Using Net-Zero Energy Projects to Enable Sustainable Economic Redevelopment at the Former Brunswick Air Naval Base

S. Huffman

Produced under direction of the Environmental Protection Agency by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-09-1752 and Task No WFD5.1001

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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NATIONAL RENEWABLE ENERGY LABORATORY

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Executive Summary

The Brunswick Naval Air Station is a naval air facility and Environmental Protection Agency (EPA) Super Fund site that is being cleaned up, and closed down. The State of Maine has established a new entity, the Midcoast Regional Redevelopment Authority (MRRA), to repurpose the property and over 100 buildings on the site. As part of this repurposing, MRRA has renamed the property Brunswick Landing, and under a contract through EPA asked the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) to do a comprehensive analysis of the property to look for renewable energy as well as sustainable economic redevelopment opportunities that could be used to redevelop the site. NREL analyzed eight different renewable energy technologies: solar photovoltaics (PV), solar domestic hot water heating (SDHW), solar ventilation preheating, wind, fuel cells, micro gas turbines, biomass combined heat and power (CHP), and geothermal heat pumps as well as opportunities for energy efficiency upgrades in the buildings and infrastructure.

The objective of this report is not only to look at the economics of individual renewable energy technologies, but also to look at the systemic benefits that can be gained when cost-effective renewable energy technologies are integrated with other systems and businesses in a community; thus multiplying the total monetary, employment, and quality-of-life benefits they can provide to a community. This also included looking for opportunities for industrial symbiosis which can be defined as the concept of using the waste from one process as a feedstock for another process; lowering "disposal" costs, and up-cycling the former "waste" into a value-added commodity.

The technology that offers the strongest combined economic opportunity is a CHP system; due to the abundant wood resources in the area, the system's quick payback, and the system's ability to be combined systemically with other micro-enterprises.

By utilizing the State of Maine's Community Based Renewable Energy Production Incentive Pilot Program,[1] the Midcoast Regional Redevelopment Authority (MRRA) can enter into a long-term agreement with the Maine public utility commission (PUC) and the local utility that ensures MRRA would be paid for their cost to generate the wood-powered electricity, plus a reasonable profit. This rate can go up to a maximum of $0.10/kilowatt hour (kWh) and contracts can be signed for up to 20 years. In addition, by leasing the power plant from a third party, MRRA could indirectly take advantage of significant federal tax incentives that would reduce the installed cost of the system. Calculations show that under a worst-case scenario, if MRRA installed a 2 megawatt (MW) wood-powered boiler and steam turbine to generate electrical power and installed a distribution pipeline system to distribute waste heat from the turbine to heat buildings (with no incentives for the pipeline), and if there were no building tenants to purchase the waste heat, the payback of the system would be 10 years. There are a number of ways in which the project could be structured. One of these scenarios would involve MRRA leasing the biomass CHP system for 10 years during which time MRRA would have $133,000/yr in positive cash flow (not counting any heat sales). This money could be put into escrow and at the end of the 10-year lease, the system could be bought by MRRA for fair market value of $2 million, which would be the amount that would have accumulated in escrow from the positive

[1] DSIRE. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME13F&re=1&ee=1. Accessed March 28, 2011.

cash flow over those 10 years. These paybacks are based on taking advantage of the Federal Production Tax Credit and the Modified Accelerated Cost Recovery System (MACRS) (Depreciation) with a bonus 50% the first year.

In addition, waste heat from the power plant can be leveraged in a number of ways to spur economic growth or to create new businesses. A fairly typical way to do this is to give away free heat to entice new tenants to sign leases. However, the heat could also be leveraged to pay for part of a tenant's building energy improvements when combined with tax incentives, thus increasing the impact of the long-term PUC/utility contract and the resulting waste-heat resource on the physical infrastructure of the property.

By combining a CHP system with other optional systems, the waste hot water and carbon dioxide coming from the wood power plant could be used to jumpstart a greenhouse industry growing local foods and providing jobs all winter long. Carbon dioxide from power plants is commonly used in Europe to accelerate the growth of greenhouse crops by at least 30%. The moist, heated air resulting from the wood chip drying process could be used for locally grown produce that could be cultivated year-round in greenhouse facilities.

This strategy ties in nicely with the large tourism and retiree industry in the Midcoast region and the burgeoning local and quality food movement. In addition, Bowdoin College also represents a huge potential bulk market and has committed themselves to supporting the purchase of local food. None of these large markets have local organic buying options during the winter season, which stretches for over 8 months of the year.[2]

Many additional optional business opportunities can be added around the main starting biomass CHP cluster, which generates electricity and heat for the buildings. These are proposed later in this report. An analysis of the full potential for the manufacturing sector is outside the scope of this report. However, many other symbiotic business opportunities will become available as additional businesses relocate in Brunswick Landing and as more information emerges about possible manufacturing processes, wastes, and feedstocks. It is recommended that this be investigated further in the future.

By taking advantage of a newly-created corporate structure named low-profit limited liability company (L3C), which allows a nonprofit to control a for-profit corporation as long as it has a social mission, this biomass CHP business, or the new businesses in Brunswick Landing's business incubator, could access new sources of capital that have not been traditionally accessible to start-up companies. In addition, Brunswick can take advantage of NREL's prescreening of DOE's holdings of clean-tech intellectual property to act as technology matchmaker with potential local entrepreneurs for future start-ups.

In addition, initial discussions with consultants who specialize in other tax incentives not related to renewable energy, such as New Market tax incentives, indicate that there is a high possibility that Brunswick Landing would qualify for these tax incentives for the projects proposed. These

[2] Preliminary cash flows based on standard greenhouse industry figures show that a high-density greenhouse growing lettuce has a simple payback of 2.4 years. Combining a greenhouse business with the installation of a CHP system gives Brunswick a customer for waste heat and revenue to offset the cost of the CHP system. The greenhouse could provide a revenue stream even if other buildings at Brunswick fill up slowly.

tax incentives would be in addition to the tax incentives already included in the financial calculations presented in this report.

Every site has different renewable resources. In addition to the biomass, we evaluated seven renewable technologies, of these, only solar ventilation preheating was found to be economically viable for large-scale deployment. Solar ventilation preheating was found to have a payback of approximately 7.4 years if done as a standalone project, and a payback of approximately two years if done during the upgrading of the facade of a building. State tax incentives and rebates would buy down the cost enough to allow a very small solar PV and a very small wind system to become economically viable for demonstration purposes, but not on a large scale at this time. Natural gas micro turbines were found to have a payback of 6.2 years, but this would require that 1 MW of capacity be installed at one time and that all of its waste heat be sold. This would be a challenge with the current low occupancy rate and uncertainty at Brunswick Landing. Selling only 50% of the heat would make the payback increase to 17 years.

The conclusion of this study finds that by combining an aggressive building energy efficiency retrofit program with a biomass CHP system, it appears that Brunswick Landing could become one of the first net-zero energy developments in the country.

We recommend MRRA proceed to a more detailed implementation analysis to determine the optimal mix of technologies, partner companies, and financing mechanisms that MRRA might utilize to implement a project.

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1 Introduction

1.1 Scope of Work

The U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) was asked by the Environmental Protection Agency (EPA) to analyze the Former Brunswick Naval Air Station (BNAS) in terms of the business opportunities available to revitalize the property utilizing renewable and sustainable technologies.

This analysis was performed as part of the RE-Powering America's Land initiative[3], a partnership between EPA and NREL to site renewable energy (RE) on potentially contaminated land or mine sites.

Eight different renewable energy technologies were analyzed in terms of their cost effectiveness: solar photovoltaics (PV), solar domestic hot water heating (SDHW), solar ventilation air preheating, wind, fuel cells, biomass combined heat and power (CHP), micro gas turbines, and geothermal (ground source heat pumps). In addition, NREL looked at strategies for incentivizing and implementing projects that would increase the energy efficiency of the buildings on the site as well as projects to utilize currently wasted local resources, such as waste heat and materials to create new opportunities for economic growth on the property and in the Brunswick area.

1.2 Study Location

BNAS is located at 43° 53' north latitude and 69° 55' west longitude. It experiences an average of 7,194 heating degree days per year and an average of 375 cooling degree days per year.

BNAS is one of Midcoast Maine's major employers, and is in the process of being closed and repurposed for private and public uses. This repurposing has the potential to create an economic hardship for the area. In addition, it was determined before closing the base that solvents present while the property was under the control of the Navy are now seeping into the ground aquifer. The EPA has instituted a remediation program, which pumps up water from the aquifer to the surface and treats it using mechanical air-stripping technology. The Navy will continue this remediation until traces of the solvent have been remediated.

The BNAS property is now under the management of the Midcoast Regional Redevelopment Authority (MRRA), a new non-profit entity created by the State of Maine. This redevelopment entity has also been dually chartered as a non-profit utility. Some of the property has been converted to various colleges, military services, and municipalities. The remaining property has been renamed Brunswick Landing and will be used for commercial development. The redevelopment authority is currently planning to reposition Brunswick Landing as a green development park, and the developers want to use renewable energy as the centerpiece theme around which the redevelopment of the property takes place. Currently, most of the buildings are empty. This also means that at this time there are very few long-term contracts with tenants or the accompanying long-term cash flow that goes with them. Based on these conditions, it would be preferable to propose a project that is not dependent on stable internal cash flow from long-term tenants, rent, or electrical or heating utility purchases. Given the limited cash flow, it would

[3] http://www.epa.gov/oswercpa/ Accessed Sept 18, 2011

also be preferable to propose a project that has a good chance of attracting an outside source of financing and a long-term revenue stream to help secure that financing. Most of the buildings on the base are old and not energy efficient and, therefore, will be relatively expensive to heat or cool over the long term.

2 Estimate of the Energy Consumption of the Existing Facilities

2.1 Analysis of Potential Energy Consumption on the Site

2.1.1 Energy Consumption Analysis Methodology and Assumptions and Limitations

Due to the sheer size and number of buildings on the base, and the limited budget of this study, there was no way to do an in-depth detailed energy study of each building. Even if there were the time and budget to do these studies as a part of this report, because the tenants, uses, and processes that go into these buildings are currently unknown, it is doubtful that it would be a wise expenditure at this time.

Therefore, we decided that a valuable strategy would be to build four different "template" building models based on the four general building type categories found on the base. These four different building types were modeled using e-Quest energy modeling software and were based on the most typical building skin configurations for each of the four different building types. The internal energy consumption used to model these building types was based on surveys of average energy consumption by buildings of similar types in the region. Ventilation rates were based on code requirements for each of the building types. These building templates were then used to estimate the energy demand and consumption of approximately 110 buildings on the site.

2.1.2 Limitations of these Estimates

It is important to note that these estimates were performed to get an idea of base load infrastructure needs, and are based on the typical consumption in buildings of these types. They should not be used to estimate the energy demand or consumption for any specific building. These estimates are general in nature and may not be accurate for particular buildings. Because almost all of the buildings on the base are currently empty, there is no way to estimate the types of processes they may have occurring in them. These estimates do not account for the energy consumption of any industrial machinery.

These estimates were used for macro-level (high-level) modeling of a hypothetical district heating pipeline and the potential loading that might occur on it during peak consumption periods. These models were also used to estimate the potential energy savings from performing energy efficiency retrofits on generic building types.

Energy savings retrofits and new equipment retrofit projects should perform their own detailed energy analysis of each building and should not rely on the estimates used for this high-level analysis.

This analysis found that if all the buildings on the property were occupied, they might have a peak heating demand somewhere in the range of 50-million Btu/hour and a peak electric demand of approximately 3.5 MW, not accounting for any specialized manufacturing equipment loads.

3 Renewable Energy and Energy Efficiency Screenings

All of the analyses were done with the assumption that these systems were being installed as retrofits to existing systems or services and that there was no avoided cost that could be claimed by the fact that existing equipment needed to be replaced anyway. In such cases, the total cost of the renewable energy systems would remain the same, but the payback might be calculated based only on the added incremental cost of the renewable energy system minus the cost of a new conventional system. This was calculated for the solar ventilation air preheating system.

In addition, there are numerous grant programs, both federal and state (Efficiency Maine specifically), that are indeterminate as to whether they might be awarded to the projects being analyzed. Therefore, while there is a great likelihood that a project done at Brunswick Landing might receive additional grants, these indeterminate incentives and their possible effects on paybacks were not calculated into any of these financial analyses.

3.1 Biomass CHP (Cogeneration)

3.1.1 Biomass CHP Technology Overview

When considering the generation of electricity using wood as a fuel, there are two basic technologies that can be used: steam turbines (shown in Figure 1) or internal combustion (IC).

3.1.2 Steam Turbines

Steam turbine technology has been around for many years and is very mature. It relies on high-pressure steam generated by a wood-fired boiler. It is this steam pressure moving from an area of higher pressure to an area of lower pressure that turns a turbine on a shaft connected to a generator. The steam forces its way past a series of turbine blades, and as it loses energy, the water condenses and is re-injected into the boiler. The condensation of the steam at the exit of the turbine system not only allows the steam to be liquefied so it can reenter the boiler, but it also creates a vacuum on the exit side of the turbines that exerts even more force on the blades.

3.1.2.1 Boilers

Before the steam can be created, the energy must be taken out of the wood fuel as efficiently as possible. Modern day wood steam boilers do not use cord wood like that used in a home fireplace. First, the wood is reduced in size so the heat can be better controlled. Moisture may also be removed so that it does not retain excess heat as it exits through the exhaust.

Next, the wood goes through one of two processes—either the wood size is further reduced into a powder and is burned in a normal steam-boiler heat exchanger, using a wood-powder burner instead of a liquid-fuel burner, or the wood is heated in a special sealed chamber known as a gasifier. Gasifiers are sealed, heated chambers where a process similar to pyrolysis takes place. During the gasification process, the structure of the wood breaks down and hydrogen and carbon monoxide gas, as well as some other gasses, are produced. From there, these gasses are moved to another chamber where oxygen is introduced in a controlled manner and the gasses combust. The heated products of combustion next move to the same type of heat exchanger used in other steam boilers, and the heat is transferred into water where it turns into steam.

3.1.3 Internal Combustion

The other main technology used for the creation of electricity around the world is the IC engine. One of the largest manufacturers of IC engines for this purpose is Jenbacher, an Austrian division of GE that uses natural gas as a fuel.[4] In recent years, their engines have rivaled fuel cells in efficiency, reaching up to 48% efficiency. Over a number of years in Europe, they have used the gas from coal gasifiers to fire IC engines to produce electricity. In the last few years, they have also started using the gas from wood gasifiers to do the same.

Running IC engines on wood gas is nothing new. Germans invented the process during World War II because of fears they would be cut off from Middle Eastern oil. Indian companies have been operating IC engine generators for years. Traditionally, one of the problems with using wood gas has been the forming of gaseous tars in the gasification process. There are two ways of dealing with these tars. In India, they run water through a counter-flow water spray column that condenses and washes the tars out of the gasses. Tests show long-term operation of such systems with no problems while meeting European Union (EU) air quality standards. This is an inexpensive way of dealing with these tars in India because there are no water pollution standards and the polluted water can be dumped. The second method typically used in the United States is the catalyst method, where a catalyst is used to “crack” the tar gasses down into more manageable gasses, which are burned in the engine cylinders. The gasification company currently partnering with Jenbacher (Nexterra) is now using both processes: the water method when there is an existing waste water treatment plant on site, and the catalyst method when there is not. In any case, both methods deal with the tars effectively.

There may be a number of other methods that could be explored that may be even more cost-effective than waste water treatment for dealing with the tar residues of the water method.

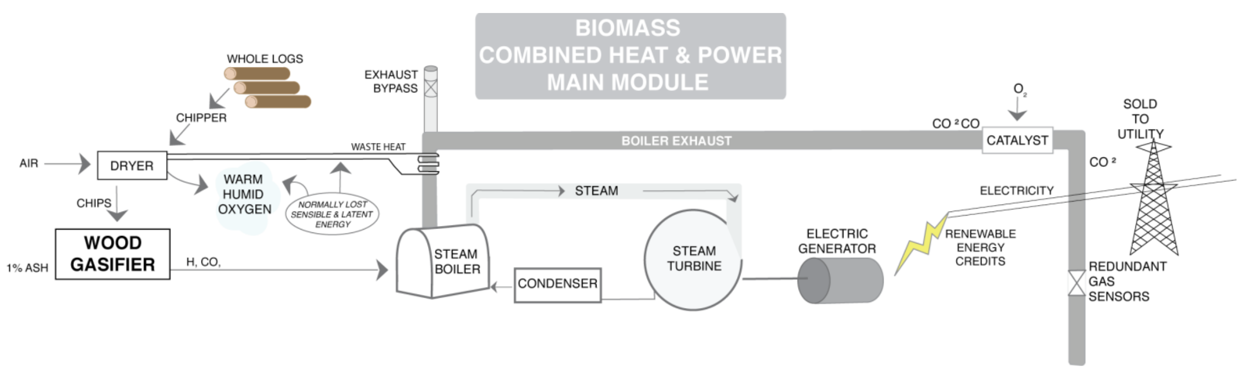

Figure 1. Biomass combined heat and power schematic. *Illustration by Colleen McCulla*

3.1.4 Pros and Cons of Each Technology

Steam turbine technology has been around for years and is the most mature of the technologies listed. However, its electrical efficiency is only in the range of 30%. This is the percentage of the total heat-energy contained in the original fuel, which is converted into electricity.

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[4] http://www.gepower.com/prod_serv/products/recip_engines/en/index.htm Accessed March 24, 2011.

IC engine technology is also very mature, having been around almost as long as steam turbines. IC engines are a technology that maintenance people typically feel comfortable with due to familiarity with automobile engines or diesel generators. However, these same maintenance people may not feel as comfortable with the wood gasifiers these IC engines would be tied to. IC engines can have an electrical efficiency of up to 48%, which is 60% higher than a steam turbine's 30% electrical efficiency. Potential issues seem to center around dealing with tars when they are not washed out with a water spray. While they can be dealt with using catalysts, these are expensive to replace when they wear out. This gasifier/IC engine system is currently only offered by one manufacturer alliance, Nexterra and Jenbacher, in the United States.[5]

Gasifiers are one of the most efficient ways of utilizing wood, and the only method of converting wood into gas for use in IC engines. Issues involve starting and stopping the gasifier quickly. From a cold start, the process often initially requires the use of a supplemental gas-fired burner to heat the gasification chamber. After the process is started, the fuel provides its own process heat. To modulate a gasifier, the unit is essentially sealed up so that no oxygen can enter the conversion chamber, and the conversion process slows until it stops. The project we are proposing would be operating continuously at a steady state, so stopping and starting should not be an issue.

Wood powder burner boilers are a technology first developed in Sweden by one of the largest manufacturers of marine boiler burners in the world. They are currently partnering in the United States with Babcock Wilcox,[6] who is guaranteeing their burners on projects where they are providing the boilers. While the technology is proven in Sweden, the drawback is that American buyers are not as familiar with this technology, so they tend to be less comfortable with it from a familiarity standpoint. The first projects are just now being installed in the United States (Jackson Labs located in Bar Harbor Maine[7]).

3.1.5 Additional Systems

All biomass systems have the potential to release particulate matter in the form of un-combusted carbon particles. These can be removed from the exhaust air stream in variety of ways, bag filters, electrostatic precipitators (approximately 90% efficient[8]), or reverse flow water spray scrubbers (virtually 100% effective). The last of these is the most effective in removing particulate matter from exhausts; however, there is an exhaust fan pressure drop penalty with any of these technologies as you go higher in efficiency.

3.1.6 Biomass Fuel

Any biomass project requires assurance that sufficient quantity of fuel will be available. Fortunately, Maine is a state with abundant forest resources. However, no resource is inexhaustible, especially if it is not properly managed and cared for by balancing use with propagation.

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[5] http://www.nexterra.ca/ Site accessed July 25, 2011
[6] Phone Conversation with Leo Dwyer U.S. Rep for PetroKraft
[7] http://www.jax.org/news/archives/2010/biomass_plant.html. Accessed March 24, 2011.
[8] http://www.isesp.org/ICESP%20X%20PAPERS/PDFS/Paper%206A4.pdf.

There is currently discussion linking the sustainability and carbon claims for biomass projects to how long it takes to re-grow the trees used as fuel[9] in these projects. Of course, this goes back to the conditions under which the trees are re-grown. Active and aggressive soil management is strongly recommended. In addition, minimizing the soil compacting impact of heavy timber harvesting equipment by only harvesting during hard ground freeze conditions or possibly substituting alternative harvesting methods such as cable or helicopter harvesting during warm months should be aggressively investigated.

For this analysis, we used a cost of fuel of $40/ton (conservative) for wet-chipped wood at 50% moisture chipped directly into containers to ensure clean chips without dirt or stones. The cleanliness of the fuels used for biomass projects invariably has a huge effect on the long-term viability of projects due to the problems it can cause with the equipment. Cheap, dirty fuel is no bargain if your burning chamber and equipment must be cleaned every few days or if its lifetime is cut in half.

An effective way of dealing with this issue is to develop a relationship with a property owner willing to partner with you by establishing a long-term purchasing contract and by utilizing advanced sustainable tree re-growth acceleration techniques for both partners' benefits. This ensures a long-term, stable-priced fuel supply with a sustainability pedigree that can easily be defended as requirements become increasingly stringent in the biomass world. It also ensures the forest-owner fixed, long-term yields and cash flow, which they can bring to a bank and use to obtain financing to purchase harvesting equipment.

One way of accomplishing this is may be to negotiate a long-term, fixed contract with the State of Maine Bureau of Purchasing. Initial discussions with the Maine Public Reserve Land Unit indicate that this may be a possibility.

Active, aggressive soil management in forests should be strongly investigated. This includes leaving limbs and branches in the forest and possibly inoculating them with native microbes to enhance the soil microbiological levels optimal for speedy tree re-growth. This might also include establishing defined log transport paths and handheld chainsaw cutting combined with cable system transport of logs to avoid soil-damaging compaction by heavy harvesting equipment, which limits the depth to which oxygen and root activity can penetrate.

One of the biggest potential problems in any biomass energy project is the cleanliness of the fuel used in the project. Wood chipped in the forest onto the ground and then loaded into trucks with backhoes can have dirt and stones scraped up with the chips in the process. Trees drug through the dirt and then chipped at another location without the removal of its bark can lead to the same issues. "Urban wood" reclaimed from construction or demolition projects have these issues of contaminants as well. Some gasification systems can accept biomass in a fairly "dirty" state and thus may give the operator the flexibility of using cheaper, more diverse fuel sources. With most gasification systems, when these non-organic, "dirty" substances enter a biomass system along with the wood, they can't be gasified, and will need to be removed from the system in one way or another. Depending on the type and temperature of the system, that may mean that workers

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[9]Walker, Cardellichio, Colnes, Gunn, Kittler, Perschel, Recchia, Saah "Biomass Sustainability and Carbon Policy." June 2010 Brunswick, ME: Manomet Center for Conservation Sciences Natural Capital Initiative.

need to shut down the system and get into the gasifier and chip slag out of the system once a week. In other, less fortunate situations, it may mean that the gasifier breaks down and stops operating. This emphasizes the importance of making sure biomass purchasers know the condition of the fuel they're purchasing and have acceptance tests in place to verify the cleanliness, moisture content, and ash content of the chips they are buying. In addition, it's important to have a back-up supply of wood. Without this, a plant operator may want to refuse a shipment of dirty fuel, but without a readily available clean substitute, the electrical generation system would be forced to be shut down to avoid damaging the system with a load of dirty fuel (possibly incurring stiff penalties on utility contracts).

3.1.7 Biomass CHP Technology Screening Methodology

For the purposes of this analysis project, cost estimates were made for each of the two technologies. Actual prices were obtained from some of the top manufacturers in the field. These prices were costed together with operations and maintenance (O&M) and fuel prices based on the efficiency and moisture content of the fuel proposed. These costs were loaded into a cash flow spreadsheet customized for this project with the specific financing mechanisms proposed, as well as the specific federal and local incentives applicable for these configurations. For this analysis, it is assumed that the heat would be sold to tenants at a 20% discount compared to the cost of heating with natural gas as an incentive for them to buy heat from MRRA and not use natural gas.

For the purposes of this costing estimate, a size of 2 MW wood-powered boiler and steam turbine, electrical-generating plant was initially selected.

3.1.8 Biomass CHP Screening Results

Calculations show that under a worst case scenario, a 2 MW wood-powered boiler and steam turbine, electrical-generating plant including a waste-heat distribution pipeline system with no incentives for the pipeline and no tenants to sell the heat to would have a system payback of 10 years. Economies of scale for larger sized plants in the 10 MW range indicate that installed cost savings in the 50% range per megawatt may be possible compared to costs of a 2 MW system. Projections show approximately the same payback for a biomass internal combustion system.

MRRA has the capacity to install a 15 MW system on the site based on the size of the incoming utility line. If an additional utility connection were possible, the MRRA could install up to 30 MW of power on site and still take advantage of the State of Maine Community-Based Renewable Energy Production Incentive Pilot Program.[10] According to the rough modeling done, the existing buildings on the campus could only use as much heat as a 6 MW steam power plant would produce. However, additional new ventures described later in this document might be able to consume much more heat.

3.1.9 Additional Potential Savings and Income

3.1.9.1 Buildings

Given the fact that one of the biggest assets in MRRA's possession at this time is a huge quantity of empty buildings, the calculations have not included any costs for constructing buildings to

[10] http://www.state.me.us/mpuc/electricity/community_pilot.shtml. Accessed March 24, 2011.

house the biomass power systems described above. This also holds true for the existing storage tanks. This may present an additional opportunity for this project depending on the tax and business structure selected for the project, as the buildings, including all of the areas used to house and store fuel for a project, are eligible for all of the same tax incentives (52.5% cost reduction) as the equipment itself. This might also hold true for the tanks if refurbished, insulated, and used as buffering tanks for the hot water distribution portion of the CHP system.

3.1.9.2 Renewable Energy Certificates

Additional opportunities for increased income from the project may come from selling renewable energy certificates (RECs) accrued by the project to Massachusetts, which has a higher level of stringency for biomass RECs but also pays higher prices. At this point, the project has been calculated using an actual quote based on Maine RECs obtained from one of the leading traders of RECs in the country.

3.2 Heat Distribution Pipeline to Buildings

An analysis of the payback for installing a pipeline to distribute heat to the buildings on the base was performed. For this analysis, it was assumed that all the buildings in one section of the base were occupied. This analysis utilized the heat-consumption estimates that were described previously in this section.

Using the buildings' winter heat-consumption estimates, a pipeline was mapped out and sized assuming the worst case scenario in terms of the heat-utilization ability of the equipment installed in the buildings. A hypothetical 10-inch (in) diameter pipeline, 2,555 feet (ft) long, was laid out along Orion Street. The pipeline is large enough to supply all of the buildings on the coldest day of the year. Installation of new pipe was estimated at $534/ft utilizing a European low-energy loss, twin-tube system with a stacked supply and a return line integral to each installed unit. Based on the estimated heat consumption of these buildings in an average year, it was found that installing a 10-in pipe would have approximately a 10-year payback with no incentives if all the buildings were purchasing heat.

The pipeline size is based on a worst case scenario that assumes heating for the coldest day of the year, and equipment with the lowest ability to utilize low-temperature heat installed in the buildings. There are other options that could be considered; the majority of the days of the year the ambient temperatures are within a certain range, which means the heat distribution system is sized to accommodate only a very few hours per year. An alternate strategy might be utilizing some of the boilers that already exist on the base to supply the heat in a few buildings on the coldest days of the year. This would allow optimizing the financial performance of the pipeline installed as well as unused, existing assets.

3.3 Storage Tanks (Old Fuel Tanks)

Another possible strategy might be to insulate the fuel tanks already on the base to serve as storage for hot water. Given the fact that they are already located next to one of the largest buildings on the base might allow the storage of hot water during off-peak times and utilize it during peak-heating times to reduce the size of the pipeline. The two tanks together could store enough water to heat one of the large hangers for 2-9 days depending on the type of equipment installed in the building.

Given the uncertainty of which building tenants will choose to locate in, it is the intent of this analysis to simply show an estimate of what a possible payback would be if a distribution network were installed in a fully occupied area of the base. It is outside the scope and granularity of this study to analyze all of the different potential layout configurations that might be possible to optimize the cost of a distribution network on the base.

3.4 Cooling

Depending on the type of wood power plant installed, it may be possible to distribute hot water at a temperature of around 200° Fahrenheit (F). If radiant heating systems were retrofitted in the buildings, it this would allow the pipeline to be reduced in size to approximately 6 in, due to the fact that you can keep on extracting heat from the water all the way down to 100° F, thus requiring less water to be distributed. 200° F water is also hot enough to operate small absorption chillers, the chillers could be used to cool buildings in the summer, providing additional ways to consume waste hot water during the summer months as well as in the winter.

3.5 Dehumidification and Drying

If 200° F water were distributed to the buildings, the water could be used to provide dehumidification, or process drying, with liquid desiccant systems. One of the big advantages of salt-based liquid desiccants is that they do not thermally degrade over time, such as when ice melts or hot water becomes lukewarm. This means they can be stored in simple plastic containers or plastic-lined steel containers (i.e., old fuel tanks) without any insulation. Storing liquid desiccant could be a cheap way of allowing a processor to store heat from one period of the day for use during another period of the day, when they have their peak production. This is basically another form of peak shaving—only using another form of energy to accomplish the same goal.

3.6 Energy Efficiency

Energy efficiency and good O&M is essential for any development claiming to deal with energy responsibly. There is a direct relationship between providing good O&M of equipment and the amount of energy saved over time. This is true of existing equipment as well as new equipment. Often, purchasers only look at the first cost and see the cost of maintaining equipment as a burden while forgetting the cost of the energy wasted in operation. Dollars invested in jobs to maintain equipment are almost always more than paid for by the energy savings they bring. In a very real sense, there is an opportunity to reclaim wasted energy dollars and turn them into good-paying maintenance jobs in the area.

All of the energy rating systems, which have been created in the last 10 years, acknowledge these realities and have different ways of dealing with them. There are a number of different ways in which MRRA can be responsible in dealing with this piece of their energy strategy, including:

1) Perform detailed energy audits and deep-energy retrofits on all buildings bundled as part of the lease.
2) Create programs that incentivize building owners to take advantage of tax credits and low- or no-interest loans to retrofit buildings before or after occupancy; this could be accomplished by using rebates and waste heat from the power plant to pay resident companies "in-swap" for heat to cover their building retrofit loan payments each month.

3) Create a volume-buying coalition for the area to lower the cost of purchasing high-cost items like high-tech energy saving windows.

4) Use these retrofit projects to jump start an energy retrofitting business willing to be located in Brunswick Landing.

5) Create a bundled maintenance service buying group for the companies in Brunswick Landing, which includes regularly scheduled maintenance of tenants' equipment.

6) Provide industry-specific customized energy efficiency design services for IT companies providing data warehousing.

3.7 NREL Assistance with Deep Building Retrofits and New Building Design

NREL can provide free assistance to MRRA and any of its tenants or property purchasers through the Department of Energy (DOE) Commercial Buildings Partnership. The program will provide state-of-the-art energy engineering and modeling services, and design assistance for all the buildings on military-type campuses, provided there is a commitment on the part of the controlling entity to deep retrofits (creating at least 30% energy savings) and high levels of energy efficiency in new buildings (50% savings compared to standard buildings).[11]

3.8 Energy Standards

Part of establishing any community is setting up boundaries that protect the citizens and their investments in the community. Whether building codes that establish safety standards and standards of best practice, zoning laws, or appearance standards that protect property values, standards are put into place to protect solid, long-term economics in a community.

Communities around the country are putting in place energy standards that protect the long-term economies in their communities and invest in their children's futures.

We recommend that Brunswick Landing establish an energy standard for the property that will address new construction as well as existing buildings. This will add-to and protect the green image that is built for the property, and prevent charges of green-washing from outside groups.

Any kind of standard or rule becomes much easier for tenants or builders to accept and follow if they feel like they are getting something for their trouble. In the past, utilities would provide rebates for customers to install energy saving equipment. In this case, rebates or waste heat produced by the wood-powered heating plant could be used to incentivize builders or new tenants to build or retrofit their properties up to high energy standards.

Each of these concepts on its own is not as effective as when operating together in a system. NREL is currently helping to develop a new, comprehensive energy standard for a new community being established on the redeveloped Barber's Point Air Naval Station, now renamed the community of Kalaeloa.[12] While the standard is not completed yet, and Brunswick Landing would need their standard to be customized for their climate, Brunswick's standard could be developed based on the work that has previously been done to develop Kalaeloa's standard.

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[11] http://www1.eere.energy.gov/buildings/commercial_initiative/building_partnerships.html Accessed March 24, 2011.

[12] http://www.hcdaweb.org/kalaeloa. Accessed March 24, 2011.

3.8.1 Examples of Progressive Building Codes and Resolutions for Future Codes

3.8.1.1 Colorado

The City of Boulder, Colorado, now requires all new homes to be 30% – 75% better than the 2006 International Energy Conservation Code (IECC). Boulder County went a step further by requiring homes over 5,000 ft^2 to achieve a home energy rating index of less than 10, which represents near zero-energy performance.

10-7.5-3 Mandatory Green Building Requirements

(a) Energy Efficiency. An applicant for a building permit for each new dwelling shall demonstrate that the building is more energy efficient than a building that meets the minimum requirements of Chapter 10-7, "International Energy Conservation and Insulation Code," B.R.C. 1981. Table 1 lists the minimum energy efficiency requirements.

TABLE 1 – Tiers for Energy Efficiency Thresholds

Type of Project	Square Footage	Energy Efficiency Thresholds Above Code
New Construction		
	Up to 3,000	30 percent more energy efficient than 2006 IECC
	3,001-5,000	50 percent more energy efficient than 2006 IECC
	5,001 and up	75 percent more energy efficient than 2006 IECC
Multi-unit Dwellings	Applies to all	30 percent more energy efficient than 2006 IECC*

* The city manager is authorized to develop a HERS rating sampling protocol for multi-dwelling projects to ensure compliance with this section.

Figure 2. City of Boulder, Colorado,[13] building requirements

3.8.1.2 California

The California PUC and the California Energy Commission have adopted a *Long Term Energy Efficiency Strategic Plan*[14] that requires all new homes to be zero energy by 2020 and all new commercial buildings to be zero energy by 2030.

3.8.1.3 Texas

3.8.1.3.1 City of Austin

"In February 15, 2007, the city council passed Resolution No. 20070215-23, the Austin Climate Protection Plan, calling for the drafting of new building codes consistent with reducing energy use in single-family homes by 65% and all other public and private buildings by 75% by 2015. The November 2006 version of the Austin Energy Code will serve as a reference."[15]

[13] http://www.bouldercolorado.gov/files/LEAD/Green%20Building/final_green_points_ordinance_7565.pdf. Accessed March 24, 2011.

[14] http://www.californiaenergyefficiency.com/index.shtml. Accessed March 24, 2011
http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EE+General+Info/eesp.htm. Accessed March 24, 2011.

[15] http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=TX19R&CurrentPageID=1&RE=1&EE=1. Accessed March 24, 2011.

3.8.1.3.2 City of Frisco

"The residential green building program began in 2001 under Ordinance No. 01-05-39, which required that all single-family residential structures platted after May 31, 2001 receive the EPA Energy Star designation for energy efficiency. The original ordinance was amended in 2006 with additional requirements for structures with building permits filed after June 30, 2007. These new structures are required to meet Energy Star specifications with a score of 83 or lower on the Home Energy Rating System (HERS) index. An Energy Star designation requires a HERS score of 85 or lower."[16]

Table 1. Comparison of Various Building Energy Designations and Green Sound-Bites

Metric	Benefits	Drawbacks	More Information
Net Zero Rating Systems: LEED, Green Globes, Energy Star	Can be defined for a building- or community-scale	Many definitions lead to confusion and no consensus regarding what is net zero	See document providing a variety of definitions for net zero; http://www.nrel.gov/docs/fy06osti/39833.pdf
	Many definitions increase the chance that there will be a good definition for a particular application	The role of RECs or green power purchases is often ambiguous and could counteract the good intentions associated with net-zero planning; it is important to define the role that RECs and green power purchasing should play in a net-zero application	
	Can be defined such that it includes indices beyond building energy use (such as transportation, water use, and embodied energy)Includes indices beyond building energy use (such as transportation and water use)	Well developed and used for building-scale, but relatively new for communities	LEED: http://www.usgbc.org/DisplayPage.aspx?CategoryID=19; Green Globes: http://www.greenglobes.com/; Energy Star: http://www.energystar.gov/index.cfm?c=business.bus_index

[16] http://www.ci.frisco.tx.us/departments/planningDevelopment/greenbuilding/Pages/ResidentialGreenBuilding.aspx. Accessed March 24, 2011.

	Rating system requirements (such as LEED-Silver) are becoming broadly adopted by industry, the government, and cities as a building standard	Some rating system certification levels are not very stringent, allowing entities to gain certification by implementing no or minimal energy reducing strategies	
Greenhouse Gas (GHG) Reduction Requirements	Can include indices beyond building energy use (such as transportation, water use, etc)	GHG accounting can be very time consuming There is currently no broadly accepted GHG accounting methodology	
Building Code Requirements	Very recognizable standard that all builders are familiar with	Building codes are only applicable to buildings and do not impact other indices (such as transportation and water use)	See examples above of progressive building codes throughout the United States
Embodied Energy/Life Cycle Assessment	Can include indices beyond building energy use (such as the energy use associated with the materials used in the construct of a building)	Calculating embodied energy can be very complex and time consuming	Embodied Energy: http://www.yourhome.gov.au/technical/fs52.html; Life Cycle Assessment: http://www.epa.gov/nrmrl/lcaccess/
International Energy Conservation Code	Encourages energy efficiency in building design	It could be hard to set reduction goals tied to embodied energy Relatively new standard	http://www.iccsafe.org/e/prodshow.html?prodid=3800S06

Other Factors		Building codes are only applicable to buildings and do not impact other indices (such as transportation and water use)	

3.9 Incentives

3.9.1 Federal Incentives for Biomass

1) The Federal Business Energy Investment Tax Credit[17] provides a tax credit for biomass energy systems based on the capital cost of the system in an amount equal to 30% of the purchase price. The federal business energy tax credit cannot be utilized if the renewable energy production tax credit (PTC) is utilized.

2) The Renewable Energy PTC[18] offers for-profit businesses a tax credit based on the amount of energy produced by a system over a number of years. It allows open-loop biomass generation systems (using non-managed forest wood) to take a tax credit of $0.011/kWh of electricity generated each year for 5 years. It allows closed-loop biomass systems (using biomass energy crops or managed forest wood) to claim $0.022/kWh for 10 years. Both types of systems must be put into service before 2013. The PTC cannot be utilized if the federal business energy tax credit is utilized. The U.S. Treasury Department Renewable Energy Grants,[19] otherwise known as the Treasury 1603 program, offers for-profit businesses an up-front payment equal to 30% of the capital cost of the system if significant portions of the funding have been committed before the end of 2011. It may be taken in lieu of either the renewable energy tax credit or the renewable energy PTC, but only through the end of 2011.

3) Modified Accelerated Cost Recovery System (MACRS)[20] allows businesses to recover investments in renewable energy equipment through depreciation deductions. Biomass energy systems can be depreciated over 5 years. If installed before the end of 2011, then 100% can be depreciated in the first year. Assuming a third-party for-profit owner of the system had an appetite for tax credits and assuming a 30% corporate tax rate, this would amount to a reduction in cost of approximately 22.5%. In 2012, only 50% can be depreciated in the first year.

[17] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1. Accessed March 24, 2011.
[18] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F&re=1&ee=1. Accessed March 24, 2011.
[19] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=1 Accessed March 24, 2011.
[20] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1 Accessed March 24, 2011.

4) The Renewable Energy Production Incentive (REPI)[21] is for non-profit electric generators and provides an incentive payment of up to $.022/kWh of electricity generated depending on the federal appropriation each year for up to 10 years.

5) The U.S. Department of Agriculture (USDA) Rural Energy for America Program (REAP) Grants and Loan Guarantees[22] can provide grants of up to 25% of the capital cost of a system and loan guarantees of up to $25 million. Biomass energy systems are eligible to apply for either grants or loans.

6) The New Era Rural Technology Competitive Grants Program (RTP)[23] (USDA-NIFA-RTP-003380) will make grants of up to $300,000 available to community colleges or advanced technological centers, located in a rural area, for technology development, applied research, and training necessary to produce graduates capable of strengthening the nation's technical, scientific, and professional workforce in the fields of bioenergy, pulp and paper manufacturing, and agriculture-based renewable energy resources.

7) In the past, the Biomass Crop Assistance Program (BCAP)[24] has provided federal funding directly to biomass producers. While it is not certain that funding will be forthcoming in 2011, there is a chance that the federal government's BCAP will be extended or modified. If this is the case, then this incentive, which is paid directly to biomass fuel producers, might exert downward pressure on the price of biomass fuel supplies and thus provide additional savings to a biomass project. This incentive has not been added into any of the calculations in this report.

3.9.2 State of Maine Incentives for Biomass

1) The Community-Based Renewable Energy Production Incentive (pilot program)[25] provides a generator two choices. The first option is to enter into a long-term contract with a local utility for the purchase of energy, capacity resources (peaking), or RECs at a price not to exceed $0.10/kWh for up to 20 years. This includes renewable electricity generation systems (including biomass) up to 30 MW in size. The program is very similar to pre-deregulation utility funding programs previously administered by the Maine PUC. The PUC requires the local utility to enter into a purchasing agreement with the generator at a price approved by the PUC as determined by a transparent look at the finances of the generator allowing for a "reasonable rate of return" on investment. The electric generator is permitted to sell the associated RECs and carbon credits separately from the electricity if the local utility has already met their state mandated renewable energy portfolio percentage requirement. The PUC is the entity that certifies RECs awarded to the project. As an alternative to a long-term contract, the generator may instead choose to have the RECs associated with their project multiplied by 150%.

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[21] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US33F&re=1&ee=1 Accessed March 24, 2011.
[22] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US05F&re=1&ee=1 Accessed March 24, 2011.
[23] http://www.grants.gov/search/search.do?mode=VIEW&oppId=58802 Accessed March 24, 2011.
[24] http://www.fsa.usda.gov/FSA/webapp?area=home&subject=ener&topic=bcap Accessed March 24, 2011.
[25] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME13F&re=1&ee=1http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME13F&re=1&ee=1 Accessed March 24, 2011.

2) Maine's Voluntary Renewable Resources Grants,[26] supported by the state's Voluntary Renewable Resources Fund and administered by the Maine PUC, provide funding for small-scale demonstration projects designed to educate communities on the value and cost effectiveness of renewable energy. Maine's Voluntary Renewable Resources Fund, a public benefits fund, was established in 2000 and is supported by contributions made by consumers on their electric bills. Applications for Voluntary Renewable Resources Grants are available only during specified application periods; funding is made available when a certain amount has been collected as a result of voluntary contributions. In addition, Efficiency Maine will make funds available from the American Recovery and Reinvestment Act (ARRA) to supplement this grant program.[27]

3) Grants up to $50,000 are generally available to Maine-based non-profit organizations (including community-based non-profits), electric cooperatives, quasi-municipal corporations and districts, schools, and community action programs. To qualify for grant funding, renewable energy resources generally (1) must qualify as a small, power-production facility under Federal Energy Regulatory Commission rules or (2) must not exceed 100 MW in capacity and use one or more of the following resources to generate electricity: fuel cells, tidal power, solar energy, wind energy, geothermal energy, hydropower, biomass energy, and municipal solid waste used in a generator in conjunction with recycling. There is a 20% cost-share requirement for grant funding.

4) Initial discussions with the Maine Public Reserve Land Unit indicate that since this is a state-initiated redevelopment project, it may be possible to negotiate a long term purchasing contract from the State Bureau of Purchasing. This will fully secure the fuel price for the life of the project and reduce the perceived risk for any potential financiers.

3.9.3 Federal Incentives for Pipeline

It is uncertain if these tax incentives can be utilized for leasing pipelines due to the fixed nature of pipelines. This should be further investigated with a tax specialist.

1) The Federal Business Energy Investment Tax Credit[28] provides a tax credit for CHP energy systems based on the capital cost of the system in an amount equal to 30% of the purchase price. The federal business energy tax credit cannot be utilized if the renewable energy PTC is utilized.

2) MACRS[29] allows businesses to recover investments in renewable energy equipment through depreciation deductions. Biomass energy systems can be depreciated over 5 years. If installed before the end of 2011, 100% can be depreciated in the first year. In 2012, only 50% can be depreciated in the first year.

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[26] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME03F&re=1&ee=1http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME03F&re=1&ee=1 Accessed March 24, 2011.

[27] http://www.maine.gov/mpuc/recovery/ Accessed March 24, 2011.

[28] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1

[29] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1

3.9.4 Federal Incentives for Energy Efficiency

The Federal Energy-Efficient Commercial Buildings Tax Deduction[30] of $1.80/ft^2 is available to owners of new or existing buildings who install (1) interior lighting, (2) building envelope, or (3) heating, cooling, ventilation, or hot water systems that reduce the building's total energy and power cost by 50% or more in comparison to a building meeting minimum requirements set by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2001. Energy savings must be calculated using qualified computer software approved by the Internal Revenue Service (IRS).

These deductions are available primarily to building owners, although tenants may be eligible if they make construction expenditures. Tenants could be given a grant and free heat for a predetermined length of time if they participate. [Possible scenario: Tenants might be given a low-interest loan from MRRA (or from Efficiency Maine), which is then used to install radiant floor heating systems (approximate cost $3/ft^2). These systems would conserve heat in large hangar buildings when the doors are opened. The tenant can pay off half the cost of the loan with their tax credit and the other half with their "free heat" provided by MRRA. This allows two incentives to work together. Half of the incentive comes from MRRA through a formerly wasted resource, which now drives efficiency, and the other comes from the tenant who uses their business tax credit.]

The USDA Rural Energy for America Program (REAP)[31] offers competitive grants to eligible entities to provide assistance to agricultural producers and rural small businesses to become more energy efficient and to use renewable energy technologies and resources. These grants are generally available to state government entities, local governments, tribal governments, land-grant colleges and universities, rural electric cooperatives and public power entities, and other entities, as determined by the USDA. These grants may be used for conducting and promoting energy audits and for providing recommendations and information related to energy efficiency and renewable energy. Of the total REAP funding available, approximately 9% is dedicated to competitive grants for energy technical assistance.

3.9.5 State of Maine Incentives for Energy Efficiency

For retrofit projects, the amount of the Efficiency Maine custom incentive may be up to 35% of the total cost of the efficiency project, including labor. For new construction and major renovations, as well as replacement of failed equipment, the incentive may be up to 75% of the incremental cost of high-efficiency equipment over standard equipment. The incentive cap applies in all cases. Efficiency Maine reserves the right to monitor and inspect subsidized installations and energy use of the products for which incentives are paid: refrigerators, lighting, chillers, heat pumps, central air conditioners, energy management systems/building controls, motors, and custom or other products pending approval. There is a maximum of $300,000/year in incentives.

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[30] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US40F&re=1&ee=1http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US40F&re=1&ee=1. Accessed March 24, 2011.

[31] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US05F&re=1&ee=1http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US05F&re=1&ee=1. Accessed March 24, 2011.

Efficiency Maine's small business low-interest loan program[32] provides loans of up to $35,000 at 1% interest to small businesses to support approved energy efficiency measures. Efficiency Maine, a program of the Maine PUC, administers this program with the assistance of the Finance Authority of Maine (FAME), who completes underwriting and credit rating. Businesses with less than $5 million in annual sales or less than 50 full-time employees are generally eligible.

[32] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME04F&re=1&ee=1. Accessed March 24, 2011.

4 Solar Photovoltaics

Solar photovoltaics (PV) are semiconductor devices that convert sunlight directly into electricity. They do so without any moving parts and without generating any noise or pollution. They must be mounted in an un-shaded location; rooftops, carports, and ground-mounted arrays are common mounting locations. The amount of energy produced by a panel depends on the several factors. These factors include the type of collector, tilt and azimuth of the collector, temperature, level of sunlight, and weather conditions. An inverter is required to convert the direct current (DC) to alternating current (AC) of the desired voltage compatible with building and utility power systems. The balance of the system consists of conductors/conduit, switches, disconnects, and fuses. Grid-connected PV systems feed power into the facility's electrical system and do not include batteries.

PV panels are made up of many individual cells that all produce a small amount of current and voltage. These individual cells are connected in series to produce a larger current.

4.1 Roof-Mounted Systems

In many cases, a roof is the best location for a PV system. Roof-mounted PV systems are usually more expensive than ground-mounted systems, but a roof is a convenient location because it is out of the way and is usually un-shaded. Large areas with minimal rooftop equipment are preferred, but equipment can sometimes be worked around if necessary. If a building has a sloped roof, a typical flush-mounted crystalline silicon panel can achieve power densities on the order of 11 DC-Watt/ft^2. For buildings with flat roofs, rack-mounted systems can achieve power densities on the order of 8 DC-Watt/ft^2 with a crystalline silicon panel. Typically, PV systems are installed on roofs that either are less than 5 years old or have over 30 years of life left. Because no roof area is available on the sites studied, no roof-mounted analysis was conducted.

4.1.1 PV System Components

The PV system considered here has these components:

1) PV arrays, which convert light energy to DC electricity
2) Inverters, which convert DC to AC, and provide important safety, monitoring, and control functions
3) Various wiring, mounting hardware, and combiner boxes
4) Monitoring equipment.

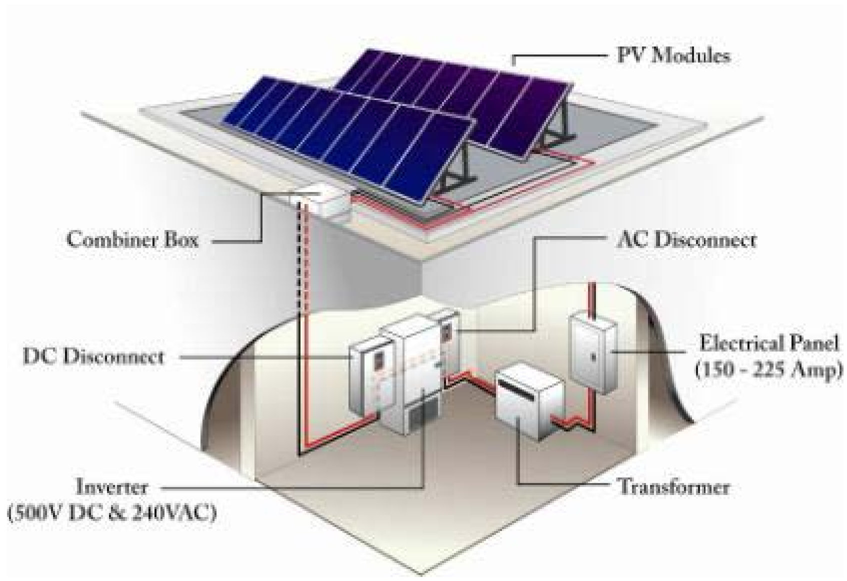

Figure 3. Major components of a grid-connected PV system. *Credit: NREL*

4.1.2 PV Array

The primary component of a PV system, the PV array, converts sunlight to electrical energy; all other components simply condition or control energy use. Most PV arrays consist of interconnected PV modules that range in size from 50 peak DC-Watts to 300 peak DC-Watts. Peak watts are the rated output of PV modules at standard operating conditions of 25°C (77°F) and insolation of 1,000 Watts/m². Because these standard operating conditions are nearly ideal, the actual output would be less under typical environmental conditions. PV modules are the most reliable components in any PV system. They have been engineered to withstand extreme temperatures, severe winds, and impacts. ASTM E1038-05[33] subjects modules to impacts from one-inch hail balls at terminal velocity (55 mph) at various parts of the module. PV modules have a life expectancy of 20-30 years, and manufacturers warranty them against power degradation for 25 years.

4.1.3 Inverters

PV arrays provide DC power at a voltage that depends on the configuration of the array. This power is converted to AC at the required voltage and number of phases by the inverter. Inverters enable the operation of commonly used equipment such as appliances, computers, office equipment, and motors. Current inverter technology provides true sine wave power at a quality often better than that of the serving utility. The locations of both the inverter and the balance-of-system equipment are important. Inverters are available that include most or all of the control systems required for operation, including some metering and data-logging capability. Inverters must provide several operational and safety functions for interconnection with the utility system. The Institute of Electrical and Electronic Engineers, Inc (IEEE) maintains standard *"P929 Recommended Practice for Utility Interface of Photovoltaic (PV) Systems,"* which allows manufacturers to write "Utility-Interactive" on the listing label if an inverter meets the

[33] ASTM Standard E1038, 2005, "Standard Test Method for Determining Resistance of Photovoltaic Modules to Hail by Impact with Propelled Ice Balls ," ASTM International, West Conshohocken, PA, 2005, DOI: 10.1520/E1038-05. http://www.astm.org/Standards/E1038.htm . Accessed March 24, 2011.

requirements of frequency and voltage limits, power quality, and non-islanding inverter testing. Underwriters Laboratory maintains "*UL Standard 1741, Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems,"* which incorporates the testing required by IEEE 929 and includes design (type) testing and production testing. A large choice of inverter manufacturers is available.[34]

4.1.4 Operation and Maintenance

The PV panels come with a 25-year performance warranty. The inverters, which come standard with a 5-year or 10-year warranty (extended warranties available), would be expected to last 10-15 years. System performance should be verified on a vendor-provided website. Wire and rack connections should be checked. For this economic analysis, an annual O&M cost of 0.17% of total installed cost is used based on the O&M cost of other fixed-tilt, grid-tied PV systems. For the case of single-axis tracking, an annual O&M cost of 0.35% of total installed cost is used based on existing single-axis tracking system O&M.

4.1.5 Photovoltaics Screening Methodology

For this analysis, a PV system cost of $4.50/W was established from costing data based on some of the most recent projects installed in the Northeast United States. Next, the solar radiation data for the installation site was used to calculate the electricity production during an average year at the site based on years of solar radiation data measurements taken. These calculations were made using the Hybrid Optimization Model for Electric Renewables (HOMER) calculation software (originally developed at NREL) and confirmed using NREL's Renewable Energy Optimization modeling software. These softwares base their calculations on comparing the solar radiation that would hit a panel tilted at an optimal 43° from horizontal in the specified geographic location over a 1-year period to the amount of solar radiation that would strike the same panel during a standardized rating test over an equivalent 1-year period. Based on this comparison of the radiation differences over a year, the program calculates the electrical output of the panel in kilowatt-hours based on the peak watt rating of the panel. The efficiency and the size of the panels are irrelevant in this calculation because the information is already inherently contained within the measurement of the panel by peak watt. The efficiency of the panel for these purposes only affects the size of the panel. Therefore, a peak watt of PV will be different in size depending on the efficiency of the panel. Either way, the quantity of energy produced per peak watt will be equally affected by the amount of sun available in the local site no matter the efficiency of the panel. The software assumes some system losses associated with wiring and inverters and assigns the system an overall efficiency of 80%.

The resulting quantity of electricity that HOMER calculated would be generated in Brunswick was next loaded into a life cycle analysis software program, which was customized to calculate the impact of all the specific federal and state financial incentives, which are available to provide financial assistance for this particular project.

[34] Go Solar California, a joint effort of the California Energy Commission and the California Public Utilities Commission, provides consumer information for solar energy systems. See http://www.gosolarcalifornia.org/equipment/pvmodule.php. Accessed March 24, 2011.

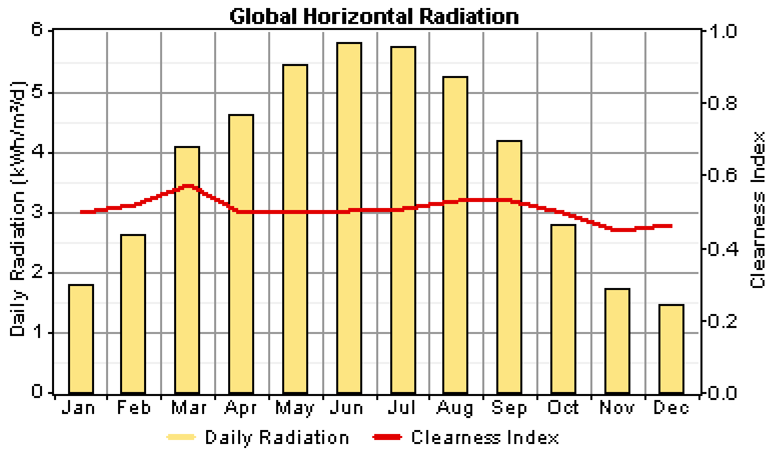

Figure 4. Graph of solar radiation and clearness index

Table 2. Solar Radiation and Clearness Index Data for Brunswick Maine

Month	Clearness Index	Daily Radiation ($kWh/m^2/day$)
January	0.498	1.780
February	0.521	2.610
March	0.572	4.070
April	0.496	4.620
May	0.497	5.430
June	0.501	5.810
July	0.510	5.730
August	0.530	5.240
September	0.531	4.170
October	0.498	2.800
November	0.447	1.740
December	0.467	1.470

4.1.6 Photovoltaics Screening Results

Due to the differences in solar radiation received in different parts of the world, the amount of electricity generated by PV panels varies significantly. The results of this screening show that even with significant state and federal incentives (in excess of over 52.5%), which "buy-down" the first cost of PV systems, the calculations on a large system of 100 kW results in a payback of approximately 16 years.

Table 3. Cost Effectiveness and Impact of Maine Incentive on PV

Size (kW)	Cost with Incentives ($)	Electricity Generated (kWh/year)	Income from kWh Generated ($)	Payback (years)
100	$211,750	132,324	$13,232	16
1	$138	1,323	$132	1*
1.5	$1,206	1,985	$199	6.1*
2	$2,275	2,646	$264	8.6*

*Since the state incentive is aimed at incentivizing smaller systems, when installing a smaller project, the state incentive has a proportionally larger impact on the payback. To illustrate this, notice that the 100 kW system has a payback of 16 years, but the 1 kW system has a payback of 1.04 years. As the system gets larger, the payback gets longer, so a 1.5 kW system has a payback of 6.1 years, and a 2 kW system has a payback of 8.6 years.

4.2 Incentives

4.2.1 Federal Incentives for Photovoltaics

1) The Federal Business Energy Investment Tax Credit[35] provides a tax credit for PV energy systems based on the capital cost of the system in an amount equal to 30% of the purchase price.

2) The U.S. Treasury Department Renewable Energy Grants,[36] otherwise known as the Treasury 1603 program, offers for-profit businesses an upfront payment equal to 30% of the capital cost of the system if significant portions of the funding have been committed before the end of 2011. It may be taken in lieu of either the renewable energy tax credit or the renewable energy PTC, but only through the end of 2011.

3) MACRS[37] allows businesses to recover investments in renewable energy equipment through depreciation deductions. PV energy systems can be depreciated over 5 years. If installed before the end of 2011, 100% can be depreciated in the first year. After this in 2012, only 50% can be depreciation in the first year.

4) REPI[38] is for non-profit electric generators and provides an incentive payment of up to $0.022/kWh of electricity generated depending on the federal appropriation each year for up to 10 years.

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[35] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1. Accessed March 24, 2011.

[36] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=1. Accessed March 24, 2011.

[37] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1. Accessed March 24, 2011.

[38] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US33F&re=1&ee=1 Accessed March 24, 2011.

5) REAP[39] can provide grants of up to 25% of the capital cost of a system and loans of up to $25 million. PV energy systems are eligible to apply for either grants or loans.

4.2.2 Regional Incentives for Photovoltaics

1) The Boston-based non-profit organization New Generation Energy[40] offers low-interest loans for the installation of solar electric and solar water heating systems via its Community Lending Program. The solar loans are available to companies (including sole-proprietorship) and non-profits in New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont) with an emphasis on those located in low- and middle-income communities. Loans are available for up to $100,000, and the interest rate is currently 5.0%; although, certain projects may be awarded grants and receive a lower interest rate. Only projects applying for loans are eligible for grants.

4.2.3 State of Maine Incentives for Photovoltaics

1) The Community-Based Renewable Energy Production Incentive (Pilot Program)[41] provides a generator two choices. The first option is to enter into a long-term contract with a local utility for the purchase of either energy, capacity resources (peaking), or RECs at a price not to exceed $0.10/kWh for up to 20 years. This includes renewable electricity generation systems (including PV) up to 30 MW in size. The program is very similar to pre-deregulation utility funding programs previously administered by the Maine PUC. The PUC requires the local utility to enter into a purchasing agreement with the generator at a price approved by the PUC as determined by a transparent look at the finances of the generator allowing for a "reasonable rate of return" on investment. The electric generator is permitted to sell the associated RECs and carbon credits separately from the electricity if the local utility has already met their state mandated renewable energy portfolio percentage requirement. The PUC is the entity that certifies RECs awarded to the project. As an alternative to a long-term contract, the generator may instead choose to have the RECs associated with their project multiplied by 150%.

2) The State of Maine Solar Rebate Program[42] provides a rebate of 25% of the cost of a solar PV system or $1,000, whichever is less. It is funded by an assessment on the state's transmission and distribution utilities. A total of $500,000 in funding will be available for rebates annually. Of this sum, the PUC has allocated 60% to rebates for solar-thermal systems, 20% to rebates for PV systems, and 20% to rebates for wind-energy systems. During fiscal years 2009-2010 and 2010-2011, this rebate program is increased by $500,000/year with money allocated from ARRA.

3) Maine's Voluntary Renewable Resources Grants,[43] supported by the state's Voluntary Renewable Resources Fund and administered by the Maine PUC, provide funding for small-

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[39] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US05F&re=1&ee=1 Accessed March 24, 2011.
[40] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME14F&re=1&ee=1. Accessed March 24, 2011.
[41] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME13F&re=1&ee=1 Accessed March 24, 2011.
[42] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME08F&re=1&ee=1 Accessed March 24, 2011.
[43] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME03F&re=1&ee=1 Accessed March 24, 2011.

scale demonstration projects designed to educate communities on the value and cost effectiveness of renewable energy. Maine's Voluntary Renewable Resources Fund, a public benefits fund, was established in 2000 and is supported by contributions made by consumers on their electric bills. Applications for Voluntary Renewable Resources Grants are available only during specified application periods; funding is made available when a certain amount has been collected as a result of voluntary contributions. In addition, Efficiency Maine will make funds available from ARRA to supplement this grant program.[44]

> Grants of up to $50,000 are generally available to Maine-based non-profit organizations (including community-based non-profits), electric cooperatives, quasi-municipal corporations and districts, schools, and community action programs. To qualify for grant funding, renewable energy resources generally must (1) qualify as a small power production facility under Federal Energy Regulatory Commission rules or (2) not exceed 100 MW in capacity and use one or more of the following resources to generate electricity: fuel cells, tidal power, solar energy, wind energy, geothermal energy, hydropower, biomass energy, and municipal solid waste used in a generator in conjunction with recycling. There is a 20% cost-share requirement for grant funding.

[44] http://www.maine.gov/mpuc/recovery/. Accessed March 24, 2011.

5 Solar Domestic Water Heating

5.1 Solar Domestic Hot Water Technology Overview

Solar domestic hot water (SDHW) heating systems transform the radiation coming from the sun into heat energy that then heats domestic hot water normally used for showers, hand washing, or cooking. These systems normally include an insulated storage tank that stores water for use during times when the sun is not shining. The most common types of systems are flat plates bonded to pipes (fin tubes) through which a liquid flows. These fin tubes are contained either within an insulated box with a glass front or within vacuum-encapsulated glass cylinders that look somewhat like large diameter clear fluorescent light bulb tubes. The fin tubes typically have a black selective surface plated on them, which reduces the amount of heat that they lose by re-radiation once they heat up. The fin tubes are connected together in groups by tubular headers connecting them at the top and the bottom so that water can enter the tubes at one end and leave at the other end. There are a number of strategies to prevent freezing in cold climates, but the two most successful and common are to either run antifreeze in the collector, or run water in the collector and drain it out when there is not sufficient heat produced to keep the collector from freezing. Both strategies use a heat exchanger to transfer the heat from the fluid flowing through the collector into the water in your domestic hot water system and storage tank. The use of a double-walled heat exchanger is often required by code to prevent the contamination of domestic water by either the antifreeze or non-potable water running through the collectors. Antifreeze has a 50% lower heat transfer capacity than water, which means that for the same size collector you may not be able to collect as much heat. Antifreeze systems are pressurized and therefore should include expansion tanks, pressure relief valves, flush and fill valves, and controls. Drain-back systems are not pressurized and so require some additional energy for pumping compared to a pressurized system and should also include flush and fill valves and controls. SDHW systems are typically sized to provide 40% - 70% of domestic water heating requirements. The conventional hot water heating system or an instantaneous hot water heater is often used as a back-up or boost to the solar system.

5.2 Solar Domestic Hot Water Screening Methodology

The analysis for this technology was performed using NREL's Renewable Energy Optimization software program. The program calculated the energy savings that could be expected using the average yearly daily solar radiation data for this geographic location obtained from NREL's GIS National Solar Resource Database. The system savings were calculated assuming system panels were installed at a fixed slope of 43° from horizontal, which is the optimal angle of installation at this latitude. The results of this analysis calculated the energy saved by the system as well as the projected first cost and yearly O&M costs. These were next loaded into a spreadsheet customized with the state and federal incentives that apply for this technology.

5.3 Solar Domestic Hot Water Screening Results

The payback on this system was calculated to be 36.8 years. While it is not uncommon for a well-designed SDHW system to operate over a lifetime of 40 years, this high payback time is bound to make some question the wisdom of installing such a system. Something to keep in mind, however, is the fact that the current low costs of natural gas may not last forever.

Low natural gas prices are affecting electric generation prices as well; if this system were replacing an electric hot water heating system, the payback would be approximately 8.5 years. If this system were replacing an electric hot water system with rates similar to those being incentivized by the Community-Based Renewable Energy Production Incentive ($0.10/kWh, which is more in line with previous northeastern rates), the payback would be approximately 6 years.

Figure 5. Flat plate (boxed) solar domestic hot water heating system for showers and laundry at Chickasaw National Recreation Area in Oklahoma. *Credit: Andy Walker, NREL*

5.4 Incentives

5.4.1 Federal Incentives for Solar Domestic Hot Water

1) The Federal Business Energy Investment Tax Credit[45] provides a tax credit for SDHW systems based on the capital cost of the system in an amount equal to 30% of the purchase price.
2) The U.S. Treasury Department Renewable Energy Grants,[46] otherwise known as the Treasury 1603 program, offers for-profit businesses an upfront payment equal to 30% of the capital cost of the system if significant portions of the funding have been committed before the end of 2011. It may be taken in lieu of either the renewable energy tax credit or the renewable energy production tax credit but only through the end of 2011.
3) MACRS[47] allows businesses to recover investments in renewable energy equipment through depreciation deductions. SDHW systems can be depreciated over 5 years. If installed before the end of 2011, 100% can be depreciated in the first year. In 2012, only 50% can be depreciated in the first year.

[45] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1. Accessed March 24, 2011.
[46] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=1. Accessed March 24, 2011.
[47] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1. Accessed March 24, 2011.

4) REAP[48] can provide grants of up to 25% of the capital cost of a system and loans of up to $25 million. SDHW systems are eligible to apply for either grants or loans.

5.4.2 Regional Incentives for Solar Domestic Hot Water

1) The Boston-based non-profit organization New Generation Energy[49] offers low-interest loans for the installation of solar electric and solar water heating systems via its Community Lending Program. The solar loans are available to companies (including sole-proprietorship) and non-profits in New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont), with an emphasis on those located in low- and middle-income communities. Loans are available for up to $100,000, and the interest rate is currently 5.0%; although, certain projects may be awarded grants and receive a lower interest rate. Only projects applying for loans are eligible for grants.

5.4.3 State of Maine Incentives for Solar Domestic Hot Water

1) The State of Maine Solar Rebate Program[50] provides a rebate of 25% of the cost of a solar-thermal system or $1,000, whichever is less. It is funded by an assessment on the state's transmission and distribution utilities. A total of $500,000 in funding will be available for rebates annually. Of this sum, the PUC has allocated 60% to rebates for solar-thermal systems, 20% to rebates for PV systems, and 20% to rebates for wind-energy systems. During fiscal years 2009-2010 and 2010-2011, this rebate program is increased by $500,000/year with money allocated from ARRA.

[48] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US05F&re=1&ee=1. Accessed March 24, 2011.

[49] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME14F&re=1&ee=1. Accessed March 24, 2011.

[50] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME08F&re=1&ee=1. Accessed March 24, 2011.

6 Solar Preheating of Ventilation Air

6.1 Solar Vent Preheat Technology Overview

All commercial buildings are required by code to bring in a certain amount of outside ventilation air into the building when occupied to provide oxygen and to exhaust indoor air pollution. During the winter, this air can be preheated by drawing the air through vertical perforated metal south-facing exterior wall panels that are heated by the sun. These unobtrusive wall panels look very much like metal siding and can be retrofitted on to the south-facing walls of a building and actually improve the exterior appearance of the building. At the same time, any heat lost through that south facing wall is sucked back into the building along with the preheated ventilation air as it passes across the surface, thus eliminating any heat loss from that south wall during the daytime hours.

6.2 Solar Vent Preheat Screening Methodology

The analysis for this technology was performed using NREL's Renewable Energy Optimization software program. Average yearly daily solar radiation data for the location was obtained from NREL's GIS National Solar Resource Database. The results of this analysis provided the energy saved by the system as well as the projected first cost and yearly O&M costs. These were next loaded into a spreadsheet customized with the state and federal incentives that apply specifically for this technology.

6.3 Solar Vent Preheat Screening Results

Screening results find a payback of approximately 7.4 years when doing standalone projects and approximately two years when done as part of a remodeling of the building façade. Under this remodeling scenario, the panels would be installed as part of a project to re-skin the south side of the building and the solar air heating system would be used instead of an alternate siding material. A conservative allowance of $5/ft^2 of wall area was subtracted from the cost of the solar system due to the fact that an alternate siding product would not need to be added to that portion of the building to improve its appearance.

6.4 Incentives

6.4.1 Federal Incentives for Solar Ventilation Air Preheating Systems

1) The Federal Business Energy Investment Tax Credit[51] provides a tax credit for solar ventilation air preheating systems based on the capital cost of the system in an amount equal to 30% of the purchase price.

2) The U.S. Treasury Department Renewable Energy Grants,[52] otherwise known as the Treasury 1603 program, offers for-profit businesses an upfront payment equal to 30% of the capital cost of the system if significant portions of the funding have been committed before the end of 2011. It may be taken in lieu of either the renewable energy tax credit or the renewable energy PTC but only through the end of 2011.

[51] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1. Accessed March 24, 2011.

[52] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=1. Accessed March 24, 2011.

3) MACRS[53] allows businesses to recover investments in renewable energy equipment through depreciation deductions. Solar ventilation air pre-heating systems can depreciate over 5 years. If installed before the end of 2011, 100% can be depreciated in the first year. In 2012, only 50% can be depreciated in the first year.

4) REAP[54] can provide grants of up to 25% of the capital cost of a system and loans of up to $25 million. Solar ventilation air pre-heating systems are eligible to apply for either grants or loans.

6.4.2 State of Maine Incentives for Solar Ventilation Air Preheating Systems

1) The State of Maine Solar Rebate Program[55] provides a rebate of 25% of the cost of a solar-thermal system or $1,000, whichever is less. It is funded by an assessment on the state's transmission and distribution utilities. A total of $500,000 in funding will be available for rebates annually. Of this sum, the PUC has allocated 60% to rebates for solar-thermal systems, 20% to rebates for PV systems, and 20% to rebates for wind-energy systems. During fiscal years 2009-2010 and 2010-2011, this rebate program is increased by $500,000/year with money allocated from ARRA.

[53] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1. Accessed March 24, 2011.
[54] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US05F&re=1&ee=1. Accessed March 24, 2011.
[55] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME08F&re=1&ee=1. Accessed March 24, 2011.

7 Wind Turbines

7.1 Wind Technology Overview

Wind turbines transform the kinetic energy in the wind into electrical energy by turning turbine blades connected to the shaft of a generator, which produces electricity when rotated. These machines are generally classified into two different categories: horizontal axis and vertical axis machines. No matter what the category, the critical factors determining how cost effective an installation will be are the wind resources available in an area (wind speed and variability), and access to a transmission line to transport the power to a location where it can be used. The power produced by a wind turbine goes up exponentially as wind speed increases. If the wind speeds are too low, it will hurt the project's electricity generation.

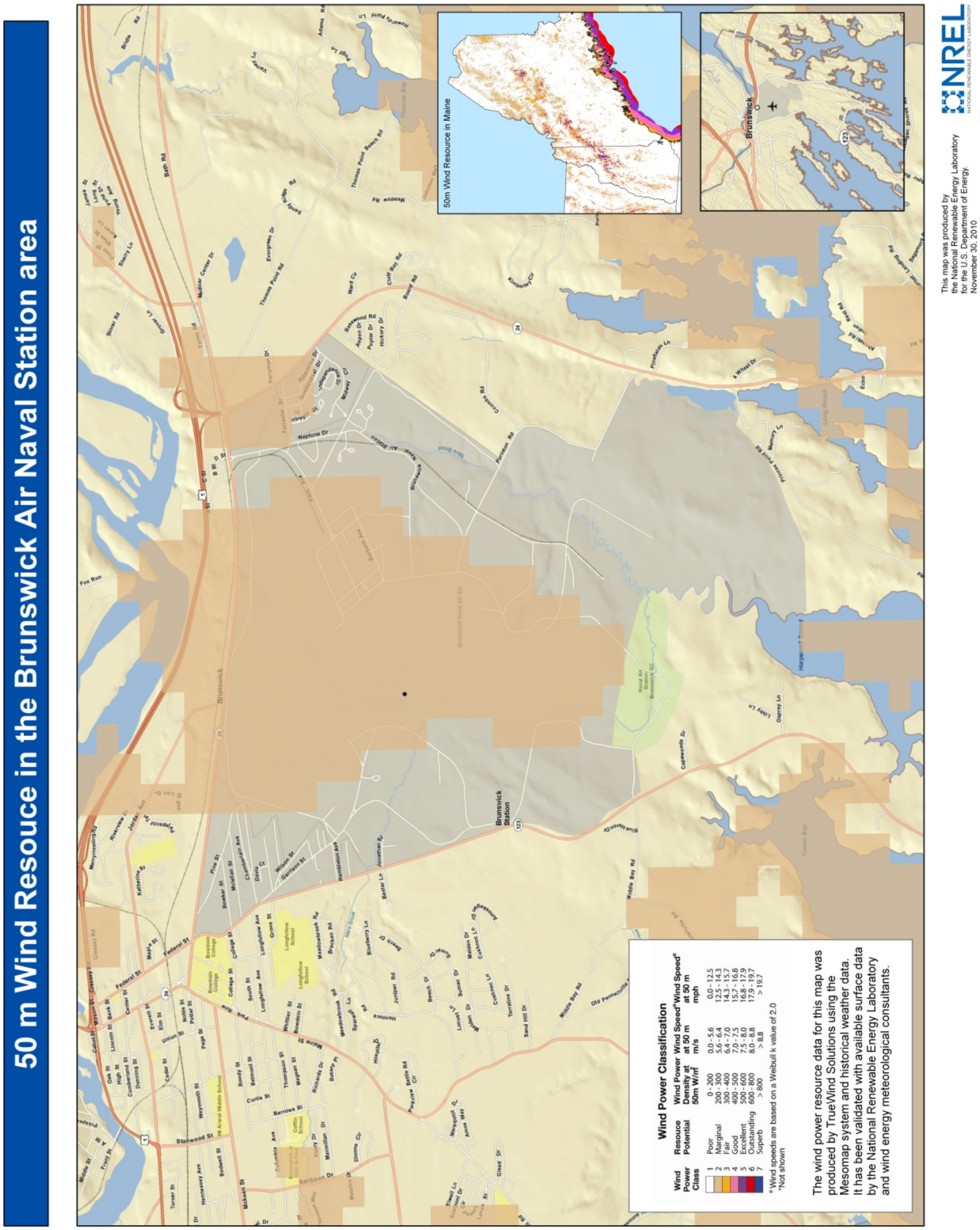

Figure 6. Brunswick Naval Air Station wind resources map

7.2 Wind Screening Methodology

Wind data for the BNAS was obtained from the NREL National Wind Database and loaded into the NREL Renewable Energy Optimization software program, which used this data to calculate the energy that could be produced at the site along with the projected cost of the wind energy system that could be installed at the site. This data was next loaded into a spreadsheet program customized with the specific local and federal incentives that are applicable to this location.

7.3 Wind Screening Results

As shown in Figure 6, the wind resources on the Brunswick Landing property are rated as "marginal," which might not be surprising since they are located at an airport. You can see from the inset map of the state that wind resources just off-shore from Brunswick are extremely good and probably a much better site for investment of resources in capturing wind energy than Brunswick Landing. Based on our calculations for this site, the paybacks for wind energy systems from 100 kW down to 10 kW, even with heavy subsidy, are in the range of 15 years. The payback on smaller systems of around 3 kW in size were skewed lower to about 8.8 years due to the State of Maine wind rebates, which provide a maximum of $1/W up to a maximum of 4 kW.

7.4 Incentives

7.4.1 Federal Incentives for Wind Energy Systems

1) The Federal Business Energy Investment Tax Credit[56] provides a tax credit for wind energy systems based on the capital cost of the system in an amount equal to 30% of the purchase price.

2) The renewable energy PTC[57] offers for-profit businesses a tax credit based on the amount of energy produced by a system and it is taken over a number of years. It allows wind energy systems to take a tax credit of $0.022/kWh of electricity generated each year for 10 years. Systems must be put into service before 2013.

3) The U.S. Treasury Department Renewable Energy Grants,[58] otherwise known as the Treasury 1603 program, offers for-profit businesses an upfront payment equal to 30% of the capital cost of the system if significant portions of the funding have been committed before the end of 2011. It may be taken in lieu of either the renewable energy tax credit or the renewable energy PTC but only through the end of 2011.

4) MACRS[59] allows businesses to recover investments in renewable energy equipment through depreciation deductions. Wind energy systems can be depreciated over 5 years. If installed before the end of 2011, 100% can be depreciated in the first year. In 2012, only 50% can be depreciated in the first year.

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[56] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1. Accessed March 24, 2011.

[57] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F&re=1&ee=1. Accessed March 24, 2011.

[58] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=1. Accessed March 24, 2011.

[59] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1. Accessed March 24, 2011.

5) REPI[60] is for non-profit electric generators and provides an incentive payment of up to $0.022/kWh of electricity generated depending on the federal appropriation each year for up to 10 years.

6) REAP[61] grants and loan guarantees can provide grants of up to 25% of the capital cost of a system and loans of up to $25 million. Wind energy systems are eligible to apply for either grants or loans.

7.4.2 State of Maine Incentives for Wind Energy Systems

1) The Community-Based Renewable Energy Production Incentive (Pilot Program)[62] provides a generator two choices. The first option is to enter into a long-term contract with a local utility for the purchase of either energy, capacity resources (peaking), or RECs at a price not to exceed $0.10/kWh for up to 20 years. This includes renewable electricity generation systems (including wind) up to 30 MW in size. The program is very similar to pre-deregulation utility funding programs previously administered by the Maine PUC. The PUC requires the local utility to enter into a purchasing agreement with the generator at a price approved by the PUC as determined by a transparent look at the finances of the generator allowing for a reasonable rate of return on investment. The electric generator is permitted to sell the associated RECs and carbon credits separately from the electricity if the local utility has already met their state mandated renewable energy portfolio percentage requirement. The PUC is the entity that certifies RECs awarded to the project. As an alternative to a long-term contract, the generator may instead choose to have the RECs associated with their project multiplied by 150%.

2) The State of Maine Wind Rebate Program[63] provides a rebate of 25% of the cost of a wind energy system or $1,000, whichever is less. It is funded by an assessment on the state's transmission and distribution utilities. A total of $500,000 in funding will be available for rebates annually. Of this sum, the PUC has allocated 60% to rebates for solar-thermal systems, 20% to rebates for PV systems, and 20% to rebates for wind-energy systems. During fiscal years 2009-2010 and 2010-2011, this rebate program is increased by $500,000/year with money allocated from ARRA.

3) Maine's Voluntary Renewable Resources Grants,[64] supported by the state's Voluntary Renewable Resources Fund and administered by the Maine PUC, provides funding for small-scale demonstration projects designed to educate communities on the value and cost effectiveness of renewable energy. Maine's Voluntary Renewable Resources Fund, a public benefits fund, was established in 2000 and is supported by contributions made by consumers on their electric bills. Applications for Voluntary Renewable Resources Grants are available only during specified application periods; funding is made available when a certain amount

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[60] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US33F&re=1&ee=1. Accessed March 24, 2011.
[61] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US05F&re=1&ee=1. Accessed March 24, 2011.
[62] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME13F&re=1&ee=1. Accessed March 24, 2011.
[63] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME08F&re=1&ee=1. Accessed March 24, 2011.
[64] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME03F&re=1&ee=1. Accessed March 24, 2011.

has been collected as a result of voluntary contributions. In addition, Efficiency Maine will make funds available from ARRA to supplement this grant program.[65]

Grants of up to $50,000 are generally available to Maine-based non-profit organizations (including community-based non-profits), electric cooperatives, quasi-municipal corporations and districts, schools, and community action programs. To qualify for grant funding, renewable energy resources generally must (1) qualify as a small power production facility under Federal Energy Regulatory Commission rules or (2) must not exceed 100 MW in capacity and use one or more of the following resources to generate electricity: fuel cells, tidal power, solar energy, wind energy, geothermal energy, hydropower, biomass energy, and municipal solid waste used in a generator in conjunction with recycling. There is a 20% cost-share requirement for grant funding.

4) The State of Maine Sales and Use Tax Refund provides incentives for Community Wind Generators generating under 10 MW of power.

[65] http://www.maine.gov/mpuc/recovery/. Accessed March 24, 2011.

8 Geothermal Heat Pumps

8.1 Geothermal Heat Pump Technology Overview

Heat pumps are devices similar to air conditioners. They have a compressor and heat exchangers and they move heat from one area to another using a refrigerant gas contained in a piping loop connecting two heat exchangers with a compressor (pump) between the two. In a standard air conditioner, the hot air inside a building flows over one of the heat exchangers located inside the building, and the heat is transferred into the refrigerant gas in the tubes. The compressor then compresses this gas and pumps the heat over to the other heat exchanger located outside the building. Eventually enough heat is pumped out of the building and the compressor turns off. A heat pump works the same way except in the winter it reverses direction and pumps heat from the outside of the building to the inside. During temperatures below 30°F, these air-based heat pumps do not work very well because there is very little heat in the air to pump into the building, so electric heating coils are used to provide additional heating.

A more efficient version of this is a heat pump that uses a heat exchanger buried in the ground instead of out in the air. The reasoning behind these systems is that the ground is a constant temperature of 55°F and, therefore, there is always a supply of heat to pump into buildings in the winter.

These systems use one of two types of heat exchangers: either the exterior heat exchanger consists of a pipe with refrigerant in it running directly into the ground, or, more commonly, a separate pipe with water pumped through it runs into the ground, which then connects to another heat exchanger to transfer its heat into the refrigerant loop located inside the building. These exterior ground-heat exchange loops can be installed horizontally or vertically. Typically the horizontal units are only installed when systems are installed in new installations due to the fact that the surrounding ground often has already been excavated for construction and the marginal costs may be lower. Vertical wells are typically drilled by water well drilling companies and increasingly are designed by them as well. In either case, the size of the heat exchanger that needs to be installed and, therefore, the final installed cost of the heat exchanger, is highly dependent on the soil conditions in the area. Without doing a test drill in close proximity to the site, there is no way of knowing exactly what the soil type is and therefore what the heat conductivity of the soil is and how much rock might be encountered. The conductivity of the soil will determine how deep or long the holes for the heat exchanger will need to be. The less conductive, the longer or deeper the heat exchanger will need to be and the more hours the contractor will need to be on site to drill or excavate.

8.2 Geothermal Heat Pump Screening Methodology

For this analysis, we used the 10,000 ft^2 warehouse template energy model created during the energy modeling of the base. We compared the energy consumed heating the building using natural gas to the electrical energy used to heat the building using a ground source heat pump. It was determined that using a simplified bundled electrical cost of $0.07/kWh underestimated the true utility cost of the system by 40% due to the under-apportioning of the demand cost incurred solely by the heating systems, which peak in the winter. Costs for the compressor units were estimated using standard average costs. The cost of the ground heat exchange systems was determined by talking with well drilling firms in the region to determine costs.

8.3 Geothermal Heat Pump Screening Results

Energy modeling of a 10,000 ft^2 template warehouse building determined that the savings in heating costs from utilizing a ground source heat pump versus a natural gas heat source would be $2,166/year. System cost estimates came to approximately $126,700. After subtracting federal incentives of approximately 35% and a state incentive of approximately $80/ton of capacity, the costs were reduced to $80,355, resulting in a payback of 37 years.

At the building currently used for remediating ground water at Brunswick Landing, because there is already a well on site, pumping up groundwater, the cost of installing a system would be dramatically lower. If that tainted water were first run through a heat exchanger, the heat in that ground water could be utilized for heating the building. The cost after incentives would be $16,155 per 10,000 ft^2 of space resulting in a payback of 7.5 years compared to natural gas heating.

8.4 Incentives

8.4.1 Federal Incentives for Geothermal Heat Pump Systems

1) The Federal Business Energy Investment Tax Credit[66] provides a tax credit for geothermal heat pump systems based on the capital cost of the system in an amount equal to 10% of the purchase price.
2) The U.S. Treasury Department Renewable Energy Grants,[67] otherwise known as the Treasury 1603 program, offers for-profit businesses an upfront payment equal to 10% of the capital cost of the system if significant portions of the funding have been committed before the end of 2011. It may be taken in lieu of the business energy investment tax credit but only through the end of 2011.
3) MACRS[68] allows businesses to recover investments in renewable energy equipment through depreciation deductions. Geothermal heat pump systems can be depreciated over 5 years. If installed before the end of 2011, 100% can be depreciated in the first year. This would amount to a savings of approximately 25% off the installed cost of the system. In 2012, only 50% can be depreciated in the first year.

8.4.2 State of Maine Incentives for Geothermal Heat Pumps

4) Efficiency Maine Business Incentive[69] provides $80 for each ton of system capacity for ground source heat pumps.

9 Fuel Cells

9.1 Fuel Cell Technology Overview

Fuel cells do not create new electricity; they simply release or transform energy from one form into another (similar to an IC engine changing the chemical energy in gasoline into mechanical

[66] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1. Accessed March 24, 2011.
[67] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=1. Accessed March 24, 2011.
[68] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1. Accessed March 24, 2011.
[69] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME06F&re=1&ee=1. Accessed March 24, 2011.

energy or a battery transforming chemical energy into electrical energy). As such, they need an outside source of fuel to power them. The fuel used for many fuel cells is hydrogen, and this can come from a number of different sources. It can come from stripping hydrogen out of non-renewable sources such as natural gas, using a device called a reformer (which is the most common method of obtaining hydrogen today), or it can come from renewable sources such as solar PV, which can be used to hydrolyze water into hydrogen and oxygen.

In either case, the cost of fuel cells is still much higher than the cost of standard generating technologies, and their core components also have a shorter lifetime, needing to be changed out every 5-10 years depending on the technology. There are other operating advantages to fuel cells that make them attractive and are driving their growth in particular market segments today.

One manufacturer, Bloom Energy, is promising cheaper costs in the future based on the technology using cheaper catalysts. Though they have not revealed the cost or operating data for the units, they are currently installing and owning their units and then selling the power to companies from their units at a rate of around $0.13/kWh.[70] No further details are available.

One of the markets currently adopting fuel cells rapidly is the forklift market. The big advantage that fuel cells bring to this segment is not energy savings as much as their ability to be refueled rapidly compared to batteries. Eliminating combustion fumes from diesel forklifts and losses in worker productivity from recharging electric forklifts allows these units, even though they are expensive, to pay for themselves. In addition, these fuel cell power packs can be retrofitted into existing electric lifts without the need to buy a whole new forklift truck.

Typically expensive hydrogen refueling units are manufactured and leased by hydrogen distributors for use at warehousing locations.

If a manufacturer or warehousing concern chooses to locate at Brunswick Landing in the future, there might be an opportunity to consider installing a hydrogen station to refuel their forklifts. This hydrogen refueling station may also qualify for federal incentives as an alternate vehicle refueling station and could be used to fuel other vehicles coming to or used on the site.

9.2 Fuel Cell Screening Results

None of our cost analyses were able to get fuel cells used solely to generate electricity and heat to pay for them based solely on energy savings; in fact, a 20-year life cycle analysis showed that a 400 kW fuel cell power plant cost $7 million more to operate than electricity purchased at $0.10/kWh.

9.3 Incentives

9.3.1 Federal Incentives for Fuel Cells

1) The Federal Business Energy Investment Tax Credit[71] provides a tax credit for fuel cell energy systems based on the capital cost of the system in an amount equal to 30% of the purchase price.

[70] Fehrenbacher, K. (20 January 2011). "Bloom Energy Launches Electric Service Program." *Reuters News Service*.
[71] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1. Accessed March 24, 2011.

2) The U.S. Treasury Department Renewable Energy Grants,[72] otherwise known as the Treasury 1603 program, offers for-profit businesses an upfront payment equal to 30% of the capital cost of the system if significant portions of the funding have been committed before the end of 2011. It may be taken in lieu of either the renewable energy tax credit or the renewable energy PTC but only through the end of 2011.

3) MACRS[73] allows businesses to recover investments in renewable energy equipment through depreciation deductions. Fuel cell energy systems can be depreciated over 5 years. If installed before the end of 2011, 100% can be depreciated in the first year. This would amount to a savings of approximately 22.5% of the installed cost of a unit. In 2012, only 50% can be depreciated in the first year.

4) REAP[74] grants and loan guarantees can provide grants of up to 25% of the capital cost of a system and loans of up to $25 million. Fuel cell systems that use renewable fuels are eligible to apply for either grants or loans.

9.3.2 State of Maine Incentives for Fuel Cells

1) Community-Based Renewable Energy Production Incentive (pilot program)[75] provides a generator two choices. The first option is to enter into a long-term contract with a local utility for the purchase of either energy, capacity resources (peaking), or RECs at a price not to exceed $0.10/kWh for up to 20 years. This includes renewable electricity generation systems (including fuel cells) up to 30 MW in size. The program is very similar to pre-deregulation utility funding programs previously administered by the Maine PUC. The PUC requires the local utility to enter into a purchasing agreement with the generator at a price approved by the PUC as determined by a transparent look at the finances of the generator allowing for a reasonable rate of return on investment. The electric generator is permitted to sell the associated RECs and carbon credits separately from the electricity if the local utility has already met their state-mandated renewable energy portfolio percentage requirement. The PUC is the entity that certifies RECs awarded to the project. As an alternative to a long-term contract, the generator may instead choose to have the RECs associated with their project multiplied by 150%.

2) Maine's Voluntary Renewable Resources Grants, supported by the state's Voluntary Renewable Resources Fund and administered by the Maine PUC, provides funding for small-scale demonstration projects designed to educate communities on the value and cost effectiveness of renewable energy. Maine's Voluntary Renewable Resources Fund, a public benefits fund, was established in 2000 and is supported by contributions made by consumers on their electric bills. Applications for Voluntary Renewable Resources Grants are available only during specified application periods; funding is made available when a certain amount

[72] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=1. Accessed March 24, 2011.
[73] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1. Accessed March 24, 2011.
[74] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US46F&re=1&ee=1. Accessed March 24, 2011.
[75] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME13F&re=1&ee=1. Accessed March 24, 2011.

has been collected as a result of voluntary contributions. In addition, Efficiency Maine will make funds available from ARRA to supplement this grant program.[76]

> Grants of up to $50,000 are generally available to Maine-based non-profit organizations (including community-based non-profits), electric cooperatives, quasi-municipal corporations and districts, schools, and community action programs. To qualify for grant funding, renewable energy resources generally must (1) qualify as a small power production facility under Federal Energy Regulatory Commission rules or (2) must not exceed 100 MW in capacity and use one or more of the following resources to generate electricity: fuel cells, tidal power, solar energy, wind energy, geothermal energy, hydropower, biomass energy, and municipal solid waste used in a generator in conjunction with recycling. There is a 20% cost-share requirement for grant funding.

[76] http://www.maine.gov/mpuc/recovery/. Accessed March 24, 2011.

10 Micro Gas Turbines

10.1 Micro Gas Turbine Overview

Micro gas turbines are miniature turbines that combust natural gas through the turbine, thus creating rotational motion that turns a generator to produce electricity. These units have not been perfected for the combustion of wood gas yet. Therefore, when comparing them with other technologies used to generate electricity from natural gas, such as an IC engine at up to 48% efficiency, they have a relatively low electrical efficiency at 20%-30% efficiency.

10.2 Micro Turbine Analysis Methodology

The installed cost of the equipment needed to generate 1 MW of power from natural gas was estimated and entered into a cash flow spreadsheet customized with the federal and state incentives applicable for this technology to estimate the payback period.

10.3 Micro Gas Turbine Screening Results

Micro turbines convert an even lower percentage of the energy consumed into electricity, which means that the finances of the system are even more dependent on the sale of heat.

Calculations show that the system has a payback of approximately 6.3 years if all of the heat is sold, 17 years if only 50% of the heat is sold, and 25 years if no heat is sold. Given the current occupancy of the buildings at Brunswick Landing this may not be a wise risk. If smaller, individual 60 kW units were installed they would theoretically have a payback of 7.8 years. However, since these systems need a third party to finance and lease them in order to get the 52.5% federal tax incentive buy-down, individual units would be impossible under that financing structure. The financing structure utilized by energy service companies generally requires a minimum project size of $1 million-$2 million in order to justify the financing costs required for such a project.

10.4 Incentives

10.4.1 Federal Incentives for Micro Gas Turbines

1) The U.S. Treasury Department Renewable Energy Grants,[77] otherwise known as the Treasury 1603 program, offers for-profit businesses an upfront payment equal to 30% of the capital cost of the system if significant portions of the funding have been committed before the end of 2011. It may be taken in lieu of either the renewable energy tax credit or the renewable energy PTC but only through the end of 2011.

2) MACRS[78] allows businesses to recover investments in renewable energy equipment through depreciation deductions. Fuel cell energy systems can be depreciated over 5 years. If installed before the end of 2011, 100% can be depreciated in the first year. This would amount to a savings of approximately 22.5% of the installed cost of a unit. After this in 2012, only 50% can be depreciation in the first year.

There are no state incentives available for this technology aside from the Maine state allowance to use net metering if used in a CHP system.

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77 http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US53F&re=1&ee=1. Accessed March 24, 2011.

78 http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1. Accessed March 24, 2011.

11 Anaerobic Bio Digesters

11.1 Potential Tenant

MRRA is currently in talks with a tenant who is interested in creating a large, anaerobic bio-digester on site. They plan on digesting mainly bio-solids settled out of the sewage from the Portland waste water treatment plant.

11.2 Potential Synergies

There are a number of potential synergies that might occur between the proposed wood-burning power plant and this type of anaerobic digester:

1) The waste heat from the wood power plant could be used to pre-process the bio-solids. This pre-processing serves to liquefy the bio-solids and can cut the next step of digesting the materials in half. This means that either the size of the capital equipment required for the digester would be cut in half or the digester could accommodate twice the throughput of materials if more materials were available.
2) If the digester gas were cleaned sufficiently, it might allow it to be burned in the MRRA wood boiler or IC engines without the removal of carbon monoxide, which might also reduce the cost for the digester operator as opposed to attempting to sell the gas back to the gas utility, which would require very extensive gas cleaning.
3) The digesters might present an additional resource for the disposal of organic manufacturing or cooking waste materials such as waste vegetable oils.
4) It is possible that after slow introduction, the digester could use the waste water from a wood gas shower column cleanser as feedstock to produce methane.
5) Any digester processing bio-solids from a municipal waste water treatment plant will have proteins in the material. When proteins break down, they produce sulfur compounds that have a bad odor similar to rotten eggs. These compounds can also damage steel equipment. One of the most common and economic methods of removing sulfur compounds from the digester biogas is to run the gas through tanks filled with iron filings. The high surface area provides the perfect surface on which the sulfur can react and turn into rust. The steel processing going on at the nearby Bath Iron Works should provide an inexpensive, readily accessible source of waste machined steel shavings, which can become a resource for cleansing the biogas produced at the site from sulfur.

11.3 Potential Issues to be Aware of and Questions to Ask the Digester Operator

Use of digester gas in the wood power plant would require transparent access of both parties to the gas testing results to avoid any potential harm that might come to the engines or boilers burning the gas if contaminants were not cleaned properly.

There are multiple questions to ask the digester operator, including:

1) How much experience does the operator have in operating digesters?
2) How much experience does the operator have in operating digesters of this size digesting this type of substrate?
3) How do you plan to dispose of the liquids and solids leaving the digester?

4) How do you plan to deal with heavy metals in these residues?
5) How many different digesters do you plan to operate at one time? (Redundancy issues if one unit becomes poisoned.)
6) What is your back-up plan for disposing of the contents of a digester that becomes irrecoverably fouled/“poisoned” so the bacteria die and cannot operate?
7) How do you plan on cleaning the biogas produced?
8) How do you plan on storing the biogas produced?
9) What type of safety systems will be incorporated in the system?
10) Do you plan on adding odorant to the biogas produced?

12 Smart Grid Strategies and Technologies

12.1 Smart Grid Overview

The term smart grid refers to a group of strategies involving how power is transmitted and managed on the wires portion of the electrical system. These strategies revolve around several areas:

1) Managing electric demand: In Maine, independent system operators are entities that are required to have an available supply of electricity to consumers whenever they demand it—they must always have a pool of sufficient generating equipment ready to power up and generate power at a moment's notice. Alternatively, they may purchase power from another generator at a much higher price. Because these generators are turned off much of the time, the capital cost just to have these generators ready and waiting to meet a potential demand for power is enormous. Therefore, the utilities want to find ways to pass on these costs to the consumers who require these non-steady spikes in demand for power and also give other consumers the option to opt out if they decide they do not want to pay the higher cost for electricity during those more expensive peak-demand time periods. By sending out real-time energy pricing signals, the consumers can then make decisions to not use electricity during times of high demand to save money. This not only saves the consumer money but can also save the utility money.
2) Automated switching: By automating relays in the transmission and transformer system, outage times will be reduced by allowing system operators to transfer loads electronically instead of needing to send a person physically out to switching and transformer stations.
3) Peak shaving using electric vehicle batteries: Under this scenario, a utility might choose to pay the owner of an electric vehicle to use some of the power in their vehicle's battery to supply the grid during a peak electrical demand spike.
4) Peak shaving by rolling blackouts of storage-inherent appliances: Under this scenario, a utility might communicate with appliances such as a hot water heater and tell it to turn off for 15-minutes during peak power demand time periods. Because these types of appliances have storage inherent in their nature, a short off-cycle is hard to notice.

12.2 Smart Grid Recommended Strategy

12.2.1 Hardware

At this time, based on the rapidly evolving landscape within the smart grid world and the very few tenants and known electric loads on the property, the smart grid team at NREL recommends waiting until additional tenants have located on the property to determine the wisest strategy to pursue terms of what equipment to install.

12.2.2 Metering

With very few tenants on the property, the most cost-effective and sensible strategy for collecting metering data from individual meters is to use wireless transponders that transmit the data back to a centralized building management system (BMS). This BMS "front end" is equipment MRRA will need to have on the property already to accomplish other functions such as monitoring the systems in buildings rented out or managed for maintenance. This system would also be used to monitor the hot water distribution system and bill the buildings for hot water. Given the fact that these systems already need to be in place, nothing will be wasted if the metering data is later transmitted to a different front end.

12.2.3 Test-Bed Opportunity

The smart grid team at NREL is currently looking for a clean-slate location that would be willing to partner with NREL to test new concepts using electric vehicle batteries combined with smart grid technology to provide peak shaving for utilities.

13 Introduction to Systemic Economics and Opportunities

To create a long-lasting stable economy, it is important for Brunswick Landing to build with a long-term economic vision. This vision may build on opportunities that could be called systemic, synergistic, or cooperative opportunities and benefits. Around the world, thinking is starting to shift toward enhancing the environment for entrepreneurship through these types of cooperative opportunities, such as public-private cooperative partnerships, cooperative marketing of the companies in a whole region instead of only individual companies, and systemic production. In the same way in which investment advisors have advised investors for years to "diversify, diversify, diversify" to achieve stable long-term gains, there is now a new openness to the idea of diversified systemic output coming from integrated production entities or regions.

13.1 Industrial Symbiosis

Industrial symbiosis can be boiled down to the concept of the waste from one process becoming the food for another process. In effect, this is collaboration between different industries for mutual economic and environmental benefit. It seeks to maximize the total economic output from the limited resources in a region by eliminating every bit of waste or inefficiency, and capitalizing on the synergy between companies. This method optimizes the output from the whole system instead of maximizing the output from only one company. The result is the maximization of the total overall output and opportunities within the whole community. Two examples of industrial symbiosis can be seen in Kalundburg, Denmark, and Lubei, China.

Denmark is one of the countries most identified with energy efficiency, as evidenced by the fact that they have the largest number of towns in the world that have built combined heat and power (CHP) systems. Under this scenario, relatively small electric generating plants are built close to cities so the waste heat from these plants can be used to heat homes and businesses. In the United States, our large centralized power plants are normally located miles from cities, and the waste heat produced in the process of generating electricity (about 60%) is often directed to large cooling towers and vented to the sky.

By locating these smaller plants close to cities and using the waste heat, these combined systems are often up to 90% efficient[79] compared to most large, centralized power plants, which could be only 30% efficient by the time the power gets to the user.

13.1.1 Danish Industrial Symbiosis

Kalundburg, Denmark,[80] currently scavenges sulfur from the exhaust stacks of its power plant. This process keeps the sulfur out of the air, but also eliminates air pollution penalties, and produces a new value-added product, gypsum, which is then used to produce two-thirds of the output of Gyproc Corporation's drywall plant nearby. The waste fly ash from the boilers at the same coal-fired plant is used by a concrete plant in the area as a substitute for energy intensive cement, and some of the waste heat from the plant is used to heat a fish farm nearby.

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[79] http://www.ambottawa.um.dk/NR/rdonlyres/C3F9F1D4-BEA9-4C29-A1FD-1D7CC8617B84/0/combinedheat.pdf
[80] http://www.symbiosis.dk/industrial-symbiosis.aspx. Accessed March 24, 2011.

Adjacent to the power plant is the Statoil oil refinery. Statoil receives the steam for its refining processes from the power plant and in turn shares its water used in processing with the power plant. It also sends the gas that it formerly flared to the open air over to the Gyproc plant for use in its drywall production process. Around the corner, Novo Nordisk, one of the largest names in the biotech industry worldwide, has a factory growing enzymes. Waste hot water produced by the electric power plant heats this factory. In turn, Novo Nordisk sends the wastes from their factory in the form of yeast slurries and other organic wastes to area farms to be used as fertilizers and pig feed. Alcoholic wastes from this same plant are sent to the city's waste water treatment plant nearby, which then converts them into methane gas for use in generating electricity. The city sends purified water back to the factory.

Figure 8 shows a diagram of some of the interactions between the various entities in Kalundborg and the gradual integration of the various companies and public systems over the years.

In Kalundborg, all of these industrial relationships are voluntary, but the local government originally recognized the opportunities for the local economy and created the environment by putting in place incentives that made it attractive for the companies to cooperate.

According to studies done by the city, the value of these wastes that were captured over 30 years through 1994 amounted to approximately $160 million. This is the equivalent to $160 million added to the local economy.

Kalundborg is next planning to add a bio-fuels cluster to this systemic cooperation of processes, which is already in the area.[81]

[81] Cluster Biofuels Denmark. http://www.kalundborg.dk/Erhvervsliv/The_Green_Industrial_Municipality/Cluster_Biofuels_Denmark_(CBD).aspx. Accessed March 24, 2011.

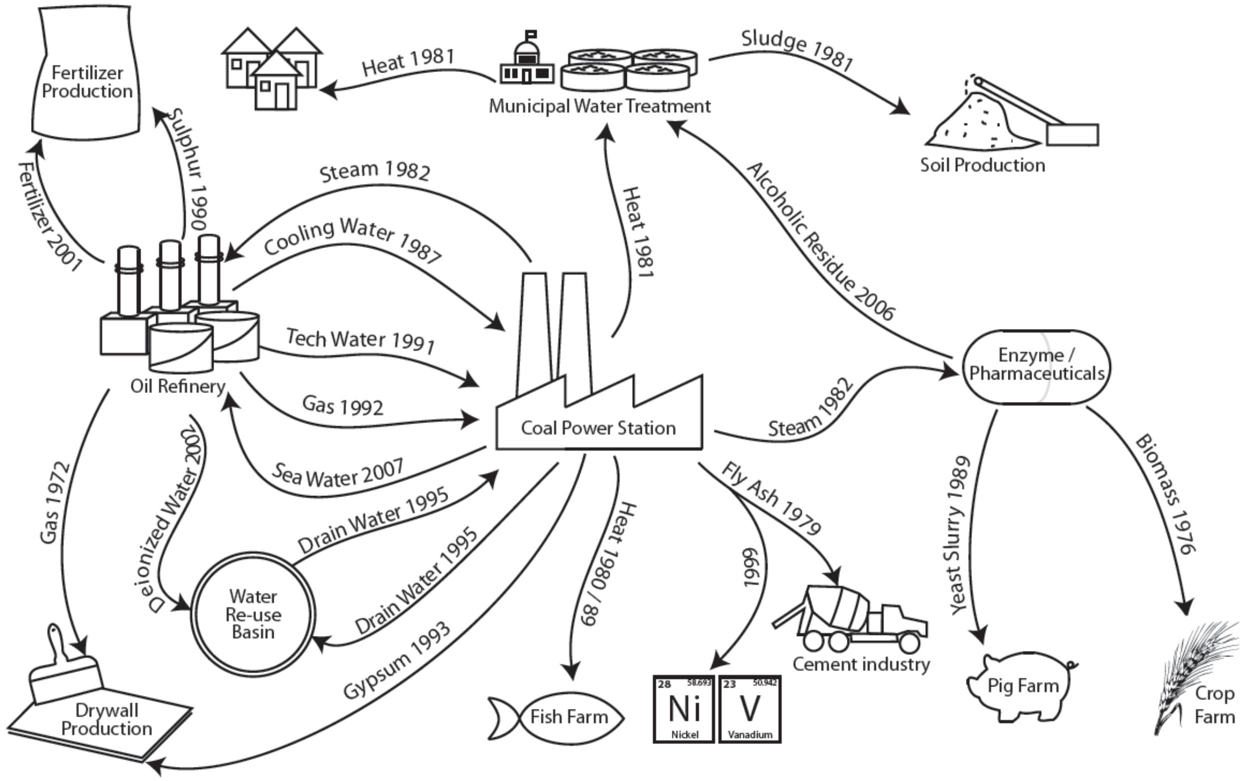

Figure 7. Diagram of industrial symbiosis in Kalundborg, Denmark. *Illustration by Troy Wuelfing & Gabriel Grant*

13.1.2 Chinese Industrial Symbiosis

The port city of Lubei in eastern China has created another industrial symbiosis. This project starts by taking in large quantities of fresh seawater, which is rich with algae, seaweed, and plankton. The seaweed is separated and processed into a dried seaweed food product. The rest of the water flows into ponds growing shrimp. The shrimp eat the algae and plankton, thus cleaning the water. Once the shrimp are fully grown, they are harvested and processed, and a material called chitin is extracted from the leftover shells (chitin is also present in lobster shells). This chitin is next processed into a material known as chitosan, which is used for manufacturing high-tech fabrics. The water continues on from the shrimp ponds to other ponds growing muscles, which extract even more “food” from the water. From there, the ocean water, having been cleansed of most biological matter, continues on to a processing facility where gypsum, sodium chloride, and bromide are extracted from the water. Next, the water is heated by (and at the same time provides cooling for) the nearby coal-fired power plant. Some of the power plant’s electricity is also used to extract ammonium phosphate from the water. The sulfuric acid from a nearby cement factory is next used to process the ammonium phosphate extracted from the water into a feedstock for the cement factory along with the fly ash from the coal-fired power plant previously mentioned. In the final stage, a pilot project at the plant next took the water one step further by running it though a reverse osmosis filter to create potable drinking water. A full view of the plant in Figure 9 shows that the plant started off with only seawater and coal and ended up with 10 different products as well as drinking water.[82]

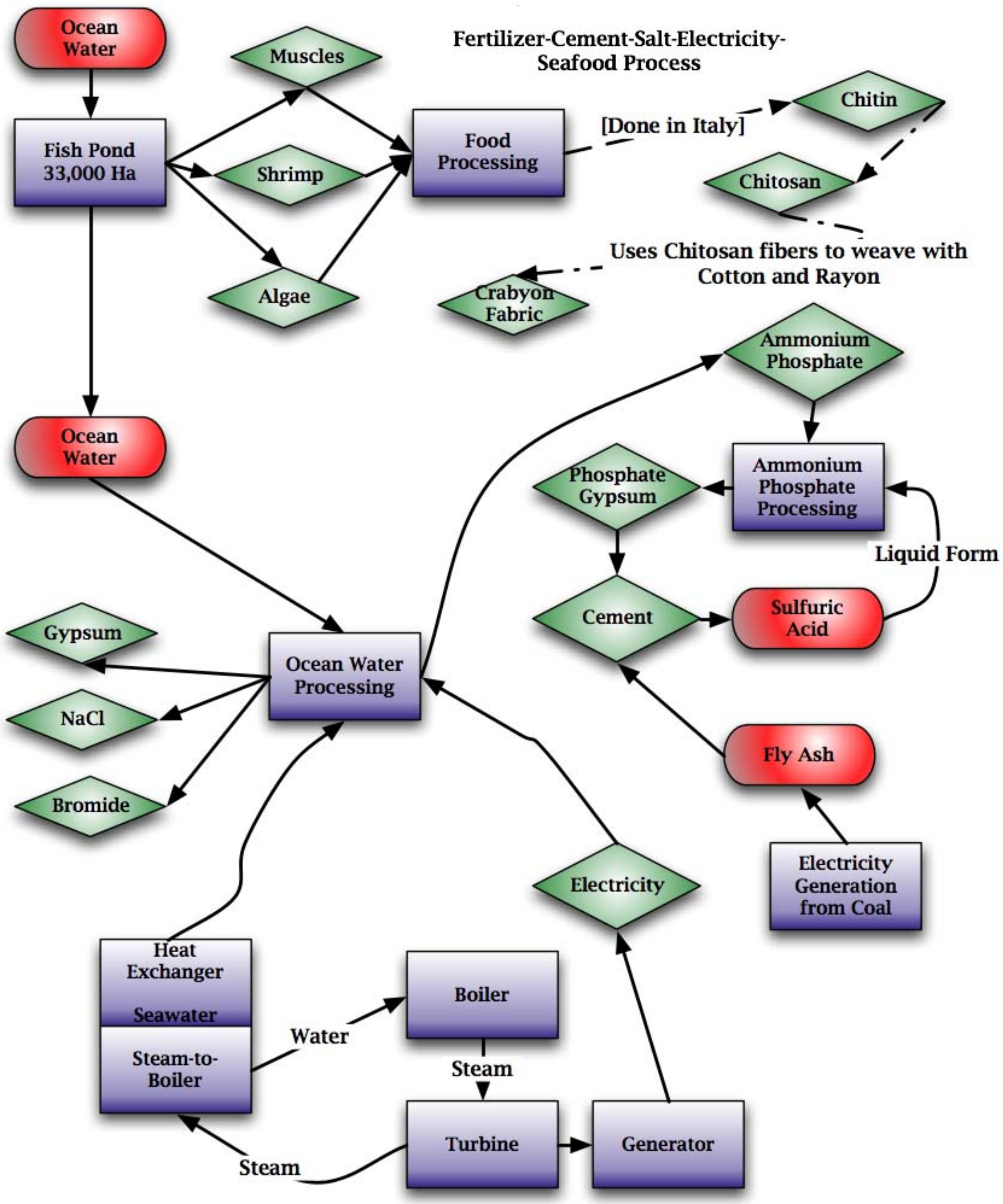

Figure 8. Diagram of industrial symbiosis in Lubei, China. *Illustration by Li Kangmin sustainability consultant Wuxi China*

13.1.3 Interrelationship but not Dependency

It is important to recognize that while each of the processes can take advantage of the waste materials from other processes in the cluster, they are not dependent on those other processes.

[82] Li Kangmin, sustainability consultant Wuxi China in discussions with the author in 2006

Each one of the processes is independent and can continue to operate on its own even if one of the others stumbles for some reason.

13.1.4 Systemic Renewable Energy

Even with growing demand and falling prices in the renewable energy sector, it is possible to miss the systemic opportunities available to a community if these technologies are only looked at individually and not integrated with other economic systems in the community.

The attempt of this report is not only to look at the economics of individual renewable energy technologies but also to look at the systemic benefits that can be gained when cost-effective renewable energy technologies are integrated with other systems and businesses in a community thus multiplying the total monetary, employment, and quality-of-life benefits they can provide to a community.

14 A Vision of Possible Systemic Opportunities at Brunswick Landing

Introduction to the Vision

This section presents a vision of some of the systems which could be combined at BNAS starting with the core Biomass CHP system and the existing local resources and local market trends in the area. This is only one scenario for Brunswick moving forward, but not the only one. In addition the "options" presented are just that, optional technology modules which can be mixed and matched to the core CHP system as desired by the community or added one at a time gradually.

Economics

There are the two schools of thought of basic economics: the supply side (increasing the flow of money into the system) and the demand side (reducing the flow of money out of the system). Both approaches have great merit, and to ignore one side or the other risks losing great potential benefit.

This report attempts to integrate both schools of economic thought and bring to bear the greatest total economic benefit for Brunswick. We do this by recommending projects that "reduce the demand" (drain) of money away from Brunswick while also "increasing the supply" of money into Brunswick.

This report is only meant to be a starting point that shows examples of a few of the possible business options that could be linked together systemically and is not meant to be an exhaustive list of the possible options for Brunswick.

14.1 Where Your Money Comes From (Sources of Income)

Previous studies, such as the 2007 Economic Research Associates (ERA) report[83] on BNAS identified tourism and retirees as major sources of income entering the Brunswick area. These sectors and ways in which the income from these sectors can be enhanced through integrated planning of the energy and natural resources available in the area are discussed later in this report. Additional areas identified in the ERA study[84] were information technology (IT), personal aircrafts, and composite materials. While IT is addressed in the efficiency section of the report, the other two industries require much more in-depth analysis in terms of exactly what equipment and specialized processes might be utilized by the specific companies choosing to locate at Brunswick Landing. These processes can be further explored for opportunities for energy efficiency and industrial symbiosis as these potential tenant companies emerge.

[83] Economic Research Associates (Jan 17, 2007) Brunswick Naval Air Station: Project # 16746 Prepared for The Matrix Group.

[84] Economic Research Associates (Jan 17, 2007) Brunswick Naval Air Station: Project # 16746 Prepared for The Matrix Group.

14.2 Where your Money Goes (Expenditures)

Our analysis of area economic demographics in the ERA report[85] and U.S. Bureau of Labor Statistics (BLS) figures[86] indicate that some of the largest expenditures of money leave the local Brunswick economy for utilities, transportation, and food.

14.2.1 Food

BLS statistics show that average Brunswick households spend 12.4% of their yearly income on food, or approximately $6,419 per household. Because a relatively small percentage of that food is produced locally this means that a large part of that 12.4% is leaving the local economy every year. A recent study[87] in Portland, Oregon, found that every dollar spent on locally produced food at the farmer's market adds $3.30 in local economic impact. In contrast, most if not all of the same dollar spent at the grocery store immediately leaves the area. Nearly all of the food from the grocery store comes from outside the state and most often from outside the country. In the same study,[88] the City of Portland found that the best way to increase that 33% multiplying effect on the economy was to extend the season of the farmer's market; which could also be done by growing food during the winter in greenhouses.

14.2.2 Utilities

The other item at the top of the list of Brunswick resident expenditures that transfer money out of the local economy is utility expenditures. This report will analyze how these dollars can be spent locally on renewable energy technologies, thus keeping the utility dollars within the local Brunswick economy.

14.3 Renewable Energy Systems

Renewable Energy Systems rely on local renewable resources to create the energy they produce. Because renewable energy systems are distributed and local, more of the money spent over the lifetime of the system remains in the region.

Of all the renewable resources analyzed, this study shows that the strongest opportunity, due to the abundant wood resources in the area, is a biomass CHP system (see Figure 10). By utilizing the area's strength in wood resources, Brunswick can begin to create diversified economic growth for the region.

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85 Economic Research Associates (Jan 17, 2007) Brunswick Naval Air Station: Project # 16746 Prepared for The Matrix Group.

86 http://www.bls.gov/cex/2007/msas/norteast.pdf.

87 Barney and Worth Inc. (November 2008). "Growing Portland's Farmer's Market." Prepared for the City of Portland, Oregon.

88 Barney and Worth Inc. (November 2008). "Growing Portland's Farmer's Market." Prepared for the City of Portland, Oregon.

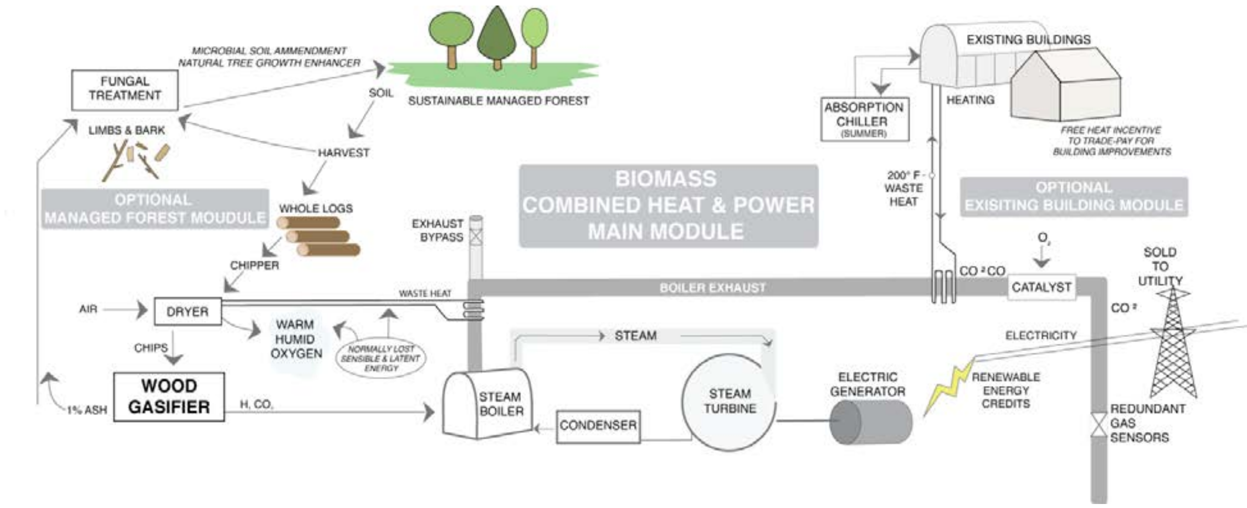

Figure 9. Biomass combined heat and power system. *Illustration by Colleen McCulla*

Creating a wood-powered electric generation system would allow MRRA to create "green" sustainable electricity and to be one of the first net-zero commercial developments in the world. This project would allow MRRA to leverage a number of different opportunities. By utilizing the State of Maine Community-Based Renewable Energy Production Incentive Pilot Program,[89] MRRA can enter into a long-term agreement with the public utility commission (PUC) and the local utility that ensures MRRA the cost to generate the wood-powered electricity plus a reasonable profit. The PUC has the authority to mandate a rate of up to $0.10/kWh that the utility will pay to MRRA, and contracts can be signed for up to 20 years. In addition, if MRRA created a L3C corporation (as described in Section 15.1) to operate the project could take advantage of the Production Tax Credit (PTC)[90] which would provide 2.2¢/kWh in tax incentives to the L3C corporation. On top of these federal incentives, the project could also take advantage of the Modified Accelerated Cost Recovery System (MACRS)[91] with a bonus depreciation of 50% of the value of the project in the first year of operation, and the other 50% depreciated over 7 years.

Tenants and other companies located on site would still be able to purchase lower cost power from Central Maine Power at about $0.07/kWh, while all of the power output from the wood power plant was sold to Central Maine Power at $0.10/kWh.

If a piping network were built to connect all of the buildings on the campus with the wood-powered electric generating plant, the waste heat from the wood power plant (if designed correctly) could be used to heat the buildings in the winter and (with additional equipment) cool the buildings in the summer. These systems may also qualify for the first year 50% Bonus depreciation.

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89 DSIRE. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME13F&re=1&ee=1. Accessed March 24, 2011.

90 DSIRE. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F&re=1&ee=1 Accessed Sept 18, 2011

91 DSIRE. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1. Accessed March 24, 2011.

Beyond the environmental and surface economic benefits, this waste heat can be used as leverage to incentivize further economic growth at Brunswick Landing.

One way of leveraging this resource is to offer free heat for a number of years to new businesses that choose to locate on the property. A precedent for this can be seen in the apartment rental industry and provides an additional way to market the property and attract the attention of potential tenants.

MRRA can use the heat in other ways to add value, which can create growth. By doing energy improvements on its property, businesses could receive a business tax deduction from the federal government through the Energy Efficient Commercial Buildings Tax Deduction.[92] This would pay for a portion of the cost of the improvement project. In addition, MRRA could offer free heat as a form of pay-in-trade for the facility upgrade, which increases property and tax values and attracts new tenants with the opportunity to rent a facility with upgraded comfort and appearance.

Low/no interest loans guaranteed by the federal government as well as grants could be procured for these energy projects from various federal and state programs. Free heating might be provided for the number of years required to pay off these loans.

Another benefit of this program is that often when energy improvements are done (like adding exterior wall insulation), these improvements also end up providing additional value to the property in the form of cosmetic improvements. Even for projects that do not involve adding a new cosmetic surface; if they involve adjacent surfaces, they can often lower the incremental costs of doing cosmetic improvements, thus improving the real estate value and tax base to the city's and the Navy's benefit. The Navy has a cooperative agreement with MRRA that allows it to benefit from improving property values.

14.4 Leveraging Win-Win Systemic Incentives

In the previously described pay-in-trade scenario, Brunswick would contribute an incentive of free heat to pay off part of the improvement loan. The tenant or property owner would contribute tax deduction money, time, and effort to apply for low interest loans toward the improvement of the property. This provides a win for the business owner who ends up with lower utility costs over the long term and a win for MRRA by improving the appearance of the BNAS building stock and property values as well as improving the local economy by keeping utility money in Brunswick where it can create local jobs and businesses in the local economy. The waste heat is first transformed into avoided rent for the tenant and next when combined with the tax deductions is transformed into jobs for local remodeling companies. In the end, these incentives "trickle down" from the energy efficiency incentive programs and turn these dollars many more times in the local economy than simply spending the money on utility bills that leave the region. Projects can become a catalyst, which can leverage and bring additional outside federal and state resources into the community that would not have been coming into the area otherwise.

[92] DSIRE. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US40F&re=1&ee=1. Accessed March 24, 2011.

14.5 Option of Creating a Greenhouse Industry

Another opportunity for leveraging free heat from the wood power plant is to invest in starting up a whole new industry in the area, which (like the Kalundborg model[93]) can take maximum advantage of the waste resources being shed from this particular power plant. Due to the large amount of waste heat and carbon dioxide, which may be available from the wood-powered electric generators on the property, there is a good opportunity to start up a greenhouse industry growing salad greens and fresh herbs using rain water. Rainwater collected from the greenhouse roofs could water the plants, the reduced cost heat would lower the cost of growing food for the region, and the carbon dioxide would accelerate the growth of the plants by at least 30%.[94] This carbon dioxide growth strategy is used extensively in Europe. Operators of large commercial greenhouses such as Backyard Farms in Madison, Maine,[95] where they mainly grow tomatoes, actually purchase commercial bottled carbon dioxide to enrich the carbon dioxide levels in the greenhouses and thus accelerate the growth of their plants. In the future, absorbing carbon dioxide directly with plants might also allow MRRA to claim carbon credits for carbon sequestration (or possibly better described as carbon short-cycling). Estimated start-up costs for a half-acre greenhouse is in the range of $280,000. Based on the wholesale price of produce, the simple payback of such a combined system would be in the range of 2.4 years.

Figure 10. Hydroponic lettuce growing in a greenhouse. *Credit: Mary Donnel*

14.6 Aquaponics

Growing techniques have even been developed that combine hydroponics with organic growing techniques. The process has extremely high growth density and utilizes the biologically cultured

[93] http://www.symbiosis.dk/industrial-symbiosis.aspx. Accessed March 24, 2011.
[94] Discussions with European Greenhouse CO_2 enrichment system manufacturers and greenhouse operators while attending Green-Sys 2007 March 2007 Naples Italy
[95] Ladd, C. (31 March 2010). "Giant Greenhouses Mean Flavorful Tomatoes All Year." *New York Times.*

wastes of fish being farmed in adjacent ponds as liquid fertilizer to grow lettuce using a method called thin-film hydroponic technology. Essentially, the lettuce roots are submerged between two layers of plastic, which have a nutrient liquid continually flowing between them. In normal hydroponic greenhouses, the nutrients flowing through these sheets are synthetic fertilizers. In this variation, the nutrients are natural fertilizers created by culturing the wastes of the fish being fed and raised in tanks nearby. This culturing (using the same bacteria that is in everyday yogurt), improves the usability of the nitrogen in the fish waste. By growing the lettuce in different stages in a greenhouse, the harvest can be timed so that there is a continual flow of produce being harvested every day, and it provides continuous stable full-time employment for workers without the need for boom-bust cycles. Preliminary indications are that a half-acre traditional thin-film hydroponic growing operation in this area could produce about 130,000 lbs of lettuce per year and about $110,000/year in profits.[96]

United States Department of Agriculture (USDA) statistics indicate that the average American eats 34.5 lbs of lettuce per year.[97] Ninety-three percent of the lettuce consumed in the United States is grown on the border between Arizona and California. This means the fuel bill just for shipping the lettuce to the tri-city area around Brunswick is in the range of $153,000/year.[98]

In addition, hydroponic systems use 90% less water than if this lettuce was being grown in Arizona and California using conventional, non-greenhouse lettuce-growing methods.[99]

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[96] Donnel, M. Telephone conversation. Professional greenhouse financial planner spreadsheet model, January 2011

[97] Commodity Profile: Lettuce, UC Davis Agricultural Marketing Resource Center http://aic.ucdavis.edu/profiles/lettuce.pdf. Accessed March 24, 2011.

[98] Commodity Profile: Lettuce, UC Davis Agricultural Marketing Resource Center http://aic.ucdavis.edu/profiles/lettuce.pdf. Accessed March 24, 2011.

[99] Commodity Profile: Lettuce, UC Davis Agricultural Marketing Resource Center http://aic.ucdavis.edu/profiles/lettuce.pdf.

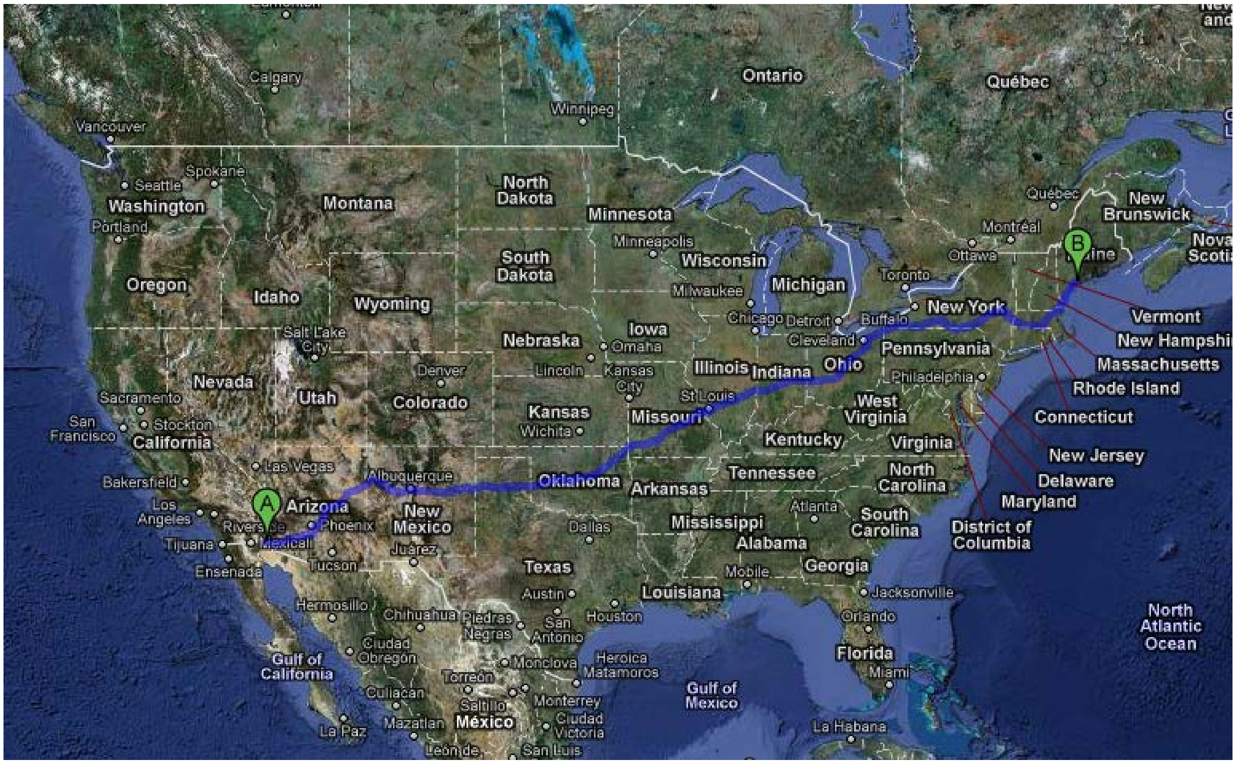

Figure 11. Map of the 3,026 miles that lettuce must travel from California to Brunswick, Maine.
Credit: ©Europa Technologies Image ©2009 Sanborn ©Google Gray Buildings ©2008 Sanborn

There are a number of other produce products that could also be grown in these greenhouses. Possibilities include herbs, tomatoes, or fresh flowers. Other possibilities might be contract "designer vegetables" for high-end restaurants or weekly mixed boxes of vegetables pre-sold direct to residents using a community-supported agriculture (CSA) business model. Given the fact that Brunswick Landing is located less than four miles from the main campus of Bowdoin College as well as having a Bowdoin satellite campus located adjacent to Brunswick Landing, Bowdoin would provide a huge "local-food-friendly" potential market for the food produced in the greenhouses. With 1,700 students, Bowdoin College could easily use that much lettuce on its own.

14.7 Fish and Aquaculture Option

Asian carp, sometimes called Shanghai bass, can be raised in aquaculture tanks inside the greenhouses using sustainable feeds. There are a few possibilities as to where the feed can come from. Fish raised in fish farms have more recently been raised using unsustainable methods, which utilize fish feed pellets made from industrial byproducts and ground-up fish meal made from the excess fish found in nets that cannot be sold for high prices. A much more sustainable source of protein to feed these fish are naturally grown insects and "fishing worms" grown on restaurant and grocery store food and produce wastes. This process "up-cycles" the value of these food wastes instead of "down-cycling" them into low value products like lawn compost. Additional profits can be made by charging restaurants for hauling away their "waste." Another source of feed for the fish could be leftover waste grain substrate used in mushroom growing operations as described in section 14.9.

The Food Channel[100] lists two of the top-10 trends in seafood to be "Sustainable Aquaculture" and "Baby Boomer Interest in Seafood." With the baby boomers entering their retirement years, these two factors combine to make this an attractive industry that could fit in perfectly with the regional "foodie" movement[101] and the local retiree market.

14.8 Freshwater Crab

Freshwater crab can be raised using materials that are most like the food they eat in their normal environment: dead fish parts. By utilizing the fish wastes produced by some of the few local fish processing plants surviving in the area, it may be possible to raise freshwater crab.

14.8.1 Insects and Worms as Fish Food

The kitchen scraps collected from local restaurants could provide food for insects grown as natural feed for the fish (see Figure 12). In addition, seasonal agricultural surpluses such as potatoes can be fed to insects which transform them into compact nutrient rich protein. These insects could then be easily dried and stored for use at a later time for fish feed.

14.8.2 Nursery "Starter Pots"

The nitrogen rich insect and worm wastes (called castings) from the insects being grown for fish food could be molded into nursery planting pots creating a value-added product with a proven market.

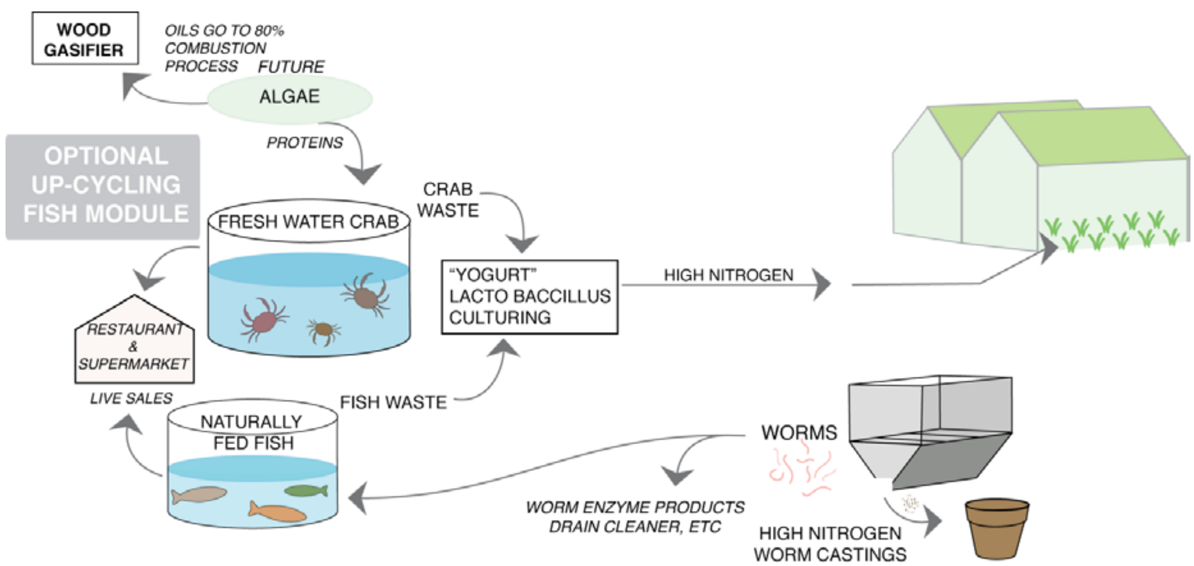

Figure 12. Greenhouse and aquaculture fish and crab module interactions.
Illustration by Colleen McCulla

[100] http://www.foodchannel.com/articles/article/top-10-trends-in-seafood/.
[101] (22 October 2010). "Midcoast Maine: Invasion of the Foodies." *The Week*; p. 36

14.8.3 Worm Enzyme Business

In addition to using worms as feed for fish, there are a number of other ways they can be used. Worms create huge quantities of natural enzymes. One of the current products produced from worm enzymes is drain clog-up preventer. The worm enzymes gradually eat away at the grease and other materials that accumulate on sink drains to prevent them from forming clogs. The worm enzymes could be removed and the high protein worm bodies dehydrated to be sold or used later for high protein fish feed.

14.9 Mushrooms

Another local waste opportunity that fits into this system could be to collect the waste coffee grounds from coffee houses in the area[102] as a low cost, sterile medium on which gourmet shitake or oyster mushrooms can be grown (see Figure 13). Examples of previous profitable projects occurred in New Mexico, Colombia, and California.[103]

Additional resources that would normally be considered wastes leftover from the wood power plant , are large amounts of moisture and heat exhausted from the equipment used to pre-dry the green wood chips before they enter the wood-burning system. Normally there is no way to capture and utilize all of this sensible and latent heat and it is lost to the atmosphere. But in the winter, this moist heat, which would otherwise be lost, could be used to heat mushroom "growing houses," which require a constant flow of moist oxygen rich outside air so the mushrooms can grow faster.

[102]Hitachi Foundation Entrepreneur award based on ZERI inspired mushroom industry selling gourmet mushrooms grown on waste coffee grounds to Whole Foods. http://www.hitachifoundation.org/our-work/yoshiyama-young-entrepreneurs-program/meet-our-entrepreneurs/alex-velez-and-nikhil-arora

[103] "Sustainable or Not Sustainable? Mushrooms and Coffee." *The Specialty Coffee Chronicle*. http://www.zeri.org/mush.pdf. Accessed March 24, 2011.

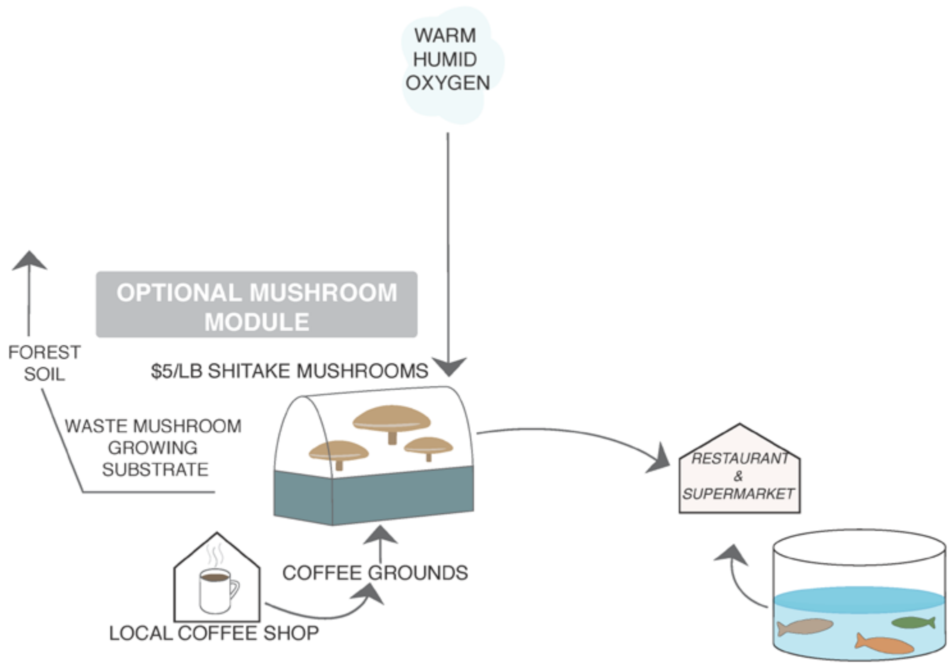

Figure 13. Optional mushroom module interaction. *Illustration by Colleen McCulla*

14.10 Greenhouses on Roofs

In addition, both greenhouses and mushroom houses (with the exception to those containing fish farms) could be retrofitted onto the roofs of existing buildings by adding additional exterior support if necessary. This could provide a green image similar to a "green roof" and may improve the building's appearance while also having the potential to decrease original building's utility bills. In some cities including New York,[104] businesses like Whole Foods are looking at rooftop greenhouses as a strategy to increase the percentage of food produced inside the city while responding to buyer's desires for local food. Brunswick Landing could increase the overall area of space available to develop by installing rooftop greenhouses in areas/spaces that would normally not be attractive for new potential tenants.

14.11 The Local Food Movement

The national news weekly *The Week* recently ran a story under the heading "Midcoast Maine Invasion of the Foodies,"[105] commenting that, "Thanks to an influx of former urbanites, the small towns of Midcoast Maine have developed an appetite for good food that seems 'insatiable,'" according to Meredith Goad in the Portland Maine *Press Herald*. The article went on to say "no wonder the Midcoast possesses a 'growing reputation as a great place to eat.'" The increasing demand for foods that are locally grown means that the only way to obtain them year-

[104] http://ny.curbed.com/archives/2010/11/29/bks_first_whole_foods_to_have_rooftop_greenhouse_gowanus_views.php.
[105] (22 October 2010). "Midcoast Maine: Invasion of the Foodies." *The Week*; p. 36

round is to use a greenhouse. The availability of local, organically grown food all year long provides added economic growth to the area amenities, and could increase the likelihood of attracting additional tourism and second-home-buying residents who desire a lifestyle with access to locally grown food and who may be serial entrepreneurs.

14.12 On-Site Restaurants and High Value-Added Food Processing

On-site restaurants and a regional food processing incubator kitchen would provide an opportunity to create higher value (higher profit) products while eliminating spoilage losses from the foods being grown in the greenhouses and fish tanks. This would also provide an added amenity for the existing on-site hotel and the convention center business Brunswick is hoping to attract. Food grown on the premises with access to live freshwater fish and crabs is a unique attraction and a huge draw for various ethnic populations and food aficionados.[106] This live-fish business strategy also limits competition from the existing ocean-based fish industry in the area. The on-site restaurant kitchen might also initially be able to serve a dual purpose as the incubator kitchen and be eligible for the grant programs associated with them.

14.13 Additional Businesses

The optional business clusters discussed above are only options. Individual options are not required to be exercised and as such some may or may not be implemented. Other options may exist in the large number of lobsters harvested in the area. Lobster shells are high in a substance called chitin, which can be extracted and turned into chitosan. Chitosan is a material which can be used in the manufacture of edible antimicrobial food wrap,[107] high tech fabrics, and biomedical devices with anti-microbial properties.[108]

Additional in-depth investigations will no doubt uncover additional potential interactive business opportunities. As new businesses enter Brunswick Landing and the Midcoast area in general, the opportunities for interactive business opportunities will expand. This is especially true of manufacturers with specialized manufacturing processes that result in unique wastes, which also could be seen as unique opportunities. Ongoing analysis of all of these potential interactive opportunities should continue to be explored.

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[106] Meyers, J.J.; Govindasamy, R.; Ewart, J.W.; Liu, B.; You, Y.; Puduri, V.S.; O'Dierno, L.J. "Consumer Analysis of and Business Network Development for Ethnic Live Seafood Markets in the Northeast Region Fish and Seafood Division of N.J. Dept Agriculture." Abstract Aquaculture America 2006

[107] http://www.youtube.com/watch?v=Ia4gwKYAdh4

[108] Vol. 007, Pg 32 Food Technology International http://www.fpiinternational.com/articles/ingredients_additives/032_FTI007.pdf

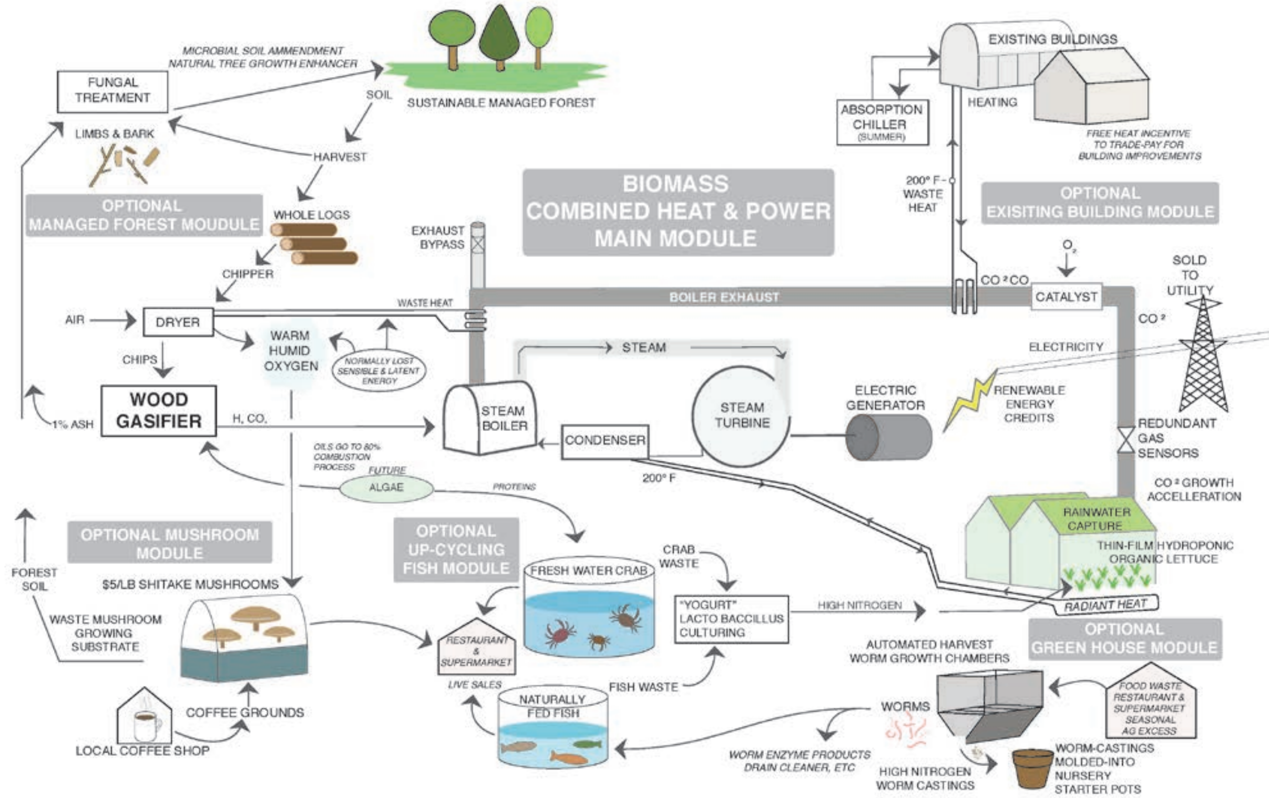

Figure 14. Biomass CHP with all optional module interactions. *Illustration by Colleen McCulla*

14.14 Transportation

While a full analysis of transportation needs and possible solutions is beyond the scope of this study, several initial synergies have been proposed. These include the possibility of using the batteries from electric vehicles to back-feed electricity into the local utility grid during periods of peak electric demand. A processing facility could be created to reclaim waste oils from regional restaurants to create biodiesel. The same trucks transporting the oils could also transport restaurant food scraps, which would then be used to feed and grow insects to feed the aquaculture fish. The transport costs of both of these could offset the avoided tipping fees normally paid by restaurants to garbage haulers but now paid to transport "insect food" and biodiesel feed stock.

14.15 Food Miles

Significant amounts of fuel, money, and carbon are spent each year on transporting food and other materials into the region. The costs associated with these functions need to be included in a total accounting of the economics, energy, and carbon in the area.

As previously mentioned in the discussion of the role economics plays in the local economy, quick calculations show the transportation of just lettuce into the tri-city area around Brunswick costs $153,000/year in diesel fuel alone, not counting capital costs, depreciation for wear and tear on the truck, driver salaries, or trucking company profit.[109]

It is recommended that a full study be done on the local food shed of the area to determine the opportunities and vulnerabilities that exist.

As locally grown food is substituted for transported food, there are additional benefits that occur such as the opportunity for local entertainment centered on higher quality food grown in the area. The growth of venues like the Food Channel[110] demonstrates the ways in which Americans have started to rediscover the entertainment value of food. Worldwide movements like the "slow food" movement also indicates that there are a growing number of people who value the social interactions and accompanying community that this creates as local food turns into an opportunity for celebrations and enhanced quality of life.[111]

14.16 Eco-Tourism

Eco-tourism strategies can manage an influx of non-residents visiting an area while minimizing their impact. For example, offering a tour bus service for out-of-town visitors would save fuel by allowing more people to take the train up from areas like Boston to the Midcoast region, then providing local transportation to get them out to the local tourist towns (see Figure 15). The bus could be fueled with locally produced biodiesel or possibly bio-gas. Brunswick Landing's hotel and on-site restaurants could become a "base camp" for these train-tourists. If marketed effectively, the sustainable features at Brunswick Landing could easily turn it into a national eco-tourist destination spot. The Green Zone in Umea, Sweden, developed such a project, which quickly became an eco-tourist destination.[112]

14.17 Unemployed and Veterans

Discussions of locating a "one-stop-shop" for social services and daycare at Brunswick Landing might mean that local residents who are out of work could take public transportation or drive out to a one-stop center, where they could then be plugged into job openings at the newly created greenhouses and mushroom growing businesses or the restaurants and hotels. Agriculture and greenhouse jobs are now also being used as an effective environment in which veterans can transition from overseas environments to conventional jobs.[113]

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[109] Commodity Profile: Lettuce, UC Davis Agricultural Marketing Resource Center http://aic.ucdavis.edu/profiles/lettuce.pdf

[110] Villarreal, Y July 20, 2011 (TV Gorging on Food-Show Programming) Los Angeles Times; Watching What We Eat: The Evolution of Television Cooking Shows Collins, K, Continuum Publications Group 2009

[111] Slow Food. www.slowfood.com. Accessed March 24, 2011.

[112] Nyquist, A. (2005). Telephone conversation with the planner and architect of The Green Zone Sweden. http://www.greenzone.nu/index_e.shtml. Accessed March 24, 2011.

[113] Brown, P L. (5 Feb, 2011). "Helping Soldiers Trade Their Swords for Plows" *New York Times* http://www.nytimes.com/2011/02/06/us/06vets.html?_r=1 http://www.farmvetco.org/;

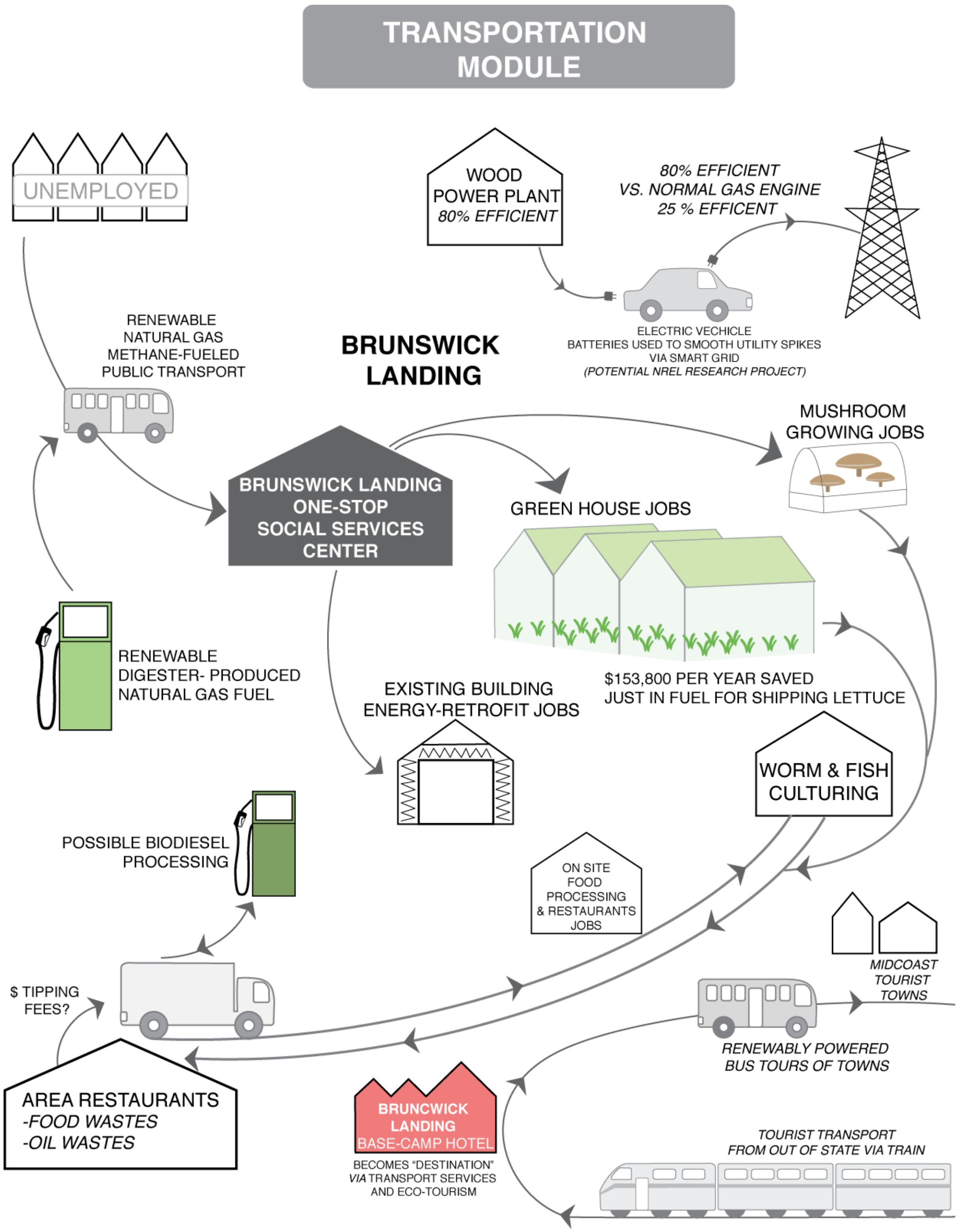

Figure 15. Preliminary diagram of some transportation options. *Illustration by Colleen McCulla*

14.18 Incentives

14.18.1 Federal Programs These Systems May Qualify For

1) USDA Conservation Innovation Grants[114] (CIG) is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, Environmental Quality Incentives Program funds are used to award competitive grants to non-federal governmental or non-governmental organizations, tribes, or individuals.

   CIG enables the Natural Resources Conservation Service (NRCS) to work with other public and private entities to accelerate technology transfer and adoption of promising technologies and approaches to address some of the nation's most pressing natural resource concerns. CIG will benefit agricultural producers by providing more options for environmental enhancement and compliance with federal, state, and local regulations. NRCS administers CIG.

2) USDA Risk Management Agency[115] (RMA) is a program that has in the past funded agricultural job training programs serving veterans transitioning from the military into civilian life.

3) USDA Rural Development Fund[116] (RDF) is a program that funds community development projects in areas classified as non-urban. Under these criteria, Brunswick Landing qualifies as a rural area.

4) Small Business Administration (SBA) Loans[117] are loans provided to small businesses to assist them in the expansion of their business.

5) New Markets Tax Incentive Program[118] provides tax incentives to induce private sector investment in economically distressed communities. Initial discussions with consultants who specialize in New Market tax incentives indicate that there is a high possibility that Brunswick Landing would qualify for these tax incentives. These tax incentives would be in addition to the tax incentives already included in the financial calculations presented in this report.

14.19 Alternate Remediation Project

The existing remediation program currently in place at the site of the former BNAS is effectively treating the traces of solvents found in groundwater. While the system is effective, it also uses a tremendous amount of energy. Currently, the tainted groundwater is pumped up from the aquifer and treated with a mechanical "air stripping" system, which evaporates the solvent into the atmosphere thus using a great deal of electricity for fans in the process. A complimentary project could resolve two problems with one solution while also saving a huge amount of energy and money for the Navy. This project could take the water, which is already being pumped up from the aquifer, and use it to water bushy low-coppiced hybrid poplars grown in sealed growing

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114 http://www.nrcs.usda.gov/technical/cig/index.html. Accessed March 24, 2011.
115 http://www.rma.usda.gov/aboutrma/agreements/. Accessed March 24, 2011.
116 http://www.rurdev.usda.gov/Home.html. Accessed March 24, 2011.
117 http://www.sba.gov/category/navigation-structure/loans-grants Accessed July 25, 2011
118 http://www.novoco.com/new_markets/resources/maps_data.php Accessed Sept 18, 2011

containers. The powerful fungus growing in symbiosis with the roots of these plants have the ability to break down and remediate hydrocarbon substances into harmless elemental components. Fungus is now being used in collaborative research by Battelle for the Department of Homeland Security to break down pollutants such as relatives of Sarin nerve gas and biological agents such as small pox.[119] By utilizing this biological method as well as the natural transpiration of the plant, the water is cleaned and at the same time the growth of the tree is accelerated by having access to additional water to facilitate its growth. The process yields clean water and biomass,[120] as well as energy savings from the elimination of the fan energy. Occasionally the biomass could then be harvested, dried, and used to fuel the CHP system.

[119] Stamets, P. Mycelium Running 2005 Pg 36, 94,95, Ten Speed Press, Berkeley, California http://books.google.com/books?id=NPI8_-omzvsC&pg=PA94&lpg=PA94&dq=paul+stamets+sarin&source=bl&ots=39jw3X9mZN&sig=D3eTFbms46oA5KUi-tFq1E4_Gmo&hl=en&ei=OvORTZi8Joubtwel6rRy&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBgQ6AEwAA#v=onepage&q&f=false

[120] E.Aitchison, S. Kelley, P. Alvarez, J. Schnoor May/June 2000; 72,3 "Phytoremediation of 1,4- Dioxane by Hybrid Poplar Trees" *Water Environment Research*;

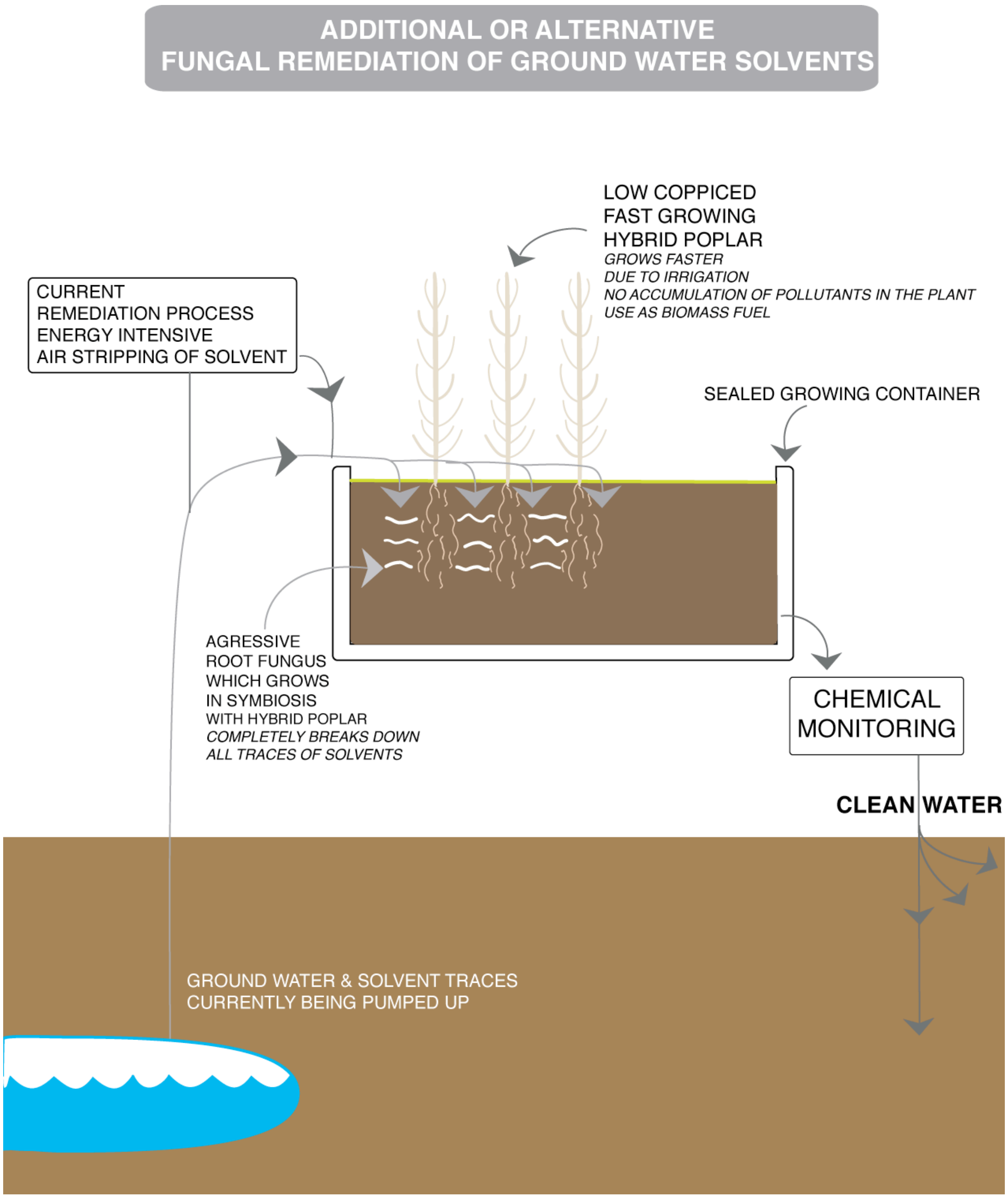

Figure 16. Optional phyto-remediation module. *Illustration by Colleen McCulla*

15 Additional Financing and Incentive Options

15.1 L3C Corporate Structure

The newly created L3C corporate structure[121], which will go into effect in Maine on July 1, 2011, allows newly created start-up (or low-profit) corporations to take money from non-profit foundations if the company's goals are in line with the foundation's mission. This could, for instance, be fostering the rebuilding of an economically distressed area, promoting environmentally sensitive energy growth, or sponsoring research in new technologies or medicines. The foundation must agree to a limited or low return, but will still be repaid instead of the money being an outright grant. This allows the foundation to give away its IRS-mandated 5% of its principle each year and yet still preserve some of that principle over time by getting it back. The company in return has new sources of funding opened up to it that it traditionally would not have access to. This funding can be especially valuable for lower return ventures like start-ups and can actually be used to buy-down the risk of a venture. Because these L3C companies can segment their investors, they could possibly give a lower return during start-up mode and then switch to giving a higher rate of return in order to get the kind of investments required for second phase funding. This may be a way for start-ups to possibly leap-frog the "funding valley of death" between proof-of-concept and reaching the $5 million threshold so common for venture capital financing nowadays.[122]

15.2 Other Mechanisms

The tax code allows the use of tax-exempt bonds by private sector developers even if backed by DOE guarantees. These tax-exempt bonds can also be used in combination with other incentives such as Treasury 1603 grants, PTC/ITC, and new market tax credits.

1) Clean Renewable Energy Bonds (CREBs): The federal government buys down the interest rate of the bond; no funding is currently in place but new funds could be announced at any time
2) Qualified Energy Conservation Bonds (QECBs): The federal government buys down the interest rate of the bond; no funding is currently in place but new funds could be announced at any time
3) Other bonds: Build America Bonds (BAB); Recovery Zone Bonds
4) Property Assessed Clean Energy (PACE): This method allows a municipality to issue land-secured (real estate) bonds to finance renewable energy projects done on these properties. Property owners are then allowed to pay off the bonds through their property taxes. It is not envisioned that this could be used at Brunswick Landing at this time.
5) Small Business Administration (SBA) – 7A loan, 90% loan guarantee, Small Business Innovative Research (SBIR) grants, and Small Business Technology Transfer (SBTT) programs: These programs may be accessed by the various companies that started up through MRRA's incubator. NREL has strong relationships within the small business administration's Washington office, which may be able to provide assistance with various projects and start-ups.

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[121] http://americansforcommunitydevelopment.org/downloads/What%20is%20the%20L3C%20080711-1.pdf
[122] http://americansforcommunitydevelopment.org/concept.php

15.3 State of Maine Incentives for Alternative Fuels

1) The State of Maine Office of Energy Independence and Security will issue a report on February 15, 2011, with recommendations for an alternative fuel incentive program.
2) The State of Maine Clean Vehicles Refueling Station Loan Fund, a revolving loan fund, may be used for direct loans and grants to support the production, distribution, and consumption of clean fuels and biofuels.
3) The Finance Authority of Maine may insure up to 100% of mortgage payments with respect to mortgage loans for clean fuel vehicle projects.

16 Conclusion

This analysis has found that a Biomass CHP system appears to be an attractive renewable energy opportunity which will not only pay for itself but which will also provide an opportunity to use the waste heat to attract new tenants to the existing buildings, and create new business and job opportunities at the former Brunswick Naval Air Station.

Initial analysis shows that leasing a Biomass CHP system over a 10 year period would provide free heat during that time which could be used to entice new tenants to the property as well as providing the cash flow to purchase the CHP system at the end of the lease. Many energy projects are financed over 15 or 20 years. These longer finance periods would provide additional positive cash flow for MRRA, property redeveloper at the former BNAS site.

Additional cashflow analyses can be run to allow MRRA to customize the project to suit their financial preferences closer to the time the project is implemented.

Appendix A. Information on Renewable Energy Certificates, Carbon Credits, and Green Claims

Renewable Energy Certificates

Retail Products

Renewable Energy Credits (RECs) are documentation provided by a certifying authority that certain standards have been met regarding the methods used to generate electricity promoted as being renewable. They may be sold by the entities generating the renewable power to other entities that want to offset their consumption of non-renewable energy sources. Sometimes this is done because a renewable energy generator is producing more power than they can use on their site or because (as is the case often with wind farms) the generation source is not associated with a particular energy-consuming site.

However, if a site sells all of its RECs, it cannot make any energy claims about its site.

Generally, a generator would want to first attempt to sell their certificates to utilities within their own state that are mandated by the Public Utility Commission (PUC) to obtain a certain percent of their electricity portfolio from renewable sources.

If all of the utilities in the state have met their portfolio requirement, the next place to attempt to sell the certificates is to other utilities in neighboring states, which are connected to the same independent operator's power pool. These utilities, however, may be subject to different, more stringent rules governing the specifics of the types of renewable energy projects and where they can be located. This is especially true related to biomass projects.

If none of these utilities are interested in purchasing the certificates, another buying source would be the private (or voluntary) market. This consists of private companies or individuals who have independently decided to offset their energy consumption of their own volition. Because these purchases are voluntary (not required as with the utilities), the selling price of certificates on this market are often lower than the prices obtained from utilities.

Table A-1 summarizes voluntary REC products available to retail customers nationally or regionally.

The potential income from selling possible earned credits has not been figured into any calculations in this report.

Company and product listings do not represent endorsement by either NREL or the DOE.

Table A-1. National Retail REC Products

National Retail REC Products (Last updated August 2010)					
Certificate Marketer	**Product Name**	**Renewable Resources**	**Location of Renewable Resources**	**Residential Price Premiums***	**Certification**
3 Phases Renewables	Green Certificates	100% biomass, geothermal, hydro, solar, wind	Nationwide	1.2¢/kWh	Green-e
3Degrees	Renewable energy certificates	100% new wind	Nationwide	1.5¢/kWh	Green-e
Native Energy	Cool Watts	100% new wind	Nationwide	0.8¢/kWh	Green-e
Native Energy	Remooable Energy	100% new biogas	Pennsylvania	0.8¢/kWh-1.0¢/kWh	***
Bonneville Environmental Foundation	Solar Green Tags	100% new solar	Nationwide	5.6¢/kWh	Green-e
Bonneville Environmental Foundation	Wind & Solar Green Tags Blend	50% new wind, 50% new solar	Nationwide	2.4¢/kWh	Green-e
Bonneville Environmental Foundation	Wind Green Tags	100% wind	Nationwide	2.0¢/kWh	Green-e
Bonneville Environmental Foundation	Denali Green Tags (Alaska only)	100% new wind	10% Alaska, 90% nationwide	2.0¢/kWh	Green-e
Bonneville Environmental Foundation	Zephyr Energy (Kansas Only)	50% new low-impact hydropower	Midwest, West	2.0¢/kWh	Green-e
Carbon Solutions Group	CSG Clean Build	biomass, biogas, wind, solar, hydro	Nationwide	0.9¢/kWh	Green-e
Carbonfund.org	*My* Green Future	99% new wind, 1% new solar	Nationwide	0.5¢/kWh	Green-e
Choose Renewables	Clean Watts	100% new wind	Nationwide	1.7¢/kWh	Green-e
Community Energy	New Wind Energy	100% new wind	Nationwide	2.5¢/kWh	Green-e
Good Energy	Good Green RECs	Various	Nationwide	0.4¢/kWh-1.5¢/kWh	Green-e
Green Mountain Energy	Be Green RECs	Wind, solar, biomass	Nationwide	1.4¢/kWh	—

Juice Energy	Positive Juice - Wind	100% wind	Nationwide	1.1¢/kWh	Green-e
MMA Renewable Ventures	PVUSA Solar Green Certificates	100% solar	California	3.3¢/kWh	Green-e
Maine Renewable Energy/Maine Interfaith Power & Light	Maine Wind Watts	100% new wind	Maine	2.0¢/kWh	Green-e
Mass Energy Consumers Alliance	New England Wind Fund	100% new wind	New England	~5.0¢/kWh (donation)	—
Premier Energy Marketing	Premier 100% Wind REC	100% wind	Nationwide	0.95¢/kWh-2.0¢/kWh	Green-e
Renewable Choice Energy	American Wind	100% new wind	Nationwide	0.5¢/kWh	Green-e
SKY energy, Inc.	Wind-e Renewable Energy	100% new wind	Nationwide	2.4¢/kWh	Green-e
Santee Cooper	SC Green Power	Landfill gas, solar	South Carolina	3.0¢/kWh	Green-e
Sky Blue Electric	Sky Blue 40	100% wind	Nationwide	4.2¢/kWh	Green-e
Sterling Planet	Sterling Wind	100% new wind	Nationwide	1.85¢/kWh	Green-e
Terra Pass	Green-e RECs	100% new wind	Nationwide	0.5¢/kWh	Green-e
Village Green Energy	Village Green Power	Solar, wind, biogas	California, nationwide	2.0¢/kWh-2.5¢/kWh	Green-e
Waverly Light & Power	Iowa Energy Tags	100% wind	Iowa	2.0¢/kWh	—
Wind Current	Chesapeake Windcurrent	100% new wind	Mid-Atlantic States	2.5¢/kWh	Green-e
Wind Street Energy	Renewable Energy Credit Program	Wind	Nationwide	~1.2¢/kWh	—

Notes:
* Product prices are updated as of August 2010. Premium may also apply to small commercial customers. Large users may be able to negotiate price premiums.
** Product is sourced from Green-e and ERT-certified RECs. ERT also certifies the entire product portfolio.
*** The Climate Neutral Network certifies the methodology used to calculate the carbon dioxide emissions offset.
NA = Not applicable.

Source: National Renewable Energy Laboratory

Greenhouse Gas Offsets

Retail Greenhouse Gas Offset Products

Table A-2 summarizes GHG offset products (also known as carbon credits or carbon offsets) available to retail customers nationally and derived at least in part from renewable energy generation projects.

If MRRA decides to advertise Brunswick Landing as being operationally carbon neutral, it could still sell some of the extra carbon credits it has yearly until Brunswick Landing is fully occupied. The list represents the range of prices that carbon credits are currently selling for.

The potential income from selling possible earned credits has not been figured into any calculations in this report.

Company and product listings do not represent endorsement by either NREL or the DOE.

Table A-2. Greenhouse Gas Offset Products

National Greenhouse Gas Offsets Retail Products (as of August 2010)					
Offset Marketer	**Product Name**	**Reduction Projects**	**Location of Projects**	**Residential Price Premiums***	**Certification**
3Degrees	Verified Emission Reductions	Methane capture, wind, forest management	Brazil, China, India	~$15	Gold Standard, Green-e, UNFCCC CDM, CA Climate Action Registry, VCS, CCX
Blue Source	Goldman Sachs and Blue Source Carbon Offsets	Methane capture, efficiency, carbon sequestration, industrial gas destruction	Nationwide	Commercial customers only	ERT
Bonneville Environmental Foundation	BEF Carbon Offsets	New wind, new solar, watershed restoration	Nationwide	~$29	Green-e
Carbonfund.org	Zero Carbon	Wind, methane capture, biomass, RECs, reforestation	Nationwide, Brazil	$10	CCX, ERT, Climate Community and Biodiversity Standards, UNFCCC JI

Clear Sky Climate Solutions	Carbon Offsets	Forestry/reforestation, methane capture, rangeland management	Panama, Wisconsin, Pennsylvania, Texas, Montana	$12	CCX, Climate Community and Biodiversity Standard
Colorado Carbon Fund	Project C	Local energy efficiency and renewable energy projects	Colorado	$20	—
Community Energy	Community Carbon Offsets	New wind	Nationwide	~$12	Green-e
Conservation Services Group	ClimateSAVE	New wind	Texas	~$21	Green-e
Dominion	Carbon Offset Program (NC customers only)	Energy conservation and renewable energy	North Carolina	~$17	—
Duke Energy	Carbon Offset Program (IN, SC, & NC customers only)	Energy conservation and renewable energy	North Carolina, South Carolina, Virginia	~$17	—
E-BlueHorizons	Carbon Offsets	Landfill gas (including efficiency and reforestation)	Massachusetts, New Hampshire	$5	CCX, ERT
EcoVoom	Clean Energy Credits	Hydro, wind (including efficiency and CO_2 offsets)	Nationwide	~$10	—
Element Markets	Verified Emission Reductions	Various (including methane capture, renewable energy, and energy efficiency)	Nationwide	Commercial customers only	Climate Action Reserve, CCX, VCS
GT Environmental Finance	Resource Carbon Reduction Projects	Landfill gas, biomass, renewable energy, forestry	Nationwide	Commercial customers only	Climate Action Reserve, VCS
Green Mountain Energy	BeGreen Carbon Offsets	Wind, biomass, reforestation	Nationwide	$14	—
Hess Corporation	Hess C-Neutral	Methane capture, renewable energy	Wyoming	Commercial customers only	VCS, Green-e
LightWind Energy	EndFossilFuel Carbon Offset	Various (including wind, solar, biomass, and geothermal)	Texas	$12	Green-e

LiveNeutral	Drive/Fly/HomeNeutral & By The Ton	Various (including efficiency and CO_2 offsets)	Nationwide	$12	CCX
Luminant Energy	Green House Gas Renewable Offsets	New wind	Texas	Commercial customers only	Green-e
NW Natural / Climate Trust	Smart Energy Average Option	Methane capture	Oregon	~$24	—
NW Natural / Climate Trust	Smart Energy Climate Neutral Option	Methane capture	Oregon	10.49¢/therm	—
NativeEnergy	Vintage Carbon Offsets	Methane capture	Connecticut	$15.43	ERT
NextEra Energy Resources	Carbon Offsets	Wind	Nationwide	Commercial customers only	Green-e
Pacific Gas and Electric	Climate Smart	Various local projects	California	$4.31/mo.	—
Progress Energy	Carbon Offset Program (NC customers only)	Energy conservation, renewable energy	North Carolina	~$20	—
Renewable Choice Energy	Bundled Wind and Carbon Offsets	Wind, landfill gas, methane capture, avoidance	Nationwide	~$6	ERT
Sacramento Municipal Utility District	Carbon Offset Program	Local carbon reduction projects	California	$10/month	—
Solar Electric Light Fund	Carbon Neutral Club	Global PV projects	International	$10 (donation)	—
Standard Carbon	Carbon Neutral Offsets	Methane capture, efficiency, renewables, carbon sequestration	Iowa	$15	CCX
Sterling Planet	Voluntary Carbon Units	Landfill gas	South Carolina	$20	VCS, Green-e
Sustainable Travel International	Carbon Offsets	Reforestation, biomass, hydro, wind	International	~$25	Green-e, Gold Standard, CDM, VCS, Plan Vivo and the Climate, Community and Biodiversity Alliance
Terra Pass Inc.	Terra Pass Carbon Offsets	Wind, biogas, methane capture	Nationwide	~$13.50	CCX, Green-e

The Carbon Neutral Company	The Carbon Neutral Company Offset	Methane capture, renewables	Brazil, China, Turkey	Commercial customers only	Green-e
VERUS Carbon Neutral	VERUS Carbon Neutral Certification	Biomass, methane capture, sequestration	Brazil, Georgia (U.S.)	$2.75	CCX

Notes:
* Product prices are all based on a metric ton of carbon dioxide avoided and were updated as of August 2010. Large users may be able to negotiate price premiums.
NA = Not applicable.

Primary Third-Party Certification

Environmental Resources Trust (ERT)
Climate Community and Biodiversity Standard (CCBS)
Green-e Climate
Voluntary Carbon Standard
Gold Standard
United Nations Framework Convention on Climate Change Clean Development Mechanism (UNFCCC CDM)
United Nations Framework Convention on Climate Change Joint Implementation (UNFCCC JI)

Appendix B. Financial Spreadsheet

Biomass 2MW Steam Turbine (Condensing)	Assumptions
Size of System Watts	2,000,000
Initial Cost Steam Turbine and Boiler Installed	$8,400,000
ESCO Profit percentage	19%
Cost Boiler & Turbine after ESCO Profit	$9,996,000
Cost Boiler & Turbine after ESCO and Incentives	$9,996,000
Federal Incentives (1603 cash grant)	0.0%
State Incent (none)	$0
Apportioned Pipeline Cost	$1,260,795
Apportioned Pipeline Cost after ESCO Profit	$1,500,346
Total Boiler Turbine & Pipe after ESCO and Incentives	**$11,496,346**
Percentage of total to be financed	**70.0%**
Loan on project	**$8,047,442**
Electrical Efficiency of unit	30%
MM Btu Fuel /Hr	22.753333
Nat Gas Produced Heat $/ MMBtu	$6.80
Wood Fuel Cost/MM Btu	$3.43
Fuel Cost for 24/7 Operation / Yr	$683,665
Fuel Escalation Rate	0.00%
Total Electricity produced (kwh)/Yr	17,520,000
Electricity sell rate $/kwh	$0.10
Electrical Sales Income Total per year	$1,752,000
Peak Heat Produced by this System MM Btu/Hr	15.927333
Peak Heat of Pipeline for Entire Campus MM Btu/Hr	53.009536
Heat Produced MMBtu/yr	139,523
Heat Needed MM Btu /Yr	84,020
Heat Usable MMBtu /(9 mo)	105,120
Heat Sell Price Discount vs Nat Gas	20%
% Heat Given Free	100%
Quantity Heat Given Free MM/Yr	105,120
Peak Heat Given Free MM Btu	15.927333
Heat Income $/ Yr	$0
REC rate quote Feb 2011 /MWh (Spectron) **Maine**	$7.00
Total REC Sales $/yr	$122,640
REC Escalation Rate	0%
O&M cost per KWH	$0.017
OM Escalation Rate	0.00%
Total O&M cost/yr	$297,840
Replacement Lifetime Yrs	40
Years of Analysis	20
Discount rate	0%
Corp Tax Rate	0%
Loan Interest Rate	4%
Simple Payback Yrs	**9.93**
Leveraged IRR	**10.34%**