The True Cost of Energy

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The True Cost of Energy

Community-Engaged Research in Environmental Studies (ENVR 417) – Group 3

Bryan Lehrer, Gwyn Browning, and David Kurey

Fall 2014
Executive Summary

This project was a collaboration between students taking the environmental studies capstone course and community partners Julie Rosenbach and John Rasmussen with the purpose of supplementing current research on sustainable and cost effective energy sources at Bates College, by examining externalities. In order to compare and contrast the externalities of a fossil fuel against a feasible alternative energy, focus was placed on natural gas and biomass. The overall goal of the project was to elucidate the positive and negative impacts of different energy options on the environment and society, leading to a recommendation of the best energy option for Bates College.

Consideration for sustainable practice on the Bates College campus began in 2007 when the college president at the time, Elaine Tuttle Hansen, signed the American College and University Presidents Climate Commitment (Climate Action Plan 1). This action initiated a campus wide effort to reduce greenhouse gas (GHG) emissions to the extent of achieving climate neutrality. In other words, Bates made mitigation of current emissions and offsetting immitigable emissions a priority in the attempt to have zero GHG emissions. To outline this process, Bates College generated the Climate Action Plan (CAP) in 2010, which identified sources of emissions on campus and provided three different plans to achieve climate neutrality. The document highlights the role of fossil fuels as a significant source of GHG emissions and presents biomass as a possible mitigation strategy (CAP 21). Although the positive and negative implications of these energy sources in regard to GHG emissions is clearly stated and well supported in the CAP, the positive and negative implications of energy sources in other important realms of sustainable thought, such as the environment and society were not considered in depth.

To supplement the research on GHG emissions, this project identified and analyzed externalities of natural gas and biomass relevant to Bates College. These externalities, defined as societal and environmental costs not reflected in the market price of fuel (Koomey et. al. 1), were organized into five different categories and each category was ranked on a scale of 1 to 10, with one representing an energy source that consists of extremely negative externalities and ten representing an energy source that consists of extremely positive externalities. For each ranking an analysis of the externalities and for each category a comparative examination of the energy sources was included.

This project found that biomass was not only the best option to mitigate GHG emissions on campus, but the best energy option for Bates College when considering the externalities of the two energy sources. In all five categories, biomass ranked higher than natural gas. At the time of this project, nearly five years after the publishing of the Climate Action Plan, fossil fuels are still being used on campus. The results of this project show that the initial investment to change the main steam plant’s infrastructure from fossil fuels to biomass is well worth the money, considering the environmental and societal implications in addition to the reduction of GHG emissions.
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List of Acronyms
BLS – Bureau of Labor Statistics
CAP – Climate action plan
CRI – Corridor Resources Inc.
EIA – United States Energy Information Administration
EPA – United States Environmental Protection Agency
GHG – Greenhouse gases (i.e. carbon dioxide, carbon monoxide, etc.)
IPCC – Intergovernmental Panel on Climate Change
LNG – Liquefied natural gas
MFPC – Maine Forest Products Council
MMBtu – Million British thermal units
MTCDE – Metric tons of carbon dioxide emissions
PHMSA – Pipeline and Hazardous Materials Safety Administration
SHG – Stone House Group
SPE – Society of Petroleum Engineers
Introduction

Climate change, a global phenomenon caused by anthropogenic greenhouse gas emissions, came to the forefront of sustainable practice in the early 1990s when the Intergovernmental Panel on Climate Change published its first assessment report, providing strong scientific evidence of global climate change (IPCC). The result was a shift in sustainable thought that still resonates in planning strategies, stressing the need for alternative fuels with low greenhouse gas emissions in comparison to fossil fuels.

Achieving sustainability became a goal of many institutions of higher education. Anthony Cortese suggests a sustainable ideological framework for colleges and universities that emphasizes interdisciplinary participation, between education, the external community, research and operations (17). He goes on to identify the important advantages of creating a sustainable future, which include increased external respect, cooperation and satisfaction across the university, fulfillment of higher education’s moral and social responsibilities, and reduced economic, social and environmental costs (Cortese 20). Bates College has an interdisciplinary environmental studies department that incorporates education with research, often in the external community. However, Bates College falls short with regard to operations, due to the continued use of fossil fuels. Therefore, Bates College is at risk of losing the important advantages Cortese describes relating to the overall image of the college as a sustainable member of the world community.

In 2007, Bates College signed the American College and University Presidents Climate Commitment, which was an initiative started by higher education institutions to reduce GHG emissions on college campuses (CAP 1). The initiative required signatories to complete a comprehensive inventory of all GHG emissions and develop “an institutional action plan” for becoming climate neutral by a specified year (Presidents Climate Commitment). In response to these requirements, Bates finalized the “Climate Action Plan” in January 2010, highlighting sources of current emissions and methods for achieving climate neutrality by 2020 (CAP). Climate neutrality, a relatively new idea, is best defined as having no net carbon emissions by reducing current carbon emissions and offsetting immitigable carbon emissions. The CAP shows that the main GHG emissions at Bates College come from campus heating operations and purchased electricity (CAP 2).

To evaluate the full extent of these GHG emissions, Bates College measures its carbon footprint by looking at the college’s energy consumption by energy source, which takes into account “a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product” (Carbon Trust). In order to make positive strides towards becoming climate neutral and environmentally sustainable, a thorough and comparative reassessment of these systems is necessary. Not only emissions, but the external costs of an energy source’s environmental and social effects, known as externalities, must be
evaluated and the prices internalized. Therefore, Bates must ensure that traditional energy platforms (fuels such as oil and natural gas) are being consumed relative to their cost, carbon content, and externalities. This necessitates a comparison of fossil fuels to alternative energy sources, such as biomass, biofuel, and solar.

Alternative energies usually have fewer harmful social and environmental consequences than fossil fuels. However, alternative energies are currently not as competitive in the market due to their higher initial capital cost and site specificity. In some cases alternative fuels are economically beneficial, even before accounting for externalities. Internalizing externalities can make alternative energies even more competitive, by providing the impetus for investing in infrastructural changes, thereby making the initial cost feasible (Owen 634). Due to site specificity of alternative energy, biomass emerges as a significant option for Bates College as an alternative energy source, since Maine has a surplus of wood. The surplus drives down the market price of wood chips, making biomass cheaper than any other common fuel. Accordingly, our project looks at biomass as the forerunning alternative energy option for Bates to adopt.

Below is a brief section introducing the major fuel types that will be analyzed and compared.

Natural Gas

The current operational infrastructure at Bates College utilizes #2 oil and natural gas, accounting for a significant portion of GHG emissions on campus. Although the on-campus central plant has a duel fuel capability, meaning it can either run on #2 oil or natural gas, the predominant fuel is natural gas, since its market price is cheaper (CAP 37). The central plant provides the steam for heating and hot water needs to over 80% of the structures on campus, but the remaining 20% that are not connected to the centralized infrastructure use oil (CAP 19). The use of natural gas and oil for heating on-campus buildings, known as “stationary sources,” is the second largest source of gross emissions at Bates College, accounting for 40% of the total metric tons of carbon dioxide emissions (MTCDE) after electricity (CAP 2). Therefore, fossil fuels are a significant source of GHG emissions on the Bates College campus. However, they can be mitigated. To better understand the true cost of natural gas at Bates College, examining the environmental and social consequences of natural gas by tracing it from consumption to production is integral to achieving climate neutrality and supplementing the argument for mitigation.

The transportation and consumption of natural gas in Maine is facilitated by pipelines. When natural gas is consumed at Bates College it is present in its gaseous form and primarily consists of methane. Upon combustion, natural gas emits carbon dioxide into the atmosphere (Hrastar 28). The natural gas consumed at Bates College is purchased from one of four gas utilities in Maine, a company known as Unitil that serves the Lewiston-Auburn area (Welch 2). Unitil provides service pipelines for customers, linking them to natural gas resources, namely major interstate pipelines, such as the Maritimes and Northeast pipeline, which transports natural
gas from Canadian sources (Maritimes and Northeast Pipeline). Maine does not produce any natural gas, meaning it has to import all of it from out-of-state and most of this natural gas is from Canada (Energy Information Administration “Maine Profile Analysis”). In 2013, the EIA reported that the Maritimes and Northeast pipeline imported over 41 billion cubic feet of natural gas into the United States (EIA “Net Interstate Movements”). Although the Maritimes and Northeast Pipeline services cities and towns in Maine, most of the natural gas goes to markets in New Hampshire and Massachusetts (EIA “Maine Profile Analysis”). The proximity of this major pipeline to the Lewiston-Auburn area is significant, because the existing infrastructure surrounding natural gas makes it a cost effective and relatively stable energy option for Bates College.

The natural gas transported into Maine via the Maritimes and Northeast Pipeline, comes from three major Canadian sources: the Sable Offshore Energy Project, Corridor Resources McCully Project, and Canaport TM LNG receiving and Re-gasification Terminal (Maritimes and Northeast Pipeline). The Sable Offshore energy project has at least five offshore platforms off the coast of Nova Scotia, an onshore gas plant, and an onshore fractionation plant, that separates leftover natural gas liquids (Exxon Mobil). The Corridor Resources McCully Project is located in New Brunswick and consists of 35 drilled wells, 26 of which have been completed and are currently producing natural gas. Well exploration is carried out through fracture stimulation, using propane instead of fresh water as a fracturing fluid with additives (Corridor Resources). The Canaport TM LNG receiving and regasification terminal is located in St. John, New Brunswick and receives shipments of liquefied natural gas (LNG) from vessels originating from various parts of the globe, such as the Middle East, North Africa, and Latin America. Canaport processes the LNG imports by returning the liquefied natural gas back to the gaseous state before sending it through Maritimes and Northeast Pipeline (Canaport LNG). Therefore, natural gas that enters Maine through the Maritime and Northeast Pipeline and then is consumed by Bates College comes from a variety of different sources with different environmental and social consequences to be considered.

A brief sampling of the externalities associated with the production, transportation and consumption of natural gas, demonstrates the necessity of investigating alternative energies. Over the course of exploration, extraction, and transportation, natural gas, methane, can be directly released into the atmosphere through accidental leakages, which is extremely detrimental to the atmosphere, due to methane’s ability to function as a powerful greenhouse gas (National Research Council 12). In addition, recent developments into the recovery of natural gases from shale, using hydraulic fracturing techniques, poses health and safety risks to surrounding communities, since these techniques have been linked to the contamination of the drinkable groundwater (Hrastar 240). Moreover, hydraulic fracturing, or fracking, has significant risks with unknown long term consequences. The demand for natural gas in the Northeast has also increased in recent years, demonstrating the potential for prices to become increasingly volatile. Although Bates College is close to a natural gas pipeline and natural gas emits fewer greenhouse
gases than oil when combusted, the high social and environmental costs warrant investigation into new energy resources, such as biomass.

**Biomass**

Looking at biomass’ feasibility as a replacement utility to cover Bates’ heating needs leads to a few interesting realizations.

Of the different fuels examined in this study, biomass most likely has the fewest negative externalities associated with its consumption. It is a fuel that is produced as a natural byproduct of pre-existing, renewable, and sustainably paced timber harvesting operations—all of which take place within Maine, and thus contribute to the local economy (MFPC 2). In this sense, not only does biomass evade unintended or undesirable externalities, but also it can be seen as leading to positive externalities (Saâ Ez et al. 472).

Besides photovoltaic cells used to capture solar energy, biomass plants like those potentially implemented at Bates have a proven track record of the cleanest emissions. This all occurs through a process called gasification, which refers to the two-phase combustion method that partially inhibits the conversion of carbon found in wood chips to CO$_2$ (Quaak et al. 7). But even if this were not the case, the CO$_2$ released through burning wood is carbon already native to the earth’s surface, at least according to the EPA (EPA "Framework for Assessing Biogenic CO$_2$ Emissions from Stationary Sources"). In this sense, it is much different from carbon released from fossil fuel combustion, which is carbon previously trapped in the earth’s crust. It is important to note though that certain operational practices, such as shipping biomass, consumes fossil fuels, but at a much lower rate than using these fuels for actual heating needs.

The surprising thing about biomass is that, based on all of these diminished negative externalities (and even positive externalities), one would expect the fuel source to be expensive. In almost any other context, a similar renewable energy source would have a premium attached to its “green” characteristics. But because of the nature of supply chains in Maine and northern New England, Biomass is actually the least expensive source of energy that can be used for heating. This is simply due to the staggering amount of timberland in Maine, since 89% of all land in Maine is classified as timberland (Maine Forest Service 4). What this amounts to is a price of $7.00/Btu less than Natural Gas, which is the already-cheap (ignoring externalities) fuel currently used by Bates to heat the campus (Stone House Group 24). Thus in terms of economic feasibility, the only true barrier facing implementation of Biomass is the high initial fixed costs of designing and constructing a Biomass system specific to Bates. Certain estimates place such a facility anywhere between $6 and $11 million (SHG 25).

Examining the externalities of each fuel source may provide the insight and impetus to overcome the large initial investment for biomass, propelling Bates College toward a more sustainable future. Not only will the goal of climate neutrality by 2020 be a step closer, but the role of Bates College as a model of sustainability can be realized.
Methodology

Pricing Externalities- A Complex Procedure

At the onset of this project, our goal was to reevaluate information in regard to the “true cost of energy.” The ideal materialization of this was in the form of a discreet price, or in other words the formation of another column on a pre-existing spreadsheet that tabulated costs of various fuel types. This column would list an aggregate price for both (positive and negative) externalities associated with these fuel types. The desire was for this number to create an adjusted price that could adequately inform Bates policy makers of the underlying desirability of any given fuel. To give an example of what this looks like, picture fuel X which costs $10.00 per MMBtu, but is also proven to lead to large amounts of pollution that costs $1.00 per MMBtu to mitigate. Thus if this pollution is the only externality associated with Fuel X’s use, then its “true cost” would be $11.00. Such an informed price might make other fuels—like for instance Fuel Y whose price is $10.50, with no further negative externalities—seem relatively cost feasible.

With this framework in mind, we set out to find the price of externalities associated with all of the potential fuels that Bates could use to operate its steam plant, and to meet other small-scale energy demands. These were listed as Biomass, #2 Oil, Natural Gas, Bio-Diesel, Solar, Electricity, and Wind.

We primarily aimed at finding externality prices through searching academic literature for already-compiled figures of externality pricing. There were a couple reasons for this. On one hand, the three members of our group acknowledged our significant lack of expertise, resources, or time, to be able to commit towards original research. It simply would have not been feasible given these constraints to produce remotely accurate figures for externalities. PhD economists spend years developing pricing models, and even then, the field is still a relatively new one with no set procedure on how to go about these calculations. Furthermore when the margins between the prices of different fuels are already so close, we were weary of introducing biased, or worse, simply incorrect estimates. Even slightly biased estimates have the potential for significant damage considering that Bates spends upwards of $4 million each year on energy.

The extraction of figures from academic spheres proved to be complicated as well. For one, despite our expectations, it seemed to be the case that scholars didn’t frequently address the issue of pricing externalities. While scholars commonly talk about externalities in a general sense, they rarely commit to explicit monetary estimates of these externalities. The reasoning for this is simple. In the end, even the most quantitatively skilled economist must rely on some subjective assumptions to be able to conjure estimates. An example of this is the classic case of Value of a Statistical Like (VSL) modeling. In estimating the dollar worth of a human life, economists assume that this value is equivalent to things such as one’s labor output or even money saved from raising the speed limit (Ashenfelter, et al.). In the realm of externalities, such far-reaching
assumptions are not the standard of producing price estimates. In attempts to avoid these assumptions in the first place, scholars seem to focus their attention on other realms.

But this does not mean that pricing estimates don’t exist. We actually came upon several of these estimates (Gowrisankaren, et al. 16). Unfortunately, it was immediately clear how harnessing these figures might be problematic. As stated above, it was common within the scholarly literature to call upon assumptions that were not entirely easy to accept or applicable. Due to the nature of these assumptions, many estimates seemed to exist for scholarly application rather than practical applications like at Bates. Another applicability problem arose with location. For example, the externality pricing estimates for PV cells was from a case study completed in Europe, which meant that for a whole myriad of reasons, applying the model to Maine would be problematic (Gowrisankaren, et al. 1).

A New Numerical Approach

With the unintended setbacks in our original research plan, we were forced to rethink our approach. Our community partners Julie Rosenbach and John Rasmussen helped us reform a plan of research that could more adequately work around the imposed constraints while still maintaining relevance and accuracy towards Bates. The goal of this refocusing was to keep the emphasis on numerical information, since this kind of information is what policy makers prefer to utilize in decision-making processes. However, instead of narrowly focusing on producing prices for externalities, our focus shifted towards producing numbers that reflect these externalities. It was deemed that accuracy of information trumped the finality of a singular pricing estimate contained within another row of a spreadsheet.

Another important development from this meeting was the decision to focus our research effort on only natural gas and biomass. There were two reasons for this. Committing research towards all of the fuel types listed previously proved to not be impossible, but it was clear that in great quantity we lost quality of information. Having a variety of different fuels to research meant that uncovering potentially important details would be difficult. Most importantly though, the reason for restricting research to only natural gas and biomass was due to the relevance of these particular fuels to Bates College. Bates currently uses natural gas as its primary fuel source for heating needs (CAP 37). The only other fuel that is similarly cost effective is biomass. Matter of fact, the cost per MMBtu for biomass is cheaper than natural gas. The setback of biomass is that it requires an expensive initial investment in facilities. Fuels like solar and bio-diesel whose high costs make them less feasible (even when accounting for externalities) were no longer researched after this point.

To further simplify our process the protocol for research from this point forward involved isolating several major groups of externalities and evaluating natural gas and biomass within these groupings. The reasoning behind the selection of categories is a direct result of conversations with our community partners. It was communicated that these categories would
yield the most important information for Bates policy makers. The categories are listed as: safety, local economic impact, GHG emissions, other forms of pollution, and publicity effects (see Figure 1). “Safety” refers to risk of injuries within all steps of the production and supply process of a fuel. “Local economic impact” refers to local job creation and the flow of money. “GHG emissions” looks at the measurement of carbon dioxide emissions and its equivalents. “Pollution” looks at pollutants from additional emissions, release of hazardous materials, and their health effects apart from global warming. Finally, “Publicity” refers to positive or negative perceptions surrounding the usage of different fuel types.

When researching these categories a hierarchy of preferences regarding information was established. If accurate and applicable pricing estimates existed for any of these externalities, we first used this. If not, we then sought out quantified information that speaks to cost, even if not explicitly related to a dollar value. Finally, if a category truly evaded any form of quantification, we used qualitative sources to make inferences about what this quantification might look like.

The manifestation of this research was a table that clearly organized information into columns with the main types of externalities, characteristics of each externality, methods of valuation, data associated with each externality, and the sources of the information. Table 12 in Appendix B works as a template for each of these externality tables.

After completing much of this research it became clear that while we had assembled an amalgamation of very useful statistics, these numbers did not directly supply a coherent overview of each externality. They often stood by themselves, not necessarily feeding into a singular narrative. A policy maker with a lot of time on their hands could certainly filter through this research and get a grasp of the “the true cost of energy,” but time is exactly the thing that these individuals lack. In response to this we decided to add a summarizing component to each section of externalities. This is a numerical scale from 1-10 that rates each fuel based on its lean towards whether it possesses mostly positive or mostly negative externalities. A “10” represents a category consisting of high amounts of positive externalities or beneficial features, while a “1” represents a high amount of negative externalities or negative features.

The rest of our report is a direct extension of all points made above. For each externality grouping there will be two tables that summarize relevant quantified findings for biomass and natural gas. After each table is a discussion about where these numbers come from and what they mean. At the very end of the results and discussions section we created a table that summarizes our rankings (Table 10). Finally we provide a section on what these findings amount to and what they mean for Bates policy makers.
Results and Discussion

Health / Safety

Local Economic Impact

Greenhouse Gas Emissions

Pollution

Publicity

Figure 1. The five main categories of externalities. Each of the categories is associated with a color to help orient the reader during the transition from natural gas results and discussion to biomass results and discussion within each category.

Health and Safety

Natural Gas Results and Discussion

Table 1. Externalities related to the health and safety of natural gas.

<table>
<thead>
<tr>
<th>Externalities</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities/Injuries</td>
<td>Production: Extraction Onshore and Offshore Drilling</td>
<td>Fatality rate in comparison to all other occupations in U.S.</td>
<td>(2003-2010) 27.1 versus 3.8 deaths per 100,000 workers</td>
<td>Gunter et al</td>
</tr>
<tr>
<td></td>
<td>Transportation: Pipeline related incidents</td>
<td># of fatalities and injuries in U.S.</td>
<td>2012 12 Fatalities 57 Injuries</td>
<td>PHMSA</td>
</tr>
<tr>
<td></td>
<td></td>
<td># of fatalities and injuries in state of Maine</td>
<td>2012 0 Fatalities 0 Injuries</td>
<td>PHMSA</td>
</tr>
</tbody>
</table>
### Equipment Condition

<table>
<thead>
<tr>
<th>Equipment Condition</th>
<th>Age of pipelines</th>
<th>Maritime and Northeast Pipeline</th>
<th>1999</th>
<th>Maritimes and Northeast Pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Effects¹</td>
<td>Contaminated ground and surface water near sites using fracturing methods</td>
<td>Analysis of chemicals used in fracturing</td>
<td>-</td>
<td>Spellman Corridor Resources</td>
</tr>
</tbody>
</table>

¹*This excludes health effects resulting from combustion of a fuel source. Health effects resulting from combustion will be evaluated later in the GHG emissions and pollution sections.*

Three significant externalities, arising from health and safety issues within the natural gas industry, consist of occupational hazards that result in fatalities and injuries, the condition of infrastructural equipment, and the effect of environmental contamination on human health during the extraction process. The incredibly volatile nature of methane inherently creates a risky working environment, where accidents can mean the end of someone’s life. Ideally, energy collected in a low risk environment is preferable, so in order to reflect the priceless value of human life and health in relation to energy, these externalities are important to consider. The natural gas industry as a high risk occupation naturally has a high social cost.

A number of fatalities and injuries in United States are related to the production, transportation, and consumption of natural gas, contributing to the dangerous and unsafe nature of the industry. According to the Center of Disease Control, the fatality rate for working in onshore or offshore drilling is seven times higher than working in any other occupation in the United States (Gunter et al.). Although Maine imports most of its natural gas from Canada, the statistic is still relevant, because it demonstrates the inherent danger in occupations surrounding the production of natural gas. National safety standards and working conditions may differ, but the companies that own these energy sources are multinational corporations that impose standards of operation regardless of boundaries. Therefore the production of natural gas and more specifically the process of extraction is an occupation with a high social cost.

Since Maine doesn’t produce natural gas, instate fatalities or injuries would occur around natural gas pipelines. The number of reported fatalities and injuries due to a natural gas pipeline incident in Maine in 2012 was zero. However, incidents surrounding pipelines are still a hazard, since the number of fatalities due to pipeline incidents in the United States was 12 and the number of injuries, 57, in 2012 (PHMSA). Although workers for the natural gas industry in Maine haven’t been visibly injured, the potential for injuries is still there, which merits attention when considering fuel safety, pushing the social cost of fuel higher.

The lack of fatalities or injuries in the past twenty years in the state of Maine may be related to the relatively new condition or well-scheduled maintenance of the main pipelines.
The Maritimes and Northeast pipeline was installed in 1999, making it about fifteen years old. With relatively new and well-maintained technology, the hazards of natural gas pipelines can be decreased, but not entirely eliminated. In the state of Maine the only damage sustained by natural gas pipelines has been property damage. Therefore on a regional scale the negative externality of safety hazards is less discernable, but not absent.

The externality regarding health effects goes beyond the fatality and injury statistics to show a subtle form of injury that natural gas can have on a local community. During the process of hydraulic fracturing, water or propane mixed with chemicals is pumped into a drilling well at high pressure in order to stimulate fracturing. Once the rock is fractured, previously inaccessible natural gas can be extracted. Sometimes these cracks extend into groundwater reservoirs, where the chemical additives contaminate drinking water supplies. Many of the chemical additives used in hydraulic fracturing are unknown, because companies aren’t required to disclose them. The Corridor Resources Inc., which supplies natural gas to the Maritimes and Northeast Pipeline, disclosed some of the additives used in their fracturing fluid. Although the transparency is admirable, the nature of the chemicals leaves a lot to be desired. In the description of the additive chemical Activator XL-105, it says that the chemical may be “possibly carcinogenic to humans,” and that its, “ecotoxicity and bioaccumulation capacity [are] not determined” (CRI A2). The lack of information itself becomes an externality, since the cautionary approach is not being utilized and communities near fracking operations are placed at risk by exposing them to chemicals with unknown implications. Despite careful documentation of water tables in environmental assessment reports, there is no guarantee that fracturing fluids won’t contaminate drinking water supplies. Drinking water is absolutely necessary to survive and exposing a community to unknown hazardous chemicals is a high social cost.

With more negative externalities than positive externalities regarding health and safety, we decided that natural gas would be rated a 2. Natural gas in Maine hasn’t been a significant source of personal injury, however the natural gas industry relative to other occupations is comparatively unsafe and the technique of hydraulic fracturing can contaminate the drinking water of surrounding communities, demanding a high social cost.
**Biomass Results and Discussion**

Table 2. Externalities related to the health and safety of biomass.

<table>
<thead>
<tr>
<th>Externalities</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities/Injuries</td>
<td>National Fatality Rate for Logging in 2010</td>
<td>Deaths per 100,000 workers</td>
<td>73.7</td>
<td>BLS</td>
</tr>
<tr>
<td></td>
<td>Maine Fatalities in 2012 for Logging</td>
<td>Total</td>
<td>8</td>
<td>Maine BLS</td>
</tr>
<tr>
<td></td>
<td>Maine Injury rate 2012 for Logging</td>
<td>% of Employees injured in</td>
<td>3.7</td>
<td>Maine BLS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Logging and Forest Industry</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A hypothetical biomass facility that Bates would build would run on wood chips. While biomass plants can run on a virtually any type of biomass, a facility in Maine is particularly poised to take advantage of the state’s high concentration of wood biomass (Smith, Miles et al.). Figure 2 shows this high concentration of forested area relative to other states in the US.

Accordingly it is safe to assume that this woody biomass would have to be harvested somehow. The method that is currently used to harvest woody biomass is through preexisting logging operations. Thus in determining the safety and health implications of biomass, one must consider the occupational hazards presented in the logging industry. Logging is consistently labeled as one of the most dangerous occupations in the US. In 2010 there were 73.7 deaths per 100,000 workers making logging the deadliest industry in the country. In 2012, Maine saw 8 occupational fatalities come from Logging and Forestry operations and a 3.7% rate of injury. This was the highest of any industrial sector in Maine (Maine BLS 5; Maine BLS 1).

In some senses these figures do not speak well towards biomass’ marks towards safety and health. The woodchips that sit in the center of the biomass equation come from an industry that is consistently the most dangerous to its workers. But at the same time, it’s important to note that the actual woodchip manufacturing process is a preexisting component of logging. The woodchips that biomass facilities rely on are not harvested specifically for these facilities. Rather, they are natural byproducts of logging that is already occurring. Accordingly it cannot be confirmed that woodchip demand from biomass facilities is directly causing workplace fatalities or accidents.
As stated more thoroughly in the subsequent section on post-combustion emissions, biomass creates a sizable amount of ash waste. In an interview with Gus Libby (see below), he told us there have been a few occasions where still-smoldering ash has ignited the local landfill, necessitating a response by the Waterville fire department. Although an event like this has never caused any safety concerns, this might not be the case in future scenarios if these fires were to become more severe and spread to nearby populated areas.

Overall, the potentially dangerous nature of biomass consumption added up to be only minor concern. We accordingly rate the fuel slightly under average at a 4.

**Local Economic Impact**

*Natural Gas Results and Discussion*

Table 3. Externalities related to the local economic impact of natural gas.

<table>
<thead>
<tr>
<th>Externalities</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jobs</td>
<td>Natural Gas Distributors</td>
<td>Number of Jobs</td>
<td>Bangor Natural Gas – 30</td>
<td>Pipeline and Gas Journal Phone Interviews w/HR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maine Natural Gas – 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Summit Natural Gas – 66</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unitil – N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Jobs in Maine</td>
<td>Number of Jobs</td>
<td>610,516 Jobs</td>
<td>Maine Center for Workforce Research and Information</td>
</tr>
<tr>
<td></td>
<td>Percentage of Total Jobs</td>
<td></td>
<td>0.02%</td>
<td></td>
</tr>
<tr>
<td>Locality</td>
<td>Proximity to Lewiston</td>
<td>Miles</td>
<td>Bangor – 107</td>
<td>Google Maps Company Websites</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maine – 19</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Summit – 37</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unitil – 35</td>
<td></td>
</tr>
<tr>
<td>Cash Flow</td>
<td>Flow of Money out of Maine</td>
<td>Company Ownership/Headquarters Location</td>
<td>Bangor – Energy West (Great Falls, MT)</td>
<td>Company Websites</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maine – Iberdrola (Biscay, Spain)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Summit – Summit Utilities Inc. (Litteton, Co)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unitil – Unitil Corp. (Hampton, NH)</td>
<td></td>
</tr>
</tbody>
</table>
The first and second externalities in the table above illustrate the local economic impact that natural gas companies have on Maine as a whole, and also in Lewiston as a subset as well. The Maine Public Utilities Commission lists sixteen registered natural gas suppliers for Maine residents’ use. The list is intended to be a resource for residents to aid them in choosing the supplier with the most competitively priced natural gas for their specific needs. Only 4 of those registered 16 natural gas supplies are located in Maine. Since none of the companies list their total number of employees in the public domain, we called each company and spoke with members of Human Resources. Unitil declined to comment, citing the company’s right to withhold confidential information. However, Unitil is Maine’s largest natural gas company so we inferred that it would likely be larger than the rest and contain at least 70 employees. The results, shown above, display the relatively small number of jobs this industry supports in Maine. The natural gas industry employs just under 200 people, while Maine currently employs 610,516 people, which effectively accounts for 0.02% of the total employment in Maine (Maine Center for Workforce Research and Information).

In addition to the total number of jobs, it is also important for our purposes to identify the economic effect natural gas has on Lewiston itself. All of these companies, with the exception of Maine Natural Gas, are located more than 30 miles away (Google Maps). We assumed that the majority of the employees from each company live within a closer proximity than 30 miles to their place of work. Therefore, we found that, on the whole, the natural gas industry in Maine does not clearly or directly support Lewiston’s economy. Finally, we concluded that much of the money from natural gas sales goes directly out of state to headquarters of the companies that own the largest four Maine natural gas companies. For example, Maine Natural Gas, one of the largest suppliers of natural gas to Maine, is owned by a Spanish energy company Iberdrola (Maine Energy IQ). Another example is Summit Natural Gas of Maine, which is owned by the New York City-based investment bank JP Morgan (Maine Energy IQ). As a result, much of the revenues from Maine residents purchasing natural gas are going directly out of Maine. Granted, there are employees working in Maine who earn a wage, but the majority of any company’s revenues go to where that company is headquartered. Since this industry is so small in terms of Maine employment, as it does not positively affect the Maine economy or Lewiston economy directly in a positive manner, and in fact, directs cash flow out of Maine, we have collectively decided to rate the Local Economic Impact externality as a 2.
### Biomass Results and Discussion

Table 4. Externalities related to the local economic impact of biomass.

<table>
<thead>
<tr>
<th>Externalities</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jobs</td>
<td>Total Logging Jobs in Maine</td>
<td>Number of Jobs</td>
<td>1610</td>
<td>Maine Center for Workforce Research and Information</td>
</tr>
<tr>
<td></td>
<td>Short-term Biomass Plant Employment Creation</td>
<td>75</td>
<td>Associated Press</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permanent Employment Creation</td>
<td>4</td>
<td>Contact @ Colby College</td>
<td></td>
</tr>
<tr>
<td>Locality</td>
<td>Proximity to Lewiston of Woodchips</td>
<td>Miles</td>
<td>&lt; 50</td>
<td>Contact @ Colby College</td>
</tr>
<tr>
<td></td>
<td>Proximity of wood chip Broker</td>
<td>63.8</td>
<td>Google Maps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proximity of boiler manufacturer</td>
<td>195.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow of Money</td>
<td>Purchase of wood chips</td>
<td>Dollar Amount to Location</td>
<td>$1-3 Million to Cousineau in Anson ME</td>
<td>Stone House Group</td>
</tr>
<tr>
<td></td>
<td>Construction of plant</td>
<td>$6-11 Million throughout New England</td>
<td>Contact @ Colby College</td>
<td></td>
</tr>
</tbody>
</table>

One of the unique benefits for Bates if a biomass facility was to be installed is that nearly all purchases related to the design, construction, use, and post-use of the facility would take place in New England, if not in Maine.

Bates would very likely purchase a gasification boiler from Chiptec technologies located in Vermont. The engineering, consulting, and architectural design of the facility could additionally be sourced locally. Considering these initial investments would amount to anywhere from $6-11 million, this is a significant amount of money being invested in local commerce.

More important though, the continued operation of the biomass facility would benefit the immediately local Maine economy. The wood chip supplier that both Colby and Middlebury use
has an office in North Anson, ME. Furthermore, this supplier can guarantee that chips be sourced in a 50-mile radius to Bates. This means that anywhere from $1-3 million annually would be injected into Lewiston-Auburn and its immediate surroundings (Stone House Group).

This number, when compared to other energy sources, is difficult to match. In the recent past where natural gas has seen consistent praise due to high levels of domestic production, biomass can be seen as offering even more on this front.

There is also the consideration of the creation of new jobs, as a response to the increased demand for wood chips that Bates would create. During Colby’s production phase, the plant was estimated to create 75 jobs, 3 to 4 of which would remain permanent after construction was completed (Portland Press Herald). Bates can expect to see a similar spike in created employment opportunities if it was to carry forward with biomass.

The culmination of these significantly positive economic effects allowed us to rate biomass at an 8 in this category.

**GHG Emissions**

*Natural Gas Results and Discussion*

Table 5. Externalities related to the GHG emissions of natural gas.

<table>
<thead>
<tr>
<th>Externalities</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ Emissions</td>
<td>Bates emissions due to combustion of Natural Gas in main steam plant</td>
<td>Emissions (MTCDE) in fiscal year of 2009</td>
<td>7,502 MTCDE</td>
<td>CAP 2</td>
</tr>
</tbody>
</table>

The Bates College Climate Action Plan reported that 7,502 metric tons of carbon dioxide equivalents were emitted into the atmosphere by the main steam plant in 2009 (CAP 2). Since the main steam plant has been running on natural gas in recent years, the amount of greenhouse gases emitted is representative of natural gas GHG emissions at Bates College (CAP 37). This amount of GHG emissions is rather high and presents an important externality to internalize in the cost of natural gas at Bates.

In comparison to other fossil fuels, such as oil and coal, natural gas is an incredibly clean burning fuel, which means it doesn’t emit as much greenhouse gases per Btu (EIA “Natural Gas”). For every billion Btu, natural gas releases 117,000 lbs. of CO₂, while oil releases 164,000 lbs. and coal releases 208,000 lbs. (see Table 13 in Appendix B). Not only is natural gas cleaner
burning than fossil fuels, but biomass as well. Natural gas’s reduced emissions appears to be a positive externality, but the fact that natural gas is emitting carbon dioxide previously sequestered in the earth, makes its total GHG emissions a negative externality. Rather than carbon cycled on a biological timescale, carbon sequestered in a geological timescale is being released when natural gas is burned, causing noticeable changes in the earth’s atmosphere that would normally occur over hundreds of thousands of years.

Extensive research has been conducted by scholars, including the IPCC, on the social and environmental consequences of climate change. These consequences include increased damage due to stronger storms and floods, loss of biodiversity, sea level rise, and changing composition and distribution of diseases (see Figure 4 in Appendix A). Although a significant portion of these predictions are based on historic trends and biogeochemical processes, the generation of quantified values and estimates is incredibly difficult to do with accuracy. Therefore, it is difficult to internalize the cost of global climate change from GHG emissions in the market price of fuel.

Recognizing that natural gas is a fossil fuel that emits GHG gases, thereby contributing to climate change, while simultaneously acknowledging natural gas’s ability to perform as a cleaner burning energy source, inspired us to give natural gas a ranking of 4.

**Biomass Results and Discussion**

Table 6. Externalities related to the GHG emissions of biomass.

<table>
<thead>
<tr>
<th>Externalities</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ Emissions from combustion</td>
<td>From combustion of raw wood</td>
<td>Lbs./MMBtu</td>
<td>213</td>
<td>PFPI</td>
</tr>
<tr>
<td></td>
<td>From combustion of raw wood</td>
<td>Metric Tons / Year</td>
<td>3387.04</td>
<td>Stone House Group, PFPI</td>
</tr>
<tr>
<td></td>
<td>Under Carbon Neutrality Assumption</td>
<td>Metric Tons / Year</td>
<td>0</td>
<td>EPA</td>
</tr>
<tr>
<td>CO₂ Emissions from transportation</td>
<td>For 18-Wheeler to travel 100 miles delivering chips, assuming that avg. rate is 2 trips per day</td>
<td>Metric Tons / Year</td>
<td>61.75</td>
<td>EIA</td>
</tr>
</tbody>
</table>

When analyzing biomass’ GHG emissions, the only significant GHG in question is Carbon Dioxide. The first thing to note about biomass is that it does emit levels of carbon
dioxide similar to other fossil fuels. For every MMBtu of wood chip Biomass combusted, 213 lbs. of CO₂ is emitted (PFPI). Because of the gasification technology available in a biomass facility that Bates would purchase, this estimate can be significantly decreased, but exact estimates of this decrease are not available.

The big issue to consider in regards to biomass is its labeling as being carbon neutral. Carbon neutrality refers to a fuel’s effect on the overall level of carbon dioxide in the atmosphere. If a fuel is carbon neutral, its combustion causes no net increase in carbon dioxide. For biomass this means that it is harvested from preexisting organic matter that is already part of earth’s natural carbon cycle. When it is burned, its reaming carbon can be injected back into this same system via a soil amendment, eventually being reabsorbed by trees, which are then subsequently harvested again. A simplistic diagram of this process compared to the carbon emissions cycle of fossil fuels is provided in the appendix as Figure 3 (Washington Forest Protection Association). The EPA recently published a report officially classifying biomass as “related to the natural carbon cycle,” or carbon neutral (EPA "Framework for Assessing Biogenic CO₂ Emissions from Stationary Sources "). While this classification is based of a review of current research, it’s not to say that this verdict is uncontested. Some believe biomass’ status as carbon neutral to be problematic (Johnson 165). The reasoning for this comes from failure in believing in the simplistic explanation that establishes carbon neutrality. Critics believe that in reality the systems that govern whether or not something is carbon neutral are incredibly complex. Specifically, these critics think that the process of carbon reabsorption rarely happens in a predictable or dependable way. Depending on the setting, this would lead to a slight net increase in carbon dioxide in the atmosphere.

For the purposes of this report, we agree with the EPA’s viewpoint on biomass’ carbon neutrality. The reasoning for this is two-fold. For one, the survey process that the EPA has undergone addresses the academic consensus of biomass carbon neutrality in a more thorough manner compared to the specific criticisms of individual scholars. Secondly, in the case of Maine biomass, the forests are particularly adept of rapidly progressing through the carbon cycle (Benjamin 2010). Years of sustainable logging practices in Maine have ensured that trees are readily available to absorb emitted carbon back into the system. This is especially true compared to other areas in the US with a lesser forest density.

The only component left in determining the greenhouse gases associated with biomass use comes from use of fossil fuels during the transportation of the material, which amounts to 61.75 metric tons per year (EIA “How much carbon dioxide is produced by burning gasoline and diesel fuel”)

Overall biomass can be viewed a good method of reducing carbon dioxide emissions, even if you disagree with the neutrality assumption. But in the end, not producing emissions cannot be viewed as a positive externality. Rather, this is just a neutralizing factor. Accordingly we rate biomass at a 5.
Pollution

Natural Gas Results and Discussion

Table 7. Externalities related to pollution from natural gas.

<table>
<thead>
<tr>
<th>Externalities</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaks of CH₄</td>
<td>Nature of CH₄</td>
<td>In comparison to CO₂</td>
<td>-</td>
<td>EPA 2014</td>
</tr>
<tr>
<td></td>
<td>Annual global methane emissions due to oil and natural gas industry</td>
<td>Billion cubic meters of methane released</td>
<td>94 billion m³</td>
<td>SPE 2014</td>
</tr>
<tr>
<td>Environmental Consequences</td>
<td>Noise Pollution</td>
<td>Decibels</td>
<td>40-55 dBA</td>
<td>AMEC</td>
</tr>
<tr>
<td></td>
<td>Hydrology</td>
<td>Use of ground water</td>
<td>-</td>
<td>AMEC</td>
</tr>
<tr>
<td></td>
<td>Habitat Disturbance</td>
<td>Discussion</td>
<td>-</td>
<td>AMEC</td>
</tr>
<tr>
<td></td>
<td>Seismic Activity</td>
<td>Discussion</td>
<td>-</td>
<td>Spellman 4</td>
</tr>
<tr>
<td>Emissions</td>
<td>Carbon monoxide (CO)</td>
<td>Pounds of each GHG emitted per million BTU of energy consumed (lbs./MMBTU)</td>
<td>0.04</td>
<td>EIA 1999</td>
</tr>
<tr>
<td></td>
<td>Sulfur dioxide (SO₂)</td>
<td></td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nitrogen oxides (NOₓ)</td>
<td></td>
<td>0.092</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Particulates (PM)</td>
<td></td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Formaldehyde (CH₂O)</td>
<td></td>
<td>0.001</td>
<td></td>
</tr>
</tbody>
</table>

The externalities arising from the environmental impacts of natural gas are extensive. In addition, these externalities are often difficult to measure, since they differ depending on location and magnitude. Consequently many of these externalities are analyzed and discussed in the context of their environmental components and don’t have values to help define them. However, focus was given to externalities arising from natural gas production in Nova Scotia and New Brunswick, Canada, since most of the natural gas Bates consumes comes from this area of the world.

One of the most serious forms of pollution in the natural gas industry is the release the methane directly into the atmosphere. According to the Society of Petroleum Engineers (SPE),
over 94 billion cubic meters of natural gas is emitted annually by the oil and natural gas industry (2). This is roughly equivalent to $10-28 billion worth of natural gas (SPE 2). Not only is it a loss of profit, but the direct release of methane into the atmosphere is worse than the release of carbon dioxide, since it is a stronger greenhouse gas. Methane, over a 100 year period, has a climate impact twenty times that of carbon dioxide, since it can absorb more radiation, thereby retaining more heat in the atmosphere (EPA “Methane Emissions”). Methane emissions are especially prevalent in offshore production, making up one quarter of the methane emissions from the production sector (SPE 3). Offshore extraction platforms are miles away from the coast, making it difficult to get all of the natural gas to the market. Therefore the excess methane is flared, meaning it is continually combusted on the platform until there is room in the storage containers. Trapped gas, coming up from the well can also escape through cracks in the machinery (SPE 3). The release of methane into the atmosphere is a serious issue, because it is a potent greenhouse gas, increasing the environmental cost of natural gas.

Besides methane emissions, environmental degradation and disturbances result from the production process of natural gas. Based on the environmental impact assessment for Corridor Resources’ well exploration project, the major environmental impacts of production were noise pollution, hydrology, and habitat disturbance. Noise pollution occurs due to the running machinery and can reach up to 50 decibels during the day and 40 decibels at night (AMEC 48). This amount of noise can alter the behavior of migratory birds, species at risk, or campers trying to appreciate the recreational activities of the area. By altering the patterns of animals and tourists, local communities can be impacted. In addition, hydrology is a significant environmental concern, because hydraulic fracturing techniques need to use significant amounts of fresh water, draining local supplies and thereby affecting local communities. Environmental degradation is often the result of moving heavy equipment and trucks in rural areas. It can also occur with the accidental release of hazardous materials. The altered landscape makes it difficult for species to survive and it influences changes in their behavior (AMEC 42). Last, a controversial source of environmental degradation can be found in earthquakes caused by fracking. Although it is hard to directly link seismic activity to fracking, it has been found that in some areas without historical evidence of seismic activity, that there are now earthquakes after fracking has occurred (Spellman 4). Therefore natural gas exploration and extraction can have a long-lasting effect on local communities and natural areas, accumulating a large social and environmental cost.

Furthermore, natural gas emits other harmful gases besides greenhouse gases, adding to its environmental cost. Ideally, natural gas is pure methane that forms carbon dioxide when combusted. However, natural gas can contain impurities, which leads to unwanted emissions of other gases upon combustion (Spellman 28). Low levels of carbon monoxide, nitrogen oxides, sulfur dioxide, particulate matter, and formaldehyde can be released into the atmosphere (EIA “Natural Gas 1998”). Yet low levels of formaldehyde can cause respiratory ailments (Spiro 29).
The emission of harmful gases is certainly a negative externality to be internalized, however it is relatively minor compared to the environmental pollution during production.

Even though it is impossible to know the exact origin of natural gas at Bates, knowing that most of the natural gas in Maine comes from southeast Canada, suggests that externalities associated with onshore and offshore production must be considered in the true cost of fuel. Therefore taking into consideration methane leakages, the environmental consequences of production, including accidents, and the emission of harmful gases, natural gas has a high social cost in the category of pollution, earning a 2.

Biomass Results and Discussion

Table 8. Externalities related to pollution from biomass.

<table>
<thead>
<tr>
<th>Externalities</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Emitted Byproducts</td>
<td>Fly Ash</td>
<td>Tons per Year</td>
<td>200-250</td>
<td>Colby Biomass Plant</td>
</tr>
<tr>
<td>Maximum Emitted Byproducts</td>
<td>CO</td>
<td>Lbs. / MMBtu</td>
<td>0.15</td>
<td>Maine EPA</td>
</tr>
<tr>
<td></td>
<td>SO₂</td>
<td></td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NOₓ</td>
<td></td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td></td>
<td>0.017</td>
<td></td>
</tr>
</tbody>
</table>

When a log is burned over a fire, what is left in a solid state is ash. This is the carbon content of the log that was not rendered into CO₂ via the combustion process. A large-scale biomass gasification chamber works in a surprisingly similar way. An interview we held with Gus Libby, the project manager of Colby’s biomass plant, helped further clarify this waste disposal process (Libby).

After the biomass material is burned, ashen waste is created that needs to be disposed of. Two main technologies, which have been applied in the Middlebury and Colby biomass facilities, help facilitate this in a safe way. The first capture device used is called a cyclonic separator. It sends the flue gas, which is a product of biomass combustion, spinning around a cylinder, which allows for particulate matter to be caught along the sides of the cylinder. This device alone has been proven to sufficiently catch airborne particulates, but as a backup, some facilities also use an Electrostatic Precipitator, which uses magnetism to catch smaller particulates.

The combination of these two techniques means that smaller scale biomass facilities will capture nearly all of their ash before it is emitted into the surrounding air. The question then becomes what is to be done with this ash, which totals around 200-250 tons per year for Colby. Because of its high carbon-content, the ash can be given to agricultural amendment companies who can refine the ash into a fertilizer. If this connection cannot be made though, ash also can be
packaged and sent to landfills. This does not pose a particularly dangerous or costly threat though when considering the EPA’s environmental regulations for landfills (EPA “Landfills”)

The combustion of biomass leads to emissions of other gasses besides carbon dioxide. The other emissions that are most important to identify are Nitrous Oxides, Sulfur Dioxides, Carbon Monoxide, and Volatile Organic Compounds, all of which have been proven to lead to negative health effects (World Health Organization). Although because of the advanced emissions control techniques of gasification plants and the relatively clean nature of wood chips, these dangerous gasses kept at bay. Colby’s biomass plant, using Best Available Control Technologies (BACT) easily meets the emissions standards established by the Maine EPA (Colby College). These levels are listed as .025 lbs./MMBtu SO2, 0.25 lbs./MMBtu NOx, 0.15 lbs./MMBtu CO, and .017 lbs./MMBtu VOC. A plant at Bates can expect similar outcomes.

Other forms of pollution such as noise or visibility have been rendered insignificant relative to other fuels. Because of this, as well as the other effect discussed above, we rate biomass well at a 7.
### Publicity

**Natural Gas and Biomass Results and Discussion**

Table 9. Externalities related to natural gas and biomass publicity.

<table>
<thead>
<tr>
<th>Externalities</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results from Google Search: &quot;Colby College Biomass Gasification&quot;</td>
<td>General search</td>
<td>5900</td>
<td>Google</td>
<td></td>
</tr>
<tr>
<td>Results from Google Search: &quot;Middlebury College Biomass Gasification&quot;</td>
<td>General search</td>
<td>2760</td>
<td>Google</td>
<td></td>
</tr>
<tr>
<td>Results from Google Search: &quot;Colby College Biomass&quot;</td>
<td>&quot;Exact Words&quot; search</td>
<td>50</td>
<td>Google</td>
<td></td>
</tr>
<tr>
<td>Results from Google Search: &quot;Middlebury College Biomass&quot;</td>
<td>&quot;Exact Words&quot; search</td>
<td>65</td>
<td>Google</td>
<td></td>
</tr>
<tr>
<td>Results from Google Search: &quot;Colby College Biomass&quot;</td>
<td>&quot;News&quot; search</td>
<td>50</td>
<td>Google</td>
<td></td>
</tr>
<tr>
<td>Results from Google Search: &quot;Middlebury College Biomass&quot;</td>
<td>&quot;News&quot; search</td>
<td>214</td>
<td>Google</td>
<td></td>
</tr>
<tr>
<td>Maine newspaper mentions for the word &quot;biomass&quot;</td>
<td>Years 1994-2015</td>
<td>1,891</td>
<td>Maine Newsstand – Database of all newspapers in Maine</td>
<td></td>
</tr>
</tbody>
</table>

The above results illustrate the publicity that biomass has triggered. A major focus here will be the publicity that has been generated for Colby and Middlebury for their respective
biomass plants. The hypothesis is that both of these case studies will serve as illustrations for publicity effects that can be expected at Bates. The first results are from several different types of Google searches, the number of results of which are adequate proxies for Internet publicity. The first of these is a general search of “[College Name] Biomass gasification.” The gasification component is added to control for unwanted results. For Middlebury and Colby, this search returns 2760 and 5900 results respectively. The next two searches are for news results as well as pages with the exact wording, “[College Name] Biomass.” This returns a more precise list of pages related to biomass. Both of these searches generate over 50 results for both the colleges. From these results it is clear that their biomass plants generate significant amounts of publicity ranging from a variety of different sources.

In addition to Internet publicity, an additional search was completed within Maine newspapers. After doing a search of using the keyword “biomass,” it appears 1,891 times over the past 20 years (Maine Newsstand). Compared to other, similar searches regarding other energy sources, this number is quite low. We decided this is due to the more recent surge of biomass as an energy source. This is seen in our results regarding the years that had more publications on biomass.

What does all this mentioning amount to? The increased exposure received by Middlebury and Colby attract attention to the school for their environmental stewardship and ultimately help the school become more popular with to the public. With the vast amount of liberal arts colleges in the US, this differentiation factor can be important for the decision making process of college applicants.

Another important publicity effect that biomass could create for Bates relates to the climate action plan. The acquisition of a biomass plant and subsequent reduction in CO2 emissions is likely the only way that Bates would meet its pledge to become carbon neutral by 2020. If Bates were to reach this goal, it would certainly reflect well on the college and drive publicity. If Bates was not to reach this goal, it could reflect poorly on the college.

Considering all of these positive publicity effects, we rate Biomass as an 8 on our externality scale.

We did not decide to tabulate natural gas in terms of its publicity effects. This is due to the fact that the college currently uses natural gas and does not generate any publicity from this. The only effect that we could think of is the relationship between natural gas and hydraulic fracturing. This practice has generated negative publicity from environmental interest groups in the past. But it is unclear that Bates’ supply of natural gas contains gas that was extracted via fracking. Unitil, Bates’ natural gas provider would not reveal to us whether or not their pool of natural gas contained “fracked” gas. While it certainly could be assumed that this is in fact the case, this is an assumption that we did not want to make ourselves for the sake of accuracy.
Accordingly we could not comment on the potential negative attention Bates could receive from using “fracked” natural gas.

The ambiguous nature of natural gas’ publicity-related externalities led us to rate the fuel as a 5.

### Comparing Natural Gas and Biomass Ratings

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Price/MMBTU</th>
<th>Health and Safety</th>
<th>Local Economic Impact</th>
<th>GHG Emissions</th>
<th>Pollution</th>
<th>Publicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>$19</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Biomass</td>
<td>$8</td>
<td>4</td>
<td>8</td>
<td>5</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

*Table 10. Rankings for each categorical group of externalities, comparing natural gas and biomass.*

This table summarizes the individual rankings given to each fuel for each different externality category. For reminder: a ‘1’ represents high amounts of negative externalities or undesirable qualities, while a ‘10’ represents high amounts of positive externalities or desirable qualities. We see here that biomass scores higher in each and every category. Two sections that highlight particularly well the benefits of biomass over natural gas are publicity and local economic impact. Here biomass isn’t just neutral, but significantly positive. We recognize that the numbers represented here are incredibly subjective, and we want to be very open about this. These ratings are meant to be used in a very glancing way. Our community partners mentioned that the “Heating Fuel Comparison” spreadsheet that sparked this project was useful for its quick-reference capabilities. We created this rating system for this feature alone and not for its substantive weight. However, the visible trend that biomass has more positive externalities and negative externalities that are less objectionable than those of natural gas sets biomass apart as the more sustainable and cost-effective option when considering the true cost of energy.

### Outcomes and Implications

**Outcomes**

The purpose of this project was to determine the “true” cost of energy. Although Bates has traditionally been only concerned with dollar per unit energy values, we prove here that it is also crucial to consider the externalities associated with each energy source. When purchasing fuels on a massive scale like Bates does, paying attention to the sum of externalities has very real implications that could completely change a fuel’s attractiveness.
Our results suggest that of the two types of energy we focused on, natural gas had more negative externalities. Consequently, biomass has a much lower social cost. Of the five externalities we decided to focus on, to provide a well-rounded picture of each energy resource, biomass rated the best. Our methodology considered economic impacts, which are certainly important, but it also took into account less-measurable factors like safety and publicity. The goal here was to not only place numbers on seemingly obvious externalities, but to also highlight externalities that often go overlooked. Overall, we want to stress to Bates policymakers that biomass, as a heating fuel source for Bates, has a much lower external social cost than natural gas and should be considered for implementation. Biomass wood chips are currently cheaper than natural gas per MMBtu, but an expensive initial investment into infrastructural changes is required in order to use biomass. This means that a long payback period is needed to start earning a return on investment. We suggest here that the low social costs of biomass should make both the initial investment and long payback period worth it.

Implications

The implications of the research presented here are broader than just a recommendation to policy makers. A major theme that came from our findings is that oftentimes it is hard to put an exact price tag on a fuel’s externalities. In our case, we weren’t very successful at this. Even getting just a general sense of externalities was not an easy task. Our final recommendation for biomass is likely due to the fact that it was only being compared to one other fuel, and a very different fuel at that. What if our task was to compare Natural Gas and Oil? Or Biomass and Solar? Or all four? It is clear that this type of analysis becomes increasingly complex in non-ideal scenarios.

But at the same time, these challenges should by no means act as an inhibitor. Just because it may be hard to quantify something does not mean that it shouldn't be analyzed at all. Our project was in some ways the direct result of this assumption. While we couldn't find dollar amounts for externalities, we were able to find powerful information that could only be explained qualitatively. At an institution like Bates, it is important to be able to also accept this information in the same light as a price tag. This point speaks to a much larger context than just Bates and heating fuel. In a modern day global policy environment where an incredible amount of emphasis is placed on sophisticated and robust pricing models, it is important to consider that alongside every numerical narrative, there also exists a less-quantifiable narrative as well. We hope that the project presented here can help illustrate the harmony and disharmony that these two narratives create, as well as their significant role in energy policy decisions.
Next Steps

For Policy Makers

In the spring of 2014, an environmental consultant will come to Bates and evaluate the feasibility of installing a biomass gasification plant. This study will at once present new findings and confirm old ones.

We know that the current market for wood chips is able to supply one MMBtu of energy at a cheaper rate than any other readily available fuel. Bates would save money purchasing biomass energy. We also know that this purchasing can’t happen without the initial investment in a new gasification facility.

What we don’t know is the projection for how this pricing gap is going to look like in the future. The consultants in their study will be able to model these pricing trends and reveal a set of outcomes that will closely align with what the future may hold. These pricing models have important implications for the economic feasibility of biomass at Bates. In a hypothetical model where the price of wood chips rises 25% and the price of natural gas shrinks 25%, this will mean that the projected payoff to cover the costs of the facility could increase by several years. This is due to the high amounts of money Bates spends on energy each year.

Thus what would happen if the consultant group came back with a predicted scenario such as the one just presented? This is where the findings of our report may prove valuable. In this situation, policy makers at Bates will be tasked with deliberating over the option of biomass. They will see a projected payoff period upwards of a decade and might think that the college would be wise finding other areas to invest in.

Our findings might help keep biomass in the picture though. We recommend in the future that our report is made readily available during these times of important decision-making.

For further research

We came across much scientific controversy over some of our quantitative information, thus for future researchers on the topic of externalities, we recommend that current findings are constantly monitored. For instance, if the EPA as not carbon labels biomass in the next few years neutral, our final results would be swayed in a different direction.

Further down the road when research methods of environmental economists grow stronger, we also recommend that the original goal of this report be revisited. That is, we recommend that researchers go back and check the literature in externality valuation and see if accurate and transferable monetary estimates for various fuel types have been developed. While during the writing of this paper, scholars had not necessarily achieved this, in the next several years this being done is not unimaginable.
References Cited


Bangor Natural Gas. Telephone interview. 2 Dec. 2014.


<http://www.soep.com/cgi-bin/getpage?pageid=1/0/0>.


<http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6216a2.htm>.


Maine Natural Gas. Telephone interview. 2 Dec. 2014.


Summit Natural Gas. Telephone interview. 2 Dec. 2014.


Appendix A – Figures

Figure 2. The map shows the US states labeled according to their timberland percentage. Note Maine as the only state with greater than 85% timberland.

Figure 3. An illustration of the carbon cycle in relation to different fuel sources. On the left is a basic illustration of biogenic carbon or carbon generated via carbon neutral biomass. To the right is a basic illustration of the carbon generation process associated with fossil fuel use.
Figure 4. The chart, created by the IPCC, illustrates the societal and environmental impacts of climate change, through an increase in average global temperature.
Appendix B – Tables

Table 11. Heating Fuel Comparison.

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Unit Cost ($/gal)</th>
<th>Energy Content (Btu)</th>
<th>Cost per million Btu</th>
<th>Cost per delivered million Btu</th>
<th>Oil Equivalent Cost per gallon adjusted for Sys. Eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane</td>
<td>$2.80</td>
<td>91,000</td>
<td>$31</td>
<td>$34</td>
<td>$4.92</td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance</td>
<td>$0.130</td>
<td>3,413</td>
<td>$38</td>
<td>$38</td>
<td>$5.94</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>$0.130</td>
<td>3,413</td>
<td>$38</td>
<td>$38</td>
<td>$2.18</td>
</tr>
<tr>
<td>Wood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pellets/Bricks</td>
<td>$220.00</td>
<td>13,900,000</td>
<td>$17</td>
<td>$20</td>
<td>$2.92</td>
</tr>
<tr>
<td>Wood Chips</td>
<td>$60.00</td>
<td>10,300,000</td>
<td>$6</td>
<td>$5</td>
<td>$1.20</td>
</tr>
<tr>
<td>Wood shavings</td>
<td>$60.00</td>
<td>9,000,000</td>
<td>$4</td>
<td>$6</td>
<td>$0.80</td>
</tr>
<tr>
<td>Cord Wood</td>
<td>$260.00</td>
<td>16,800,000</td>
<td>$15</td>
<td>$23</td>
<td>$3.30</td>
</tr>
<tr>
<td>#2 Fuel Oil</td>
<td>$3.30</td>
<td>138,000</td>
<td>$24</td>
<td>$30</td>
<td>$4.30</td>
</tr>
<tr>
<td>Bio-diesel (B-100) *</td>
<td>$3.30</td>
<td>119,296</td>
<td>$28</td>
<td>$35</td>
<td>$5.02</td>
</tr>
<tr>
<td>Natural Gas (standard efficiency)</td>
<td>$1.53 per ccf</td>
<td>100,000</td>
<td>$15</td>
<td>$19</td>
<td>$2.75</td>
</tr>
<tr>
<td>Natural Gas (high efficiency)</td>
<td>$1.53 per ccf</td>
<td>100,000</td>
<td>$15</td>
<td>$17</td>
<td>$2.45</td>
</tr>
<tr>
<td>Central Plant Steam (Net. Gas)</td>
<td>$1.40 per ccf</td>
<td>100,000</td>
<td>$14</td>
<td>$19</td>
<td>$2.76</td>
</tr>
</tbody>
</table>

Note: Central Steam System Efficiency decreased by 10% for losses, distribution and steam/hotwater conversion.

* Cost of bio-diesel shown is a verbal quote from Maine Standard Biodiesel- based on 1 year contract.

This table was created by our community partner John Rasmussen and was used in meetings between Bates employees to quickly compare various fuels over their costs. The most informative column here is the “Cost per delivered million Btu,” as it controls for efficiency and energy content. Accordingly, it makes sense why Bates currently chooses natural gas for their heating needs. The goal of our project was to expand this spreadsheet to include an additional column that represents the dollar cost of externalities associated with each fuel, which could be used for more educated decision making. For reasons stated throughout this report, this exact column proved to be difficult to construct and thus as an alternative, we have created our externality rating system.

Table 12. Externality table template.

<table>
<thead>
<tr>
<th>Externality Type</th>
<th>Characteristics</th>
<th>Valuation</th>
<th>Data</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>The type of externality being considered</td>
<td>Further details</td>
<td>The unit of measurement, or way that the data is captured</td>
<td>The actual statistic/data</td>
<td>Where the information came from</td>
</tr>
</tbody>
</table>

This template shows the methodology behind the creation of tables seen in the results section.
Table 13. Combustion emissions of different fossil fuels in pounds per billion Btu.

<table>
<thead>
<tr>
<th>Air Pollutant</th>
<th>Natural Gas (lbs/BiBtu)</th>
<th>Oil (lbs/BiBtu)</th>
<th>Coal (lbs/BiBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>117,000</td>
<td>164,000</td>
<td>208,000</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>40</td>
<td>33</td>
<td>206</td>
</tr>
<tr>
<td>Nitrogen oxides (NOₓ)</td>
<td>92</td>
<td>448</td>
<td>457</td>
</tr>
<tr>
<td>Sulfur dioxide (SO₂)</td>
<td>0.6</td>
<td>1,122</td>
<td>2,591</td>
</tr>
<tr>
<td>Particulates (PM)</td>
<td>7.0</td>
<td>84</td>
<td>2,744</td>
</tr>
<tr>
<td>Formaldehyde (CH₂O)</td>
<td>0.750</td>
<td>0.220</td>
<td>0.221</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.000</td>
<td>0.007</td>
<td>0.016</td>
</tr>
</tbody>
</table>

The table was created by the United States Energy Information Administration and was used to compare natural gas emissions to other fossil fuel emissions.