

Preliminary Feasibility Study and Strategic Deployment Plan  
for  
Renewable and Sustainable Energy Projects

University of Connecticut

Storrs Campus, Mansfield CT



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The Connecticut Center for Advanced Technology, Inc<sup>1</sup> (CCAT) developed this Preliminary Feasibility Study and Strategic Deployment Plan for Renewable and Sustainable Energy Projects at the University of Connecticut (UConn) Storrs campuses through collaboration with many members of UConn's faculty and staff. Specifically, CCAT acknowledges the contributions of UConn's Office of Environmental Policy, the Center for Clean Energy Engineering, and Facilities Operations.



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<sup>1</sup> CCAT helps private and public entities to apply innovative tools and practices to increase efficiencies, improve workforce development and boost competitiveness. CCAT's Energy Initiative works to improve the economic competitiveness of the region by advancing community-supported solutions to reduce energy costs and increase reliability. As part of this goal, CCAT's Energy Initiative develops regional models for improved energy use, and helps to foster partnerships between industry, government and academia to promote renewable energy, hydrogen and fuel cell technology.

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## **Introduction**

This Preliminary Feasibility Study and Strategic Deployment Plan (Plan) for Renewable & Sustainable Energy Projects identifies and assesses target locations for the development of 12 demonstration-scale renewable and sustainable energy projects for the following technologies: solar thermal, solar photovoltaic, wind, fuel cells, geothermal, and biofuels. The development of renewable and sustainable energy projects at the University of Connecticut (UConn) at Storrs will facilitate 1) technology transfer and 2) collaborative research into green energy sources and smart storage; 3) reduce carbon dioxide (CO<sub>2</sub>) and other greenhouse gases (GHG);, and 4) integrate environmental principles into the student's learning experience. These clean and renewable energy technologies will reduce GHG emissions by displacing emissions associated with the use of fossil fuels for electric generation, thermal energy, and/or transportation. The deployment of renewable and sustainable energy technologies identified in this Plan is consistent with the implementation of "The University of Connecticut Climate Action Plan". Furthermore, this Plan compliments and expands upon the potential development opportunities for renewable and sustainable energy technologies identified within the Preliminary Feasibility Study and Strategic Plan for the Depot Campus.

## Executive Summary

This Plan was developed to address UConn's energy and environmental policy to:

- Reduce greenhouse gas (GHG) emissions;
- Support education and research interests
- Address economic viability, including first cost and return on investment; and
- Enhance community involvement.

This Plan specifically addresses the deployment of six renewable and sustainable energy technologies (solar thermal, solar photovoltaics (PV), wind energy, geothermal, fuel cell, and biomass) at 12 locations on the main and Depot Campuses, for the following buildings:

- |   |   |
|---|---|
| • Center for Clean Energy Engineering (Depot)       | • Information Technology Engineering Building |
| • Dairy Bar   | • Longley Building (Depot)                    |
| • Homer Babbidge Library                            | • North Campus (Field)                        |
| • Horsebarn Hill Sciences Complex Building #4 Annex | • Putnam Refectory                            |
| • Hollister Hall (Depot)                            | • Shippee Hall                                |
|   | • Thompson Hall                               |

The results of the analyses of the renewable and sustainable energy technologies at these locations provide opportunities to reduce GHG emissions and air pollutants through a reduction in fossil fuel use. The results also suggest opportunities to support education and research activities, and integrate environmental principles into the students' learning experience. The deployment sites that may provide the best opportunity for education and awareness based on access, use, and visibility include the following deployment clusters: 1) Center for Environmental Sciences and Engineering (Building #4 Annex), 2) the Center for Clean Energy Engineering (C2E2) and Longley Building, and 3) the Homer Babbidge Library and the Information Technology Engineering Building. In addition, the UConn Dairy Bar may be an excellent location to highlight a demonstration scale renewable energy technology because it attracts large numbers of students, faculty, and visitors year-round.

Based on the analyses, between approximately 5 tons and 9.5 tons of GHG emissions could be reduced using solar PV, wind, or passive solar thermal systems annually. Other high efficiency technologies, such as fuel cells and geothermal systems, can reduce fossil fuel use and GHG emissions associated with the production of electricity and/or thermal energy. Renewable energy in the form of biodiesel can be used in boilers and vehicles at UConn to reduce GHG emissions. In 2010, UConn consumed approximately 250,000 gallons of fuel oil for its oil fired boilers and transportation fleet. Currently, approximately 2-5 percent of the annual fuel requirement for UConn's bus system is supplemented with biodiesel. If 20 percent of UConn's annual diesel/fuel oil consumption (50,000 gallons) were displaced with locally produced biodiesel, UConn could reduce GHG emissions by approximately 400 tons, annually.

Demonstration-scale renewable energy technologies identified in this Plan are typically more expensive than conventional technologies. The larger the renewable energy system, the greater the first cost will be; however, larger systems may be more economical on a \$/kW basis than smaller systems of the same technology.



**Table 1- Summary of Renewable Energy Technologies, Costs, and Capacity**

<b>Technology</b>	<b>First Cost</b>	<b>Demonstration Scale Capacity</b>	<b>System Cost</b>
<b>Solar Thermal</b>	\$150 per Square Foot of Collector Area	32 – 700 Square Feet	\$5,000 - \$105,000
<b>Solar PV</b>	\$5,430/kW to	10 kW	\$54,000
<b>Wind</b>	\$6,800/kW	10 kW	\$68,000
<b>Fuel Cells</b>	\$5,500/kW to \$8,000/kW	100 - 400 kW	\$750,000 - \$2,700,000
	\$10,000/kW	5 kW	\$50,000
<b>Geothermal</b>	\$9,000 – 10,000 per ton	3.1 – 40 tons	\$28,000 - \$400,000

The consequence of these economics implies that most demonstration-scale renewable energy systems will not achieve a financial payback within the life of the system without incentives. This is especially the case at UConn’s main campus where a very efficient cogeneration facility can provide economical electricity and thermal energy to the buildings on campus that are connected to a steam loop. Furthermore, the availability of renewable energy resources, such as wind, may limit to some extent the amount of renewable energy that can be produced with existing renewable energy technologies.

Federal business investment tax credits and accelerated depreciation benefits assist in making demonstration-scale renewable energy systems economically viable within the life of certain renewable energy systems. Federal investment tax credits are currently available at 30 percent of the project cost and accelerated depreciation benefits may be monetized by a tax paying entity for eligible technologies consistent with current law. In addition to these federal incentives, additional incentives, such as an up front capital grant or a production payment may be necessary to achieve a financial payback within the life of certain renewable energy systems. With federal and state incentives, large fuel cell systems (>100 kW) may provide attractive opportunities to achieve a financial payback within the life of the system. In addition, a biodiesel production facility may be a financially attractive opportunity if it can be operated profitably, safely, and without impacting the character of the Depot Campus.

All demonstration scale renewable energy technologies evaluated provide opportunities for education, and academic and research involvement. As discussed above, the availability of renewable energy resources limits to some extent the amount of renewable energy that can be produced with existing renewable energy technologies and resources. However, with continued research, renewable energy systems such as solar PV or wind may achieve greater efficiency that would provide greater electrical or thermal output. In addition to increasing efficiency, the development of new less expensive materials or new production methods may reduce system costs to a point where demonstration-scale renewable energy systems are cost effective without federal or state incentives.

The deployment of renewable energy systems, as detailed in this Plan, could also support research efforts for power system planning, and integration of these technologies into a smart grid. Further, the deployment of a variety of renewable energy systems, such as solar PV, wind, and fuel cells, in close proximity to end users could also support research efforts to refine power conditioning.

Table 2 below provides a summary of the potential renewable energy technologies evaluated, and estimates of the potential annual renewable energy production and potential annual reductions of GHG emissions for the deployment sites assessed.

**Table 2 – Summary of Potential Renewable Energy Applications at the University of Connecticut at Storrs**

<b>Technology</b>	<b>Example Locations</b>	<b>Potential Renewable Energy Generation Capacity</b>	<b>Potential Annual Renewable Energy Production</b>	<b>Potential Annual Reductions of CO2 Emissions (Lbs)</b>
<b>Solar Thermal</b>	Dairy Bar	36 SQFT	≈6.8 MMBtu	≈995
	Shippee Hall	700 SQFT	≈130 MMBtu	≈18,837
	Hollister Hall	145 SQFT	≈27 MMBtu	≈3,896
	Putnam Refectory	530 SQFT	≈100 MMBtu	≈14,485
	Horsebarn Hill Sciences Complex Building #4 Annex	32 SQFT	≈6 MMBtu	≈889
<b>Solar PV</b>	Center for Clean Energy Engineering	10 kW	≈11,520 kWh	≈10,575
	Homer Babbidge Library	10 kW	≈11,520 kWh	≈10,575
	Horsebarn Hill Sciences Complex Building #4 Annex	10 kW	≈11,520 kWh	≈10,575
	Information Technology Engineering Building	10 kW	≈11,520 kWh	≈10,575
<b>Wind</b>	Homer Babbidge Library	10 kW	≈5,305 kWh	≈4,933
	North Campus	10 kW	≈5,305 kWh	≈4,933
	Longley Building (Depot Campus)	10 kW	≈5,305 kWh	≈4,933

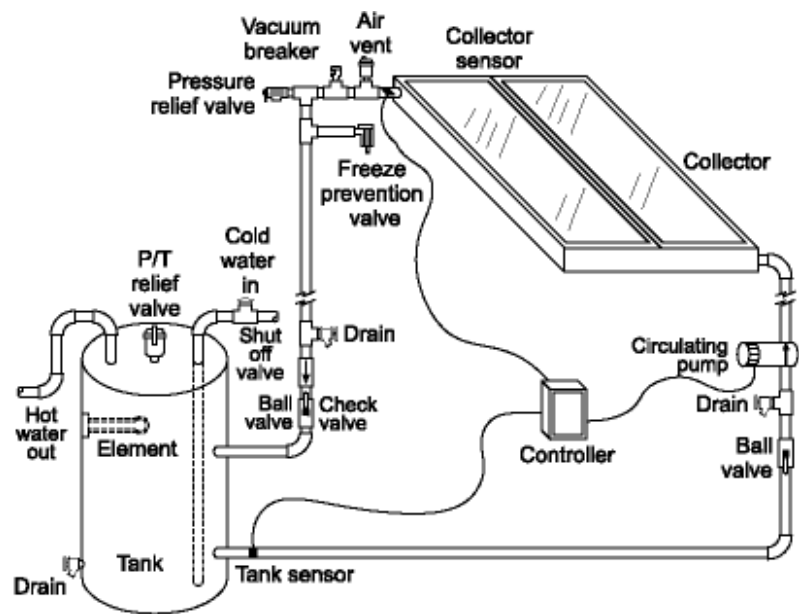
**Table 2 – Summary of Potential Renewable Energy Applications at the University of Connecticut at Storrs – Cont.**

<b>Technology</b>	<b>Example Locations</b>	<b>Potential Renewable Energy Generation Capacity</b>	<b>Potential Annual Renewable Energy Production</b>	<b>Potential Annual Reductions of CO2 Emissions (Lbs)</b>
<b>Fuel Cell</b>	Homer Babbidge Library	300- 400 kW	≈2.27 million – ≈3.25 million kWh	≈534,000 – ≈860,000
	Horsebarn Hill Sciences Complex Building #4 Annex	5 kW	≈39,000 kWh	≈14,300
	Information Technology Engineering Building	100 – 200 kW	≈0.85 million – ≈1.7 million kWh	≈72,000 – ≈144,000
<b>Geothermal</b>	Thompson Hall (Depot Campus)	40 Tons	≈1,017 MMBtu	≈60,875
	Horsebarn Hill Sciences Complex Building #4 Annex	3.1 Tons	≈106 MMBtu	≈5,200
<b>BioGas</b>	Center for Clean Energy Engineering	7 kW	TBD	TBD
<b>Biodiesel B100</b>	Longley Building (Depot Campus)	150,000 (Gallons per Year)	≈75,000 (Gallons per Year)	≈800,000 – ≈1.2 million

## SOLAR THERMAL

Solar thermal technology uses sunlight to capture thermal energy primarily for use in domestic hot water applications. Solar thermal systems typically consist of one or more solar thermal collectors, which heats water, and a storage tank. There are two types of solar thermal systems: active, which have circulating pumps and controls, and passive, which do not. Passive solar water heating systems are typically less expensive than active systems, but are less efficient. However, passive systems can be more reliable and may last longer. Solar thermal systems produce savings by reducing the amount of fossil fuel that would be consumed to produce thermal energy (Btus) for water heating.

Figure 1 - Solar Thermal System<sup>2</sup>



General siting criteria to consider when evaluating potential buildings/areas for the installation of a solar thermal system includes:

- Sites with sun exposure for 6-8 hours per day;
- Building/structure capable of supporting renewable energy equipment without significant reinforcing;
- Building/structure has flat roof or sufficient pitch and orientation to maximize solar potential;
- Building/structure area sufficiently large to support renewable energy equipment;
- Building/structure roof materials allow installation of renewable energy equipment and will not need to be replaced within the life of the renewable energy equipment; and
- Sites that utilize oil-fired boilers/furnaces to provide domestic hot water.

Solar thermal systems are best sized to function with existing thermal generation/storage infrastructure at a facility. While not necessarily financially attractive relative to other investment opportunities, solar thermal systems can achieve a payback within their useful life, but this is dependent upon the amount of thermal energy that is being displaced and the cost of fuel used to generate that thermal energy by conventional systems. Furthermore, solar thermal systems provide emissions reductions throughout the life of the system. Such reductions are also dependent upon the amount of thermal energy that is being displaced and the type of fuel used to generate that thermal energy by conventional systems.

<sup>2</sup>U.S. DOE, NREL, Sandia National Laboratories, "Solar Thermal Systems: Solar Heating R&D," <http://www.nrel.gov/docs/gen/fy04/36831m.pdf>, 2004

A summary of potential sites selected for detailed analysis is as follows:

**Table 3 – Summary of Solar Thermal Analysis**

<b>Building</b>	<b>Calculated Annual Energy Consumption (MMBtu)</b>	<b>Potential Renewable Energy Generation Capacity (SQFT)</b>	<b>Potential Annual Renewable Energy Production (MMBtu)</b>	<b>Potential Annual Reductions of CO2 Emissions (Lbs)</b>	<b>Percent of Hot Water Demand Served by Potential Renewable Energy System</b>
Dairy Bar (Ice Cream Production Only)	34.2	36	≈6.8	≈995	20%
Shippee Hall	1,314	700	≈130	≈18,837	10%
Hollister Hall	268.4	145	≈27	≈3,896	10%
Putnam Refectory	500	530	≈100	≈14,485	20%
Horsebarn Hill Sciences Complex Building #4 Annex	8.2	32	≈6	≈889	74%
<b>Total:</b>	<b>2,124.8 MMBtu</b>		<b>269.8 MMBtu</b>	<b>39,102 lbs/year</b>	

## UConn Dairy Bar

### **UConn Dairy Bar Site**

The UConn Dairy Bar, located at 3636 Horsebarn Hill Road Extension on the UConn main campus, is a food sales establishment that offers ice cream produced on-site.

### **Solar Thermal System Visibility**

In general, because solar thermal systems are deployed as roof mounted systems, their visibility by the public may be limited. However, the Dairy Bar is a two story building, which may make the solar collectors visible from adjacent buildings. Furthermore, if this site is selected for development, a monitoring display could be installed in the Dairy Bar lobby with details on the solar thermal system's rooftop location and performance data.

**Figure 2 - Aerial View of UConn Dairy Bar Site**



### **Domestic Hot Water Demand and Solar Thermal System Sizing**

Based on information provided by operating / production personnel, the Dairy Bar has a total annual clean-in-place (CIP) hot water consumption (for the ice cream manufacturing) of approximately 68,400 gallons using approximately 34.2 MMBtu of thermal energy for the calculated domestic hot water demand per year. As a demonstration project, the solar thermal system has been sized to provide approximately 20 percent or 6.8 MMBtu of the thermal energy for the calculated CIP hot water use. Based on a solar thermal system efficiency of 40 percent and the anticipated solar insolation for the Storrs area, the proposed solar thermal system's collector area would be approximately 36 square feet. An approximately 36 square foot solar thermal system could fit on the existing roof structure; however, a structural analysis of Dairy Bar has not been completed for this potential application.

## **Environmental Benefits of a Solar Thermal System**

Solar thermal systems create environmental benefits by displacing fossil fuels used to produce thermal energy. The UConn Dairy Bar site currently uses thermal energy produced from natural gas by the cogeneration system on campus. The proposed solar thermal system would produce 6.8 MMBtus of thermal energy per year. Because of efficiency losses from the cogeneration plant and the building heating distribution system, it is estimated that there may be a reduction of approximately 8.5 MMBtus of natural gas consumed for domestic hot water resulting in the following emissions reductions annually:<sup>3</sup>

- ≈0.782 lbs / year of NO<sub>x</sub>;
- ≈0.0051 lbs / year of SO<sub>2</sub>; and
- ≈995 lbs/year of CO<sub>2</sub>.

## **Regulatory Restrictions (Siting)**

There are no state regulatory restrictions on the installation and/or use of solar thermal systems. Solar thermal systems are not within the jurisdiction of the Connecticut Siting Council. The Town of Mansfield does not exercise jurisdiction over building improvements installed on UConn's Storrs campuses.<sup>4</sup>

## **Environmental Impacts and Permitting**

The operation of an approximately 36 square foot solar thermal system would not generate any noise, air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required. In addition, no adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern are anticipated.

## **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>5</sup> does not contain any information which would indicate a conflict with deploying a solar thermal system at this site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of PV systems at new facilities on campus.<sup>6</sup> Although mechanically there are significant differences between a solar thermal system that heats water and a PV system that produces electricity, they are very similar in appearance. A solar thermal system could be roof mounted; consequently, no land use impacts are anticipated.

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<sup>3</sup> EIA, "Natural Gas 1998: Issues and Trends – Chapter 2: Natural Gas and the Environment," [http://tonto.eia.doe.gov/pub/oil\\_gas/natural\\_gas/analysis\\_publications/natural\\_gas\\_1998\\_issues\\_trends/pdf/chapter2.pdf](http://tonto.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf), 1998

<sup>4</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

<sup>5</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>6</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

## **Capital Cost**

Typical costs for solar thermal systems approximate \$150 per square foot of solar thermal collector area. Consequently, a 36 square foot solar thermal system that could provide approximately 20 percent of the calculated CIP hot water consumption would have a capital cost of approximately \$5,430.<sup>7</sup>

## **Operation and Maintenance Cost**

Operation and maintenance costs for solar thermal systems are likely to be small. Maintenance of solar thermal systems is likely to involve periodic inspection of the collectors to ensure that vegetation isn't shading the collector area and that the collectors are clean; inspection of piping for potential fluid leaks; inspection of flashing and sealing around roof penetrations; inspection of nuts and bolts attaching the collectors to support structures; and inspection of the pressure relief valve for proper operation.<sup>8</sup>

## **Economics and Funding**

At present, solar thermal systems require public funding to subsidize system costs sufficiently to justify investment on a financial basis. Capital grants, federal business investment tax credits, and accelerated depreciation benefits are required to achieve a financial payback within the life of the system. However, because of the relatively small size and cost of a demonstration solar thermal project at the Dairy Bar, it is questionable if a third party private entity, which could monetize the tax credits and depreciation, will invest/develop such a project. A third party private entity may develop the potential Dairy Bar site if it were included in a coordinated and comprehensive build out with other solar thermal systems on the campuses at Storrs.

### *Analysis of Grant Funding for Financial Feasibility*

A solar thermal system installed at the UConn Dairy Bar would not achieve a financial payback within the projected life of the system without a capital grant. The primary drivers are the initial cost of the system and relatively low energy costs at the site. However, a solar thermal system could achieve a financial payback within the life of the system and an internal rate of return of 9.33 percent with a capital grant of \$5,054.

## **Site Orientation and Generation Loads**

An approximately 36 SQFT solar thermal system could be located on the roof of the UConn Dairy Bar, and could be oriented towards the south for optimal yield. Given the height of the roof area above ground level, the proximity and height of nearby vegetation, it is suggested that the solar thermal panels be located as on the northeast side of the building as close as possible to the water storage tank and oriented towards the south. Analysis of the site indicates that the site could support more than 36 square feet of solar thermal capacity; however, a structural analysis of Dairy Bar has not been completed for this potential application.

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<sup>7</sup> Solar thermal system may not include water storage tank and installation costs.

<sup>8</sup> U.S. DOE EERE, "Solar Heating Systems Maintenance and Repair,"

[http://www.energysavers.gov/your\\_home/water\\_heating/index.cfm/mytopic=12950](http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12950) , February 2011



## Shippee Hall

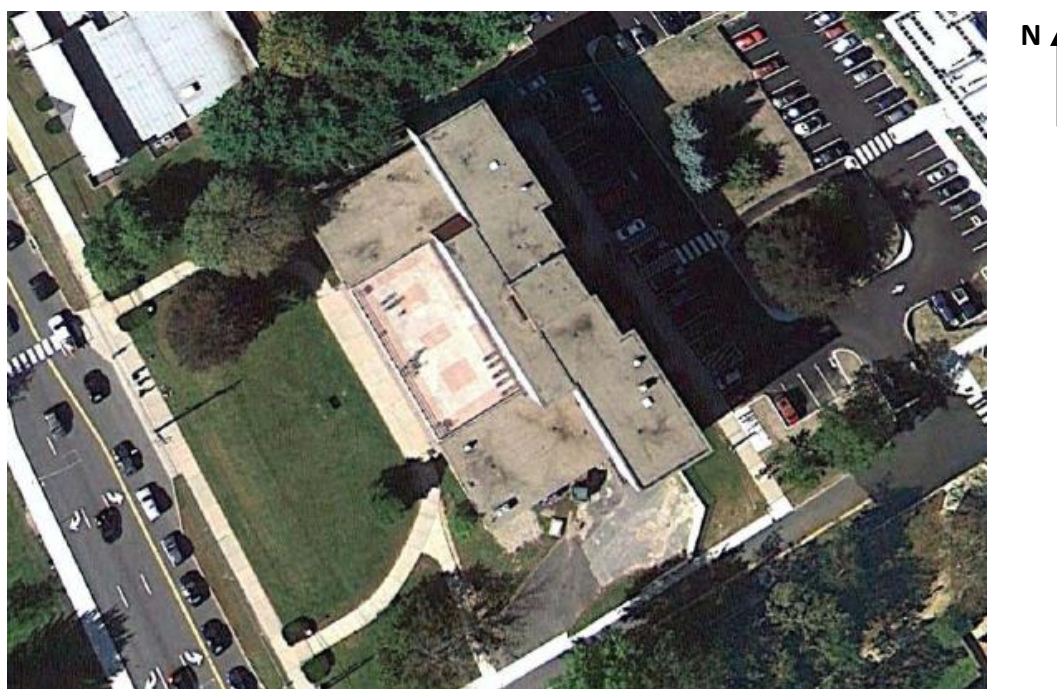
### **Shippee Hall Site**

The Lester E. Shippee Residence Hall (Shippee Hall), located at 1288 Storrs Road on the main campus at Storrs, is home to several Learning Communities, including the Fine Arts Learning Community and Connecting With the Arts Learning Community, as well as overflow housing for the Honors Community in Buckley Hall.<sup>9</sup> Shippee Hall currently houses approximately 300 residents. In addition, Shippee Hall has facilities for food preparation for catered functions.

### **Solar Thermal System Visibility**

In general, because solar thermal systems are deployed as roof mounted systems, their visibility by the public may be limited. However, if this site is selected, a monitoring display could be installed in the lobby with details on the solar thermal system's rooftop location and performance data.

**Figure 3 - Aerial View of Shippee Hall Site**



### **Domestic Hot Water Demand and Solar Thermal System Sizing**

As discussed above, Shippee Hall is used as both a residence hall and for the preparation of meals for catered functions. In order to calculate the domestic hot water demand for the residence hall, it is assumed that approximately 300 students will occupy the residence hall during the school year (late August through mid-May; 266 days), and that approximately 166 students (55 percent) will occupy this residence hall during the

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<sup>9</sup> University of Connecticut Residential Life, "Student Housing – Shippee," <http://reslife.uconn.edu/shippee.html>, March, 2012

summer session (Mid-May through late August; 99 days). In order to calculate the domestic hot water demand for the meal preparation, it is assumed that on average approximately 1,080 meals are prepared each day for catered functions during the school year, and approximately 540 meals are prepared each day for catered functions during the summer session for a total of approximately 340,000 meals per year.<sup>10</sup> It is estimated that the total domestic hot water demand for both the residents and meal preparation throughout the year is approximately two million gallons using 1,314 MMBtu of thermal energy for the calculated domestic hot water demand per year. The solar thermal system has been sized to provide approximately 10 percent or approximately 130 MMBtu of the thermal energy for the calculated annual domestic hot water demand. Based on a solar thermal system efficiency of 40 percent and the anticipated solar insolation for the Storrs area, the proposed solar thermal system's collector area would be approximately 700 square feet. An approximately 700 square foot solar thermal system could fit on the existing roof structure; however, a structural analysis of Shippee Hall has not been completed for this potential application.

### **Environmental Benefits of a Solar Thermal System**

Solar thermal systems create environmental benefits by displacing fossil fuels used to produce thermal energy. Shippee Hall currently uses thermal energy produced from natural gas by the cogeneration system on campus. The proposed solar thermal system would produce approximately 130 MMBtu of thermal energy per year. Because of efficiency losses from the cogeneration plant and the building heating distribution system, it is estimated that there may be a reduction of approximately 161 MMBtu of natural gas consumed for domestic hot water usage resulting in the following emissions reductions annually:<sup>11</sup>

- ≈14.81 lbs / year of NO<sub>x</sub> emissions;
- ≈0.097 lbs / year of SO<sub>2</sub> emissions; and
- ≈18,837 lbs/year of CO<sub>2</sub>.

### **Regulatory Restrictions (Siting)**

There are no state regulatory restrictions on the installation and/or use of solar thermal systems. Solar thermal systems are not within the jurisdiction of the Connecticut Siting Council. The Town of Mansfield does not exercise jurisdiction over building improvements installed on UConn's Storrs campuses.<sup>12</sup>

### **Environmental Impacts and Permitting**

The operation of an approximately 700 square foot solar thermal system would not generate any noise, air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required. In addition, no adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern are anticipated.

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<sup>10</sup> Information regarding occupancy and meal preparation provided by UConn on April 8, 2011.

<sup>11</sup> EIA, "Natural Gas 1998: Issues and Trends – Chapter 2: Natural Gas and the Environment," [http://tonto.eia.doe.gov/pub/oil\\_gas/natural\\_gas/analysis\\_publications/natural\\_gas\\_1998\\_issues\\_trends/pdf/chapter2.pdf](http://tonto.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf), 1998

<sup>12</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

## **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>13</sup> does not contain any information which would indicate a conflict with deploying a solar thermal system at this site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of PV systems at new facilities on campus.<sup>14</sup> Although mechanically there are significant differences between a solar thermal system that heats water and a PV system that produces electricity, they are very similar in appearance. A solar thermal system could be roof mounted; consequently, no land use impacts are anticipated.

## **Capital Cost**

Typical costs for solar thermal systems approximate \$150 per square foot of solar thermal collector area. Consequently, a 700 square foot solar thermal system that could provide approximately 10 percent of the calculated domestic hot water consumption for Shippee Hall would have a capital cost of approximately \$105,000.<sup>15</sup>

## **Operation and Maintenance Cost**

Operation and maintenance costs for solar thermal systems are likely to be small. Maintenance of solar thermal systems is likely to involve periodic inspection of the collectors to ensure that vegetation isn't shading the collector area and that the collectors are clean; inspection of piping for potential fluid leaks; inspection of flashing and sealing around roof penetrations; inspection of nuts and bolts attaching the collectors to support structures; and inspection of the pressure relief valve for proper operation.<sup>16</sup>

## **Economics and Funding**

At present, solar thermal systems require public funding to subsidize system costs sufficiently to justify investment on a financial basis. Capital grants, federal business investment tax credits, and accelerated depreciation benefits are required to achieve a financial payback within the life of the system. For the analyses detailed below, deployment is assumed to take place in 2012, thereby forfeiting the 2011, 100 percent accelerated depreciation monetization benefit. Instead, a 50 percent first year bonus depreciation monetization structure is assumed as provided under current law.<sup>17</sup>

Federal investment tax credits are currently available at 30 percent of the project cost and accelerated depreciation benefits can be monetized by the developer. Hence, the project economics of a solar thermal system would clearly be attractive if it were developed by a third party developer capable of garnering all of the available tax credits and accelerated depreciation benefits associated with renewable energy projects.

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<sup>13</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>14</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

<sup>15</sup> Solar thermal system may not include water storage tank and installation costs.

<sup>16</sup> U.S. DOE EERE, "Solar Heating Systems Maintenance and Repair," [http://www.energysavers.gov/your\\_home/water\\_heating/index.cfm/mytopic=12950](http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12950), February 2011

<sup>17</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

### *Analysis of Grant Funding for Financial Feasibility*

A solar thermal system installed at Shippee Hall would not achieve a financial payback within the projected life of the system without a capital grant, investment tax credits, and depreciation. The primary drivers are the initial cost of the system and relatively low energy costs at the site. However, a solar thermal system could achieve a financial payback within the life of the system, an internal rate of return of 9.3 percent, and a net present value of \$2,770 with a capital grant of \$61,250.<sup>18</sup>

### **Site Orientation and Generation Loads**

An approximately 700 square foot solar thermal system could be located on the roof of Shippee Hall, and could be oriented towards the south for optimal yield. Given the height of the roof area above ground level, the proximity and height of nearby buildings, and the lack of vegetation near Shippee Hall, no shading impacts are anticipated. Analysis of the site by UConn indicates that Shippee Hall has approximately 2,950 square feet of south facing roof area that could support approximately 700 square feet of solar thermal collectors; however, a structural analysis of Shippee Hall has not been completed for this potential application.

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<sup>18</sup> Assumes an installed cost of \$150/sqft or a total installed cost of \$105,000, a discount rate of seven percent, and receipt of all applicable tax credits and accelerated depreciation benefits.

## Hollister Hall

### **Hollister Hall Site**

Hollister Hall, located at 2016 Hillside Road on the main campus at Storrs, is part of the West Campus Residence Halls and was the first environmental learning community, "EcoHouse", which opened on the main campus in the Fall of 2009. Approximately 50 undergraduate students practice a more sustainable lifestyle together in Hollister Hall.<sup>19</sup>

### **Solar Thermal System Visibility**

In general, because solar thermal systems are deployed as roof mounted systems, their visibility by the public may be limited. However, Hollister Hall is a four story building, which may make the solar collectors visible from adjacent buildings. Furthermore, if this site is selected, a monitoring display could be installed in the lobby with details on the solar thermal system's rooftop location and performance data.

**Figure 4 - Aerial View of West Campus Residence Halls (Hollister Hall Site)**



### **Domestic Hot Water Demand and Solar Thermal System Sizing**

As discussed above, Hollister Hall is used as a residence hall. In order to calculate the domestic hot water demand for this residence hall, it is assumed that approximately 128 students will occupy this residence hall during the school year (late August through mid-May; 266 days), and that approximately 70 students (55

<sup>19</sup> Uconnhuskies.com, "Green Awareness Day," <http://www.uconnhuskies.com/ot/green-week.html>, March 2012



percent) will occupy this residence hall during the summer session (Mid-May through late August; 99 days). It is estimated that the total domestic hot water demand for the residents at Hollister Hall throughout the year is approximately 537,000 gallons using 268.4 MMBtu of thermal energy for the calculated domestic hot water demand per year. As a demonstration project, the solar thermal system has been sized to provide approximately 10 percent or 26.9 MMBtu of the thermal energy for the calculated annual domestic hot water demand. Based on a solar thermal system efficiency of 40 percent, and the anticipated solar insolation for the Storrs area, the proposed solar thermal system collector area would be approximately 145 square feet. An approximately 145 square foot solar thermal system could fit on the existing roof structure; however, a structural analysis of Hollister Hall has not been completed for this potential application.

### **Environmental Benefits of a Solar Thermal System**

Solar thermal systems create environmental benefits by displacing fossil fuels used to produce thermal energy. Hollister Hall currently uses thermal energy produced from natural gas by the cogeneration system on campus. The proposed solar thermal system would produce 26.9 MMBtu of thermal energy per year. Because of efficiency losses from the cogeneration plant and the building heating distribution system, it is estimated that there is a reduction of approximately 33.3 MMBtu of natural gas consumed for domestic hot water usage resulting in the following emissions reductions annually:<sup>20</sup>

- ≈3.06 lbs / year of NO<sub>x</sub>;
- ≈0.019 lbs / year of SO<sub>2</sub>; and
- ≈3,896 lbs/year of CO<sub>2</sub>.

### **Regulatory Restrictions (Siting)**

There are no state regulatory restrictions on the installation and/or use of solar thermal systems. Solar thermal systems are not within the jurisdiction of the Connecticut Siting Council. The Town of Mansfield does not exercise jurisdiction over building improvements installed on UConn's Storrs campuses.<sup>21</sup>

### **Environmental Impacts and Permitting**

The operation of an approximately 145 square foot solar thermal system would not generate any noise, air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required. In addition, no adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern are anticipated.

### **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>22</sup> does not contain any information which would indicate a conflict with deploying a solar thermal system at this site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of PV systems at new facilities

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<sup>20</sup>EIA, "Natural Gas 1998: Issues and Trends – Chapter 2: Natural Gas and the Environment," [http://tonto.eia.doe.gov/pub/oil\\_gas/natural\\_gas/analysis\\_publications/natural\\_gas\\_1998\\_issues\\_trends/pdf/chapter2.pdf](http://tonto.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf), 1998

<sup>21</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

<sup>22</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

on campus.<sup>23</sup> Although mechanically there are significant differences between a solar thermal system that heats water and a PV system that produces electricity, they are very similar in appearance. A solar thermal system could be roof mounted; consequently, no land use impacts are anticipated.

### **Capital Cost**

Typical costs for solar thermal systems approximate \$150 per square foot of solar thermal collector area. Consequently, a 145 square foot solar thermal system that could provide approximately 10 percent of the calculated domestic hot water consumption for Hollister Hall would have a capital cost of approximately \$21,750.<sup>24</sup>

### **Operation and Maintenance Cost**

Operation and maintenance costs for solar thermal systems are likely to be small. Maintenance of solar thermal systems is likely to involve periodic inspection of the collectors to ensure that vegetation isn't shading the collector area and that the collectors are clean; inspection of piping for potential fluid leaks; inspection of flashing and sealing around roof penetrations; inspection of nuts and bolts attaching the collectors to support structures; and inspection of the pressure relief valve for proper operation.<sup>25</sup>

### **Economics and Funding**

At present, solar thermal systems require public funding to subsidize system costs sufficiently to justify investment on a financial basis. Capital grants, federal business investment tax credits, and accelerated depreciation benefits are required to achieve a financial payback within the life of the system. For the analyses detailed below, deployment is assumed to take place in 2012, thereby forfeiting the 2011, 100 percent accelerated depreciation monetization benefit. Instead, a 50 percent first year bonus depreciation monetization structure is assumed as provided under current law.<sup>26</sup>

Federal investment tax credits are currently available at 30 percent of the project cost and accelerated depreciation benefits can be monetized by the developer. Hence, the project economics of a solar thermal system would clearly be attractive if it were developed by a third party developer capable of garnering all of the available tax credits and accelerated depreciation benefits associated with renewable energy projects.

#### *Analysis of Grant Funding for Financial Feasibility*

A solar thermal system installed at Hollister Hall would not achieve a financial payback within the projected life of the system without a capital grant, investment tax credits, and depreciation. The primary drivers are the initial cost of the system and relatively low energy costs at the site. However, a solar

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<sup>23</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

<sup>24</sup> Solar thermal system may not include water storage tank and installation costs.

<sup>25</sup> U.S. DOE EERE, "Solar Heating Systems Maintenance and Repair," [http://www.energysavers.gov/your\\_home/water\\_heating/index.cfm/mytopic=12950](http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12950), February 2011

<sup>26</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

thermal system could achieve a financial payback within the life of the system, an internal rate of return of 7.9 percent, and a net present value of \$233 with a capital grant of \$12,500.<sup>27</sup>

### **Site Orientation and Generation Loads**

An approximately 145 square foot solar thermal system could be located on the roof of Hollister Hall, and could be oriented towards the south for optimal yield. Given the height of the roof area above ground level, the proximity and height of nearby buildings, and the presence of vegetation near Hollister Hall, there may be some shading impacts. However, an analysis of the site indicates that Hollister Hall has approximately 5,500 square feet of roof area which could make locating the solar collectors in an area that is not impacted by shading feasible. A structural analysis of Hollister Hall has not been completed for this potential application.

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<sup>27</sup> Assumes an installed cost of \$150/sqft or a total installed cost of \$21,750, a discount rate of seven percent, and receipt of all applicable tax credits and accelerated depreciation benefits.



## Putnam Refectory

### **Putnam Refectory Site**

The Putnam Refectory (Putnam Hall), located on Alumni Drive on the main campus at Storrs, is a dining hall and home to the Hill Stop Grab & Go, which features made-to-order grinders and wraps. Putnam Hall is located adjacent to and serves meals for the residents of the Hilltop Residence Halls, which consist of two high-rise towers, Ellsworth and Hale Halls.

### **Solar Thermal System Visibility**

In general, because solar thermal systems are deployed as roof mounted systems, their visibility by the public may be limited. However, Putnam Hall is a two story building, which may make the solar collectors visible from ground level and adjacent buildings. Furthermore, if this site is selected, a monitoring display could be installed in the lobby with details on the solar thermal system's rooftop location and performance data.

**Figure 5 - Aerial View of the Putnam Hall Site**



### **Domestic Hot Water Demand and Solar Thermal System Sizing**

As discussed above, Putnam Hall is used for the preparation and serving of meals for two nearby residence halls. In order to calculate the domestic hot water demand for this dining hall, it is assumed that on average approximately 1,214 meals are prepared each day for approximately 343 days for a total of approximately 416,000 meals per year.<sup>28</sup> It is estimated that the total domestic hot water demand for the preparation and service of meals throughout the year is approximately one million gallons using 499.7 MMBtu of thermal energy for the calculated domestic hot water demand per year. As a demonstration project, the solar thermal system has been sized to provide approximately 20 percent or 100 MMBtu of the thermal energy for the calculated annual domestic hot water demand. Based on a solar thermal system efficiency of 40 percent and the anticipated solar

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<sup>28</sup> Information regarding meals preparation provided by UConn on January 5, 2012.

insolation for the Storrs area, the proposed solar thermal system collector area would be approximately 530 square feet. An approximately 530 square foot solar thermal system could fit on the existing roof structure; however, a structural analysis of Putnam Hall has not been completed for this potential application.

### **Environmental Benefits of a Solar Thermal System**

Solar thermal systems create environmental benefits by displacing fossil fuels used to produce thermal energy. Putnam Hall currently uses thermal energy produced from two natural gas fired boilers located in the building. The proposed solar thermal system would produce 100 MMBtu of thermal energy per year. Because of efficiency losses from the boilers, it is estimated that there is a reduction of approximately 124 MMBtu of natural gas consumed for domestic hot water usage resulting in the following emissions reductions annually:<sup>29</sup>

- ≈11.39 lbs / year of NO<sub>x</sub>;
- ≈0.074 lbs / year of SO<sub>2</sub>; and
- ≈14,485 lbs/year of CO<sub>2</sub>.

### **Regulatory Restrictions (Siting)**

There are no state regulatory restrictions on the installation and/or use of solar thermal systems. Solar thermal systems are not within the jurisdiction of the Connecticut Siting Council. The Town of Mansfield does not exercise jurisdiction over building improvements installed on UConn's Storrs campuses.<sup>30</sup>

### **Environmental Impacts and Permitting**

The operation of an approximately 530 square foot solar thermal system would not generate any noise, air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required. In addition, no adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern are anticipated.

### **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>31</sup> does not contain any information which would indicate a conflict with deploying a solar thermal system at this site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of PV systems at new facilities on campus.<sup>32</sup> Although mechanically there are significant differences between a solar thermal system that heats water and a PV system that produces electricity, they are very similar in appearance. A solar thermal system could be roof mounted; consequently, no land use impacts are anticipated.

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<sup>29</sup>EIA, "Natural Gas 1998: Issues and Trends – Chapter 2: Natural Gas and the Environment," [http://tonto.eia.doe.gov/pub/oil\\_gas/natural\\_gas/analysis\\_publications/natural\\_gas\\_1998\\_issues\\_trends/pdf/chapter2.pdf](http://tonto.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf), 1998

<sup>30</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

<sup>31</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>32</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

## Capital Cost

Typical costs for solar thermal systems approximate \$150 per square foot of solar thermal collector area. Consequently, a 530 square foot solar thermal system that could provide approximately 20 percent of the calculated domestic hot water consumption for Putnam Hall would have a capital cost of approximately \$79,500.<sup>33</sup>

## Operation and Maintenance Cost

Operation and maintenance costs for solar thermal systems are likely to be small. Maintenance of solar thermal systems is likely to involve periodic inspection of the collectors to ensure that vegetation isn't shading the collector area and that the collectors are clean; inspection of piping for potential fluid leaks; inspection of flashing and sealing around roof penetrations; inspection of nuts and bolts attaching the collectors to support structures; and inspection of the pressure relief valve for proper operation.<sup>34</sup>

## Economics and Funding

At present, solar thermal systems require public funding to subsidize system costs sufficiently to justify investment on a financial basis. Capital grants, federal business investment tax credits, and accelerated depreciation benefits are required to achieve a financial payback within the life of the system. For the analyses detailed below, deployment is assumed to take place in 2012, thereby forfeiting the 2011, 100 percent accelerated depreciation monetization benefit. Instead, a 50 percent first year bonus depreciation monetization structure is assumed as provided under current law.<sup>35</sup>

Federal investment tax credits are currently available at 30 percent of the project cost and accelerated depreciation benefits can be monetized by the developer. Hence, the project economics of a solar thermal system would clearly be attractive if it were developed by a third party developer capable of garnering all of the available tax credits and accelerated depreciation benefits associated with renewable energy projects.

### *Analysis of Grant Funding for Financial Feasibility*

A solar thermal system installed at Putnam Hall would not achieve a financial payback within the projected life of the system without a capital grant, investment tax credits, and depreciation. The primary drivers are the initial cost of the system and relatively low energy costs at the site. However, a solar thermal system could achieve a financial payback within the life of the system, an internal rate of return of 9.33 percent, and a net present value of \$2,133 with a capital grant of \$46,235.<sup>36</sup>

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<sup>33</sup> Solar thermal system may not include water storage tank and installation costs.

<sup>34</sup> U.S. DOE EERE, "Solar Heating Systems Maintenance and Repair,"

[http://www.energysavers.gov/your\\_home/water\\_heating/index.cfm/mytopic=12950](http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12950), February 2011

<sup>35</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012),"

[http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

<sup>36</sup> Assumes an installed cost of \$150/sqft or a total installed cost of \$79,500, a discount rate of seven percent, and receipt of all applicable tax credits and accelerated depreciation benefits.

### **Site Orientation and Generation Loads**

An approximately 530 square foot solar thermal system could be located on the roof of Putnam Hall, and could be oriented towards the south for optimal yield. Given the height of the roof area above ground level, the proximity and height of nearby buildings, and the lack of vegetation near Putnam Hall, no shading impacts are anticipated. An analysis of the site indicates that Putnam Hall has well over 2,000 square feet of south facing roof area on the southeast side of the building that could support approximately 530 square feet of solar thermal collectors; however, a structural analysis of Putnam Hall has not been completed for this potential application.

## **Horsebarn Hill Sciences Complex Building #4 Annex**

### **Horsebarn Hill Sciences Complex Building #4 Annex Site**

Building #4 Annex, located on Horsebarn Hill Road on the main campus at Storrs, is used by faculty and staff to promote multidisciplinary research, education and outreach in environmental sciences, engineering, policy, and sustainability.<sup>37</sup>

### **Solar Thermal System Visibility**

A solar thermal system could be deployed on the south facing roof of the Building #4 Annex building. Although the south facing side of Building #4 Annex building is not visible from the street, it may be visible from other locations on the main campus. In addition, if this site is selected, a monitoring display could be installed in the facility's lobby with details on the solar thermal system's location and performance data.

**Figure 6 - Aerial View of Horsebarn Hill Sciences Complex Building #4 Annex Site**



### **Domestic Hot Water Demand and Solar Thermal System Sizing**

As discussed above, Building #4 Annex is used by faculty and students for research and educational activities, as well as providing analytical services. In order to calculate the domestic hot water demand for Building #4 Annex, it is assumed that on average approximately 35 members of the faculty and staff utilizes the building approximately 250 days per year.<sup>38</sup> It is estimated that the total domestic hot water demand for hand washing and cleaning throughout the year is approximately 13,125 gallons using 8.2 MMBtu of thermal energy for the calculated domestic hot water demand per year. Approximately 32 square feet of solar thermal collector area

<sup>37</sup> University of Connecticut Center for Environmental Sciences and Engineering, <http://www.cese.uconn.edu/>, March 2012

<sup>38</sup> Information regarding meal preparation provided by UConn on January 10, 2012.

could provide approximately 74 percent or 6 MMBtu of the thermal energy for Building #4 Annex based on a solar thermal system efficiency of 40 percent and the anticipated solar insolation for the Storrs area. An approximately 32 square foot solar thermal system could fit on the existing roof structure however, a structural analysis of Building #4 Annex has not been completed for this potential application.

### **Environmental Benefits of a Solar Thermal System**

Solar thermal systems create environmental benefits by displacing fossil fuels used to produce thermal energy. Building #4 Annex currently uses thermal energy produced from natural gas by a boiler located in the building. The proposed solar thermal system would produce 6 MMBtu of thermal energy per year. Because of combustion efficiency losses from the boiler, it is estimated that there is a reduction of approximately 7.6 MMBtu of natural gas consumed for domestic hot water usage resulting in the following emissions reductions annually:<sup>39</sup>

- ≈0.7 lbs / year of NO<sub>x</sub>;
- ≈0.005 lbs / year of SO<sub>2</sub>; and
- ≈889 lbs/year of CO<sub>2</sub>.

### **Regulatory Restrictions (Siting)**

There are no state regulatory restrictions on the installation and/or use of solar thermal systems. Solar thermal systems are not within the jurisdiction of the Connecticut Siting Council. The Town of Mansfield does not exercise jurisdiction over building improvements installed on UConn's Storrs campuses.<sup>40</sup>

### **Environmental Impacts and Permitting**

The operation of an approximately 32 square foot solar thermal system would not generate any noise, air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required. In addition, no adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern are anticipated.

### **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>41</sup> does not contain any information which would indicate a conflict with deploying a solar thermal system at this site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of PV systems at new facilities on campus.<sup>42</sup> Although mechanically there are significant differences between a solar thermal system that heats water and a PV system that produces electricity, they are very similar in appearance. A solar thermal system could be roof mounted; consequently, no land use impacts are anticipated.

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<sup>39</sup>EIA, "Natural Gas 1998: Issues and Trends – Chapter 2: Natural Gas and the Environment," [http://tonto.eia.doe.gov/pub/oil\\_gas/natural\\_gas/analysis\\_publications/natural\\_gas\\_1998\\_issues\\_trends/pdf/chapter2.pdf](http://tonto.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf), 1998

<sup>40</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

<sup>41</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>42</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004



## **Capital Cost**

Typical costs for solar thermal systems approximate \$150 per square foot of solar thermal collector area. Consequently, a 32 square foot solar thermal system that could provide approximately 74 percent of the calculated domestic hot water consumption for Building #4 Annex would have a capital cost of approximately \$4,800.<sup>43</sup>

## **Operation and Maintenance Cost**

Operation and maintenance costs for solar thermal systems are likely to be small. Maintenance of solar thermal systems is likely to involve periodic inspection of the collectors to ensure that vegetation isn't shading the collector area and that the collectors are clean; inspection of piping for potential fluid leaks; inspection of flashing and sealing around roof penetrations; inspection of nuts and bolts attaching the collectors to support structures; and inspection of the pressure relief valve for proper operation.<sup>44</sup>

## **Economics and Funding**

At present, solar thermal systems require public funding to subsidize system costs sufficiently to justify investment on a financial basis. Capital grants, federal business investment tax credits, and accelerated depreciation benefits are required to achieve a financial payback within the life of the system. However, because of the relatively small size and cost of the demonstration solar thermal project at Building #4 Annex, it is questionable if a third party private entity, which could monetize the tax credits and depreciation, will invest/develop such a project. A third party private entity may develop the potential Building #4 Annex site if it were included in a coordinated and comprehensive build out with other solar thermal systems around the campus.

### *Analysis of Grant Funding for Financial Feasibility*

A solar thermal system installed at Building #4 Annex would not achieve a financial payback within the projected life of the system without a capital grant. The primary drivers are the initial cost of the system and relatively low energy costs at the site. However, a solar thermal system could achieve a financial payback within the life of the system and an internal rate of return of 3.83 percent with a capital grant of \$4,066.

## **Site Orientation and Generation Loads**

An approximately 32 square foot solar thermal system could be located on the roof of Building #4 Annex and could be oriented towards the south for optimal yield. Given the height of the roof area above ground level, the proximity and height of nearby buildings, and the lack of vegetation near the building, no shading impacts are anticipated. An analysis of the site indicates that the building has sufficient roof area on the south or west side of the Building #4 Annex to support approximately 32 square feet of solar thermal collectors; however, a structural analysis of buildings have not been completed for this potential application.

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<sup>43</sup> Solar thermal system may not include water storage tank and installation costs.

<sup>44</sup> U.S. DOE EERE, "Solar Heating Systems Maintenance and Repair," [http://www.energysavers.gov/your\\_home/water\\_heating/index.cfm/mytopic=12950](http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12950), February 2011

## SOLAR PHOTOVOLTAIC (PV)

Photovoltaic (PV) cells convert sunlight directly into electricity. There are now three generations of PV technologies available on the market: traditional PV cells are flat plates made from silicon; second generation PV cells, or “thin film” cells, which consist of layers of semiconductors only a few micrometers thick; and third generation PV cells made from a diverse set of materials, including solar inks, solar dyes, and conductive plastics. Typically, traditional PV cells are more expensive on a \$ / kW basis of installed capacity than second or third generation PV cells, but traditional PV cells have a higher efficiency.<sup>45</sup> This analysis assumed that traditional PV systems would be deployed at a capacity factor of 13.15 percent.

**Figure 7 - Solar PV<sup>46</sup>**



In general, PV systems are technically feasible in Connecticut anywhere adequate electrical interconnections and a sound building roof or secure ground mount area exist. The Department of Energy National Renewable Energy Laboratory (NREL's) PV Watts model reports a value of 4.35 kWh/M<sup>2</sup>/day of incident solar radiation in Mansfield, Connecticut. Typically, PV systems are engineered for the greatest average kWh output per year in order to

maximize the amount of electrical energy that can be net metered. Consequently, yields are optimized when the PV panels are mounted such that they face due south along an inclined plane. General siting criteria to consider when evaluating potential buildings for the installation of PV systems include:

- Sites with sun exposure for 6-8 hours per day;
- Building/structure capable of supporting renewable energy equipment without significant reinforcing;
- Building/structure has flat roof or sufficient pitch and orientation to maximize solar potential;
- Building/structure area sufficiently large to support renewable energy equipment
- Building/structure roof materials allow installation of renewable energy equipment and will not need to be replaced within the life of the renewable energy equipment; and
- Sites that have a daytime (peak) electric demand.

### Solar Related Research

UConn faculty is engaged in research for power electronics, energy conversion, renewable energy, and smart grid applications. This research is of high value to advance the commercial viability of energy

<sup>45</sup> National Renewable Energy Laboratory, “Learning About Renewable Energy,” [http://www.nrel.gov/learning/re\\_photovoltaics.html](http://www.nrel.gov/learning/re_photovoltaics.html), December 06, 2011

<sup>46</sup> Sandia National Laboratories; [http://www.sandia.gov/LabNews/ln02-10-12/pv\\_1260.jpg](http://www.sandia.gov/LabNews/ln02-10-12/pv_1260.jpg)



technologies, and has high value for student education. Further, this research can be conducted on demonstration scale applications.

Dr. Sung-Yeul Park is a professor of Electrical Engineering is primarily interested in implementing a power conditioning system that would integrate the electricity from a variety of alternative energy resources into one usable electrical output. Dr. Park's research goal is to increase efficiency, reliability and stability of these systems. Dr. Park is interested in pursuing two main venues: purchasing a commercial system and analyzing how it operates or designing and building a novel system and controlling certain aspects of its operational dynamics. Dr. Park would like to tie the systems use into his research and student education. To implement such a system, a variety of electricity-producing energy sources must be in near proximity. Moreover, Dr. Park might be interested in making a small, portable unit with micro-wind, micro-solar, fuel cells, conventional grid electricity attached to it that he could utilize a power conditioning system on. Dr. Park is already working with the smart grid/smart building group on campus.

Dr. Alexander G. Agrios, Assistant Professor, and Dr. Howard Epstein, Professor, both of UConn's Department of Civil & Environmental Engineering and Center for Clean Energy Engineering are working with SolarChange from Fairfield, CT. They are involved in a solar demonstration project which uses a solar concentrator approach to produce electricity and hot water. They have installed six roof top units (6' x 4' wide x 3' high) on the flat roof of the Cap Lab at the Depot Campus.

Dr. Zhang, Assistant Professor in UConn's Electrical & Computer Engineering Department, is interested in research areas that involve renewable and sustainable energy, integration of solar and wind energy conversion systems into smart grid systems, reliability evaluation of PV and wind farms, and power system planning and operation. Dr. Zhang has worked extensively on PV generation and has published several IEEE Transactions papers on PV power system reliability evaluation, modeling and control. Dr. Zhang has identified the PV power system as one of his main research areas, and has submitted several grant proposals about grid interconnection of PV systems.

Dr. Peter Luh, SNET Professor of Communications & Information Technologies at UConn's Department of Electrical & Computer Engineering, Dr. Sung-Yeul Park, Dr. Peng Zhang Dr. Alex Agrios, and Dr. Laurent Michel are members of a multidisciplinary research group working on integration of an ultra large PV farm into power systems.

A summary of potential sites selected for detailed analysis is as follows:

**Table 4 – Summary of Solar PV Analyses**

	<b>Building</b>	<b>Existing/Estimated Annual Energy Consumption (kWh)</b>	<b>Potential Renewable Energy Generation Capacity</b>	<b>Potential Annual Renewable Energy Production (kWh)</b>	<b>Potential Annual Reductions of CO2 Emissions (lbs)</b>	<b>Percent of Annual Electricity Demand Served by Potential Renewable Energy System</b>
Depot Campus	Center for Clean Energy Engineering (C2E2)	435,059 (2010)	10 kW	≈11,520	≈10,575	2.6%
Main Campus	Homer Babbidge Library	6,333,618 (2011)	10 kW	≈11,520	≈10,575	0.2%
	Horsebarn Hill Sciences Complex Building #4 Annex	321,467 (2011)	10 kW	≈11,520	≈10,575	3.6%
	Information Technology Engineering Building	2,224,985 (2011)	10 kW	≈11,520	≈10,575	0.5%
<b>Total:</b>			<b>40 kW</b>	<b>46,080 kWh</b>	<b>42,300 lbs/year</b>	

## Center for Clean Energy Engineering

### **Center for Clean Energy Engineering Site**

The Center for Clean Energy Engineering (C2E2), located at 44 Weaver Road on the Depot Campus at Storrs, engages in advanced technological research related to clean energy technologies. C2E2 has 16,000 square feet of laboratory and office space, equipment for prototype manufacturing, cell assembly, materials characterization, and fuel cell testing and diagnostics.

A 400 kW phosphoric acid fuel cell will be installed at the facility as a result of a grant from the American Recovery and Reinvestment Act of 2009. The installation of a 10 kW photovoltaic (PV) system in addition to the fuel cell will demonstrate C2E2's leadership in clean energy, and support academic interests for integrating clean energy technologies through a microgrid and/or smart grid. The facility is on the Depot Campus' master electrical meter; consequently, electricity produced at C2E2 can be utilized in other facilities on the Depot Campus.

### **Solar PV System Visibility**

The potential location for a 10 kW PV system is the south facing roof near the entrance to the facility (Figure 8), which would provide optimal orientation for system yield and would be in an area of high public visibility. If the site is selected a monitoring display could be installed in the facility's lobby to provide performance data for a 10 kW PV system.

**Figure 8 - Aerial View of the Center for Clean Energy Engineering**



## **Environmental Benefits of 10 kW PV System**

PV systems are an on-peak zero emissions renewable energy technology. As such, their avoided emissions benefits are equal to the on peak marginal emissions rate (lbs/MWh) of electric power within the region. The 2009 Calculated New England Marginal Emission Rates (lb/MWh) values are depicted in Appendix I. A 10 kW PV system located at the Depot Campus is expected to generate approximately 11,520 kWh per year, or 11.52 MWh. A 10 kW PV system could therefore result in the following emissions reductions annually:

- ≈1.95 to 2.19 lbs / year of NO<sub>x</sub>;<sup>47</sup>
- ≈2.76 lbs / year of SO<sub>2</sub>; and
- ≈10,575 lbs / year of CO<sub>2</sub>.

## **Regulatory Restrictions (Siting)**

There are no state regulatory restrictions on the installation and/or use of PV systems. Certificates of Environmental Compatibility and Public Need are not required for "...any customer-side distributed resources project or a facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts, as long as such project meets air and water quality standards of the Department of Environmental Protection..."<sup>48</sup> Consequently, a 10 kW PV system would be exempt from Siting Council regulations for an electric generation facility. In addition, the Town of Mansfield does not exercise jurisdiction over building improvements, such as for PV systems, installed on UConn's campuses at Storrs.<sup>49</sup>

## **Environmental Impacts and Permitting**

The operation of a 10 kW PV system would not generate any noise, air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required. In addition, no adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern are anticipated.

## **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2000 UConn Outlying Parcels Master Plan<sup>50</sup> does not contain any information which would indicate a conflict with deploying a PV system at this potential site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of PV systems at new facilities on campus.<sup>51</sup> The Green Depot Campus Initiative seeks to develop and demonstrate clean and

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<sup>47</sup> Based on a range of the on-peak ozone and non-ozone seasons

<sup>48</sup> Connecticut General Statutes, Sec. 16-50k

<sup>49</sup> Phone call with Mansfield Department of Building and Housing Inspection

<sup>50</sup> University of Connecticut, "Outlying Parcels Master Plan," [http://masterplan.uconn.edu/images/OPMP\\_5\\_22\\_2000.pdf](http://masterplan.uconn.edu/images/OPMP_5_22_2000.pdf), June 2000

<sup>51</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

efficient energy systems capable of using a multitude of conventional and renewable fuels.<sup>52</sup> A 10 kW PV system at C2E2 could be roof mounted; consequently, no land use impacts are anticipated.

### **Capital Cost**

A 10 kW PV system is anticipated to cost \$68,000, based on the average cost \$6.80/kw.<sup>53</sup> Actual project costs may be higher or lower.

### **Operation and Maintenance Cost**

Operations and maintenance cost is assumed to be 1.82 cents per kWh.<sup>54</sup> Actual maintenance may be higher or lower, depending on factors such as the weather and labor costs. Maintenance for PV systems is generally minimal because of the absence of moving parts; however, inspection of the system and components should be performed monthly to ensure system performance. A monitoring system could also be installed with a 10 kW PV system to measure system performance so that noticeable decreases in performance under similar conditions can be identified.<sup>55</sup>

### **Economics and Funding**

In general, recommended projects are configured as behind the meter applications with third party ownership.<sup>56</sup> This means that the electricity produced by the system would displace the retail value of energy used in the building. For PV systems funded through the Zero Emissions Renewable Energy Credit (ZREC) Program, a maximum payment of 38.5 cents per kWh<sup>57</sup> is possible for systems less than or equal to 100 kW. The economics of grid-connected PV systems providing wholesale power at this scale may be prohibitive. As such, this approach is not recommended in this deployment plan.

At present, PV systems require public funding to bring system costs down sufficiently to justify investment on a financial basis. Federal business investment tax credits and accelerated depreciation benefits are required to make a PV system economically viable within the life of the PV system. For the analyses detailed below, deployment is assumed to take place in 2012, thereby forfeiting the 2011, 100

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<sup>52</sup> University of Connecticut Climate Action Plan: Guiding the Path Towards Carbon Neutrality, "Section 5: Education, Research, & Outreach,"

[http://www.ecohusky.uconn.edu/pcc/documents/8\\_Section5\\_EducationOutreach.doc](http://www.ecohusky.uconn.edu/pcc/documents/8_Section5_EducationOutreach.doc), 2007

<sup>53</sup> Average based on PV systems installed through the Clean Energy Finance and Investment Authority's (CEFIA – formerly the Connecticut Clean Energy Fund) Onsite DG Program. Material provided by Christin A. Cifaldi; email from the Clean Energy Finance and Investment Authority (CEFIA), 10/24/2011.

<sup>54</sup> The estimate of operations and maintenance cost was based on NREL's estimate of maintenance costs (\$/kW/year) multiplied by the system size (kW) divided by the projected PV system output (kWh/year).

<sup>55</sup> California Energy Commission, "A Guide to Photovoltaic (PV) System Design and Installation,"

[http://www.energy.ca.gov/reports/2001-09-04\\_500-01-020.PDF](http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF), June 2001

<sup>56</sup> Projects on a master meter would fit this configuration as well

<sup>57</sup> Public Act 11-80 Section 108 b specifies that systems less than 100 kW will receive "the weighted average accepted bid price in the most recent solicitation for systems greater than one hundred kilowatts but less than two hundred fifty kilowatts, plus an additional incentive of ten per cent." As such, a ZREC incentive of \$.35/kWh is assumed plus an additional incentive of 10 percent of \$.35/kWh.

percent accelerated depreciation monetization benefit. Instead, a 50 percent first year bonus depreciation monetization structure is assumed as provided under current law.<sup>58</sup>

Federal investment tax credits are currently available at 30 percent of the project cost and accelerated depreciation benefits are monetized by a developer. Hence, the project economics of a 10 kW PV system would clearly be more attractive if it were developed by a third party developer capable of garnering all of the available tax credits and accelerated depreciation benefits associated with renewable energy projects.

#### *Zero Emissions Renewable Energy Credit Program (ZREC Program)*

An option for funding a PV system on the Depot Campus is to submit an application for funding for the upcoming ZREC incentive program created as part of Connecticut Public Act 11-80. This program is expected to begin in 2012 and will utilize a competitive performance based production incentive that would provide grants for actual energy produced based on a \$/MWh basis over a period of 15 years.

A 10 kW PV project for a large CL&P customer under October 2011 rates would achieve a positive cash flow for all years if a fifteen year finance period is selected to match the ZREC program incentive payment period at \$.385/kWh with an avoided electricity cost of 13.20 cents per kWh (a total energy value of \$.517/kWh). The project would have a nine year payback, an internal rate of return of 9.42 percent, and a net present value of \$6,449.<sup>59</sup>

#### **Site Orientation and Generation Loads**

A 10 kW PV system could be located on the south facing roof of C2E2 and could be oriented towards the south for optimal yield. Given the height of the roof area above ground level, the proximity and height of nearby buildings, and the lack of vegetation near C2E2, no shading impacts are anticipated. Analysis of the site using U.S. Department of Energy software indicates that the site could support more than 10 kW of PV capacity; however, a structural analysis of C2E2 has not been completed for this potential application.

A 10 kW PV system at C2E2 could produce 11,519 kWh/year with an estimated capacity factor of 13.15 percent. When combined, the electric output from the 10 kW PV system and the electric output from a 400 kW fuel cell (a 400 kW phosphoric acid fuel cell is estimated to produce 3,250,000 kWh per year, initially), are not expected to exceed the aggregate annual load of the Depot Campus (measured at approximately 4,500,000 kWh/year). Use of net metering will ensure that the full retail value of the electricity produced at C2E2 is captured by the project. This potential deployment site was also assessed in the Preliminary Feasibility Study and Strategic Plan for the Depot Campus.

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<sup>58</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

<sup>59</sup> Assumes an installed cost of \$6.80 per watt or a totaled installed cost of \$68,000, a discount rate of seven percent, and receipt of all applicable tax credits and accelerated depreciation benefits.

Potential sites that were analyzed for the deployment of 10 kW of PV capacity at the main campus at Storrs include the Homer Babbidge Library, the Horsebarn Hill Sciences Complex Building #4 Annex, and the Information Technology Engineering Building. Because a 10 kW PV system at any of the three potential deployment sites identified above would have very similar project characteristics, the environmental benefits, regulatory requirements, permitting, capital and maintenance costs, and project economics would be the same and are summarized below.

### **Homer Babbidge Library**

#### **Homer Babbidge Library Site**

The Homer Babbidge Library, located at 369 Fairfield Way on the main campus at Storrs, has the largest public collection of research in Connecticut and houses computer labs, instruction classrooms, digitizing and scanning services, tutor and writing services, the Map and Geographic Information Center, and the Roper Public Opinion archives.

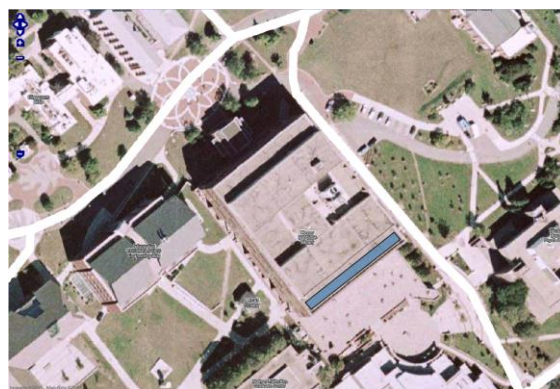
#### **Solar PV System Visibility**

The potential site where a 10 kW PV system could be deployed is located on the southeast side near the top of the Homer Babbidge Library (Figure 9 & Figure 9). As such, it would not be highly visible from ground level or from other areas of the campus. However, if the potential site is selected, a monitoring display could be installed in the Library's lobby with details on the PV system's location, orientation and performance data.

**Figure 9 - South Facing Roof Area of the Library**



**Figure 10 – Arial of Homer Babbidge Library**





## **Horsebarn Hill Sciences Complex Building #4 Annex**

### **Horsebarn Hill Sciences Complex Building #4 Annex Site**

Building #4 Annex, located on Horsebarn Hill Road on the main campus at Storrs, is used by faculty and staff to promote multidisciplinary research, education and outreach in environmental sciences, engineering, policy, and sustainability.<sup>60</sup>

### **PV Public Visibility**

The potential site where a 10 kW PV system could be deployed is on the south facing roof of Building #4 Annex. Although the south facing side of the Building #4 Annex is not visible from the street, it is visible from other locations on the main campus. In addition, if the potential site is selected, a monitoring display could be installed in the facility's lobby with details on the PV system's location, orientation and performance data.

**Figure 11 – Aerial View of Horsebarn Hill Sciences Complex Building #4 Annex**



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<sup>60</sup> University of Connecticut Center for Environmental Sciences and Engineering, <http://www.cese.uconn.edu/>, March 2012



## **Information Technology Engineering Building**

### **Information Technology Engineering Building Site**

The Information Technology Engineering (ITE) Building, located at 371 Fairfield Way at the main campus at Storrs, provides students and faculty in the School of Engineering with a 350-seat auditorium, research labs, administrative and faculty offices, and an atrium.

### **Solar PV System Visibility**

The potential site where a 10 kW photovoltaic (PV) system could be deployed is located on the southeast facing roof near the top of ITE Building. As such, it would be highly visible from ground level and from other areas of the main campus at Storrs. If the potential site is selected, a monitoring display could be installed in the facility's lobby with details on the PV's location, orientation, and performance data.

**Figure 12 – Aerial View of the ITE Building**



### **Environmental Benefits of 10 kW PV System**

PV systems are an on-peak zero emissions renewable energy technology. As such, their avoided emissions benefits are equal to the on peak marginal emissions rate (lbs/MWh) of electric power within the region. The 2009 Calculated New England Marginal Emission Rates (lb/MWh) values are depicted in Appendix I. A 10 kW PV system located at the Main Campus is expected to generate approximately 11,520 kWh per year, or 11.52 MWh. A 10 kW PV system at each of the potential sites at the main campus could therefore result in the following emissions reductions annually:

- $\approx 1.95$  to  $2.19$  lbs / year of  $\text{NO}_x$ ;<sup>61</sup>
- $\approx 2.76$  lbs / year of  $\text{SO}_2$ ; and
- $\approx 10,575$  lbs / year of  $\text{CO}_2$ .

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<sup>61</sup> Based on a range of the on-peak ozone and non-ozone seasons

## **Regulatory Restrictions (Siting)**

There are no state regulatory restrictions on the installation and/or use of PV systems. Certificates of Environmental Compatibility and Public Need are not required for "...any customer-side distributed resources project or a facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts, as long as such project meets air and water quality standards of the Department of Environmental Protection..."<sup>62</sup> Consequently, a 10 kW PV system would be exempt from Siting Council regulations for an electric generation facility. In addition, the Town of Mansfield does not exercise jurisdiction over building improvements, such as for PV systems, installed on UConn's campuses.<sup>63</sup>

## **Environmental Impacts and Permitting**

The operation of a 10 kW PV system would not generate any noise, air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required. In addition, no adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern are anticipated.

## **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>64</sup> does not contain any information which would indicate a conflict with deploying a PV system at this site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of PV systems at new facilities on campus.<sup>65</sup> A 10 kW PV system could be roof mounted; consequently, no land use impacts are anticipated.

## **Capital Cost**

A 10 kW PV system is anticipated to cost \$68,000, based on the average cost \$6.80/kw.<sup>66</sup> Actual project costs may be higher or lower.

## **Operation and Maintenance Cost**

Operations and maintenance cost is assumed to be 1.82 cents per kWh.<sup>67</sup> Actual maintenance may be higher or lower, depending on factors such as the weather and labor costs. Maintenance for PV systems is generally minimal because of the absence of moving parts; however, inspection of the system and components should be performed monthly to ensure system performance. A monitoring system could also

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<sup>62</sup> Connecticut General Statutes, Sec. 16-50k

<sup>63</sup> Phone call with Mansfield Department of Building and Housing Inspection

<sup>64</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>65</sup> University of Connecticut, "Campus Sustainable design Guidelines," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

<sup>66</sup> Average based on PV systems installed through the Clean Energy Finance and Investment Authority's (CEFIA – formerly the Connecticut Clean Energy Fund) Onsite DG Program. Material provided by Christin A. Cifaldi; email from the Clean Energy Finance and Investment Authority (CEFIA), 10/24/2011.

<sup>67</sup> The estimate of operations and maintenance cost was based on NREL's estimate of maintenance costs (\$/kW/year) multiplied by the system size (kW) divided by the projected PV system output (kWh/year).

be installed with a 10 kW PV system to measure system performance so that noticeable decreases in performance under similar conditions can be identified.<sup>68</sup>

## **Economics and Funding**

In general, recommended projects are configured as behind the meter applications with third party ownership.<sup>69</sup> This means that the electricity produced by the system would displace the retail value of energy used in the building. For PV systems funded through the ZREC program, a maximum payment of 38.5 cents per kWh<sup>70</sup> is possible for systems less than or equal to 100 kW. The economics of grid-connected PV systems providing wholesale power at this scale may be prohibitive. As such, this approach is not recommended in this deployment plan.

At present, PV systems require public funding to bring system costs down sufficiently to justify investment on a financial basis. Federal business investment tax credits and accelerated depreciation benefits are required to make a PV system economically viable within the life of the PV system. For the analyses detailed below, deployment is assumed to take place in 2012, thereby forfeiting the 2011, 100 percent accelerated depreciation monetization benefit. Instead, a 50 percent first year bonus depreciation monetization structure is assumed as provided under current law.<sup>71</sup>

Federal investment tax credits are currently available at 30 percent of the project cost and accelerated depreciation benefits are monetized by a developer. Hence, the project economics of a 10 kW PV system would clearly be more attractive if it were developed by a third party developer capable of garnering all of the available tax credits and accelerated depreciation benefits associated with renewable energy projects.

### *Zero Emissions Renewable Energy Credit Program (ZREC Program)*

An option for funding a PV system on the Depot Campus is to submit an application for funding for the upcoming ZREC incentive program created as part of Connecticut Public Act 11-80. This program is expected to begin in 2012 and will utilize a competitive performance based production incentive that would provide grants for actual energy produced based on a \$/MWh basis over a period of 15 years.

For each of the sites evaluated on the main campus at Storrs, a 10 kW PV project for a large CL&P customer under October 2011 rates would achieve a positive cash flow for all years if a fifteen year finance period is selected to match the ZREC program incentive payment period at \$.385/kWh with an avoided electricity cost of 11.35 cents per kWh (a total energy value of \$.4985/kWh). The project would have a nine year payback, an internal rate of return of 8.49 percent, and a net present value of \$3,864.<sup>72</sup>

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<sup>68</sup> California Energy Commission, "A Guide to Photovoltaic (PV) System Design and Installation," [http://www.energy.ca.gov/reports/2001-09-04\\_500-01-020.PDF](http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF), June 2001

<sup>69</sup> Projects on a master meter would fit this configuration as well

<sup>70</sup> Public Act 11-80 Section 108 b specifies that systems less than 100 kW will receive "the weighted average accepted bid price in the most recent solicitation for systems greater than one hundred kilowatts but less than two hundred fifty kilowatts, plus an additional incentive of ten per cent." As such, a ZREC incentive of \$.35/kWh is assumed plus an additional incentive of 10 percent of \$.35/kWh.

<sup>71</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

<sup>72</sup> Assumes an installed cost of \$6.80 per watt or a totaled installed cost of \$68,000, a discount rate of seven percent, and receipt of all applicable tax credits and accelerated depreciation benefits.

## **Site Orientation and Generation Loads**

A 10 kW PV system could be located on the south facing roof of the Homer Babbidge Library, the Horsebarn Hill Sciences Complex Building #4 Annex, and/or the ITE Building and could be oriented towards the south for optimal yield. Given the height of the roofs area above ground level, the proximity and height of nearby buildings, and the lack of vegetation near the buildings, no shading impacts for any of the sites are anticipated. Analysis of all three buildings using U.S. Department of Energy software indicates that the buildings could support more than 10 kW of PV capacity on the roofs of the buildings; however, a structural analysis of the Homer Babbidge Library, the Horsebarn Hill Sciences Complex Building #4 Annex, or the ITE Building has not been completed for these potential applications.

A 10 kW PV system at the Homer Babbidge Library, the Horsebarn Hill Sciences Complex Building #4 Annex, and/or the ITE Building could each produce 11,520 kWh/year with an estimated capacity factor of 13.15 percent. The potential buildings on UConn's main campus utilizes energy produced by a cogeneration system; consequently, actual system economics may be more challenging because UConn's avoided electric utility cost is most likely lower than it would be if it purchased power from the grid.

## Ground Mounted Systems

In situations where a building's remaining roof life and or structural integrity to support roof mounted systems is inadequate, ground mounted systems may be a possibility. Ground mounted systems are more accessible and easy to maintain, but may impact future land uses and may be subject to vandalism or theft. Ground mounted PV systems can be installed in a fixed position or with tracking, in order to maximize the system's productivity. Flat-plate PV panels in a fixed position have some advantages including lower cost and fewer moving parts. However, because PV panels installed in a fixed position do not adjust to variations in the sun's angle or movement throughout the day, the amount of electricity produced would be less than a tracking PV system. In some parts of the country, concentrating solar power (CSP) technologies use mirrors to reflect and concentrate sunlight which creates thermal energy that can then be used to produce electricity via a steam turbine or heat engine that drives a generator.

Estimates indicate that approximately four to six acres of land may be required to support the installation of 500 kW (DC) of ground mounted PV capacity. Since UConn owns more than 4,000 acres of land in the Town of Mansfield with a variety of undeveloped parcels, including the soon to be developed Technology Park on the north campus in Storrs, sufficient land area exists to accommodate a land-based solar array of this size. This system could provide energy for the Tech Park or could offset the anticipated energy demand from the Reclaimed Water Facility (approximately 500 kW). The Reclaimed Water Facility is currently under construction on the north campus and should be operational by the end of 2012.<sup>73</sup>

The installed cost for 500 kW (DC) of PV capacity is estimated to be approximately \$3.6 million, based on an estimated installed cost of \$7.28 / W.<sup>74</sup> UConn could enter into an Energy Services Agreement (ESA) type contract backed by state production incentives and/or federal incentive programs that could allow for the development of renewable energy projects with little to no upfront costs to the host site. Development of this type of project would align with the recommendations outlined in UConn's Climate Action Plan that include a commitment to renewable energy goals for the campus' energy supply and incorporation of alternative energy sources into new construction, thereby reducing UConn's carbon footprint.

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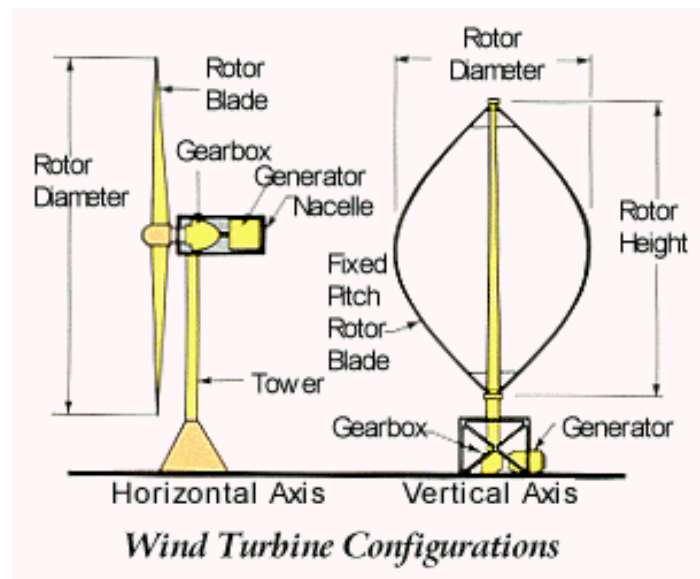
<sup>73</sup> Correspondence from UConn dated January 27, 2012.

<sup>74</sup> National Renewable Energy Laboratory, "The Open PV Project," <http://openpv.nrel.gov/>. November 18, 2009.

## SMALL SCALE WIND

All wind turbines function by capturing kinetic energy in the wind and turning it into mechanical power. Blades capture the wind over their swept area to turn a shaft, which connects to a generator to produce electricity.<sup>75</sup> Small wind systems typically range in size from 20 watts to 100 kW.<sup>76</sup> In general, the economics of small wind energy systems at the main or Depot Campuses at UConn may not be cost effective without financial support, including capital grants, tax credits, depreciation, and production incentives due to the suspected wind resources in the area.

**Figure 13 - Small Wind Systems<sup>77</sup>**



Small wind turbines can be separated into two basic types determined by orientation of the turbine. Wind turbines that rotate with a horizontal axis are more common, while vertical axis wind turbines are less frequently used for electric generation. A tower-mounted horizontal axis turbine system typically consists of a wind turbine, a guyed or self supporting tower, foundations for the tower and guy wires, tower guy wires, electrical grounding, electrical power meter or interconnection point. Most wind turbines currently in use are horizontal axis turbines. These systems typically take advantage of wind resources at a hub height of 30 meters (100 feet) or greater.<sup>78</sup>

The availability of wind resources is very important when siting wind turbines. The greater the wind resources, the more electricity can be generated per turbine rotor swept area. The available power in the wind is proportional to the cube of its speed, so if the average wind speed doubles from 4.5 meters/second to 9 meters/second, the power available to the wind generator increases by a factor of 8. The main and Depot Campuses at UConn are predominately within the upper limit of a Class I or lower limit of a Class II wind resource area. Class II wind resources at a 10 meter hub height (33 feet) are defined as having an average wind speed of 4.5 to 5.1 meters per second (9.8 – 11.5 miles per hour) or a wind power density of 100 watts per meter squared.<sup>79</sup>

Aside from the presence of adequate wind resources, technical considerations for mounting wind turbine systems include electric grid interconnection under various scenarios. Roof mounted systems may be the

<sup>75</sup> Energy Efficiency & Renewable Energy, "Wind Powering America,"

<http://www.windpoweringamerica.gov/windmaps/>, February 7, 2012

<sup>76</sup> NREL, "Small Wind Electric Systems," <http://www.nrel.gov/docs/fy07osti/42005.pdf>, 2002

<sup>77</sup> American Wind Energy Association; [http://archive.awea.org/faq/wwt\\_basics.html](http://archive.awea.org/faq/wwt_basics.html)

<sup>78</sup> EERE, Energy Basics, "Wind Turbines,"

[http://www.eere.energy.gov/basics/renewable\\_energy/wind\\_turbines.html](http://www.eere.energy.gov/basics/renewable_energy/wind_turbines.html), August 2011

<sup>79</sup> Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. National Renewable Energy Laboratory; <http://rredc.nrel.gov/wind/pubs/atlas/tables/1-1T.html>

least costly because the electrical interconnections are more readily available. Moreover, roof mounted systems also have the advantage of not requiring the use of additional land area to site the turbine. General criteria to consider when evaluating potential buildings for the installation of a small wind turbine system include:

- Sites that provide unobstructed wind resources; and
- Building/structure capable of supporting renewable energy equipment without significant reinforcing.

In addition, there are a few issues that are typically associated with the development of wind turbines: tower failures, noise, visibility, avian mortality, and ice throw. These concerns are usually attributed to large wind turbines and wind turbine farms; however, these concerns may also be raised during consideration of small wind systems, and must be addressed in a site specific manner.

*Turbine/Tower failures:* Turbines mounted on towers are engineered to withstand high winds. Proper installation and annual maintenance of a wind turbine/tower would reduce the likelihood of a tower failing. Several common reasons for tower failure include improper torque on guy line grip clips, improper guy line tensioning, improper guy line radii, improper anchor installation, improper torque on tower connections, and improper height of installed guy lines.<sup>80</sup>

*Noise:* Turbine and blade noise can be modeled to estimate noise levels for compliance with noise regulations at receptor sites for various land uses. Residential receptors typically have more stringent regulatory requirements than commercial or industrial receptors.

*Visibility:* Visibility can be modeled to determine the impact on the view shed and surrounding land uses during various times of the year. For educational purposes, potential sites that are visible from many locations would be favorable. However, the shadow caused by the sun on the rotating wind turbine rotors may cause a “flicker” shadow. The “flicker” shadow is usually caused when the sun is relatively low in the sky and behind the tower. The impact of flicker can be minimized with proper siting in a site specific manner.

*Avian Mortality* – the majority of the research conducted on avian mortality has focused on large wind turbines and wind turbine farms. It has been estimated that approximately two birds’ fatalities may result from avian collisions with a wind tower annually, which accounts for less than 0.01 percent of all anthropogenic avian fatalities annually.<sup>81</sup> Guyed towers, because of the presence of guy wires, are more likely to result in avian collisions than self supporting monopole towers.

*Icing:* When ice forms and builds up on the blades, the rotor will turn more slowly, which would reduce the danger of ice being thrown off.<sup>82</sup> To minimize potential problems with icing, the turbine rotors can be purchased with a black finish, heated elements, or braked to reduce the potential for ice throw. In addition, the tower/turbine can be located in an area that is inaccessible to pedestrians.

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<sup>80</sup> Installation Manual - BWC EXCEL Wind Turbine and Guyed-Lattice Towers, September 2011

<sup>81</sup> A Summary and Comparison of Bird Mortality from Anthropogenic Causes with an Emphasis on Collisions, Erickson et al, USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005.

<sup>82</sup> American Wind Energy Association, “Small Wind,” [http://archive.awea.org/smallwind/toolbox2/factsheet\\_public\\_safety.html](http://archive.awea.org/smallwind/toolbox2/factsheet_public_safety.html), March 2012

### Small Wind Related Research

The School of Engineering at UConn provides students with both classroom instruction and hands-on laboratory experience. As such, UConn is well suited to evaluate innovative wind turbine designs and applications on the main or Depot Campuses. For the purpose of assessing the economic and environmental benefits of small wind turbine systems, this analysis will evaluate a commercially available 10 kW horizontal axis wind turbine system.

A summary of potential sites selected for detailed analysis is as follows:

**Table 5 – Summary of Small Wind Analyses**

<b>Building</b>	<b>Existing/Estimated Annual Energy Consumption (kWh)</b>	<b>Potential Renewable Energy Generation Capacity</b>	<b>Potential Annual Renewable Energy Production (kWh)</b>	<b>Potential Annual Reductions of CO2 Emissions (lbs)</b>	<b>Percent of Annual Electricity Demand Served by Potential Renewable Energy System</b>
Homer Babbidge Library	6,333,618 (2011)	10 kW	≈5,305	≈4,933	0.8%
North Campus	N/A	10 kW	≈5,305	≈4,933	N/A
Longley Building (Depot Campus)	336,000 (Occupied)	10 kW	≈5,305	≈4,933	1.6%
<b>Total:</b>		<b>30 kW</b>	<b>15,915 kWh</b>	<b>14,799 lbs/year</b>	



## Homer Babbidge Library

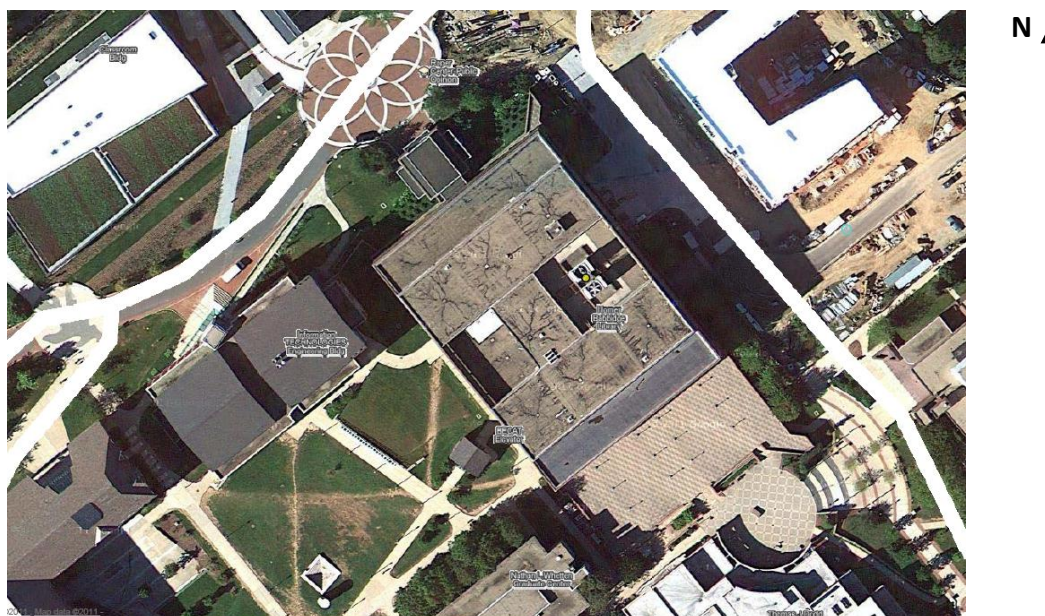
### **Homer Babbidge Library Site**

The Homer Babbidge Library, located at 369 Fairfield Way on the main campus at Storrs, has the largest public collection of research in Connecticut and houses computer labs, instruction classrooms, digitizing and scanning services, tutor and writing services, the Map and Geographic Information Center, and the Roper Public Opinion archives.

### **Small Wind System Visibility**

The potential site where a 10 kW small wind system could be deployed is on top of the building, located on the east/central portion of the roof area. It is anticipated that if the turbine is installed on a tower, approximately 10 meters above the roof, it would be visible from various locations on campus. Based on a visibility analysis, a wind turbine on a 10 meter tower on top of an approximately 60 foot tall building would be visible from approximately 37 percent of the land area within one mile of the Homer Babbidge Library (Figure 17).<sup>83</sup> Consequently, the Homer Babbidge Library may provide an excellent opportunity to increase awareness regarding the deployment of renewable technology on the main campus at Storrs.

**Figure 14 - Aerial View of Homer Babbidge Library Site**



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<sup>83</sup> Land area depicted in Figure 17 as having visibility of a 10 meter tower on top of the Babbidge Library may be affected by other buildings and vegetation at eye level.

## Environmental Benefits of a 10 kW Small Wind System

Small wind power systems are a zero emissions, renewable energy technology. As such, their avoided emissions benefits are equal to the annual average emissions rate (lbs/MWh) of electric power within the region. The 2009 Calculated New England Marginal Emission Rates (lb/MWh) values are depicted in Appendix I. A 10 kW small wind system located at the Storrs campuses is expected to generate 5,305 kWh per year, or 5.305 MWh. A 10 kW small wind system could therefore result in the following emissions reductions annually:

- ≈0.9 lbs / year of NO<sub>x</sub>;<sup>84</sup>
- ≈1.16 lbs / year of SO<sub>2</sub>; and
- ≈4,933 lbs / year of CO<sub>2</sub>.

## Regulatory Restrictions (Siting)

There are no state regulatory restrictions on the installation and/or use of small wind systems. Certificates of Environmental Compatibility and Public Need are not required for “...any customer-side distributed resources project or a facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts, as long as such project meets air and water quality standards of the Department of Environmental Protection...”<sup>85</sup> Consequently, a 10 kW small wind system would be exempt from Siting Council regulations for an electric generation facility. In addition, the Town of Mansfield does not exercise jurisdiction over building improvements, such as for wind systems, installed on UConn’s Storrs campuses.<sup>86</sup>

## Environmental Impacts and Permitting

The operation of a 10 kW small wind system would not generate any air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required.

A 10 kW turbine is expected to generate as much as 55 decibels of sound, which is approximately the same as a conversation between two people one meter apart.<sup>87,88</sup> According to Connecticut DEEP regulations (Sec. 22a-69-3.5 (b)), “No person in a Class B Noise Zone shall emit noise exceeding the levels stated herein and applicable to adjacent Noise Zones.”

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<sup>84</sup> Based on a range of the off-peak ozone and non-ozone seasons

<sup>85</sup> Connecticut General Statutes, Sec. 16-50k

<sup>86</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

<sup>87</sup> Canadian Centre for Occupational Health and Safety, “Noise – Basic Information,”

[http://www.ccohs.ca/oshanswers/phys\\_agents/noise\\_basic.html](http://www.ccohs.ca/oshanswers/phys_agents/noise_basic.html), January 9, 2006

<sup>88</sup> American Wind Energy Association, “Small Wind,”

[http://archive.awea.org/smallwind/toolbox2/factsheet\\_public\\_safety.html](http://archive.awea.org/smallwind/toolbox2/factsheet_public_safety.html), March 2012

The noise threshold for a Class B emitter to a receptor in any land use category is as follows:<sup>89</sup>

	<i><b>Class C Receptor</b></i>	<i><b>Class B Receptor</b></i>	<i><b>Class A Receptor/Day</b></i>	<i><b>Class A Receptor/Night</b></i>
<i><b>Class B Emitter</b></i>	62 dBA	62 dBA	55 dBA	45 dBA

While there are no residences proximate to the Homer Babbidge Library, detailed noise modeling may be necessary to avoid disruption/annoyance to students and/or faculty on campus.

According to available mapping, there are no Natural Diversity Data Base Areas, which represent known locations, both historic and extant, of state listed species and significant natural communities, identified at or immediately proximate to the Homer Babbidge Library. State listed species are those listed as Endangered, Threatened or Special Concern under the Connecticut Endangered Species Act (Connecticut General Statutes, Section 26-303).<sup>90</sup> Because the wind turbine could be installed on top of an existing building that is not designated as an historic building,<sup>91</sup> no adverse impacts on scenic resources or historic buildings are anticipated.

### **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>92</sup> does not contain any information which would indicate a conflict with deploying a small wind system at this site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of small wind systems at new facilities on campus.<sup>93</sup> The 10 kW small wind system could be roof mounted; consequently, no land use impacts are anticipated.

### **Capital Cost**

The average installed cost of small wind turbines sold in the U.S. in 2010 was \$5,430/kW.<sup>94</sup> A 10 kW small wind system is anticipated to cost approximately \$54,000, and would include the cost of the turbine,

<sup>89</sup> Connecticut Department of Energy and Environmental Protection, "Control of Noise," <http://www.ct.gov/dep/lib/dep/regulations/22a/22a-69-1through7.pdf>, March, 2012

<sup>90</sup> Natural Diversity Database Areas - July 2011, GIS Shapefile, Connecticut Department of Energy and Environmental Protection.

<sup>91</sup> Correspondence from Stacey S. Vairo, State and National Register Coordinator, Connecticut State Historic Preservation Office received November 1, 2011.

Department of Economic and Community Development (DECD)

<sup>92</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>93</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

<sup>94</sup> American Wind Energy Association, "2010 U.S. Small Wind Turbine Market Report," [http://www.awea.org/learnabout/smallwind/upload/AWEA\\_SmallWind\\_GMS2011Report\\_Final.pdf](http://www.awea.org/learnabout/smallwind/upload/AWEA_SmallWind_GMS2011Report_Final.pdf), 2010

inverter, guyed tower, tower wires, shipping, foundation and anchoring, wire run, turbine installation and tower erection, electrical hook-up, and inspection fees.<sup>95</sup>

### **Operation and Maintenance Cost**

Maintenance for small wind systems at this scale is likely to cost between \$200 and \$700 per year.<sup>96</sup> A maintenance cost of \$500 per year would equate to nine cents per kWh based on the expected output of a 10 kW small wind system at the main campus. This maintenance typically involves inspecting and tightening bolts and electrical connections, inspecting the machines for corrosion and the guy wires for tension, inspecting and replacing any worn leading edge tape on the turbine blades, replacing the turbine and/or bearings after 10 years.<sup>97</sup> A monitoring system could also be installed with a 10 kW small wind system to measure system performance so that noticeable decreases in performance under similar conditions can be identified.<sup>98</sup>

### **Economics and Funding**

In general, recommended projects are configured as behind the meter applications with third party ownership.<sup>99</sup> This means that the electricity produced by the system would displace the retail value of energy used in the building. For small wind systems funded through the ZREC program, a maximum payment of 38.5 cents per kWh<sup>100</sup> is possible for systems less than or equal to 100 kW. The economics of grid connected renewable distributed generation systems providing wholesale power at this scale may be prohibitive even with available incentives. As such, this approach is not recommended in this deployment plan.

At present, small wind systems require substantial public funding to justify investment on a financial basis. Capital grants, federal business investment tax credits, accelerated depreciation benefits, and a production incentive are required to make a small wind system economically viable within the life of the system. For the analyses detailed below, deployment is assumed to take place in 2012, thereby forfeiting the 2011, 100 percent depreciation monetization benefit. Instead, a 50 percent first year bonus depreciation monetization structure is assumed as provided under current law.<sup>101</sup>

Federal investment tax credits are currently available at 30 percent of the project cost and depreciation benefits can be monetized by the developer. Hence, the project economics of a 10 kW small wind system

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<sup>95</sup> Bergey.com, "Retail Price List," <http://production-images.webapeel.com/bergey/assets/2012/3/6/98837/PriceList-March.pdf>, March 2012

<sup>96</sup> American Wind Energy Association, "2010 U.S. Small Wind Turbine Market Report," [http://www.awea.org/learnabout/smallwind/upload/AWEA\\_SmallWind\\_GMS2011Report\\_Final.pdf](http://www.awea.org/learnabout/smallwind/upload/AWEA_SmallWind_GMS2011Report_Final.pdf), 2010

<sup>97</sup> U.S. DOE EERE, "Installing and Maintaining a Small Electric Wind System," [http://www.energysavers.gov/your\\_home/electricity/index.cfm/mytopic=10990](http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10990), February 9, 2011

<sup>98</sup> California Energy Commission, "A Guide to Photovoltaic (PV) System Design and Installation," [http://www.energy.ca.gov/reports/2001-09-04\\_500-01-020.PDF](http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF), June 2001

<sup>99</sup> Projects on a master meter would fit this configuration as well

<sup>100</sup> Public Act 11-80 Section 108 b specifies that systems less than 100 kW will receive "the weighted average accepted bid price in the most recent solicitation for systems greater than one hundred kilowatts but less than two hundred fifty kilowatts, plus an additional incentive of ten per cent." As such, a ZREC incentive of \$.35/kWh is assumed plus an additional incentive of 10 percent of \$.35/kWh.

<sup>101</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

would clearly be more attractive if it were developed by a third party developer capable of garnering all of the available tax credits and depreciation benefits associated with renewable energy projects.

#### *Pro Forma Analysis of Grant Funding for Financial Feasibility*

A 10 kW small wind system installed at the Homer Babbidge Library would not achieve a financial payback within the projected life of the system. The primary driver is the initial cost of the system and the lack of sufficient wind resources in the area. Estimates of system yields at a hub height of approximately 30 meters above ground level indicate that the system would have a capacity factor of approximately six percent. However, a 10 kW small wind system could achieve a four year financial payback, an internal rate of return of 10 percent, and a net present value of \$3,212 with a capital grant of \$23,000,<sup>102</sup> an installed cost of \$5.43 per watt, a ZREC of \$0.385/kWh for fifteen years, a discount rate of seven percent, and receipt of all applicable tax credits and depreciation benefits.

#### **Site Orientation and generation loads**

The small wind turbine system could be mounted on the roof of the Homer Babbidge Library. The top of the Homer Babbidge Library is taller than any adjacent building or vegetation; consequently, no obstruction of wind resources is anticipated.

A 10 kW small wind turbine system at Homer Babbidge Library could produce 5,305 kWh/year with an estimated capacity factor of six percent. The potential site on UConn's main campus utilizes energy produced by a cogeneration system; consequently, actual system economics may be more challenging because UConn's avoided electric utility cost is most likely lower than it would be if it purchased power from the grid. Because of the relatively small amount of electricity produced and the variable and intermittent nature of wind resources through the day and year, it is not anticipated that the operation of a 10 kW small wind turbine system would adversely impact the operation of the University's cogeneration facility.

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<sup>102</sup> Assumes an installed cost of \$5.43 per watt or \$54,300, a ZREC of \$0.385/kWh for fifteen years, a discount rate of seven percent, and receipt of all applicable tax credits and depreciation benefits.



## North Campus Site

### North Campus Site

The potential site at north campus would be located approximately 400 northeast of the Alan Busby Suites at 917 Tower Court Road on the main campus at Storrs and approximately 400 feet southwest of the UConn marching band practice field.

### Small Wind System Visibility

Based on a visibility analysis, a 30 meter (100 feet) tall tower and wind turbine would be visible from approximately 58.29 percent of the land area within one mile of the potential north campus site (Figure 18).<sup>103</sup> Consequently, the potential north campus site may provide an excellent opportunity to increase awareness regarding the deployment of renewable technology on the main campus at Storrs.

**Figure 15 -Aerial View of North Campus Site**



### Environmental Benefits of 10 kW Small Wind System

Small wind power systems are a zero emissions, renewable energy technology. As such, their avoided emissions benefits are equal to the annual average emissions rate (lbs/MWh) of electric power within the region. The 2009 Calculated New England Marginal Emission Rates (lb/MWh) values are depicted in Appendix I. A 10 kW small wind system located at the main campus is expected to generate 5,305 kWh per year, or 5.305 MWh. A 10 kW small wind system could therefore result in the following emissions reductions annually:

<sup>103</sup> Land area depicted in Figure 18 as having visibility of a 30 meter tower and wind turbine at the North Campus site may be affected by other buildings and vegetation at eye level.

- ≈0.9 lbs / year of NO<sub>x</sub>;<sup>104</sup>
- ≈1.16 lbs / year of SO<sub>2</sub>; and
- ≈4,933 lbs / year of CO<sub>2</sub>.

### Regulatory Restrictions (Siting)

There are no state regulatory restrictions on the installation and/or use of small wind systems. Certificates of Environmental Compatibility and Public Need are not required for "...any customer-side distributed resources project or a facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts, as long as such project meets air and water quality standards of the Department of Environmental Protection..."<sup>105</sup> Consequently, a 10 kW small wind system would be exempt from Siting Council regulations for an electric generation facility. In addition, the Town of Mansfield does not exercise jurisdiction over building improvements, such as for wind systems, installed on UConn's Storrs campuses.<sup>106</sup>

### Environmental Impacts and Permitting

The operation of a 10 kW small wind system would not generate any air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required.

A 10 kW turbine is expected to generate as much as 55 decibels of sound, which is approximately the same as a conversation between two people one meter apart.<sup>107,108</sup> According to Connecticut DEEP regulations (Sec. 22a-69-3.5 (b)), "No person in a Class B Noise Zone shall emit noise exceeding the levels stated herein and applicable to adjacent Noise Zones:". The noise threshold for a Class B emitter to a receptor in any land use category is as follows:<sup>109</sup>

	<i><b>Class C Receptor</b></i>	<i><b>Class B Receptor</b></i>	<i><b>Class A Receptor/Day</b></i>	<i><b>Class A Receptor/Night</b></i>
<i><b>Class B Emitter</b></i>	62 dBA	62 dBA	55 dBA	45 dBA

While there are no residences proximate to the North Campus Site, detailed noise modeling may be necessary to avoid disruption/annoyance to students and/or faculty on campus.

According to available mapping, there are no Natural Diversity Data Base Areas, which represent known locations, both historic and extant, of state listed species and significant natural communities, identified at

<sup>104</sup> Based on a range of the off-peak ozone and non-ozone seasons

<sup>105</sup> Connecticut General Statutes, Sec. 16-50k

<sup>106</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

<sup>107</sup> Canadian Centre for Occupational Health and Safety, "Noise – Basic Information,"

[http://www.ccohs.ca/oshanswers/phys\\_agents/noise\\_basic.html](http://www.ccohs.ca/oshanswers/phys_agents/noise_basic.html), January 9, 2006

<sup>108</sup> American Wind Energy Association, "Small Wind,"

[http://archive.awea.org/smallwind/toolbox2/factsheet\\_public\\_safety.html](http://archive.awea.org/smallwind/toolbox2/factsheet_public_safety.html), March 2012

<sup>109</sup> Connecticut Department of Energy and Environmental Protection, "Control of Noise,"

<http://www.ct.gov/dep/lib/dep/regulations/22a/22a-69-1through7.pdf>, March, 2012

or immediately proximate to the North Campus site. State listed species are those listed as Endangered, Threatened or Special Concern under the Connecticut Endangered Species Act (Connecticut General Statutes, Section 26-303).<sup>110</sup>

According to available mapping and information, there are no inland wetland soils, defined as "Any of the soil types designated as poorly drained, very poorly drained, alluvial, and floodplain by the National Cooperative Soil Survey, as may be amended from time to time, of the Natural Resources Conservation Service of the United States Department of Agriculture" at the potential north campus site.<sup>111</sup>

The potential north campus site is located in a cleared field, which has been used for agricultural production. The potential north campus site is located approximately 300 feet west of an 327-foot tower and an 80-foot tower, earth station dishes, and telecommunications shelters.<sup>112</sup> Because the wind turbine could be installed proximate to existing tower structures and there are no designated historic buildings on/near the potential north campus site, no adverse impacts on scenic resources or historic buildings are anticipated.

### **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>113</sup> does not contain any information which would indicate a conflict with deploying a small wind system at this site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of small wind systems at new facilities on campus.<sup>114</sup> The 10 kW small wind system could be deployed in an open field at the North Campus site; consequently, some open space could be unavailable for future development at or near the wind system site.

### **Capital Cost**

The average installed cost of small wind turbines sold in the U.S. in 2010 was \$5,430/kW.<sup>115</sup> A 10 kW small wind system at the North Campus site is anticipated to cost approximately \$54,000, and would include the cost of the turbine, inverter, guyed tower, tower wires, shipping, foundation and anchoring, wire run, turbine installation and tower erection, electrical hook-up, and inspection fees.<sup>116</sup>

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<sup>110</sup> Natural Diversity Database Areas - July 2011, GIS Shapefile, Connecticut Department of Energy and Environmental Protection.

<sup>111</sup> Inland Wetland Soils; GIS Shapefile, Connecticut Department of Energy and Environmental Protection. The original data was collected from published surveys from 1962 to 1981, field mapping from 1985 through 2001 and additional attribute documentation to 3/23/2007. GIS Shapefile, Connecticut Department of Energy and Environmental Protection. Wetlands/Watercourses/Waterbodies Map, Town of Mansfield Plan of Conservation and Development, April 2006.

<sup>112</sup> Docket 179 - Findings of Fact, Connecticut Siting Council, November 19, 1997.

<sup>113</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>114</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

<sup>115</sup> American Wind Energy Association, "2010 U.S. Small Wind Turbine Market Report," [http://www.awea.org/learnabout/smallwind/upload/AWEA\\_SmallWind\\_GMS2011Report\\_Final.pdf](http://www.awea.org/learnabout/smallwind/upload/AWEA_SmallWind_GMS2011Report_Final.pdf), 2010

<sup>116</sup> Bergey.com, "Retail Price List," <http://production-images.webapeel.com/bergey/assets/2012/3/6/98837/PriceList-March.pdf>, March 2012



## Operation and Maintenance Cost

Maintenance for small wind systems at this scale is likely to cost between \$200 and \$700 per year.<sup>117</sup> A maintenance cost of \$500 per year would equate to nine cents per kWh based on the expected output of a 10 kW small wind system at the main campus. This maintenance typically involves inspecting and tightening bolts and electrical connections, inspecting the machines for corrosion and the guy wires for tension, inspecting and replacing any worn leading edge tape on the turbine blades, replacing the turbine and/or bearings after 10 years.<sup>118</sup> A monitoring system could also be installed with a 10 kW small wind system to measure system performance so that noticeable decreases in performance under similar conditions can be identified.<sup>119</sup>

## Economics and Funding

In general, recommended projects are configured as behind the meter applications with third party ownership.<sup>120</sup> This means that the electricity produced by the system would displace the retail value of energy used in the building. For small wind systems funded through the ZREC program, a maximum payment of 38.5 cents per kWh<sup>121</sup> is possible for systems less than or equal to 100 kW. The economics of grid connected renewable distributed generation systems providing wholesale power at this scale may be prohibitive even with available incentives. As such, this approach is not recommended in this deployment plan.

At present, small wind systems require substantial public funding to justify investment on a financial basis. Capital grants, federal business investment tax credits, accelerated depreciation benefits, and a production incentive are required to make a small wind system economically viable within the life of the system. For the analyses detailed below, deployment is assumed to take place in 2012, thereby forfeiting the 2011, 100 percent depreciation monetization benefit. Instead, a 50 percent first year bonus depreciation monetization structure is assumed as provided under current law.<sup>122</sup>

Federal investment tax credits are currently available at 30 percent of the project cost and depreciation benefits can be monetized by the developer. Hence, the project economics of a 10 kW small wind system would clearly be more attractive if it were developed by a third party developer capable of garnering all of the available tax credits and depreciation benefits associated with renewable energy projects.

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<sup>117</sup> American Wind Energy Association, "2010 U.S. Small Wind Turbine Market Report," [http://www.awea.org/learnabout/smallwind/upload/AWEA\\_SmallWind\\_GMS2011Report\\_Final.pdf](http://www.awea.org/learnabout/smallwind/upload/AWEA_SmallWind_GMS2011Report_Final.pdf), 2010

<sup>118</sup> U.S. DOE EERE, "Installing and Maintaining a Small Electric Wind System," [http://www.energysavers.gov/your\\_home/electricity/index.cfm/mytopic=10990](http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10990), February 9, 2011

<sup>119</sup> California Energy Commission, "A Guide to Photovoltaic (PV) System Design and Installation," [http://www.energy.ca.gov/reports/2001-09-04\\_500-01-020.PDF](http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF), June 2001

<sup>120</sup> Projects on a master meter would fit this configuration as well

<sup>121</sup> Public Act 11-80 Section 108 b specifies that systems less than 100 kW will receive "the weighted average accepted bid price in the most recent solicitation for systems greater than one hundred kilowatts but less than two hundred fifty kilowatts, plus an additional incentive of ten per cent." As such, a ZREC incentive of \$.35/kWh is assumed plus an additional incentive of 10 percent of \$.35/kWh.

<sup>122</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

### *Analysis of Grant Funding for Financial Feasibility*

A 10 kW small wind system installed at the North Hillside site would not achieve a financial payback within the projected life of the system. The primary driver is the initial cost of the system and the lack of sufficient wind resources in the area. Estimates of system yields at a hub height of 30 meters above ground level indicate that the system would have a capacity factor of approximately six percent. However, a 10 kW small wind system could achieve a four year financial payback, an internal rate of return of 10 percent, and a net present value of \$3,212 with a capital grant of \$23,000.<sup>123</sup>

### **Site Orientation and Generation Loads**

Although the potential north campus site is high in elevation relative to the adjacent land and is used for agricultural production, adjacent vegetation may impact available wind resources. It is recommended that wind monitoring equipment be deployed at the potential north campus site prior to undertaking development of the 30 meter tower and 10 kW small wind turbine system to confirm the wind resources in the area.

A 10 kW small wind turbine system at the potential north campus site could produce 5,305 kWh/year with an estimated capacity factor of six percent. The electricity produced by the 10 kW small wind turbine system could be integrated with the electricity produced by the University's cogeneration system; consequently, actual system economics may be more challenging because UConn's avoided electric utility cost is most likely lower than it would be if it purchased power from the grid. Because of the relatively small amount of electricity produced and the variable and intermittent nature of wind resources through the day and year, it is not anticipated that the operation of a 10 kW small wind turbine system would adversely impact the operation of the University's cogeneration facility.

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<sup>123</sup> Assumes an installed cost of \$5.43 per watt or \$54,300, a ZREC of \$0.385/kWh for fifteen years, a discount rate of seven percent, and receipt of all applicable tax credits and depreciation benefits.

## Longley Building

### Longley Building Site

The Longley Building, located at 270 Middle Turnpike (Route 44) on the Depot Campus at Storrs is the location of the Connecticut Transportation Institute, and is also used for storage.

### Small Wind System Visibility

The potential site where a 10 kW small wind system could be deployed is on top of the Longley Building. It is anticipated that if the turbine is installed on a tower, approximately 10 meters above the roof of an approximately 40 foot tall building, it would be visible from various locations on the Depot Campus. Based on a visibility analysis, a wind turbine 70 feet above ground level would be visible from approximately 32.15 percent of the land area within one mile of the Longley Building (Figure 19).<sup>124</sup> Consequently, the Longley site may provide an excellent opportunity to increase awareness regarding the deployment of renewable technology on the Depot Campus at Storrs.

**Figure 16 - Aerial View of Longley Building Site**



<sup>124</sup> Land area depicted in Figure 19 as having visibility of a 100 foot tall turbine at the North Campus site may be affected by other buildings and vegetation at eye level.

## Environmental Benefits of a 10 kW Small Wind System

Small wind power systems are a zero emissions, renewable energy technology. As such, their avoided emissions benefits are equal to the annual average emissions rate (lbs/MWh) of electric power within the region. The 2009 Calculated New England Marginal Emission Rates (lb/MWh) values are depicted in Appendix I. A 10 kW small wind system located at the Depot Campus is expected to generate 5,305 kWh per year, or 5.305 MWh. A 10 kW small wind system could therefore result in the following emissions reductions annually:

- ≈0.9 lbs / year of NO<sub>x</sub>;<sup>125</sup>
- ≈1.16 lbs / year of SO<sub>2</sub>; and
- ≈4,933 lbs / year of CO<sub>2</sub>.

## Regulatory Restrictions (Siting)

There are no state regulatory restrictions on the installation and/or use of small wind systems. Certificates of Environmental Compatibility and Public Need are not required for “...any customer-side distributed resources project or a facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts, as long as such project meets air and water quality standards of the Department of Environmental Protection...”<sup>126</sup> Consequently, a 10 kW small wind system would be exempt from Siting Council regulations for an electric generation facility. In addition, the Town of Mansfield does not exercise jurisdiction over building improvements, such as for wind systems, installed on UConn’s Storrs campuses<sup>127</sup>

## Environmental Impacts and Permitting

The operation of a 10 kW small wind system would not generate any air emissions, or wastewater effluents; consequently, no air emission or wastewater discharge permits are required.

A 10 kW turbine is expected to generate as much as 55 decibels of sound, which is approximately the same as a conversation between two people one meter apart.<sup>128,129</sup> According to Connecticut DEEP regulations (Sec. 22a-69-3.5 (b)), “No person in a Class B Noise Zone shall emit noise exceeding the levels stated herein and applicable to adjacent Noise Zones.”

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<sup>125</sup> Based on a range of the off-peak ozone and non-ozone seasons

<sup>126</sup> Connecticut General Statutes, Sec. 16-50k

<sup>127</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

<sup>128</sup> Canadian Centre for Occupational Health and Safety, “Noise – Basic Information,”

[http://www.ccohs.ca/oshanswers/phys\\_agents/noise\\_basic.html](http://www.ccohs.ca/oshanswers/phys_agents/noise_basic.html), January 9, 2006

<sup>129</sup> American Wind Energy Association, “Small Wind,”

[http://archive.awea.org/smallwind/toolbox2/factsheet\\_public\\_safety.html](http://archive.awea.org/smallwind/toolbox2/factsheet_public_safety.html), March 2012

The noise threshold for a Class B emitter to a receptor in any land use category is as follows:<sup>130</sup>

	<b><i>Class C Receptor</i></b>	<b><i>Class B Receptor</i></b>	<b><i>Class A Receptor/Day</i></b>	<b><i>Class A Receptor/Night</i></b>
<b><i>Class B Emitter</i></b>	62 dBA	62 dBA	55 dBA	45 dBA

While there are no residences proximate to the Longley Building, detailed noise modeling may be necessary to avoid disruption/annoyance to students and/or faculty on campus.

According to available mapping, there are no Natural Diversity Data Base Areas, which represent known locations, both historic and extant, of state listed species and significant natural communities, identified at or immediately proximate to the North Campus site. State listed species are those listed as Endangered, Threatened or Special Concern under the Connecticut Endangered Species Act (Connecticut General Statutes, Section 26-303).<sup>131</sup> Because the wind turbine could be installed on top of an existing building that is not designated as an historic building,<sup>132</sup> no adverse impacts on scenic resources or historic buildings are anticipated.

#### **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2000 UConn Outlying Parcels Master Plan<sup>133</sup> does not contain any information which would indicate a conflict with deploying a small wind system at this potential site. The 2004 Sustainable Design Guidelines of the Master Plan specifies examining the application and economic feasibility of small wind systems at new facilities on campus.<sup>134</sup> The Green Depot Campus Initiative seeks to develop and demonstrate clean and efficient energy systems capable of using a multitude of conventional and renewable fuels.<sup>135</sup> A 10 kW small wind system at Longley Building could be roof mounted; consequently, no land use impacts are anticipated.

#### **Capital Cost**

The average installed cost of small wind turbines sold in the U.S. in 2010 was \$5,430/kW.<sup>136</sup> A 10 kW small wind system at Longley is anticipated to cost approximately \$54,000, and would include the cost of

<sup>130</sup> Connecticut Department of Energy and Environmental Protection, "Control of Noise," <http://www.ct.gov/dep/lib/dep/regulations/22a/22a-69-1through7.pdf>, March, 2012

<sup>131</sup> Natural Diversity Database Areas - July 2011, GIS Shapefile, Connecticut Department of Energy and Environmental Protection.

<sup>132</sup> Correspondence from Stacey S. Vairo, State and National Register Coordinator, Connecticut State Historic Preservation Office received November 1, 2011.

Department of Economic and Community Development (DECD)

<sup>133</sup> University of Connecticut, "Outlying Parcels Master Plan," [http://masterplan.uconn.edu/images/OPMP\\_5\\_22\\_2000.pdf](http://masterplan.uconn.edu/images/OPMP_5_22_2000.pdf), June 2000

<sup>134</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

<sup>135</sup> University of Connecticut Climate Action Plan: Guiding the Path Towards Carbon Neutrality, "Section 5: Education, Research, & Outreach,"

[http://www.ecohusky.uconn.edu/pcc/documents/8\\_Section5\\_EducationOutreach.doc](http://www.ecohusky.uconn.edu/pcc/documents/8_Section5_EducationOutreach.doc), 2007

<sup>136</sup> American Wind Energy Association, "2010 U.S. Small Wind Turbine Market Report," [http://www.awea.org/learnabout/smallwind/upload/AWEA\\_SmallWind\\_GMS2011Report\\_Final.pdf](http://www.awea.org/learnabout/smallwind/upload/AWEA_SmallWind_GMS2011Report_Final.pdf), 2010

the turbine, inverter, guyed tower, tower wires, shipping, foundation and anchoring, wire run, turbine installation and tower erection, electrical hook-up, and inspection fees.<sup>137</sup>

### **Operation and Maintenance Cost**

Maintenance for small wind systems at this scale is likely to cost between \$200 and \$700 per year.<sup>138</sup> A maintenance cost of \$500 per year would equate to nine cents per kWh based on the expected output of a 10 kW small wind system at the Depot campus. This maintenance typically involves inspecting and tightening bolts and electrical connections, inspecting the machines for corrosion and the guy wires for tension, inspecting and replacing any worn leading edge tape on the turbine blades, replacing the turbine and/or bearings after 10 years.<sup>139</sup> A monitoring system could also be installed with a 10 kW small wind system to measure system performance so that noticeable decreases in performance under similar conditions can be identified.<sup>140</sup>

### **Economics and Funding**

In general, recommended projects are configured as behind the meter applications with third party ownership.<sup>141</sup> This means that the electricity produced by the system would displace the retail value of energy used in the building. For small wind systems funded through the zero emission renewable energy credit (ZREC) program, a maximum payment of 38.5 cents per kWh<sup>142</sup> is possible for systems less than or equal to 100 kW. The economics of grid connected renewable distributed generation systems providing wholesale power at this scale may be prohibitive even with available incentives. As such, this approach is not recommended in this deployment plan.

At present, small wind systems require substantial public funding to justify investment on a financial basis. Capital grants, federal business investment tax credits, accelerated depreciation benefits, and a production incentive are required to make a small wind system economically viable within the life of the system. For the analyses detailed below, deployment is assumed to take place in 2012, thereby forfeiting the 2011, 100 percent accelerated depreciation monetization benefit. Instead, a 50 percent first year bonus depreciation monetization structure is assumed as provided under current law.<sup>143</sup>

Federal investment tax credits are currently available at 30 percent of the project cost and depreciation benefits can be monetized by the developer. Hence, the project economics of a 10 kW small wind system

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<sup>137</sup> Bergey.com, "Retail Price List," <http://production-images.webapeel.com/bergey/assets/2012/3/6/98837/PriceList-March.pdf>, March 2012

<sup>138</sup> American Wind Energy Association, "2010 U.S. Small Wind Turbine Market Report," [http://www.awea.org/learnabout/smallwind/upload/AWEA\\_SmallWind\\_GMS2011Report\\_Final.pdf](http://www.awea.org/learnabout/smallwind/upload/AWEA_SmallWind_GMS2011Report_Final.pdf), 2010

<sup>139</sup> U.S. DOE EERE, "Installing and Maintaining a Small Electric Wind System," [http://www.energysavers.gov/your\\_home/electricity/index.cfm/mytopic=10990](http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10990), February 9, 2011

<sup>140</sup> California Energy Commission, "A Guide to Photovoltaic (PV) System Design and Installation," [http://www.energy.ca.gov/reports/2001-09-04\\_500-01-020.PDF](http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF), June 2001

<sup>141</sup> Projects on a master meter would fit this configuration as well

<sup>142</sup> Public Act 11-80 Section 108 b specifies that systems less than 100 kW will receive "the weighted average accepted bid price in the most recent solicitation for systems greater than one hundred kilowatts but less than two hundred fifty kilowatts, plus an additional incentive of ten per cent." As such, a ZREC incentive of \$.35/kWh is assumed plus an additional incentive of 10 percent of \$.35/kWh.

<sup>143</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011



would clearly be more attractive if it were developed by a third party developer capable of garnering all of the available tax credits and depreciation benefits associated with renewable energy projects.

#### *Analysis of Grant Funding for Financial Feasibility*

A 10 kW small wind system installed at the Longley building would not achieve a financial payback within the projected life of the system. The primary driver is the initial cost of the system and the lack of sufficient wind resources in the area. Estimates of system yields at a hub height of 30 meters above ground level indicate that the system would have a capacity factor of approximately six percent. However, a 10 kW small wind system could achieve a four year financial payback, an internal rate of return of 11 percent, and a net present value of \$4,621 with a capital grant of \$23,000.<sup>144</sup>

#### **Site Orientation and Generation Loads**

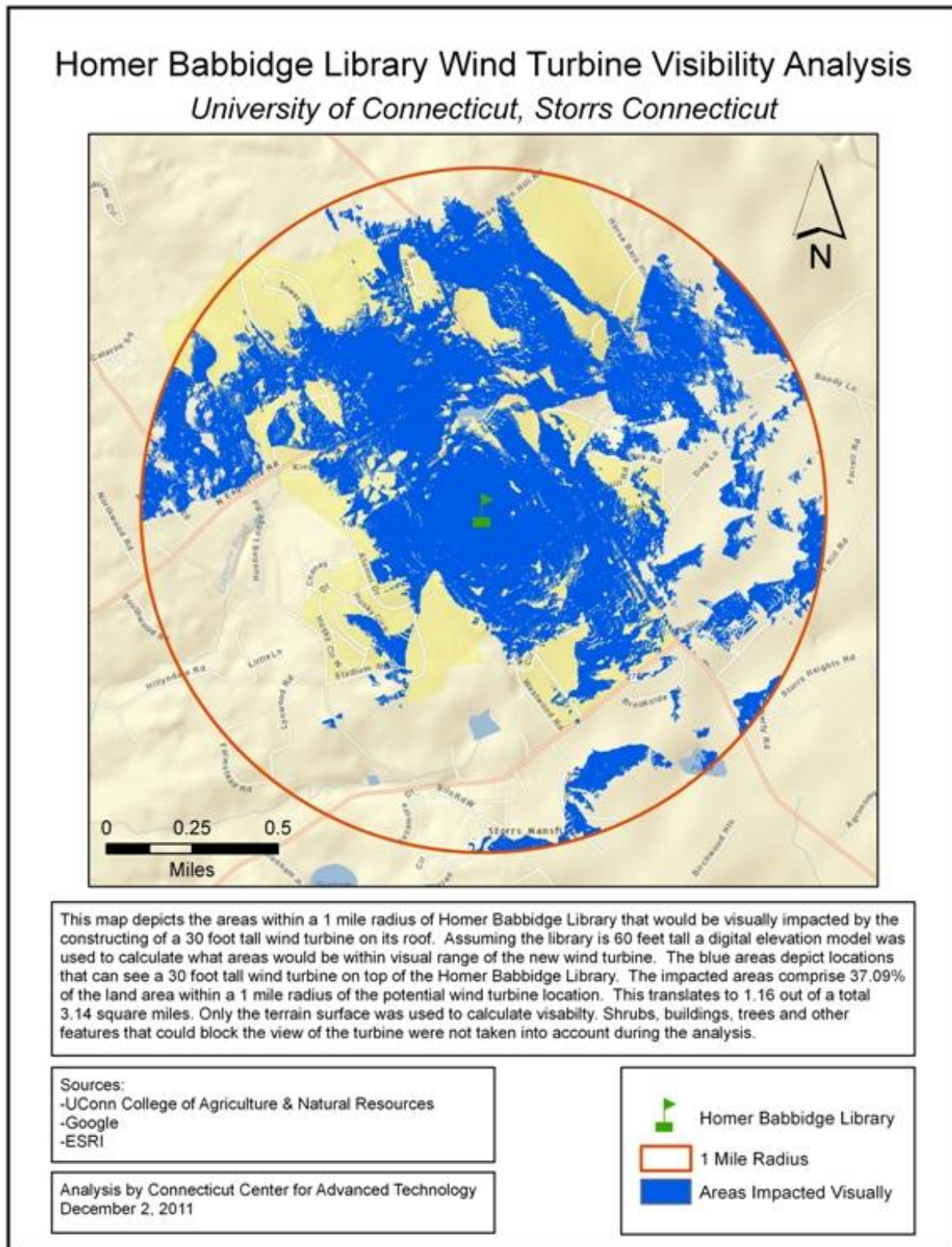
A 10 kW small wind turbine system could be mounted on the roof of the Longley Building. The wind turbine top of the Longley Building is taller than any adjacent building or vegetation; consequently, no obstruction of wind resources is anticipated.

The Longley Building is served by a single utility service from Connecticut Light and Power through a master meter for the whole Depot Campus. It is estimated that the Longley Building consumes a total of approximately 440,000 kWh annually. A 10 kW small wind turbine system at the Longley Building could produce 5,305 kWh/year, with an estimated capacity factor of six percent, and provide approximately 1.2 percent of the Longley Building's electrical requirements. This potential deployment site was also assessed in the Preliminary Feasibility Study and Strategic Plan for the Depot Campus.

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<sup>144</sup> Assumes an installed cost of \$5.43 per watt or \$54,300, a ZREC of \$0.385/kWh for fifteen years, a discount rate of seven percent, and receipt of all applicable tax credits and depreciation benefits.

**Figure 17 – Visibility Analysis for a Small Wind System at the Homer Babbidge Library**





**Figure 18 – Visibility Analysis for a Small Wind System at the North Campus Site**

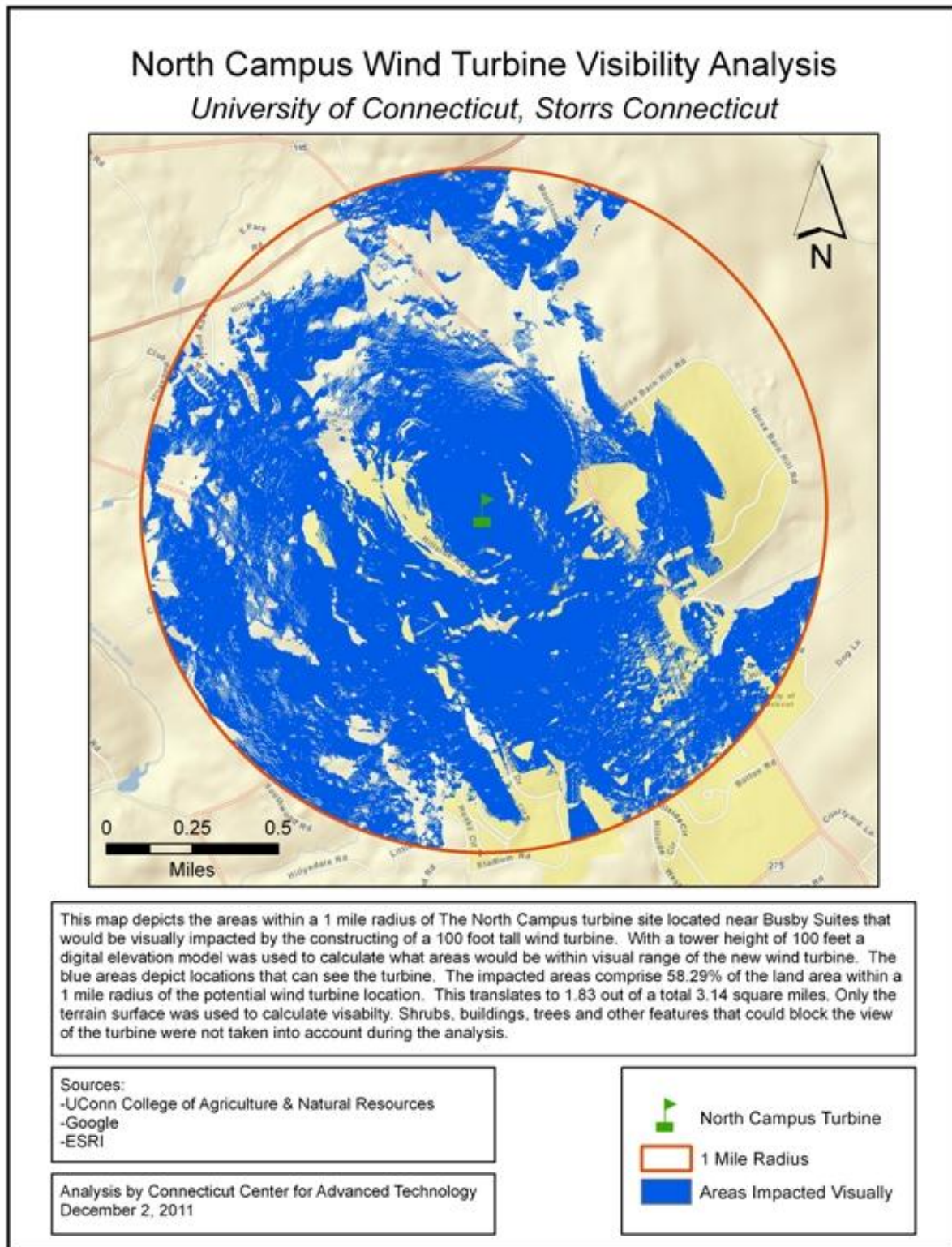
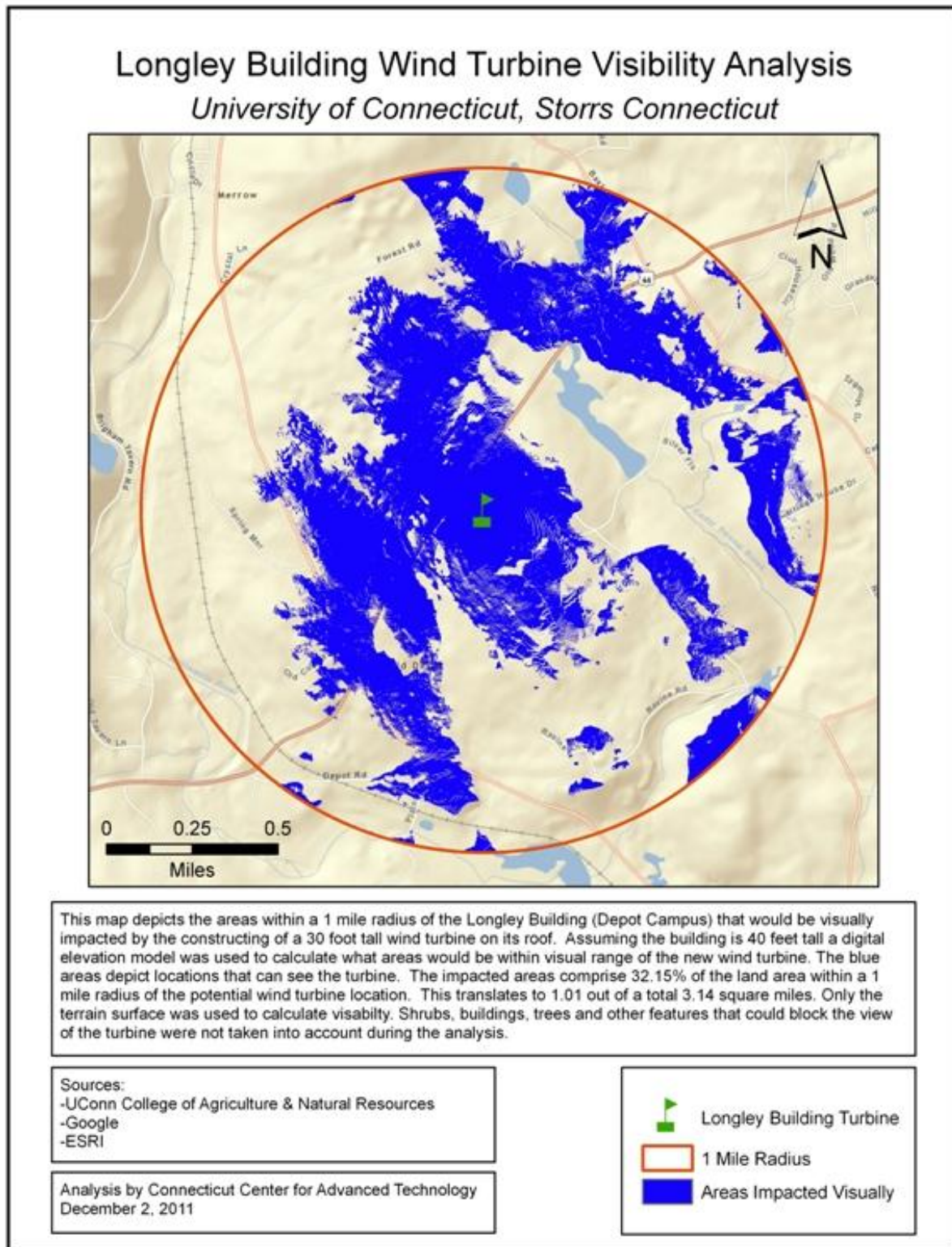


Figure 19 - Visibility Analysis for a Small Wind System at the Longley Building Site

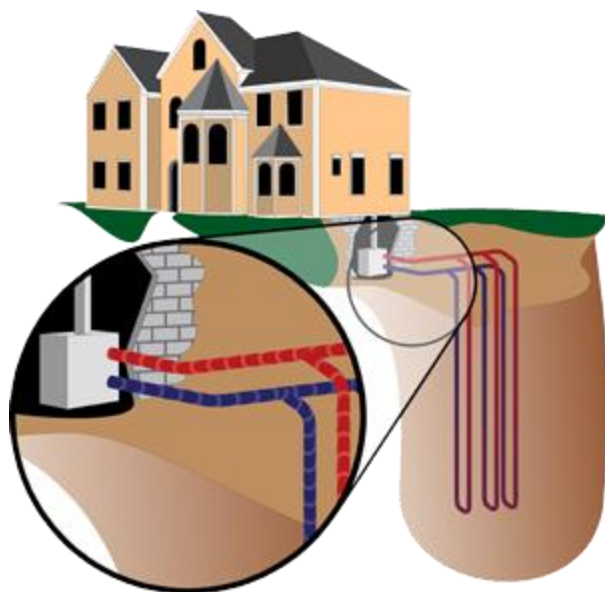


## GEO THERMAL

Geothermal heat pumps are used for space heating and cooling as well as water heating. Geothermal heat pump systems utilize the naturally occurring thermal energy from the ground in order to provide heating and cooling to buildings. Heat pump systems offer individual space temperature controls and work best for systems with multiple zones. Heat pump systems also fit well into systems with a dedicated outside air system (DOAS) with a conventional heat source because heat pumps often do not provide a high enough temperature rise to meet indoor requirements.

**Figure 20 - Geothermal Heat Pump System<sup>145</sup>**

There are two basic types of geothermal heat pump systems closed loop and open loop systems. Closed loop systems use water or an antifreeze solution that is circulated through plastic pipes typically beneath the earth's surface. Open loop systems typically use well or surface water as the heat exchange fluid that circulates directly through the heat pump system and then the water returns to the ground through the well or surface discharge. The use of existing wells may provide an opportunity for the supply of thermal energy without the added costs associated with well installation. At this time, commercial heat exchange products that extract or expel thermal energy from/to existing well water infrastructure are not well developed, but this application may represent an opportunity for selected development using faculty resources.<sup>146 147</sup>



General criteria to consider when evaluating potential buildings/areas for the installation of geothermal heat pump systems include:

- Sites that utilize boilers/furnaces to provide thermal energy; and
- Buildings that have significant cooling loads and are not served by the existing “chill” loop, or sites with or near equipment used for absorption chilling, or sites that have chilled water cooling.

<sup>145</sup> Connecticut Clean Energy Fund, “Geothermal Heat Pump Incentive Program – Commercial,” [www.ctcleanenergy.com/YourBusinessorInstitution/GeothermalIncentiveProgramCommercial/tabid/521/Default.aspx](http://www.ctcleanenergy.com/YourBusinessorInstitution/GeothermalIncentiveProgramCommercial/tabid/521/Default.aspx), march 2012

<sup>146</sup> International Ground Source Heat Pump Association, “What is Geothermal,” [www.igshpa.okstate.edu/geothermal/geothermal.htm](http://www.igshpa.okstate.edu/geothermal/geothermal.htm), March 2012

<sup>147</sup> U.S. DOE EERE, “Types of Geothermal Heat Pump Systems,” [www.energysavers.gov/your\\_home/space\\_heating\\_cooling/index.cfm/mytopic=12650](http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12650), February 9, 2011

### Geothermal Related Research

UConn has the capacity to undertake research related to geothermal efficiency, use of heat transfer, and performance. This research would be consistent with on-site demonstration and operation to improve opportunities for technology commercialization, student education, and public outreach.

Gary A. Robbins, Professor of Geology, Department of Natural Resources and the Environment, is interested in the use of geothermal technology as 1) a teaching aid for a number of water-related courses in Geosciences, Natural Resources, and Engineering; and 2) to undertake research on improving the efficiency of geothermal systems, including convection. Further, Professor Robbins may seek to construct monitoring wells near heat exchange borings, heat exchange borings that can accommodate alternative designs. A demonstration scale geothermal system would support Professor Robbins' outreach programs for the public on the workings and advantages of geothermal systems.

A summary of potential sites selected for detailed analysis is as follows:

**Table 6 – Summary of Geothermal System Analyses**

<b>Building</b>	<b>Calculated Annual Energy Consumption (Natural Gas Only) (MMBtu)</b>	<b>Potential Renewable Energy Generation Capacity (Tons)</b>	<b>Potential Annual Renewable Energy Production (MMBtu)</b>	<b>Potential Net Annual Reductions of CO<sub>2</sub> Emissions (lbs)</b>	<b>Percent of Floor Area Served by Potential Renewable Energy System</b>
Thompson Hall (Depot)	3,087	40	≈1,017	≈60,875	41%
Horsebarn Hill Sciences Complex Building #4 Annex	4,020	3.1	≈106	≈5,200	3.3%
<b>Total:</b>	<b>7,107 MMBtu</b>		<b>1,123 MMBtu</b>	<b>54,900 lbs/year</b>	



## **Thompson Hall**

### **Thompson Hall Site**

Thompson Hall, located at 30 Ahern Lane on the Depot Campus at Storrs, serves as the University's Technical Services facility, which supports academic research and administrative activities including computer repair, electrical/electronic support, glass technology, mechanical technology, office equipment, and theft-security.

### **Geothermal System Visibility**

In general, because geothermal systems are deployed underground, their public visibility is minimal. However, if this site is selected for development, a monitoring display could be installed in the lobby/entrance with details on the geothermal system's location and performance data.

**Figure 21 - Aerial View of Thompson Building Site**



### **Heating and Cooling Demand and Geothermal System sizing**

Thompson Hall has a central chilled water system that may be suitable for conversion to a geothermal heat pump system. The chilled water piping from the chillers to the chilled water coils in the air-handling units may also be able to serve as the heat pump loop between the ground-coupled heat source/sink and air-handlers inside the building. Thompson Hall has approximately 34,000 square feet of floor space, and

is currently served by two natural gas fired hot water heaters, a dual fuel boiler (natural gas and oil), and a 40 ton chiller.

The capacity of a geothermal system designed to serve the equivalent of a 40 ton chiller will produce 480,000 Btu per hour. In 2010, Thompson Hall consumed approximately 3,087 MMBtu of natural gas for heating and domestic hot water. A 40 ton geothermal system at approximately 480,000 Btu per hour could provide heat to approximately 14,000 square feet or 41 percent of Thompson Hall.<sup>148</sup> Assuming a combustion efficiency of 80 percent for the existing boilers and a coefficient of performance (COP) of 4.0, approximately 1,017 MMBtu of natural gas would be displaced by approximately 74,500 kWh of electricity.

Assuming 100 percent of the cooling load is served by a 40 ton geothermal system and a COP of 4.0, the annual electrical consumption for cooling would be reduced from approximately 48,220 kWh to approximately 36,165 kWh per year, for an annual savings of approximately 12,000 kWh per year.

### **Environmental Benefits of a Geothermal Heat Pump System**

As detailed above, a geothermal system would increase electricity consumption and reduce natural gas consumption during heating periods, and decrease electricity consumption during periods that require cooling. The 2009 Calculated New England Marginal Emission Rates (lb/MWh) values are detailed in Appendix I.

The geothermal system located at Thompson Hall is expected to have the following emissions characteristics:

- An increase of 62.5 MWh of electricity consumption for the geothermal system would result in an increase of the following emissions annually:
  - ≈10.6 lbs of NO<sub>x</sub>;
  - ≈13.8 lbs of SO<sub>2</sub>; and
  - ≈58,125 lbs of CO<sub>2</sub>.
- A reduction of 1,017 MMBtus of natural gas consumed due to the geothermal system would result in a decrease of the following emissions annually:<sup>149</sup>
  - ≈93.6 lbs of NO<sub>x</sub>;
  - ≈0.6 lbs of SO<sub>2</sub>; and
  - ≈119,000 lbs/year of CO<sub>2</sub>.

The application of a geothermal system would result in the following net emissions reductions / increase by pollutant annually:

- A decrease of ≈83 lbs of NO<sub>x</sub>;

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<sup>148</sup> Does not include natural gas used for domestic hot water.

<sup>149</sup>EIA, "Natural Gas 1998: Issues and Trends – Chapter 2: Natural Gas and the Environment," [ftp://tonto.eia.doe.gov/pub/oil\\_gas/natural\\_gas/analysis\\_publications/natural\\_gas\\_1998\\_issues\\_trends/pdf/chapter2.pdf](ftp://tonto.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf), 1998

- o An increase of  $\approx 13.15$  lbs of  $\text{SO}_2$ ; and
- o A decrease of  $\approx 60,875$  lbs of  $\text{CO}_2$ .

### **Regulatory Restrictions (Siting)**

There are no state regulatory siting restrictions for the installation and/or use of geothermal systems. The Town of Mansfield does not exercise jurisdiction over building improvements installed on UConn's Storrs campuses.<sup>150</sup>

### **Environmental Impacts and Permitting**

Closed loop geothermal heat pump systems do not result in any point source air or water discharges; therefore, no air emissions or water discharge permit is required. An open loop heat pump system that discharges water to waters of the state, including all surface waters, ground waters and Publicly Owned Treatment Works may require a permit.<sup>151</sup> For open loop heat pump systems, Connecticut DEEP uses both individual and general permits to regulate discharge activities. Individual permits are issued directly to an applicant, whereas general permits, which are less costly and may be quicker to obtain, are permits issued to authorize similar minor activities by one or more applicants. For open loop heat pump systems that circulate and discharge less than 50,000 gallons per day (GPD), a general permit may be required. For open loop heat pump systems that circulate and discharge more than 50,000 GPD, an "individual" discharge permit will be required.<sup>152</sup>

There are no Natural Diversity Data Base Areas, which represent known locations, both historic and extant, of state listed species and significant natural communities, identified at or immediately proximate to Thompson Hall. State listed species are those listed as Endangered, Threatened or Special Concern under the Connecticut Endangered Species Act.<sup>153</sup> Because the geothermal system would be installed underground at an existing building that is not designated as an historic building,<sup>154</sup> no adverse impacts on scenic resources or historic buildings are anticipated.

According to available mapping and information, there are no inland wetland soils, defined as "Any of the soil types designated as poorly drained, very poorly drained, alluvial, and floodplain by the National Cooperative Soil Survey, as may be amended from time to time, of the Natural Resources Conservation Service of the United States Department of Agriculture" adjacent to Thompson Hall.<sup>155</sup>

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<sup>150</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

<sup>151</sup> Sections 22a-416 through 22a-438 of the Connecticut General Statutes (CGS) and Sections 22a-430-1 through 22a-430-7 of the Regulations of Connecticut State Agencies (RCSA)

<sup>152</sup> Personal communications with the Department of Energy and Environmental Protection, January 20, 2012, February 14, 2012; [http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324208&depNav\\_GID=1643](http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324208&depNav_GID=1643)

<sup>153</sup> (Connecticut General Statutes, Section 26-303), Natural Diversity Database Areas - July 2011, GIS Shapefile, Connecticut Department of Energy and Environmental Protection.

<sup>154</sup> Correspondence from Stacey S. Vairo, State and National Register Coordinator, Connecticut State Historic Preservation Office received November 1, 2011.

Department of Economic and Community Development (DECD)

<sup>155</sup> Inland Wetland Soils; GIS Shapefile, Connecticut Department of Energy and Environmental Protection. The original data was collected from published surveys from 1962 to 1981, field mapping from 1985 through 2001 and additional attribute documentation to 3/23/2007. GIS Shapefile, Connecticut Department of Energy and

## Site Restrictions Due to Land Use / Master Planning Considerations

The 2000 UConn Outlying Parcels Master Plan<sup>156</sup> does not contain any information which would indicate a conflict with deploying a geothermal system at this potential site. The Green Depot Campus Initiative seeks to develop and demonstrate clean and efficient energy systems capable of using a multitude of conventional and renewable fuels.<sup>157</sup> A geothermal system would be deployed underground. The development of a geothermal system may limit future land use development plans directly over or near a geothermal system.

## Capital Cost

The cost of a geothermal system will depend on whether the system will require drilling vertically deep wells, use existing wells, or use loops in a horizontal fashion below ground. The cost of drilling wells also will vary depending on the terrain, depth, and other local factors.<sup>158</sup> A 40 ton geothermal system is estimated to cost approximately \$403,000. Geothermal projects funded under the American Recovery and Reinvestment Act program in Connecticut have exhibited the following characteristics:

**Table 7 – Average System Size and Cost for Geothermal Projects in Connecticut (October 2009 – November 2011)**<sup>159</sup>

	<b>Residential</b>	<b>Commercial</b>
Average System Size	4.8 Tons	40.7 Tons
Average System Cost (\$/Ton)	\$8,782	\$10,085

## Operation and Maintenance Cost

Maintenance costs for geothermal systems are typically lower than for conventional technologies.<sup>160</sup> This is most likely due to the fact that the heat pump involves no combustion of fossil fuels and consists primarily of low cost pumps and pipe systems.

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Environmental Protection. Wetlands/Watercourses/Waterbodies Map, Town of Mansfield Plan of Conservation and Development, April 2006.

<sup>156</sup> University of Connecticut, "Outlying Parcels Master Plan," [http://masterplan.uconn.edu/images/OPMP\\_5\\_22\\_2000.pdf](http://masterplan.uconn.edu/images/OPMP_5_22_2000.pdf), June 2000

<sup>157</sup> University of Connecticut Climate Action Plan: Guiding the Path Towards Carbon Neutrality, "Section 5: Education, Research, & Outreach," [http://www.ecohusky.uconn.edu/pcc/documents/8\\_Section5\\_EducationOutreach.doc](http://www.ecohusky.uconn.edu/pcc/documents/8_Section5_EducationOutreach.doc), 2007

<sup>158</sup> The University of Alabama, Geo-Heat Center, Oregon Institute of Technology "Cost Containment for Ground-Source Heat Pumps," <http://geoheat.oit.edu/pdf/tp72.pdf>, Kavanaugh, Steve; Gilbreath, Christopher, December 1995

<sup>159</sup> Clean Energy Finance and Investment Authority, Geothermal Heat Pump Incentive Program - Commercial <http://www.ctcleanenergy.com/YourBusinessorInstitution/GeothermalIncentiveProgramCommercial/tabid/521/Default.aspx>, March 2, 2012

<sup>160</sup> U.S. DOE EERE, "Selecting and Installing a Geothermal Heat Pump System," [www.energysavers.gov/your\\_home/space\\_heating\\_cooling/index.cfm/mytopic=12670](http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12670), February 9, 2011



## Economics and Funding

At present, geothermal systems require significant state and federal funding to be competitive with conventional technologies. The economics of geothermal projects may be improved if development is undertaken and financed by a third party for-profit developer capable of garnering all of the federal business investment tax credits and accelerated depreciation benefits associated with renewable energy projects.<sup>161</sup> For systems deployed in 2012, a 50 percent first year bonus depreciation monetization structure is assumed as provided for under current law.<sup>162</sup>

### *Pro Forma Analysis of Grant Funding for Financial Feasibility*

A 40 ton geothermal system installed at Thompson Hall is estimated to cost approximately \$400,000, and would not achieve a financial payback within the projected life of the system. The primary driver is the initial cost of the system and relatively low natural gas prices used by conventional technology. However, a geothermal system could achieve a financial payback within 2 years and an internal rate of return of 8.17 percent with a capital grant of approximately \$267,000.<sup>163</sup>

## Site Orientation and Generation Loads

The geothermal system could be deployed underground near Thompson Hall depending on the location of underground utilities. Because geothermal systems are installed five or more feet below grade, or consist of wells that extend tens to hundreds of feet below grade where the temperature is nearly constant, orientation of the system relative to direction (north or south side) is not critical. A 40 ton geothermal system is calculated to produce approximately 1,017 MMBtu for heating and 40,184 ton-hours for cooling per year. It is anticipated that approximately 41 percent of the building's heating requirements and 100 percent of the cooling requirements will be met with a 40 ton geothermal system. This potential deployment site was also assessed in the Preliminary Feasibility Study and Strategic Plan for the Depot Campus.

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<sup>161</sup> A developer may include the original equipment manufacturer.

<sup>162</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

<sup>163</sup> Assumes an installed cost of \$10,085 per ton, a discount rate of seven percent, and receipt of all applicable tax credits and accelerated depreciation benefits.

## **Horsebarn Hill Sciences Complex Building #4 Annex**

### **Horsebarn Hill Sciences Complex Building #4 Annex Site**

Building #4 Annex, located on Horsebarn Hill Road on the main campus at Storrs, is used by faculty and staff to promote multidisciplinary research, education and outreach in environmental sciences, engineering, policy, and sustainability.

### **Geothermal System Visibility**

In general, because geothermal systems are deployed underground, their public visibility is minimal. However, if this site is selected for development, a monitoring display could be installed in the lobby/entrance with details on the geothermal system's location and performance data.

**Figure 22 – Aerial View of Building #4 Annex Site**



### **Heating and Cooling Demand and Geothermal System Sizing**

The Building #4 Annex is approximately 23,000 square feet in area, and is estimated to use approximately 4,020 MMBtu of thermal energy annually.<sup>164</sup> Currently, the Building #4 Annex is supplied with thermal energy by natural gas fired boilers for space heating and domestic hot water. The cooling system consists of a chiller/cooling tower, which provides the chilled water to the Building #4 Annex, and an air cooled condenser that may provide back-up for the building.

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<sup>164</sup> Correspondence from UConn dated February 2, 2012

The capacity of a geothermal system at Building #4 Annex has been designed to replace fan coil unit #30, which serves approximately 770 square feet or approximately 3.3 percent of the building's floor area. A 3.1 ton geothermal system at Building #4 Annex could produce 25,000 Btu per hour.<sup>165</sup> In 2011, Building #4 Annex consumed approximately 4,020 MMBtu of natural gas for heating and domestic hot water.

Assuming a combustion efficiency of 80 percent for the existing boilers and a COP of 4.0, approximately 106 MMBtu of natural gas would be displaced by approximately 7,760 kWh of electricity.

Based on a 3.1 ton geothermal system and a COP of 4.0, the annual electrical consumption for cooling would be reduced from approximately 3,700 kWh to approximately 2,800 kWh per year, for an annual savings of approximately 900 kWh per year.

### **Environmental Benefits of a Geothermal Heat Pump System**

As detailed above, a geothermal system would increase electricity consumption and reduce natural gas consumption during heating periods, and decrease electricity consumption during periods that require cooling. The 2009 Calculated New England Marginal Emission Rates (lb/MWh) values are detailed in Appendix I.

A 3.1 ton geothermal system located at Building #4 Annex is expected to have the following emissions characteristics:

- An increase of 6.86 MWh of electricity consumption for the geothermal system would result in an increase of the following emissions annually:
  - ≈1.2 lbs of NO<sub>x</sub>;
  - ≈1.5 lbs of SO<sub>2</sub>; and
  - ≈6,380 lbs of CO<sub>2</sub>.
- A reduction of 106 MMBtus of natural gas consumed due to the geothermal system would result in a decrease of the following emissions:<sup>166</sup>
  - ≈9.8 lbs of NO<sub>x</sub>;
  - ≈0.06 lbs of SO<sub>2</sub>; and
  - ≈12,400 lbs/year of CO<sub>2</sub>.

The application of a geothermal system would result in the following net emissions reductions / increase by pollutant annually:

- A decrease of ≈8.6 lbs of NO<sub>x</sub>;
- An increase of ≈ 1.4 lbs of SO<sub>2</sub>; and
- A decrease of ≈6,020 lbs of CO<sub>2</sub>.

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<sup>165</sup> Does not include natural gas used for domestic hot water.

<sup>166</sup>EIA, "Natural Gas 1998: Issues and Trends – Chapter 2: Natural Gas and the Environment," [http://tonto.eia.doe.gov/pub/oil\\_gas/natural\\_gas/analysis\\_publications/natural\\_gas\\_1998\\_issues\\_trends/pdf/chapter2.pdf](http://tonto.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf), 1998

## **Regulatory Restrictions (Siting)**

There are no state regulatory siting restrictions on the installation and/or use of geothermal systems. The Town of Mansfield does not exercise jurisdiction over building improvements installed on UConn's Storrs campuses.<sup>167</sup>

## **Environmental Impacts and Permitting**

Closed loop geothermal heat pump systems do not result in any point source air or water discharges; therefore, no air emissions or water discharge permit is required. An open loop heat pump system that discharges water to waters of the state, including all surface waters, ground waters and Publicly Owned Treatment Works may require a permit.<sup>168</sup> For open loop heat pump systems, Connecticut DEEP uses both individual and general permits to regulate discharge activities. Individual permits are issued directly to an applicant, whereas general permits, which are less costly and may be quicker to obtain, are permits issued to authorize similar minor activities by one or more applicants. For open loop heat pump systems that circulate and discharge less than 50,000 GPD, a general permit may be required. For open loop heat pump systems that circulate and discharge more than 50,000 GPD, an "individual" discharge permit will be required.<sup>169</sup>

There are Natural Diversity Data Base Areas, which represent known locations, both historic and extant, of state listed species and significant natural communities, proximate to Building #4 Annex. However, the area immediately south and east of Building #4 Annex is not within the boundary of Natural Diversity Data Base Area buffer. State listed species are those listed as Endangered, Threatened or Special Concern under the Connecticut Endangered Species Act (Connecticut General Statutes, Section 26-303).<sup>170</sup> Because the geothermal system would be installed underground at an existing building that is not designated as an historic building,<sup>171</sup> no adverse impacts on scenic resources or historic buildings are anticipated.

According to available mapping and information, there are no inland wetland soils, defined as "Any of the soil types designated as poorly drained, very poorly drained, alluvial, and floodplain by the National Cooperative Soil Survey, as may be amended from time to time, of the Natural Resources Conservation Service of the United States Department of Agriculture" adjacent to and immediately south of Building #4 Annex.<sup>172</sup> Soil types that are designated as poorly drained have been identified to the east of Building #4 Annex.

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<sup>167</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

<sup>168</sup> Sections 22a-416 through 22a-438 of the Connecticut General Statutes (CGS) and Sections 22a-430-1 through 22a-430-7 of the Regulations of Connecticut State Agencies (RCSA)

<sup>169</sup> Personal communications with the Department of Energy and Environmental Protection, January 20, 2012, February 14, 2012; [http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324208&depNav\\_GID=1643](http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324208&depNav_GID=1643)

<sup>170</sup> Natural Diversity Database Areas - July 2011, GIS Shapefile, Connecticut Department of Energy and Environmental Protection.

<sup>171</sup> Correspondence from Stacey S. Vairo, State and National Register Coordinator, Connecticut State Historic Preservation Office received November 1, 2011.

Department of Economic and Community Development (DECD)

<sup>172</sup> Inland Wetland Soils; GIS Shapefile, Connecticut Department of Energy and Environmental Protection. The original data was collected from published surveys from 1962 to 1981, field mapping from 1985 through 2001 and

## Site Restrictions Due to Land Use / Master Planning Considerations

The 2000 UConn Outlying Parcels Master Plan<sup>173</sup> does not contain any information which would indicate a conflict with deploying a geothermal system at this potential site. A geothermal system would be deployed underground; consequently, no land use impacts are anticipated; however, the development of a geothermal system may limit future land use development plans directly over or near a geothermal system.

## Capital Cost

The cost of a geothermal system will depend on whether the system will require drilling vertically deep wells, use existing wells, or use loops in a horizontal fashion below ground. The cost of drilling wells also will vary depending on the terrain, depth, and other local factors.<sup>174</sup> A 3.1 ton geothermal system is estimated to cost approximately \$11,700. A Geothermal projects funded under the American Recovery and Reinvestment Act program in Connecticut have exhibited the following characteristics:

**Table 8 – Average System Size and Cost for Geothermal Projects in Connecticut (October 2009 – November 2011)**<sup>175</sup>

	<b>Residential</b>	<b>Commercial</b>
Average System Size	4.8 Tons	40.7 Tons
Average System Cost (\$/Ton)	\$8,782	\$10,085

## Operation and Maintenance Cost

Maintenance costs for geothermal heat pumps are typically lower than for conventional technologies.<sup>176</sup> This is most likely due to the fact that the heat pump involves no combustion of fossil fuels and consists primarily of low cost pumps and pipe systems.

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additional attribute documentation to 3/23/2007.GIS Shapefile, Connecticut Department of Energy and Environmental Protection. Wetlands/Watercourses/Waterbodies Map, Town of Mansfield Plan of Conservation and Development, April 2006.

<sup>173</sup> University of Connecticut, “Outlying Parcels Master Plan,”

[http://masterplan.uconn.edu/images/OPMP\\_5\\_22\\_2000.pdf](http://masterplan.uconn.edu/images/OPMP_5_22_2000.pdf), June 2000

<sup>174</sup> The University of Alabama, Geo-Heat Center, Oregon Institute of Technology “Cost Containment for Ground-Source Heat Pumps,” <http://geoheat.oit.edu/pdf/tp72.pdf>, Kavanaugh, Steve; Gilbreath, Christopher, December 1995

<sup>175</sup> Clean Energy Finance and Investment Authority, Geothermal Heat Pump Incentive Program - Commercial <http://www.ctcleanenergy.com/YourBusinessorInstitution/GeothermalIncentiveProgramCommercial/tabid/521/Default.aspx>, March 2, 2012

<sup>176</sup> U.S. DOE EERE, “Selecting and Installing a Geothermal Heat Pump,”

[www.energysavers.gov/your\\_home/space\\_heating\\_cooling/index.cfm/mytopic=12670](http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12670), February 9, 2011

## Economics and Funding

At present, geothermal systems require significant state and federal funding to be competitive with conventional technologies. The economics of geothermal projects may be improved if development is undertaken and financed by a third party for-profit developer capable of garnering all of the federal business investment tax credits and accelerated depreciation benefits associated with renewable energy projects. For systems deployed in 2012, a 50 percent first year bonus depreciation monetization structure is assumed as provided for under current law.<sup>177</sup>

### *Pro Forma Analysis of Grant Funding for Financial Feasibility*

A 3.1 ton geothermal system installed at Building #4 Annex is estimated to cost approximately \$27,000, and would not achieve a financial payback within the projected life of the system. The primary driver is the initial cost of the system and relatively low natural gas prices used by conventional technology. However, a geothermal system could achieve a financial payback within 2 years, an internal rate of return of 8.71 percent, and a net present value of \$820 with a capital grant of approximately \$16,700.<sup>178</sup>

## Site Orientation and Generation Loads

A geothermal system could be deployed adjacent to the building, possibly on the south side near the chiller/cooling tower to facilitate integration with the buildings HVAC equipment. Because geothermal systems are installed five or more feet below grade, or consist of wells that extend tens to hundreds of feet below grade where the temperature is nearly constant, orientation of the system relative to direction (north or south side) is not critical. Alternatively, an open loop geothermal heat pump system may be considered due to the presence of approximately 20 existing wells located to the north and east of Building #4 Annex. It is estimated that a 3.1 ton open loop geothermal heat pump system would require approximately 8,900 gallons of water per day.<sup>179</sup> A detailed analysis of water resources to sustain operational requirements would need to be undertaken. A 3.1 ton geothermal system is calculated to produce approximately 106 MMBtu for heating and approximately 3,100 ton-hours for cooling per year. It is anticipated that by replacing fan coil unit #30, approximately 3.3 percent of the building's heating requirements will be met with a 3.1 ton geothermal system.

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<sup>177</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

<sup>178</sup> Assumes an installed cost of \$8,700 per ton, a discount rate of seven percent, and receipt of all applicable tax credits and accelerated depreciation benefits.

<sup>179</sup> Iowa Energy Center Energy Resource Station, "Geothermal Heat Pump Systems – GeoExchange Technology," [http://www.michigan.gov/documents/CIS\\_EO\\_KC-MAY06-Workshop\\_159640\\_7.pdf](http://www.michigan.gov/documents/CIS_EO_KC-MAY06-Workshop_159640_7.pdf), Klaassen, Curtis, 2006



## STATIONARY FUEL CELLS

Fuel cells can be used to provide electricity for vehicle, stationary and portable power applications. Stationary power is the most mature application for fuel cells. Stationary fuel cell units are used for backup power, power for remote locations, distributed generation for buildings, and co-generation (in which excess thermal energy from electricity generation is used for heating or cooling). In general, the thermal energy produced by fuel cells is suitable for space heating/cooling, domestic hot water, and process hot water applications.

**Figure 23 - Fuel Cell System**<sup>180</sup>



While there are several types of fuel cells, there are currently four commercially available fuel cell technologies for stationary power applications: phosphoric acid, molten carbonate, proton exchange membrane, and solid oxide. Phosphoric acid fuel cells are currently only available in 400 kW systems; molten carbonate fuel cells are currently available in 300 kW, 1,400 kW, and 2,800 kW systems; proton exchange membrane fuel cells are currently available in 5 – 120 kW systems; and solid oxide fuel cells are available in

100 kW and 200 kW systems. These base fuel cell units can be, and often are, combined for greater capacity and an increased economy of scale. Phosphoric acid and molten carbonate fuel cells that provide thermal energy can reach higher system efficiencies ( $\approx 90$  percent) than electric only (solid oxide) fuel cells that have a system efficiency of approximately 52 percent.

As discussed above, fuel cells can be used to provide electricity for a variety of applications. For baseload, stationary power applications, general siting criteria to consider when evaluating potential buildings for the installation of a fuel cell system include:

- Sites that are serviced by, or proximate to, natural gas or methane;
- Sites that have a fairly constant electric demand throughout the day and year; and
- Sites with a substantial domestic hot water demand and/or significant cooling and heating loads.

### Fuel Cell Related Research

UConn has significant opportunities to conduct fuel cell related research including thermal utilization, electrolyte efficiency, and system operation. The operation of fuel cells on campus could provide valuable opportunities to improve performance and commercialization, provide students with hands-on education, and serve to promote public outreach.

<sup>180</sup>Photo courtesy of UTC Power; (Depot Campus, Storrs)

The Center for Clean Energy Engineering (C2E2) operates as a multidisciplinary research, education and outreach center focusing on sustainable energy engineering. C2E2 undertakes fundamental and applied research in clean and efficient energy systems, including fuel cells.

Jeffrey McCutcheon, a professor of Chemical, Materials and Biomolecular Engineering, specializes in engineered membranes processes. Professor McCutcheon is interested in installing a demonstration-scale osmotic heat engine, which could produce electricity utilizing waste heat, which would be the first of its kind in the United States. The osmotic heat engine could be deployed in locations with access to waste heat, including phosphoric acid, molten carbonate, or proton exchange membrane fuel cells. The research has the potential of being a high profile renewable energy project due to its innovative nature.

A summary of potential sites selected for detailed analysis is as follows:

**Table 9 – Summary of Fuel Cell System Analyses**

<b>Building</b>	<b>Existing/Estimated Annual Energy Consumption (kWh)</b>	<b>Average Hourly Demand (kW)</b>	<b>Electric Generation Capacity of Commercial Fuel Cell Units (kW)</b>	<b>Potential Annual Renewable Energy Production (kWh)<sup>181</sup></b>	<b>Potential Annual Reductions of CO2 Emissions (lbs)</b>	<b>Percent of Electric Demand Served by Potential Renewable Energy System</b>
Homer Babbidge Library	6,333,618 (2011)	723	300-400	≈2,270,000 to ≈3,250,000	≈534,000 to ≈860,000	36% - 51%
Information Technologies Information Building	2,224,985 (2011)	254	100 - 200	≈850,000 to ≈1,700,000		38% - 76%
Horsebarn Hill Sciences Complex Building #4 Annex	321,467 (2011)	36	5	≈39,000	≈14,300	12%

<sup>181</sup> Based on an 85 - 93 percent availability factor.



## **Homer Babbidge Library**

### **Homer Babbidge Library Site**

The Homer Babbidge Library, located at 369 Fairfield Way on the main campus at Storrs, has the largest public collection of research in Connecticut and houses computer labs, instruction classrooms, digitizing and scanning services, tutor and writing services, the Map and Geographic Information Center, and the Roper Public Opinion archives.

### **Homer Babbidge Library Loads and Average Fuel Cell System Output**

In 2011, the Homer Babbidge Library consumed 6,333,618 kWh<sup>182</sup> and consumed approximately 31,600 MMBtu of thermal energy.<sup>183</sup> The Homer Babbidge Library has approximately 410,000 square feet of floor space, and is serviced by three electric meters that had peak electric demands of 590 kW, 584 kW, and 224 kW in 2011.<sup>184</sup> Currently, the Homer Babbidge Library is supplied with thermal energy by the steam loop primarily for space heating and domestic hot water. Fuel cell systems with the best economic performance will capture both the retail value of the electricity produced and, for fuel cells which produce waste heat, displace thermal energy. Table 10 below provides expected annual system electric and thermal productivity for fuel cells with heat recovery for large stationary power applications:

**Table 10 - Expected System Electric and Thermal Productivity for Fuel Cells with Heat Recovery**

	<b>~10 Year Avg. Electric Output (kWh/year)</b>	<b>10 Year Avg. Thermal Output (MMBtus/Year)</b>
300 kW MCFC	2,270,000	6,370
400 kW PAFC	3,250,000	15,612

Based on the annual electric demand and the projected thermal demand, a 400 kW phosphoric acid or 300 kW molten carbonate fuel cell may be a best fit for the provision of electricity based on the Homer Babbidge Library's electric demand. From a thermal standpoint, UConn would need to determine whether additional thermal energy from a fuel cell could supplement the campus' cogeneration system and central heating plant.

### **Fuel Cell System Visibility**

A fuel cell system could be deployed directly adjacent to the building, possibly on the north, southeast or southwest side in order to maximize public visibility of the system. In addition to locating a fuel cell

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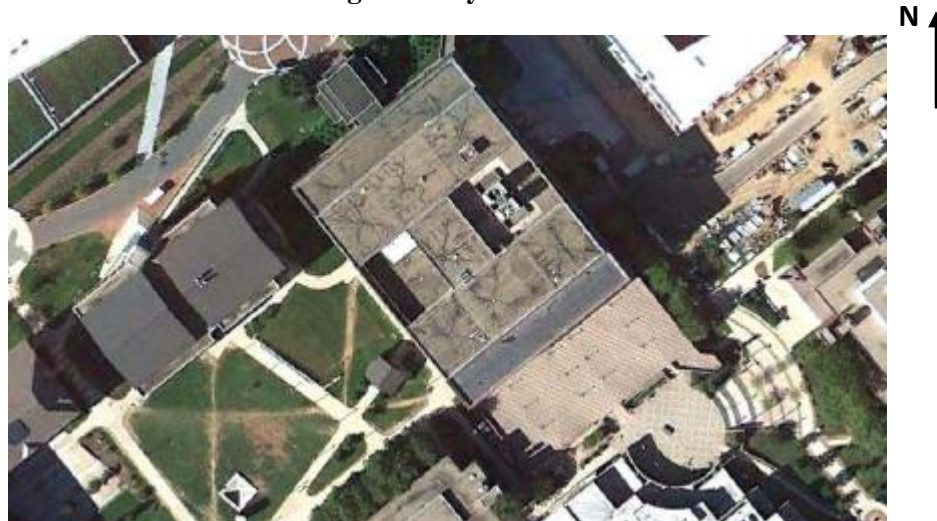
<sup>182</sup> Correspondence from UConn dated January 4, 2012.

<sup>183</sup> Correspondence from UConn dated February 2, 2012

<sup>184</sup> Correspondence from UConn dated January 4, 2012

system in a prominent, high visibility location, a monitoring display could be installed in the lobby with information on the fuel cell, how it works, and performance data.

**Figure 24 – Aerial View of Homer Babbidge Library Site**



### **Environmental Benefits of a Fuel Cell System**

Fuel cells that provide baseload power for stationary power applications are typically configured to operate on a hydrogen rich fuel, such as natural gas. Fuel cells that provide baseload power for stationary power applications are a low emissions renewable energy technology. As such, the avoided emissions benefits are equal to the annual average emissions (lbs/MWh) of electric power within the region (Appendix I) and the emissions associated with the provision of thermal energy, less the emissions from a fuel cell.

**Table 11 - Emission Values for Fuels Cells (300 kW – 400 kW) Operating on Methane**

<b>Air Emissions</b>	<b>Emissions Values<sup>185</sup> (lb/MWh)</b>
<b>NO<sub>x</sub></b>	.01 - <.07
<b>SO<sub>2</sub></b>	.0001
<b>CO<sub>2</sub> (with heat recovery)</b>	487 - 680
<b>CO<sub>2</sub> (without heat recovery)</b>	980 – 1,050

<sup>185</sup> UTC Power PureCell System Model 400 Product Data Sheet, DFC 300 Product Data Sheet, FuelCell Energy; 2-10-12.

## Regulatory Restrictions (Siting)

Certificates of Environmental Compatibility and Public Need (Certificate) are not required for “(1) fuel cells built within the state with a generating capacity of two hundred fifty kilowatts or less, or (2) fuel cells built out of state with a generating capacity of ten kilowatts or less”. Further, “the council shall, in the exercise of its jurisdiction over the siting of generating facilities, approve by declaratory ruling ... (B) the construction or location of any fuel cell, unless the council finds a substantial adverse environmental effect, or of any customer-side distributed resources project or facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts.”<sup>186</sup> In order to confirm compliance with applicable environmental regulations and receive a formal decision regarding the applicability of a Certificate for a fuel cell system, a Petition for Declaratory Ruling is required to be filed with the Connecticut Siting Council. The Town of Mansfield does not exercise jurisdiction over building improvements, such as for fuel cell systems, installed on UConn’s campus.<sup>187</sup>

## Environmental Impacts and Permitting

The operation of a fuel cell system would generate noise, air emissions, and potentially a wastewater discharge.

Phosphoric acid fuel cells create 60 decibels of noise at 33 feet.<sup>188</sup> Molten carbonate fuel cells can create 65 decibels of noise at 10 feet.<sup>189</sup> According to Connecticut DEEP regulations (Sec. 22a-69-3.5 (b)), “No person in a Class B Noise Zone shall emit noise exceeding the levels stated herein and applicable to adjacent Noise Zones.” The noise threshold for a Class B emitter to a receptor in any land use category is as follows:<sup>190</sup>

	<i>Class C Receptor</i>	<i>Class B Receptor</i>	<i>Class A Receptor/Day</i>	<i>Class A Receptor/Night</i>
<i>Class B Emitter</i>	62 dBA	62 dBA	55 dBA	45 dBA

While there are no residences proximate to the Homer Babbidge Library, noise impacts should be considered when selecting a technology and the exact location for a fuel cell system, and detailed noise modeling may be necessary to avoid disruption/annoyance to students and/or faculty on campus.

As discussed above, the application of a fuel cell system with natural gas as a fuel will generate air emissions. However, because of the low emission characteristics of this technology, a 300 kW or 400 kW

<sup>186</sup> Connecticut General Statutes, Sec. 16-50k

<sup>187</sup> Phone call with Mansfield Department of Building and Housing Inspection

<sup>188</sup> UTC Power, “The PureCell Model 400 Energy Solution,” 2011  
[http://www.utcpower.com/files/DS0112\\_PureCell\\_400\\_111011.pdf](http://www.utcpower.com/files/DS0112_PureCell_400_111011.pdf)

<sup>189</sup> FuelCell Energy, “DCF1500 Key Features,”  
<http://www.fuelcellenergy.com/files/FCE%201500%20Product%20Design-lo-rez%20FINAL.pdf>, December, 2010

<sup>190</sup> Connecticut Department of Energy and Environmental Protection, “Control of Noise,”  
<http://www.ct.gov/dep/lib/dep/regulations/22a/22a-69-1through7.pdf>, March, 2012

fuel cell may not require a new source review general permit for air emissions pursuant to Section 22a-174-3a of the Regulations of Connecticut State Agencies.<sup>191</sup>

In addition, some fuel cells both consume and discharge water. It is anticipated that any wastewater from a fuel cell at the Homer Babbidge Library would be discharged to UConn's wastewater collection and treatment system, but such discharge is not expected to be significant. According to the Connecticut DEEP, a Miscellaneous General Permit for wastewater discharge may be required.<sup>192</sup>

**Table 12 - Water Consumption and Discharge Rates for Phosphoric Acid and Molten Carbonate Fuel Cells**

	<b>Water Consumption (gallons per minute)</b>	<b>Water Discharge (gallons per minute)</b>
Phosphoric Acid Fuel Cells	none during normal operating conditions when ambient temperatures are below 85° F. Less than 1 gpm above 86 ° F.	none during normal operating conditions. Maximum of 1 gpm at 110 ° F
Molten Carbonate Fuel Cells	.9 average, 10 during WTS backflush	.45 average, 10 during WTS backflush

The deployment of a fuel cell at the Homer Babbidge Library is not expected to result in any adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern.

#### **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>193</sup> does not contain any information which would indicate a conflict with deploying a fuel cell system at this site. The 2004 Sustainable Design Guidelines specifies exploring “fuel cells and other alternative energy supply systems. Capture the heat created from fuel cells as a strategy to increase operational efficiency.”<sup>194</sup> In terms of land use, a 300 kW or 400 kW fuel cell system would require the following space requirements:

<sup>191</sup> Department of Energy & Environmental Protection, “Air Emission – New Source Review Program,” [http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324136&depNav\\_GID=1643](http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324136&depNav_GID=1643), October 2009

<sup>192</sup> Bureau of Materials Management and Compliance Assurance, “General Permit for Miscellaneous Discharges of Sewer Compatible (MISC) Wastewater,” [http://www.ct.gov/dep/lib/dep/Permits\\_and\\_Licenses/Water\\_Discharge\\_General\\_Permits/misc\\_gp.pdf](http://www.ct.gov/dep/lib/dep/Permits_and_Licenses/Water_Discharge_General_Permits/misc_gp.pdf), April 30, 2011

<sup>193</sup> University of Connecticut, “Storrs Campus Master Plan Update,” <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>194</sup> University of Connecticut, “Campus Sustainable Design Guidelines,” <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

**Table 13 - Dimensions of Fuel Cell Stack and Balance of Plant for Phosphoric Acid and Molten Carbonate Fuel Cells**

	<b>Length</b>	<b>Width</b>	<b>Height (Max)</b>
300 kW Molten Carbonate Fuel Cell	28'	20'	15' 1'
400 kW Phosphoric Acid Fuel Cell + Optional Cooling Module Setup Lengthwise	43' 3"	8'	9' 11"

### **Capital Cost**

A fuel cell system is expected to cost between \$5,500 and \$8,000 per kW. Actual project costs may be higher or lower.

### **Operation and Maintenance Cost**

In general, it is reasonable to assume that operations and maintenance costs will be approximately one and one half to two cents per kWh. Operation and maintenance of fuel cell systems is typically handled by or through the original equipment manufacturer or project developer, and usually involves cleaning, replacement of filters, inspection of all fluid connections, routine water purification measurements, and to verify proper function of all communications equipment.

### **Economics and Funding**

In general, recommended projects are configured as behind the meter applications. This means they would displace the full per kWh retail value of the electricity produced by the system. In addition, for systems funded through the Low Emissions Renewable Energy Credit (LREC) program, a maximum payment of \$200/MWh is possible. This program is expected to begin in 2012 and will utilize a competitive performance based production incentive for actual energy produced based on a \$/MWh basis over a period of 15 years. The economics of grid connected fuel cell systems providing wholesale power at this scale may be prohibitive. As such, this approach is not recommended in this deployment plan.

The economics of fuel cell projects may be improved if development is undertaken and financed by a third party for-profit developer capable of garnering all of the federal business investment tax credits and accelerated depreciation benefits associated with renewable energy projects.<sup>195</sup> For systems deployed in 2012, a 50 percent first year bonus depreciation monetization structure is assumed as provided for under current law.<sup>196</sup>

A 300 kW or 400 kW fuel cell system installed at the Homer Babbidge Library could achieve a financial payback within the life of the system.<sup>197</sup> The economics of fuel cell systems will vary based on such

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<sup>195</sup> A developer may include the original equipment manufacturer.

<sup>196</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

<sup>197</sup> Assumes receipt of all applicable tax credits and depreciation benefits, a discount rate of 7 percent, natural gas at \$8 / MMBtu, and an LREC value of \$100 / MWh.

factors as capital and installed costs, thermal output and utilization, state and federal incentives, and electrical output and costs.

### **Site Orientation and Generation Loads**

Fuel cell systems are designed for installation outdoors under a variety of weather conditions. A fuel cell system could be located directly adjacent to the Homer Babbidge Library for enhanced public education. A 300 kW or 400 kW fuel cell system is calculated to produce between approximately 2,270,000 and 3,250,000 kWh and between approximately 6,370 and 15,612 MMBtu per year. It is anticipated that all of the electricity generated by a 300 kW or 400 kW fuel cell system would be used by UConn. UConn has supported the installation of a proton exchange membrane fuel cell on the main campus, and plans to install a 400 kW phosphoric acid fuel cell at the Depot Campus. The addition of another fuel cell on campus would demonstrate UConn's interest in, and contributions to, the advancement of hydrogen and fuel cell technology.

## **Information Technology Engineering Building**

### **Information Technology Engineering Site**

The Information Technology Engineering Building (ITE), located at 371 Fairfield Way at the main campus at Storrs, provides students and faculty in the School of Engineering with classrooms, a high-tech, 350-seat auditorium, research labs, administrative and faculty offices, and a spacious atrium.

### **Information Technology Engineering Building Loads and Average Fuel Cell System Output**

In 2011, the ITE Building consumed 2,294,985 kWh with a peak electric demand of 430 kW. The ITE Building is approximately 130,000 square feet in area, and is estimated to use approximately 11,000 MMBtu of thermal energy annually.<sup>198</sup> Currently, the ITE Building is supplied with thermal energy by the steam loop primarily for space heating and domestic hot water. Fuel cell systems with the best economic performance will capture both the retail value of the electricity produced and, for fuel cells which produce waste heat, displace thermal energy. Table 14 below provides expected annual system electric and thermal productivity for fuel cells without heat recovery for large stationary power applications:

**Table 14 - Expected System Electric and Thermal Productivity for Fuel Cells without Heat Recovery**

	<b>~10 Year Avg. Electric Output (kWh/year)</b>	<b>10 Year Avg. Thermal Output (MMBtus/Year)</b>
100 kW SOFC	850,000	NA <sup>199</sup>
200 kW SOFC	1,700,000	NA

Based on the annual electric demand, a 100 or 200 kW solid oxide fuel cell may be the best fit for the provision of electricity based on the ITE Building's electric demand. From a thermal standpoint, since solid oxide fuel cells do not produce a substantial amount of thermal energy as waste heat for site use, the ITE Building would continue to receive thermal energy from the campus' cogeneration system and central heating plant.

### **Fuel Cell System Visibility**

A fuel cell system could be deployed directly adjacent to the building, possibly on the north side of the ITE Building in order to maximize public visibility of the system. In addition to locating a fuel cell system in a prominent, high visibility location, a monitoring display could be installed in the lobby with information on the fuel cell, how it works, and performance data.

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<sup>198</sup> Correspondence from UConn dated February 2, 2012

<sup>199</sup> Solid oxide fuel cells do not produce a substantial amount of thermal energy.



**Figure 25 – Aerial View of ITE Building Site**



### Environmental Benefits of a Fuel Cell System

Fuel cells that provide baseload power for stationary power applications are typically configured to operate on a hydrogen rich fuel, such as natural gas. Fuel cells that provide baseload power for stationary power applications are a low emissions renewable energy technology. As such, the avoided emissions benefits are equal to the annual average emissions (lbs/MWh) of electric power within the region (Appendix I) less the emissions from a fuel cell.

**Table 15 - Emission Values for Fuels Cells (100 kW – 200 kW, No Heat Recovery)**

Air Emissions	Emissions Values <sup>200</sup> (lb/MWh)
NO <sub>x</sub>	0.01 - <.07
SO <sub>2</sub>	0.0001
CO <sub>2</sub> (without heat recovery)	773

<sup>200</sup> Bloom Energy ES-5000 and ES 5400 Product Data Sheets.

## Regulatory Restrictions (Siting)

Certificates of Environmental Compatibility and Public Need (Certificate) are not required for “(1) fuel cells built within the state with a generating capacity of two hundred fifty kilowatts or less, or (2) fuel cells built out of state with a generating capacity of ten kilowatts or less.” Further, “the council shall, in the exercise of its jurisdiction over the siting of generating facilities, approve by declaratory ruling ... (B) the construction or location of any fuel cell, unless the council finds a substantial adverse environmental effect, or of any customer-side distributed resources project or facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts.”<sup>201</sup> In order to confirm compliance with applicable environmental regulations and receive a formal decision regarding the applicability of a Certificate for a fuel cell system, a Petition for Declaratory Ruling is required to be filed with the Connecticut Siting Council. The Town of Mansfield does not exercise jurisdiction over building improvements, such as for fuel cell systems, installed on UConn’s campus.<sup>202</sup>

## Environmental Impacts and Permitting

The operation of a fuel cell system would generate noise, air emissions, and potentially a wastewater discharge.

Solid oxide fuel cells create 70 decibels of noise at 6 feet.<sup>203</sup> According to Connecticut DEEP regulations (Sec. 22a-69-3.5 (b)), “No person in a Class B Noise Zone shall emit noise exceeding the levels stated herein and applicable to adjacent Noise Zones.” The noise threshold for a Class B emitter to a receptor in any land use category is as follows:<sup>204</sup>

	<i><b>Class C Receptor</b></i>	<i><b>Class B Receptor</b></i>	<i><b>Class A Receptor/Day</b></i>	<i><b>Class A Receptor/Night</b></i>
<i><b>Class B Emitter</b></i>	62 dBA	62 dBA	55 dBA	45 dBA

While there are no residences proximate to the ITE Building, noise impacts should be considered when selecting a technology and the exact location for a fuel cell system, and detailed noise modeling may be necessary to avoid disruption/annoyance to students and/or faculty on campus.

As discussed above, the application of a fuel cell system with natural gas as a fuel will generate air emissions. However, because of the low emission characteristics of this technology, a 100 kW or 200 kW fuel cell may not require a new source review general permit for air emissions pursuant to Section 22a-174-3a of the Regulations of Connecticut State Agencies.<sup>205</sup>

<sup>201</sup> Connecticut General Statutes, Sec. 16-50k

<sup>202</sup> Personal communication with the Mansfield Department of Building and Housing Inspection

<sup>203</sup> Bloom Energy ES-5700 Energy Saver Product Data Sheet; 2-12-12.

<sup>204</sup> Connecticut Department of Energy and Environmental Protection, “Control of Noise,”

<http://www.ct.gov/dep/lib/dep/regulations/22a/22a-69-1through7.pdf>, March, 2012

<sup>205</sup> Department of Energy & Environmental Protection, “Air Emission – New Source Review Program,”

[http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324136&depNav\\_GID=1643](http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324136&depNav_GID=1643), October 2009

In addition, some fuel cells both consume and discharge water; however, a 100 kW or 200 kW solid oxide fuel cell would not discharge wastewater to UConn's wastewater collection and treatment system. Accordingly, a Miscellaneous General Permit for wastewater discharge may not be required.<sup>206</sup>

Installation of a fuel cell at the ITE Building is not expected to result in any adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern.

### **Site Restrictions Due to Land Use / Master Planning Considerations**

The 2006 Storrs Campus Master Plan Update<sup>207</sup> does not contain any information which would indicate a conflict with deploying a fuel cell system at this site. The 2004 Sustainable Design Guidelines specifies exploring "fuel cells and other alternative energy supply systems. Capture the heat created from fuel cells as a strategy to increase operational efficiency."<sup>208</sup> In terms of land use, a 100 kW or 200 kW solid oxide fuel cell system would require the following space requirements:

**Table 16 - Dimensions of Fuel Cell Stack and Balance of Plant for Solid Oxide Fuel Cells**

	<b>Length</b>	<b>Width</b>	<b>Height (Max)</b>
100 kW Solid Oxide Fuel Cell	15' 6"	8' 6"	6' 9"
200 kW Solid Oxide Fuel Cell	26' 5"	8' 7"	6' 9"

### **Capital Cost**

A fuel cell system is expected to cost between \$5,500 and \$8,000 per kW. Actual project costs may be higher or lower.

### **Operation and Maintenance Cost**

In general, it is reasonable to assume that operations and maintenance costs will be approximately one and one half to two cents per kWh. Operation and maintenance of fuel cell systems is typically handled by or through the original equipment manufacturer or project developer, and usually involves cleaning, replacement of filters, inspection of all fluidic connections, perform routine water purification measurements, and to verify proper function of all communications equipment.

### **Economics and Funding**

In general, recommended projects are configured as behind the meter applications. This means they would displace the full per kWh retail value of the electricity produced by the system. In addition, for systems funded through the Low Emissions Renewable Energy Credit (LREC) program, a maximum

<sup>206</sup> Bureau of Materials Management and Compliance Assurance, "General Permit for Miscellaneous Discharges of Sewer Compatible (MISC) Wastewater," [http://www.ct.gov/dep/lib/dep/Permits\\_and\\_Licenses/Water\\_Discharge\\_General\\_Permits/misc\\_gp.pdf](http://www.ct.gov/dep/lib/dep/Permits_and_Licenses/Water_Discharge_General_Permits/misc_gp.pdf), April 30, 2011

<sup>207</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>208</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

payment of \$200/MWh is possible. This program is expected to begin in 2012 and will utilize a competitive performance based production incentive for actual energy produced based on a \$/MWh basis over a period of 15 years. The economics of grid connected fuel cell systems providing wholesale power at this scale may be prohibitive. As such, this approach is not recommended in this deployment plan.

The economics of fuel cell projects may be improved if development is undertaken and financed by a third party for-profit developer capable of garnering all of the federal business investment tax credits and accelerated depreciation benefits associated with renewable energy projects.<sup>209</sup> For systems deployed in 2012, a 50 percent first year bonus depreciation monetization structure is assumed as provided for under current law.<sup>210</sup>

A 100 kW or 200 kW solid oxide fuel cell system installed at the ITE Building could achieve a financial payback within the life of the system.<sup>211</sup> The economics of fuel cell systems will vary based on such factors as capital and installed costs, thermal output and utilization, state and federal incentives, and electrical output and costs.

### **Site Orientation and Generation Loads**

Fuel cell systems are designed for installation outdoors under a variety of weather conditions. A fuel cell system could be located directly adjacent to the ITE Building for enhanced public education. A 100 kW or 200 kW fuel cell system is calculated to produce between approximately 850,000 kWh and 1,700,000 kWh per year. It is anticipated that all of the electricity generated by a 100 kW or 200 kW fuel cell system would be used by UConn. UConn has supported the installation of a proton exchange membrane fuel cell on the main campus, and plans to install a 400 kW phosphoric acid fuel cell at the Depot Campus. The addition of another fuel cell on campus would demonstrate UConn's interest in, and contributions to, the advancement of hydrogen and fuel cell technology.

As an alternative, a larger 800 kW – 1.4 MW fuel cell system located between the Homer Babbidge Library and the ITE building could provide electricity and thermal energy for both buildings. Such a configuration may provide for reduced costs through economy of scale, and support research interests for integration of distributed energy resources and Smart Grid technologies.

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<sup>209</sup> A developer may include the original equipment manufacturer.

<sup>210</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

<sup>211</sup> Assumes receipt of all applicable tax credits and depreciation benefits, a discount rate of 7 percent, natural gas at \$8 / MMBtu, and an LREC value of \$100 / MWh.

## **Horsebarn Hill Sciences Complex Building #4 Annex**

### **Horsebarn Hill Sciences Complex Building #4 Annex Site**

Building #4 Annex, located on Horsebarn Hill Road on the main campus at Storrs, is used by faculty and staff to promote multidisciplinary research, education and outreach in environmental sciences, engineering, policy, and sustainability.

### **Building #4 Annex Loads and Average Fuel Cell System Output**

In 2011, the Building #4 Annex consumed 321,467 kWh<sup>212</sup> and had a peak electric demand of 147 kW. The Building #4 Annex is approximately 23,000 square feet in area, and is estimated to use approximately 3,200 MMBtu of thermal energy annually.<sup>213</sup> Currently, the Building #4 Annex is supplied with thermal energy by natural gas fired boilers for space heating and domestic hot water. The cooling system consists of a chiller/cooling tower, which provides the chilled water to the Building 4 Annex, and an air cooled condenser that may provide back-up for the Building #4 Annex.

**Table 17- Expected System Electric and Thermal Productivity for Fuel Cells That Can Meet Smaller Base and Peaking Loads:**

	<b>~10 Year Avg. Electric Output (kWh/year)</b>	<b>10 Year Avg. Thermal Output (MMBtus/Year)</b>
5 kW PEM	39,000	152

Based on the annual electric demand and the projected thermal demand, a 5 kW proton exchange membrane fuel cell may be a best fit for the provision of electricity based on the Building #4 Annex's electric and thermal demand. Currently, 5 kW fuel cell systems are commercially available for backup power or baseload power applications. For this potential site, a 5 kW fuel cell system for baseload power was assessed. From a thermal standpoint, UConn would need to determine whether thermal energy from a fuel cell could supplement the building's heating system. Fuel cell systems with the best economic performance will capture both the retail value of the electricity produced and, for fuel cells which produce waste heat, displace thermal energy.

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<sup>212</sup> Correspondence from UConn dated January 4, 2012.

<sup>213</sup> Correspondence from UConn dated February 2, 2012

### **Fuel Cell System Visibility**

A fuel cell system could be deployed directly adjacent to the building, possibly on the south side near the chiller/cooling tower for possible integration with the buildings HVAC equipment. In order to maximize public awareness of the system, a monitoring display could be installed in the lobby with information on the fuel cell, how it works, and performance data.

**Figure 26 – Aerial View of Building #4 Annex Site**



### **Environmental Benefits of a Fuel Cell System**

Fuel cells that provide power for stationary power applications are typically configured to operate on a hydrogen rich fuel, such as natural gas. Fuel cells that provide baseload power for stationary power applications are a low emissions renewable energy technology. As such, the avoided emissions benefits are equal to the annual average emissions (lbs/MWh) of electric power within the region (Appendix I) and the emissions associated with the provision of thermal energy, less the emissions from a fuel cell.



**Table 18 - Emission Values for a 5 kW Fuel Cell Operating on Methane**

<b>Air Emissions</b>	<b>Emissions Values<sup>214</sup> (lb/MWh)</b>
<b>NO<sub>x</sub></b>	negligible
<b>SO<sub>2</sub></b>	negligible
<b>CO<sub>2</sub> (without heat recovery)</b>	≈ 1,060

### **Regulatory Restrictions (Siting)**

Certificates of Environmental Compatibility and Public Need (Certificate) are not required for “(1) fuel cells built within the state with a generating capacity of two hundred fifty kilowatts or less, or (2) fuel cells built out of state with a generating capacity of ten kilowatts or less.” Further, “the council shall, in the exercise of its jurisdiction over the siting of generating facilities, approve by declaratory ruling ... (B) the construction or location of any fuel cell, unless the council finds a substantial adverse environmental effect, or of any customer-side distributed resources project or facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts.”<sup>215</sup> Consequently, a Petition for Declaratory Ruling is required to be filed with the Connecticut Siting Council for any fuel cell. The Town of Mansfield does not exercise jurisdiction over building improvements, such as for fuel cell systems, installed on UConn’s campus.<sup>216</sup>

### **Environmental Impacts and Permitting**

The operation of a fuel cell system would generate noise, air emissions, and potentially a wastewater discharge.

A 5 kW fuel cell system is expected to generate 60 decibels at three feet.<sup>217</sup> According to Connecticut DEEP regulations (Sec. 22a-69-3.5 (b)), “No person in a Class B Noise Zone shall emit noise exceeding the levels stated herein and applicable to adjacent Noise Zones.”

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<sup>214</sup> ClearEdge Power - Corporate Overview and System Specifications for Commercial Applications; “How Can a ClearEdge5 System Help California Reach AB32, Which Mandates 20 percent CO2 Emissions Reductions By 2020”, 2-13-12.

<sup>215</sup> Connecticut General Statutes, Sec. 16-50k

<sup>216</sup> Personal correspondence with Mansfield Department of Building and Housing Inspection

<sup>217</sup> Clear Edge Power - Corporate Overview and System Specifications for Commercial Applications; 2-13-12



The noise threshold for a Class B emitter to a receptor in any land use category is as follows:<sup>218</sup>

	<b><i>Class C Receptor</i></b>	<b><i>Class B Receptor</i></b>	<b><i>Class A Receptor/Day</i></b>	<b><i>Class A Receptor/Night</i></b>
<b><i>Class B Emitter</i></b>	62 dBA	62 dBA	55 dBA	45 dBA

While there are no residences proximate to the Building #4 Annex, noise impacts should be considered when selecting a technology and the exact location for a fuel cell system, and detailed noise modeling may be necessary to avoid disruption/annoyance to students and/or faculty on campus.

As discussed above, the application of a fuel cell system with natural gas as a fuel will generate air emissions. However, because of the low emission characteristics of this technology, a 5 kW fuel cell may not require a new source review general permit for air emissions pursuant to Section 22a-174-3a of the Regulations of Connecticut State Agencies.<sup>219</sup>

In addition, some fuel cells both consume and discharge water. It is anticipated that any wastewater from a fuel cell at the Building #4 Annex would be discharged to UConn's wastewater collection and treatment system, but such discharge is not expected to be significant. According to the Connecticut DEEP, a Miscellaneous General Permit for wastewater discharge may be required.<sup>220</sup> Water consumption and discharge information for a 5 kW proton exchange membrane fuel cell is as follows:

**Table 19 - Water Consumption and Discharge Rates for a 5 kW Proton Exchange Membrane Fuel Cell**

	<b>Water Consumption (gallons per minute)</b>	<b>Water Discharge (gallons per minute)</b>
Proton Exchange Membrane Fuel Cells	.016	.0056

The deployment of a 5 kW fuel cell at the Building #4 Annex is not expected to result in any adverse impacts on scenic resources, historic buildings, or endangered species or species of special concern.

<sup>218</sup> Connecticut Department of Energy and Environmental Protection, "Control of Noise," <http://www.ct.gov/dep/lib/dep/regulations/22a/22a-69-1through7.pdf>, March, 2012

<sup>219</sup> Department of Energy & Environmental Protection, "Air Emission – New Source Review Program," [http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324136&depNav\\_GID=1643](http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324136&depNav_GID=1643), October 2009

<sup>220</sup> Bureau of Materials Management and Compliance Assurance, "General Permit for Miscellaneous Discharges of Sewer Compatible (MISC) Wastewater," [http://www.ct.gov/dep/lib/dep/Permits\\_and\\_Licenses/Water\\_Discharge\\_General\\_Permits/misc\\_gp.pdf](http://www.ct.gov/dep/lib/dep/Permits_and_Licenses/Water_Discharge_General_Permits/misc_gp.pdf), April 30, 2011

## Site Restrictions Due to Land Use / Master Planning Considerations

The 2006 Storrs Campus Master Plan Update<sup>221</sup> does not contain any information which would indicate a conflict with deploying a fuel cell system at this site. The 2004 Sustainable Design Guidelines specifies exploring “fuel cells and other alternative energy supply systems. Capture the heat created from fuel cells as a strategy to increase operational efficiency.”<sup>222</sup> In terms of land use, a potential fuel cell system would require the following space requirements:

**Table 20 - Dimensions of Fuel Cell Stack and Balance of Plant for a 5 kW Proton Exchange Membrane Fuel Cell**

	Length	Width	Height (Max)
5 kW Proton Exchange Membrane Fuel Cell	36"	27"	70"

## Capital Cost

A 5 kW fuel cell system is expected to cost approximately \$10,000 per kW.<sup>223</sup> Actual project costs may be higher or lower.

## Operation and Maintenance Cost

In general, it is reasonable to assume that operations and maintenance costs will be approximately one and one half to two cents per kWh. Operation and maintenance of fuel cell systems is typically handled by or through the original equipment manufacturer or project developer, and usually involves cleaning, replacement of filters, inspection of all fluidic connections, perform routine water purification measurements, and to verify proper function of all communications equipment.

## Economics and Funding

In general, recommended projects are configured as behind the meter applications. This means they would displace the full per kWh retail value of the electricity produced by the system. In addition, for systems funded through the Low Emissions Renewable Energy Credit (LREC) program, a maximum payment of \$200/MWh is possible. This program is expected to begin in 2012 and will utilize a competitive performance based production incentive for actual energy produced based on a \$/MWh basis over a period of 15 years. The economics of grid connected fuel cell systems providing wholesale power at this scale may be prohibitive. As such, this approach is not recommended in this deployment plan.

The economics of fuel cell projects may be improved if development is undertaken and financed by a third party for-profit developer capable of garnering all of the federal business investment tax credits and

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<sup>221</sup>University of Connecticut, “Storrs Campus Master Plan Update,” <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>222</sup> University of Connecticut, “Campus Sustainable Design Guidelines,” <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

<sup>223</sup> CNET, “ClearEdge touts home fuel cell over solar panels”, February 28, 2011. Fuel Cell and Hydrogen Energy Association, “ClearEdge Touts Residential Fuel Cells Units- Jackie Autry Receives a Fuel Cell”, March 3, 2011.

accelerated depreciation benefits associated with renewable energy projects.<sup>224</sup> For systems deployed in 2012, a 50 percent first year bonus depreciation monetization structure is assumed as provided for under current law.<sup>225</sup>

A 5 kW fuel cell system installed at the Building #4 Annex could achieve a financial payback within the life of the system.<sup>226</sup> The economics of fuel cell systems will vary based on such factors as capital and installed costs, thermal output and utilization, state and federal incentives, and electrical output and costs.

### **Site Orientation and Generation Loads**

Fuel cell systems are designed for installation outdoors under a variety of weather conditions. A fuel cell system located at the Building #4 Annex could supplement other renewable energy technologies, and serve as a cluster for enhanced public education. A 5 kW fuel cell system is calculated to produce approximately 39,000 kWh and approximately 152 MMBtu of thermal energy per year. It is anticipated that all of the electricity generated by a 5 kW fuel cell system would be used by UConn. UConn has supported the installation of a proton exchange membrane fuel cell on the main campus, and plans to install a 400 kW phosphoric acid fuel cell at the Depot Campus. The addition of another fuel cell on campus would demonstrate UConn's interest in, and contributions to, the advancement of hydrogen and fuel cell technology.

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<sup>224</sup> A developer may include the original equipment manufacturer.

<sup>225</sup> Dsireusa.org, "Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008 – 2012)," [http://dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US06F&re=1&ee=1](http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F&re=1&ee=1), October 14, 2011

<sup>226</sup> Assumes receipt of all applicable tax credits and depreciation benefits, a discount rate of 7 percent, natural gas at \$8 / MMBtu, and an LREC value of \$100 / MWh.

## BIOFUELS

Biomass energy resources and biodiesel can both be considered for deployment at UConn Campus. Biomass gasification involves the use of biomass as a feedstock (forest, agricultural, and certain organic wood wastes), heat, and pressure in a controlled gasifier environment to make a hydrogen-rich fuel. This hydrogen rich fuel can then be used by various technologies to produce electricity and thermal energy. The use of biomass for solid-fuel boilers, which are designed to burn agriculture crop residues, such as corn stover or wheat straw, forest residues, etc. could also produce steam or hot water. The biomass steam can be used in a topping-cycle electrical generator to produce electricity first, then low-pressure steam or hot water for other thermal purposes with the turbine-generator exhaust steam.

Biodiesel is a renewable fuel that can be manufactured from new and used vegetable oils, animal fats, and recycled restaurant grease. Biodiesel's physical properties are similar to those of petroleum diesel, but it is a cleaner-burning alternative. The use of biodiesel can reduce emissions of pollutants that impact air quality, and greenhouse gas emissions.<sup>227</sup> Biodiesel can be produced using a variety of esterification technologies. The oils and fats are filtered and preprocessed to remove water and contaminants. If free fatty acids are present, they can be removed or transformed into biodiesel using special pretreatment technologies. The pretreated oils and fats are then mixed with an alcohol (usually methanol) and a catalyst (usually sodium hydroxide or potassium hydroxide). The oil molecules (triglycerides) are broken apart and reformed into methyl esters and glycerin, which are then separated from each other and purified.

General criteria to consider when evaluating potential buildings/areas for the installation of a biofuels facility includes:

- Sites with access to both water and sewer service connections;
- Sites at or near a source of biomass energy resources;
- Truck access for the transport of feedstock, production materials, finished product, or waste materials; and
- Opportunity to use waste heat to reduce process costs.

### Biogas Related Research

Richard Parnas, a professor of Chemical Engineering Department and the Institute of Materials Science conducts research into continuous flow biodiesel reactors as well as spectroscopic remote testing technology.

Steven Suib, a professor of Inorganic and Environmental Chemistry has conducted research into novel biofuel catalysts for biofuel production. The development of new catalysts will enable the utilization of new feedstocks for biodiesel production.

Radenka Maric, a professor in the Chemical, Materials & Biomolecular Engineering Department and Ioulia Valla, an Assistant Research Professor in the Chemical, Materials & Biomolecular Engineering Department plan to continue to conduct research on biomass gasification using the small scale

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<sup>227</sup> U.S. DOE EERE, "Vehicle Technologies Program," <http://www.afdc.energy.gov/afdc/pdfs/47504.pdf>, February 2011

gasification system donated by the City of Stamford. The research will involve 1) the integration of the gasifier with fuel cell systems, and 2) finding methods for cleaning and reforming remaining tars in the gasification stream without resorting to low temperature clean up methods. This research will enable the energy value of low value hydrocarbons to be utilized in energy generation, improving the efficiency of the overall process. This small scale gasification system will be used to size and specify the components for a lab scale gas clean up device to be used at the proof of concept stage. The input gas for this system will be a simulated syngas, in order to retain control over the process parameters of the system. The proof of concept system would be tested over a variety of process conditions to optimize its performance and determine the operating range limitations.<sup>228</sup>

Jackie Sung, a professor of Mechanical Engineering, who specializes in fuels and combustion and Challa Kumar, a professor of Chemistry who specializes in biocatalysts are interested in helping pursue the development of a gasification or methanation facility on the Storrs campuses. Given a variety of fuel feedstocks, the facility would be able to make gaseous or liquid fuels depending on the demand.

Farhed Shah, a professor of Agriculture and Resource Economics, specializes in conducting economic analyses in a variety of fields, particularly on water resources. Deep Mukherjee is a graduate student working with Dr. Shah who specializes in energy economics. Professor Shah and Mr. Mukherjee are interested in performing cost/benefit analyses of biogas or composting facilities that may be deployed. The analyses would examine the efficacy and potential of these technologies and may include externalities such as reduction in harmful emissions and economic impact on the local community.

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<sup>228</sup> Correspondence from the University of Connecticut dated January 20, 2012

## **Longley Building - Biodiesel**

### **Longley Building Site**

The Longley Building, located at 270 Middle Turnpike on the Depot Campus at Storrs, is the location of the Connecticut Transportation Institute, and is also used for storage.

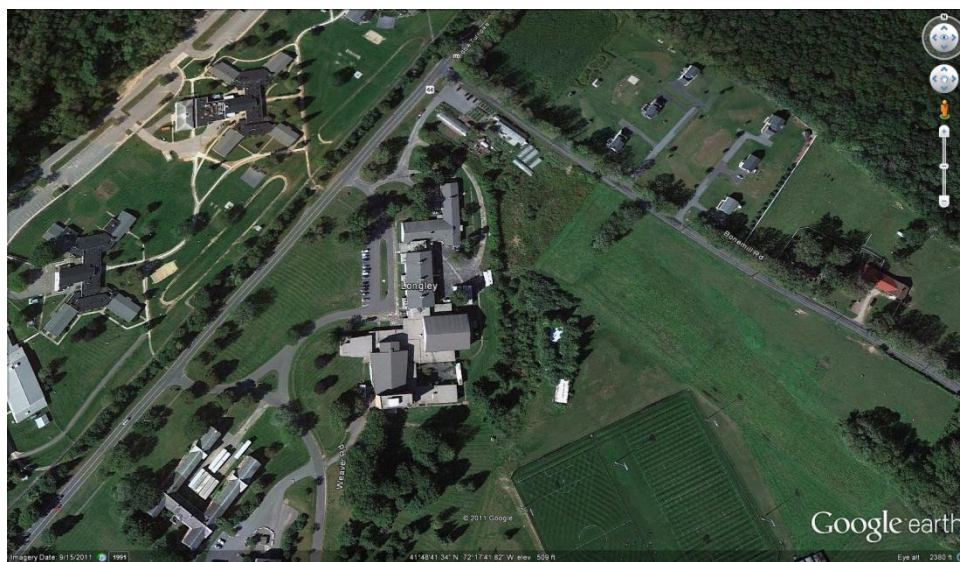
### **Overview**

UConn's Chemical Engineering Department seeks to develop a demonstration scale 150,000 GPY continuous flow biodiesel production system, which when operated 24/7 may produce approximately 75,000 GPY.<sup>229</sup> This biodiesel production system would require approximately 1,500 square feet of indoor space, ideally approximately 50 feet long by 30 feet wide by 12 feet high. The former gymnasium at the Longley Building, which is currently used for storage, could accommodate the system's indoor space requirements.<sup>230</sup> The biodiesel production facility could utilize yellow grease to produce biodiesel.

### **Biodiesel System Visibility**

A biodiesel production system at the Longley Building would be primarily located inside the building; however, some equipment including methanol and product storage tanks would need to be located outside the building. If this site is selected for development, a monitoring display could be installed at the Longley Building or at the Center for Clean Energy Engineering with details on the biodiesel production system.

**Figure 27 - Aerial View of Longley Building Site**



<sup>229</sup> Personal communication with Dr. Richard Parnas, January 6, 2012.

<sup>230</sup> Personal communication with Dr. Richard Parnas, February 25, 2011.



## Environmental Benefits of Biodiesel Production and Utilization

The environmental benefits of biodiesel production are accrued from using the finished biodiesel product and displacing diesel fuel and its associated emissions. Biodiesel produced at UConn could be used for the University's fuel oil boilers and emergency generators, and diesel-fueled vehicles. UConn has approximately 40 oil fired boilers at the Storrs campuses that consumed approximately 120,000 gallons of fuel (heating) oil in 2010.<sup>231</sup> In addition, approximately 130,000 gallons of diesel fuel were used by the University's shuttle buses in 2010. If approximately 20 percent of the University's fuel oil requirements (50,000 gallons per year) were displaced by biodiesel, UConn could realize the following emissions impacts:

**Table 21 – Estimated Annual Emissions Impacts of Using 50,000 Gallons of B100 Biodiesel**

<b>B100 Gallons</b>	<b>Emissions</b>	<b>Lbs of Emissions Reduced/Increased</b>
50,000	<b>NO<sub>x</sub></b>	+745
	<b>SO<sub>2</sub></b>	-221
	<b>CO<sub>2</sub></b>	-806,000

If approximately 75,000 gallons of the University's fuel oil requirements were displaced by biodiesel, UConn could realize the following emissions impacts:

**Table 22 – Estimated Annual Emissions Impacts of Using 75,000 Gallons of B100 Biodiesel**

<b>B100 Gallons</b>	<b>Emissions</b>	<b>Lbs of Emissions Reduced/Increased</b>
75,000	<b>NO<sub>x</sub></b>	+1,162
	<b>SO<sub>2</sub></b>	-331
	<b>CO<sub>2</sub></b>	-1,209,000

## Regulatory Restrictions (Siting)

There are no state regulatory siting restrictions on the development of a biodiesel production facility in Connecticut. The Town of Mansfield does not exercise jurisdiction over building improvements installed on UConn's Storrs campuses.<sup>232</sup>

## Environmental Impacts and permitting

The operation of a biodiesel production facility is not expected to generate substantial noise; however, noise impacts should be considered when determining the facility's equipment configuration and operational requirements. Detailed noise modeling may be necessary to avoid disruption/annoyance to

<sup>231</sup> Information obtained from UConn, September 21, 2011.

<sup>232</sup> Personal communication with the Mansfield Department of Building and Housing Inspection and Mansfield Fire Department

students and/or faculty on campus.

In general, permitting requirements will ultimately depend on the technology deployed at the facility, the type of feedstocks, storage requirements, and operations. Typically, permits are required for onsite processing of waste grease and other feedstocks. According to DEEP, most permitting/compliance requirements have so far originated from the State Fire Marshall's Office. Consistency with all applicable fire code regulations will be required for completion and operation of a biodiesel production facility.

A biodiesel production facility would most likely have to comply with Emergency Planning and Community Right-to-Know (EPCRA) guidelines because it is a facility that would store or handle chemicals. Chemical Hazard Reporting Form may be required by the local emergency planning committee, DEEP, and University and/or local fire response personnel for any material requiring a material safety data sheet (such as methanol).

There may be air emissions associated with the use of methanol; consequently, an air permit may be required if methanol emissions exceed allowable thresholds.

Development of a Spill Prevention, Control and Countermeasures (SPCC) Plan addressing oil storage as for facilities which have greater than 1,320 gallons of oil stored in above ground tanks may be required. If the facility has already prepared an SPCC Plan, or a Stormwater Pollution Prevention Plan, or some other emergency or contingency plan, that plan may be amended to incorporate provisions to comply with regulatory requirements.<sup>233</sup>

Connecticut DEEP uses both individual and general permits to regulate discharge activities. Individual permits are issued directly to an applicant, whereas general permits, which are less costly and may be quicker to obtain, are permits issued to authorize similar minor activities by one or more applicants. A biodiesel production facility will require consistency with General Permit Registrations, including Industrial Stormwater and Miscellaneous Discharges of Sewer Compatible Wastewaters Miscellaneous Discharges of Sewer Compatible (MISC) Wastewater. For sites with a footprint greater than 5 acres, a Construction Stormwater General Permit may also be required.<sup>234</sup>

There are no Natural Diversity Data Base Areas, which represent known locations, both historic and extant, of state listed species and significant natural communities, identified at or immediately proximate to Longley Building. State listed species are those listed as Endangered, Threatened or Special Concern under the Connecticut Endangered Species Act (Connecticut General Statutes, Section 26-303).<sup>235</sup> Because the biodiesel production facility would be installed primarily within an existing building that is

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<sup>233</sup> Ross Q. Bunnell, PE. *Environmental Requirements for Biodiesel Facilities*, 2007. Robert Hannon, Connecticut Department of Energy and Environmental Protection, dated 2/28/2012.

<sup>234</sup> Connecticut Department of Energy and Environmental Protection, "General Permits – An Environmental Permitting Fact Sheet," [http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324154&depNav\\_GID=1643](http://www.ct.gov/dep/cwp/view.asp?a=2709&q=324154&depNav_GID=1643), February 2012

<sup>235</sup> Natural Diversity Database Areas - July 2011, GIS Shapefile, Connecticut Department of Energy and Environmental Protection.

not designated as an historic building,<sup>236</sup> no adverse impacts on scenic resources or historic buildings are anticipated.

### **Site Restrictions Due to Land Use / Master Planning Considerations**

The Outlying Parcels Master Plan seeks to preserve the character of UConn's Depot Campus relative to historic features and natural beauty.<sup>237</sup> A small scale biodiesel production facility may be consistent with the goals of the Master Plan. However, UConn should consider the impact that a biodiesel production facility may have on the character of the Depot Campus when designing or configuring the site. The 2004 Sustainable Design Guidelines specifies exploring "fuel cells and other alternative energy supply systems. Capture the heat created from fuel cells ..." as a strategy to increase operational efficiency.<sup>238</sup> A biodiesel production plant located at Longley Building, which utilizes waste heat from a fuel cell located at the Center for Clean Energy Engineering, would be consistent with this aspect of the 2004 Sustainable Design Guidelines. The 2006 Storrs Campus Master Plan Update<sup>239</sup> does not contain any information which would indicate a conflict with deploying a biodiesel production facility at this site.

### **Capital Cost**

The capital costs for a biodiesel production facility can range from \$950,000 for a 500,000 GPY facility to \$15 million for a 30 million GPY facility.<sup>240</sup> It is estimated that a 150,000 GPY biodiesel production facility could have a capital cost between \$300,000 to \$750,000.

### **Operation and Maintenance Cost**

Maintenance of a biodiesel production facility may include routine maintenance on the reactor and storage tanks, inspection of the ventilation system, and inspection of the wastewater treatment and discharge systems where applicable. Operation and maintenance cost will vary depending on the size of the facility, reaction efficiency and characteristics, capacity utilization, and reactor installation and construction quality.

### **Economics and Funding**

The economics of a biodiesel production facility is dependent on several factors including: (1) the facility's capital cost; (2) the cost of the biodiesel feedstocks; (3) the cost of methanol and other reactants; (4) the value of all products and co-products; (5) utility costs; (6) prevailing labor costs; (7) the facility's capacity utilization; (8) permitting costs; and (9) the availability of grant funding.

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<sup>236</sup> Correspondence from Stacey S. Vairo, State and National Register Coordinator, Connecticut State Historic Preservation Office received November 1, 2011.

Department of Economic and Community Development (DECD)

<sup>237</sup> University of Connecticut, "Outlying Parcels Master Plan," [http://masterplan.uconn.edu/images/OPMP\\_5\\_22\\_2000.pdf](http://masterplan.uconn.edu/images/OPMP_5_22_2000.pdf), June 2000

<sup>238</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

<sup>239</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

<sup>240</sup> Ascension-Publishing, "A Study on the Feasibility of Biodiesel Production in Georgia," Table 3, p. 11, <http://www.ascension-publishing.com/BIZ/HD41.pdf>, Shumaker, George, 2000

Currently, the Connecticut Center for Advanced Technology, Inc. (CCAT) administers Connecticut's Biodiesel Programs. At present, all biodiesel production and distribution facilities funding is committed or expended. However, grants are available on a per gallon basis for the production of biodiesel.

### **Summary**

UConn is estimated to use approximately 250,000 gallons of diesel per year for heating and transportation. A 150,000 GPY biodiesel production facility could produce approximately 75,000 GPY of domestically produced biodiesel each year. If all of the 75,000 gallons of biodiesel is used and displaces the use of conventional diesel fuel and its associated emissions, UConn could reduce CO<sub>2</sub> emissions by approximately 1.2 million pounds per year. The production and use of biodiesel was also assessed in the Preliminary Feasibility Study and Strategic Plan for the Depot Campus.

## Center for Clean Energy Engineering - Biogas

### **Center for Clean Energy Engineering Site**

The Center for Clean Energy Engineering (C2E2), located at 44 Weaver Road on the Depot Campus at Storrs, engages in advanced technological research related to clean energy technologies. C2E2 has 16,000 square feet of laboratory and office space, equipment for prototype manufacturing, cell assembly, materials characterization, and fuel cell testing and diagnostics. C2E2 is located approximately 2,000 feet southwest of UConn's compost facility located off Route 32 in Mansfield.

### **Overview**

The City of Stamford, in partnership with the U.S. Department of Energy, CH2MHILL, and Carlin Contracting developed a demonstration scale a gasification system as part of a pilot research and development project to demonstrate that dried and pelletized wastewater residuals (sludge) can be used as a renewable energy source to generate electrical power.<sup>241</sup> The City of Stamford has agreed to donate the small scale gasification system and electric generator to UConn.

### **Gasification System Visibility**

The small scale gasification system and electric generator, which measures approximately 8 feet by 12 feet horizontal and less than 10 feet vertical, was constructed and mounted onto a 16 foot trailer for easy transportation. Given the system's size, visibility considerations are expected to be minimal. If the gasification model is located at C2E2, students from various colleges at the university can view the system, perform experiments, and create business concepts consistent with their educational goals.

**Figure 28 - Aerial View of the Compost facility and the Center for Clean Energy Engineering**



<sup>241</sup> Stamford Biogas; <http://www.stamfordbiogas.com/>, March 2012

## **Environmental Benefits of Biogas Production and Utilization**

A small scale gasification system and electric generator would achieve environmental benefits by displacing fossil fuels used to produce electricity. However, the gasification process will generate a gas that contains carbon monoxide, carbon dioxide, hydrogen, methane, and ethane/ethylene.<sup>242</sup>

Consequently, UConn will need to ensure compliance with the Connecticut Department of Energy and Environmental Protection air permitting requirements.

## **Regulatory Restrictions (Siting)**

Certificates of Environmental Compatibility and Public Need are not required for "...any customer-side distributed resources project or a facility or grid-side distributed resources project or facility with a capacity of not more than sixty-five megawatts, as long as such project meets air and water quality standards of the Department of Environmental Protection..."<sup>243</sup> However, in order to confirm compliance with applicable environmental regulations and receive a formal decision regarding the applicability of a Certificate for a small scale gasification system and electric generator, a Petition for Declaratory Ruling may be required to be filed with the Connecticut Siting Council. The Town of Mansfield does not exercise jurisdiction over building improvements, such as for fuel cell systems, installed on UConn's campuses.<sup>244</sup>

## **Site Restrictions Due to Land Use / Master Planning Considerations**

The Outlying Parcels Master Plan seeks to preserve the character of UConn's Depot Campus relative to historic features and natural beauty.<sup>245</sup> A small scale gasification system and electric generator may be consistent with the goals of the Master Plan. However, UConn should consider the impact that a gasification system and electric generator may have on the character of the Depot Campus when configuring the trailer mounted system at the site. The 2004 Sustainable Design Guidelines specifies exploring "fuel cells and other alternative energy supply systems" and "identification of systems that increase the operational efficiencies."<sup>246</sup> A small scale gasification system and electric generator located at C2E2, would be consistent with this aspect of the 2004 Sustainable Design Guidelines. The 2006 Storrs Campus Master Plan Update<sup>247</sup> does not contain any information which would indicate a conflict with deploying a small scale gasification system and electric generator at this site.

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<sup>242</sup> Stamford Bio-Gas, [http://www.stamfordbiogas.com/tests\\_data.html](http://www.stamfordbiogas.com/tests_data.html)

<sup>243</sup> Connecticut General Statutes, Sec. 16-50k

<sup>244</sup> Phone call with Mansfield Department of Building and Housing Inspection

<sup>245</sup> University of Connecticut, "Outlying Parcels Master Plan," [http://masterplan.uconn.edu/images/OPMP\\_5\\_22\\_2000.pdf](http://masterplan.uconn.edu/images/OPMP_5_22_2000.pdf), June 2000

<sup>246</sup> University of Connecticut, "Campus Sustainable Design Guidelines," <http://masterplan.uconn.edu/images/SDG-web.pdf>, November 2004

<sup>247</sup> University of Connecticut, "Storrs Campus Master Plan Update," <http://masterplan.uconn.edu/images/6-0331storrs-small.pdf>, January 2006

## **Capital Cost**

The small scale gasification system and 7 kW electric generator would be donated by the City of Stamford.<sup>248</sup> As such, there would not be a substantial capital outlay associated with this project.

## **Operation and Maintenance Cost**

Operation costs associated with collection, delivery and processing of biomass feedstock would be minimized given C2E2's proximity to UConn's compost facility. UConn's compost facility receives 10 to 15 truckloads on dry manure from UConn's agricultural operations each week.<sup>249</sup> The small scale gasification system could process up to 20 kilograms (44 pounds) of biomass material per hour. The maintenance of the biogas system would include routine maintenance for the electric generator (i.e. changing the oil, tune up, etc.), as well as ensuring proper functionality of the system's other components.

## **Economics and Funding**

The economics of a small scale gasification system and electric generator may be challenged due to labor input requirements and the amount of electricity that could be generated by the system. However, this small scale gasification system and electric generator would be used primarily to support research for cleaning and reforming tars in the gas stream to improve energy utilization. As such, the economic viability of the project as an investment grade renewable energy project is not applicable.

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<sup>248</sup> Correspondence from UConn dated August 30, 2011.

<sup>249</sup> University of Connecticut Office of Environmental Policy, "UConn Compost Facility – Facility Information," <http://www.ecohusky.uconn.edu/facilityinfo.htm>, March 2012



## **Conclusion**

This Plan demonstrates the potential viability of six renewable technologies (solar thermal, solar PV, wind, geothermal, fuel cells, and biofuels), to operate at selected facility sites on the main and Depot Campuses at Storrs. Operations will reduce GHG emissions, support research, provide economic return on investment with use of federal and state incentives, and will enhance community involvement.

Analytical modeling identifies the potential reduction of approximately 1,570,000 to 2,370,000 lbs/year of GHG emissions, approximately 1,400 MMBtus of renewable thermal energy production, 3.22 to 5.05 million kWh/year in renewable electricity production, and reductions of 50,000 to 75,000 gallons per year of diesel fuel consumption. The energy produced may include processing of waste (biomass), notably to reduce waste management costs and produce fungible fuels (biodiesel) to be used in buildings and for transportation in UConn's vehicles. The deployment of these technologies is consistent with UConn's GHG emissions reduction efforts, economic development, state environmental policy, and federal energy policy. Furthermore, some of the deployment sites identified herein have also been assessed within the Preliminary Feasibility Study and Strategic Plan for the Depot Campus.

Appendix I - The 2009 Calculated New England Marginal Emission Rates (lb/MWh) Values<sup>250</sup>

Ozone / Non-Ozone Season Emissions (NO <sub>x</sub> )					
Air Emission	Ozone Season		Non-Ozone Season		Annual Average (All Hours)
	On-Peak	Off-Peak	On-Peak	Off-Peak	
NO <sub>x</sub>	0.17	0.13	0.19	0.16	0.17
Annual Emissions (SO <sub>2</sub> and CO <sub>2</sub> )					
Air Emission		Annual			Annual Average (All Hours)
		On-Peak	Off-Peak		
SO <sub>2</sub>		0.24	0.19		0.22
CO <sub>2</sub>		918	943		930

<sup>250</sup> ISO New England, "2009 ISO New England Electric Generator Air Emissions Report-System Planning Department," [www.iso-ne.com/genrtion\\_resrcs/reports/emission/final\\_2009\\_emissions.pdf](http://www.iso-ne.com/genrtion_resrcs/reports/emission/final_2009_emissions.pdf), March 2011