestry worldwide. This impressive goal has in many ways been achieved, yet there is more work to be done. FSC sets forth principles, criteria, and standards that span economic, social, and environmental concerns. The FSC standards represent the world's strongest system for guiding forest management toward sustainable outcomes. Like the forestry profession itself, the FSC system includes stakeholders with a diverse array of perspectives on what represents a well-managed and sustainable forest. (Forest Stewardship Council US, 2010)

Fossil carbon
Geologic in origin; sequestered over geologic time frames

kWh; kiloWatthour
Watts used (in thousands) times Hours of use (production or consumption) a common unit of electrical energy

MMBtu – One Million British Thermal Units
A standard unit of measurement used to denote both the amount of heat energy in fuels and the ability of appliances and air conditioning systems to produce heating or cooling. A BTU is the amount of heat required to increase the temperature of a pint of water (which weighs exactly 16 ounces) by one degree Fahrenheit. Because BTUs are measurements of energy consumption, they can be converted directly to kilowatt-hours (3412 BTUs = 1 kWh) or joules (1 BTU = 1,055.06 joules). A wooden kitchen match produce approximately 1 BTU, and air conditioners for household use typically produce between 5,000 and 15,000 BTU.
MBTU stands for one million BTUs, which can also be expressed as one decatherm (10 therms). MBTU is occasionally used as a standard unit of measurement for natural gas and provides a convenient basis for comparing the energy content of various grades of natural gas and other fuels. One cubic foot of natural gas produces approximately 1,000 BTUs, so 1,000 cu.ft. of gas is comparable to 1 MBTU. MBTU is occasionally expressed as MMBTU, which is intended to represent a thousand thousand BTUs. (British Thermal Unit)

MTCDE
Metric Tonnes of Carbon Dioxide Equivalent; the standard normalization measure for greenhouse gas emissions.

Proximate and Ultimate Analyses
Biomass fuels are characterized by what is called the "Proximate and Ultimate analyses". The "proximate" analysis gives moisture content, volatile content (when heated to 950 C), the free carbon remaining at that point, the ash (mineral) in the sample and the high heating value (HHV) based on the complete combustion of the sample to carbon dioxide and liquid water. (The low heating value, LHV, gives the heat released when the hydrogen is burned to gaseous water,

corresponding to most heating applications and can be calculated from the HHV and H2 fraction.)

The "ultimate" analysis" gives the composition of the biomass in wt% of carbon, hydrogen and oxygen (the major components) as well as sulfur and nitrogen (if any). (Biomass Energy Foundation)

REC; Renewable Energy Credit

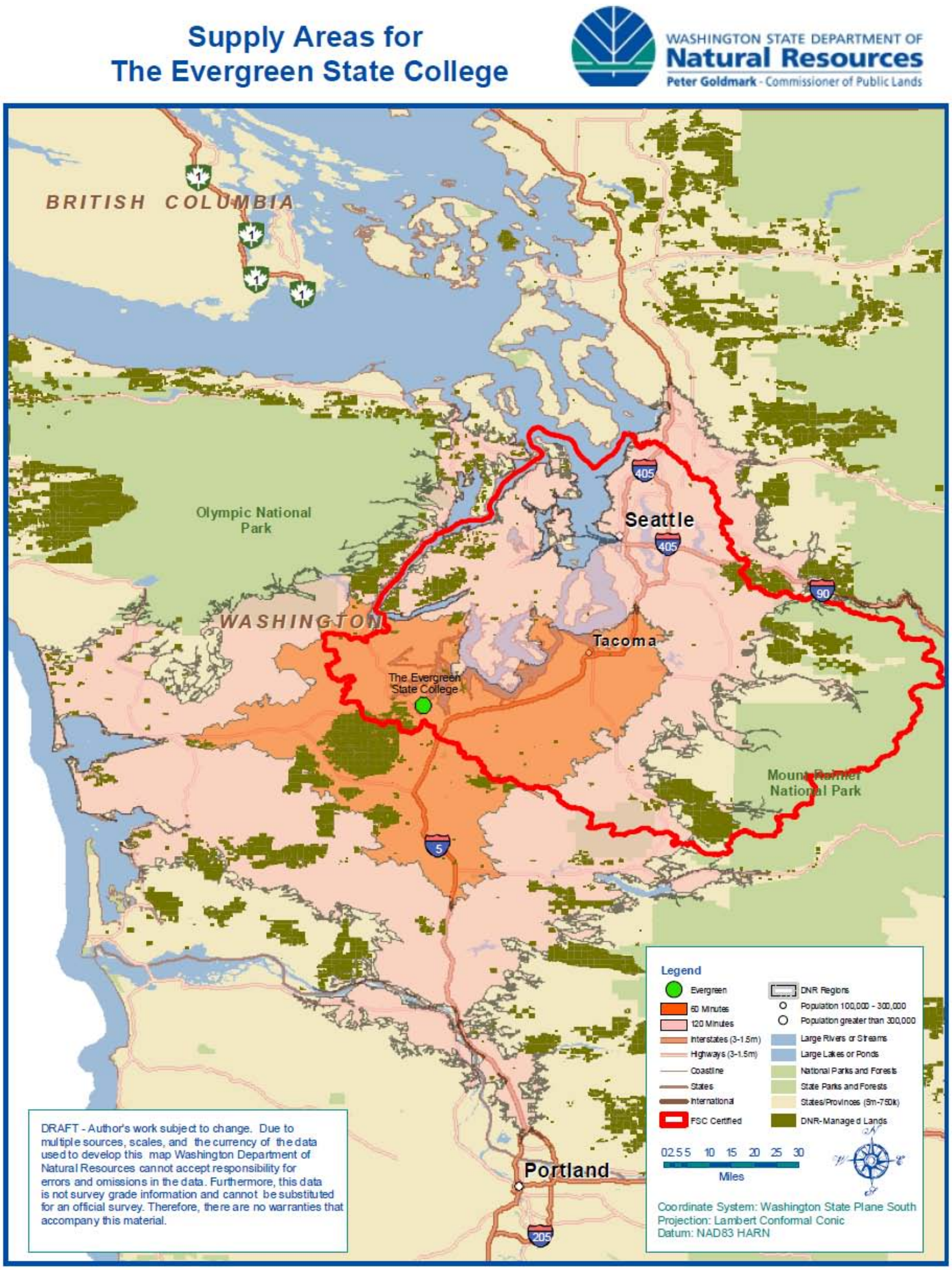
As renewable generators produce electricity, they create one REC for every 1000 kilowatt-hours (or 1 megawatt-hour) of electricity placed on the grid. The REC product is what conveys the attributes and benefits of the renewable electricity, not the electricity itself.

RECs serve the role of laying claim to and accounting for the associated attributes of renewable-based generation. The REC and the associated underlying physical electricity take separate pathways to the point of end use. As renewable generators produce electricity, they have a positive impact, reducing the need for fossil fuel-based generation sources to meet consumer demand. RECs embody these positive environmental impacts and convey these benefits to the REC owner.

Therm

A common measure of natural gas reflecting the energy content of the gas rather than the volume, because energy content of natural gas varies by volume.

Appendix 7 – Fuel Supply Resource Area



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